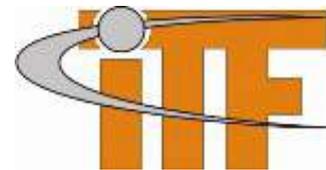




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LATVIA UNIVERSITY OF AGRICULTURE
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FOREWORD

The 5-th International Scientific Conference APPLIED INFORMATION AND COMMUNICATION TECHNOLOGIES aims to cover practical aspects of ICT applications in different fields encouraging interdisciplinary approach and contacts among scientists from different branches. Our goal is to bring together researchers, scientists, engineers, practitioners, educators and students to achieve.

The collection of international scientific conference proceedings contains 59 reports by authors from Latvia, Lithuania, Estonia, Ukraine, Russian Federation, Japan. The reports are divided into the following seven parts:

- Modelling and Simulation Technologies
- ICT Tools and Methods
- Industrial Applications of ICT
- Information Technology in Biology
- ICT in Agriculture
- ICT in Education
- ICT in Agrometrics Studies

We are sure that because of the high quality of the participants the goals of the conference will be met. Many thanks to all the contributors and participants in the conference.

Asoc. prof. Aleksandrs Gailums

Chairman of Organizing Committee
Latvia University of Agriculture

ICT TOOLS AND METHODS

DEVELOPMENT OF THE TOOL FOR TRANSFORMATION OF THE TWO-HEMISPHERE MODEL TO THE UML CLASS DIAGRAM: TECHNICAL SOLUTIONS AND LESSONS LEARNED

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Abstract: *The Unified Modeling Language (UML) is an industrial standard for object-oriented software specification, which offers notational conventions for system modelling at the initial stage of software development. Despite the number of different approaches to development of UML class diagram based on formal transformations of its elements from the problem domain, still there is no widespread tool available for automatic generation of UML class diagram from some form of the problem domain description. Four components form the architecture required for development of such a tool, namely, the drawing environment for source model, export of source elements for their transformation to target, definition of transformation rules themselves, import of the target model into some UML-compatible modelling environment. The paper presents the process of how BrainTool was developed by a research group in Riga Technical University and how it generates the UML class diagram from the two-hemisphere model. Authors of the paper share their experience on the selection of technical solutions for BrainTool implementation and mention several lessons learned during the development process.*

Keywords: Model transformation tool, Two-hemisphere model, UML class diagram, BrainTool, Sparx Enterprise Architect.

Introduction

Models play an important role in the development of software systems. Currently, models and model transformations are the central component in software development and it is clear that the importance of models will increase (van der Aalst, 2007). Models can be used to specify the system in a graphical view, understandable to analysts, developers and even customers. Usually, the system model is organized as a set of diagrams, where specific notation is defined for each diagram and regulates diagram syntax and semantics. As far as system models are abstractions that portray the essentials of a complex problem or structure by filtering out non-essential details, models make the problem easier to understand. Thus the systematic approach to derivation of the system model from the information about the problem domain and the tool supporting the automation of this process is strictly required. Forester's research (Vollmer et al., 2010) confirms that tools to support models and modeling at the initial stage of software development are the modern trend in business process modelling and analysis. Therefore, the focus of the automation of software development is shifted from automatic code generation from the UML diagrams to the automatic modelling of the UML diagrams and further code generation from them. Here, the valuable diagram became the UML class diagram, which specifies the structure of the developed system and static information about system behaviour. The UML class diagram is used to model class specification and serve as a "bridge" between the information about problem domain and the information required for definition of software components and their architecture. Currently, researchers are trying to achieve a high enough level of automation in the creation of the UML class diagram and its derivation from information about the problem domain. Moreover, an increasing number of developers admits the necessity to model system at the initial stage of the software development project, and the models are increasingly used to specify the system and its processes at the business level (Rittgen, 2010; Vollmer et al., 2010).

The authors of (Loniewski et al., 2010) shows the result of analysis of different approaches to transformation of the problem domain description into the UML class diagram during last 10 years, published in four digital libraries (IEEEExplore, ACM, Science Direct, Springerlink). The survey states that there exist enough approaches with different types of solutions for the generation of a UML class diagram and half of them are automated and supported by tools. However, the authors of (Loniewski et al., 2010) stress that these tools are not widely used practically and are created to approve the automation level of the approach offered by their vendors (Loniewski et al., 2010). Other researchers investigating the functionality of the UML modelling tools and model transformation tools raise the question about the ability to define the tool chain to cover all the necessary activities for software system development. For example, the authors of (Kappel et al., 2011) mention the lack of a conceptual view on the integration problem and appropriate reuse mechanisms for already existing integration knowledge, which forces the developer to define model transformation code again and again for certain recurring integration problems in an implementation-oriented manner, resulting in low productivity and maintainability of

integration solutions. The authors of the paper consider that the maturity level of advanced modelling and model transformation tools is not enough to support the full chain of software system development. Thereby, despite the number of approaches to automatic creation of the system model and further code generation from it, the variety of tools supporting the system modelling at the initial stage of software development is reduced to UML editors and “tight” code generators.

The authors of the paper solve the task of tool development to support generation of the UML diagram from the initial model of the problem domain expressed in terms of the two-hemisphere model (Nikiforova, 2002) and analyse technical abilities of current solutions to create such a tool. The tool is titled BrainTool as it supports the two-hemisphere model, the name of which comes from the cognitive psychology and analogy with the human brain. The main idea of creation of such a tool creation is to borrow the architectural and practical solutions used for the implementation of the code generator from the system model, where the code also is considered as a model. Here, the problem is to raise up the level of abstraction generating the system model from the domain model to ensure more precise source for code generation.

The paper is structured as follows. The four components needed to implement such a tool-generator define the rest of the paper. The second section describes the essence of the two-hemisphere model and the technical solution for the diagramming of such a model. The third section offers the pseudo code of the main transformations defined by the two-hemisphere model-driven approach, which allows generating the UML class diagram from the initial information about the problem domain, expressed in terms of business processes and conceptual classes. The fourth section raises the issues in the presentation of the generated model, namely diagram layout and a modern solution for its algorithmisation. The solution for the presentation of the UML class diagram and the problems concerning the layout of the generated diagram are discussed in the fifth section. The sixth section mentions several incompatibilities among modelling tools in solution of the task of model import/export and gives several recommendations on how to complete these problems. The authors analyse the variety of modern system modelling and code generation tools and define the position of BrainTool in the seventh section. In the conclusion the authors discuss the technical solutions and lessons learned in solving the task of development of such a model generator and stress the necessity to elaborate the area of tool development and model usage during software development.

Development of the Two-Hemisphere model editor

The main idea of displaying the initial information about the system with two interrelated models – the business process model and the concept model was introduced in 2002 (Nikiforova, 2002). The name of the approach, the two-hemisphere model, was defined in (Nikiforova and Kirikova, 2004), where the hypothesis about how to use two interrelated models to share the responsibilities between object classes was demonstrated on the example of a driving school. By analogy with the human brain, which consists of two hemispheres harmonically interrelated for an adequate human behaviour, the two-hemisphere model requires the harmony of the presentation of the problem domain for future software development with two interrelated models. Here, the business process model displays behaviour of the system; the concept model displays a skeleton of the system’s static structure. So far, the first task authors had to solve was to develop the modelling environment or a two-hemisphere model editor which would give the possibility to create model, to operate with it and to save the model in a format suitable for further transformation. Figure 1 shows the general view of BrainTool, which is developed to support the two-hemisphere model and is the object of the experiment. The screen of BrainTool is divided into three parts. The information panel on the left side of the screenshot shows the list of elements defined by the two-hemisphere model. The working area of the tool is divided into three drawing frames - the process model, the concept model and the resulting class diagram (at the bottom). The tree view of all objects defined in all models (including the resulting model) is shown in the right part of the screenshot in Figure 1.

To solve the task of the development of modelling environment for the two-hemisphere model, the authors had to pick a technology for implementation of the model editor and transformation. The .NET environment and C# programming language were selected for the experiment on the development of the model editor. The following non-functional requirements would be the key factors in technology selection:

- Rapid development.
- Minimalistic interface not associated with any IDEs.
- Non-commercial availability.
- Cross-platform support.

Authors consciously didn’t use a special environment for creation of modelling language, such as Eclipse, MetaEdit, Visual Studio Visualisation and Modeling SDK or Isis GME because the aim of the experiment was to try to create the tool from scratch and to catch potential problems for future developers. Therefore, the selection of .NET environment and implementation of the model editor in C# also may not be the best choice for development of such a tool, but is quite good for the experiment.

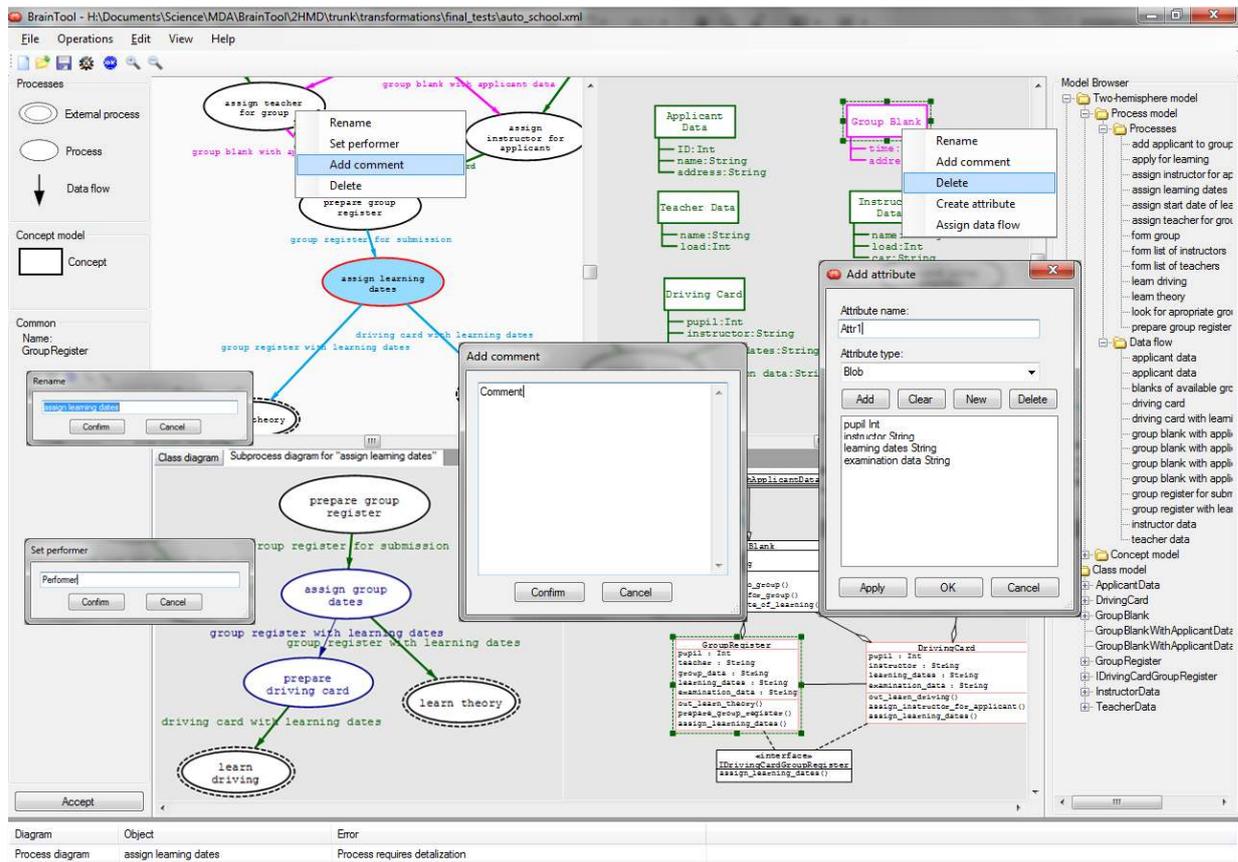


Fig.1. General view of BrainTool.

The fact that the diagramming environment for the creation of the two-hemisphere model and operating with it was developed by a group of 4 programmers in two months allows the authors to claim that the programming environment and the selection of the programming language is not the determining factor in development of such a tool. In turn, despite the fact that development in Eclipse of a model editor with similar complexity as the two-hemisphere model maybe would require only one programmer and one week, the authors can claim again that the selection of the environment has an impact only on the time, cross-platform support etc. The result of the experiment done and the lesson learned is the fact that the development of the modelling environment with up-to-date technologies is possible and real and the implementation environment is not a factor which could deadlock or stop the attempt to create such a tool.

Implementation of transformations from the Two-Hemisphere model to the UML class diagram

The two-hemisphere model driven transformations are based on the transformation of graphs, where nodes of one graph become the edges of the other graph, and edges of the first graph become the nodes of the other. The meaning of objects in an object-oriented philosophy gives a possibility to share responsibilities based on the direct graph transformation, where the data flow outgoing from the internal process becomes the owner of this process for performing it as an operation.

The essence of the transformation is illustrated on the left side of Figure 2. The business process model (graph G1 in Figure 2) is interrelated with the concept model (graph G2 in Figure 2) as follows – concepts in the concept model define data types for events between business processes. The main idea of the transformation is based on graph theory. The business process model is transformed into intermediate model (graph G3 in Figure 2), when edges of the business process model became nodes of intermediate model, and nodes of business process model became edges of the intermediate model. The intermediate model serves as a base for construction of the communication model. The concept model allows determining classes with attributes. The communication diagram serves as a base for the definition of classes-owners of methods. Details about usage of the two-hemisphere model are expressed in (Nikiforova et al., 2008; Nikiforova and Pavlova, 2009; Nikiforova and Pavlova, 2011).

The right side of Figure 2 shows the interpretation of the transformations defined by the approach after the transformations have been studied for the implementation. So far, the left side of the Figure 2 shows the transformations defined by the approach of the theoretical investigation of the sharing responsibilities among objects and the right side of the Figure 2 shows the situation as it is simplified for tool development. The elements of the business process model are transformed into the UML class diagram directly. The edges of

business process model became the nodes of the UML class diagram. The nodes of business process model became the methods of the classes, which were the outgoing data flows of the exact business process.

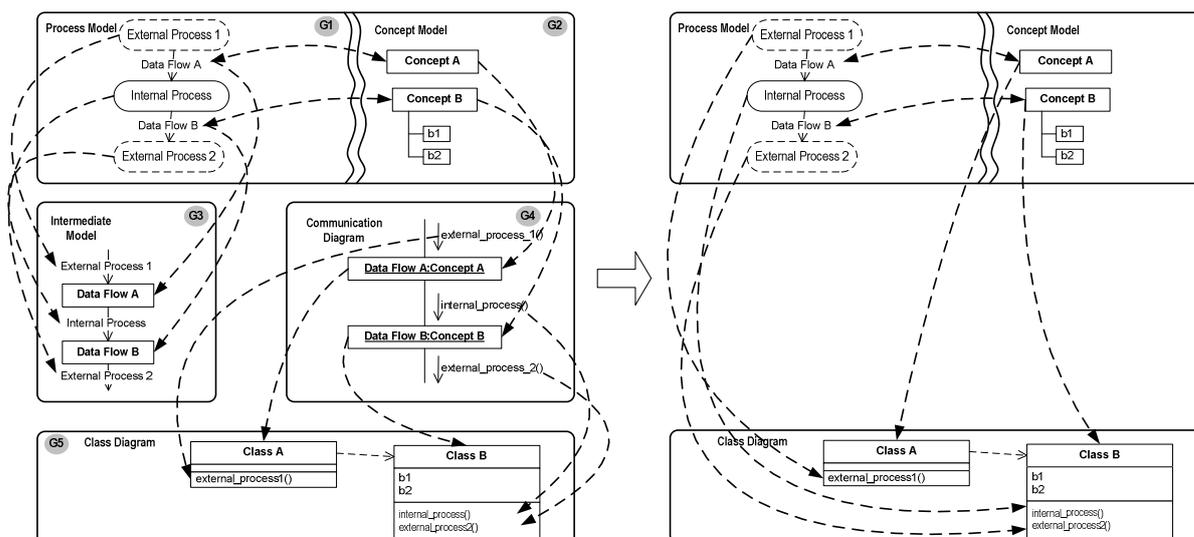


Figure 2. Simplification of the two-hemisphere model transformation for its implementation.

In correspondence with (Kleppe et al., 2003) the transformation is the automatic generation of a target model from a source model according to a transformation definition. In the case of BrainTool, the source model is the two-hemisphere model consisting of the process diagram, the set of concepts and linkage of the concept to the data flows. The target is the UML class diagram, which is a set of classes, class methods, class attributes, interfaces and relationships between classes and interfaces.

To define model transformations it is also necessary to find an appropriate platform. Various transformation languages exist, for example ATLAS (Eclipse, 2011), OMG QVT (OMG, 2005) and others. However, it is necessary to integrate the model transformation component with the model editor and present a way to extend the tool with new transformation definitions. In this case C# lacks the integration with model transformation languages. The easiest way to create the bridge between the model editor and the model transformer is to define transformations as external programs executed by the tool. It allows potential contributors to extend the tool by using any programming language that is capable of understanding BrainTool's XML format. Authors have chosen the Python language because of its script nature and high expressiveness, which enables rapid transformation implementation.

The first transformation task is to generate classes of resulting UML class model. Classes are created from concepts and retain their attributes. Following high-level pseudocode expresses the idea of this transformation:

```
func generate_classes(process_model pm, concept_model cm, class_model clm)
  for each concept in cm do
    clm.create_class_from(concept)
  for each process in pm do
    u_inputs = node.input_set().cardinality
    outputs = len(node.outputs())
    u_outputs = node.output_set().cardinality

    if u_inputs = 1 and u_outputs = 1 and outputs != 1 then
      for each output in node.outputs() do
        clm.create_class_from(output)
        clm.define_generalization(output, node.input_set())
```

Example in Figure 2 shows the simplest transformation case, when a process has one input event and one output event. However, based on combinatorics we have determined 19 transformation cases, which are described in (Nikiforova and Pavlova, 2009). The transformation cases differ from one another with the number and combinations of input and output events and their types expressed as concepts. All 19 cases allow conclusions about classes – owners of methods, and about relations among classes, where it is possible to define such kinds of relationships as aggregation, generalization, dependency and association (Nikiforova and Pavlova, 2009).

Cardinalities (the number of different concepts linked to data flows) of process' inputs and outputs are used to determine generalization between the classes created. Also this information is used to define aggregation, association and dependency between elements of the UML class diagram. Processes from the process model become class methods as a result of the transformation, which can be expressed in such a pseudocode fragment:

```
func assign_methods(process_model pm, concept_model cm, class_model clm)
  for each process in pm do
    classes = node.get_classes(clm)
    inter = null
    if len(classes) > 1 then
```

```

inter = clm.create_or_get_interface(classes, node)

for each c in classes do
  c.add_method(node)
  if inter != null then
    clm.define_realisation(c, inter)

```

Method assignment to classes gives the possibility to define interfaces and realisation relationship in the UML class diagram. So, as a result, the target model consists of classes with methods and attributes, interfaces with methods and five types of relationships: generalization, dependency, aggregation, association and realisation.

Presentation of the UML class diagram and problems concerning the layout of the diagram

When performing model transformations with models represented by diagrams, the issue of the diagram layout becomes very important to solve. Contents of the target model gained may differ from the source model highly and the information about the layout of the source model may be unusable in this case. One more aspect that makes this task important is the perceptual aspect. The model should be demonstrative enough so a developer could check as fast as possible if the result received from series of transformations satisfies his needs.

The target model in the two-hemisphere model-driven approach is the UML class diagram, which can be represented as a graph. Initially the general graph layout algorithm can be used to place elements of the UML class diagram, for example – force-based algorithm (Dwyer, 2001). However, the UML class diagram is a specific graph, which requires special representation to be as demonstrative as possible. Relations between elements of the diagram may be vital for model understanding and general purpose layout techniques may fail in making this information representative enough. Therefore, several researchers turn their attention to repurposing the specific algorithms to solve the layout problem in the UML class diagram scope, e.g. (Eichelberger, 2005; Andriyevska et al., 2005).

Authors of (Wong and Dabo, 2006) propose specific requirements for a class diagram representation based on perceptual theory. The authors of the present paper analyse issues in the area of the UML class diagram layout in (Galapovs and Nikiforova, 2011b; Galapovs and Nikiforova, 2011a), where several recommendations on the main requirements for the layout algorithm were defined. However, such an algorithm is not trivial in comparison to other graph layout techniques and still the problem is not solved. Moreover, some of the requirements for the UML class diagram layout, e.g. those defined in (Wong and Dabo, 2006), are conflicting. It also slows down the creation of the solution for the automatic layout in a modelling tool like BrainTool. According to (Hofman and Piasecki, 2006) there is no deterministic algorithm to find the optimal solution in such a case. The current version of BrainTool requires the target model to be laid out manually. However, this problem is not tool-specific and the layout algorithm can be integrated with BrainTool at any moment it might be defined.

Several issues in solving the task of model interchange between modelling tools

The modern trend, which is model driven software development, states the ability to define tool sets, which are integrated to make a complete development environment. In our case, the set can be defined as a tool for the UML class diagram creation (it is BrainTool) plus the powerful modelling environment for operation with UML diagrams and further code generation from them. Therefore, to become compatible with such the modelling environment, the created tool has to have export abilities of the generated UML class diagram and its further import into such a modelling environment.

Initially the Sparx Enterprise Architect is selected as the environment to try to import the UML class diagram from BrainTool. However, authors faced problems importing the XMI file containing the information about the UML class diagram, and defined according the existing standard (XMI, 2005), with loss of the geometry, and import into several other UML modelling tools even failed. The authors of the paper stated the task to check abilities of import/export between several different tools, and the results of the experiment are shown in Table 1. Cells of Table 1 show lacking information during import of XMI file generated from the tool listed in the left side of the table and imported into the tool listed at the top of the table.

For example, during the export of the UML class diagram from the ArgoUML tool and import of it into the SPARX Enterprise Architect tool, the model loss attribute types, method argument types, diagram geometry and relations. Otherwise, import of the UML class diagram from SPARX Enterprise Architect tool into the ArgoUML tool is failed at all. The main lesson learned about the model interchange between various Model-Driven Development tools can be stated as a lack of XMI support in current solutions.

The problem can be solved, for example, by introducing a certification standard for tools that generate and interchange the UML diagrams. However, such a certification needs to be introduced by a well recognized development community, e.g. IEEE or the vendor of the object-oriented philosophy - OMG.

Related work

Since beginning of the eighties numerous cases of model generated software systems have been offered to attack problems regarding software productivity and quality (Balzer, 1985). CASE tools developed up to that time were oversold on their “complete code-generation capabilities” (Krogstie, 2005). Nowadays, similar arguments are introduced by the Object Management Group (OMG) Model Driven Architecture (MDA) (OMG, 2003), using and integrating Unified Modeling Language (UML) models (OMG, 2004) at different levels of abstraction. Manipulation with models enables the automation of software development with CASE tools supporting model driven software development (Frankel, 2003; Kleppe et al., 2003; Mellor and Balcer, 2002).

Most of today's tools combine a number of functions in a more or less open fashion. The traditional CASE tools provide a model editor and a model repository. A code generator based on a scripting language and plugged into a CASE tool provides the transformation tool and transformation definition editor. In that case, the transformation repository is simply text files (Kleppe et al., 2003).

The variety of “model-driven” tools can be divided into tools to support code generation from the UML model, and tools created for the definition of the system model itself. The second group of the tools is so called “UML editors”, where tools developers propose different levels of automation of the model creation itself. BrainTool demonstrated in this paper can be classified as a tool for creation of the UML class diagram, where the result of the generation – the UML class diagram expressed in XMI format – is importable either into UML editors, like UMLet 11.3 (UMLet, 2011), Umbrello (Umbrello, 2011), Together (Borland, 2012) or code generation tools, like Sparx Enterprise Architect (Sparx, 2012), UML Studio (UML Studio, 2009), Visual Paradigm for the Unified Modeling Language (Visual Paradigm, 2011), ArgoUML (Tigris, 2009), MagicDraw (MagicDraw, 2011), IBM Rational Software Architect (IBM, 2011), Eclipse (Eclipse, 2011).

As for now, the generation of the UML class diagram from existing source code (e.g. Java) is widely used by software developers to visualize and understand the software structure. For example:

- ESS-Model, which allows obtaining class diagram with associations and inheritance by simple drag-and-drop of source files – Java .java and .class and Delphi .pas and .dpr (ESS-Model, 2003).
- AgileJ Structure Views, which allows displaying Java-specific information, is IDE specific and automatically handles layout elements of class diagram (AgileJ Structure Views, 2011).
- BOUML is a free modelling tool, which allows UML modelling, as well Java, C++, PHP, Python, Idl code generation, as well class diagram generation from C++, Java and PHP source files (BOUml, 2011)
- ObjectAid as Eclipse plug-in provides a visual representation for Java source files. ObjectAid does not execute any reverse engineering; it displays source files in a different view. When a developer adjusts the diagram or the source file, the other view is adjusted accordingly (ObjectAid, 2011).

Another variety of tools are tools which generate the class diagram from a predefined data structure. For example Sparx Enterprise Architect has this feature. One more tool which allows generating class diagram from data model is Visual Paradigm. Generation of the UML class diagram from pre-defined data structures requires a solid contribution of the software specialist to define all these structures. It is already modelling of the UML class diagram itself. In contrast to these tools, BrainTool generates the class diagram from initial information about the system, which is understandable for the business analyst and doesn't require software knowledge for modelling of business processes. Usually the UML class diagram is constructed in the analysis phase, before code writing. Therefore the tool, which generates the class diagram in the initial stage of the project, is very useful. It allows automatic creating the static structure of the developed system and serves as a base for further code, avoiding mistakes and mismatches between requirements and implementation.

Conclusions

The main idea of the research presented in the paper is to try to develop a tool for automatic generation of the UML class diagram from scratch. Moreover, the tool has to be able to work with the initial presentation of the problem domain expressed in terms of the two-hemisphere model, to validate the initial model and to identify problematic elements which break the transformation process, to generate the UML class diagram from it based on the pre-defined transformations, to visualize the target model in the form of the UML class diagram and to export the generated UML class diagram into a UML compliant tool. As a result BrainTool is developed to support the required functionality. The authors share several lessons they've learned in engineering a MDA-supporting tool within the scope of the paper.

One of the key lessons learned during the experiment with BrainTool implementation is the selection of the development environment and technologies. Deeper after-experimental analysis of available technologies and the essence of the tool as a software product allow the authors to claim that any general purpose programming language or specific environment for such tool creation may be used. In this case the determining factor is the available resources and previous experience of the developers.

Authors' decision about developing transformation as a standalone application has many advantages. There is no need to integrate transformation language support into model editor and it is possible to use a general purpose programming language for transformation definition. It allows defining more universal transformation rules.

Also it enables possible contributors not familiar with specific transformation languages to define their own model transformations. As another advantage it makes tool components more independent from each other, thus easing parallel development of them.

So, the implementation of the modelling environment for transformation of one model into another and programming of such the transformations is the task which is solved during the experiment. The open questions still exist in the area of the target model layout and its import into other modelling tools. The issue of diagram layout is not the problem of the tool; it is a problem of the algorithm itself. The universal algorithm satisfying all the requirements for element placement at the modelling area has not been developed and is being investigated by researchers. Currently, the resulting class diagram requires manual element positioning in order to increase the model's perceptual capabilities. However, the authors claim that any solution can be easily integrated within BrainTool. The authors consider the layout as another kind of transformation where the source model is the generated class diagram "as is" and the target is the laid out model. Using such a point of view makes it easy to add automatic diagram layout at any development stage.

Another problem is a lack of standardization and certification support in model interchange. Authors would introduce plug-ins for different tools where each plug-in can also be considered as a transformation from UML class diagram to tool-specific XMI document, if it is still impossible to integrate the unified standard of the diagrams into the tools themselves.

The working version of BrainTool enables to operate with the two-hemisphere model and to generate the set of the elements of the UML class diagram, which in turn is used to generate code fragments. The further efforts of the authors will be turned to the refinement of the transformation rules to be able to extend the set of the class elements with the aim to improve code generation abilities in general.

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CULTURE COLOUR PREFERENCES FOR CROSS-CULTURAL WEBSITE DESIGN

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Abstract: *Users from various cultures not only speak different languages, but also think and act differently. These differences impact process of how users perceive and use information systems, including websites. Therefore there is emerging need for models, methods and technologies for design of usable cross-cultural websites. One of the main tasks relating to usable cross-cultural website design is to gather data about cultural preferences for a selected culture. In this article methods for culture colour preference identification are summarized. Improved method is introduced for gathering not only colour names, but also colour saturation data from websites. The comparison of results of two method executions is performed within a process for gathering Japanese website design colour preferences. From results of scanning web browser rendered website images, it can be seen that extracting colour saturation data give more precise and different results than executing the colour code extraction method.*

Keywords: cross-cultural design, website, colour extraction, usability.

Introduction

Websites is a widespread communication tool. Initially Internet services, including websites, were developed typically for users from western countries mainly in English language. But only 8-10% of the world population and 35% of website users use English as their primary communication language (Takasaki & Mori, 2007). It is concluded by various authors that such cultural differences as language, perception of information, thinking patterns and communication style can significantly impact website usability (Rau et al., 2011). Because of such conclusions there is increased demand for research about cross-culturally usable website design models, methods and technologies.

There are two design strategies known in a cross-cultural design. One is internationalization and the another is localization (Smith et al., 2004). Internationalization is a process that includes tasks for design of product or service that is not sensitive against culture differences (Marcus & Baumgartner, 2004). Usually product internationalization is achieved with avoidance of design elements that are culture sensitive, such as religious references and symbols (Young, 2008). Localization is a process that includes product or service adaptation for certain language and culture (Young 2008; Marcus & Baumgartner, 2004). For example, to perform localization of website, besides translation of language, such tasks as use of time zones, format of currency, use of colour, product and service name decision and others must be considered (Vyncke & Brengman, 2010). In various studies researchers conclude that localization strategy must be used to achieve improved product usability results (Simon, 2001; Marcus & Rau, 2009; Cyr et al., 2005).

To use localization strategy for cross-cultural website design, there is a need to identify variables or dimensions which can be diverse in various culture websites. One such dimension is colours that are used in culture websites.

The aim of this article is to summarize and improve identification process of culture colour preference for design of cross-cultural websites. To reach the aim, following tasks are brought forward:

- Summarize methods to identify culture colour preference for cross-cultural website design.
- Suggest method to identify culture colour preferences by scanning existing websites and collecting data about used colours and colour saturation.

Materials and methods

Various studies suggest evaluation of certain cultural dimension groups. For example, Barber and Badre (Barber & Badre, 1998) suggest such dimensions as colour, spatial organization, fonts, shapes, icons, metaphors, geography, language, flags, sounds, motions, writing direction and navigation.

Smith (Smith & Yetim, 2004) mentions colour, colour combinations, banners, trust signs, metaphors, language and navigation. Cyr and Trevor-Smith performed analysis of design elements in 30 websites from Germany, Japan and USA. They concluded that symbols, colours, links, navigation maps, search functions, layout of information and language are the dimensions that differ across cultures (Cyr & Trevor-Smith, 2004). Aykin and Milewski (Aykin & Milewski, 2005) highlight such dimension groups as graphics, language and translation, formatting of objects, colour and layout. Rau with co-authors (Rau et al., 2011) also suggest similar dimension groups which are language, format, presentation, layout, graphics and colour.

It can be seen that practically every division mention colour as one of the culture variable or dimension, that is important for design of usable cross-cultural information systems.

Humans learn colour associations and those associations are bound with culture. Meaning of certain colour in various cultures can be different (Barber & Badre, 1998; Clarke, 2005). For example, Chakraborty and Norcio (Chakraborty & Norcio, 2009) study shows confirmation of previously published Barber and Badre red colour association observations with people from China and USA. Other studies also confirm such associations (Choong, 2006). Callahan admits that inattentive selection of colours for website design can impact cross-cultural usability (Callahan, 2006a).

Ashok and Jacko (Ashok & Jacko, 2009) mention an example about the widespread use of red colour in Indian wedding ceremony, while Christian ceremonies usually use white colour. Therefore, when designing Indian wedding agency website the use of white colour as predominant is not acceptable.

Barber and Badre also conclude that the use of colours for cross-cultural website design can impact user expectations towards navigation, content, links and overall impression of system (Barber & Badre, 1998).

For example, Cyr with co-authors analyse *SAMSUNG* localized websites with users from various cultures. This study shows that, for example, Japanese users regardless of the fact that they have the Japanese version of *SAMSUNG* website prefer Hong Kong website. Japanese users found colour, image saturation, animation and layout of Hong Kong version more suitable and attractive than Japanese one (Cyr et al., 2005).

Simon (Simon, 2001) concludes that Asian culture people prefer darker colours, but European and North American users prefer brighter colours. Colours are often linked to religion that predominates in culture. For example, saffron yellow colour is sacred colour in Indian, Sikh, Jain and Buddhist religions (Rau et al., 2011).

Colour application in website design also can be linked to politics. For example, Malaysian government websites never include green colour as predominant. It is related to the fact that government opposition official colour is green (Hussein et al., 2009). Barber and Badre in their study (Barber & Badre, 1998) conclude that when designing websites for government institutions, all studied countries, except Brazil, gave preference to colour scheme which is predominant in cultures country flag. For example, French government websites designs mostly use blue, white and red colour, while Libyan government websites use green as a predominant colour.

Colour meaning is also linked to context of application. For analysis of colour meaning Bourges-Waldegg and Scrivener (Bourges-Waldegg & Scrivener, 1998) propose a model that includes 3 concepts such as colour, meaning and context. For example, purple (colour) represents God (meaning) in Japanese religion (context). The other authors also recommend to use this model for colour meaning collection and analysis for selected culture (Callahan, 2006b).

When generalized, Chattopadhyay with co-authors conclude that blue colour is most universal for website design (Chattopadhyay et al., 2002). Kondratova and Goldfarb (Kondratova et al., 2007) in their study analyse websites from 26 countries and conclude that most universal colours are white, black, various tones of grey, various tones of blue and light yellow. These authors also present prototype tool that allow to automate website content analysis (Kondratova et al., 2007). According to those authors this tool also can be used for culture colour preference analysis. Designers using this tool can scan target culture domain websites, examine and extract colour names from website *Cascade Style Sheet (CSS)* code. However, Kondratova and Goldfarb admit that this tool cannot read colours from images. In case website colours are not defined using *CSS*, that tool cannot determine colours that are used in website. This tool also cannot determine colour saturation, which means that colour of a single word letter can have same weight as a whole page background (Kondratova et al., 2007). There is a need for methods that allow determining as well as colour saturation from rendered websites in user's web browsers.

The content analysis of target culture websites is one of the most used methods for identification of culture colour preferences for a cross-cultural website design (Kondratova et al., 2007). Usually for such analysis certain set of websites from a target culture is selected. Often, this set is built from the most popular websites using website visiting statistics. For example, Kondratova and Goldfarb (Kondratova et al., 2007) use *Google* statistics, while the other authors (Vitols et al., 2011) use also *Amazon Alexa* website statistics.

For identification of colour preferences other methods also can be used. One of suggested methods is from Chavan's *Quick and Dirty User Profiling Technique (QDUPT)* (Chavan, 1999). *QDUPT* basically includes three methods that can be viewed as heuristic and allows product designers to acquire basic preferences from the target culture. One of the methods, for target culture user preferences suggests performing analysis of the most popular local music videos and movies within last 5 years.

Based on Chavan's suggestion and Braun and Rose study (Braun & Rose, 2007) with application of these methods for Korean preference identification, we suggest to use these methods for colour preference identification. When combining such methods overall method for colour preference identification can be developed (Fig. 1).

As a target culture for this study we selected Japan. To acquire Japanese website colours, the third and the fourth method from Fig. 1 were used. Analysis of 100 most used local websites in Japan has been performed.

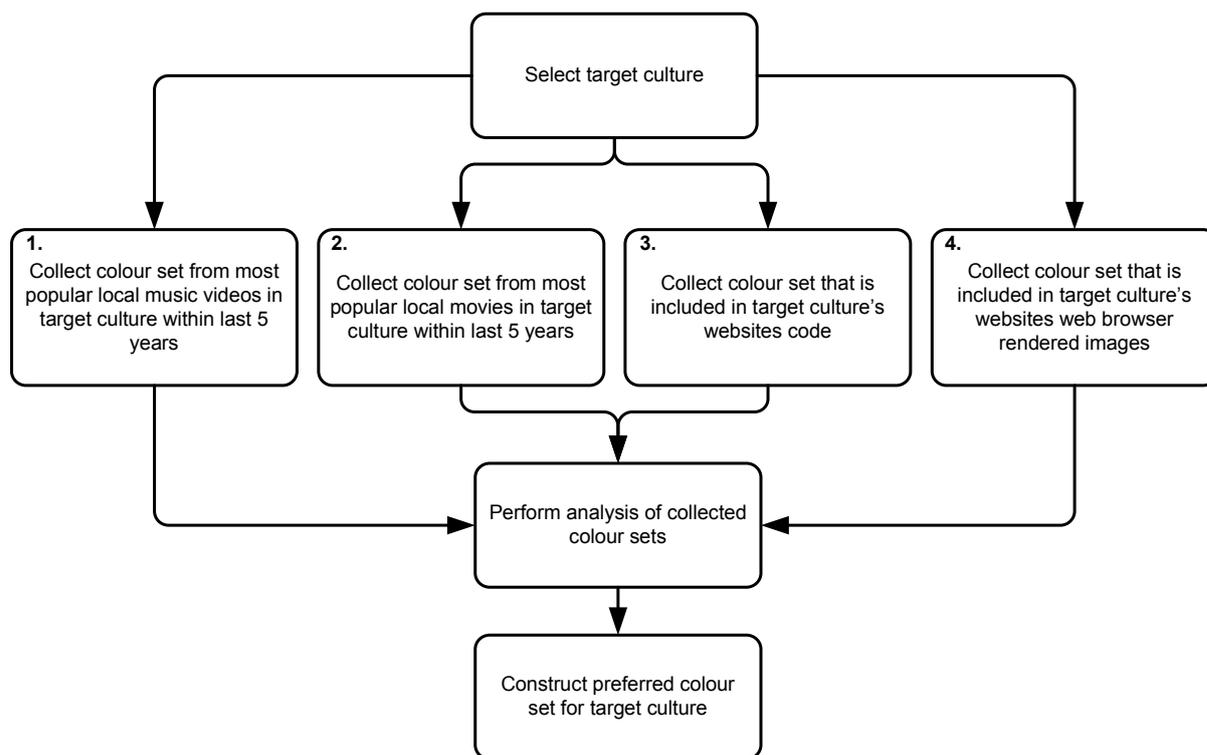


Fig. 1. Methods to identify culture colour preference.

To gather such data there is a need to scan web browser rendered website content and examine website codes. As more than 90% of Japanese websites use *CSS* for coding colours (Vitols et al., 2011), *CSS* code scanning must be performed. *CSS* can be added to website by embedding *CSS* into the base code, usually *HTML* code, by adding inline *CSS* to *HTML* tags or by linking to a separate *CSS* file. Linking to a separate *CSS* file is the most common method for Japanese website design, which were discovered during our previous study (Vitols et al., 2011).

To execute the third method mentioned in Fig. 1 there is a need to perform the following operations:

1. Scan selected website source code for extraction of *CSS*.
2. Extract *CSS* files, including those that are formatted by importing *CSS* file from within another *CSS* file.
3. Extract *CSS* file and run the code with *CSS* parser software for colour code extraction in hexadecimal notation for the combination of Red, Green, and Blue colour values.
4. Clean colour codes from values that are not written as 3 double digit numbers, starting with a # sign.
5. Get rid of colour code duplicates which appear in multiple *CSS* files within a single website.
6. Convert shorthand hexadecimal notation that abbreviates 3-character *CSS* colours into 6-character notation.
7. Load extracted data into database and perform data analysis.

To execute the fourth method mentioned in Fig. 1 there is need to perform the following operations:

1. Select a tool that can scan websites and prepare screenshot of an index page for each website.
2. Set up screenshot preparation properties and write a batch file for screen shot preparation tool.
3. Execute colour analysis of prepared screen shots with an image analysis script.
4. Collect colour and colour saturation data.
5. Load collected data into database and perform data analysis.

Results and discussion

To collect data about 100 most popular Japanese websites, *Amazon Alexa Top Sites* website statistics was used. The sites in the *Alexa Top Sites* lists are ordered by their 1 month *Alexa* traffic rank. The 1 month rank is calculated using a combination of average daily visitors and page views over the past months. The site with the highest combination of visitors and page views is ranked number 1. Target culture websites which were chosen are listed in *Alexa Top Sites* Japanese list and are written in Japanese language. Data about popular websites was collected during November 2011.

For extraction of colour codes from *CSS* files, we used *CSS* parser for colour code extraction written in *JavaScript* and published by *ThriveSmart* (ThriveSmart, 2007). This *CSS* parser script allows extracting colour codes from *CSS* files in hexadecimal notation for combination of red, green, and blue colour values. Extracted values were imported in *Microsoft Excel* for corrupt and duplicate colour code identification. With *Microsoft Excel* conversion of shorthand hexadecimal notation colour codes to 6-character notation was also performed. Afterwards data was loaded with *Oracle SQL Loader* into *Oracle Express Edition* database and data analysis with *SQL* language queries was performed.

For extraction of colours from rendered website we used the following tools and steps. To prepare screenshot of an index page for each website *WebShot 1.8.8* (Moinvaziri, 2011) tool was used. *WebShot* allows automating whole website index page screenshot preparation. For automation of process *WebShot* batch file was created and executed. Screenshot size was dynamically adjusted to website index page size and screenshots were saved in *JPG* image file format. Screenshot was prepared using *Internet Explorer 8* web browser with *Trident* layout engine.

For analysis of screenshots, the web based image analysis tool was developed using *PHP* language. As a base for the image analysis tool, *Color Extract PHP* class developed by Csongor Zalatnai and Kepler Gelotte was used (Zalatnai & Gelotte, 2011). Image analysis tool allows extracting most common colours in image and identifying saturation of each colour in a given image. 50 most common colours from each website screenshot were extracted. Afterwards data was loaded with *Oracle SQL Loader* into *Oracle Express Edition* database and data analysis with *SQL* language queries was performed.

After the data analysis, colours were arranged by most used ones. To rank results of *CSS* code extraction method we count instances of certain colour. For example, black colour with hexadecimal notation #000000 was identified 165 times, while grey colour with hexadecimal notation #CCCCCC was identified 117 times.

To rank results of website rendered image analysis method we identified overall percentage of colour saturation in screenshots of analysed websites. Overall more than 3000 unique colours were identified using *CSS* code extraction method and 2460 unique colours using website rendered image analysis method. 100 most used colours were ranked. Ranked results can be partially seen in Table 1 and Table 2.

Table 1

Most used colours in Japanese website design collected using CSS code analysis method

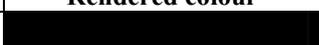
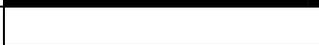
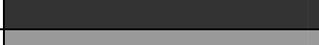
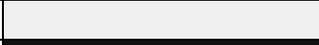
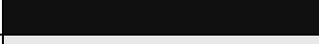
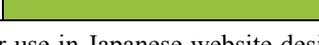
Rank	Rendered colour	Hexadecimal notation
1.		000000
2.		ffffff
3.		cccccc
4.		333333
5.		999999
6.		666666
7.		dddddd
8.		ff0000
9.		eeeeee
10.		aaaaaa

Table 2

Most used colours in Japanese website design collected using rendered image analysis method

Rank	Rendered colour	Hexadecimal notation
1.		507088
2.		ffffff
3.		808080
4.		f8f8f8
5.		587890
6.		f0f0f0
7.		101010
8.		e8e8e8
9.		f0f0e8
10.		98c040

To display proportions of colour use in Japanese website design, we grouped collected colours using the colour wheel of basic colour groups (Mollon, 2003). Basic colours of the colour wheel are blue, red and yellow. The secondary colours are green, orange and purple (Mollon, 2003). We used these 6 colours to generalize results and give approximate saturation for each of these colour groups in Japanese website design. As additional to 6 main colours we also included grey, but exclude white and black. The results of this division are displayed in Figure 2 and Figure 3.

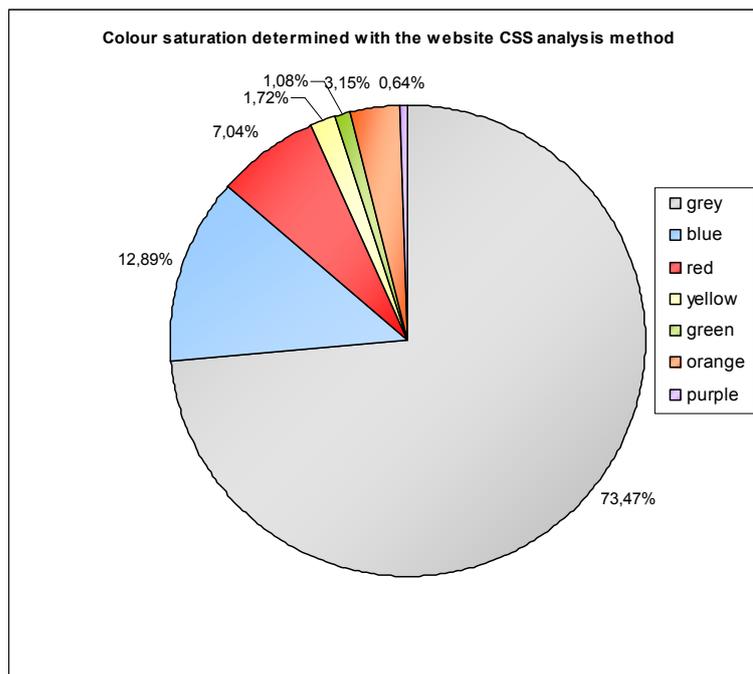


Fig. 2. Basic colour group saturation in Japanese website design. Determined with the website CSS analysis method.

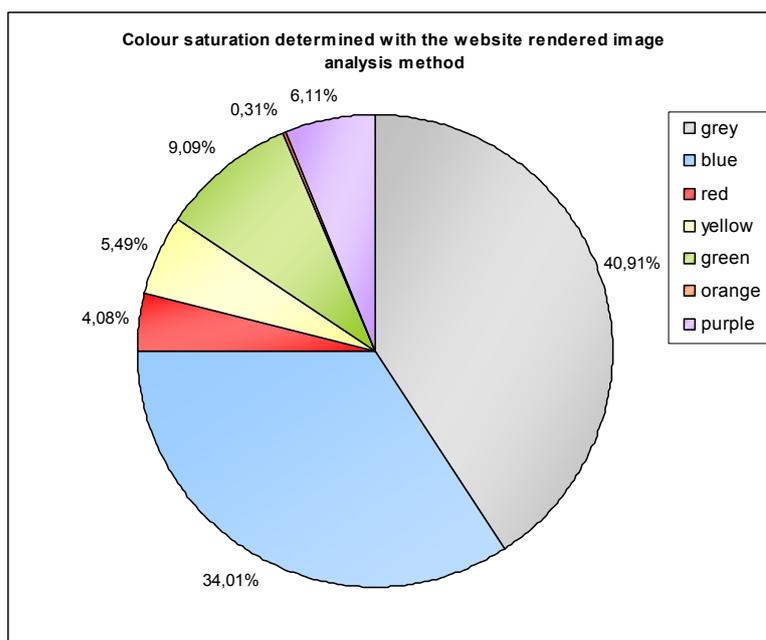


Fig. 3. Basic colour group saturation in Japanese website design. Determined with the website rendered image analysis method.

As it can be seen in Figure 2 and Figure 3 that large portion of website colour saturation takes grey and blue colour variations.

It is seen that Japanese website designers mostly use blue, gray and green colour combinations as main for their website design. This confirms previously gathered results from manual evaluation of Japanese websites (Vitols et al., 2011).

Conclusions

As we compared the results from each method, we found there is a significant difference. The method when snapshot of rendered website is taken and examined gives more precise results with taking into account data about colour saturation and colours from images that published in the website.

Suggested software solutions successfully assist execution of both reviewed methods and can be used in further studies.

Website content analysis with scanning CSS files is one of the most used methods for identification of culture colour preferences for cross-cultural website design. However this method provides only rough colour preference data.

For execution of rendered image analysis method only index page snapshot for each website was examined. Snapshot evaluation of multiple pages from a single website could give slightly different and more precise results. However main page usually include design frame, banner and central image which can give close to reliable colour saturation data of the website.

It is seen that Japanese website designers mostly use blue, grey and green colour combinations as main for their website design. These results partly confirm results that were gathered by Chattopadhyay (Chattopadhyay et al., 2002) and Kondratova (Kondratova et al., 2007).

Proposed method which allows determining colour saturation further can be used for development of cross-cultural website design consulting software.

Acknowledgements

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EVALUATION METHODS OF NETWORK INTRUSION DETECTION SYSTEMS

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Abstract: *A Intrusion detection system is system designed to detect attempts compromise the integrity, confidentiality or availability of the protected network and associated computer systems. A Network Intrusion Detection System (NIDS) aims to detect attempted compromises by monitoring network traffic for indications that a attempted compromise is in progress, or a internal system is behaving in a manner which indicates it may already be compromised. One important problem when designing Intrusion Detection Systems or a new security mechanism against computer attacks is that there is no universally accepted methodology to test and to evaluate them. There is several approaches, data sets and criteria's for NIDS evaluation. To investigate situation in NIDS evaluation, we review the current state of experimental practice in this area. We also discuss problems that have been blocked successful measurements in this area and suggestions for possible improvements and research directions for nowadays networks.*

Keywords: intrusion detection, network security, IDS evaluation.

Introduction

More and more computers are attacked by hackers, malwares, spywares, botnets and other malicious software. Various approaches have been devised to protect computer networks and it's data flow, but still contemporary methods have failed in attack against sophisticated attacks and malwares. Security experts and researchers try to find more effective approaches and methods for computer network and system protection. Intrusion detection systems (IDS) have become very important and effective tool for security infrastructure effectiveness improvement that is the reason of very active research in this field. The same time more and more organisations looking for information to implement IDS in their information technology (IT) infrastructure.

The goal of an Intrusion Detection System (IDS) is to monitor network assets in order to detect misuse or anomalous behaviour. Several types of IDS have been proposed in the literature, and they can be divided into two broad classes, i.e., net- work based (NIDS) and host based (HIDS) (Pietro and Mancini, 2008). HIDS analyses events such as process identifiers and system calls, mainly related to OS information. On the other hand, a network-based IDS analyses network related events: traffic volume, IP addresses, service ports, protocol usage, etc. (Garciateodoro et al., 2009). This paper concentrates on NIDS, because these systems are more popular and widely used.

The research in NIDS can be classified as either signature-based or anomaly-based detection techniques, these two are main intrusion detection methods in this area, less popular and quite new method is specification-based detection and hybrid detection. Signature-based schemes (also denoted as misuse-based) seek defined patterns, or signatures, within the analysed data. For this purpose, a signature database corresponding to known attacks is specified a priori. These systems are more popular in commercial products due its high accuracy. On the other hand, anomaly-based detectors attempt to estimate the "normal" behaviour of the system to be protected, and generate an anomaly alarm whenever the deviation between a given observation at an instant and the normal behaviour exceeds a predefined threshold. Another possibility is to model the "abnormal" behaviour of the system and to raise an alarm when the difference between the observed behaviour and the expected one falls below a given limit (Garciateodoro et al., 2009). Anomaly-based systems are more popular in academic research due its higher potential to discover novel attacks in comparison to signature-based systems. Specification-based detection approaches are neither misuse based, nor anomaly-based, in specification-based systems the experts' knowledge determines the operating limits (threshold) of a system. Once the correct (or allowed) system behaviour is specified. The events deviating from the specification would generate an alert (Ko et al., 2001). This method is not widely used in practice, because specifying the behaviour of a large number of privileged programs running in real operating environments is a daunting and difficult task, in spite of its appealing principles, specification-based detection still remains in infancy. Hybrid intrusion detection systems consist of two or more detection approaches, mostly it consist of both signature and anomaly detection (Bashah et al., 2005).

As interest in NIDS has grown and several detection approaches, learning algorithms, system architectures and data sources have been proposed (Wu and Banzhaf 2010; Tsai et al. 2009; Kabiri and Ghorbani, 2005), this makes pay attention on evolution of IDS, which is very important and the same time difficult task in this field. IDS evaluation have been researched already before (Cunningham et al., 1999; Tavallae et al., 2008; Das, 2000; Salah and Kahtani, 2010), but there is still no common criteria and evaluation model for all kinds of NIDS. This is difficult task, because need to find common criteria for detection rate and testing environment what would be as much as possible realistic. It is important to mention that this research not evaluating detection methods, but

systems, the same time we are not making comparison of systems, but looking for evaluation methodology. Most of researches concentrate on intrusion detection method testing or on comparisons of systems, but there is lack of IDS evaluation methodology, which has quite different requirements.

This paper concentrates on comparative study of NIDS evaluation methods for identifying most important criteria for NIDS evaluation and find common model for NIDS effectiveness testing. We have tried to collect published work during period 2006-2011, where main focus is concentrated on used datasets, testing environment, effectiveness characteristics and testing methods.

Materials and methods

In this research analyses of 200 scientific publications and published papers have been made during the period of 2006-2011. Trying to be as much as possible objective we collected all available papers about intrusion detection which could be found in ScienceDirect. Of course we excluded all short papers and abstracts which did not contain evidence of experimental study and evaluation methodology.

To assess publications about intrusion detection systems, analysis of research was done through several factors which shown in "Figure 1":

- **System type** – NIDS have several limitations, for example these systems tends to drop packets in high-speed networks and also cause network latency. This becomes a main challenge for system performance. To assess the system type we analysed: 1) system architecture – centralized or distributed system; 2) detection type – signature based, anomaly-based, specification-based or hybrid; 3) system intelligence – sensor systems, agent-based systems.
- **Evaluation metrics** – to evaluate NIDS there are many demands, it is not necessary to cover all of them in evaluation study, but choose most important of user needs. We tried to find objectives and evaluation metrics for system testing. It is important to know, such information like effectiveness, user friendliness, flexibility, system security and interoperability with other systems is main criteria or sub criteria for system.
- **Datasets or data collection method** – evaluation data is important component of any intrusion detection system, mostly these data are necessary for system detection effectiveness measurement.
- **Experiments** – this phase not always receive proper attention in publications. Poor experimental practice can deface results of evaluation. In this research several experiment factors was analysed – experimental environment, experimental setup and repeatability of experiments. There is lot of criteria what must to be analysed like specification of datasets, simulation tools, algorithms, evaluation criteria, etc.
- **Analysis of results** – also important role of evaluation is result analysis and validation. There must be some method to check credibility of obtained results, report of research should give clear explanation of results to ensure that these results are consistent and not attributed to an error.

In the analysing process also was evaluated how repeatable and valid is this research. If it is no clear explanation of experimental setup and what experiments was performed, than validity of collected data can't be very high. Validity of data comes also from data processing process, there is important to look how data are collected and provided to evaluation and is it clear explanation of data measurement process.

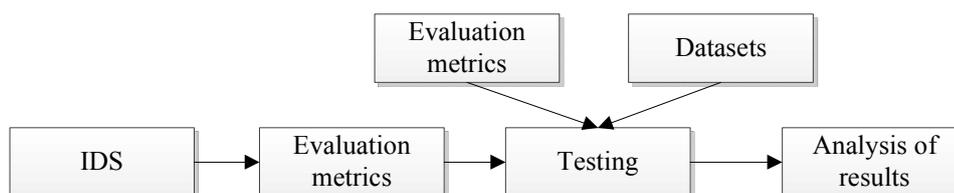


Fig. 1. Evaluation of IDS research papers

Main characteristics of IDS evaluation was collected during research process. Main focus of this activity was on getting characteristics for different types of NIDS systems and common criteria as well. It is important because there is wide spectrum of NIDS and each method has different needs, for example system accuracy with such criteria like False Positive and False Negative will be relevant to all NIDS, but training phase for system testing will be related just to anomaly or hybrid systems.

Results and discussion

As it was expected than most of research was concentrated on anomaly detection process and just few of them was evaluated whole system, most of research publications was evaluated just one of detection methods (see Table 1). As it was pointed before anomaly detection is most popular in scientific research field. Detection method evaluation concentrates on checking if the system detects attacks or not, but there is missing such method analysis in real network, number of false alarms can be much greater when in measurement comes such criteria as system load and network traffic speed. Some of research papers using snort or other popular IDS as test system for their detection methods, which gives more validity and repeatability to the results, but often there is missing information about hardware configuration in experiments. Speaking about evaluation metrics, most of papers concentrate on artificial intelligence testing, mostly testing them on some simulation tools or Mat Lab. The problem is that information about experimental setup and self-experiments, that makes validity of experiments in low level. Another important aspect of experimental setup is datasets, where most of publications did not specify which part in data set is for training and which is for testing. Such datasets as DARPA and KDD giving great validity, but if there is no proper description about use of this datasets, than validity of results is going down. Also another important fact in evaluation of systems is that even if system is tested than most of results showing such thinks like detection rate or system accuracy, but not concentrate on system and memory load, there is missing information about technical environment.

Table 1

System type	
Anomaly intrusion detection method	132
Signature-based intrusion detection method	23
Hybrid intrusion detection	45
Evaluation metrics	
Algorithms of artificial intelligence	127
Statistics-based approach	26
System evolution or method integration in system	17
New architecture and other components implementation in IDS model	14
Comparison of two or more methods	16
Datasets or data collection	
DARPA data set	53
KDD data set	68
Other data sets	38
Self-generated attacks or collected real traffic	41
Experiments	
Network simulator	27
Laboratory network	46
Computing performance testing	86
Other	41
Analysis of results	
Comparison of the proposed approach with other author works	53
Pictures and graphics without explanation of evaluation metrics	19
Analysis of system accuracy percentage	78
Self-developed evaluation metrics	50

Lei Wei in his paper "Evaluation of Detection System" (Wei, 2007) suggests his mind, six key criteria:

- **Effectiveness.** IDS are able to detect attacks and the percentage of false alarms.
- **Efficiency.** IDS should consume less time and memories to detect intrusions and to report warning messages.
- **Ease of use.** An intrusion detection system should not be too hard to allow a user who is not a security expert to operate it.
- **Security.** An Intrusion Detection System that has the ability to defend.
- **Interoperability.** An Intrusion Detection System is able to interoperate with another one in some extension.
- **Collaboration.** IDS may be brought with other security mechanisms together to enhance computer system security.

During this research has been discovered such criteria like system scalability, intelligence, signature and rules updates etc:

- **Scalability.** Nowadays are so many growing institutions with lot of branches, but with one local network, so it should be possibility to add new segments to network and monitor them through single interface.
- **Modularity.** System must be dynamic. It is great risk if such system is static and if once system is implemented it won't be possible to change it to our particular needs.

Such criteria can be made even more in specific situations, for example if we evaluate some commercial products so it will be necessary to look also on available support and update availability to this product or if it is hybrid or signature based system so it is important to know about signature updates.

Criteria are important part of evaluation process, but we believe that most important part of IDS evaluation is setting testing objectives, it is necessary to collect enough background information before testing. Lei Wei in the same article (Wei, 2007) propose framework for automatic IDS evaluation which shown in "Figure 2". To get a report about the test result, there are around ten steps:

1. The process chooses a malware to attack the target system and sets configuration of the target system.
2. The process uses a sandbox, VMware, to build a virtual network for a test.
3. The evaluation system sets the attack configuration on the virtual attacker.
4. The virtual attacker machine attacks the target and, meanwhile, the traffic traces are documented and recorded by the system. Alarms raised by IDS are also collected.
5. The recorded data are saved into a data set in the shared disk.
6. The virtual attacker and target machines are restored to their initial configuration for next round of test.
7. IDS Evaluator picks out all the traffic traces of a test case from the data set.
8. The IDS Evaluator put those traffic traces to the tested IDS.
9. IDS Result Analyser gets those traffic traces as well as the alarms generated by the IDS. It compares the traffic traces against the alarms to figure out the number of intrusions are detected by the IDS in the test scenario.
10. The evaluation framework generates the report.

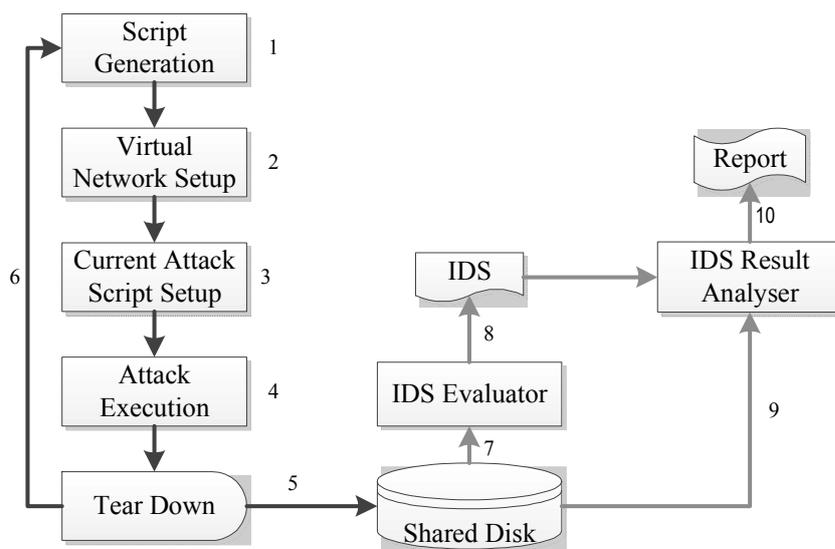


Fig. 2. The working process of Automatic Intrusion Detection System (Wei, 2007)

The main problem in automatic evaluation is that there is missing IDS analysis within particular infrastructure. Even if we make automatic evaluation and comparison with other systems anyway network infrastructure should be analysed. We extended this process with five more steps which can be seen in "Figure 3". Such automatic evaluation can be done if it is necessary compare some systems, but not for implementing system in organization network infrastructure. New security approaches should match the nature of the security problems, capable of adapting the strategy to new threats/attacks and of generating solutions dynamically. Each new service can include different compositions of many new technological equipment and software solutions, and these compositions entail different complex threats and risks. The composition of services does not necessarily imply that the upper services inherit the security attributes of its components. Each new composition adds and amplifies vulnerabilities and threats, and therefore each new service would require a specific security analysis (Atay and Masera, 2011). Evaluation process should start from gathering user requirements for their network infrastructure and get information about environment characteristics and specific of NIDS, for example system type or architecture. (see Figure 3). From gathered information correct objectives and evaluation metrics can be set. Just after these steps can be started script generation and setting up of testing environment.

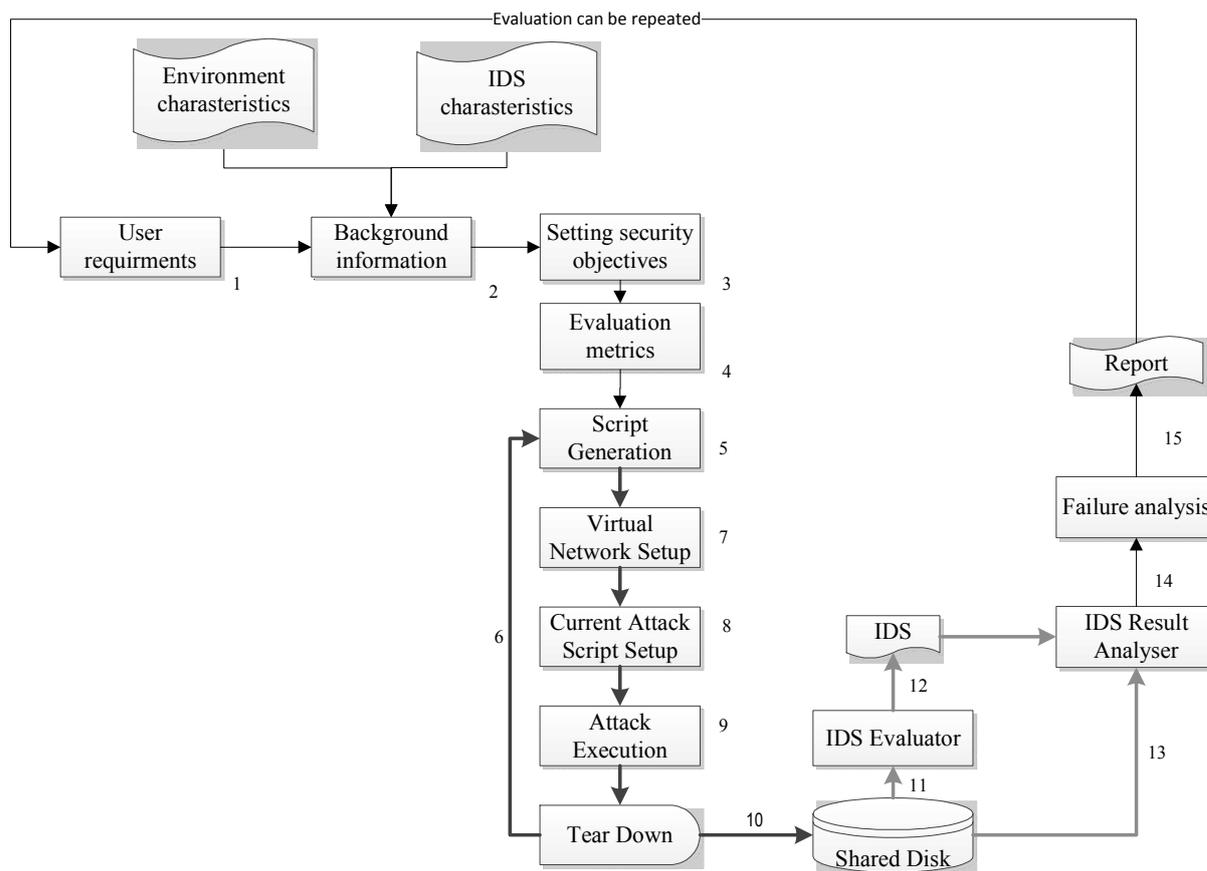


Figure 3. NIDS evaluation for particular network infrastructure.

Conclusion

Implementation and evaluation of NIDS is difficult task, because of different types of systems and granularity of testing requirements. Analysing information about experimental research in NIDS, great difference and many disadvantages in NIDS evaluation was discovered. Most of the papers contain just part of system evaluation and do not cover enough background information. Such disadvantages do not provide experimental repeatability and reduce validity of collected data.

This research also showed that IDS evaluation for system implementation in particular environment also must be collected background information before evaluation and evaluation criteria set up. Finally, such evaluation must be repeated after results analysis and discovering of failure situations.

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BALLOON LAYOUT GENERALIZATION FOR PRACTICAL GRAPH DRAWING APPLICATION

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Abstract: *Graph drawing model used in practical applications is different from the one usually considered in theoretical research. In this paper we draw attention to the main differences between these two models and consider practical implementation of graph balloon layout style while using realistic drawing graph model. Balloon layout is used as a base for more general graph layout style for real-life applications. Various graph classes and important practical metrics are used to compare proposed graph layout style with other graph layout algorithms.*

Keywords: data visualization, graph balloon layout, graph drawing, node placement.

Introduction

In theoretic papers authors usually try to prove just some layout properties on really specific class of graphs. Most typical graph classes that are considered are trees, planar graphs and sparse graphs and even if more general graph classes are used only small graphs are taken into consideration. This approach is not good enough for practical applications because users that are not experts in graph theory or even computer science should not have to know the difference between graph classes and there should not be restrictions that graph layout can position a graph, but cannot perform layout on the same graph with just one additional node or edge. Also limited number of nodes usually hides practically unusable time complexity of the algorithm. While analyzing theoretical properties of the algorithm we can wait relatively long just to produce the best possible result but in practical applications we have to take into consideration usability property - users do not want to wait long for perfect layout, they want to be able to trade performance for quality.

Necessity for layout described in this paper appeared when we noticed that existing cluster layout produces easy to spot layout problems and produces crossings between inter-cluster edges. Our existing cluster layout consists of five steps. During first step all nodes of input graph are divided in clusters where similar nodes are put in the same cluster but different nodes are positioned in different clusters. Such clustering approach generally means that most of edges connect two nodes in the same cluster, but just few edges connect nodes of different clusters. The second step of cluster layout algorithm positions each cluster separately. Third step creates cluster graph that substitutes each cluster of nodes with single large node that is as large as positioned cluster. Produced cluster layout consists of large nodes and inter-cluster edges. Typically cluster layout is tree graph or sparse graph. The fourth step is to position cluster graph and the last fifth step positions all nodes from initial graph according to cluster position and its relative position to cluster center. Our purpose while developing algorithm presented in this paper was to create algorithm that would guarantee better cluster node placement and that we could use in the fourth step of previously described cluster layout. Our goal was to create algorithm that would position clusters in such way that if inter-cluster edge is bridge then nothing can cross it. This condition is important because bridges connects two otherwise independent subgraphs and such crossings are eye-catching even for inexperienced user and also it would guarantee that if cluster graph is tree then it is guaranteed to be laid out without any crossings. Balloon layout style (Lin, 2005) could fulfill almost all necessary properties, but it was not suitable for graphs other than trees so in this paper we describe our approach how we tailored this balloon layout suitable for general graph class.

This paper is organized in following way: second section contains definitions of the most important terms used in this paper. In the third section problem statement is defined and motivation for each requirement is explained, but in fourth section the details of the new algorithm is discussed. The fifth section contains experimental results that we produced while testing the implementation of the new algorithm.

Definitions

In this paper we consider **graph** G as a pair of sets $G = (V, E)$. V is set of nodes and E is set of edges $E \subseteq V \times V$. Each edge is unordered pair of nodes. We say that graph G does not contain **self loops** ($\forall v_1, v_2 \in V: (v_1, v_2) \in E \Rightarrow v_1 \neq v_2$) and is **connected** (between any two nodes v_1 and v_n there exists list of nodes: $v_1, v_2, v_3, \dots, v_n$ such that $\forall i \in [1, n]: v_i, v_{i+1} \in V \& (v_i, v_{i+1}) \in E$). n will be used to describe number of nodes in the graph ($n = |V|$).

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Graph G is called a rooted tree if it contains one root node r , every other node v in graph have exactly one parent node $p(v)$ and root node r is ancestor of every other node v in graph: $r = p(p(\dots p(v)))$.

We call graph G a *geometric graph* if each node has positive radius value.

A graph is called sparse if its edge-node ratio $\frac{|E|}{|V|} \leq 1.1$.

Cluster is set of nodes that have similar properties, we assume that *clustering function* $c: V \rightarrow \mathbb{N}$ is already defined and for each node in graph G we can find out its cluster number. We consider that two nodes v_1 and v_2 are in the same cluster if and only if $c(v_1) = c(v_2)$.

Graph $G = (V, E)$ with clustering function c defines *clustering graph* $G' = (V', E')$ such that for each cluster x in G there is node $n_x \in V'$ and for each edge $(u, v) \in E$ there is edge $(n_{c(u)}, n_{c(v)}) \in E'$ if and only if $c(u) \neq c(v)$.

Problem statement

We can define our problem as follows: we need to create layout algorithm that could be used for positioning cluster graph.

During our research we defined our problem as requirements for layout algorithm. We need to create layout algorithm that would have following features:

- Nodes would be positioned in force directed-layout-like style (Eades, 1984, Eades 1997);
- Algorithm would guarantee that graph bridges are positioned without crossings;
- Running time would be good enough to lay out graphs with up to 1000 nodes;
- It is possible to define neighbor cyclic order constraints;
- Layout algorithm have to be able to lay out general graph not only some specific graph class;
- Users have to be able to set minimal distance between nodes;
- Layout algorithm has to take into account aesthetic criteria.

We ask for symmetric-like node positioning style, because of two reasons. Firstly because in current version symmetric or force directed layout style (Eades, 1984, Eades 1997) is used to place cluster nodes so with new layout style users should get similar experience and secondly one of symmetric layout features is that similar subgraphs are laid out similarly. Guarantee to position planar graphs without crossings would reduce number of obvious layout problems in produced drawings and make new layout superior over previous implementation, because previously it could not guarantee such feature. In theoretical research running time is usually overlooked because produced drawing properties are considered far more important than performance, in our case it is critically important to take into consideration worst case running time of the algorithm even before it is implemented to understand if users will wait until algorithm produces the result. Exact values were chosen by following computations - assume that users typically will layout graphs with no more than 1000000 nodes ($n = 1000000$) and clustering will divide them into roughly \sqrt{n} clusters, that means in cluster graph we will have to layout graph with about 1000 nodes. And typically user would not mind to wait 1 second for layout, but it would not be satisfied if they would have to wait more than 5 minutes, so we should get algorithm with running time not much worse than $O(n^2)$. We have to be able to set cyclic order of neighbors because when we position each cluster separately we fix node relative positions and when we merge cluster layout result with cluster internal layout results we can rotate each cluster around its center, but we cannot change the order of nodes. Cluster graphs typically are sparse graphs, but still we cannot make any assumptions about some specific graph classes so unlike in theoretical research we have to produce layout that will support any graph. Since users may have their individual preferences on how close clusters should be positioned to each other, we have to provide an option for this. In graph drawing there are many aesthetic criteria that users consider as granted so we have to take that into consideration while designing new layout algorithm (Di Battista, 1999). Since it may not be possible to fulfill all aesthetic criteria at once we have arranged them in decreasing order by importance.

1. Node-node overlaps;
2. Node-edge crossings;
3. Edge-edge crossings;
4. Minimize edge length;
5. Minimize number of edge bends;
6. Minimize area of bounding box;
7. Minimize perimeter of bounding box;
8. Minimize angular resolution of edges;
9. Symmetry.

Necessity of first two aesthetic criteria is obvious, because such crossings and even overlaps can confuse user and it might mislead to some wrong conclusions. For example, node-node overlaps may easily look like single node even though there are two of them positioned one over another. Node-edge crossings can introduce unexpected problems in determining between cases when there are two edges connected to single node or there

is one edge that crosses some unrelated node. Edge-edge crossings, edge length and number of bends reduces readability of drawing, because if edges are longer or have more bends and they crosses more than necessary then it is more difficult to follow the path between nodes. Since these three criteria may contradict one another we have chosen this order of preference when we do not mind to have longer edges if that allows us to draw them without crossings and also we want to add bends whenever that makes edges shorter. The last group of criteria is meant for practical usability. No matter if the user chooses to print the produced drawing or manipulate with it dynamically in application he or she will almost always have rectangular canvas so it would be better if laid out graph would fit into smaller rectangle, because then users in the same area would see larger part of whole graph or the same graph can be viewed in larger magnification. Perimeter of bounding box is similar to previous criteria only for two layouts with equal bounding box size it will prefer the one with smaller difference between width and height. This feature comes handy when we could have drawings of the same graph with bounding box 2×20 and 5×8 then we would choose 5×8 , because typically screen and paper sheet aspect ratio is roughly 3:4 or 9:16. Finally angular resolution makes it easier to distinguish edges at lower zoom level and on devices with smaller resolution.

Modified balloon layout

After research of available literature we came to conclusion that balloon layout (Lin, 2005) already fulfills many requirements. It supports minimal node distance constraint, positions nodes without crossings and can lay out trees planar also its performance is good enough to layout trees with required size. All the rest of requirements and aesthetic criteria could be met if we would apply some extra computation phases around much studied balloon layout. So our solution to previously defined problem where we need to position clusters nodes is to create new graph layout algorithm (Modified balloon layout (MB)) that would be based on balloon layout. The new algorithm should preserve useful properties of balloon layout while supporting additional requirements. First major difference between balloon layout and the new MB layout would be that MB layout would work for general graphs, it would support neighbor cyclic order constraints and would position planar graphs planar not only trees.

Our implementation of MB layout consists of three distinct phases. The first phase is initial preparation phase that prepares input graph in convenient state for next phases. The second phase is extended balloon layout phase when all nodes are positioned using updated balloon layout, but the final is edge routing phase when all edges are routed according to fixed node positions. Each of these three phases is discussed in following chapters where we describe encountered challenges and our solutions in more detail.

Initial preparation phase

Initial preparation phase is used to transform input data to more convenient form for next phases. As described previously in the input we can get any graph, positive number value that determines node spacing and collection of nodes that define neighbor cyclic order. Although second phase of MB layout runs updated balloon layout it still can process only rooted trees with circular nodes so we need to transform input graph G to some other rooted tree G_1 and additional edge list L_1 where we will put those edges of G that are not used to create G_1 . Additional edges will be used only in the final phase when they will be routed.

First step in conversion from input graph G to rooted tree G_1 is node transfer when we copy all nodes from G to G_1 and add half of node spacing value to the radius of each node in G_1 . We do this node enlargement in order to fulfill node-node spacing constraint, because even if two enlarged nodes touches each other they still preserve user defined node spacing between original nodes. This node enlargement technique is widely used in practical applications when implementing algorithms from theoretical research, because often in theoretical research nodes are considered as just points in plane.

Next step is to find rooted spanning tree in graph G . To find the best root we assumed that it should be in some sense the most central node in the graph so that all its children subgraphs would be of equal size or depth. We tried two different approaches for finding the root: the first was to take as root node with the largest number of neighbors, but the second was to compute graph center node and choose it as root node. After practical experiments with different graphs we came to conclusion that center node of graph usually divides it better than node with the most neighbors and final drawing is more compact so we chose to take graph center as root for spanning tree. Since we do not depend on any specific graph center property except for the feature that center node is located relatively close to all other nodes we use approximated graph center finding algorithms (Boitmanis, 2006). After root node is chosen breath-first-search algorithm is started from root node to find all child-parent relations between all nodes and define rooted tree. In figure 1 A is root and solid lines mark parent-child relations.

The last step of the first phase is to determine child order. For some nodes in input graph necessary neighbor order can be fixed so it has to be maintained during conversion from input graph G to rooted tree G' . For those nodes that does not have fixed neighbor order it should be computed in order to shorten additional edge length. Child order is computed using PQ-tree data structure (Booth, 1976). For each node in G' separate PQ-tree is created and it describes all valid child orderings. Afterwards all additional edges are processed and for each edge

its logical path is created. Logical path in tree goes from source node to target node and it contains all sibling nodes between source and target nodes. Logical path between nodes **H** and **M** in Figure 1 is marked with dashed line. For top most layer of logical path in respective PQ-tree constraint that C and E nodes have to be next to each other is inserted. For all other levels constraints that H node has to be at the end and M should be in the beginning of children order are inserted. When all additional edges are processed PQ-trees define optimized child orderings that is used for setting children order in rooted tree.

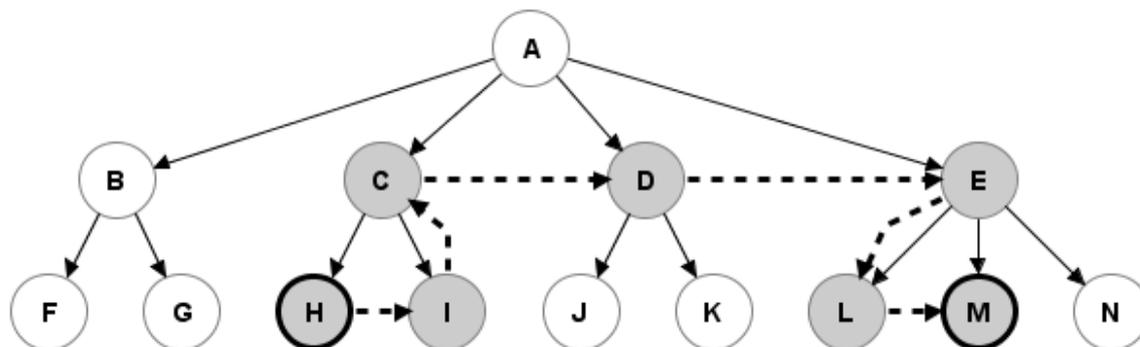


Fig. 1. Example rooted tree with 13 nodes.

Node placement phase

From previous preparation phase this phase receives only rooted tree with defined children ordering. Node placement phase is responsible for creating as compact node placement as possible while preserving planarity. Each node is laid out individually and each node layout consists of two steps in the first step correct starting position is created, but in the second step children positions are improved to make the drawing more compact. Both of these steps are applied for each node and all tree nodes are processed bottom up. First start by processing all leaf nodes, but all other nodes process only after all children nodes are processed. This traversal processes each node only once and allows to use previously computed results that were acquired while positioning children. While processing a node all computations related to this node are done in normalized coordinate plane where node is located in coordinates $(0,0)$, ray from $(0,0)$ to $(-\infty, 0)$ goes to the parent and cannot be crossed by any edge or node from processed node's subgraph this guarantees that it will be possible to position parent somewhere on x axis in its negative range and obtain planar drawing.

Both steps of leaf node layout are trivial, because leaf node is positioned in the origin of the coordinate axis and convex hull of the node is calculated (de Berg, 2008). Node placement phase for leaf nodes can be done in $O(1)$ time, because convex hull can be approximated by predefined (constant) number of points on the circle and that are placed in regular intervals.

Placement of non-leaf nodes is significantly more complex. The first step balloon layout of children subgraphs is computed when all children subgraphs are positioned around the parent node. To position all children around the parent node it is necessary to find minimal acceptable distance that convex hulls of the children subtrees do not overlap and none of the children subtrees overlap with the parent node. Such minimal distance with acceptable precision can be found using binary search. If there is still some space left around currently processed node after all children nodes are positioned it is important to decide how to use it. While implementing algorithm several different approaches were investigated and the best approach was to center align unused space around negative x axis. This approach allows to improve layout compactness around nodes with small number of children.

After the first step all children subgraphs are positioned around the parent node in equal distances and satisfies planarity requirement. The second step tries to improve node compactness by moving children subgraphs towards the currently processed node. Children movement is done in strictly determined order. Children are ordered in ascending by their degrees if there are multiple nodes with equal degree then children nodes placed with even position numbers in children order list are moved before children with odd position numbers in children order list. This ordering experimentally showed the best results and was accepted by users, because smaller subtrees e.g. leaves tend to be closer to the parent node than larger subtrees. It is obvious that degree of subtree's root node doesn't represent the size of the subtree, but in this case large chain subtree is not that different from single leaf. When moving child and its subtree towards the parent all computations are done in normalized plane of the child. In normalized plane child subtree's convex hull is moved along the x axis along towards $-\infty$ and is constrained by five objects: convex hulls of the left and right siblings, rays that connect left and right siblings with parent node and circle that represents parent node. Child can be moved to the left (towards $-\infty$) until the convex hull of the child touches to any of these five objects.

When all children are moved all child convex hulls are merged together and saved.

Edge routing phase

This is the final algorithm phase where all edges are routed. Edge routing in this phase is two-step process. First step is to find logical path in routed spanning tree between source and target nodes. Logical path in this case means such path that goes around all nodes and their subtrees that are between source and target nodes. For example in Figure 1 logical path for additional edge from H to M would be H, I, C, D, E, L, M. It is easy to see that if all logical paths on chosen rooted tree is planar and then produced drawing is also planar. The second step of edge routing process is their optimization when we delete all those edge bends that do not introduce any edge-edge or node-edge overlaps. Figure 3a illustrates result after the first routing step, but Figure 3b demonstrates the final layout result.

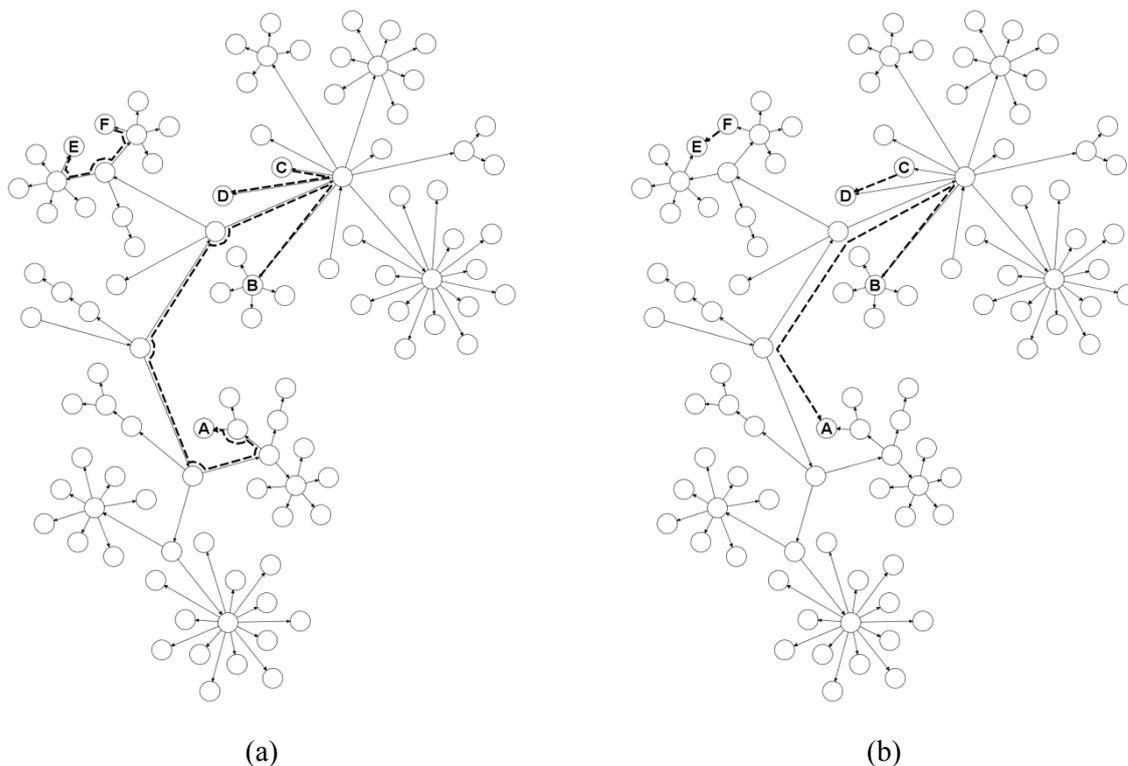


Fig. 3. Layout result during and after edge routing

Experimental results

In this part our algorithm's practical properties are analyzed. Since in practice both layout performance and quality is equally important we created testing environment to evaluate both aspects.

Performance

Performance of proposed layout algorithm was measured using random graphs of various sizes, but with fixed edge-node ratio. Edge-node ratio was chosen to be 1.1, because cluster graph usually is sparse graph and these graphs represent tree graphs with some additional edges. Measured average running times can be seen in Table 1. Running times for each graph size were obtained by running layout on collection of graphs with the same size and calculating average running time. As Figure 4 illustrates running time of proposed cluster graph layout is $O(n^2)$ and suggests that it could be used for graphs with couple of thousands of nodes.

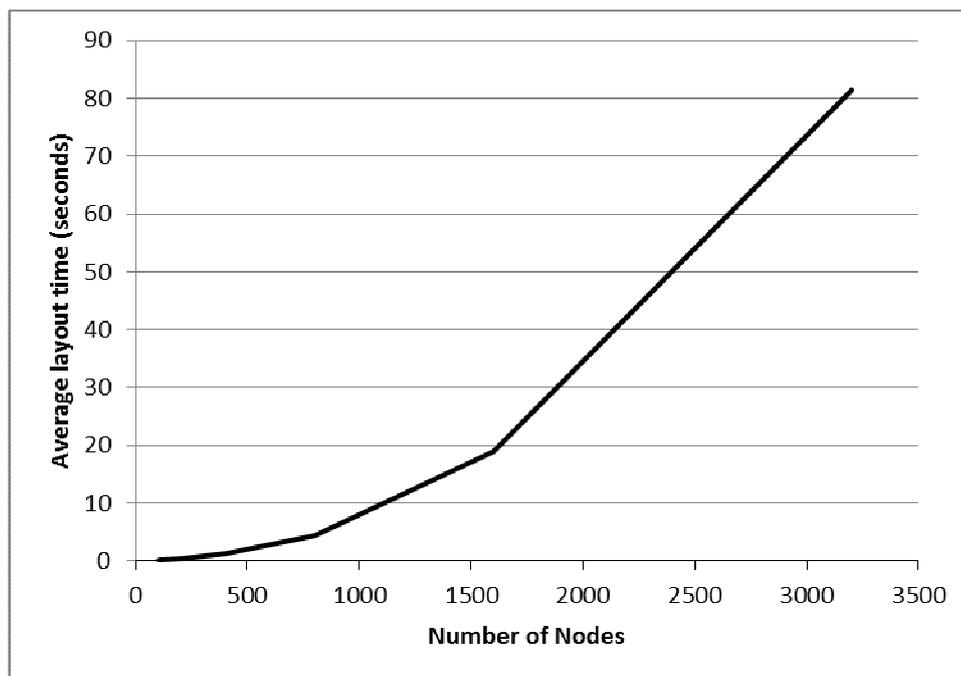


Fig. 4. Average layout time for sparse graphs.

Table 1

Average layout time for sparse graphs	
Number of nodes	Average layout time (seconds)
100	0.14
200	0.38
400	1.28
800	4.39
1600	18.98
3200	81.42

Drawing quality

To evaluate new layout's compactness it is compared with author's implementation of balloon layout (Lin, 2005). To produce balloon layout children position improvement phase is omitted. Both algorithms: balloon layout and algorithm presented in this paper (Modified balloon layout) is compared on various tree classes. Tree graphs are used to compare algorithms because of two reasons, firstly, balloon layout works only with trees and, secondly, additional edges in input graph does not require any additional space in produced drawing produced by Cluster layout so it is not necessary to add them to compare layout results of these two algorithms. Various tree classes were used because they have different properties and can test algorithms in different scenarios. Both algorithms were compared on the same set of graphs and average edge length was used to measure compactness of the graph. Average edge length was used because it is the most important aesthetic criteria of those aesthetic criteria that need to be optimized according to the previously defined aesthetic criteria priorities.

Test graph types

For compact drawing there are two different compactations needed, because there can be algorithms that can either compact siblings or compact parent and children. To test both these cases we have selected three classes of trees: random trees, trees with many children to test sibling compaction and trees with long chains of nodes to test parent-child compaction performance. Trees with many children will be called children trees, but trees with long chains will be called chain trees.

Random trees

Random trees are generated using random number generator. For each node, except the root node, randomly choose its parent node. This type of trees was used to test algorithm's results for general trees. In Figure 5 is visible how changes average edge length when size of graph increases. Table 2 contains aggregated test results that were used to produce Figure 5. As it can be seen Modified Balloon layout according to this aesthetics criteria is about 25-30 per cent better than Balloon layout.

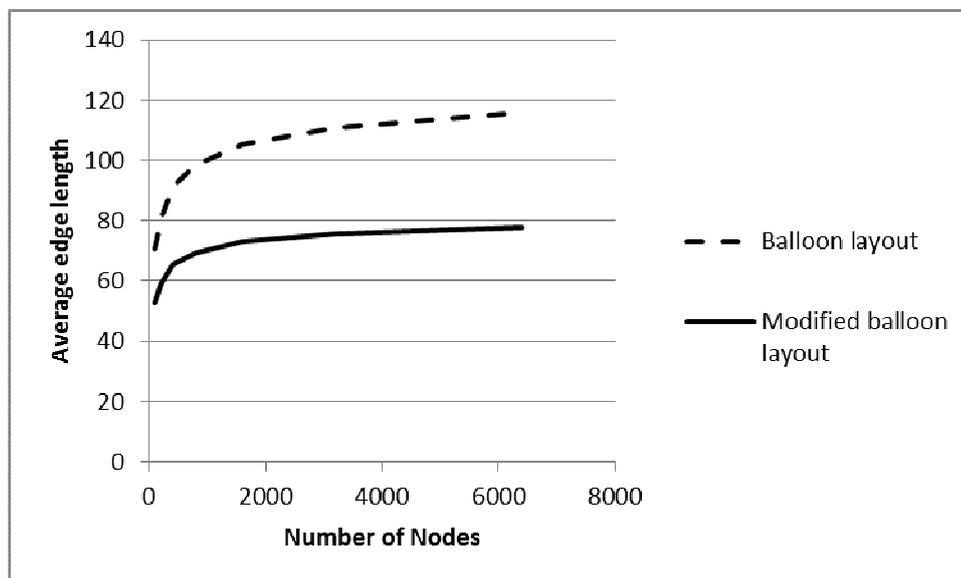


Fig. 5. Average edge length of random trees.

Table 2

Number of nodes	Average edge length	
	Balloon layout	Modified balloon layout
100	70.54	52.69
200	80.83	59.29
400	91.25	65.53
800	98.53	69.44
1600	105.39	73.04
3200	110.79	75.84
6400	115.88	77.91

Children trees

Children trees are generated using random number generator and child probability value. For each node we generate random number from range $[0,1]$ and while the generated value is less or equal to the previously chosen child probability value add new child and generate next value. With child probability **0.75** generated trees have relatively small diameter value and large number of leafs. This allows testing algorithms for their ability to compact large number of differently sized children around the parent. When looking from parent's perspective children typically are wide so it is necessary to position them in such way that there are enough room for everyone around the parent and no two child subtrees overlap with each other. Figure 6 illustrates typical children tree drawing produced with Modified Balloon layout. In Figure 7 it is visible how average edge length changes when graph size increases, but in Table 4 are the data used to produce Figure 7. We can notice that average edge length in children tree drawings produced by Modified Balloon layout is by 25-30 per cent better than Balloon layout. Although relative improvement on children trees is consistent with random tree testing results, average edge length for children trees is longer, because typically there are more children around one parent node than in random trees.

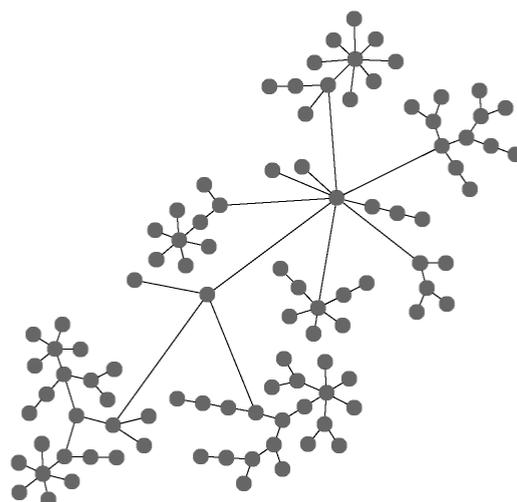


Fig. 6. Typical children tree layout result with Modified Balloon layout.

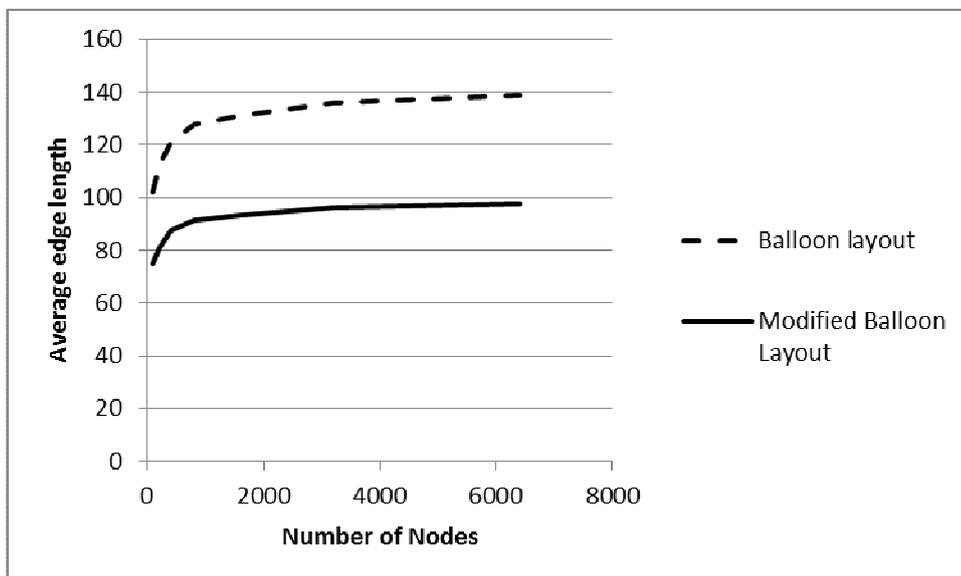


Fig. 7. Average edge length of children trees.

Table 3

Average edge length of children trees		
Number of nodes	Average edge length	
	Balloon layout	Modified balloon layout
100	102.02	74.72
200	112.06	80.83
400	120.93	87.41
800	127.44	91.08
1600	131.24	93.44
3200	135.76	96.21
6400	138.68	97.81

Chain trees

Chain trees are such trees that are composed from chains of nodes. These trees have large diameter and small amount of leafs and majority of nodes has degree equal to 2. This property makes this type of trees useful for testing algorithm's ability to choose the optimal root vertex and pack chains of nodes. When looking from parent's perspective typical child is very narrow but long so it is necessary to be able to divide the free space

around the parent so that all children would be positioned in symmetric manner. If the free space around the parent is not divided equally for all children then this can be easily seen in the final drawing that in such case does not look similar to drawings produced by force model based layouts. Figure 8 illustrates typical chain tree drawing that is created using Cluster layout. In Figure 9 it is visible how average edge length changes when graph size increases, but in Table 4 are the data used to produce Figure 9. For chain trees Modified Balloon layout produces drawings with about 15-18 per cent shorter edges, this result is slightly different from testing results with other tree classes, but it can be explained by the fact that average edge length for chain trees is significantly shorter than for children trees and children doesn't have to "fight" for the space closer to the parent.

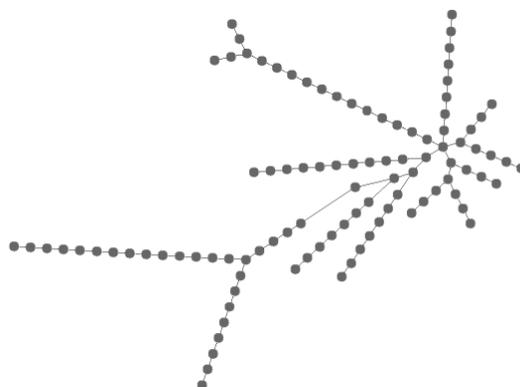


Fig. 8. Typical chain tree layout result with Modified Balloon layout.

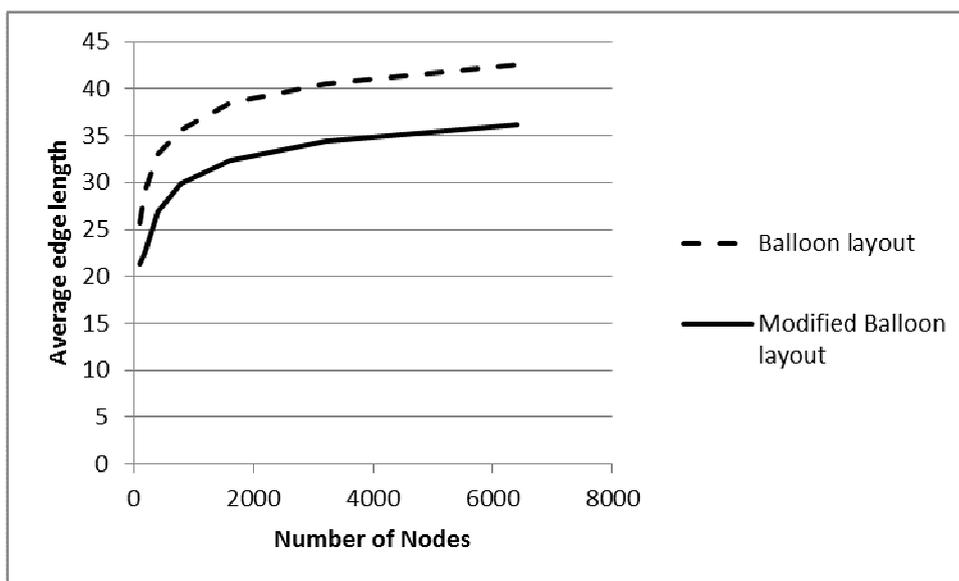


Fig. 9. Average edge length of chain trees.

Table 4

Number of nodes	Average edge length	
	Balloon layout	Modified balloon layout
100	25.70	21.29
200	29.09	22.49
400	33.05	26.92
800	35.63	29.89
1600	38.44	32.37
3200	40.49	34.33
6400	42.57	36.10

Conclusion

Cluster layout algorithm presented in this paper has several important qualities that makes it useful in practice. The most importantly this layout guarantees that bridges will not overlap with any other nodes and precise node spacing values. Produced drawings have good angular resolution and symmetry. All of these features could be achieved because this layout is combinatorial graph layout algorithm that works only with graph topology and do not use any random heuristic process. Performance testing results revealed that presented algorithm could be used in applications for laying out sparse graphs with couple of thousand nodes. This suggests that this layout could be successfully combined together with widely used cluster layouts to position clusters. Performance improvements and support for new constraints are possible topics for further research. If presented modified balloon layout would produce drawings for large graphs in reasonable time and support drawing aspect ratio constraint it would make this algorithm more useful as standalone graph layout.

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BUSINESS EVOLUTION SUPPORT WITH MYSQL TECHNOLOGIES

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Abstract: Thesis describes possible solutions for adopting existing local enterprise applications from single branch usage to two (or more) branches with shared data without modifying code of client applications. Possible solutions and their weaknesses will be described and compared.

Keywords – MySQL, federated tables, triggers, replication, adopting software.

Introduction

Small companies usually start their business as a local company. Often client application with local MySQL database connectivity is used in such companies. As application is developed by external company, almost always source code is not available and there is no way to change major data processing functionalities in compiled client application.

When business has success company grows and often wants to spread its market geographically. Along with that there appears requirement for using some common database data (for example product catalog) in all branches but some other part of data separate for every branch (as an example may be orders, customers and etc.). In addition, some fields of common data can differ from branch to branch (such as VAT, discount). Adopting existing client application by external company requires high expenses as software development, especially when in such special cases, has high costs. Choosing the way how to adopt existing information system becomes quite complicated.

Real life example

As an example there will be described some facility which manufactures certain products for local market and is located in certain site. Information system already exists in the facility and is based on MySQL database server and was developed for current locale (as shown in Fig.1.) for storing products, orders and customers.

After a certain time facility grew and opens new branch site in other place (city or country) to expand their products' market. Now there are some definite problems. First of all, both offices need to access database. Secondly, all branches require access to common data – products, but they all need separate data storage for customers, orders and other local information. Third major problem is when internet connectivity between two offices is not at broadband level – this will lead not only to slow response in client applications, but also to possible blocking of work if internet connection with database will be lost.

In the next chapter author will suggest two distinct possible solutions for solving this problem.

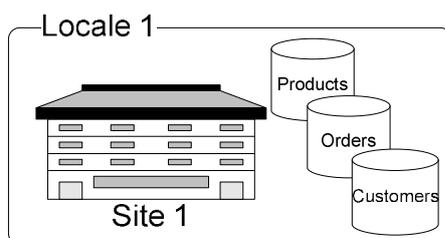


Fig. 1. Example of a local system solution.

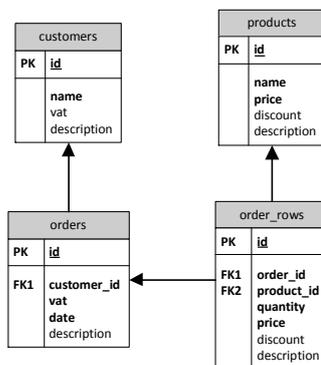


Fig.2. Example of an ER diagram.

Possible solutions

First and the easiest solution is to continue using existing information system architecture – independent local databases (as shown in Fig.2.). Every office will have independent databases and workflow will be not affected.

This solution definitely has some weaknesses:

- * If some data in products changes then all other branches require performing these changes manually in their local databases or require some additional functional tools for handling that (this comes from requirement for common data as described in 0.Introduction);
- * Some changes can be lost due to “human” factor especially if changes are made in all branches (as this operation is not automated);

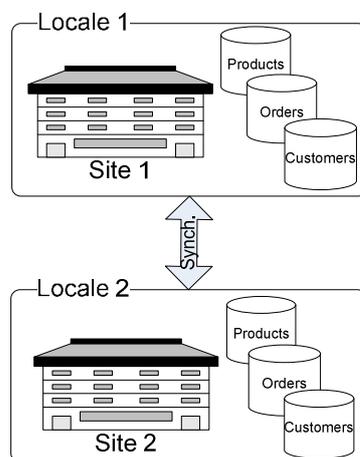


Fig.3. Independent branches.

- * Data synchronization is required to check data consistency, which will add redundant work hours to personnel;
- * Databases' administration will require additional efforts from system administrators.

On the other hand, solution has also positive points:

- ✓ Easy setup of system. Company do not need to change any client application or database application parts;
- ✓ Application response speed does not change², because each branch has separate database, which is not affected by any external load.

Second suggested possible solution is to use existing database as one shared database for all branches (as shown in Fig.3.). All data will be located in one location but accessed from multiple sites. This solution has following major weaknesses:

- * If branches perform intensive operations with database, then there will be problems with internet connectivity and information system performance due the lag of connections (if internet connectivity between two offices is not at broadband level);
- * If central database stops working or becomes inaccessible then all other branches will not be able to perform any operation on data. This will definitely stop office work;
- * Product information can include some information fields which are based on locale (for example VAT, discount) – to support this improvements are required for client information system for processing different versions of data for each locale;

The second also has positive moments:

- ✓ Administration of the system is simplified – administrator do not need to manage multiple database instances;
- ✓ Company has global representation of all information in all offices. Managers can access business critical information such as total income, total expenses and etc.

²We are not considering hardware differences there.

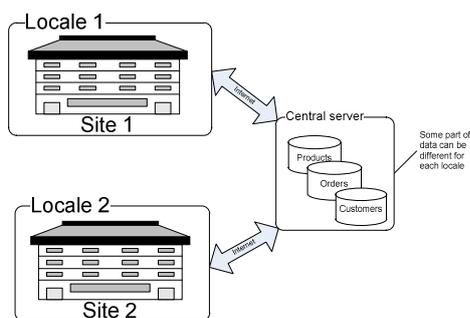


Fig.4. Example of a central system solution.

Suggested solution

Author suggests one more solution for this problem – invent some changes to the database because it is always open for modification as opposite to client application. By adding MySQL federated tables (<http://dev.mysql.com/doc/refman/5.1/en/storage-engines.html>) and replication (<http://dev.mysql.com/doc/refman/5.1/en/replication.html>) mechanisms to existing database most of requirements without having most weaknesses can be achieved. The idea is to separate tables which store common usage objects into one central database, make it as replication master server (as shown in Fig.4.). After that all branches will work with replication slaves – which will be MySQL servers installed in branch locations.

Technics

Every branch has local database plus one central database for products as described in previous chapter. For accessing central data (products) will be used Federated table storage engine 0 which provides access to remote database's tables without managing separate connection in application – this way there are no requirement for changes in facility's client application. This approach separates application's data access layer from physical database architecture. Federated tables will be used only for modifying central information (products). Replication will be setup for central data tables for all replication slaves (databases in branches). When updates are made from one location to federated table, then these changes are automatically replicated to all other branch databases and there is no need for any synchronization or manual work. Client application will execute update queries on local tables. To intercept these queries author will use triggers (<http://dev.mysql.com/doc/refman/5.1/en/create-trigger.html>) on local tables (only on replication slaves) which will resend the modifications to central server, which in turn will replicate changes to all slave servers (branches). This approach also provides possibility to separate locale based fields from common fields in central data (for example when changing all fields of products it is possible to send only specific fields' modifications to central server like name, quantity, but other changes can be applied only on local data, like VAT and discount, which are based on locale).

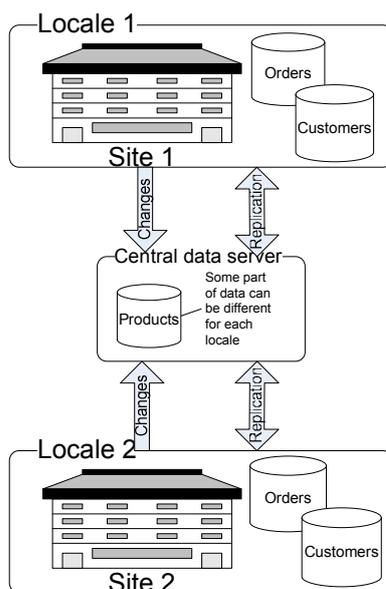


Fig.5. Suggested solution.

Comparison

Let's compare solutions and make the right choice. Author chose the following criteria (author's subjective criteria) for comparison of solutions:

- ✓ Performance (A) – how client application response speed will be affected by inventing solution;
- ✓ Efforts (B) – efforts required for implementation;
- ✓ Support for different field values in common data (C) (such as VAT, discount) – if no, then this actually eliminates solution, because it is a requirement (as mentioned in Introduction);
- ✓ Dependence on internet connectivity (D) – how important is to have internet connectivity all the time and how lack of it affects branch's work;
- ✓ Common data synchronization (E) – probability that common data is out of sync between offices;
- ✓ Support efforts (F) – efforts required to maintain solution after it is configured.

For each criteria there will be provided appropriate rating from 1 to 5, where 5 is the best rating (author's subjective rating). The table below shows solution comparison.

Table 1

Comparison of solutions							
Solution	A	B	C	D	E	F	AVG
1. Separate servers	5	3	5	5	1,5	1	3,42
2. Central server	3	5	0	1	5	5	3,17
3. Replication	4	3	5	4	4	4	4

Now more details about each criteria rating:

- Performance – second solution got rating 5, because application response speed does not change³, all branches are independent. Third solution got lower rating, because only product modifying speed is affected there, reading and modifying local data performs at the same level. First solution has the lowest rating because speed is influenced by two factors – internet connectivity and data amount stored in database;
- Efforts – first solution got the highest rating, because there is no efforts to start using central server (just connect to it via IP address and that's all). Second and third solution got lower ratings because each solution requires configuring and administrating separate servers;
- Support for different field values in common data – first solution cannot provide such functionality, because there is only one server. First solution got 0 points there, but second and third solution got maximal rating, because they provide that functionality;
- Dependence on internet connectivity – second solution is the best, because there are no any dependencies on internet connection for system functionality. First solution got lowest rating as it is high dependent on internet connection and both speed and possibility to work is influenced by internet. Third solution is also dependent, but dramatically less than first – connectivity is only required for updating common data;
- Common data synchronization – first solution leads in this position, data synchronization is not required at all. Second solution is the worth case for this criteria because it requires manual synchronizing or using additional tools / software. Also second solution never can provide near real-time synchronized data. When branch count grows situation becomes even worse. Second solution got only 1,5 points. Third solution performs that automatically and provides almost real-time data synchronization, but requires initial configuration, so why it gets only 4 points of 5;
- Support efforts – minimal support efforts are caused by first solution (efforts do not differ from initial). Second solution will require efforts associated with data synchronization, consistency checking and similar staff. Third solution adds only additional standard servers' administration and if configured correctly do not require any additional work.

Basing on the comparison table above we can conclude that in most cases suggested (third) solution is the best.

Implementation

Imagine that we have two branches: A and B which locate in different sites. Central server with common data will locate in branch A. Then company will have $N + 1$ (where N is count of branches) MySQL servers to configure.

There follows configuration file (<http://dev.mysql.com/doc/refman/5.1/en/windows-create-option-file.html>) for central server:

```
[mysqld]
port=3333
```

³ We are not considering hardware differences there.

```
binlog-format=MIXED
log-bin = company_log
relay-log = company_relay_log
server-id = 1
replicate-do-db = company
replicate-do-db = mysql
replicate-wild-do-db = mysql.%
replicate-wild-do-table = company.%
basedir="C:/DB/"
datadir="C:/DB/central/"
```

MySQL server configured this way will be started and serve as the central server. Now let's make configuration file for branch's database server:

```
[mysqld]
port=3306
federated = 1
server-id = 2
binlog-format=MIXED
log-bin = company_log
relay-log = company_relay_log
basedir="C:/DB/"
datadir="C:/DB/data/"
```

Configuration files for branch servers are almost identical, except "server-id" variable which must differ for all the servers in replication network.

Local branch servers will be started and server as a local servers for work in branch office. To setup replication we need to execute following query (<http://dev.mysql.com/doc/refman/5.0/en/show-master-status.html>) on master server (central server):

```
show master status;
```

Result will contain two columns which are required for slave setup – "File" and "Position". When we know these values we can execute configuration queries on slave server on every slave server (branch server):

```
change master to
  MASTER_HOST = 'Central.Server.Com',
  MASTER_USER = 'replication',
  MASTER_PASSWORD = 'password',
  MASTER_PORT = 3333,
  MASTER_CONNECT_RETRY = 60,
  MASTER_LOG_FILE = 'company_log.000001',
  MASTER_LOG_POS = 106;

start slave;
```

MASTER_LOG_FILE and MASTER_LOG_POS are filled with appropriate values from previous query⁴. From this moment replication is setup and working, but we need to create federated table and trigger to handle our requirements. First we create a connection for use with federated table⁵ by executing following query on every local database (slave server):

⁴ We consider there that slave servers already have a special user called "replication" with password "password" and "replication slave" privilege.

⁵ We consider there that central server already has a special user called "remote" with password "password" and required UPDATE/DELETE privilege.

```
create server CENTRAL
FOREIGN DATA WRAPPER mysql
OPTIONS(
  DATABASE 'agora',
  HOST '192.168.30.253',
  USER 'remote',
  PASSWORD 'password',
  PORT 3333);
```

After this we can create required federated table to update central data from local sites (also must be executed on slave servers):

```
CREATE TABLE remote_products (
  id int(10) unsigned DEFAULT NULL,
  name varchar(84) DEFAULT NULL,
  discount decimal(5,2) unsigned DEFAULT NULL,
  description varchar(255) DEFAULT NULL
) ENGINE=FEDERATED CONNECTION='CENTRAL';
```

Now we will define required table triggers for slave servers' table:

```
create trigger products_after_insert
after insert on products for each row
begin
  insert into remote_products(id, name, discount, description)
  values (NEW.id, NEW.name, NEW.discount, NEW.description);
end;
```

```
create trigger products_after_update
after update on products for each row
begin
  if (NEW.id <> OLD.id) or
  (NEW.name <> OLD.name) or
  (NEW.description <> OLD.description) then
    update remote_products
    set
      id = NEW.id,
      name = NEW.name,
      description = NEW.description
    where
      id = OLD.id;
  end if;
end;
```

Suggested solution is now implemented and ready for use.

Conclusion

Authors suggested solution allows expanding client application lifecycle. By adding triggers, federated table and replication we dramatically changed functionality of existing client application. We also supported different field values in common data for every branch. Provided example implementation shows how powerful can be these three technics (triggers, federated tables and replication) together when used together.

This solution is very useful when source code of applications is not available or application is not supported by its manufacturer.

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DEVELOPMENT OF BUSINESS LOGIC VALIDATOR MODULE PROTOTYPE

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Abstract: *The aim of the paper is to describe the development of business logic validator module in JAVA that will help ensure process of business data integrity on the bases of evaluation of documents. Insurance of maintainability of different web based information system document validation rules allows administrators to add, edit, delete or simply turn them off without restarting/redeploying application. Before starting the development validation's rule definition language and the rules themselves, it is necessary to analyze the documents used in practice and classify the types of web documents. Template for inspection of web document should be developed, and test algorithms set, depending on the web document templates. There are two main reasons of development of such module. First of them is to improve system's maintainability, and the second is to reduce development time by reducing the amount of equal or similar code that is used for validation. In addition at the same time the amount of errors in the program code decreases. Validation module was developed on the bases of the prototype. It was integrated in several projects. Potential problems of maintainability were observed in practice if the module is based only on static number of tests, even if they cover 90% of necessary tests. Necessity for new tests can appear for system that already has been in production. After implementation of them reinstallation of the application is required. Research was carried out to solve the problem of storage of static methods. Format of storage using an artificial neural network was analyzed as one of the possible solutions. This research is not limited only by validation of document's business logics. Validation module can be used in any other application that requires dynamic validation depending on combination of existing and empty values, or of specific format.*

Keywords: validator, business logic, maintainability.

Introduction

Building the web application of any type requires carrying out validation at different points depending on selected or entered value or value combinations. In case of application of classic style of validation when validation code allowing to validate values is written in web page server side code it is hard to maintain and almost impossible to disable, enable or add check in the form. There are many validation rules that can be repeated many times, for example (*date from* must be greater or equal to *date till*). This type of check appears in any search form which has date interval. Before starting the coding of anything identification of several levels of checks and validations are required:

1. Requirement check;
2. Value maximum and minimum length check;
3. Regular expression check;
4. Specific value or their absence combination checks;

Creation of not only a validation module but entire centralized framework for business web application development is the main idea of the work. One of the first steps is development of the JSP tag library which is bounded with database. That allows administrators to update field labels, make them required or contrary, update minimum and maximum value lengths, set field visual length and define regular expression checks. Additionally to the work already done which satisfies the first three points, the creation of validation module integrated in it is requested that allows addition or edition of validation rules. Afterwards they could be attached to the forms. Since this was something new and there was no way how to create enough preprogramed rules and even if there would be some way they would be constant and alternative was to create own script language and it's parser that would allow combine different rules after what they could be attached to the form.

Materials and methods

As the main idea is to create some sort of script language the first part of the task is creation of parser which is able to parse string type rule into structured program of type of dynamic tree that may be executed. The first operands which should be implemented are basic statements "IF", "AND", "OR", greater (">"), less ("<"), equals ("=") and not ("!"). Definition of some basic checks with these statements is possible, for example Listing 1 shows two basic rules where the first is previously mentioned date span check and the second may be used in user profile edition form where field "user_name" is necessary only during user creation process, and in other scenarios it cannot be changed. Application of only these few statements allows definition of various different validation rules that will be translated to JAVA program structure and stored in application context.

Listing 1

```
IF ((date_from != '') & (date_till != '') & (date_from > date_till) ) THEN {0001#date_from##0}
IF ((user_id = '') & (user_name = '')) THEN {0002#user_name##0}
```

As JSP tag library was already created and all web page request data are stored in *PageState* class Fig. 1 what contains data sent from client. Values that are set by getter method from database if it's edit mode and error structure that are filled in execution process and many other attributes that are required for page generation but not required in validator module. All data in application are transferred in container what basically is dictionary key and value set called *ValueHashMap* Fig. 1. Now we have two base classes one for values other for errors. By supplying both of them to validation method as pointers there is possible to use only references to value keys in rules and errors can be added to already existing error structure as shown in Listing 1. If date from is not greater then date till to error structure should be added "0001#date_from##0" where symbol "#" is separator and first part is error code by witch can be requested multi language description from database second field what failed in validation process third custom message (simple text) ant last type, it's error type (enum ordinal), for example zero means error or one warning and two information.

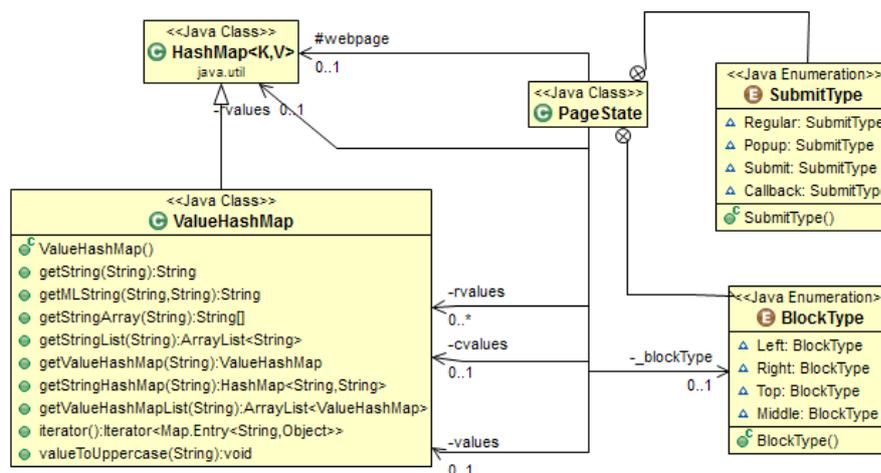


Fig.1. Web page request data container class diagram

Now, parser is created added required statements, written some rules and attached them to form. After deployment of application to the server is executed initialization of validator where are created all statement instances that are shown as message flow in Fig. 2 from pool "web application" to pool "Validator" lane "Parser". This design is for performance boost in case of rule update in real time. As validator prototype development was designed as part of framework, business logic module that communicates with database is capable to call validator to check values. To avoid duplicate code validator das not contain any kind of checks is field value requirement or value length is in allowed range or is value type correct? All these checks are provided by tag library and if they are passed successfully then if there is defined at least one rule for form executes validation process. For example in Fig. 2 pool "User" web form request triggers form metadata loading after what executes load form rules as shown in Fig.3 (required rules id's are contained in loaded form metadata structure) where is double check for validation rule in application context, it's necessary because load requests can be multiple at same time and there is possibility that after first check other thread deles rule from application context. If rule not found in application context it is requested from database as string what are supplied to Fig. 2 pool "Validator" lane "Parser" and returned java program code structure are stored in application context and returned to load requested method Fig. 2 pool "User" task "Load web form validation rules". These metadata requests are background processes. Now if user is adding or editing data in form that have rules attached and executes save action that requires validation data is processed by validator Fig. 2 pool "Validator" lane "Validator" sub process "Validates web form data", it's not completely validator process it's more like edge of two modules.

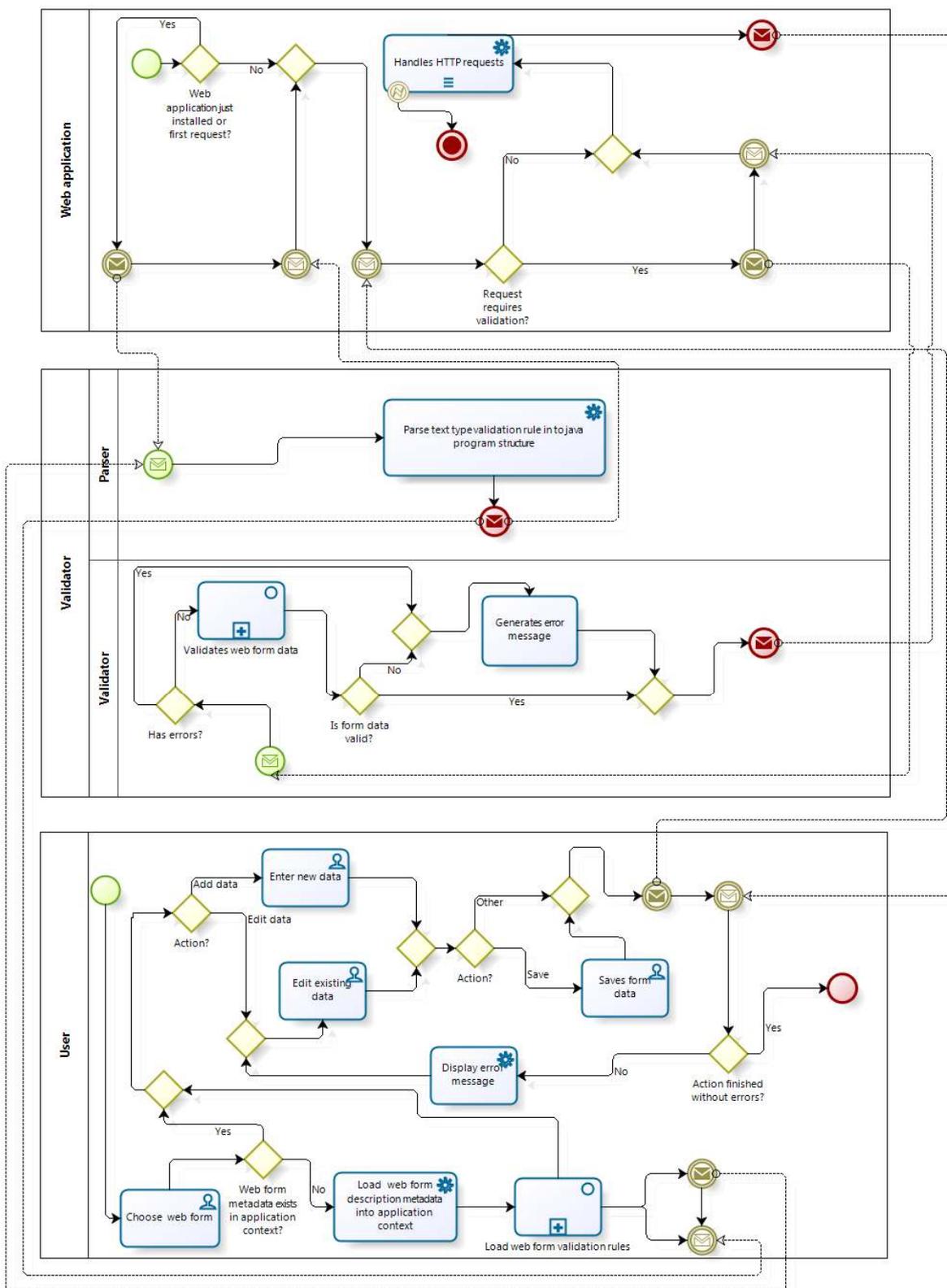


Fig.2. Validation request process model

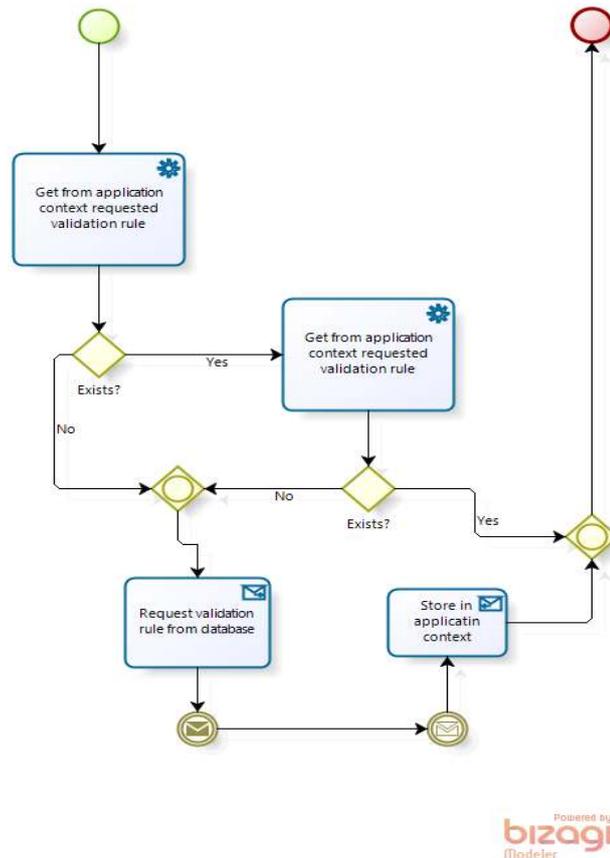


Fig.3. Validation rule request process model

Validation process is shown in Fig. 4 it contains six steps:

1. Create savable data key map – use form metadata to collect field keys that have regular expression attached;
2. Remove any other keys from hash map – delete all unnecessary or injected data and as bonus field validation process speed boost;
3. Check are all require fields filed if not there are no use to continue validation;
4. Check value length range – if all required values are filled there are necessary to check their length so entered data das not overflow database table column length;
5. Check entered value format – basically it's data type validation;
6. Rule validation – last check if all previous passed successfully;

In generally it looks like, user open's form edit's data press save button application checks if action requires validation, if yes calls validation process if there was no errors then returns to some page or in other case displays to user error message with field what caused it.

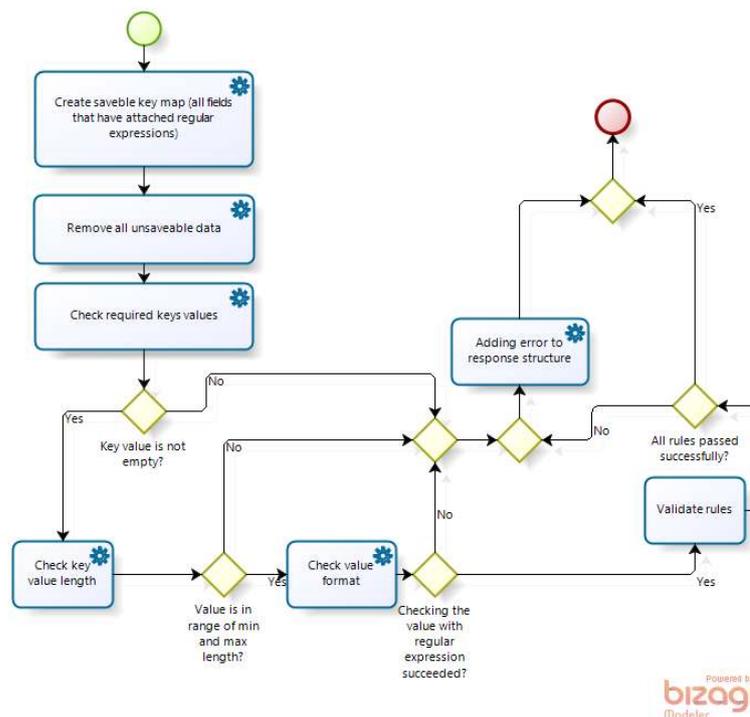


Fig.4. Form value validation process model

Results and discussion

After validation module prototype development was performed tests using different type of validation rules, enabling disabling them and results showed fast application response to update of rules. Using created language allowed to create multiple predefined rules which could be later added to one or multiple forms, but as well tests showed that it's highly unrecommended to update rule combinations in production application active state because there still is possibility to damage client data.

On this validator module prototype base was developed validator that was implemented in several real projects. Practice showed that depending on project type sometimes there is a need to add additional check statements but to apply them required application redeployment and if only change is new validation rule then it's extremely inconvenient to redeploy entire application. To solve this problem was performed research of other means how to store validation statements and one of possibilities was artificial neuron network. At first it seemed convenient way to store statements but later proved to be efficient in complicated task as image recognition because using artificial neuron network will never give 100% accurate result.

Conclusion

Based on the information gathered during the work and experience gained, it can be concluded that the program module developed in process can be used in many different applications not only in web applications, even if its primary design was for it. One of alternative usage was data received from web service validation, without big changes in program was achieved full validation integration for web service. This was achieved by defining new virtual web form metadata declaration in database, it allowed to grant rights only web service users access it and web physical requests to it were denied. Still this workaround don't show that it's possible to use it in other not web application so I want to notice that the validator module can be still extracted from main framework and if it will be supplied with rules and there will be performed value checks before executing validation, module will be operational and will validate any kind of defined rules.

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ELECTRONIC DOCUMENT MANAGEMENT OUTSOURCING AND CLOUD-COMPUTING POSSIBILITIES FOR PUBLIC SECTOR

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Abstract: *Over the past few years cloud-computing has become one of the most popular trends in information technologies. Its possibilities are used for the virtualization of different informational systems. Several developers also offer the usage of electronic document management systems "in the cloud", claiming it is a cheaper, safer and more user-friendly solution allowing productivity growth and resource saving. Regardless of many available options most organizations choose to maintain document management as a supportive process with its own servers and staff. Public sector can be viewed as a special group of organizations in this aspect. For them document management systems are significantly more important and complicated than for commercial enterprises. This article deals with the possibilities of document management system development or migration to cloud-computing and outsourcing the document management system as a support process. Special attention has been paid to details of document movement in governmental institutions, as well as to the example analysis from practice. The article inspects electronic document management in Latvian governmental organizations and marks out cloud-computing perspectives in the coming years.*

Keywords: electronic document management, public sector, cloud-computing, outsourcing.

Introduction

During the last few years cloud-computing has become the most popular direction in the IT industry. More and more companies offer cloud-computing services. According to world's most influential analytic company *Gartner*, cloud-computing has been the most important IT sector in 2011 (Petty, 2010). However, *Gartner* forecasts that in 2012 it will pull back to position 10, giving way to different mobility solutions and gadgets as tablet PCs, smartphones and their corresponding software (Petty, 2011). Though David Cearley, the Vice President of *Gartner*, claims that next year exactly the cloud-computing will become the most important battle field of such IT giants as *Microsoft*, *Google*, *Amazon* and others. The Vice President of *Gartner* particularly emphasizes the private-public cloud-computing solution development that would increase the level of safety and governance (Cooney, 2011).

Governmental institutions can be viewed as a particularly important group of organisations. Public sector pays special attention to data safety and the consequences of data loss can be very severe. As an analogue in business sector, banks could be mentioned because they also take notice of safety and stability aspects on a very high level. Governmental institutions could also be regarded as the most conservative institutions at all. Their work processes are regulated by huge amounts of different documented procedures and laws and regulations – both on the level of state and the institution itself. IT processes are no exception – actions in informational systems and data safety are regulated by safety policy, data restorability plans, working orders etc. Therefore it is not a surprise that governmental institutions choose to hire staff for the development and maintenance of information systems.

In the last years the global crisis has substantially influenced lots of countries, including Latvia. In order to improve the financial situation it is needed to undergo several consolidation procedures and look for solutions that would allow saving budget resources. Governmental institutions and their bureaucratic apparatus have always been viewed as one of the biggest consumers of state budget. Therefore the consolidation procedures are mainly applicable to the state administration. For several years there have been active discussions about outsourcing a number of state administration functions. One of the most frequent suggestions is the outsourcing of IT services. There is no unambiguous answer to the question if it would be financially beneficial. In this case it would be not enough to count together the costs of software licences, wages for the IT staff and hardware maintenance costs in every institution and compare this number to the one in a contract offered by a big IT company. Several other important aspects have to be taken into account, for instance, service quality, sphere of activity.

Initially cloud-computing services were not intended to be used in document management (DM). The only company developing this idea was *Google* with its office software package on the internet – *Google Docs*. However, in no shape it could be considered as a full-fledged document management tool. Gradually other solutions have been developed and they have started to compete with local document management systems. "After a somewhat primitive start, cloud services have burst onto the marketplace with products suited to just about any DM need, from individual users handling their personal files to huge multinational organizations seeking compliance with document retention and discovery regulations. To take advantage of the cloud's

largesse, however, you have to know what you're shopping for, or you'll find yourself drenched in confusing product pitches.” (Beckman, 2010)

Document management is surely the most important supportive process in the public sector. In every institution there are several hundred documents created daily. In order to prepare and structure this amount of information, it is not possible to avoid using electronic document management systems. Mainly document management systems are bought in public purchases, but afterwards they are maintained within the particular institution. Since document management system is only one of several informational systems maintained in every public institution, in theory it could also be migrated to solutions offered by cloud-computing. Would it be necessary? Both followers and opponents of this idea have substantial arguments. In the following we are going to cover the most important advantages of outsourced document management, as emphasized by the service providers, but – viewed through the prism of governmental institutions. In order to comprehend advantages and disadvantages better, it is necessary to subdivide four different options available for document management:

1. Full outsourcing of all document management processes, starting from the registration, continuing with the document circulation, and ending with the archiving. In this case the role of records managers in the institution itself becomes substantially smaller, but also the institution loses its own power to control its business processes.
2. Outsourcing of all IT services related to document management. In this case software-as-a-service (SaaS) document management systems and IT specialist staff of the service provider are being used. Nevertheless, document management processes take place in premises of the institution using the provided technologies.
3. Using an SaaS document management system but trusting its management to own IT specialists and records managers. In this case one has to reckon that there will not be many options of modifying, configuring and taking actions in the system because the service provider will not give the IT staff of the client access to the data bases or for the additional programming tasks.
4. Using a local document management system maintained by the IT staff of the institution. Until now this solution is the most popular among public sector institutions.

When promoting their SaaS document management solutions, the developers use wide choice of descriptive terms in order to positively characterize advantages of the using of their systems. It is easy to get confused in this amount of offers and to apprehend the promises as reality. However, most of these promises cannot be attributed directly to document management in a cloud and correctly applied to the public sector. Let us take a look at the most important arguments for choosing to outsource the document management process or to use technical solutions of cloud-computing.

1. Main advantages of outsourcing and cloud-computing

1.1. Avoiding technical decisions

Several factors have to be taken into account when choosing a solution for document management system. One of these factors is the choice of servers and platforms. In case of an outsourced solution this has to be fully taken care of by the service provider and the client only sees what end product has been delivered and used. Thus servers and updates of their software is fully the responsibility of the service provider. This is a very important reason if the institution is concerned of its IT competence or it just lacks human resources needed for the server maintenance. Along with this argument we can mention the cost factor because, when maintaining servers for a local document management system, the institution also has to pay for the software licenses of the servers and their maintenance (consumed electric energy, space in the server room etc.). Also the wages for the IT staff cannot be forgotten. However, financial gains cannot be calculated this unambiguously. It has to be taken into account that also the costs of cloud-computing service provider are the same; therefore it is possible that similar costs will come up in the service contract as well. Furthermore it is likely that the same servers in the cloud will be used by other organisations and their performance can thus be influenced negatively.

1.2. Specialist help in the optimization of document circulation process

Large part of companies offering the outsourcing of document management process agrees to assist in arranging the organizational processes and involve their specialists. As a positive aspect of this we need to mention the solution implementation experience of these specialists gathered in other companies. Of course, the overall experience and stability of the service provider have to be considered. As the main disadvantage in this case we have to name the specifics of document circulation in governmental institutions. When optimizing and digitalizing document circulation in public sector, it is not productive to use the same methods as used in the companies of private sector. There are specific document management principles in the governmental institutions and analogues cannot be found in the private sector. Therefore it cannot be guaranteed that external service providers will be capable of fully understanding the situation and using their experience. The experience of the author of this article that has been gathered in developing and implementing document management systems proofs that, even when involving qualified and experienced specialists and protractedly researching

work processes of a governmental institution, it is possible not to obtain an optimal result – an adapted document management system that fully complies with the work processes of the organization.

1.3. Short implementation period

The relatively short time needed for the implementation is often named as one of the main arguments for using an outsourced document management solution. Many service providers promise to prepare the environment and implement the system even in a week's time. This can be possible because of the factor that the system does not have to be programmed from a scratch. However, this argument is again only attributed to small organizations with a simple document flow. Document circulation in governmental institutions is that complicated that its implementation into any system, even in a ready one, can take months.

1.4. More comfortable document access for end users

Currently in the public sector one can notice a trend that all the work with the documents is being carried out only by the records managers and particular workers in every department. End users only prepare the documents and deliver them to the mentioned particular workers for further formatting, structuring and classification. This kind of approach is considered as very comfortable by lots of people. However, it does not conform to the best practices of document processing. The main problem is that the document search in this model has to be carried out by using the services of records management division or few workers. End users do not possess the tools and access rights or do not have the interest in looking for the necessary documents themselves. Outsourced document management solutions often emphasize this problem and promise that end users – every worker of the institution respectively – will have access to the document management system and to a wide choice of tools for searching, structuring and developing the documents. Nonetheless we have to take into account that this argument could also be used by any local document management system distributors as well and it is in no way specific for outsourced solutions only. Every contemporary document management system enables creating documents, structuring them into folders or by types, indicating metadata and searching by them, and giving access rights to the end users.

1.5. Following the advices of good practices

When promoting solutions of cloud-computed document management, their developers often emphasize that document circulation in the target organizations is wrong and does not comply with the so called advices of good practices. Only few of the organizations happen to have enough resources to perform a full-fledged informational governance. As mentioned before, system developers offer the help of their specialists who would carry out an investigation of the system and prepare an exact transition plan that would cover aspects of information safety, life cycle of the documents, potential costs and risks. Same as the previous argument, this aspect also does not refer to the outsourced document management process only. Also when acquiring and implementing a local document management system, the developers almost always offer the help of their specialists for the phase of system implementation. Surely, we have to take into account that it is never advisable to give all the access to external specialists and rely on their competence only – not always do they have the knowledge of complicated document circulation processes of governmental organizations.

1.6. Decrease of the amount of paper documents

When promoting the cloud-computed document management solutions, their developers mainly emphasize general advantages that would arise if transferring to electronic document management. Even though the decrease of the amount of paper documents is one of the objectives when implementing an electronic document system, there is no difference if a local or a cloud-computed document system would be used.

1.7. Document accessibility

We are living in the age of mobility and devices with the access to the internet are very popular – for instance, tablets, smartphones, and laptops. Workers in the public sector also want to access their work information during different workshop meetings, when visiting other institutions or being on a business trip. In this case cloud-computed document management system solution is a very comfortable one because it can be accessed from every part of the world where there is an internet connection. This advantage of the cloud-computing has been noticed by the local document management system developers as well and they are adapting their products so that the information would be accessible also on the public network. Majority of the contemporary document management systems already enable the portal function that makes the information accessible from the internet as well. However, in this case the IT staff of the institution have to spare extra time and find server capacities in order to ensure that the document management system can be correctly accessed from the outside (firewall, access addresses, configuration of user rights etc.). Therefore document accessibility has to be considered as one of the most important advantages for choosing a cloud-computed document management system. Nevertheless we

have to take into account the fact that these functions can also be provided by local document management systems.

2. Problems with outsourcing and cloud-computing

As can be seen, there are rather many reasons for choosing a cloud-computed document management system. Nevertheless, there are also significant contra-arguments. In the following we will cover them in a greater detail.

2.1. Data safety

Every organization is worried about the safety of their data. However, in this aspect the public institutions have special requirements and pay particular attention to information safety. If using a local document management system, document safety and usage is the responsibility of the local IT specialists, office clerks and in some cases – internal auditors. Yet when the outsourcing of document management has been chosen or a cloud-computed document management system is being used, the responsibility of data safety has to be transferred to an external company. In their turn the developers are not always ready to accept the strict data safety requirements from the side of governmental institutions. For instance, if the document management system among other things will be used for registering applications and submissions from private persons and their corresponding private data, including the person ID, the system has to comply with the prescribed safety requirements. In Latvia personal data protection and usage is regulated by the Law of Data Protection of Physical Persons (Fizisko personu datu aizsardzības likums): “Clause 13.1. Person identification codes may be processed in case if:

1. The data subject has agreed to it;
2. The procession of the identification codes derives from the objective of personal data processing;
3. The procession of identification codes is compulsory for further ensuring of data subject anonymity;
4. An admission of Data State Inspectorate (Datu valsts inspekcija) has been received.” (Fizisko personu datu aizsardzības likums, 2010, Latvian)

As one can see, in order to store personal IDs in the document management system (for instance, for the identification of mail addressees), the only available option is to obtain an admission from the Data State Inspectorate. Before issuing an admission, specialists from the Data State Inspectorate control the systems and server infrastructure safety in question. Therefore it is almost impossible for governmental institutions in Latvia to use cloud-computed solutions offered by foreign companies, but cloud-computing software-as-a-service choice in Latvia is very small or even non-existent. However, we can find offers for infrastructure-as-a-service (IaaS). In this aspect one of the pioneers in the software branch would be *Microsoft* who are going to launch the newest office software version *Office 365* in the cloud.

2.2. Emergency reaction time

However good an information system would be, one still has to consider several possible risk factors anyway. For critical information systems in business it is especially important to ensure the runtime uninterruptedness; and document management systems in public sector are ranked exactly in this category. In case of serious errors (server failures, for instance) the IT staff can immediately start the problem elimination in a local document management system. If a cloud-computing solution is being used, it takes time to report the problem, review it on the side of the service provider, and start its elimination. Moreover – it takes even more time while the provider reports the problem is solved, and the client checks if everything is working properly now and reports back on the status to the system provider. It is clear that emergency reaction time is much shorter in the case of a local document management system, if compared to an SaaS solution.

2.3. Performance

During the last few years Latvia has been one of the world leaders in internet speed, according to the latest data by Net Index: beginning of 2012 – fourth in the world after Estonia, South Korea and Lithuania (Net Index, 2012). However, we have to take into account that in case of identical parameters, system requirements and server devices a local software solution will always be significantly faster than a software being used via public network. This is caused both by the internet speed that is not always stable, connection speed on the sides of provider and client, and also by the relatively lower technological performance of the internet sites if compared to locally installed software solutions (most of the SaaS document management solutions are constructed in the web page view).

3. Global and local tendencies of the transition to SaaS document management

The significant impact cloud-computing has on the IT industry in general has been noticed also by the institutions regulating the policies and regional development directions, for instance, European Economic and Social Committee. In their report “Cloud computing in Europe” they emphasize the necessity to develop a legal

basis and standards for the usage of information systems in the cloud: “The global character of cloud computing calls for global principles and standards to be elaborated. The European Union must continue to work together with international organisations on developing such principles and standards. The EU must spearhead efforts to develop global principles and standards and stand as guarantor to ensure that these provide the high level of personal data protection intended by EU legislation.” (European Economic and Social Committee, 2011) However, the report also indicates that the cloud-computing branch is not yet fully developed and it has many flaws regarding its usage in public sector:

“Cloud computing has, to date, shown that it lacks maturity and has a number of weaknesses:

- the profusion of standards designed to regulate and control the use of CC;
- the absence of an identifiable European governing authority to enforce these;
- users, especially private individuals, lack the broad perspective needed to assess the benefits and, above all, the risks involved;
- the intrinsically fragile nature of the internet (interrupted service due to incidents, cyber attacks etc.);
- internet congestion: sluggish performance and strong growth in traffic (audio, video, spam). Limitation of the address system (IP);
- server congestion: the pooling of server resources and the resultant overbooking can trigger bottlenecks;
- the risks relating to the outsourcing of data and processing to a third party;
- the risks relating to the relocation of data and processing to another country which has another system of law;
- the social risk arising from the concentration of development, hosting and operating activities;
- the rights and obligations of both users and providers of cloudware are still unclear;
- there is no unambiguous distinction between the person responsible for processing personal data and the person actually doing the processing;
- service-level agreements are complicated and even incomprehensible for non-experts with respect to the composition, processing and transfer of user data and to users' legal rights.” (European Economic and Social Committee, 2011)

During the time the leading institutions are still resolving if it is necessary to evaluate advantages of cloud-computing, the service providers have already formed their opinion and it is clearly in favour of SaaS solutions for the public sector: “Choosing Document Management solutions in the form of Software-as-a-Service is a smart option for many government agencies. After all, federal and state governments produce large amounts of paperwork and electronic documents that need to be tracked and organized. However, developing complex systems to manage documentation can take up a great deal of time and money. Choosing SaaS Document Management allows these organizations to save money and implement their systems quickly and more effectively. Plus, Document Management as SaaS means that important documents can be accessed at any time, from more locations other than just the office computer. As more employees work remotely and need to access document while traveling, this improves efficiency.” (Greif, 2010)

If considering other groups of organizations with equally high requirements as public sector institutions, it can be seen that they are not hastening the transition of document management systems to cloud-computed solutions as well. Banks that are always mentioned as a striking example are usually maintaining all of their information systems locally – because of safety issues. Another instance could be organizations in the legal sphere, for example, law offices that are also vitally concerned about the safety of their data. The company *The American Lawyer* issued its annual study on companies in the legal sphere and their development of the IT (The American Lawyer, 2011). It is interesting that the study emphasizes the progression towards the cloud-computed solutions – because of lower costs. However, if inspecting the results in a greater detail, one can see that only few of the companies have chosen to transfer their document management solutions to the cloud (see Figure 1), and the reason behind it is the low level of data safety.

Similar results have been achieved by AIIM, one of the biggest research companies of IT trends. In their industry report of 2011 “State of ECM Industry 2011” they analyse the transition of different enterprise content management (incl. document management) functions to cloud-computed solutions (Miles, 2011). As can be seen in Figure 2, currently the content management functions are being outsourced relatively seldom. Moreover – document management ranks in one of the lowest spots on this list.

Globally there are relatively many options of different document management systems based on the SaaS principle. Most notable of them can be seen on the webpage of SaaS Directory – „Compare the Best Document Management Software” (SaaS Directory, 2012).

The situation in Latvia is crucially different because until now most of the local IT companies have not set cloud-computing as a priority. Didzis Šimis, CEO of *HORTUS Digital*, provider of multiservice IT solutions, says: “In Latvia, there are almost no specialists capable of building up a “cloud”. Building of an internal “cloud” (for one company only) is unreal. “Cloud” efficiency requires dimensions.” (Nozare.lv, 2010, Latvian)

Currently from cloud-computing services in Latvia you can find mainly Customer relationship management (CRM) solutions in the cloud – for instance, VivaCRM - <https://www.vivacrm.lv> (VivaCRM, 2012). Wide choice of solutions for e.g. book-keeping is offered by the company *Hortus Digital* (Hortus Digital, 2012). However, the user reports on the internet, when evaluating the experience of using the SaaS services based in Latvia, are mainly negative.

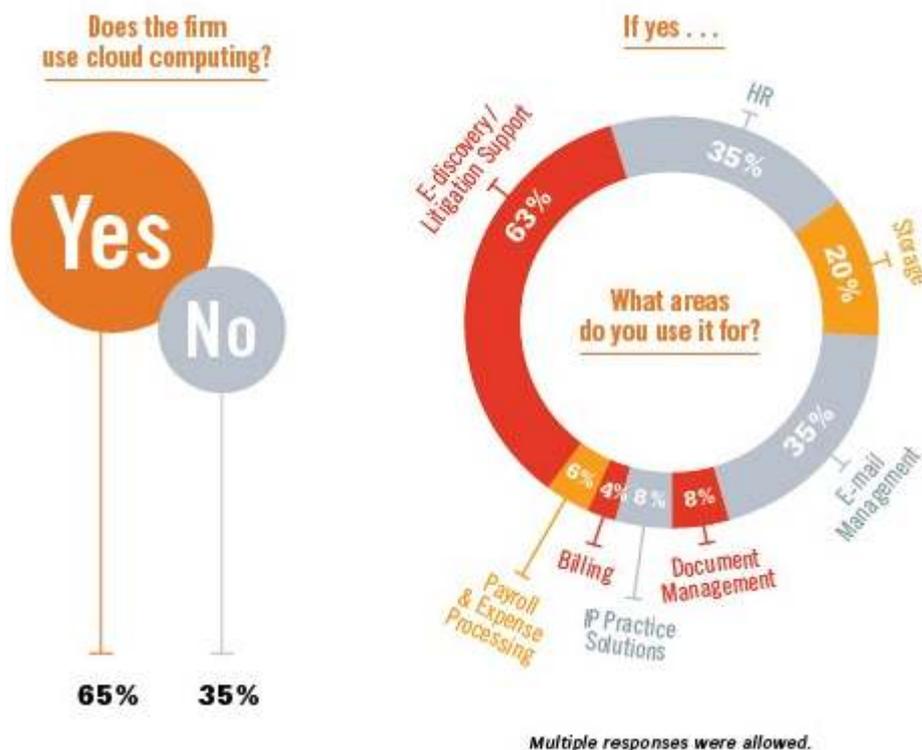


Fig. 1. Usage of cloud-computing (The American Lawyer, 2011).

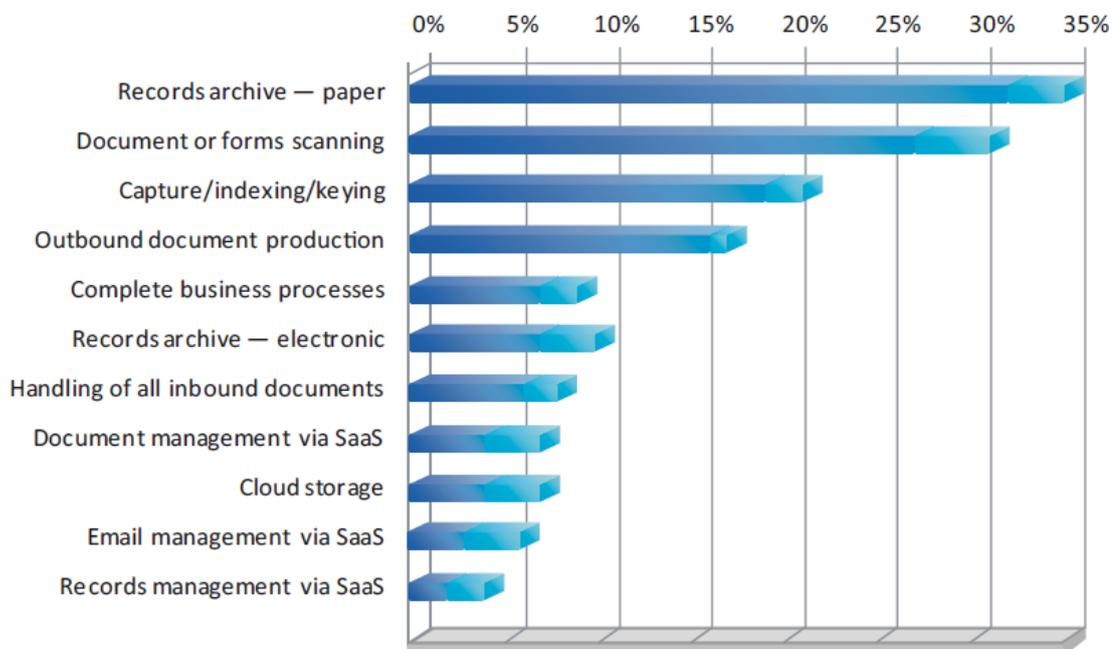


Fig. 2. ECM functions in cloud-computing (Miles, 2011).

Conclusion

The role of cloud-computed services in the IT market will only increase in the coming years but the institutions in the public sector will utilize them with great caution and will possibly remain the last of organizations sticking to maintaining local document management systems, including the ones for document management. As main

reasons behind it we can mention the mistrust towards external service providers and incomplete base of laws and regulations both in the European Union and in Latvia. The only way how to hasten the outsourcing of different state institutional processes is the pressure from the above – change of a unified IT policy of state (or even of EU) declaring the outsourcing compulsory in order to save resources in the public sector. However, this is not likely to happen, unless some significant studies of wide scope emerge on the state level shedding light on the cost-efficiency of IT processes. Even though the service providers claim that using their products means saving resources and offer different estimations, they are mainly misleading and do not show the overview.

Considering the document management as the most important supportive process in the public sector, it is not possible to foresee a full outsourcing of it in the nearest future. As the main argument not the costs of technical reasons can be mentioned, but the traditions. In public sector there is a generally approved opinion that everything about the documents within the framework of the institution has to be known by the records manager and exactly this worker is mainly responsible for them. Only the records manager has full comprehension of the whole life cycle of documents and their circulation. According to that, governmental institutions are not ready to accept even the idea that document management could be transferred from institution's records managers to a completely external company. However, even if the outsourcing of document management is not likely, there is still future for the usage of software-as-a-service type document management systems. Already now when acquiring document management solutions in public purchases, it is not prohibited to offer cloud-computed solutions. However, problems emerge if they are obviously not ready to ensure all the document management functions required by the governmental institutions. We have to take into account also the fact that in Latvia there is no real supply of SaaS document management systems. There are a few different software products based on the engine of *Microsoft SharePoint* that are capable of ensuring simple document storage and circulation functions not on a large scale, but none of them can fulfil all requirements for document management in the public sector.

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POSSIBILITIES OF APPLYING CLUSTERING ALGORITHMS IN DATA ANALYSIS

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Abstract: *Methods of data analysis and automatic processing are treated as knowledge discovery. In many cases it is necessary to classify data in some way or find regularities in the data. That is why the notion of similarity is becoming more and more important in the context of intelligent data processing systems. It is frequently required to ascertain how the data are interrelated, how various data differ or agree with each other, and what the measure of their comparison is. An important part in detection of similarity in clustering algorithms play the accuracy in the choice of metrics and the correctness of the clustering algorithms operation. Knowledge acquisition in this paper is the process of extracting knowledge from numerical data in the form of rules. Extraction of rules in this context is based on clustering methods: k-means and fuzzy c-means. With the help of k-means clustering algorithm the rules are extracted from trained neural networks. Fuzzy c-means is applied in fuzzy rule base design method. Rule extraction technique is shown through IRIS data set experimental results. Clustering and rule extraction methodology can be widely used in modeling, evaluation and risk analysis of different economic and financial processes.*

Keywords: data analysis, clustering algorithms, k-means, fuzzy c-means, rule extraction.

Introduction

Currently, intelligent data analysis (IDA) experiences the period of growth. This is mainly due to the new idea implementation at the intersection of several research areas such as artificial intelligence, statistics, and database methods. Methods of data analysis and automatic processing are treated as knowledge discovery. In many cases it is necessary to classify data in some way or find regularities in the data. That is why the notion of *regularity* is becoming more and more important in the context of intelligent data processing systems. It is frequently required to ascertain how the data are interrelated, how various data differ or agree with each other, and what the measure of their comparison is. Intelligent data analysis can also be defined as follows. This is a decision making process that is based on finding regularities in the data. The majority of methods of that kind were initially developed in the 70s-80s of the past century as a result of studying artificial intelligence methods. However, it is only lately that they have been paid great attention due to rapidly increasing necessity for data processing.

Researches conducted in the area of intelligent data analysis use a lot of different methods borrowed from several sciences. It is often emphasized that data analysis comprises points of interaction of different science fields. Among most frequently cited are: decision analysis and regression trees, Bayesian classifier, artificial neural networks, fuzzy inference, association rules, clustering, fuzzy cluster analysis, etc (Fayyad et al.,1996; Tan et al.,2005).

The main request which is put forward to the results of data analysis is that the results must always be interpreted as correctly as possible. The rules that represent the regularities found have to be stated as simple and easy to understand logical expressions (Russel et al, 2010). Namely, they must look as these logical rules:

$$\text{IF } \{(\text{Event 1}) \text{ AND } (\text{Event 2}) \text{ AND } \dots (\text{Event N})\} \text{ THEN } \dots \quad (1)$$

In what follows, the author will employ logical conditional rules (production rules) of this kind:

$$\text{IF } \underbrace{(\text{Antecedent 1}) \text{ and } (\text{Antecedent 2}) \text{ and } \dots (\text{Antecedent N})}_A \text{ THEN } \underbrace{(\text{Consequent})}_B \quad (2)$$

As scientific and practical interest in data mining was increasing, research on the possibility of processing IF-THEN rules with the help of different techniques achieved worthy attention. Thereby a knowledge base model is being obtained that can serve as a basis for further data analysis.

The motivation for studying rule extraction methods is the following:

- the amount of multidimensional data to be analyzed becomes too large for the potentialities of statistical analysis;
- previously unknown regularities are present in the data;
- the regularities found can be represented in a way that is easy to perceive and understand for the user.

The scheme shown in Figure 1 was made as a result of a study of the relevant literature. It represents the trends that nowadays dominate in the area of intelligent data analysis.

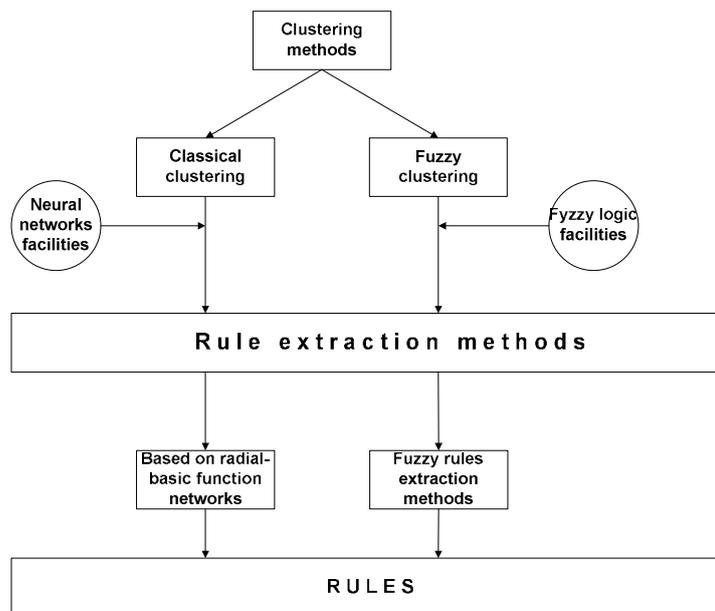


Fig. 1. Rule extraction methods using clustering

The purpose of the paper is to present the possibilities of clustering for extraction of rules by applying neural networks and fuzzy c-means algorithms.

Clustering in neural networks

Neural networks (this is a general notation of a certain class of algorithms) are able to learn from examples thus deriving hidden regularities in the data (Fausett, 1993). If a relationship among the input and output data exists (even if traditional methods do not show it), a neural network can adjust to it automatically with certain accuracy. Moreover, many neural networks allow one to evaluate the importance of particular features of the input data, to reduce data amount without losing the most essential data, to identify the approaching of the critical situation. In many cases neural networks help find regularities which cannot practically be discovered by analyzing the data manually.

Using the neural network technique it is possible to broaden the class of solvable tasks thus extending the potentialities of neural networks. The rules that help read symbolic or linguistic information from artificial neural networks have become popular. A direct way of converting neural to symbolic knowledge is through rule extraction. This process provides a limited form of an explanation facility of how a neural network may classify any given input pattern. Rule extraction is a process that discovers the hyperplane positions of the input-to-hidden units and the hidden-to-output units of a neural network. These positions are then formulated as IF-THEN rules with the most important input unit labels acting as the rule antecedents. The discovery of the hyperplane positions can be found by a number of techniques that analyze the weights and biases of the neural network (Andrews et al.,1995; Crawen et al.,1994).

Rule extraction can be carried out using a variety of neural network types such as multi-layer perceptions, Kohonen networks, radial basis function networks (RBF) and recurrent networks. Rule extraction process in a common case is shown in Figure 2.

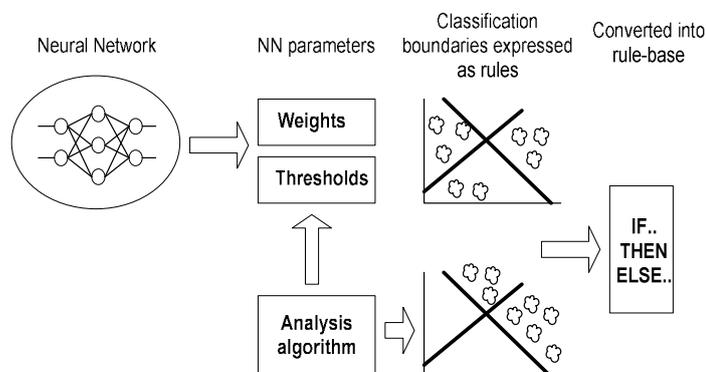


Fig. 2. Rule extraction process

In what follows, a number of approaches to rule extraction from neural networks are outlined: VIA, N-of-M, and KBAN. The advantages of rule extraction from neural networks can be summarized as follows:

- The knowledge learned by a neural network is generally difficult to understand for humans. The provision of a mechanism that can interpret the network input/output mappings in the form of rules would be very useful.
- Deficiencies in the original training set may be identified. Thus the generalization of the network may be improved by the addition/enhancement of new classes. The identification of superfluous network parameters for removal would also enhance network performance.
- Analysis of previously unknown relationships in the data. This feature has a huge potential for knowledge discovery or data mining and possibilities may exist for scientific induction.

The nature of RBF networks (Hush et al., 1993) makes them a suitable solution for rule extraction process. It is possible to extract a series of IF-THEN rules that are able to state simply and accurately the knowledge contained in the neural network. The RBF network consists of the feed forward architecture with an input layer, a hidden layer of RBF "pattern" units and an output layer of linear units. The input layer simply transfers the input vector to the hidden units, which form a localized response to the input pattern. Learning is normally undertaken as a two-stage process (see Figure 3).

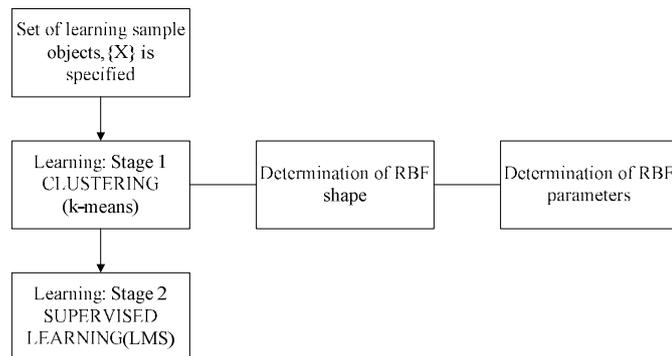


Fig. 3. Learning scheme of RBF networks

The first stage consists of an unsupervised process in which the RBF centres (hidden units) are positioned and the optimum field widths are determined in relation to the training samples. RBF training was accomplished using the k-means clustering algorithm (Everitt, 1993). It minimises the quality indicator which is determined as the sum of squared distances of all points belonging to cluster space, from the cluster centre. The name of the procedure has resulted from the calculation of the mean distances from the cluster centre, inside the cluster group. The algorithm is executed as follows:

1. Initialise the cluster centres w_j (set the initial cluster centres to the first m training data or to the m randomly chosen training data).
2. Group all patterns with the closest cluster centre i.e. for each pattern x_i , assign x_i to group j^* , where

$$\|x_i - w_{j^*}\| = \min_j \|x_i - w_j\|$$

3. Compute the sample mean for the cluster centre i.e. for each group w_j ,

$$w_j = \frac{1}{m_j} \sum_{x_i \in \text{group } j} x_i, \text{ where } m_j \text{ is the number of patterns in group } j.$$

4. Repeat by going to step 2, until no change in cluster assignments.

As a result of the algorithm execution, the final cluster centres, w_j , are determined with the restriction that the sum of squared distances of all the points, which belong to the group, from the cluster centre, has to be minimal.

The second stage of learning involves the calculation of the hidden unit to output unit weights and is achieved quite easily through a simple matrix transformation. The radial basis functions in the hidden layer are implemented by kernel functions, which operate over a localized area of input space. The effective range of the kernels is determined by the values allocated to the centre and width of the radial basis function. The Gaussian function has a response characteristic determined by equation (Hush et al., 1993):

$$Z_j(x) = \exp\left(-\frac{\|x - \mu\|^2}{\delta_j^2}\right) \quad (3)$$

The response of the output unit is calculated as

$$y = \sum_{j=i}^J W_{ij} Z_j(x) \quad (4)$$

where: W - weight matrix, Z - hidden units activations, x - input vectors, μ - parameter vector, σ - width of receptive field.

Rule extraction may be viewed in one of two ways. First, it can be seen as a technique for determining how the neural network performs any given input to output mapping. Second, the rule extraction process may often produce rules that are more accurate than the original neural network. The local nature of each RBF hidden unit enables a simple translation into a single rule:

$$\begin{aligned} &\text{IF Feature}_1 \text{ is TRUE AND IF Feature}_2 \text{ is TRUE AND IF Feature}_n \text{ is TRUE} \\ &\text{THEN Class}_x \end{aligned} \quad (5)$$

where a *Feature* is composed of upper and lower bounds calculated by the RBF centre μ_n positions, RBF width σ and feature steepness S . The value of the steepness was discovered empirically to be about 0.6 and is related to the value of the width parameter. The values of μ and σ are determined by the RBF training algorithm (Hush et al.,1993). The upper and lower bounds are calculated as follows:

$$X_{\text{lower}} = \mu_i - \sigma_i + S \text{ and } X_{\text{upper}} = \mu_i + \sigma_i - S \quad (6)$$

The rule extraction algorithm RULEX (Andrews et al.,1995) can be seen below in Figure 4:

Input:	Hidden weights μ (centre positions) Gaussian radius spread σ Steepness S
Output:	One rule per hidden unit
Procedure:	Train RBF network on data set using clustering For each hidden unit: For each μ_i $X_{\text{lower}} = \mu_i - \sigma_i + S$ $X_{\text{upper}} = \mu_i + \sigma_i - S$ Build rule by: antecedent=[X_{lower} , X_{upper}] Join antecedents with AND Add class label Write rule

Fig. 4. Rule extraction algorithm

Consequently, a base for the rules has been obtained.

Clustering in fuzzy systems

The fuzzy c-means (FCM) (Hoppner et al.,1999) algorithm allows each data point to belong to a cluster to a degree specified by a membership grade, and thus each point may belong to several clusters.

The FCM algorithm partitions a collection of K data points specified by m -dimensional vectors u_k ($k=1,2,\dots, K$) into c fuzzy clusters, and finds a cluster centre in each, minimising the objective function. FCM is different from hard k -means, mainly because it employs fuzzy partitioning, where a point can belong to several clusters with the membership values of the data points to the clusters. To accommodate the fuzzy partitioning, the membership matrix M is allowed to have elements in the range $[0, 1]$. Total membership of data points in all clusters has to possess the following feature. The sum of elements of any column has to be equal to 1, the sum of all elements must be equal to K and the objective function is set as follows:

$$J(M, c_1, c_2, \dots, c_c) = \sum_{i=1}^c J_i = \sum_{i=1}^c \sum_{k=1}^K m_{ik}^q d_{ik}^2, \quad (7)$$

where m_{ik} is the membership between 0 and 1,

c_i is the centre of fuzzy cluster i ,

$d_{ik} = \|u_k - c_i\|$ is the Euclidean distance of the k -th point from the i -th cluster centre,

$q \in [1, \infty)$ is a weighting exponent.

There are two necessary conditions for J to reach a minimum:

$$c_i = \frac{\sum_{k=1}^K m_{ik}^q u_k}{\sum_{k=1}^K m_{ik}^q} \quad \text{and} \quad m_{ik} = \frac{1}{\sum_{j=1}^c \left(\frac{d_{ik}}{d_{jk}}\right)^{2/(q-1)}}. \quad (8)$$

Jang (Jang et al.,1997) has proposed the FCM algorithm which determines the cluster centres c_i and the membership matrix M using the following steps:

1. Initialise the membership matrix M with random values between 0 and 1.
2. Calculate cluster centres c_i ($i=1,2,\dots, c$) using (8).
3. Compute the objective function according to (7). Stop if either it is below a certain threshold level or its improvement over the previous iteration is below a certain tolerance.
4. Compute a new M using (8).
5. Go to step 2.

The cluster centres can alternatively be initialised first, before carrying out the iterative procedure. The algorithm may not converge to an optimum solution and the performance depends on the initial cluster centres, just as in the case of the hard k-means algorithm.

To describe a fuzzy classification problem, the following assumptions are made. Assume, there exist p variables x_1, x_2, \dots, x_p , which are defined in the interval $X_i=[a_i, b_i]$, $a_i < b_i$. The final class set C is given for which the following distribution is valid:

$$\text{Class: } X_1 \times X_2 \times \dots \times X_p \rightarrow C.$$

The objective is to find a classifier that could solve classification problem. The fuzzy classifier is based on the set of final rules R for which the following holds:

$$R: \text{ If } x_1 \text{ is } \mu^{(1)}_R \text{ and } \dots \text{ and } x_p \text{ is } \mu^{(p)}_R \text{ Then class is } C_R, \quad (9)$$

where $C_R \in C$. The $\mu^{(i)}_R$ are assumed to be fuzzy sets in X_i , i.e. $\mu^{(i)}_R : X_i \rightarrow [0,1]$. Fuzzy sets $\mu^{(i)}_R$ are directly included in the rule. In real-world situations they can be replaced by the corresponding linguistic variables.

In solving many practical applications, the information necessary for the development and implementation of a fuzzy system can be divided into two kinds: numerical (the result of measurements) and linguistic (obtained from experts). Most of fuzzy systems are implemented using the second kind of knowledge, which is commonly represented in the form of a fuzzy rule base. It should be noted that in the cases when a fuzzy system with the numerical data has to be developed, certain important problems appear. A possible way to solve them is to use neural-fuzzy systems, where neural networks are employed for rule base optimisation. As a disadvantage of these systems, a long lasting iterative learning algorithm can be mentioned. The proposed methodology was used for knowledge base construction (Wang et al.,1992; Piegat,2001) :

1. Separation of input and output data.
2. Construction of fuzzy rules using learning set data.
3. Determination of confidence degree for each rule.
4. Formation of fuzzy rule base.
5. Defuzzification.

As a result, a rule base has been obtained.

Experimental part

During the experiment the well-known Fisher's IRIS data set was employed (Fisher,1936), containing three species classes of 50 elements each: setosa, versicolor and virginica. Each species has four attributes: SL - sepal length, SW - sepal width, PL - petal length, PW - petal width. However, it is uncommon to use this data set in cluster analysis, since the data set contains only two clusters with rather obvious separation. One of the clusters contains the Iris setosa species, while the other cluster contains both Iris virginica and Iris versicolor and is not separable without the species information Fisher used. The IRIS data set have been frequently used for examples in discriminant analysis and cluster analysis as a typical test case for many classification techniques.

Experiment 1. The first task of the experiment was defined in the following way: to perform network training by applying the RULEX algorithm at the training set containing all 50 elements of every class. The second task of the experiment was to examine the influence of parameter S on the quality of the extracted rules.

The values of parameter S were found experimentally. At each training stage, class centres and radius values were calculated according to the RULEX algorithm. Based on those values, for each class of training elements, X_{lower} and X_{upper} as well as the antecedent parts characterizing the corresponding class were calculated. Further, testing over the whole IRIS data set was made so as to determine to which extent the obtained rules correctly described elements of each class. For each class, the count of elements satisfying the rules, as well as the percentage of elements correctly describing the rules were discovered. For convenience purposes, IRIS variables SL, SW, PL and PW were denoted, respectively, as X_1, X_2, X_3 and X_4 . Table 1 shows the rules extracted at different S values, but Table 2 demonstrates the results of the experiment.

Table 1

Characteristics of the extracted rules		
	Parameter S=-0.8	Parameter S=0
Values of centres and radii	Class 1 = 5.01 3.42 1.46 0.24 Class 2 = 5.94 2.77 4.26 1.33 Class 3 = 6.59 2.97 5.55 2.03 Values of radii = 0.30 0.61 0.87	Class 1 = 5.01 3.42 1.46 0.24 Class 2 = 5.94 2.77 4.26 1.33 Class 3 = 6.59 2.97 5.55 2.03 Values of radii = 0.30 0.61 0.87
Rules correctly describe the elements of classes (%)	98	58.7
Rule of Class 1	IF (X1>= 3.80 AND < 6.21) AND IF (X2>= 2.21 AND < 4.62) AND IF (X3>= 0.26 AND < 2.67) AND IF (X4>= -0.96 AND < 1.45) THEN SETOSA	IF (X1>= 4.70 AND < 5.31) AND IF (X2>= 3.11 AND < 3.72) AND IF (X3>= 1.16 AND < 1.77) AND IF (X4>= -0.06 AND < 0.55) THEN SETOSA
Rule of Class 2	IF (X1>= 4.42 AND < 7.45) AND IF (X2>= 1.26 AND < 4.28) AND IF (X3>= 2.75 AND < 5.77) AND IF (X4>= -0.19 AND < 2.84) THEN VERSICOLOR	IF (X1>= 5.32 AND < 6.55) AND IF (X2>= 2.16 AND < 3.38) AND IF (X3>= 3.65 AND < 4.87) AND IF (X4>= 0.71 AND < 1.94) THEN VERSICOLOR
Rule of Class 3	IF (X1>= 4.82 AND < 8.36) AND IF (X2>= 1.20 AND < 4.74) AND IF (X3>= 3.78 AND < 7.32) AND IF (X4>= 0.26 AND < 3.80) THEN VIRGINICA	IF (X1>= 5.72 AND < 7.46) AND IF (X2>= 2.10 AND < 3.84) AND IF (X3>= 4.68 AND < 6.42) AND IF (X4>= 1.16 AND < 2.90) THEN VIRGINICA

Table 2

Results of training set (all 50 elements of every class)														
Cor- rect	Values of parameter S													
	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0	0.1	0.2	0.3	0.6
I	50	49	49	48	48	45	40	40	27	15	10	4	0	0
II	50	50	50	49	49	47	44	42	37	32	25	16	9	0
III	50	49	49	49	49	47	47	44	42	41	36	32	26	6
%	100	98.7	98.7	97.3	97.3	92.7	87.3	84	70.7	58.7	47.3	34.7	23.3	4

The data obtained prove that parameter S plays an essential role in the application of the RULEX algorithm: the greater the negative value of S is, the more the lower boundary of rule performance range, X_{lower} , decreases at the same time raising the upper boundary, X_{upper} , of the range. That causes the enlargement of the cluster describing antecedent part and thus increases the value of the area in which the extracted rule is fulfilled.

Experiment 2. In the first part of the experiments, two membership functions were calculated for three clusters. Two rules were acquired for Class 1, eight rules – for Class 2 and three rules for Class 3. For illustration purposes, some of the rules can be seen below:

Rule 1: if X1 is MF1 to degree 0.75 and X2 is MF2 to degree 0.87 and X3 is MF1 to degree 0.92 and X4 is MF1 to degree 1 then Class 1 to degree 0.57

Rule 2: if X1 is MF1 to degree 0.94 and X2 is MF1 to degree 0.88 and X3 is MF1 to degree 0.95 and X4 is MF1 to degree 0.92 then Class 1 to degree 0.68

In the second part of the experiments, different initial values of membership functions were selected and rule extraction was performed (see Table 3).

Table 3

Dependence of the obtained rule number on the count of initially set membership functions

Number of memberships	Class 1	Class 2	Class 3	Count
2	2	8	3	13
3	4	3	11	18
4	7	11	13	31
5	13	16	18	47

In the third part of the experiments the quality of the rules obtained was evaluated. As a result of the experiments, it has been established that the rules obtained for the particular class correctly describe class elements, i.e., for any data vector at least one obtained rule will be suitable, which brings that data vector to the

corresponding class. It has to be noted that by increasing the number of functions (as shown in Table 3), it becomes possible to obtain sufficiently many rules, which describe the data accurately.

Conclusions

In this paper the application of the rule-extraction algorithm has been shown which is based on the radial basis function (RBF) neural network classifier using clustering algorithms. After training the RBF classifier, the rules will be extracted through analyzing the parameters of the classifier. One hidden unit corresponds to one rule. Before extracting rules, the weights connecting the hidden units with output units are simplified. Further, the interval for each input in the condition part of every rule is adjusted with a view of obtaining high rule accuracy by iteration steps. This rule extraction technique is shown through IRIS data set experimental results. A conclusion can be made that the derivation of correct rules from the trained neural networks depends on the number of clusters originally set. In fact, the greater number of clusters is set, the more rules will be extracted. The extracted rules can help discover and analyse the hidden knowledge in data sets further.

On the other hand, the FCM clustering algorithm, which has been widely studied and applied, needs a priori knowledge of the number of clusters. Whenever FCM requires a desired number of clusters and initial guess positions for each cluster centre, the output rules strongly depend on the choice of initial values as the FCM algorithm forms an iteratively suitable cluster pattern in order to minimize an objective function dependent on cluster locations.

The experiments have shown that these methods can be viewed as alternatives to traditional data analysis methods. Clustering and rule extraction methodology can be widely used in modeling, evaluation and risk analysis of different economic and financial processes.

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QUALITY MODELS IN SOFTWARE PRODUCT DEVELOPMENT LIFE CYCLE

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Abstract: *Within the software product development life cycle, one may speak on qualities of four types – process quality, internal quality, external quality, and quality in use. Various quality models have been developed in the sphere of software engineering to evaluate internal and external quality of software product. All models are based on the defined hierarchic link of quality characteristics and sub-characteristics. The quality in use model of a product is also based on certain characteristics allowing evaluation of the mentioned quality. The development of quality systems and certifying of organisations in compliance with the ISO 9001 quality standards is one of the widely applied approaches in the world practice for assurance of process quality. Quality systems shall be developed according to the defined guidelines; however, no quality models are established for evaluation of process quality. The aim of the present paper is to demonstrate that quality models with earmarked quality characteristics and sub-characteristics may also be developed for the evaluation of software product development process quality.*

Keywords: software quality, software process, software process quality model.

Introduction

Software development sphere is characterised by several peculiarities:

- software product, in essence, is an abstract product, which is impossible to weight physically, to measure, or to assess it in any other way (Pressman, 2010);
- software product development period is lasting and the final result could be seen relatively late; thus, possibly causing certain obscurity and excitement from the part of a customer (Gibbs, 1994);
- requirements for the final product may be changed during the product development period (Pfleeger, 2009);
- development has a process approach (Ashrafi, 2003).

Therefore, the development of a new software product requires setting of not only quality requirements and methods for measuring the quality of a new product but also the quality assurance of its development processes. The sphere of software engineering does not discuss the quality of each individual process but focuses on the quality management systems the elaboration and maintenance of which should assure the development of a qualitative product. The mentioned sphere provides elaborated methods and an approved set of international standards determining guidelines for the development of software product. The entire standards may be classified into 4 groups consistent with the type of their use (Borzovs, Viļums, Čevere, Plūme, 1997):

- 1) standards determining the documentation of software;
- 2) standards determining the documentation of software development process;
- 3) standards determining the implementation of software quality assurance measures;
- 4) other standards related to the sphere.

Methods and standards, determining the implementation of measures for software quality assurance, describe the software quality life cycle, a quality model with the earmarked quality characteristics and sub-characteristics as well as the ways for setting and evaluation of quality requirements. However, in relation to the software development process, a model has not been sufficiently developed to evaluate the quality of processes. Several approaches have been developed for the definition, maintenance, and improvement of processes. These approaches are recorded in standards, the most popular standards being ISO 9000 and CMM (Mark, 1995).

The authors in the present paper would like to offer a method how the hierarchic quality model of software product may be transformed to the evaluation of software product development process quality. The essence of method is based on the selection of the necessary software development process for quality assurance from the universal model containing hierarchic quality characteristics.

Materials and methods

Definition of the quality model, which initially was provided by the ISO series standards and specified in the SQuERE series standards (ISO/IEC 25030, 2007), is the following: “defined set of characteristics, and relationships between them, which provides a framework for specifying quality requirements and evaluating quality.”

Historically, many software quality models have been developed and supplemented each other, and it is possible to determine and measure the quality of product by means of these models. The most well-known models are as follows:

- McCall's model;
- Boehm's model;
- FURPS model;
- Dromey's model;
- ISO 9126 model.

The entire models are based on the definition of hierarchically related characteristics and sub-characteristics of the quality indicators. These models are widely applied for the evaluation of various software products (Al-Qutaish, 2010; Khayami et al., 2009). Different modifications of models are developed for the needs of individual products (Rawashdeh and Matalakah, 2006). One of the key postulates defined by the ISO 9126 standard is the notion of software quality life cycle, which is viewed in relatively few versions trying to expand the software quality model with the process attributes (Ortega et al., 2003; Rawashdeh and Matalakah, 2006). Processes are mainly viewed as instrument furthering hopes that an adjusted and well organised process would ensure a more qualitative result.

There are also attempts to use such models for the evaluation of quality in other spheres parallel to the diversity of developed quality models. Similarly developed models have been applied in linguistics to evaluate the quality of translation since the beginning of the 1990s (King, 2003). An analogue quality model for the quality evaluation of the study process and study courses is used at Latvia University of Agriculture (Čevere and Sprōģe, 2010; Čevere and Sprōģe, 2011).

A question on the quality of software as a system element emerges with the development of software product quality models. The ISO/IEC 25030 standard offers a diversity of quality models within the system model. The authors offer supplementing the set of models with the quality model of software development processes (Fig. 1), since, consistent with the definition provided by the ISO/IEC 9126-1 standard, the quality of processes affects the quality of product (product quality develops from).

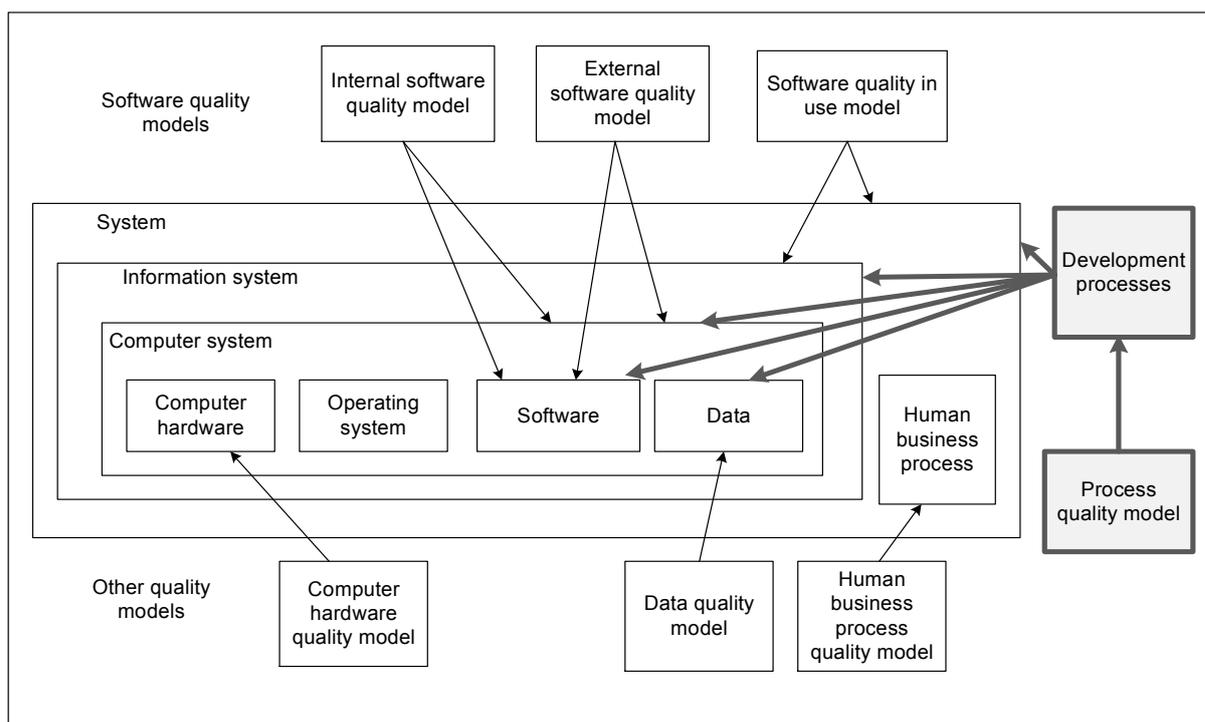


Fig. 1. Set of system quality models (ISO/IEC 25030, 2007).

The development and application of software product quality models in various other spheres ensure so many outputs that it is practically impossible to study all of them and evaluate their suitability prior to solving a particular aspect. According to Abran et al. "it is not seen to be economically feasible for either industry or the research community to investigate each of the hundreds of alternatives" (Abran et al., 2006).

Considering the diversity of quality aspects, different and various quality requirements of stakeholders as well as different evaluation contexts, the attempts to establish an identical quality model, which could serve a sufficiently broad sphere of evaluation, would turn inefficient. Instead, it is necessary to choose the base version of quality model and to develop procedure for its transformation to various authorities in use based on the previous personal and international experience. The present research develops an approach for the use of a single quality model for the evaluation of the entire system elements. The authors propose a base quality model, which

is supported by the ISO 9126 standard, and the procedure for transformation of this model consistent with each individual necessity.

The single approach means that the quality models are based on the hierarchic structure, which contains quality characteristics and corresponding sub-characteristics. The set of possible characteristics and sub-characteristics is based on the values proposed within the course of software quality valuation. Literature describes the results on revision, comparison and summarisation of many and various models. Yet, the set of these attributes is analysed once more, since the present research tries to ascribe such attributes also to the process quality models.

McCall's model is one of the most known quality models in the software engineering literature. This model serves as the basis for many other quality models. The model (McCall et al., 1977) divides all the characteristics into three major perspectives – product operations, product revision, and product transition. Respectively, 11 quality characteristics and 23 subcharacteristics are specified according to these perspectives. One and the same sub-characteristics are adjusted to several quality characteristics.

In Boehm's model, the higher level characteristics represent the actual basic usage requirements for software to which the evaluation of product shall be put – general utility of software (Berander, 2005). The higher level characteristics answer the three main questions, which are important for the evaluation of software quality:

- as-is utility – to address how well (easily, reliably and efficiently) one could use the software product;
- maintainability – to address how it is to understand, modify and retest the software product;
- portability – to address if one could use the software product when the drive environment would be changed.

The FURPS model for quality determination takes into account characteristics the first letters of which make up its name – Functionality, Usability, Reliability, Performance, and Supportability. The application of the FURPS model envisages the performance of two steps – setting of priorities and defining of quality attributes than can be measured.

Dromey's model focuses on the relations between quality attributes and sub-attributes as well as tries to relate the software product qualities to the software quality attributes (Dromey, 1995).

The ISO 9126 model defines the quality of product as a set of product characteristics. The model earmarks internal and external quality of the software product. External characteristics are characteristics influenced by the operation of a product in the provided environment, while the characteristics, which pertain to the product development aspects are internal characteristics (ISO/IEC 9126-1, 2001). The ISO 9126-1 quality model is the most useful one since it has been build.

The number of characteristics and sub-characteristics defined in McCall's, Boehm's, FURPS, ISO 9126, and Dromey's models is different (Table 1) as well as the type of their hierarchic relations is different:

- 1:n – several sub-characteristics are subjected to one quality characteristics (e.g., ISO 9126);
- n:m – each quality characteristics is related to one or several sub-characteristics (e.g., McCall).

Table 1

Description of the quality models				
Model	Number of characteristics	Number of sub-characteristics	Relationships	Metrics
McCall	11	23	n:m	+
Boehm	7	15	n:m	+
FURPS	5	28	1:n	+
Dromey	7	-	n:m	+
ISO 9126	6	27	1:n	+

The summary outlines that only one quality characteristics – “Reliability” is present in all quality models and that there are several characteristics, which are present only in one model (for example, Performance). Models demonstrate that characteristics of individual models are used as sub-characteristics in other models. Table 2 summarises quality characteristics (Ch.) present in all the models, the Column “Subch.” displays models, where these characteristics are used as quality sub-characteristics. According to Table 2, six quality characteristics (maintainability, reliability, efficiency, usability, portability, functionality) are present in at least three of the analysed quality models. These common characteristics coincide also with the quality characteristics of the ISO 9126 model.

The analysis of models has resulted in making of a list of found terms, which are used to denote characteristics and sub-characteristics. Individual terms, which could denote one and the same notion, are summarised as synonyms (for example, expandability, extensibility, or augmentability). It has to be considered that different stakeholders willing to evaluate the software quality may better understand one or the other name of the quality characteristics or sub-characteristics when choosing the existing quality model or developing a new one.

Table 2

Summary on the characteristics of the quality models

Ch. - characteristics; Subch. – sub-characteristics

Characteristics	McCall		Boehm		FURPS		Dromey		ISO 9126	
	Ch.	Subch.	Ch.	Subch.	Ch.	Subch.	Ch.	Subch.	Ch.	Subch.
Maintainability	+					+	+		+	
Flexibility	+									
Testability	+		+							+
Correctness	+									
Reliability	+		+		+		+		+	
Efficiency	+		+			+	+		+	
Integrity	+									
Usability	+				+		+		+	
Portability	+		+				+		+	
Reusability	+						+			
Interoperability	+									
Understandability			+							+
Functionality					+		+		+	
Performance					+					
Supportability					+					
Human Engineering			+			+				
Modifiability			+							

The summarised set of quality attributes was further used for the development of the base quality model and elaboration of its transformation procedure.

Results and discussion

The development of the base hierarchic quality model aggregated quality characteristics and sub-characteristics from all the previously mentioned quality models. A two-level hierarchic structure was created for this quality model (Figure 2):

- Level 1 – basic characteristics of quality;
- Level 2 – sub-characteristics of quality characteristics that are divided into:
 - basic sub-characteristics;
 - additional sub-characteristics;
 - optional sub-characteristics.

The characteristics of the base model include those quality characteristics, which are present in at least three quality models. Characteristics mentioned in the ISO 9126 model were chosen as the basic characteristics, since there are many studies on the evaluation of software product quality based on the ISO 9126 model (Fam et al., 2010; Sibisi et al., 2007). Sub-characteristics presented in the other quality models and related to the corresponding quality characteristics were chosen as additional sub-characteristics to each quality characteristics, when determining the type of relation n:m (Fig. 2). Optional characteristics and sub-characteristics of the base quality model are constructed by those characteristics and sub-characteristics, which are mentioned in McCall's, Boehm's, FURPS, and Dromey's models and not included into the basic sub-characteristics and additional sub-characteristics of the base model.

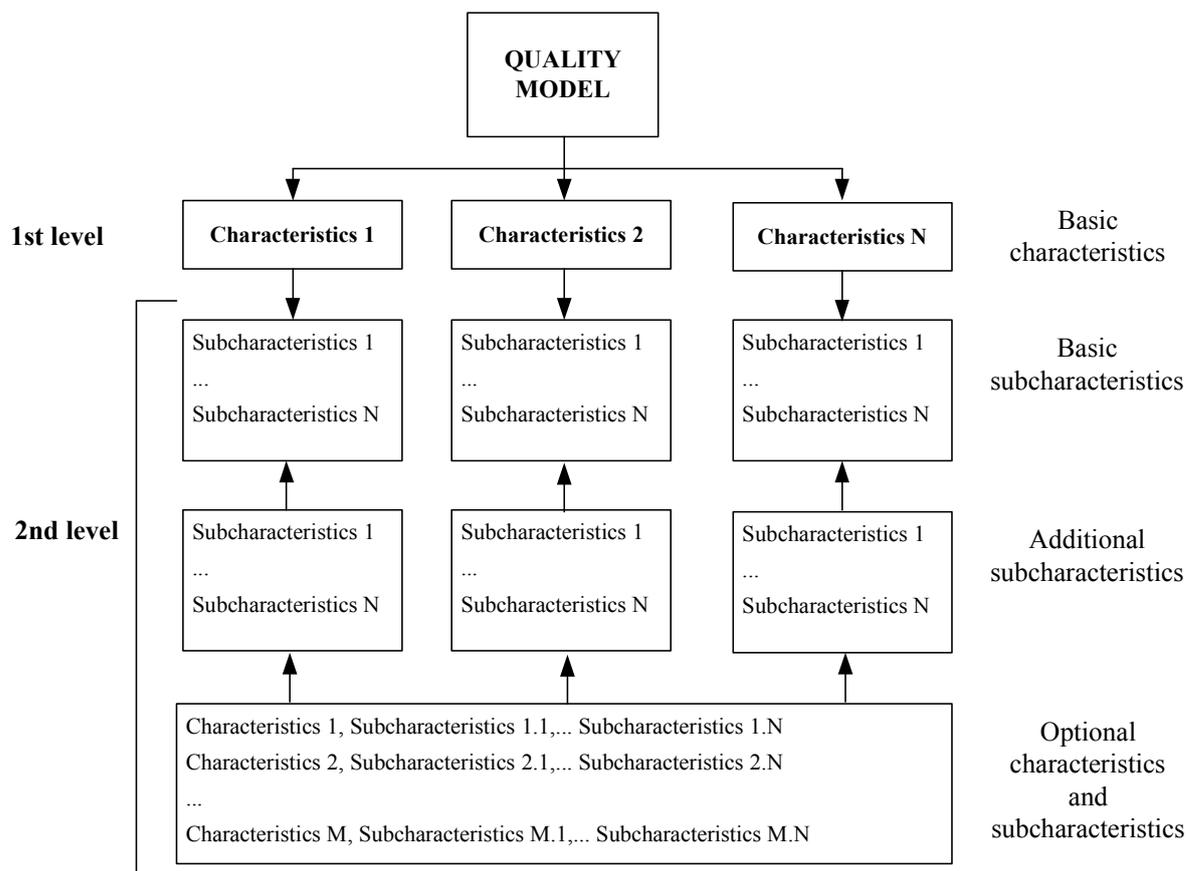


Fig. 2. Hierarchic structure of the base quality model.

The initial list of optional characteristics and optional sub-characteristics of the model consists of:

- Reusability – *Generality, Machine independence, Modularity, Self-descriptiveness*;
- Testability – *Accountability, Communicativeness, Self-descriptiveness, Structuredness, Instrumentation, Modularity, Self-descriptiveness, Simplicity*;
- Correctness – *Completeness, Consistency, Traceability*;
- Flexibility – *Expandability, Generality, Self-descriptiveness*;
- Human Engineering – *Accessibility, Communicativeness, Robustness/Integrity*;
- Integrity – *Access audit, Access control*;
- Interoperability – *Communication commonality, Data commonality, Modularity*;
- Modifiability – *Augmentability, Structuredness*;
- Performance – *Efficiency, Resource consumption, Response time, Speed, Throughput*;
- Supportability – *Adaptability, Compatibility, Configurability, Extensibility, Installability, Localisability, Maintainability, Portability, Serviceability, Testability*;
- Understandability – *Conciseness, Consistency, Legibility, Structuredness*.

Those quality sub-characteristics, which were not included into the number of additional sub-characteristics of the base model, are marked in *Italic* in the list of optional characteristics and sub-characteristics of the model. Therefore, double characteristics were not included into the final version of the model.

The summary on the experience in application the existing models evidence that one and the same notion may be used on different levels (as characteristics or sub-characteristics); for example, testability, efficiency, or as a sub-characteristic for different characteristics. Thus, they may repeat or overlap in the lists of proposed values.

The base quality model may be used both for the quality evaluation of software product and software development processes. Figure 3 outlines the software product quality model with earmarked quality characteristics, basic sub-characteristics, and additional sub-characteristics.

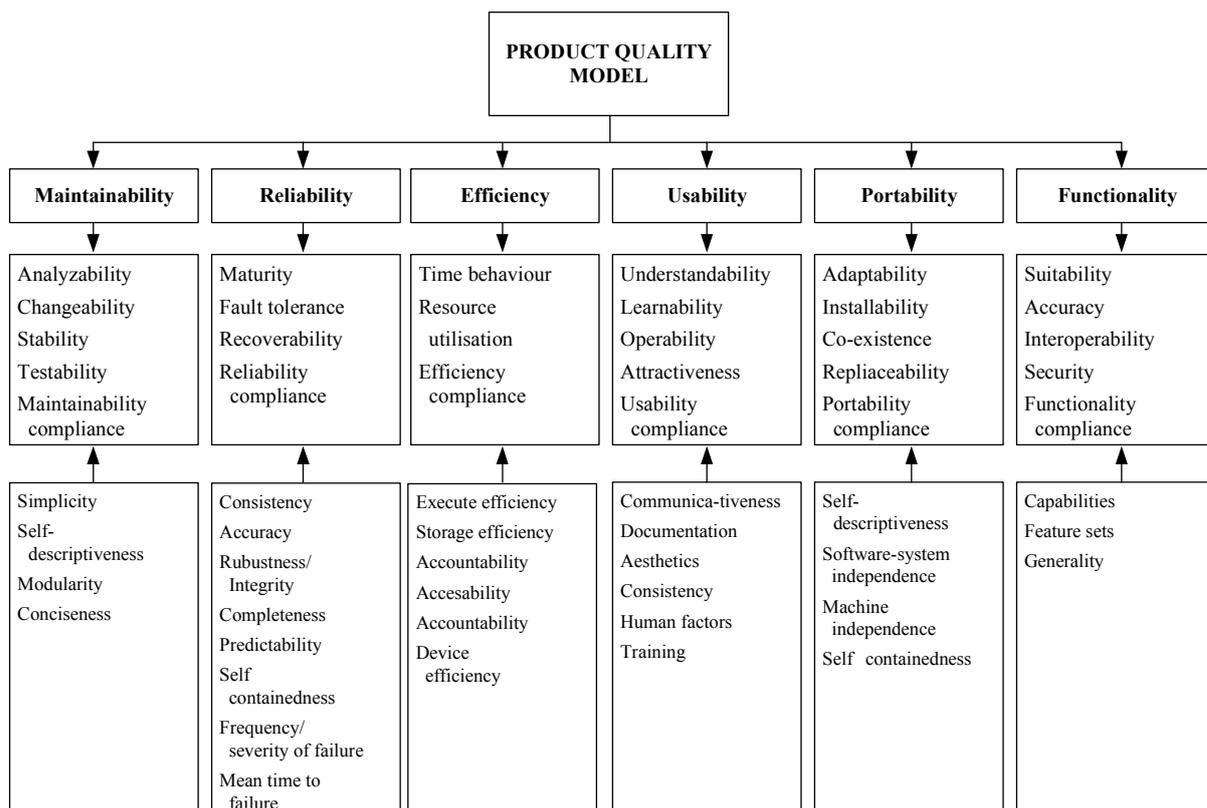


Fig. 3. The base quality model of a product.

The quality of development processes plays a significant role in the software product quality assurance. This is reflected both in the quality life cycle described in the ISO 9126 standard, and broad and successful implementation of quality assurance measures in IT companies based on the ISO 9000 standard, and TickIt and CMMI recommendations. The quality model of processes is not proposed; nevertheless undertaking of the respective quality assurance measures is related to the development of processes, evaluation, and implementation of continuous improvement measures. The quality model of processes and evaluation of quality is required in many cases, especially when creating and organising the course of processes as well as teaching the performance of these tasks. To establish a quality model, a process is viewed in its generally accepted form as transformation of input into output with the existing resources and defined management (Fig. 4).

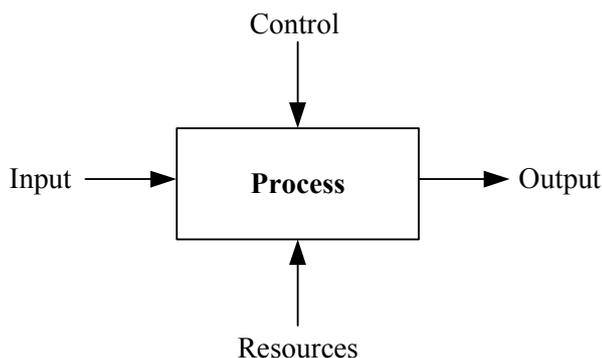


Fig. 4. Process model.

The evaluation of characteristics used in the base quality model leads to the conclusion that the majority of them may be used also as quality attributes of processes, certainly, considering that the interpretation of the notion may slightly or even significantly differ from the interpretation used in the evaluation of products. The basic difference relates to the metrics used in the evaluation of a characteristic or sub-characteristic. For example, if suitability metric “Functional implementation completeness” is used for the evaluation of a product functionality. This metric answers the question “How complete is the implementation according to requirement specifications?” and the method of application is counting the number of missing functions detected in evaluation and comparison with the number of functions described in the requirement specifications. In case of quality evaluation of processes, the use of all inputs and acquisition of outputs will be evaluated instead of specified functions. The base quality model of processes is proposed through such an approach (Figure 5). For

the comparison with the quality model of product, those sub-characteristics, which would not be suitable for the evaluation of processes, are deleted and those names of sub-characteristics, where the used term has been changed, are marked in *Italic* (for example, “data prevention” is recommended instead of “security”, “readiness”, →“maturity”, “corrigibility” →“recoverability”).

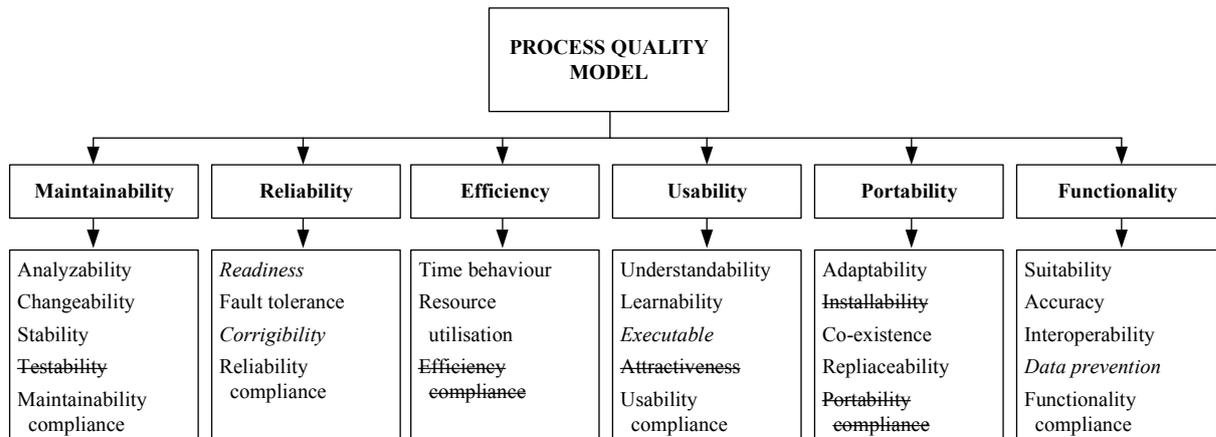


Fig. 5. The base quality model of processes.

It is envisaged to adjust the base quality model to the context of usage and requirements of stakeholders engaged in the evaluation in each individual case. In general, this adjustment shall be done consistent with the sequence of operations prescribed in the application procedure of the base model:

1. To identify/to choose the group that is eager to evaluate the quality of respective product/process.
2. To identify the quality requirements of a product/process set by the group of stakeholders.
3. To choose basic and additional quality characteristics and sub-characteristics.
4. In case of necessity, to choose optional characteristics and sub-characteristics.
5. To prioritise each selected characteristic.
6. To choose metrics for each quality characteristic/sub-characteristic.
7. To set the maximum value of each selected metric.
8. To provide the process of measuring for the selected metrics.
9. To analyse the obtained data – deviation from the set maximum value.
10. To prescribe activities for the improvement of a product/process quality.

Conclusions

The base quality model and its application procedure may be used both for the quality evaluation of software product and software development processes. Since different stakeholders are interested in the software quality and each of them has its own point of view and demands in relation to quality, then such a model is flexible in its usage. Quality may be evaluated by selecting the necessary characteristics and metrics.

The valuation of characteristics for a software product is based on metrics recommended by the ISO 9126 standards. Such a set of metrics is not published for the quality evaluation of processes; thus, recommendations for their description are prepared basing on the analogy with the quality evaluation of a product.

Quality may be evaluated in any phase of the software life cycle; however, in the particular research, when developing the base quality model, the main attention is paid to its application in preventive measures including quality training based on the model in training specialists of information technologies.

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ROBUST CLUSTER ANALYSIS IN FORECASTING TASK

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Abstract: *The article analyzes clustering problems that arise in forecasting tasks when clustering short time series of demand data. During the clustering process each object is assigned to a particular class or group of objects. The use of the same clustering algorithm does not guarantee results that would have the same interpretation if there are changes in clustering error evaluation method or the number of clusters is different. Robust clustering shows the differences in the object allocation to groups or clusters that occur when the clustering algorithm is repeatedly run using the same data set. The article provides a short description of the used methods and algorithms that are implemented in the process of data clustering and robust clustering analysis. The goal of this article is to perform the analysis of results with ambiguous interpretations and to give recommendations for solving similar problems. The clustering is carried out using *k-means* algorithm and its modification as well as clustering algorithms used in the data mining tools Weka, Orange Canvas and the statistics package Statistica. The distance calculations implement Euclidean distance. The robust clustering analysis is performed using Calinski-Harabasz approach that selects the number of clusters as an argument value in a function that is being maximized. Comparative analysis of the obtained results is carried out using a unified data set of product demand values that are defined by short time series with a fixed period of time. The conclusions of the article reflect authors' recommendations that had arisen as a result of the research.*

Keywords: clustering short time series, cluster analysis, robust clustering

Introduction

Clustering is the splitting of a data set into smaller groups of objects based on similarity features. One of the advantages of clustering is the ability to divide objects based on several properties that describe the object. Cluster analysis in contrast to mathematical statistics methods does not impose any restrictions onto analyzed objects and allows the processing of various data sets. It provides a rapid decrease in size of large information objects arrays, making them compact and easy to examine. The obtained groups or object sets are called clusters. As a result of clustering each of the data set objects is assigned a membership to one of the clusters. It is used in solving of various data analysis tasks, e.g. machine learning, pattern recognition, development of management strategies etc. Clustering does not have a unified approach or algorithm that would effectively process data of different origin. The methods used to cluster data are mostly iterative and are based on initially chosen number of clusters and data division.

But in real life there are tasks that are characterized by demand in a specific period of time or biological, economical and other processes over a certain period of time and, if the statistical information of demands is known for a short period of time, these data are called short time series. Looking for relationships in such time series using statistical methods is practically impossible, therefore solution to such tasks is looked for using cluster analysis (Written et al., 2005). These tasks include product life-cycle analysis with data mining methods (Kirshners et al., 2008), forecasting of textile product sales (Thomassey et al., 2006) etc. Short time series are often clustered using *k-means* algorithm, because previous studies show that this algorithm provides an acceptable performance speed and accuracy of the obtained results. The computation speed is necessary because there are several parallel processes in forecasting systems (Thomassey et al., 2006) and the analysis results are required soon to support the parallel processes. It is also similar in forecasting tasks when user needs results as soon as possible after entering the data into system to assist them in decision making (Parshutin et al., 2011).

The results and the selected number of clusters obtained using *k-means* clustering algorithm while processing short time series of demand are not always considered the most suitable. To process short time series of demand a modification of *k-means* algorithm (Kirshners et al., 2010) is used. But the evaluation of the results obtained by the modified clustering algorithm asks for additional study that would concentrate on the assessment of the obtained calculations accuracy.

Applied methods

Clustering algorithm

Data clustering uses normalized data that describe historical product demand information for a certain period of time. Short time series are merged into clusters using distance measure that is calculated using *Euclidean* distance (Written et al., 2005), see Equation (1). Averaged similar time series form clusters with average estimates called centroids.

$$d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (1)$$

where x_i, y_i – are two points in n -space.

Cluster analysis has to be repeated several times using the same number of clusters because *k-means* algorithm selects the initial centroids randomly. After multiple executions of the algorithm, the result with the smallest sum of squares error is chosen for the next stage. As previous studies have shown (Kirshners et al., 2010), the implementation of classical *k-means* algorithm is not effective when working with short time series, because increase in the number of clusters produces proportional increase in the sum of squares error. To avoid this “number of clusters curse”, *k-means* algorithm was modified using clustering error calculation methodology that is used to determine the most appropriate number of clusters to cluster the particular data set. In the core of *K-means* algorithm modifications is the change of clustering error calculations. When the algorithm has assigned each object to a cluster, it makes a distance matrix (see Table 1) with the distance value n_i of each object to the nearest centroid d_i .

Table 1

Instance distances to the centroids					
Number of instances c	Periods				Distance measure d
	T1	T2	...	T12	
c_1					d_1
c_2					d_2
...					...
c_i					d_i

Then, using Equation (2), it calculates the mean absolute error AE_n for each cluster by summing up object distances of the cluster and dividing the sum by the number of objects in the corresponding cluster.

$$AE_n = \frac{\sum_{i=1}^n d_i(x_j(c_i), c_i)}{n_i} \quad (2)$$

where AE_n – the mean absolute error for each cluster;
 d_i – the distance from the corresponding object to the centroid;
 c_i – centroid of i -th cluster;
 n_i – the number of instances in a cluster;
 $x(c_i)$ – time series x of cluster c_i .

The mean absolute clustering error MAE is calculated using Equation (3), by summing up absolute errors of clusters and dividing the sum by the number of clusters.

$$MAE = \frac{\sum_{i=1}^n AE_n}{n_c} \quad (3)$$

where MAE – the mean clustering absolute error;
 n_c – the number of clusters.

As a result of *k-means* algorithm modifications, it allows determining the most appropriate number of clusters that is necessary to cluster the analyzed data set. The modified algorithm served as a basis for forecasting system.

While working on improvement of the forecasting system to adapt it for working with medical and pharmacological data, arose the necessity for additional measures that would confirm the accuracy of the modified *k-means* algorithm results. Therefore there was a need for a series of experiments that would prove the robustness of clustering.

Robustness of clustering

The robustness of clustering shows the changes in the obtained final cluster distribution after several runs of the algorithm using the analyzed data set. The smaller is the change in the membership of objects to clusters after multiple runs of algorithm, the more robust are the clustering results. The obtained clustering robustness results can be used to find the most appropriate number of clusters that are necessary to cluster a data set. The assessment of clustering robustness is one of the most difficult tasks to formalize in cluster analysis. In literature there are many publications that are dedicated to clustering robustness, but most of them are devoted to

application to specific tasks and the proposed algorithms cannot be clearly interpreted from the viewpoint of mathematics. There are several approaches used to calculate the clustering robustness:

- Using indexes; the distribution level of data is determined by comparison in the clusters and then between clusters;
- Assessing the features of robustness function values, that show the correspondence of the selected clusters to the elements of a data set;
- Statistics based; the approaches that determine the most probable decision;
- Based on density distribution evaluation.

Based on literature analysis (Milligan et al., 1985; Savova et al., 2006) that evaluated different clustering robustness approaches, the basis of the experiments was chosen to be *Calinski-Harabasz* (Calinski et al., 1974) method that showed good results analyzing data sets of various types. *Calinski-Harabasz* method is based on clustering robustness RC that is calculated using Equation (4):

$$RC(k) = \frac{\sum_{i=1}^k d^2(g, c_i)}{k-1} \cdot \frac{n-k}{\sum_{i=1}^k \sum_{j=1}^{n_i} d^2(x_j(c_i), c_i)} \quad (4)$$

where $d(\cdot)$ – Euclidean distance between two points;

g – general centroid;

c_i – centroid of i -th cluster;

n – total number of instances;

n_i – number of instances in cluster c_i ;

k – number of clusters;

$x(c_i)$ – time series x of cluster c_i .

Among the obtained clustering robustness results the most suitable number of clusters k_{best} has to be found for each cluster; it is calculated using Equation (5) by maximizing function $RC(k)$:

$$k_{best} = k, RC(k) = \arg \max RC(k), \forall k \in K \quad (5)$$

where K – set of numbers of clusters that were analyzed.

The acquired clustering robustness results point to the most appropriate number of clusters that are needed to cluster the corresponding data set.

Experiments

The data used in the experiments are demand data of clothing retail company. Data set contains of 423 records with information about distribution of goods in one year. The demand data were normalized using life curve normalization (Thomassey et al., 2006). The data set was clustered using several approaches and software tools like *Weka* and *Orange Canvas* as well as application *Statistica*. In *Weka* tool the offered *k-means* algorithm was used that determined the membership of objects and the number of clusters as a result of clustering by minimizing the values of sum of squares error. In *Statistica* software *k-means* algorithm using 10-fold cross-validation calculated the training error and selected the corresponding number of clusters using the minimal value of the error. In *Orange Canvas* using *Silhouette* heuristics (Kauffman et al., 1990) an index is assessed using different numbers of clusters; maximizing the index allows choosing the most appropriate number of clusters to process the data set. The modified *k-means* algorithm initially calculates the mean absolute error and then the total clustering error in each cluster. After evaluating the total clustering error results in each cluster, the most suitable number of clusters is selected by finding the first significant minimum. *Calinski-Harabasz* method calculates the robustness of clustering in each cluster and finds the number of clusters by maximizing robustness values. The summary of all previously mentioned clustering results is shown in Table 2. In all of the inspected cases the number of clusters used in analysis was in the same range – from two up to maximum number of clusters that was calculated as \sqrt{n} where n is the number of records in the corresponding data set (Thomassey et al., 2006). This maximum has to be large enough to precisely perform cluster analysis, but not too large to avoid the impact of noise that could have a negative impact on cluster distribution. The bold emphasis in the table shows the best results obtained. Not all of the results can be interpreted equally. The algorithms used in *Weka* and *Statistica* show the same trend – the increase in the number of clusters facilitates the decrease in error. Whereas *Orange Canvas*, modified *k-means* algorithm and *Calinski-Harabasz* method show similar properties (see Fig. 1; the horizontal axis shows the number of clusters, the vertical axis shows the clustering error).

Table 2

Comparison of clustering algorithm results					
Number of clusters	<i>K-means</i> algorithm, <i>WEKA</i> (Sum of squared error)	<i>K-means</i> algorithm, <i>Statistica</i> , 10 folds cross validation (Training error)	<i>K-means</i> algorithm, <i>Orange Canvas</i> Scoring (Silhouette heuristic)	<i>Modified k-means</i> algorithm, (The mean clustering absolute error)	Clustering robustness Calinski-Harabasz
2	83,9777	2,8382	0,362	0,3950	0,4249
3	71,4050	2,8285	0,349	0,3867	0,8725
4	65,7358	2,8128	0,324	0,3650	1,2449
5	59,3787	2,7979	0,39	0,3740	0,9313
6	55,1571	2,7753	0,305	0,3667	1,0074
7	51,7346	2,763	0,343	0,3600	1,2103
8	47,8851	2,7472	0,358	0,3575	1,1150
9	45,6990	2,7345	0,296	0,3578	1,1921
10	44,4073	2,7182	0,337	0,3310	1,1564
11	43,0880	2,7073	0,346	0,3391	1,2230
12	42,3659	2,6904	0,291	0,3467	1,1927
13	40,9560	2,6758	0,277	0,3308	1,1851
14	40,9793	2,6683	0,291	0,3336	1,0951
15	40,3383	2,6598	0,286	0,3333	0,8770
16	38,9474	2,6512	0,28	0,3281	1,0640
17	36,5100	2,6482	0,275	0,3229	1,1071
18	37,6058	2,6383	0,302	0,3322	1,1078
19	36,9062	2,6239	0,27	0,3200	1,1573
20	35,7529	2,6121	0,278	0,3265	1,2279
21	35,5255	2,6016	0,288	0,3176	1,2720

At the mark of 11 and 10 clusters (marked with an arrow) a common trend can be seen – the values in the first (1) and the third (3) graph increase, whereas the second (2) graph shows a decrease at the same spot. This trend shows that the given approaches and algorithms can be used to cluster short time series (also see the values marked in bold and italic in Table 2) and it is possible to determine the most appropriate number of clusters that are needed to cluster the data set.

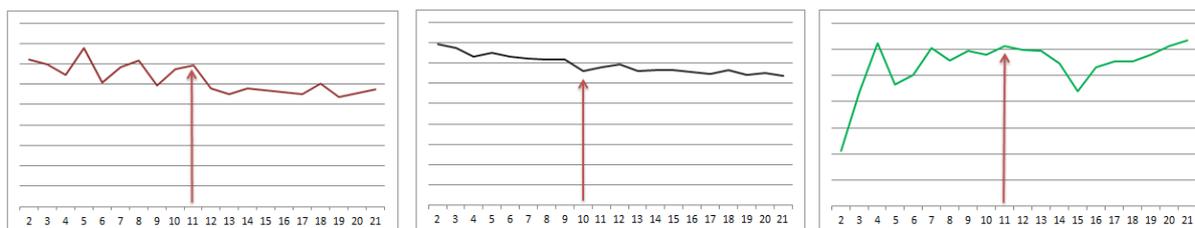


Fig. 1. The results of clustering algorithms: Left(1) – *Orange Canvas*, Middle(2) – *modified k-means* algorithm; Right(3) – robust clustering with *Calinski-Harabasz* method

Conclusion

The research results lead to conclusions that data mining software tools like the examined *Weka* and *Statistica* that implement cluster analysis using *k-means* algorithm cannot be used to cluster short time series using sum of squares error and training error calculations. The studies showed that the use of sum of squares or training error calculations leads to the trend where increase in the number of clusters leads to a decrease in error, and that marks a trend in the results that does not reveal the accuracy and robustness of the results.

Analysis of *Silhouette heuristic* approach used in *Orange Canvas* tool shows that clustering using five clusters yields the best result. As noted by the authors of (Schepers et al., 2008), this approach leads to the same results of clustering various data as *Calinski-Harabasz* method, but the result table presented earlier does not confirm this. Both the *modified k-means* algorithm and *Calinski-Harabasz* method show the same trend at the mark of five clusters and the results are comparatively worse with four and six clusters. But the increase in the number of clusters unveils similar trends with *modified k-means* algorithm. To confirm or dismiss these unified trends of features additional research was conducted to prove the validity of the error calculation methodology used in the *modified k-means* algorithm by calculating clustering robustness.

The calculations of clustering robustness showed that the modification of *k-means* algorithm, which uses total absolute clustering error, can be applied in tasks of short time series clustering. The results of this study can serve as a basis for further research to use the analyzed approach in implementations of complex systems, which deal with the clustering-based analysis of short time series.

The calculations of clustering robustness did not give a definite answer as to what is the best number of clusters. This asks for additional research in the field of clustering quality evaluation.

Future work

Although the analysis of the research results demonstrated that there is a need for alternative approaches when assessing the clustering error of short time series clustering using *k-means* algorithm, in the future the set hypothesis should be approbated using another method that would justify the validity of the obtained results. This issue could be solved using clustering precision F-measure indexes or clustering quality estimation.

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ROBUST IMAGE TOPOLOGICAL FEATURE EXTRACTION

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Abstract: *Topological image features such as ridge and valley lines provide an intuitive and powerful way of characterizing image content. The notion of ridges and valleys in digital images was introduced by Haralick already in 1983, but so far it has received fairly limited attention. The main reason is the lack of efficient and robust algorithms for their computation in discrete images. Typically lines and edges are detected using Sobel or Laplace operators; however, they significantly suffer from noise and provide disconnected or thick lines. Serious post-processing such as gap filling or skeletonization is required. Topological formulation of lines as ridges or valleys of a 3D surface overcome these limitations in an elegant way. Ridges are not sensitive to changes in contrast or brightness of the image and are less sensitive to noise, leading to superior applicability. In this paper we review image topological feature extraction methods and give a simple, efficient and robust algorithm for their computation in discrete images. We discuss the performance and characteristics of the new algorithm in practical applications including shooting target recognition and human vertebrae recognition in radiology images and show its benefits over traditional approaches.*

Keywords: image analysis, edge detection, ridge detection.

Introduction

Driven by overall technological progress, automated image analysis is becoming a necessity for numerous applications requiring improved image analysis algorithms. As provided by the current hardware, a digital image is represented as a matrix of pixels. However, pixel values themselves do not represent the contents of the image adequately. A typical image recognition process goes through several stages to get from pixels to meaningful information about the image contents. A typical scenario is:

Pixels → features
Features → objects
Objects → knowledge
Knowledge → decision

In the first step, pixels are grouped together to form lines or regions in the image with similar characteristics, thus forming features that are likely to belong to the same object. Only representative values are kept for these features like color, slope, length etc. In the second step, features are analyzed deriving groups of features belonging to the objects depicted in the image. In the third step, objects are analyzed to derive the necessary knowledge for the current application. The final step derives the business decisions from the obtained knowledge.

In this paper we will concentrate on the first step where pixel values are analyzed and line features are extracted. Line features are typically preferred to the region features since they provide concise representation of objects through object border or the object itself in case of thin objects. It is also well known that the human visual system primarily analyses lines of the image.

Several edge detection techniques have been developed to find edges in the images. Sobel and Laplace operators (Gonzalez and Woods, 2002) can be used to find places with large brightness deviations often arising from object borders. More elaborated is Canny operator (Canny, 1986) which gives already connected polylines. These techniques work well for finding object borders but are less useful for extracting thin lines such as handwritten text.

For thin lines, ridge detection methods are more adequate, which is the main subject of this paper. Image is treated as a surface in 3D space where pixel brightness represents the height of the “mountains” of the image landscape. If we look for the mountain ridges, they represent the needed lines of our image (Fig. 1).

The mathematical definition of ridges in the image is proposed by (Haralick, 1983) which has been adapted for practical uses by (Lindeberg, 1998; Lee and Kim, 1995; Steger, 1996). Ridge detection methods have been successfully applied to many fields including handwritten character recognition (Lee and Kim, 1995), road extraction from aero photo (Steger, 1996) and medical imaging (Serrat et al., 2000).

In the original implementation, ridge detection is fairly inefficient since it requires eigenvalue and eigenvector calculation. Lee and Kim (Lee and Kim, 1995) provide a discrete algorithm for faster classification of pixels into ridges, valleys peaks, etc.

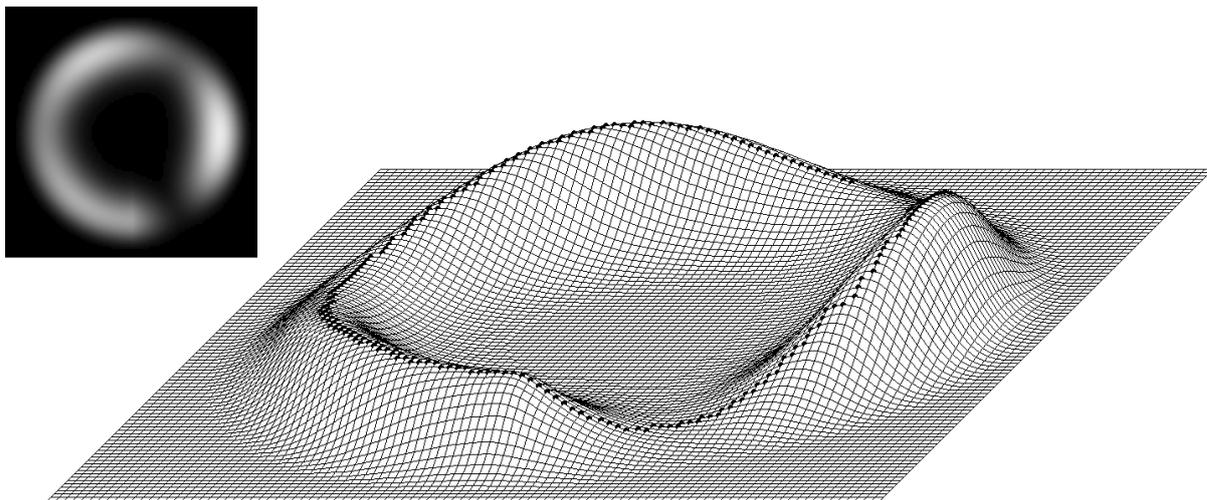


Fig. 1. A synthetic image and its 3D plot (the discrete ridge points are marked by black dots).

In this paper we review ridge detection methods and provide a simpler, higher quality and more efficient algorithm that is suitable for real-time and hardware implementations. We show its stability to noise and demonstrate its capabilities on two practical applications – shooting target recognition and human vertebrae recognition. The proposed ideas also lead to an edge detection algorithm which is faster than Canny detector and of about the same quality.

Ridges of an image

Following the ideas from (Haralick, 1983; Lindeberg, 1998), let us discuss what a ridge in an image is. First, let us consider the continuous case. A grayscale image is defined as a continuous function $f(x, y)$. Partial derivatives of the function are denoted by:

$$f_x = \frac{\partial f}{\partial x}, f_{xy} = \frac{\partial^2 f}{\partial x \partial y}, \text{ etc.}$$

If $p = (p_x, p_y)$ is a vector, then the directorial derivative in direction p is denoted by f_p :

$$f_p = f_x \cdot \frac{p_x}{\sqrt{p_x^2 + p_y^2}} + f_y \cdot \frac{p_y}{\sqrt{p_x^2 + p_y^2}}.$$

For another vector $q = (q_x, q_y)$ we can take another derivative of function f_p in direction q . Assuming for simplicity that p and q are unit vectors, we have:

$$f_{pq} = f_{xx} \cdot p_x \cdot q_x + f_{xy} \cdot p_x \cdot q_y + f_{yx} \cdot p_y \cdot q_x + f_{yy} \cdot p_y \cdot q_y. \quad (1)$$

We are interested in directional derivatives in the gradient direction and in the direction orthogonal to the gradient.

Let g be the gradient unit vector of the function f at a fixed point (x_0, y_0) :

$$g(x_0, y_0) = (g_x(x_0, y_0), g_y(x_0, y_0)) = \left(\frac{f_x(x_0, y_0)}{\sqrt{f_x^2(x_0, y_0) + f_y^2(x_0, y_0)}}, \frac{f_y(x_0, y_0)}{\sqrt{f_x^2(x_0, y_0) + f_y^2(x_0, y_0)}} \right),$$

and a vector h be orthogonal to the vector g (from now on we omit the awkward use of any exact indication of the point (x_0, y_0) , i.e. instead of $g(x_0, y_0)$ just g will be used):

$$h = (h_x, h_y) = (-g_y, g_x).$$

It is clear that at the point (x_0, y_0)

$$f_g = \sqrt{f_x^2 + f_y^2}, \text{ and } f_h = 0. \quad (2)$$

And according to the expression (1) the second order derivatives

$$f_{gg}, f_{hh} \text{ and } f_{gh}$$

can be calculated.

Definition. A point of a continuous image is called a *ridge point*, if the following conditions are satisfied:

- R1: $f_{hh} \leq 0$,
 R2: $|f_{hh}| \geq |f_{gg}|$,
 R3: $f_{gh} = 0$.

The meaning of these conditions is the following (see Fig. 2):

R1 means that f has a local maximum in direction h ,

R2 means that the surface folding in direction h is larger than in g ,

R3 means that gradient has an extremum in the direction h .

The condition R1 is the simplest one. Together with the property $f_h = 0$ (2), it means that the function f has a local maximum in direction h at a ridge point. In other words, moving from one side of a mountain range over this point in direction h we get onto another side, and it is quite natural to cross the mountain range in this direction where changes of the height are the least.

In fact, this condition is rather weak. There exist functions e.g. $-(x^2 + y^2)$, that all points satisfy the condition. However the valley points have the opposite property and are set apart.

The condition R2 is also simple. It expresses an idea that the surface folding at a ridge point is the sharpest in the direction h , sharper than in direction g among them. Because in our case $f_h = 0$, the sharpness of the folding of the surface defined by the function f is characterized by the absolute value of the second derivative f_{hh} . As an example, we can compare two functions of single variable at the point $x = 0$: $10x^2$ and $-x^2$.

Additionally, using of the absolute value of f_{gg} means that appearance of the surface folding is not important in the gradient direction, i.e. the ridge can be convex or concave. Further, $|f_{hh}|$ will be used as a measure for the ridge strength.

The condition R3 is substantially stronger than the first two. We know that $f_h = 0$ at all points (2), for the ridge point we require also that f_g has a local extremum in direction h . It is not necessary so in direction g because, moving along a ridge, the trajectory ascends or descends, yet quickness of change of surface height should be greater at both sides, i.e. orthogonal to the moving direction. Actually, in the offered form the condition corresponds to both ridges and valleys. So choice between them is made via the condition R1.

This condition is also the most meaningful in the sense that it is expressed by an equality defining a specific system of lines in the image plane, unlike the first two conditions that by inequalities define more or less wide plane areas.

The presented conditions are general and do not work in singular cases, for example when gradient is zero. Also, these conditions are useful only for analytically defined functions. To deal with images, appropriate approximations have to be used and are influenced by noise. A common way to deal with these issues is by using eigenvectors of the Hessian matrix of an image approximation. This approach is sketched in the next section.

The robust method presented in this paper uses only the ideas of the presented ridge conditions and treats them on the discrete grid directly, bypassing approximation.

Existing ridge detection methods

A common way (Serrat et al., 2000; Steger, 1996) for finding ridges is by using eigenvalues of the Hessian matrix at the given point.

The Hessian matrix is a matrix consisting of partial second derivatives of the function f

$$H = \begin{bmatrix} f_{xx} & f_{xy} \\ f_{yx} & f_{yy} \end{bmatrix}.$$

Let us consider the eigenvalues $\lambda_1, \lambda_2, |\lambda_1| \geq |\lambda_2|$ and the corresponding eigenvectors e_1, e_2 of H . Then the condition that the current point is a ridge point can be stated as $\lambda_1 \leq 0, e_1 \cdot g = 0$, where g is the gradient vector at the current point.

To apply this method to discrete images, finite difference approximations of the derivatives are used. Also the dot product of e_1 and g will not be exactly zero. This expression is replaced with a test whether there is a sign change of $e_1 \cdot g = 0$ in the direction of e_2 in the neighborhood of this pixel (Steger, 1996).

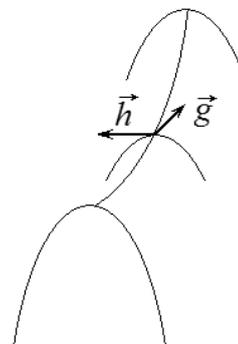


Fig. 2. A schematic picture illustrating the vectors g and h at the ridge point on the surface defined by the function f .

This ridge extraction method is rather complicated due to eigenvector calculations. The resulting implementation is rather complex and is not fast enough for real-time applications.

Lee and Kim (Lee, Kim, 1995) have proposed an approximation that operates directly on image pixels. Instead of eigenvector directions, they analyze image in four directions imposed by the pixel grid. Orthogonal directions of the greatest curvature are selected. The point is classified as ridge, valley, peak or pit based on sign changes of gradients in these directions. The algorithm is much faster and simpler than the eigenvector based algorithm.

There are disadvantages, however. The algorithm does a detailed classification of pixels in peaks and ridges but in real images in presence of noise, they cannot be distinguished clearly. To detect continuous lines, both of them should be included, but that leads to unnecessary points in the presence of noise. Another obstacle in practical applications is that the authors do not provide a way how to calculate ridge strength that is essential for cleaning out inessential lines.

The new discrete algorithm

Exploiting the ideas of the continuous definition of the ridge points, we derived a new algorithm for ridge detection. The algorithm classifies a given image point whether it is a ridge point or not. The theory tells us that the most important direction is the one in which the absolute value of the second directional derivative is maximal. This direction is perpendicular to the ridge and corresponds to direction h from the theory. In the discrete case we consider only the four grid directions (horizontal, vertical, both diagonals) through the current pixel. By adapting the conditions R1 – R3 we get the following algorithm:

1. Find the discrete direction of the maximum second derivative, let f_{hh} be that second derivative;
2. Test if the current point is a local maximum in that direction, if not, conclude that this is not a ridge point;
3. Let f_{gg} be the second derivative in the perpendicular direction;
4. Test if $|f_{hh}| \geq |f_{gg}|$, if not, this is not a ridge point;
5. return $|f_{hh}|$ as the ridge strength of the current pixel;

The second directional derivative is calculated as $2p - n_1 - n_2$ where p is the value of the central pixel and n_1 and n_2 are the values of the neighbor pixels in the chosen direction. For the diagonal directions this expression should be divided by 2 since the pixels are further apart.

See Appendix 1 for the c++ implementation of this algorithm. It is essentially simpler than Lee and Kim algorithm (although does not perform full classification into ridge, valley, peak or pit). It provides ridge strength for each pixel so that irrelevant ridges can be easily discarded. It detects ridge pixels mostly in unit thickness chains that can be easily linked together with the hysteresis thresholding and path following algorithms from Canny edge detector (Canny, 1986).

Prior to ridge detection, it is desirable to perform image smoothing with a Gaussian filter to reduce noise and prevent irrelevant ridges to appear.

Extension for edge detection

The same ideas can be easily applied to edge detection, leading to an efficient algorithm. The conditions for the pixel to be an edge pixel (Lindeberg, 1998) are:

- $f_{gg} = 0$, the second derivative of the image intensity function in the gradient direction is zero;
- $f_{ggg} < 0$, the third derivative of the image intensity function in the gradient direction is negative;

Similarly to the ridge detection algorithm, four directions of the discrete grid are analyzed. The direction of the maximum gradient value is chosen and the condition that there is an edge through this pixel is that there is a sign change of the second derivative in that direction. In summary, the edge detection algorithm is:

1. Find the discrete direction of the maximum gradient value
2. Calculate the second derivative at the neighbor points in the chosen direction
3. See if the second derivatives have opposite signs, if not, this is not an edge pixel
4. Return the gradient value of the chosen direction as the edge strength

See Appendix 2 for the c++ implementation of the algorithm. In the implementation there is an additional condition for choosing the pixel which is the closest to the edge from the two pixels on the both sides of the edge. This condition helps to produce lines of unit thickness.

This algorithm is simpler and faster than a typical implementation of Canny edge detection and has about the same quality. Fig. 3 shows the comparison of edges detected with Canny algorithm and the proposed algorithm on the popular camera man image. The quality of the detected edges is about the same.



Fig. 3. The original image (a), edges detected with Canny algorithm (b) and the proposed algorithm (c).

Practical evaluation

The proposed algorithms were applied to two practical problems. The first is shooting target recognition. The task is to automatically analyze how many points has the shooter obtained on a target like shown in Fig. 4a. The first step in this task is recognizing the score zones. They cannot be fixed nor are they perfect circles since the paper target could have been moved or bended during shooting. The only possibility is analyzing the circle lines. There are three types of lines: white lines on black background, black lines on white background and border line between black and white parts.

In the initial phase of this project it was found that only ridge and edge detection methods can reliably detect the score zones. White lines correspond to ridges, black lines to valleys and border between white and black backgrounds to edges. Valleys were detected with the same ridge detection algorithm applied to the inverse image. Ridges, edges and valleys of the target are shown in Fig. 4b. In this project performance was an important aspect since the score had to be shown immediately after each shot. To achieve acceptable shot identification quality, about 1Mpixel resolution was necessary and analysis of one frame should be done below 1 second time.



Fig. 4. (a) An image of the shooting target.
(b) Ridges (green), edges (blue) and valleys (red) of the target fragment.

The proposed ridge and edge detection methods turned out to be perfectly suitable for this application. They provided high quality zone detection together with high performance.

Ridge detection methods turned out to be very useful also for the human vertebrae radiology image recognition project. The goal of this project was to automatically analyze vertebral deformations represented in radiology images. Typical images to be analyzed are shown on Fig. 5.

The problem was set as follows: detect vertebrae in the radiology image of a human vertebral column and evaluate the distribution of heights of vertebral bodies. From investigation of the project images it becomes clear that ridges give enough information about the contours of the vertebral body to reliably detect deformations and other irregularities (Fig. 6).

The most important step in this task is recognition of zones of vertebral bodies to identify separate vertebra. There are two types of ridge lines in the image: the contours of the vertebral bodies and the lines corresponding

to various outgrowths. To separate the zones of these two types of lines, different approaches are possible. We decided to take advantage of the property that both vertebral bodies and outgrowths are laid out within well separated image regions alongside of each other. The geometrical parameters of the vertebral bodies can be determined from the property that the body has the shape of an irregular quadrilateral that comes from the projection of the body's cylindrical shape cut by the image plane. When the individual shapes are detected, it is straightforward to calculate the requested geometrical parameters and identify irregularities.

Fig. 6a demonstrates the ridge lines of the image Fig. 5a after smoothing with a Gaussian filter of radius 6 pixels, and Fig. 6b demonstrates 3D visualization of a fragment of the same image. It is clearly seen that ridges are not sensitive to the changes in contrast or brightness of the image.

The proposed ridge detection algorithm worked very well on these images delivering high quality ridge lines perfectly suitable for calculation of the necessary geometric properties of vertebra.

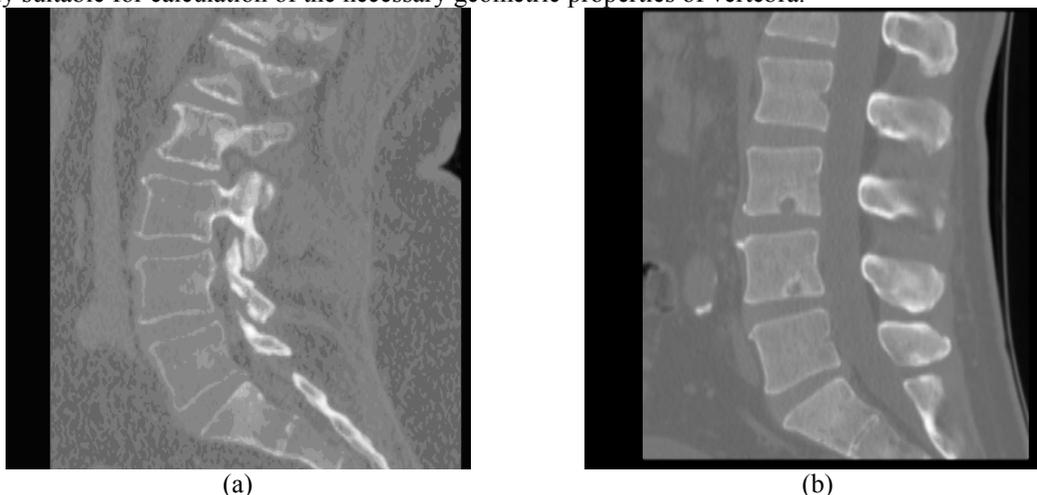


Fig. 5. Two examples of human vertebrae radiology images.

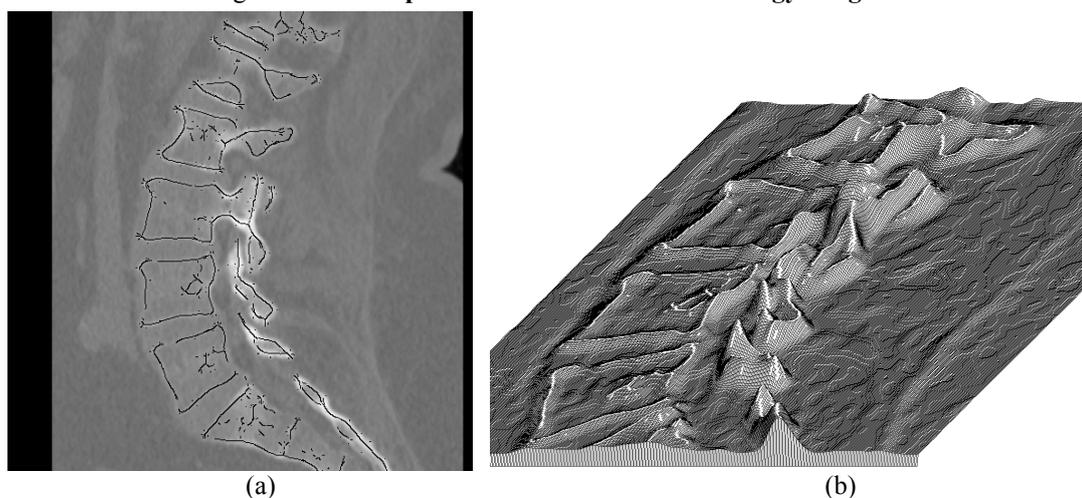


Fig. 6. (a). The ridge lines of the image Fig. 5a after smoothing with a Gaussian filter of radius 6 pixels (marked with black).
(b) 3D visualization of a fragment of the same image (ridges are marked white).

Quality and performance analysis

An important aspect of image analysis algorithms is their performance in the presence of noise. To evaluate the proposed ridge detection algorithm, we created several images by adding a different amount of Gaussian noise to the shooting target images and run the ridge detection algorithm on them. The quality of the detected ridges is shown in Fig. 7.

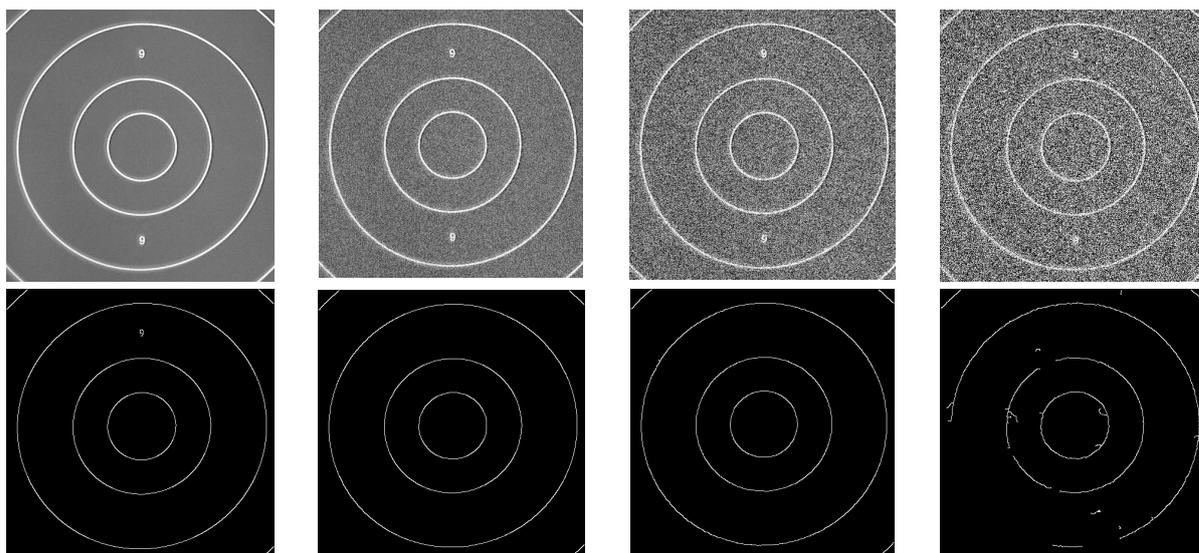


Fig. 7. The quality of the detected ridges in the presence of noise. The top row shows noisy images and the bottom row the detected ridges.

In the first three cases the algorithm has perfectly found the lines of the target. Only in the presence of very high noise (last image), lines start to break up and false lines appear. Note, that all images were processed with the same parameters – amount of smoothing and thresholds. By adjusting these parameters for each noise level we can get even better results.

We have measured the performance of the proposed ridge detection method by creating a series of images and measured how many pixels can be processed in one second. Since the amount of work per pixel is constant, this is a convenient way to present the performance of such algorithms. Our measurements showed the processing rate of 45MPix/s on AMD Athlon 2.6GHz processor utilizing one processor core. For example, such pixel rate allows processing of 108 video frames of resolution frames 720×576 per second. This time does not include optional smoothing for noise reduction. Smoothing, if required, can be implemented efficiently (Geusebroek et al., 2002).

An important aspect is how much smoothing to apply prior to ridge detection. If we apply too little smoothing, we get a lot of irrelevant lines and broken lines due to noise. If we apply too much smoothing, thin lines can be lost completely. In the practical applications we selected the amount of smoothing experimentally for each type of images. Generally, smoothing with a Gaussian filter of radius 3-5 pixels worked the best. In more complicated applications where vastly diverse images have to be analyzed automatic scale selection methods (Lindeberg, 1998; Elder and Zucker, 1998) can be used to calculate a different smoothing amount for each image or even for each part of the image.

We have compared the quality of our method to the Lee and Kim algorithm, see Fig. 8. The shooting target image is chosen for comparison. Our algorithm produces cleaner lines with less missing pixels.

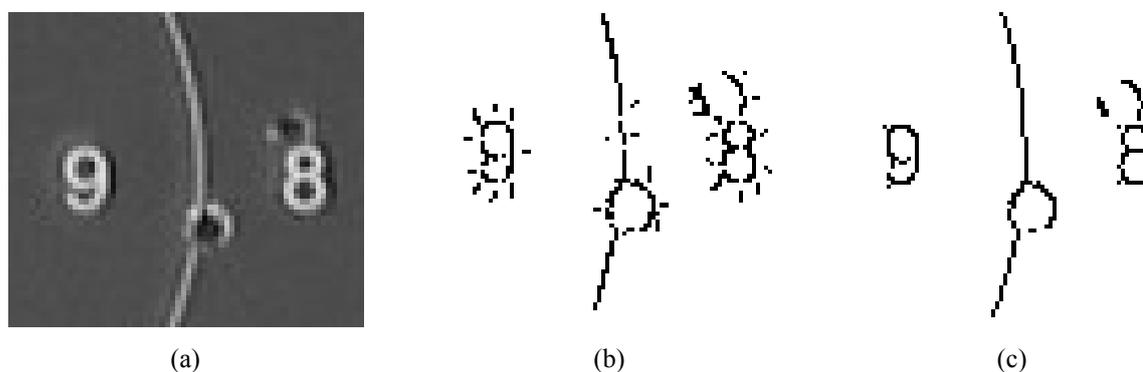


Fig. 8. The original image and the quality comparison of Lee and Kim algorithm to the proposed algorithm.

(a) original image, (b) Lee and Kim algorithm, (c) proposed algorithm.

Conclusion

We have proposed a robust and efficient method for ridge, edge and valley line detection in digital images. The proposed method extracts high quality lines that are without gaps and are of one pixel thickness. The method has low sensitivity to noise.

As shown in the provided code samples, implementation of the algorithm is simple. The ridge (and valley) detection code contains only integer operations that can be easily implemented in hardware. Edge detection code contains multiplication by $\sqrt{2}$ as the only floating point operation that can be approximated to get integer hardware implementation.

Due to the method's simplicity, high performance of 45 MPix/s is achieved that is enough for real-time video processing.

Practical value of the proposed line detection algorithms was shown on two real applications – shooting target recognition and vertebrae recognition. In both cases the ridge detection approach was the only way to achieve sufficiently high recognition quality and performance to achieve the project goals.

Acknowledgements

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Appendix 1 – source code of the ridge detection method

```
/**
    This method returns the strength of the ridge at the point (x, y).
    It returns 0, if there is no ridge.
    The method assumes that int *image holds the image values in row by row.
*/
int ridgePixelStrength(int x, int y)
{
    int *p = image + (x + y*width);
    int f = *p; // value of the central pixel
    int fpp[4]; // array for second derivatives for each direction
    int fhh, fhhI, fhh_tmp, fhhI_tmp;

    // calculate magnitudes of directional second derivatives
    // find the maximum one

    fpp[0] = 2*(f - p[1] - p[-1]);
    fpp[1] = - p[width+1] - p[-width-1];
    fpp[2] = 2*(f - p[width] - p[-width]);
    fpp[3] = - p[width-1] - p[-width+1];

    if (fpp[1]>fpp[0]){fhh = fpp[1];fhhI = 1;}
    else {fhh = fpp[0];fhhI = 0;}
```

```

if (fpp[2]>fpp[3]){fhh_tmp = fpp[2];fhhI_tmp = 2;}
else {fhh_tmp = fpp[3];fhhI_tmp = 3;}

if(fhh_tmp > fhh){fhh = fhh_tmp;fhhI = fhhI_tmp;}

fhh += 2*f; // now this is the maximum second derivative

// second derivative in the orthogonal direction
int fgg = fpp[(fhhI+2)&3] + 2*f;

int f1ofs[4] = {1, width+1, width, width-1}; // relative offsets of neighbor pixels

//get the pixels in the direction of maximum second derivative
int ofs = f1ofs[fhhI];

// ridge is when both neighbors in this direction is smaller than the central pixel
// curvarute in the found direction should be smaller than in orhogonal direction

if(p[ofs] < f && p[-ofs] < f && abs(fgg) <= fhh)
{
    return fhh;// the ridge strength is the magnitude of the second derivative in the direction
    perpendicular to ridge
}

return 0; // no ridge at this point
}

```

Appendix 2 – source code of the edge detection method (not optimized)

```

/**
 * This method returns the strength of the edge at the point (k, l).
 * It returns 0, if there is no edge.
 * The method assumes that int image[][] holds the pixel values.
 */
int edgePixelStrength(int k, int l)
{
    int f = image[k][l]; // central pixel

    int fpp[4]; // array for derivatives for each direction

    fpp[0] = abs(image[k + 1][l] - image[k - 1][l]);
    fpp[1] = abs(image[k + 1][l + 1] - image[k - 1][l - 1]) / sqrt(2);
    fpp[2] = abs(image[k][l + 1] - image[k][l - 1]);
    fpp[3] = abs(image[k - 1][l + 1] - image[k + 1][l - 1]) / sqrt(2);

    // find the direction of maximum derivative
    int fhh = fpp[0];
    int fhhI = 0;

    for (int i = 1; i < 4; i++)
        if (fpp[i] > fhh)
        {
            fhh = fpp[i];
            fhhI = i;
        }

    int f1, f2, fgg;
    bool fh;

    switch (fhhI)
    {
        case 0:
            f1 = f - 2*image[k + 1][l] + image[k + 2][l];
            f2 = f - 2*image[k - 1][l] + image[k - 2][l];
            fgg = image[k - 1][l] - 2*f + image[k + 1][l];
            break;
        case 1:
            f1 = f - 2*image[k + 1][l+1] + image[k + 2][l+2];
            f2 = f - 2*image[k - 1][l-1] + image[k - 2][l-2];
            fgg = image[k - 1][l-1] - 2*f + image[k + 1][l+1];
            break;
        case 2:
            f1 = f - 2*image[k][l+1] + image[k][l+2];
            f2 = f - 2*image[k][l-1] + image[k][l-2];
            fgg = image[k][l-1] - 2*f + image[k][l+1];
            break;
        case 3:
            f1 = f - 2*image[k - 1][l+1] + image[k - 2][l+2];
            f2 = f - 2*image[k + 1][l-1] + image[k + 2][l-2];
            fgg = image[k - 1][l+1] - 2*f + image[k + 1][l-1];
            break;
    }
}

```

```
if((f1<=0 && f2>0) || (f1>0 && f2<=0))// second derivate have opposite signs
{
    // the pixel has to be closest to zero crossing than its neighbors
    bool closest = false;
    if(fgg==0)
        closest = true;
    else if((f1<=0 && fgg<=0) || (f1>0 && fgg>0)) // sign(f1)==sign(fgg);
        closest = (abs(fgg) <= abs(f2));
    else
        closest = (abs(fgg) <= abs(f1));

    if(closest)
    {
        return abs(fhh);// result is gradient value
    }
}
return 0;
}
```

TESTING OF SOFTWARE RESPONSE TIME IN VARIOUS COMPUTING ENVIROMENTS

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Abstract: *The article describes a study about real-time performance of conventional PC by testing its response time to external events on a serial port in various conditions. For now PC's are mainly used as the supervisory control and data acquisition units on the highest level of PLC system. The results of the study will clearly show the possibilities of addressing to a conventional PC more time-critical tasks e.g. controlling microclimate in industrial buildings, apartments or green-houses; controlling slow to moderately fast changing processes in bioreactors; temperature control for drying or material melting process etc. The goal of the tests is to determine the real-time performance of software running in runtime system environment on conventional home and office computing systems with common PC hardware and multi-tasking desktop operating systems. The study will be performed on PC using a variety of OS (Windows 2000, Windows XP, Windows7 x32) and two types of runtime systems: Oracle Java Runtime and Microsoft .NET Common Language Runtime. Loading of the PC's components by concurrent tasks also will be considered. Microcontroller unit (MCU) will be used to generate the signal to the serial port to which the PC should respond and also to accurately measure the computer's response time, i.e. the MCU is used as a frame sender and computer as a forwarder. The time is measured between moment when the frame is sent out and received back to the MCU. The measured time is stored on the MCU. The computer software pools the serial port buffer to check if there is any data and once the frame is received the software immediately transmits the frame back to the sender. As a result the actual response time of the software running on the specified hardware depending on computer load and operating system features is determined. At the end of the study statistical analysis will be presented.*

Keywords: real-time, Windows 2000, Windows XP, Windows7 x32, microcontroller, PC, serial port.

Introduction

The article describes a study about real-time performance of conventional PC by testing its response time to external events on a serial port in various conditions. For now PC's are mainly used as the supervisory control and data acquisition (SCADA) units on the highest level of PLC system. Due to complexity and human user oriented software PC's are not considered to be hard real-time devices in classical interpretation (Joseph, 2003). The results of the study will clearly show the possibilities of addressing to a conventional PC more time-critical tasks e.g. controlling microclimate in industrial buildings, apartments or green-houses; controlling slow to moderately fast changing processes in bioreactors; temperature control for drying or material melting process etc. (Vilums, 2010)

Lately, in order to run user software, the virtual machines or runtime systems (Oracle Java, MS.NET Framework) are used more frequently. They have continually updated access to development tools and code libraries, they ensure software portability between different platforms, code modularity and reusability (Jönsson, 2004). Consequently, decision is made to test the PC response time to the virtual machines instead of using native code. Another reason that .NET and Java Runtime (Segovia,1999) environments are used, because it would be difficult to compare different OS in native code. It is decided to test three OS and two virtual machines using different test methods in this research. Additional factors are number of external events and frequency of these events as well as load of various PC components.

Research hypothesis is that the PC (Audette, 2004) can be reliably used for automatic control systems with response time 100 ms ... 1 s and longer. Goal of the study and conducting these tests is to determine computer and software response time in different environments and at diverse combinations of load of the computer components.

Materials and methods

Software and hardware:

Microsoft Windows operating systems where chosen as an environment to run the tests: Windows 2000, Windows XP and Windows 7. The study will be performed on x86 based PC. Two types of runtime systems will be used: Oracle Java Runtime and Microsoft .NET Common Language Runtime. Windows OS were used because of the popular application on home and office use and availability of various software tools.

Tests are carried out using DELL Latitude D830 portable computer with following hardware configuration: Intel® Core™2 Duo CPU T8300 @2.4 GHz, 2.00 GB RAM, 74.53 GB Standard disk drive, Mobile Intel® 965 Express Chipset Family. All necessary up-to date drives where installed on operating systems.

Microcontroller (MCU) development board Microchip Explorer16 with PIC24FJ 16-bit device running at 32 MHz is used as real time external device, from which data should be read and written. Software has been developed in C language using C30 student's version compiler and MPLab IDE environment. The purpose of software is to generate simulated "sensor" data, send the data out using serial port to PC, receive "command" data back from PC, measure the PC's response time and store results. Microcontroller generates and sends to PC "sensor" data frames with various periods. Each data frame contains the same data value "2220", which is recognized by PC software and responded as a "command" with the same value. Experimental data flow is shown in Fig. 1.

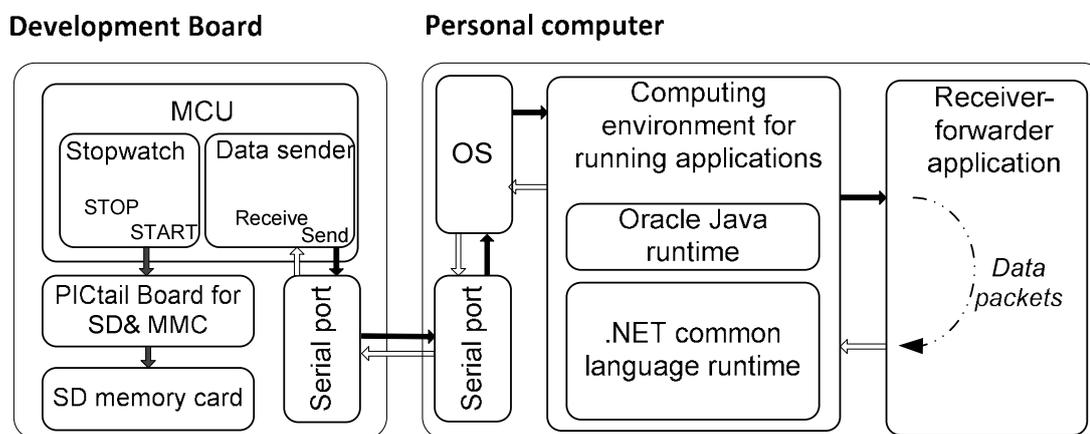


Fig.1. Route of data frames travelling through components of PC and Development board: ➡ shows the sent data frames; ⇔ shows forwarded data frames; ➡ shows measured result

The data frame is put in serial UART (Universal Asynchrony Receiver Transmitter) buffer and timer is started. The data frame is sent to the converter from the UART to RS-232 port, from which it is then sent to the PC. The data is sent at a constant speed from the serial port of controller to serial port of PC. PC reads program port buffer if the data is in the buffer, it is recognized by the .NET or Java application and then sent back to the serial port.

When the controller receives the data, UART performs a hardware interrupt, the data is read from the UART buffer and placed in the controller memory buffer, it is then checked whether the received frame is with the value "2220" and the timer is stopped. Accuracy of the measurement is affected by MCU interrupt latency which is 4 CPU command cycles (about 0.25 us) and timer tick, which is 1 us. Approximate PC response times are more than 1 ms, consequently the measurement accuracy is better than 0.1 % of measured values.

Once data has been received, then the timer measures time data frame has spent traveling back and forth and the results are recorded in the SD memory card. Experimental set-up is shown in Fig. 1.

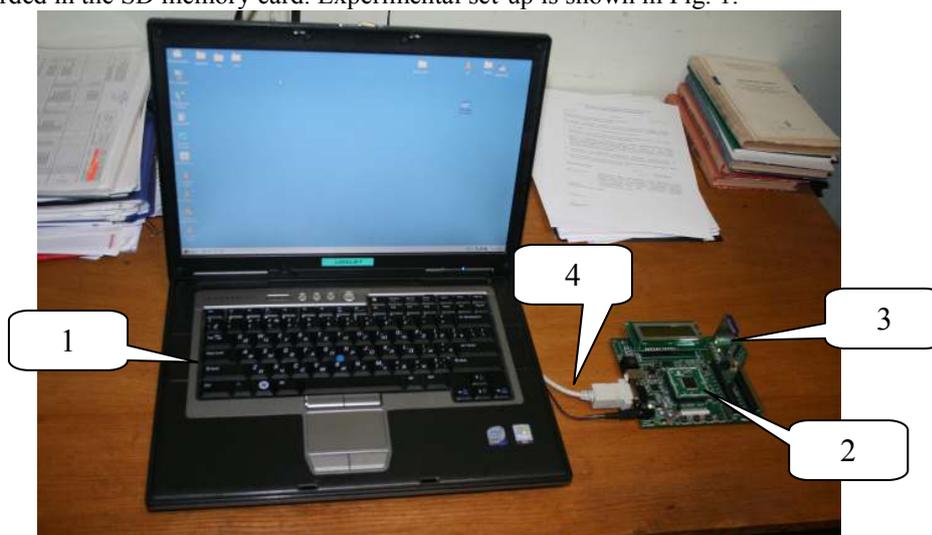


Fig. 2. Experimental set-up:

1 – PC used for tests; 2 – MCU development board; 3 – SD memory card; 4 – serial cable RS-232

The affected response time is studied under effect of four factors:

- OS (Windows 2000, Windows XP, Windows 7, 32 bit);

- runtime system (.NET, program written in C# and Java);
- 5 test methods;
- 4 PC load conditions.

Test methods:

MCU is used to generate the signal to the serial port to which the PC should respond and also to accurately measure the computer's response time, i.e. the MCU is used as data frame sender and computer as a replier. The time is measured between moment when the frame is sent out and received back to the MCU. The measured time is stored on the MCU. The computer software monitors the serial port buffer to check if there is any data and once the data frame is received the software immediately transmits the same data back to the sender. In both runtime systems built in software event mechanisms are used to respond to the MCU data. As a result the actual response time of the software running on the specified hardware depending on computer load and operating system features is determined.

Methods used for the tests are shown below (Tab. 1). The number of frames and delay time is diverse in order to simulate real environment. There will be five different tests carried out on each combination of OS, runtime environment and load of specific PC component. Each test has different number of data frames and/or delay time. Delay in seconds is a time difference between previous PC response received by MCU and next data frame sent out from MCU to PC.

Configuration for serial COM port is:

- Baud rate: 115200;
- Data bits: 8;
- Handshake: None;
- Stop bits : One;
- Parity: None.
- Input buffer size: default 4096 for .NET and Java
- Output buffer size: default 2048 for .NET and Java

Taking into consideration the baud rate, start and stop bits, the time needed for sending and receiving 4 byte data frame is $2 \cdot 4 \cdot 10 \cdot 115200^{-1} \text{ s} = 0.7 \text{ ms}$. The software of PLC development board is programmed in such a way that if PC does not respond in 60 seconds, the software sends out next data frame.

Table 1

No.	Number of frames	Delay, s
1	30	0
2	30	1
3	15	10
4	5	60
5	2	120

Load simulation for different components of PC:

Originally it is decided to use software that would simulate load for all computer components. In order to ensure that tests are being conducted under equal conditions, it is necessary to use a single developer's software program for testing all the various OS. The other option would be to use various developer programs with the same computer component load simulation algorithms. Due to the fact that all the computer components load for both of these options are not available, we have selected options shown in the table below (see tab.2).

The reason for this methodological choice is the universality of these applications and functions. File archiving is possible with the WinZip program, memory load is simulated by Obrut software and file copying is supported on all Windows OS – Windows 2000, Windows XP, and Windows 7 x 32. Obrut creates high memory and/or processor loads and thus simulate a slow or overloaded computer. Obrut can simulate varying levels of single or dual CPU usage intensity at three levels of regularity, and both virtual and physical memory loads.

Table 2

No.	Component of PC	Method of load	Application/OS function
1	RAM	Load simulation	Obrut
2	CPU	Archive of video file	WinZip
3	HDD	Process of copying 3 5 GB files to different locations and partitions of HDD	copy/paste

Computer has several components, which under load could affect the response time. For real situation the load can be different, the following tests are going to be made (tab.3).

Table 3

Load for components of PC – for testing all OS

Nr.	Combination
1	RAM
2	CPU
3	HDD
4	No load for computer components

The experimental results are analysed graphically and statistically using 3 and 4 factor univariate analysis of variance (ANOVA). SPSS20 statistical software is used for statistical analysis.

Results and discussion

Research is made online on a software program that would simulate the load on components of PC. The list of these software programs is wide enough.

To simulate load on RAM Obrut software is chosen. The reason why it is chosen is simple – this software meets specified requirements for the tests – it supports all operating systems that are included in the tests – Windows 2000, Windows XP and Windows 7 x32. Data compressing program WinZip is used to load CPU component. WinZip is supported on all the Windows operating systems so it is a good choice to use it.

Windows is currently the most popular OS used daily both at home and at work. That is the reason for decision to test different Windows OS first. The next step would be to test the Mac OS and Linux OS. It may be also good idea to test different OS used on tablet PC's and smartphones. There could be problem on finding appropriate software program that would be useful to test separate components on all these PC devices. All of the software programs are likely to have their own unique algorithm to load components of PC. Just in case if the algorithms are the same in some of the software programs, it would be impossible to verify that assumption because most developers are reluctant to reveal their algorithms. It is therefore necessary to use a single software program that is developed by the same software developer. Of course appropriate research on such software would have to be made anyway as there is a little doubt that the software would not use the same algorithm irrespective of the OS.

Initially we made tests where all the components where under load simultaneously, i.e., CPU, RAM and HDD. This test failed with the methods we used. The reason why it failed is because the moment when RAM is fully loaded, the WinZip program which is archiving a file, will stop fully loading CPU with mathematical calculations.

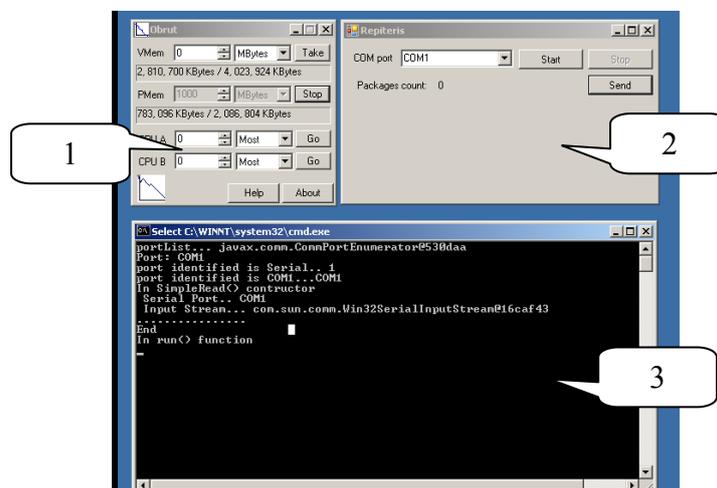


Fig.3. Screenshot of the Windows 2000 environment running the tests:

- 1 – Obrut software that simulates physical memory (RAM) load; 2 – Software program developed in C# and running .NET Runtime environment, that reads COM port, receives and sends back data packages to PLC; 3 – Software program developed in Java and running Java Oracle Runtime environment, that reads COM port, receives and sends back data packages to MCU

Three measurement repetitions are performed for each 4-factor combination (OS – 3 cases, runtime system – 2 cases, test method – 5 cases, load condition – 4 cases). In each of 5 test methods respective numbers of frames (see Tab. 1) are sent to PC and average, maximum and minimum response times are calculated. It resulted in 1080 measurement values total. The results for average grouped by runtime environment and PC load conditions are shown in Fig. 4–7.

The results show that average response times for all tests are less than 6 ms except RAM load and Windows XP – CPU load – .NET environment combination. Slightly worse results for both environments are under HDD load condition and high request frequency with no pauses between requests (first test method). The worst response times are for RAM load and requests to the PC at low frequencies in tests methods 4 and 5. It should be pointed out that CPU load condition did not affect the response times significantly with the exception of windows XP operating system.

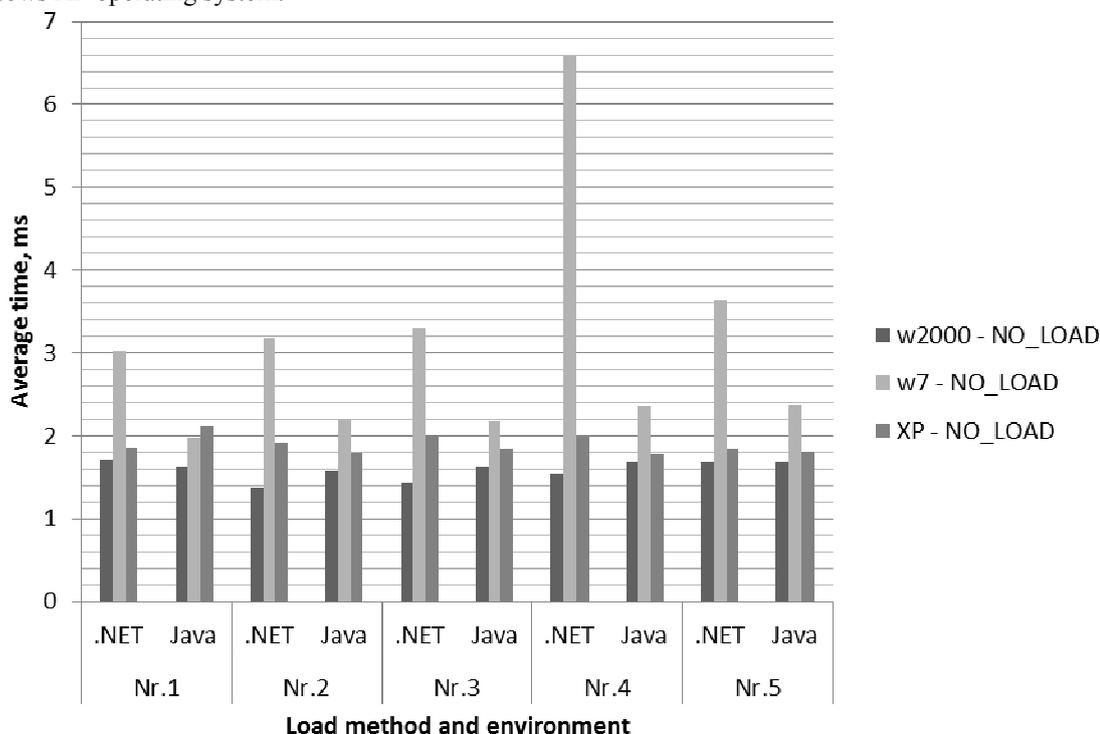


Fig. 4. Tests for all OS, environments and load methods with no load on PC components

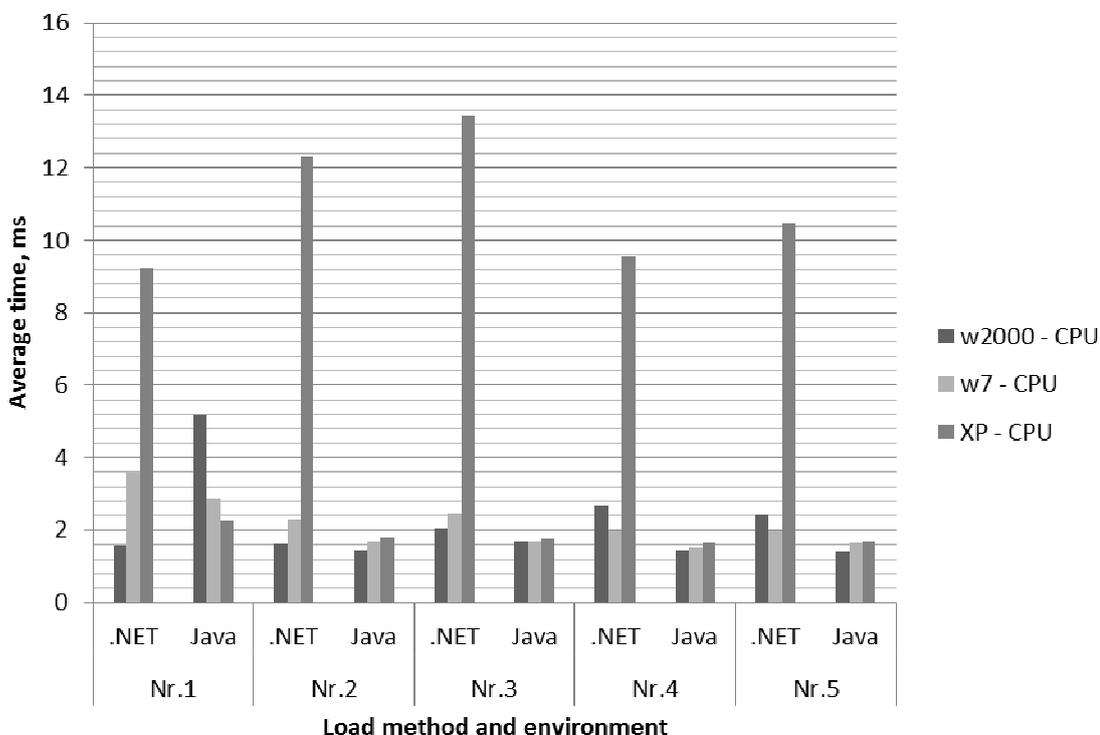


Fig. 5. Tests for all OS, environments and load methods with load on CPU

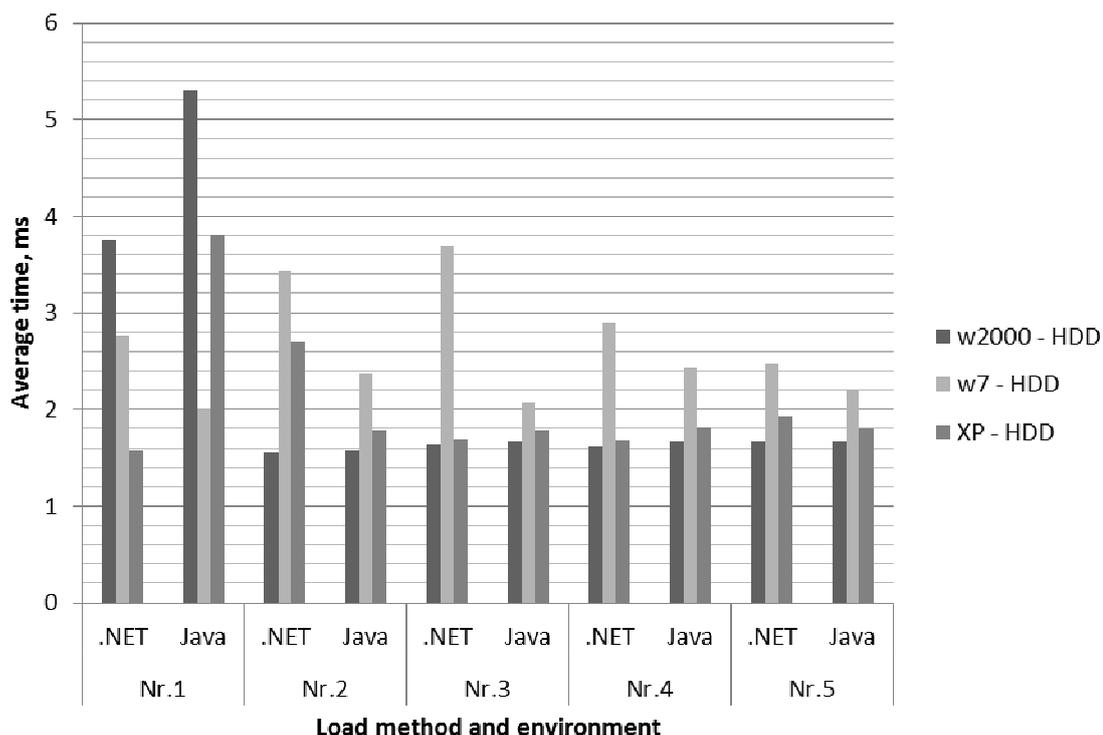


Fig. 6. Tests for all OS, environments and load methods with load on HDD

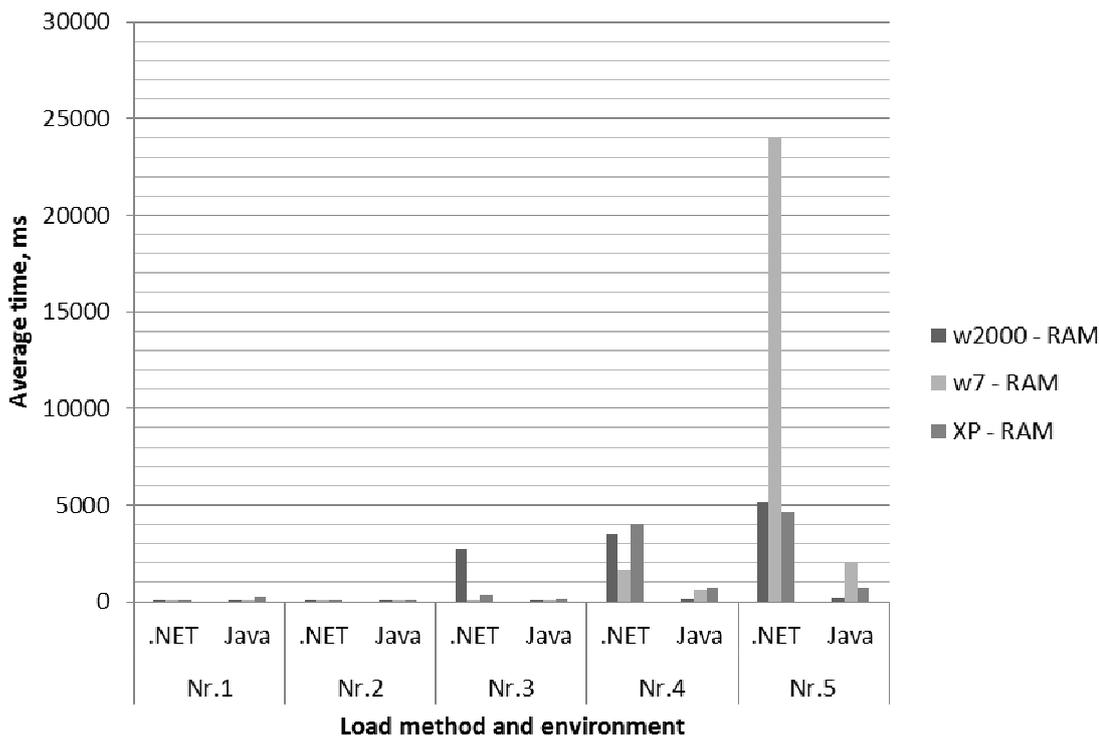


Fig. 7. Tests for all OS, environments and load methods with load on RAM

Charts of minimum and maximum values with respect to factors in general visually repeat average results therefore were not included in the paper. Maximum response times in conducted tests of more than 30 s were also observed under RAM load and Java application even failed to respond in several cases. Minimum response times for first 3 test methods differed insignificantly, but when responding on low frequency requests minimum response times reached 5 s.

Statistical analysis of variances generally approves conclusions from graphical analysis. In statistical difference between response times was assumed to be significant at the α 0.05 level.

Analysis with 4 independent factors shows that there is significant statistical difference for all factors except OS, so 3-way analysis was performed separately for both runtime environments. Pairwise comparison of average

response times for loads for both runtime environments (3-factors each) and for all experiments (4-factors) reveals also that that only RAM load condition differs significantly at the probability 95 %. In all other cases p-value was more than 0.98. Pairwise comparison for different OS reveals that average values for .NET, Java (3-factor) and all 4-factor analysis for Windows 7 significantly differ from other operating systems and are slightly worse in HDD, RAM and no load tests, but with no difference from Windows 2000 in CPU load test.

Conclusions

It can be concluded that main factors that affect response times of a conventional PC (Intel® Core™2 Duo CPU T8300 @2.4 GHz, 2.00 GB RAM, 74.53 GB Standard disk drive, Mobile Intel® 965 Express Chipset Family) for Java and .NET runtime environments and all tested operating systems were: load on RAM and necessity to respond on requests at relatively large time intervals: 60 – 120 s between requests.

Average response times for all tests except RAM load and Windows XP – CPU load – .NET environment combination are less than 6 ms. Maximum response times in conducted tests of more than 30 s were also observed under RAM load and Java application even failed to respond in several cases. Minimum response times for first 3 test methods differed insignificantly, but when responding on low frequency requests minimum response times reached 5 s.

It should be pointed out that only response time has been measured in this research. There are no tests made to determine reliability (system crash, from 1 to 2 min freeze) in long-term operation. These as well as more factor combinations are planned as further research.

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TOWARDS THE EFFECTIVE REUSE-ORIENTED RELEASE CONFIGURATION PROCESS

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Abstract: *The study describes the approach for effective reuse-oriented release configuration process aimed at supporting and effective maintenance of information technology products. Rather often the project is in the situation when there are multiple unsolved or not properly tested changes on the product release date, that were originally planned to be included into the upcoming product version by project management. The main objective of the study is to identify and implement the effective automated solution for building high-quality releases that include not all, but only tested changes. The developed algorithm produces the list of components to be included into the release build based on the list of changes planned for the upcoming release and information from the project code version control and defect tracking systems.*

Keywords: configuration management, release build, reuse-oriented process.

Introduction

The technologies enable people to communicate in new ways, provide new business models, permit businesses to operate more efficiently and take advantage of the new global network economy. Organizations use centralized information systems for managing their business processes and internal structure, and e-business has emerged as a mainstream way to facilitate business transactions around the world (Westermeier et al., 2004).

At the same time in the current situation of financial crisis it is extremely important for applied technologies to provide some economic and organizational benefits by reducing development and operating costs, and by efficient utilization of development knowledge and corporate expertise. So, the need in systematic approach and effective software engineering methods, which allow reusing experience to address recurring problems successfully, is obvious and important (Kotov et al., 2011).

Although information systems are very different, our experience shows, that most of them could be characterized by the following common features as described in Table 1, that are considered important for the purpose of the study:

Table 1

Common features of information systems	
Feature	Description
Constantly requires new changes	Long and continuous maintenance phase usually follows the system delivery to production, when defects reported by the users are resolved and information system is improved to meet new requirements, changing market or environmental conditions.
Relies on heterogeneous technologies	Information systems tend to combine several subsystems and modules that use different technologies. As a result, the system source bundle might contain hundreds or thousands of files of different type.
Requires multi-developer team for maintenance	A single developer is usually not enough for the maintenance of the information system.
Adapts agile methodologies for development	Maintenance and development stage usually takes some period of time that elapses until the next version is released.

The paper presents the results of the ongoing joint research activities related to the improvement of systematic software processes for the maintenance projects, where the product is a large information system being maintained by a team of five or more software developers using one of the iterative development methodologies. The main objective of the study is to identify and implement the effective and reusable solution for building high-quality releases that include not all, but only tested changes. The topic has a particular significance since the proposed approach may provide some economic and organizational benefits by increasing the quality of product releases, by reducing development and operating costs, and by efficient utilization of development knowledge and corporate expertise.

The following section discusses the effective release configuration process and main prerequisites for high-quality releases. It is followed by the review of the proposed release building algorithm and discussion of its proof-of-concept implementation details. Finally, the conclusions are made and future work is outlined in the last section.

Effective reuse-oriented release configuration process

A software process could be defined as a set of activities that lead to the production of a software product (Sommerville, 2001), and it is important in order to ensure efficiency, reproducibility, homogeneity, and predictable time and effort constraints. Process-driven means that the software development and maintenance is done in accordance with well defined processes that are enforced through management policies.

Being a fine-grained part of the process dimension within the reuse-oriented framework described by us in (Kotov, 2010), whose conceptual structure and the main components are outlined in Figure 1, the effective reuse-oriented release configuration process assumes proper development of

- managerial infrastructure in the form of a set of functions, responsibilities, reporting requirements, and reward, which are required to ensure proper operation of the processes, and
- technological infrastructure that includes a configuration management and quality assurance functions to support operations, as well as enforcement of testing, verification and asset certification standards.

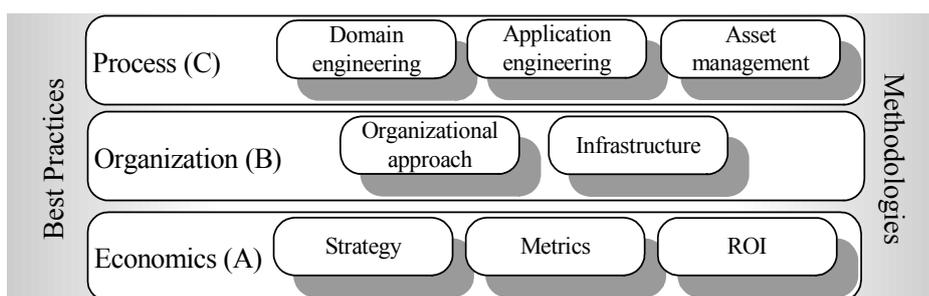


Fig. 1. The overall structure of reuse-oriented framework (Kotov, 2010).

In general, the maintenance phase of a large project assumes existence of defect tracking system, so that the project management could effectively plan which defects to be resolved and change requests implemented for the particular system release. Unfortunately, it is rather common situation in practice, when there are multiple unsolved or not tested changes on the planned release date that could not be delivered with the release. As a result the developers are faced the challenge to build a high-quality release, that includes not all, but only tested changes. However, the conventional version control systems do not offer complete automated solutions to correctly select only source code files with only tested changes.

The following important questions arise within the framework of the research: How to keep track of changes in source files effectively? Are there any other source file modifications related to the particular change? Which version of the particular source file should be released?

It is necessary to solve the following three main tasks in order to achieve the main objective of the study, to identify and implement the effective automated solution for building high-quality releases, that include not all, but only tested changes:

- Identify the general mandatory prerequisites for the process of building high-quality releases from the defined set of source code components.
- Define a release building algorithm that produces the list of components to be included into the build based on the list of changes planned to be included in the release. Each component should be validated for non-tested changes and verified if it can be included into the release build.
- Implement the release building algorithm within the framework of selected technologies.

Prerequisites for the process of building high-quality releases

First, it is necessary to adapt product defect and change request management process to manage the release process effectively. Every problem or change request should be registered through the centralized defect tracking system that makes it possible to manage and to monitor the status of every change over time.

Second, it is necessary to effectively manage the changes in the product source code in order to build the product release with certain set of tested changes included. Each unit of source code should contain information about all changes ever made, what is usually delegated to the version control systems.

However, just introducing defect tracking and source version control systems is not enough for the purpose of our research. There is a need to link those two systems together. Namely, the change identifier from the defect tracking system should be defined for any modification in the source code and propagated to the version control system. It is important to guarantee the control for this action, so that it would be impossible to commit modifications to the version control system without specifying the change identifier. For example, Subversion VCS allows you to create a special script that is triggered when the programmer commits changes to a

centralized server, where it is possible to verify if the description contains at least one change identifier and whether it actually exists in the defect tracking system.

Third, it is necessary to adapt a continuous integration process to automatically build a product from a certain source code changes, make sure that the build is successful, and meet certain quality control criteria by successful execution of integration and unit test suites. There are quite a lot of ready-made solutions of continuous integration server implementations (e.g. Hudson, Bamboo) with different administration opportunities.

In general, the following preconditions are considered important by us for making high-quality releases from the defined set of source code components:

- adapted defect and change request tracking process
- the use of source code version control
- the link between the defect tracking and code version control systems
- established continuous integration process.

Release building algorithm

The following context is set up for the purpose of defining the high-quality release building algorithm:

- The maintenance project is set up and all problems dealt with are registered in the defect tracking system JIRA (JIRA, 2012), where each change has a unique identifier and it is possible to follow its status.
- The product source code is a set of files that are stored on a central Subversion (<http://subversion.tigris.org/>) version control server.
- The iterative development approach is adapted for the maintenance project - a new version of the product is released every second week and includes changes resolved and tested during a particular two-week period. However, in practice the developers usually manage to develop more changes, while the customer prefers to see only tested changes in the new version. As a result, only limited number of changes should be included into the release.

Subversion VCS assigns a unique revision identifier to each commit of modifications in the source code. And it is possible to describe the revision by referencing change numbers from defect tracking system in its description. So, the mandatory requirement for the algorithm is the need to specify the change identifier of the JIRA system in the revision description.

The algorithm performs the search for the revisions that are related to changes planned for inclusion into the release. It is necessary to ensure that each revision includes information whether it was included in any of the previous releases. So, before you start the change identification algorithm, each revision is assigned an additional "Included to the release" Subversion specific attribute, that is empty if the revision was not included to any release yet. The steps of the proposed release building algorithm, that identifies only tested changes, are the following, and its is also conceptually outlined on Figure 2:

- Retrieve tested change identifiers from the JIRA defect tracking system.
- Prepare a special data structure to hold information about the failures in the build.
- Determine the list of Subversion revisions for each defect identifier from 1.
- Determine the list of modified files for each Subversion revision from 3.
- For every modified file perform the following:
 - Find the revision where the file was modified previously.
 - If the revision found in 5.1. has an empty "Included in the release" attribute proceed to 5.3. Otherwise, proceed to 6.
 - Determine JIRA identifier for the revision found in 5.1. Proceed to 6. if the identifier belongs to the set from 1. Otherwise, create a new record in the data structure from 2. with information about change identifier and revision number.
- Mark the revision number from 3. in separate structure.
- Check if the data structure created in 2. is empty, that means release can be build for the defined set of changes. Otherwise, release should additionally include changes from the 2. structure.
- The result of the algorithm is a structure from 6., that contains a list of Subversion revisions, that should be included to the product build, so that only tested changes are delivered to the customer.

Implementation of the release building algorithm

The Java utility application was developed as the proof-of-concept implementation of the defined release building algorithm that can be used with any Subversion code repository, with the source code available from (<http://www.cs.rtu.lv/astf/ldppg/index.htm>). The application is executable JAR file that receives some input parameters described in Table 2, and returns the raw data text file with Subversion revisions for their further

inclusion to the release build. The application relies on the functionality provided by SVNKIT library that is specially designed to expand opportunities for Subversion administration.

Table 2

Parameters for the proof-of-concept implementation of release-building algorithm	
Parameter	Description
--url	URL of the Subversion repository
--u	User name with the access right to the repository
--p	User password
--r	Subversion revision number, that should be used as a starting point for the analysis, that can be used when it is known which changes were delivered to the customer
--conf	Path to the configuration file with the list of defect numbers from JIRA to be included to the release
--svnprop	The name of Subversion revision attribute name, that defines if the particular revision was included to one of the releases

The general activities to determine the revisions to be included into the release are the following. The application execution process is also outlined in Figure 3.

- Make a list of defect identifiers planned to be included to the release in the separate file.
- Execute the application with correctly defined input parameters
- As a result the successful execution of the application the list of Subversion revisions is produces, that should be included to the release. Otherwise, the application reports the list of change identifiers that should be considered additionally.

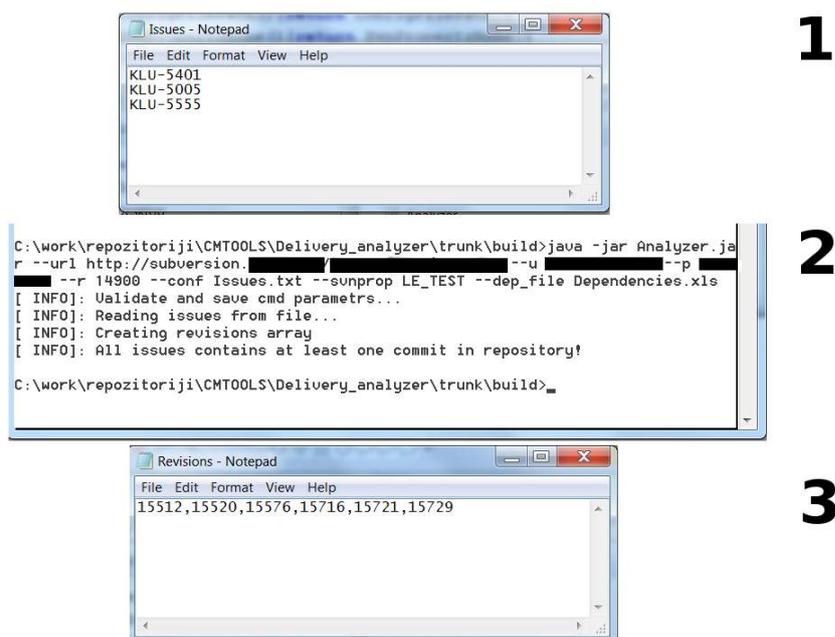


Fig. 3. The proof-of-concept application execution process.

Conclusions

The need in systematic approach and effective software engineering methods, which allow reusing experience to address recurring problems successfully, is obvious and extremely important. The study describes the approach for effective reuse-oriented release configuration process aimed at supporting and effective maintenance of information technology products that is important in order to ensure efficiency, reproducibility, homogeneity, and predictable time and effort constraints for building high-quality releases. As the main prerequisites for the effective reuse-oriented release configuration process the study defines linked product source code management and change tracking system, and working continuous integration process.

The proposed concept relies on the possibility to prepare a release build with only tested changes, and the release-building algorithm is proposed within the framework of this study, that receives a list of defects to be included in the prescribed release and produces the list of components to be included into the release build based on the information from the project code version control and defect tracking systems.

The proof-of-concept implementation of the defined release building algorithm in Java can be used with any project, that uses Subversion code version control system and adapts defined prerequisites into the development process. The future work is related to improvement of the algorithm implementation to work with other popular version control systems.

Acknowledgement

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VULNERABILITY ANALYSIS OF IP MULTIMEDIA SUBSYSTEM (IMS)

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Abstract: *NGN introduces the concept of fix-mobile convergence (FMC). NGN provides the IP multimedia subsystem (IMS) as platform to converge the wire and wireless networks. It is open and distributed architecture that can enable easy access to services, information and resources. But the same time there is lot of risks in such approach. Potential hackers can access IMS architecture to launch some attacks on IMS network. IMS security is vital important and it is beneficial to be aware of possible vulnerabilities. This paper investigates current situation in IMS security regulations, potential threats and attacks facing to IMS deployment. We also provide vulnerability discovering and analysis method with Open Source IMS Core.*

Keywords: IP Multimedia Subsystem, security, IMS vulnerabilities.

Introduction

The IP multimedia subsystem (IMS) is a standardized next-generation networking architecture that has been conceived for telecom operators willing to provide advanced services on top of both mobile and fixed networks (Ahson and Mohammad, 2009). The Next Generation Network (NGN) will be based on IP technology and IMS is a common architecture to provide multimedia services. The main idea behind this framework is to merge to most successful communications paradigms – cellular networks and the Internet. It was designed by the Generation Partnership Project (3GPP) as a part of the vision for evolving 3G mobile networks to delivering “Internet services” in 3GPP Release 5. Now it is accepted by 3GPP2, ETSI, ITU-T and developed as a unified service architecture that allow fixed-mobile convergence, and as the core of the NGN, already now some countries in Europe and Asia-Pacific areas, operators are going on the deployment of IMS.

Complete migration on all-IP architecture enable convergence of voice, video, data and mobile network technologies, it is great achievement to maintain single communication platform for all communications, from another side it is big challenge to provide adequate security for such heterogeneous network environment. Security in telecommunication networks never have been major problem, telephone systems is characterized by strict rules and strongly guarded end-nodes. It is hard to access another end point of the system if you are not recognized by another end. Telephone numbers are given only to carriers and all jurisdictions is carefully controlled. The same time IMS and Internet is characterized by widely open architecture, open end-points, based on freely available standard with lot of threats and vulnerabilities, which comes from Internet world. With this new network infrastructure, information can be reachable whenever and wherever, by who needs it. Hence, in the corporate world, the border between traditional company and office environments will diminish. Naturally these developments will inevitably come with many still unknown vulnerabilities, threats, and security risk (Atay and Masera, 2011).

Vulnerability assessment has become important are in security, but there is still a lack of vulnerability analysis in this area, many of existing assessment methods are limited possibilities and do not cover all areas when applied to IMS. The aim of this paper is to discuss current situation in IMS security and propose IMS vulnerability analysis method based on ETSI threat, vulnerability and risk analysis method (eTVRA) and ITU-T.805 Security Architecture., which analysis based on Open Source IMS Core.

Materials and methods

This paper makes IMS security evaluation derived from two approaches; (1) eTVRA and (2) ITU-T.805 Security architecture. This paper also makes research on vulnerability of IMS network, making tests with open-source IMS (OpenIMS Core). The idea for users of this Open Source software is to enable the development of IMS services and the trial of concepts around core IMS elements that are based upon highly configurable and extendable software (Anon, 2011). The Open IMS is experiment environment for developers and designers and includes new concepts, paradigms and new technologies that make it one of the best tools worldwide for IMS testing. This project is popular in academic and industry community.

The IP Multimedia Subsystem (IMS) is the key enabler for integration of multiple loosely coupled features in technical and service level. And IMS has open architecture, but its network core consists of lot of entities for cooperation between different user equipment's. Architecture of IMS provided in Figure 1 (Anon, 2011). IMS is decomposed in many functional entities and interfaces between them, where each interface is specified as reference point, which defines both the protocol over the interface and functions which it does. Main components in IMS are (Ahson and Mohammad, 2009):

- Proxy call state control function (P-CSCF) – is the first contact point within the IP multimedia core network; all SIP signaling traffic from or to the user equipment (UE) traverse via the P-CSCF. Its

address is discovered by the UE following the packet data protocol (PDP) context activation. The P-CSCF behaves like a proxy, accepting and forwarding requests and responses. It performs functions like authorizing the bearer resources for the appropriate QoS level, emergency calls, monitoring, header (de)compression, and identification of I-CSCF.

- Interrogating call state control function (I-CSCF) – is the first contact point within an operator's network. It contacts the HSS to get the address of S-CSCF to serve the user for registration. It forwards SIP requests and responses to S-CSCF. It also performs network topology hiding functionality.
- Serving call state control function (S-CSCF) – performs the session control services for the end point and maintains session state as needed by the network operator for support of the services. Within an operator's network, different S-CSCFs may have different functionalities. The important functions performed by S-CSCF include user registration/interaction with service platforms for the support of services. The S-CSCF decides whether an AS is required to receive information related to an incoming SIP session request to ensure appropriate service handling. The decision at the S-CSCF is based on filter information received from the HSS. This filter information is stored and conveyed on a per-application-server basis for each user.
- Home subscriber server (HSS) – is the equivalent of the HLR (home location register) in 2G systems but extended with two DIAMETER-based reference points. It is the master database of an IMS that stores IMS user profiles, including individual filtering information, user status information, and application server profiles.
- Application server (AS) – provides service platforms in IMS environments. It does not address how multimedia/value-added applications are programmed; only well-defined signaling and administration interfaces (IMS service control and Sh) and SIP and DIAMETER protocols are supported. This enables developers to use almost any programming paradigm within a SIP AS, such as legacy intelligent network servers (i.e., CAMEL support environments); open service access (OSA)/Parlay servers/gateways; or any proven VoIP SIP programming paradigm like SIP servlets, call programming language (CPL), and common gateway interface (CGI) scripts. The SIP AS is triggered by the S-CSCF, which redirects certain sessions to the SIP AS based on the downloaded filter criteria or by requesting filter information from the HSS in a user-based paradigm. The SIP AS comprises filter rules to decide which of the applications deployed on the server should be selected for handling the session. During execution of service logic, it is also possible for the SIP AS to communicate with the HSS to get additional information about a subscriber or to be notified about changes in the profile of the subscriber.
- Media resource function (MRF) – can be split into media resource function controller (MRFC) and media resource function processor (MRFP). It provides media stream processing resources like media mixing, media announcements, media analysis, and media transcoding as well as speech. The other three components are border gateway control function (BGCF), media gate control function (MGCF), and media gate (MG), which perform the bearer interworking between RTP/IP and the bearers used in the legacy networks.

More detailed about IMS Core component can be found in (Ahson and Mohammad, 2009; Poikselka et al., 2006). In architectural design of IMS is used layered approach where transport and bearer services are separated from IMS signaling network and session management services. IMS is split in three main layers – Service or Application layer, Control or Signaling layer, and User or Transport layer. Application layer provides an infrastructure for services development and management. Control plane routes signaling and tells the transport plane what traffic to allow, also this layer takes care of billing information. User plane provides core with access from User Equipment (UE) over mobile, Wi-Fi and broadband networks. Security organization in IMS consists of several parts – Network Domain Security (NDS), Authentication and Authentication and Key Agreement (AKA). NDS provides security between different nodes within a domain. NDS is concerned with a network that is controlled by a single administrative authority. The security domain refers to the network that is managed by a single network operator or provides IP security between different domains. Authentication provide identity management, if user wants to access the IMS network, the user will be authenticated. AKA allows organizing access security for SIP-based services. Challenge response protocols are intended to make the identification tests without having shared the password between two entities. Important component of IMS security is IPsec which provides security services for: data integrity, data origin authentication, anti-replay protection and some protection against traffic flow analysis. The access into the IMS network must have enabled security mechanisms and features such the user equipment associations is protected. It is obvious that important role in security is authenticate each entity in network. Rest of security model will be analyzed in next chapter together within vulnerability evaluation process.

Dimensions are security methods addressed to protection – Access control, Authentication, Nonrepudiation, Data confidentiality, Communication flow security, Data integrity, Availability and Privacy. Each layer is relates to unique vulnerabilities, threats and mitigation measures.

One of standards for security evaluation is ISO 15408:2009 Common Criteria for Information Technology Security Evaluation, but this standard is time and resource costly, and security guidelines are not accessible for non-security experts. For this reason, the Telecoms and Internet converged Services & Protocols for Advanced Networks (TISPAN) program at European Telecommunications Standards Institute (ETSI), a major European Telecommunication (Telco) standardization organization with worldwide influence, developed a threat, vulnerability, risk analysis (eTVRA) method to support Telco companies in a Common Criteria security evaluation. eTVRA builds on CORAS (Braber et al., 2003) and is structured to provide output that can be directly fed into a security evaluation thus easing the evaluation process (Morali et al. 2009). The vulnerability assessment in eTVRA consist of 7 steps witch shown in Figure 3 (Morali et al., 2009). The process starts with identification of the security objectives of a system or a system component, out of which security requirements are extracted. Later an inventory of the assets in the system is drafted. The purpose of using the eTVRA is to be able to identify vulnerabilities that exist in the system. Therefore, after identifying assets and their vulnerabilities, threats that exploit those vulnerabilities and cause incidents are determined. The security requirements and the threats are then extended according to threats and vulnerabilities. Then, the occurrence likelihood of the threats and their impact is analyzed and quantified. This is used in the following step to calculate the risk. Consequently, the countermeasures for treating the risk are identified. This process is applied iteratively, until the risk of unwanted incidents is reduced to an acceptable level, or whenever there are changes in the environment (Rosseb et al., 2006).

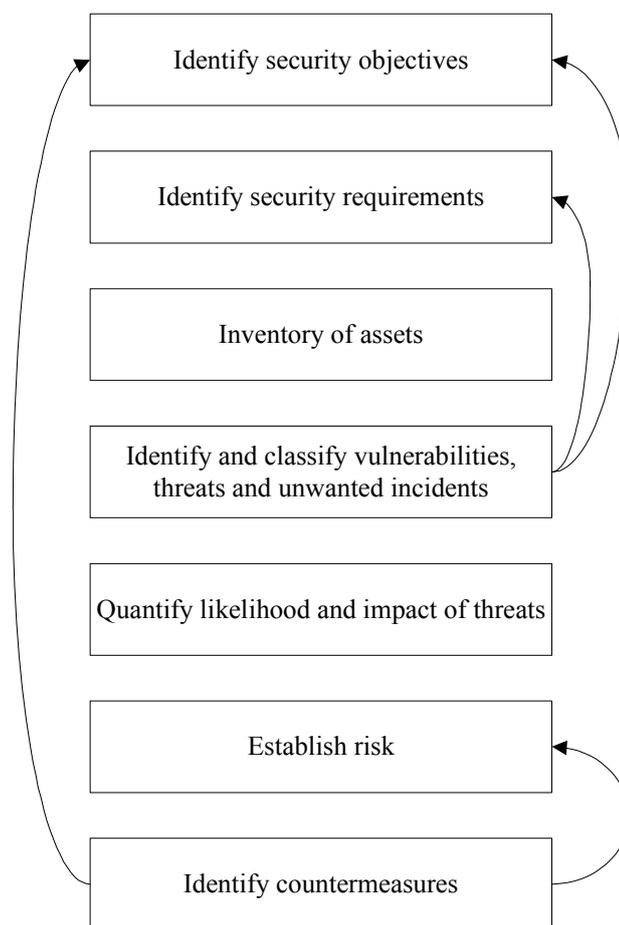


Fig. 3. Main steps of eTVRA.

.This research propose use X.805 modular security perspectives which shown in Figure4 (Anon, 2011.) to IMS Core vulnerability analysis which is extended with eTVRA.

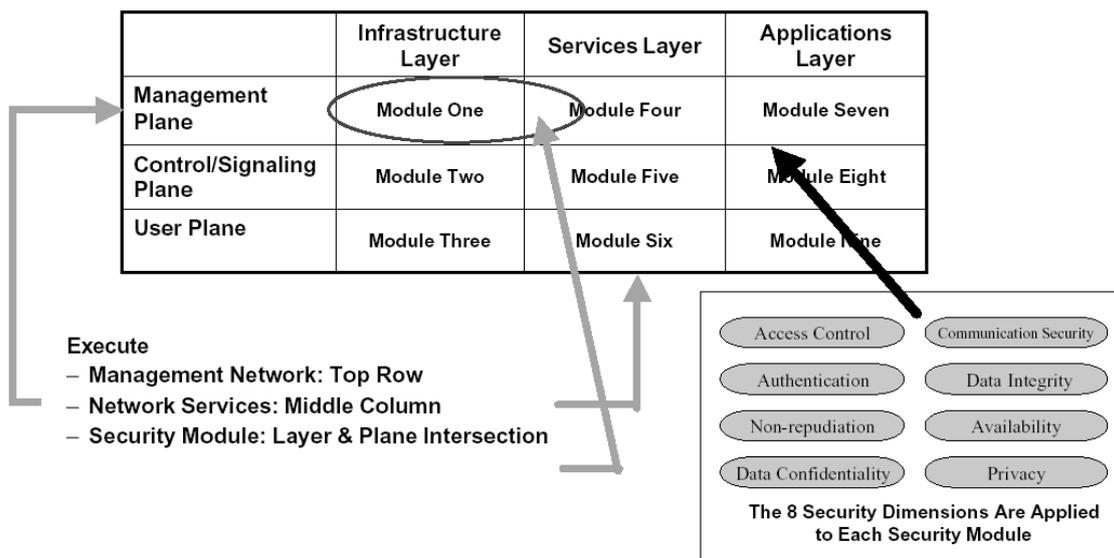


Fig. 4. Modular security perspectives from X.805 (Anon, 2011.)

There are 9 security perspectives or modules where is necessary to identify software and hardware entities in each perspective, as third factor in vulnerability analysis must be included human factor, which mean, that should be evaluated all kind of activities as well. Such solution should provide not just vulnerabilities analysis, but also better security implementation and improvement, because such model allows update security when vulnerabilities are identified.

Results and discussion

Current IMS security standards do not cover all security solutions and risk management possibilities for IMS core network. All security layers have their risks and vulnerabilities. It is important identified IMS hardware and software components and their security solutions in particular infrastructure and functional role. 3GPP IMS and ETSI have draft series of security to protect IMS, but it is still vulnerable to several attacks. ITU-T X.805 is good solution to provide fully covered, comprehensive security. Proposed model consist of eight steps (Figure 5), which basically taken from eTVRA, but some of the steps are extended with ITU-T X.805 security dimensions, layers and planes. The extensions made in proposed model are discussed in following steps description:

- **Identify context/location** – it is critical important to identify location of entity in core network and it's functional context with other entities. Aim of this step is discover location of entity or reference point and analyze it relationships with other entities in particular context.
- **Set module** – After identification of entity or reference point it should be analyzed in which module it is located and with which layer and plane it is related. That will help correctly identify security objectives.
- **Identify security objectives and requirements** - to protect IMS against vulnerabilities, it should meet all security objectives which mentioned as ITU-T X.805, but here can be exceptions which will come from context analysis.
- **Inventory of assets** – Identify hardware and software components. And categorization by security layers and planes.
- **Identify and classify vulnerabilities, threats and unwanted incidents** – combine assets with security dimensions, discovering threats, vulnerabilities and possible unwanted incidents.
- **Analyze vulnerabilities and unwanted incidents between modules** – each combination of several components can include new risks. So overall situation must be analyzed as well. During research was discovered, that eTVRA do not provide guidelines for this process.
- **Quantify likelihood and impact of threats** – in this step is established the risk of attack against any vulnerability
- **Identify countermeasures** – this is the place how to achieve goals and the provision of security dimensions.

Standards and protocols are changing all the time. IMS is quite new in networks and are in development study, it will be changed, patched and will evolve new features. That means that vulnerability analysis must be continuously updated and monitored with every change in system.

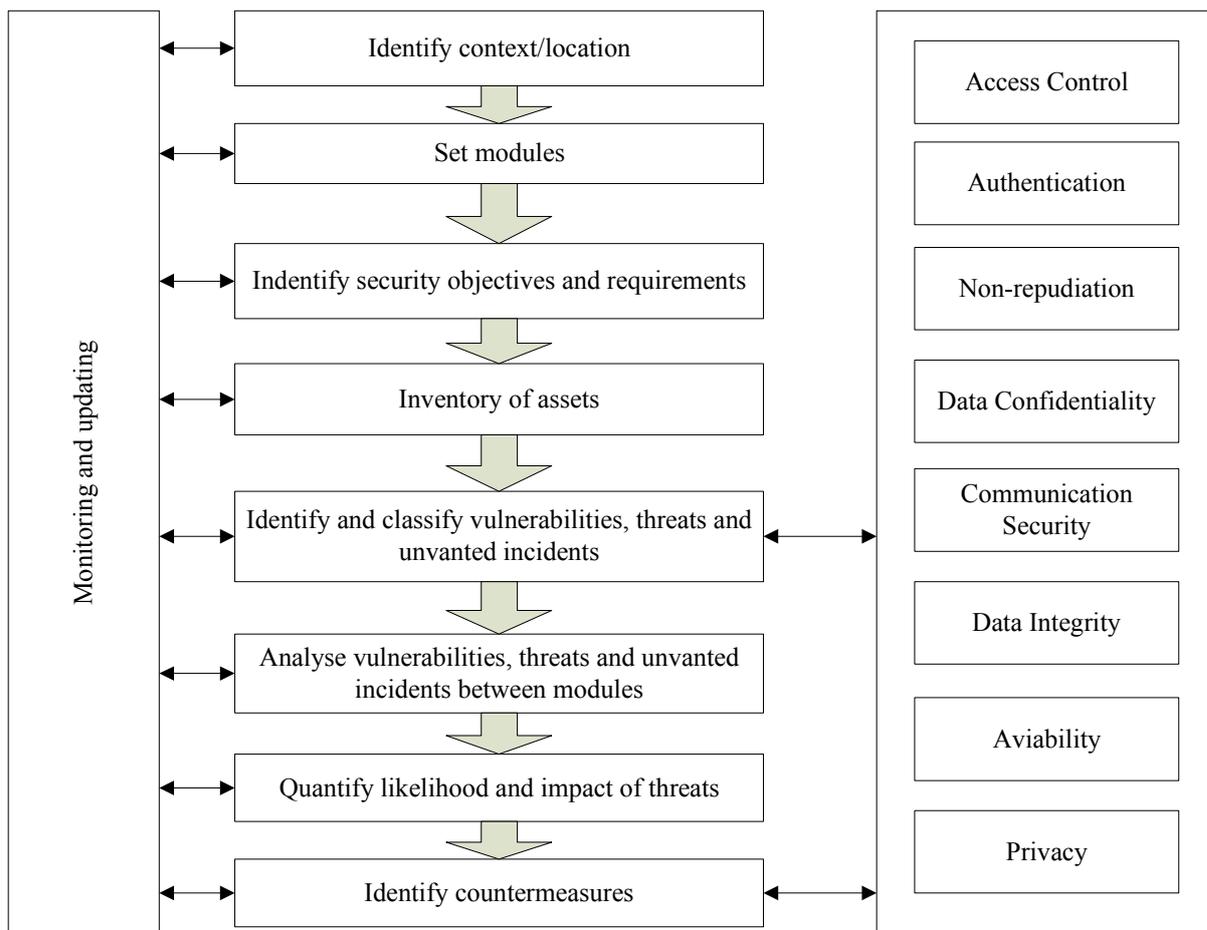


Fig. 5. Extended IMS vulnerability testing model

Research process shown, that not all security dimensions can be addressed to each module, but anyway, it must be analyzed in context of infrastructure and assets. Any entity with some functional value in this architecture can be analyzed as asset, which must be grouped according it particular security layer and plane, what is shown in Table 1. IMS vulnerability analyses were done according asset categorization below.

Table 1

IMS assets by modules

	Infrastructure Layer	Service Layer	Application Layer
Management plane	CTF, CDF, CGF, PDF	Diameter (Rf, Rx, Ro) COPS (Go)	HTTP (Ut)
Control plane	CSCF, MGCF, MRFC, BGCF, IBCF, SLF, AS, DNS, ENUM	SIP/SDP(Gm, Mw, Mg, Mi, Mj,Mk, Mr), Diameter(Ch, Dx), H248 (Mp, Mn)	SIP(ISC), Diameter(Sh, Dh)
End-user plane	IM-MGW, MRFP, HSS, UE	RTP/RTCP(Mb), User profile	Voice, IM, VIDEO, State(XCAP)

Analysis of IMS vulnerabilities shown, that IMS may be exposed by different types of attacks. Vulnerability testing was done on OPEN IMS test-bed. This project source core is part of the Open IMS playground and is used to set up test-bed in order to simulate a practical scenario. Current research summarized different security vulnerabilities below in Table 2:

Table 2

IMS vulnerability list

Vulnerability	Weakness	Security dimension	Asset module	Impact
Message spoofing	IMS has absence of IPsec protection between user equipment and P-CSCF	Authentication	Service layer Control plane	Fraud of trust
SIP SQL injection	SIP authentication controllability is unsecure	Availability	Service layer User plane	Deniel of service
Media theft	Not enough control on media streams	Non-repudiation	Infrastructure layer Management plane	Theft of services
SIP flooding	Unable effectively prevent REGISTER and INVITE message flooding	Availability	Infrastructure layer Control plane	Loss of QoS for users
RTP data sniffing	No default confidentiality from data stream	Confidentiality	Application layer User plane	Theft of information
CANCEL attack	Possibility to fake SIP CANCEL request	Integrity	Service layer Control plane	Session disruption
RTP injection	RTP protocol missing media integrity protection mechanisms	Integrity	Service layer User plane	Session disruption
Man in the Middle P-CSCF attack	Authentication using SIP must be improved	Authentication	Service Layer Control plane	Impersonation of a server
Dictionary attack	Inadequate identity protection and AKA chipper algorithm use	Authentication	Application layer Control plane	Identity theft
BYE attack	Possibility to fake SIP BYE request/ not enough confidentiality protection	Integrity	Service layer Control plane	Disruption of session
DNS Cache Poisoning	Not enough connection integrity protection	Integrity	Infrastructure plane Control plane	Loss of service
Network topology disclosure	Not protected SIP messages	Confidentiality	Infrastructure layer Control plane	Leak of network topology
HTTP Parse Attack	Improperly data ContentLenght regulation	Availability	Infrastructure layer Control plane	Loss of services
User equipment configuration tampering	Probability lack of user education in security questions	Availability	Infrastructure layer Control plane	Denial of services

Evaluation of potential threats and vulnerabilities must be repeated obligatory, so it must be monitored and updated. Most of treats are discovered by current mechanisms, like IPsec and TLS or Authentication and authorized. But such attacks like SQL injections and data flooding can't be protected and requiring extra tool implementation most effective toll for such protection should be intrusion detection and prevention tool." That would help improve protection of human related threats.

Conclusion

This paper proposes implementation of eTVRA model in IMS vulnerability analysis which is extended with ITU-T X.805 security recommendations. This paper proposes method for fully covering vulnerabilities testing. Threats and vulnerabilities of IMS core was made on Open IMS test-bed at Focus Fraunhofer. One of major protocols which is facing with many vulnerabilities is SIP protocol. In this paper was shown major threats and future quantifying of vulnerabilities analysis should be made. Also as promising technology for such treat prevention could be implementation of intrusion detection and prevention system. Research show that much vulnerability related to Application layers and control plane, what means that this parts should have extra attention for protection.

Acknowledgements

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MODELLING AND SIMULATION TECHNOLOGIES

AUTONOMUS ROBOT BEHAVIOR FOR PATH PLANNING IN CLOSED SPACE

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Abstract: *The paper deals with path planning programme for mobile robots. The aim of the research paper is to analyse motion planning algorithms that contain the design of modelling programme. The programme is needed as environment modelling to obtain the simulation data. The programme product is based on RRT algorithm and Simulated annealing (SA). The simulation data give the possibility to conduct the wide analyses for selected algorithm. Analysis means the simulation data interpretation and comparison with other data obtained using the SA for motion planning. The results of the careful analysis were considered for optimal path planning algorithms. The experimental evidence was proposed to demonstrate the effectiveness of the algorithm for steady covered space. The results described in this work can be extended in a number of directions, and applied to other algorithms.*

Keywords: robotic, robot, RRT, Simulated annealing, path planning.

Introduction

In order to achieve the wide range of the robotic application it is necessary to provide iterative motions among points of the goals. For instance, in the industry mobile robots can replace any components between a storehouse and an assembly department. Ammunition replacement is widely used in military services. Working place is possible in ports, airports, waste site and etc. Mobile robots can be used for monitoring if it is necessary to observe control points in the secret place. There are a lot of scenarios where the iterative motion is applied (Siegwart et al.,2011).

The environment for such mobile robots used is complicated, various, non – structural and dynamic by nature. Robots must get rid of the obstacles which are different in size, form, location and can appear or disappear at any time. At that time avoiding the obstacles the possible of collision risk, sensor information and movement planning imprecision, error location and uneven surface are always foreseen. Robot can be damaged, trapped or embed in any construction etc. Environmental imprecision is always very hazardous for mobile robots (Siegwart et al.,2011).

At the same time the effective utilization is required from robots. Robots should work as much as possible and fast and safely (Siegwart et al.,2011;Laan,1999;Fisher,1999). Although the safety of people and the place of their living is primary and the same can be said about the safety of robots as well.

Algorithms for motion planning have proved themselves as optimal methods in this planning. The best conditions are normally measured with a distance. But it is possible to measure the conditions mentioned differently. For instance, in order to find safe ways space robots take into consideration surface, roughness and slope. However, the effectiveness of complex, dynamic and partly unknown spaces was not investigated for a long time. Nowadays, it is little research in the choice of motion planning in the dynamic conditions. Approaches (Poldvere,1999;Ausekle,1999;Lipmaa,1999) admit that environmental structure is known as *a priori*. Admittedly, that unknown environment is static and unchangeable during some period of time in source (Villemson,2002). Source (Sokratova,2000) reflects uncertainty except the two previous statements.

Commonly, in order to work out any motion planning system which is used mobile robotic platform and it is necessary to do the following tasks:

- to familiarize with the essence of motion planning task i.e. to observe the algorithm of classical and modern planning;
- to identify the advantages and disadvantages of the algorithm;
- to select the most relevant algorithm;
- to work out system design.

The representation of working area for the robot can vary from continuous geometrical behavior to approved decomposition of topological maps. The first step for any motion planning system is permanent environmental model transformation in the map relevant to the motion planning algorithm chosen if it is possible. The motion planning distinguishes due to the influence on the discrete decomposition. The three basic decomposition strategies can be mentioned (Siegwart et al.,2011):

- Motion maps: to show the package of motion in free space;
- Unit decomposition: to distinguish empty from occupied units;
- Potential field: robot reaches the target unit if it follows the least resistance direction. That function is sometimes called as navigation function if additional conditions are added.

Then some motion planning algorithms can be briefly envisaged i.e. Rapidly-exploring random tree (RRT) and Simulated annealing (SA).

Goals

According to the mentioned above statement to compare RRT and SA algorithms by means of simulation is becoming rather interesting.

The aim of the research paper is to analyse motion planning algorithms that contain the design of modelling programme. The programme is needed as environment modelling to obtain the simulation data. The programme product is based on RRT algorithm. The simulation data give the possibility to conduct the wide analyses for selected algorithm. Analysis means the simulation data interpretation and comparison with other data obtained using the SA algorithms for motion planning.

Methods

RRT – in the last decade the motion planning algorithms on the basis of step sample have been proved as efficient ones and worked out theoretically as probable definiteness. The theoretical limits of these algorithms have not been solved so far. It is proved that RRT algorithms always converge but do not insure the optimal magnitude. The storage of the search graph starts to become impractical at high dimensions, and the need to use probabilistically complete algorithms as RRT increases.

The SA method (Kirkpatrick et al.,1984;Kirkpatrick,1984) is widely used in applied science. The well-known traveling salesman problem has effectively solved by means of this method. For instance, the arrangement of many circuit elements on a silicon substrate is considerably improved to reduce interference among the elements (Vecchi et al.,1983;Otten et al.,1989).

The use in practice and the necessity of it is connected to autonomous robots a great deal that move in the space and are able to plan route on their own. One of such robots existing in our everyday life is autonomous vacuum cleaner. Autonomous vacuum cleaners do not usually use the motion planning algorithm. They are based on different simple algorithms, for example cleaning in a spiral, crossing the premises avoiding the walls and their moving is casual after touching the walls. The philosophy of this design was proposed by the scientists of Massachusetts Institute of Technology. Robots must be like insects having primitive controlling devices aimed at the environment. As a result, an autonomous vacuum cleaner is very effective in cleaning premises, but much more time is required for them as compared with work made by a person. There is a drawback, the autonomous vacuum cleaner tidies one and the same places many times but other places are cleaned only once. The use of motion planning algorithms can raise the effectiveness of an autonomous vacuum cleaner.

Assumptions

In order to fulfill the aim of the research paper the following conditions are introduced for:

- premises where an object moves;
- robot (or object) moves around the premises;
- path the robot moves on in the premises.

The premises are presented as two – dimensional plane. The plane of premises is equally divided into the checks. The check dimensions are equal to robot dimension that moves in the premises. The robot moves only one check forward and back. During one motion the object can move to the one check from empty eight ones (eight checks around one check) paying attention to that check is not occupied by the obstacle.

RRT algorithm is introduced to the programme product as the only one which calculates the motion planning task (fully covers all empty space). The results were compared with SA algorithm data.

In this research paper both algorithms were compared practically using and combining different placement of obstacles in the unchangeable two-dimensional space. All the results were obtained on one and the same computer (2.66 GHz processor and 2GB RAM), operating systems (Microsoft Windows XP or Ubuntu 10.10 Linux were used). The following information was collected about:

- the number of covering for each check;
- the time which was necessary for both algorithms to plan the route.

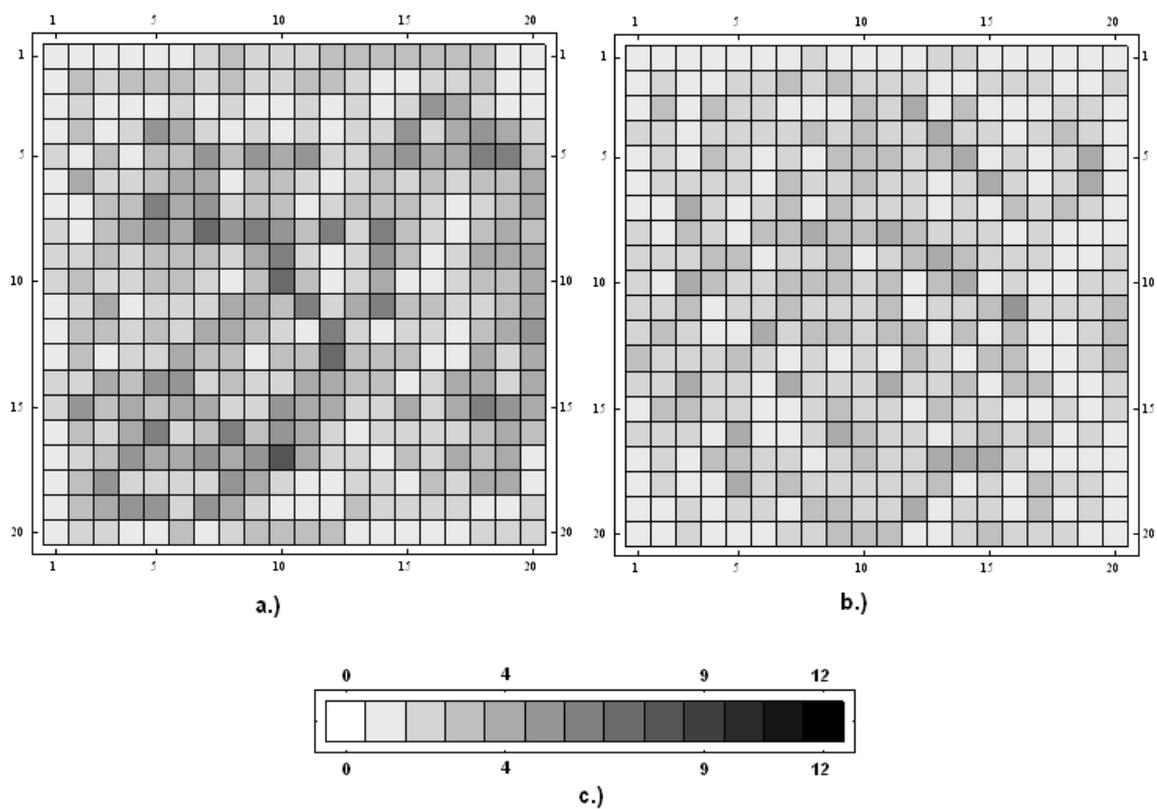


Fig. 1. Density of the covering for the space without obstacles: a – for RRT; b – for SA; c – density scale.

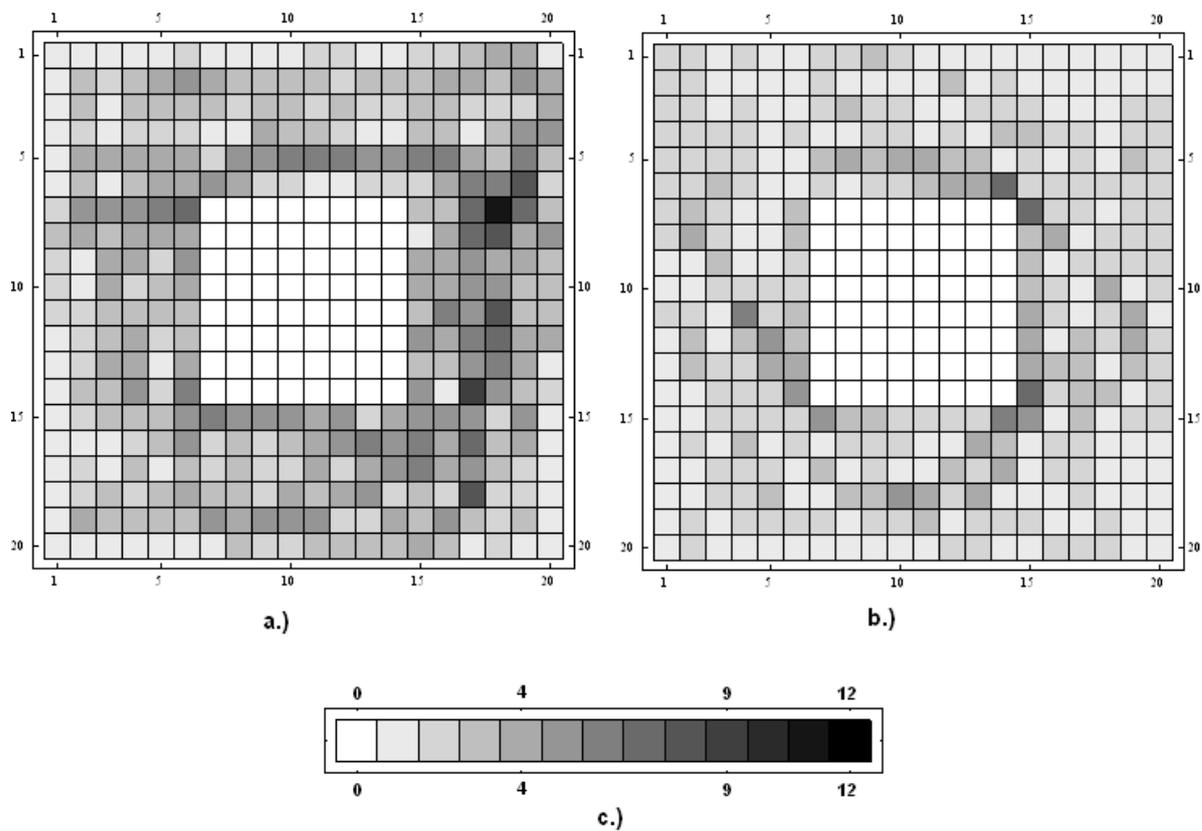


Fig. 2. Density of the covering with the obstacle consisting of 64 checks (the obstacle is in the middle of the premises): a – for RRT; b – for SA; c – density scale.

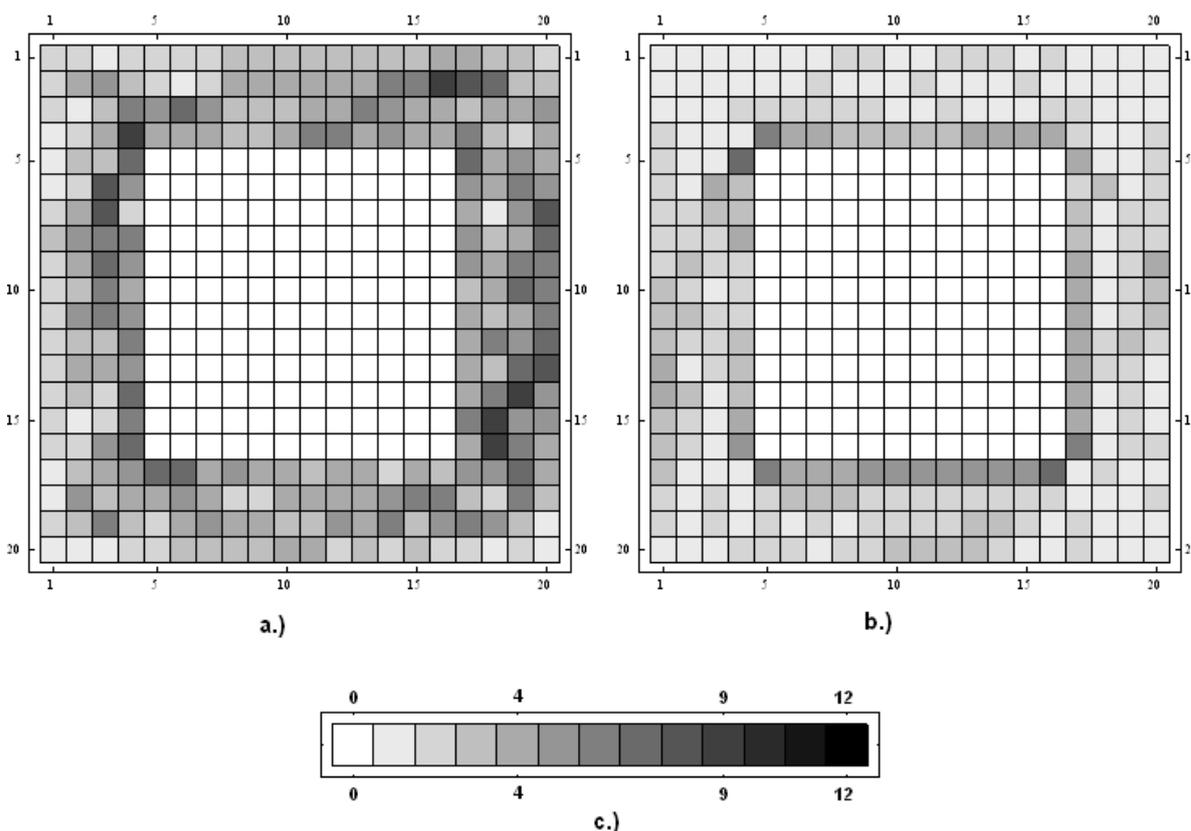


Fig. 3. **Density of the covering with the obstacle consisting of 144 checks (the obstacle is in the middle of the premises):** a – for RRT; b – for SA; c – density scale.

The given illustrations show the density of the covering (how often a robot covers each check) (Fig.1-3).

Results

Different coverings of the premises using RRT and SA algorithms in the identical conditions are shown in the research paper. The measure of the premises during simulation was not changed (20 x 20 checks) but the dimensions, placement and the number of obstacles in the premises were changed. The simplest case is when the premises do not contain any obstacles i.e. completely empty. So, for example the simulation was done in the empty premises using the both algorithms. This process was repeated several times. It is very important to stress that the principle of previously mentioned process was used for the placement of any obstacles in the premises i.e. not only in the case of utterly empty premises. The simulation data were calculated as average ratio to the number of simulation repetition. During each simulation the following characteristics were calculated:

- the number of initial empty checks;
- the time which was necessary to plan the route to cover the whole premises;
- the total number of steps taking into account the facts that a robot can move one and the same check several times.

Periods of time of motion planning for RRT and SA algorithms were compared (i.e. RRT period of time were divided with SA interval of time). The results of division were between 1.26 and 1.72 times for different placements of obstacles. It means that motion planning for SA algorithm is 1.26 times faster at least. It is very important to stress that periods of time of motion planning were between 1 and 3 minutes (3 minutes applies to RRT). Route was planned better with SA in comparison with RRT and premises were covered more regularly that was observed from Surface diagram. SA showed the better results than RRT did in case the number of occupied checks was decreased. A less number of steps were needed in the case of SA, i.e. between 27.11% and 46.91% less number of steps. It is very important to stress that the number of steps was oscillated between 542 and 1092. The total period of time for route can be between 542 and 1092 s (9 and 18.2 minutes) if considering that real robot performs 1 step a second (see Table 1).

Table 1

Some typical comparison values between RRT and SA

See Fig.	Number of free checks	t_{mp_RRT} (where t_{mp} - period of time of motion planning)	N_{RRT} (where N - number of steps)	t_{mp_SA} (where t_{mp} - period of time of motion planning)	N_{SA} (where N - number of steps)	t_{mp_RRT}/t_{mp_SA}	N_p (%) (where N_p - less number of steps for SA)
1	400	188	1092	114	796	1.65	27.11
2	336	163	1078	95	655	1.72	39.24
3	256	93	1021	74	542	1.26	46.91

Conclusion

The period of time for route is bigger than period of time for motion planning and it restricts all the process. The period of time for route planning can be decreased if computational power is increased. That is why the effectiveness of robot depends on effectiveness of route planning, i.e. from the number of steps. The using of SA can improve real robot effectiveness from 27.11% to 46.91% (the effectiveness criterion is a less number of steps for SA compared to RRT). It is very important to stress that effectiveness of process is strongly connected to energy saving and it is possible to prove that 46.91% of electric power can be saved.

Both algorithms can be successfully used in the requirements of autonomous tasks for robots, military technology and dynamic games.

Therefore, it is possible to use motion planning algorithms in other fields of studies which are out of route planning.

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INVESTMENT AND RUNNING COSTS ESTIMATION FOR HETEROGENEOUS MULTI-ROBOT SYSTEM

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Abstract: *Economic benefit of an industrial company depends on forethought deployment of an industrial production system. Authors propose the procedure for optimization of specification of multi-robot system. It uses following concepts: mission requirements are defined using components –functions of the robotic system. Components are grouped into agents – mobile robots or stationary units of a robotic system. Finally a set of agents is considered as a solution – a specification of heterogeneous robotic system, which defines types of agents and a number of their instances used to carry out a mission. The paper describes the analysis of investment and running costs of heterogeneous multi-robot system and presents development of costs estimation model used as a fitness function in genetic algorithm.*

Keywords: multi-robot system; optimization; genetic algorithm.

Introduction

Application of robotic systems in various fields is gaining popularity. Robotic systems are being used on industrial sites for production process automation (Jammes & Smit, 2005) and intelligent manufacturing (Almeida, 2011). An increasing number of applications is reported in such domains as medicine (Davies, 2010), elderly care (Hansen et al., 2010) or daily life as household companions (Parlitz et al., 2007). During the years researches have noticed variety of advances of heterogeneous robotic systems comparing with convenient ones (Weiming Shen & Norrie, 1999; Bi et al., 2008). Increasing number of applications of heterogeneous robotic systems (Kiener & von Stryk, 2010; Medvidovic et al., 2011; Wong et al., 2011) set the complex task of design and development of optimal heterogeneous robotic system. The effectiveness of production system and economic benefit of a company depends on successful deployment of industrial robotic system.

Current researches are aimed to improve performance of heterogeneous robotic system using variety of novel methods applied for intelligent control (Nouyan et al., 2009; Parker, 2008), world modeling (Coltin et al., 2010), communication (J. E. Haddad & S. Haddad, 2004; Rybski et al., 2007; Mathews et al., 2011), etc., but the configuration of the system is predefined or selected intuitively. However the performance of whole system is strongly influenced by characteristics and functionalities of the individual robots (Levi & Kernbach, 2010). Author proposes an optimization procedure, which is based on heuristic search methods, and its purpose is to reduce the space of feasible solutions and to identify non-optimal combinations at early stage with minimal effort.

The paper describes costs estimation model for heterogeneous robotic system which is used for initial evaluation of solution candidates and is implemented as fitness function for genetic algorithm. Genetic algorithm was introduced as powerful, domain-independent heuristic search technique inspired by Darwinian theory (Holland, 1975). Successful applications of genetic algorithm were reported in variety of domains, which include chemistry (Zhong & Tian, 2011), management (Gonçalves et al., 2008), logistics (Sourirajan et al., 2009), control (Jiang & Adeli, 2008). Researches demonstrate optimization of various parameters of robotic system (Martínez et al., 2009; Hondo & Mizuuchi, 2011; Saravanan et al., 2009). Author use total costs of ownership (TCO) as a universal criterion for multi-robot system applied at analysis and design stage of the project. TCO includes costs required for design, implementation, deployment and operation of such system. The aim of described costs estimation model is evaluate large number of solution candidates within reasonable amount of time.

Concept of specification optimization procedure

The scope of current research is limited to heterogeneous multi-robot systems domain and it aims to develop a formal method for optimization of specification of multi-robot system. Multi-robot system specification is a formal description of system's configuration. The specification defines types of agents (classes), their functions as well as a number of instances of each class of agents in the system. Optimal specification of multi-robot system is such configuration of the system, which maximizes objective function. Author is selected total costs of ownership (TCO) which is convenient criterion for robotic systems as it includes design, development and operating costs of system.

According to developed specification optimization procedure several concepts has been defined (see Fig. 1.). *Component* stands for a definition of function of the robotic system. Components are grouped together in order

to form an *agent* (rather, mobile robot or a stationary unit). *Solution* is a specification of heterogeneous robotic system, it defines types of agents and a number of their instances used to carry out a mission. Number of rules is applied before considering any combination of agents as a solution. Complexity analysis demonstrates that combinatorial explosion is typical for such types of optimization problems.

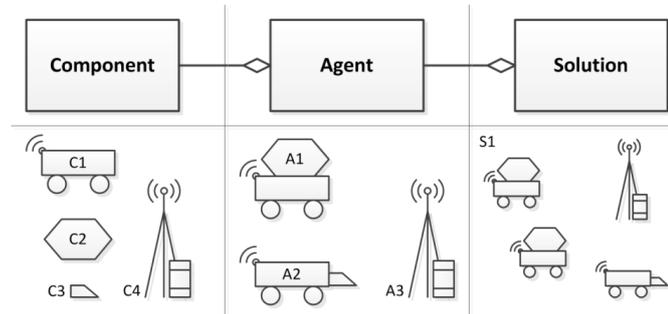


Fig.1. Conceptual model of the solution

Specification optimization is performed according to developed procedure, which specifies five consecutive steps (see Fig.2.). First of all business requirements are defined by industrialist, then optimization objective function is developed and solution space is analyzed. If the number of possible solutions is too high to evaluate all of them, then heuristic algorithms are used to narrow the scope of considerable options to the bunch of fittest solutions. Finally evaluation is performed using simulations in order to select optimal solution for particular mission. Detailed description of steps of the procedure is provided in (Komasilovs & Stalidzans 2012).

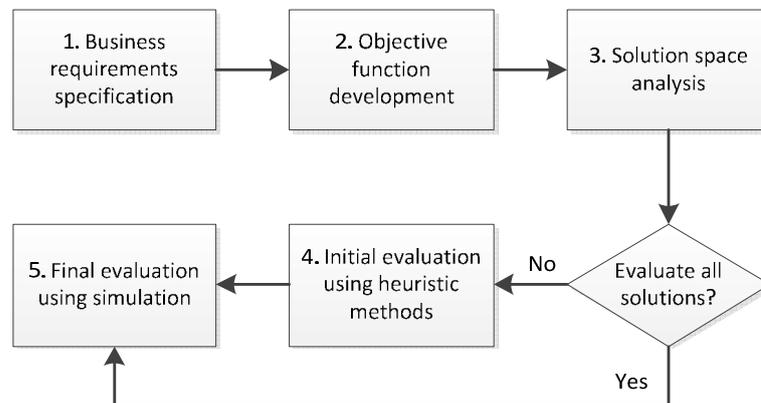


Fig.2. Specification optimization procedure

The scope of this paper is limited to step 4 of the specification optimization procedure and it describes TCO estimation model used for initial evaluation of solution candidates.

Estimation of investment costs

Within the current paper author use term investment costs to define all expenses required to design, implement and deploy multi-robot system from the scratch into production environment. Investment costs do not include expenses related to the operation of the system.

Simple model has been developed that allows fast estimation of investment costs and fast evaluation of solution candidates. Investment costs could be divided into several positions described below. Conceptual model of multi-robot system specification optimization procedure imply that the mission for such system is defined using a list of components. Costs estimation model assume that components have additional properties, which are related to the costs of particular component.

Proposed model imply that investment costs of the whole system (Q_{inv}) equals to the sum of investment expenses for agents (Q_{inv_agent}). Additionally expenses for system design are applied as a fraction of agents' expenses (c_{sys_design} coefficient).

$$Q_{inv} = (1 + c_{sys_design}) \times \sum Q_{inv_agent} \tag{1}$$

Investment costs of agents (Q_{inv_agent}) consists of design costs of particular type of agents (Q_{design}) and production expenses (Q_{prod}) of all instances of particular class of agents.

$$Q_{inv_agent} = Q_{design} + Q_{prod} \times N_{inst} \tag{2}$$

Design costs (Q_{design}) depends on the number of components (N_{comp}) involved into design of particular type of agents, and author assume that it grows exponentially. Coefficients (c_{lin} and c_{exp}) are used to tune growth dynamics according to real prices of design.

$$Q_{design} = c_{lin} \times \exp(c_{exp} \times N_{comp}) \quad (3)$$

Production costs of an agent (Q_{prod}) equals to sum of purchase prices of components (Q_{comp}) used in particular agent and agent assembly expenses (Q_{assy}).

$$Q_{prod} = \sum Q_{comp} + Q_{assy} \quad (4)$$

Assembly costs of an agent (Q_{assy}) grows exponentially depending on number of components used in the agent (N_{comp}). Author assume that each component have additional complexity index (c_{cplx}), which should be involved into assembly costs calculation.

$$Q_{assy} = c_{lin} \times \exp(c_{exp} \times N_{comp}) \times \max(c_{cplx}) \quad (5)$$

Values of Q_{comp} and c_{cplx} are defined for each component used in multi-robot system specification optimization procedure, coefficients c_{lin} and c_{exp} both for design and assembly costs estimations are defined on the level of optimization problem.

Estimation of operating costs

Within the scope of current research author defines operating costs as the expenses which are required to perform particular mission specified for specification optimization procedure. Operating costs of the heterogeneous multi-robot system are highly dependent on application peculiarities of the system because of dynamic perturbations between mobile robots of different types. The most precise method to estimate operating costs for such systems are simulations, which allow reproduction of operating environment close to real production site.

The aim of the paper is to development of fast operating costs estimation model which is used to evaluate large amount of solution candidates. Author assumes several simplifications: it is considered that agents have no downtime. Agents switch from one task to another instantly, and they are utilized for 100% of time. Also it is considered that particular agent can perform only one of its functions at time.

According to proposed model operating costs (Q_{oper}) of the system consist of energy (Q_{energ}) and maintenance (Q_{maint}) costs of equipment.

$$Q_{oper} = Q_{energ} + Q_{maint} \quad (6)$$

Maintenance costs (Q_{maint}) of the robotic system are considered to be constant over operating time of the system (T_{sys}). It is considered that maintenance rate exponentially grows of total number of agents within the system (N_{agents}).

$$Q_{maint} = c_{lin} \times \exp(c_{exp} \times N_{agents}) \times T_{sys} \quad (7)$$

Major part of operating costs of the system consists of energy expenses (Q_{energ}), like electricity or fuel costs. It depends of operating costs (Q_{oper_agent}) and operating time (T_{agent}) of each agent.

$$Q_{energ} = \sum(Q_{oper_agent} \times T_{agent}) \quad (8)$$

Operating expenses of particular agent per time unit (Q_{oper_agent}) are calculated as sum of power consumption indicators (P_{comp}) of its components.

$$Q_{oper_agent} = \sum P_{comp} \quad (9)$$

Working time estimation for particular agent is not trivial in multi-robot systems and it refers to logistics. It could be generalised as transportation problem where agents are capable to perform certain tasks with defined performance (suppliers). The mission for robotic system is to get completed defined amount of tasks (consumers). Additional parameters are defined for the mission in order to calculate dynamic attributes of the agents. General transportation problems are solved using linear programming, for instance using simplex method (Nelder & Mead 1965).

Conclusion

The paper presents costs estimation model for heterogeneous multi-robot system, which is used for initial evaluation of system's specification. It refers to step 4 of proposed specification optimization procedure, which is implemented using genetic algorithm. The model is used as fitness function for individuals of genetic algorithm population and it allows fast evaluation of solution candidates with acceptable accuracy.

Specification optimization procedure was developed as formal analysis method for heterogeneous multi-robot systems and it allows elimination of non-optimal solution branches on early stages with minimal effort.

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MODELLING AND SIMULATION OF CLOUD COMPUTING SOLUTIONS

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Abstract: *Nowadays, the designing of cloud computing systems is actual approach which is developing very quickly. The cloud computing platform can be useful in any economy domain. Using of cloud computing can increase effectiveness of rural sector through cost savings of monitoring, practically unlimited data capacity for calculating of statistic values and industry values used by domain managers and decision makers. Usually cloud computing requires reengineering of legacy software systems. It means reengineering of currently operated information systems and applications used by domain enterprises and adapting these systems for cloud platform. Solving this problem causes necessity for architecture and functionality modelling of current systems or modelling newly designed systems. Domain owners expect clearly defined vision of system deployment and operation in cloud. An architectural solution of Cloud Computing systems has its own technical peculiarities and it is necessary to precisely describe and gauge them. Behaviour of Cloud systems depends on large number of stochastic factors. For estimation of operational behaviour of such systems determined mathematical expressions usually are insufficient. This kind of systems research tasks could be effectively implemented by stochastic simulation. This paper focuses on design of UML based Domain specific language for modelling and simulation of Cloud Computing systems. Initial Design of Unified Modelling Language (UML) based Domain Specific language (DSL) described in this paper achieves synergy from in IT industry widely used UML modelling technique and the domain specific Cloud Computing extensions. As a novelty for UML modelling, especially for simulation purposes, the presented DSL is enriched by a set of stochastic attributes of modelled activities. Such stochastic attributes are usable for further implementation of discrete-event system simulators.*

Keywords: cloud computing, dsl, uml, simulation.

Introduction

This paper is devoted to modelling of Cloud Computing Solution. The authors have developed UML based domain specific modelling language for modelling structure and behaviour of Cloud solution. The structural model is made of three kinds of diagrams. High level *cloud* diagram, *service* diagram and *service deployment diagrams*. In the proposed solution to the cloud behaviour modelling there is offered to add to UML based diagrams with system describing stochastic service attributes.

As the final step for modelling the system behaviour would be use of simulation that would allow estimating performance of the system.

The cloud computing technology is a modern IT domain, where the provider of the cloud solution is occupied with the updating of hardware and software. The end-user takes advantage of the provided resources without requiring cloud users to know the location and other details of the computing infrastructure. The technology of the cloud solution consists of two logical parts - *back-end* and *front-end*. Back-end part consists of a hypervisor, hardware and software, which drives front-end virtual solutions. *Front-end* part is powered by the cloud service, used by the ultimate *end-user*. End users access cloud applications through a web browser or a light weight desktop or mobile app. The provider carries out of the Hypervisor, hardware and software.

Cloud computing is the delivery of computing as a service rather than a product as a metered service over a network.

Cloud classification

By working out the model of the cloud the authors use the following cloud classification: public cloud; private cloud; cloud of an organisation; hybrid cloud. Depending on the class, in the modelling of the system, each model has its own set of attributes. Each cloud provides its own kinds of services. Cloud solution serves such kinds of services: software as a service; platform as a service; infrastructure as a service.

Public cloud - Applications, storage, and other resources are made available to the general public by a service provider.

Community cloud - shares infrastructure between several organizations from a specific community with common concerns (security, compliance, jurisdiction, etc.), whether managed internally or by a third-party and hosted internally or externally.

Private cloud - Private cloud is infrastructure operated solely for a single organization, whether managed internally or by a third-party and hosted internally or externally.

Hybrid cloud - Hybrid cloud is a composition of two or more clouds (private, community or public) that remain unique entities but are bound together, offering the benefits of multiple deployment models.

Hybrid cloud, in point of fact, can involve all the above mentioned kinds of Cloud Computing. In its structure it is necessary to define security perimeters which determine whether the cloud is private, of an organisation or public (Buecker et al., 2011).

Application reengineering for operating in cloud

Reengineering occurs when it is necessary to transfer classic software to cloud solution.

Before starting transferring a solution to a cloud solution, it is necessary to analyse the business function. It has to be determined whether the software meets, partly meets or does not meet the requirements of the technology of Cloud Solution. Operation of the cloud depends on a lot of factors. To be possible to project the structure, the measurements and performance of Cloud Solution the authors worked out domain specific language (DSL) for cloud modelling.

Domain specific language for modelling of cloud solutions

A Domain specific language (DSL) is language for programming, specification or modelling suitable for particular problem domain specialists to solve their specific technical tasks (Achim et al. 2007, Lenz and Wienands 2006). This chapter describes domain specific language for modelling and simulation of cloud computing solutions. Proposed DSL language is based on the UML language. Currently, using UML is one of the most commonly used approaches in IT system modelling. UML belongs to the group of graphical modelling languages. Initially UML was built for information systems modelling to facilitate the development and maintenance processes. As regards system modelling, UML modelling is widely used at system development or enhancement phases (Teilans et al., 2011; Teilans et al., 2008). In this research, the UML language will be supplemented by stochastic attributes, that can be used to simulate cloud solution services.

When creating a model with the modelling language based on UML, cloud solution was divided into business logic from the service and service physical topology. In the proposed DSL language cloud solution can be represented by three types of diagrams: Cloud diagram, Service diagram and Service deployment diagram.

Cloud diagram is composed of clouds. Clouds have two attributes - name and description. Clouds are connected with *cloud connectors*, see Fig.1.

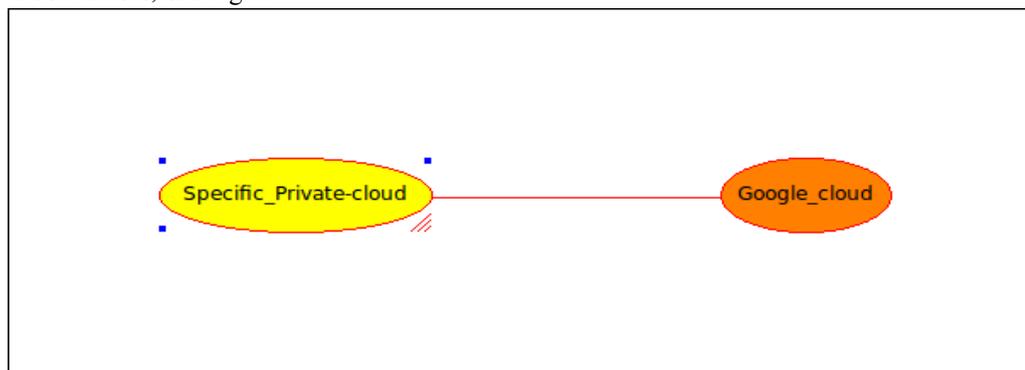


Fig. 1. Cloud diagram

For each cloud connector one or more service diagrams should be created. Service diagram depict cross-service use. Service diagram consists of services. Services are connected with the *service connectors*. Service connector can be unidirectional or bidirectional. This means that the services can use each other. The following diagram is used for modelling business solution functionality. For example, the service diagram Fig.2. shows a cloud of workshops designed for HR system functionality.

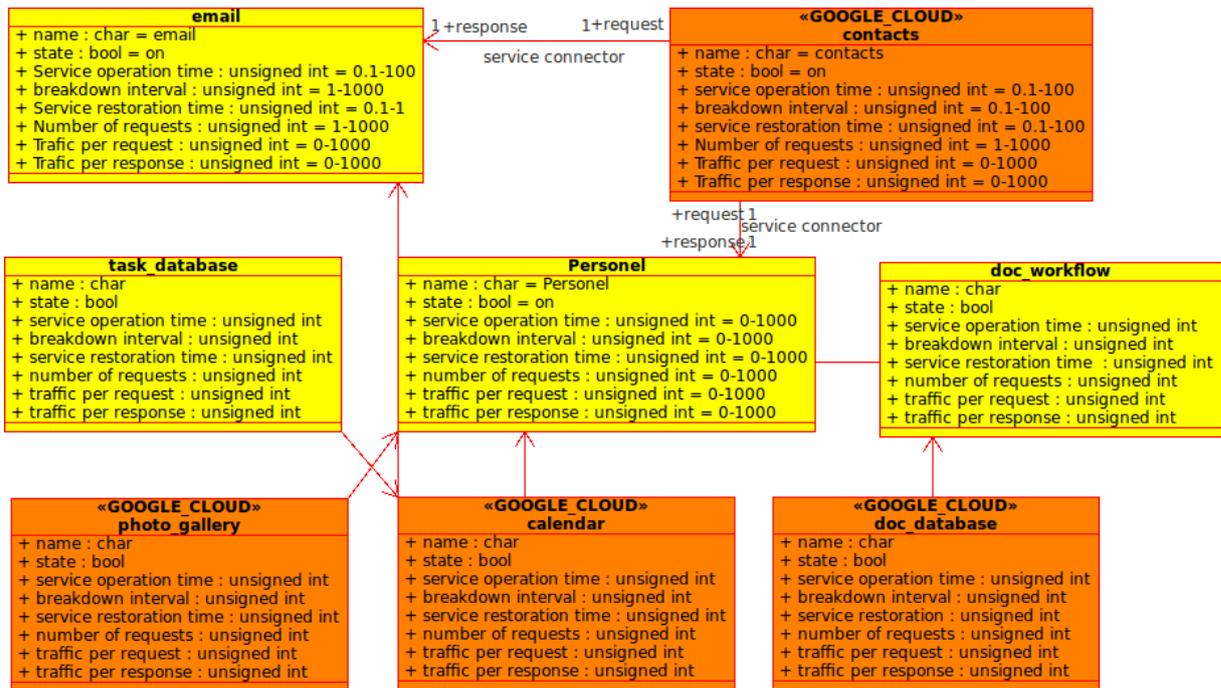


Fig. 2. Service diagram

In next step, for each *service connector*, the third kind of diagram - *service deployment diagram* - should be created Fig.3. *Service deployment diagram* represents the service sites. In *Service deployment diagram* services are connected with *site connector*. *Site connector* can be unidirectional or bidirectional. This means that service sites can use each other.



Fig. 3. Service deployment diagram

The overall DSL cloud model hierarchy diagram is shown in Fig.4.

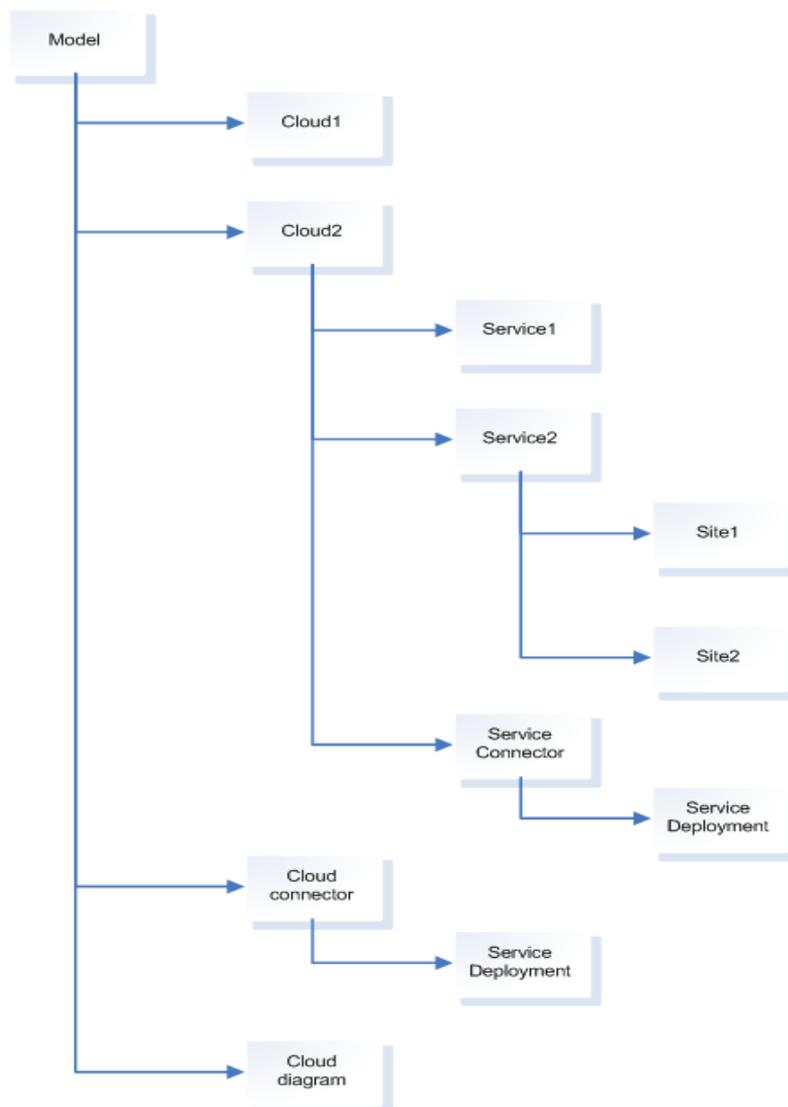


Fig. 4. DSL diagram hierarchy

Simulation of Cloud computing model

To enable model simulation several stochastic attributes were introduced for service entities. See Table 1. For these stochastic attributes it is possible to gather statistics during simulation. Each stochastic attribute is described with probability distribution function. Specific distribution function could be determined by statistical analysis of existing cloud system usage (for example - from event logs). Attributes used in simulation are described in Table 1.

Table 1

Service stochastic attributes

Service operation time	effective duration of service operation	ms
Breakdown interval	Time between service breakdowns	ms
Service restoration time	Time required to restore service after breakdown	ms
Number of requests	Requests count per time	Requests per second
Traffic per request	Number of transferred Kb	Kb
Traffic per response	Number of transferred Kb	Kb

In Model services are connected using service connectors. Cloud connectors have stochastic attributes as well. Service connectors correspond to internal network connections in real life Cloud implementation. Service stochastic attributes are described in Table 1 and Network stochastic attributes are described in Table 2. Attribute *service operation time* describe time which service consumes to handle received service request and returning data to requestor. *Breakdown interval* attribute describe interval between unexpected service breakdowns. *Service restoration time* – time spent to restore service back to functional state. *Number of requests* - request count per time unit which is used for external requests simulation. *Traffic per request and traffic per response* together with *network bandwidth* are used for simulation of network utilization. All attribute values could be defined as a probability distribution functions.

Table 2

Network stochastic attributes

Connection breakdowns interval	Time between network breakdowns	ms
Connection restoration time	Time required to restore network after breakdown	ms
Network bandwidth	Network throughput	Gb/s

Fragment of Cloud system *service diagram* in proposed DSL language Fig.5.

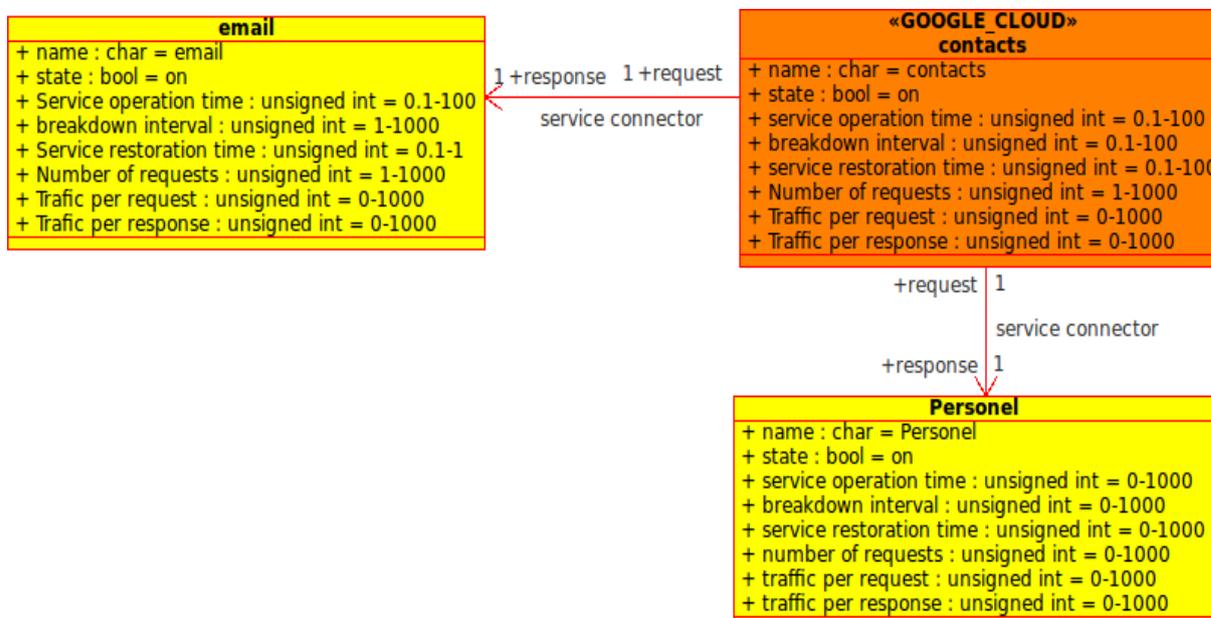


Fig.5. Services with stochastic attributes

Conclusion

The current situation within business indicates the necessity for more complicated and more effective cloud computing systems development. In the presented paper the given approach allows to perform Cloud solutions analysis which is based on the system model specification and simulation. In this way the one window approach is realized for both system developers and maintainers and for those responsible for the operation and deployment policy of a system. The presented DSL are still in the early stages. Further work will be performed to improve the Domain specific language. The second group of further activities will be devoted to implementation of an appropriate simulation engine. Model repository and tools for storing and processing simulation results will be developed for domain specific decision support. This approach will be approved on several enterprise systems decided for cloud migration.

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MODELLING OF FELLING PLANNING PROCESS

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Abstract. *The aim of the paper is to model felling planning process using GIS data. Regularities, development opportunities and the relationship between the environment and the processes of society, which previously could not be seen, using GIS techniques can now be seen and also provided. GIS is used for different types of challenges: the efficient use and search of natural resources, territorial and industrial planning, monitoring of living conditions, social care, science and education, mapping and other. The main GIS-oriented databases difference from conventional databases is their attachment to the real world coordinates. The success of felling development is based on planning, as well as any other activity. The quality of this planning will affect the quality of stand after felling, labour productivity and the cost, preservation of nature objects and public places, which are located near to felling place. Felling planning is a laborious process, which is followed within several regulations described in the laws. The essential part of process is to plan structure of exporting roads, using all geographical restrictions. To plan the felling development effectively, the logger must survey felling's surrounding. It is necessary to assess the environmental risks and set up a professional technological map. Author's recent studies in felling processes show that developing felling at first it is necessary to carry out its analysis using geographic data. For this purpose felling planning support process is modelled there. In the future such modelling of the process is going to help developers and others to plan felling effectively as well as it could significantly enhance this process.*

Keywords: GIS, felling, planning

Introduction

Nowadays, using rapidly developing GIS technological field, many planning processes based on real world coordinates, can be done and analysed effectively. GIS users analyse complex situations, visualize problems and create geographic plans and solutions. Opportunities provided by GIS help people to make faster and better decisions (Samardak, 2005; Paura et al., 2006). Benefits of using GIS technique are unquestionable. Nevertheless many processes based on geographical data sometimes are still done without it. Felling planning is one of those processes that could be automated. Its manual development is laborious and slow process (Arhipova et al., 2008).

One version of possible felling planning processes is described there. In my opinion it can be divided into six main phases:

1. Felling auction
2. Development of purchase contract
3. Preparation and issue of documents
4. Felling survey and environmental assessment
5. Environmental risk factors evaluation
6. Development of technological card

In Latvia felling process is regulated by several LR laws, such as "Forest law" 3rd part, Regulation Nr. 892 "Regulations of felling on forest lands" and Regulation Nr. 434 "Labor protection requirements in forestry". Development of technological card is part of the process, which can be automated. The effectiveness of an automated process could not be reached, drawing technological scheme manually on a paper. In the same time GIS data provide us real world coordinates and location of nature objects. An information system is being developed to reach mentioned advantages and simplify the process (Dangermond, 2005).

Materials and methods

Sub processes of felling planning are described there Fig.1.

- Felling auction – the process which aim is to sell felling;
- Development of purchase contract – the process which aim is to describe the rights and the obligations of logger and felling owner;
- Preparation and issue of documents – the process which aim is to collect and fill all needed documents;
- Felling survey and environmental assessment – the process which aim is to investigate felling place as well as possible to develop technological card effectively;
- Evaluation of the environmental risk factors – the process which aim is to prevent dangerous situations and provide workers' safety

- Development of technological card – the last phase of felling planning process, which aim is to draw up qualitative felling’s scheme.

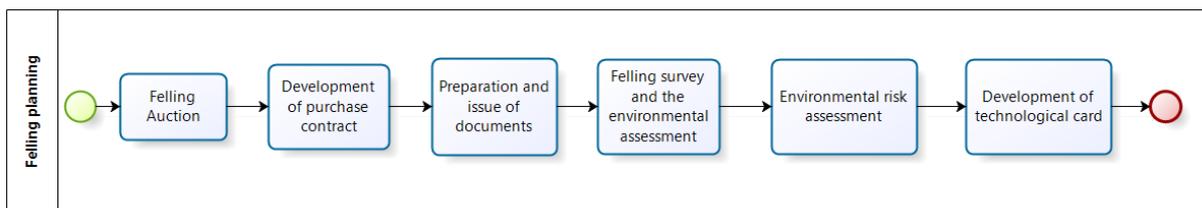


Fig. 1. Felling planning

When LSF (Latvian State Forests) or other seller wants to sell the felling, he puts it up for auction. When the start date of auction is known, participants can register themselves to take part in auction (Fig.2.). Participant offer his price for specific felling, if no one offers more, the auction ends. If hidden starting price has not been reached, felling is not sold, but if it has been reached felling is sold. If no one offers his price before the auction deadline, the seller can propose new auction time.

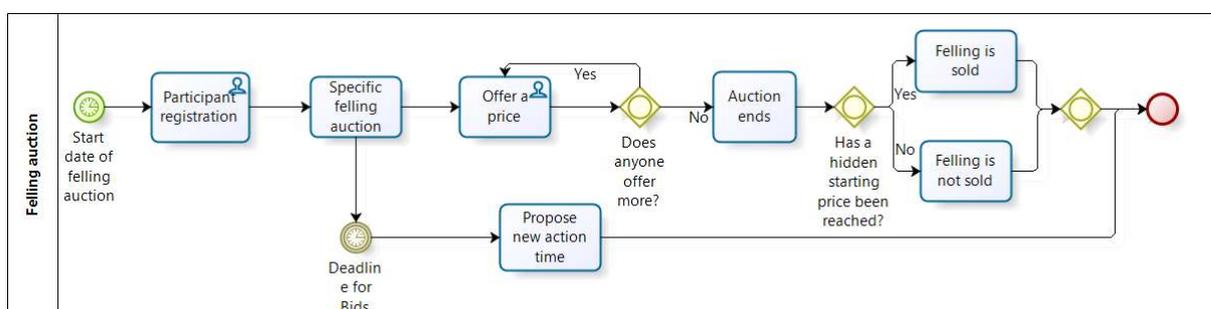


Fig. 2. Felling auction

Seller and buyer (logger) conclude felling purchase agreement where they arrange about the subject of contract (the felling area, the number of trees, volume, price per m³ and other details are described there), the purchase amount, and the period of felling development. If seller is not satisfied with details of purchase contract developed by logger, the logger should rewrite it until seller agrees. The contract describes a penalty, surrender - acceptance arrangements and other rights and obligations as well. If both sides are satisfied, then they can sign the purchase contract (Fig.3.).

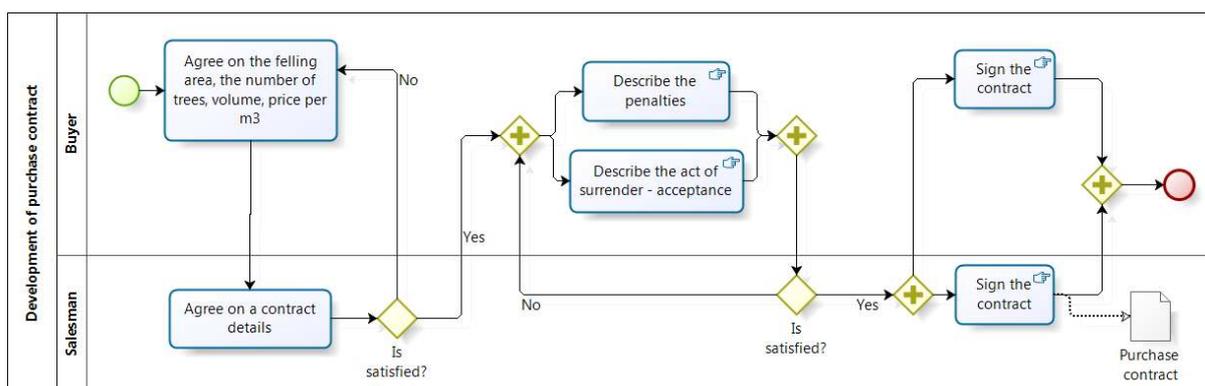


Fig. 3. Development of purchase contract

To start felling process many documents should be written and proofed. When the felling purchase agreement is signed by both sides, the next what should be done is logging task written by LSF or another seller, prepared plan of sections, the Act of business evaluation and other documents. Document package (Fig.4.) should be issued to the logger in time.

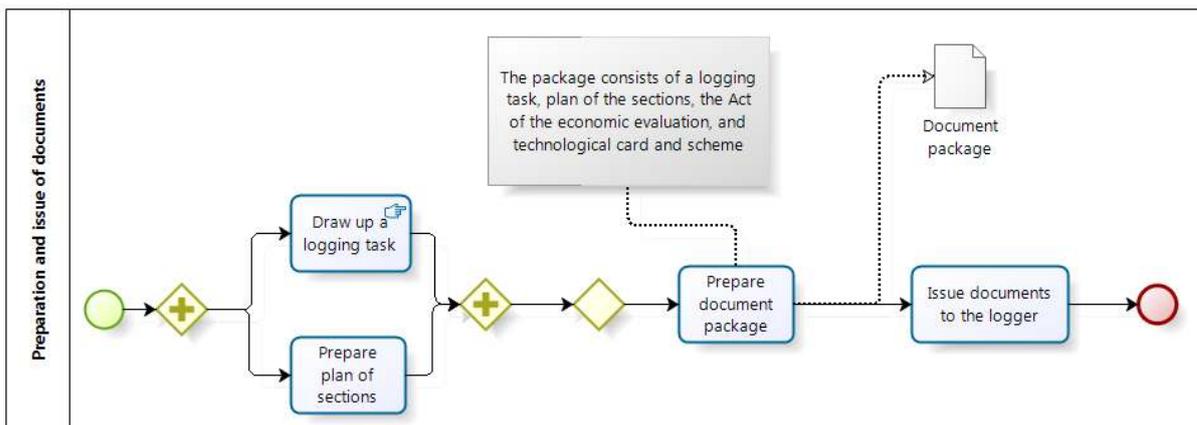


Fig. 1. Preparation and issue of documents

To perform high quality and safe development of felling, logger carefully inspects the felling place and the surrounding area, checks the location and determines the terrain of workplace. Then he measures felling place's edges and angles and evaluates the workplace position in nature (Position of roads, power lines, pipelines, and worker's stay on workplace and nearby). After the work is completed the section of the environmental assessment act should be filled (Fig.5.).

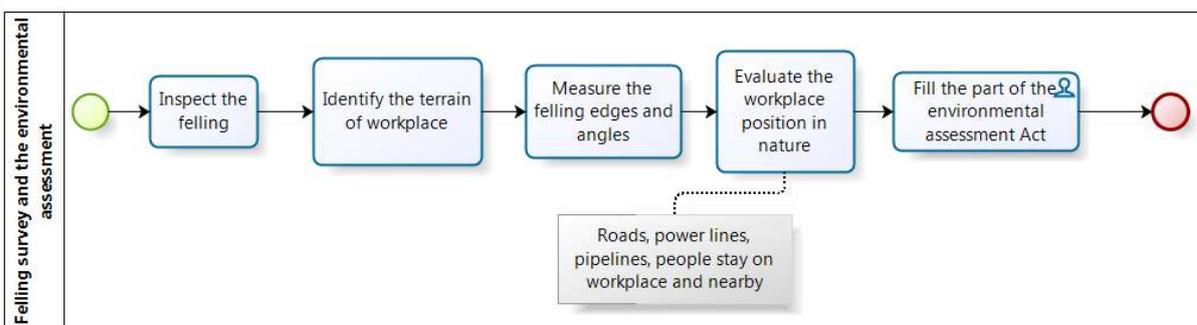


Fig. 5. Felling survey and the environmental assessment

The next step is identification of an environmental risk factors (Fig.6.), which includes factors that characterize the workplace (dangerous objects' investigation) and the environment (the bearing capacity of soil), physical factors (noise level, visual disorders), biological factors (tick-borne diseases, tick-borne encephalitis, Lyme disease, contact with poisonous animals, snakes, animals' attacks, dog's bites), and other factors. As a result of investigation the report should be prepared.

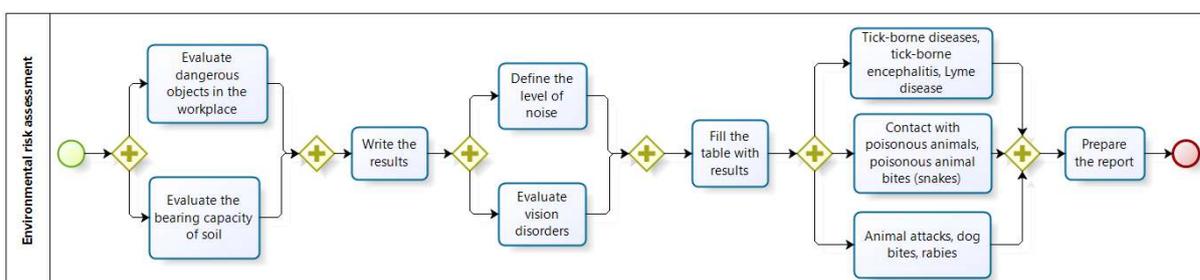


Fig. 6. Environmental risk assessment

When felling's edges and angles have been measured and all needed documents prepared, the felling technological card, including technological scheme (felling sketch) may be made (Fig.7.). The logger characterizes felling, describes used technology and draws up technological scheme. At that time, seller writes the act of business assessment. When the technological map is ready, it should be presented to the seller. If he is not satisfied with it, the buyer corrects questionable points and shows a new version of card. If the technological card satisfies the seller, then both sides sign the section "Prior to the start" of business evaluation act. The last thing that should be done before the felling development could be started is to introduce felling workers with technological scheme and card's content. Each forestry worker should sign the technological card.

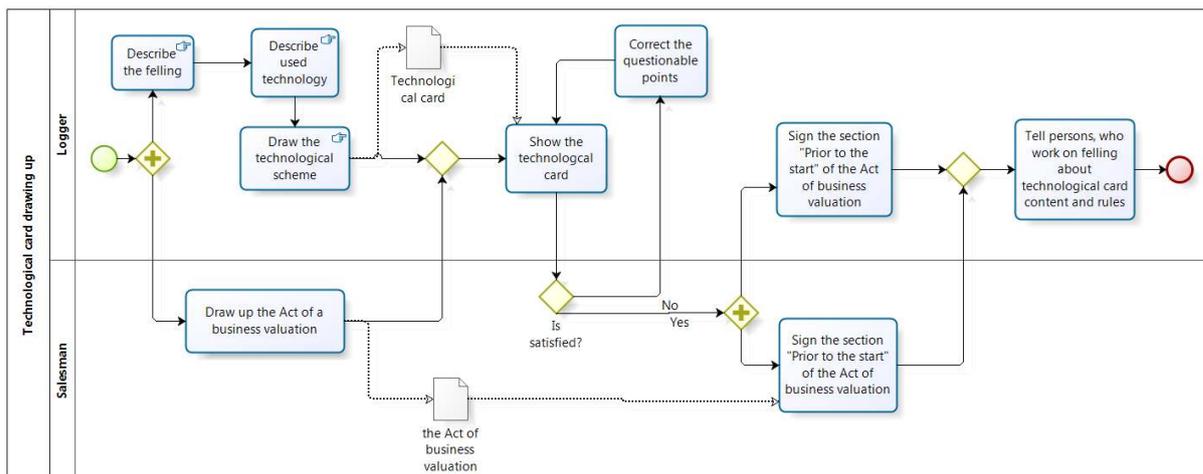


Fig. 7. Technological card drawing up

Felling sketch is integral part of technological card. Represented objects must be marked in nature, each using a different label. Scheme of felling development is drawn in such a large scale to be able to distinguish felling columns, lines, safety zones, felling direction, equipment parking and other felling objects.

The planning process is associated with normative and geographical regulations (Grinvalds et al., 2008).

- Felling area should be determined with an accuracy of $0.1 \cdot \sqrt{S}$, where S - felling area;
- The area of one example is 50 square meters;
- Felling direction must be designed perpendicular to the cutting direction;
- The technological corridor's connections should be 40-45 ° angle to stack direction;
- Stands and forestry clearings considered as the part of main felling area if they contact to the proposed felling of at least 50 meters in length;
- The maximum width of technological corridor may be 4 meters. All technological corridors' area should not exceed 20% of felling area, so the distance between the corridor's axles must not be less than 20 meters;
- Allowable felling direction is from east to west or from the northeast to the southwest if there is spruce stand in the felling direction behind the planned felling.

Results and discussion

Technological card drawing up and its documentation is the process of felling planning that is going to be integrated in the information system. The system must be designed with the Windows Forms interface. The system must support different GIS data types and databases such as shapefiles (Environmental Systems Research Institute, 1998), PostgreSQL, Oracle and others. The system must ensure all internal document composition and their maintenance.

The author of this paper is involved in the development of the information system. The author is responsible for system description and prototype development. From a usefulness point of view, the system must provide:

- handy and simple data input;
- user friendly interface;
- data export;
- correct work of geographical and normative constraints.

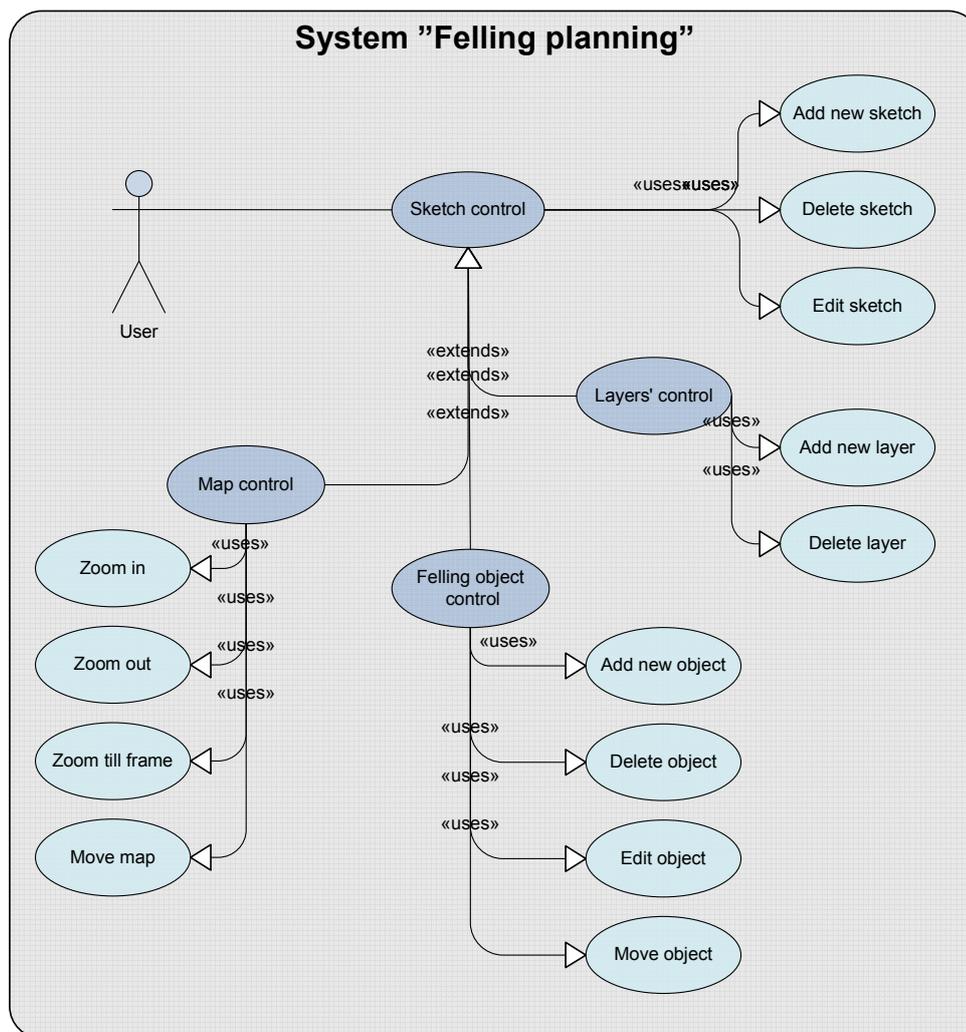


Fig. 8. System functions

Functional model of system consists of four main activities (Fig.8):

- Sketch control
- Map control
- Object control
- Layer control

Felling sketch control has the following main functions:

- New sketch adding – provides felling sketch's adding to the project. To create new sketch it is necessary to add at least one data layer and felling object. Felling scheme does not make sense without any object;
- Sketch deleting – User has an opportunity to delete any existing sketch from the system;
- Existing sketch editing – Editing the existing sketch, user can add a layer, if it is necessary or delete layer if he is not interested in it. As well as user can move, delete, edit or add object to the sketch.

Felling object control has the following four main functions:

- New object adding – This function gives user an opportunity to add new object. The system does not limit the number of items, however there are several limitations about items' location. Felling object is a technological scheme's basic element;
- Object deleting – Using this function user can delete object or objects set from a scheme in case if it loses its relevance, has wrong location or embarrass the understanding of felling scheme;
- Object editing – Object editing means that user can change object coordinates as well as its length or area;
- Object moving – using this function user can move object or objects set on the map. Location can be changed by ticking and moving object on the map, or by changing the coordinates on the coordinate table. Object movement can be considered to be editing due to changes in objects location.

Layer control has the following two functions:

- Layer adding – At the start of process user adds all necessary layers to the project. These may be sections', districts', municipalities', roads' and other thematic layers.

- Layer deleting - If developing felling sketch turns out that some layer is not required, or disturbs conceptual understanding, it is possible to delete a layer from the project. This process does not affect felling objects and their placement.

Control of map has the following main functions:

- Zooming in – This feature is necessary to draw up, edit or move small felling objects easily.
- Zooming out – This function is needed to view the common look of technological scheme and the layout of the felling plan in relation to other objects.
- Zooming till specified frame - This function is needed to zoom in specific part of the sketch. When user marks a rectangle on the map, borders of this rectangle coincides with the borders of the system map's field.
- Moving – This function is necessary to move the map in any direction to make user's activities more convenient and efficient.

Conclusion

Based on the information gathered during the work and experience gained, it can be concluded that the main part of felling planning process is technological card and felling scheme's development. The final result of developed felling depends on this process. Study of felling planning process showed that a lot of time is consumed to develop felling's technological scheme. Geographical and other restrictions must be observed developing technological card. The introduced system will automate the last process of felling planning activity. That will improve scheme's drawing up for the card's compiler.

Developing of technological scheme may be improved and more accurate using developed planning module with GPS navigators or other devices which provide position calculation.

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REGIONAL HYDROGEOLOGICAL MODEL OF LATVIA FOR MANAGEMENT OF ITS GROUNDWATER RESOURCES

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Abstract: *The countries of the world and of the European Union are developing hydrogeological models (HM) where, by means of computer modelling, the information necessary for the groundwater management is obtained. In 1996, Riga Technical University (RTU), upon assignment of the former State Geological Survey, established regional HM REMO for the central part of Latvia. REMO does not match demands of a modern water management for the whole country, the HM plane approximation step of 4000 meters is too crude. In 2010, RTU started the project of HM that includes the whole territory of Latvia and border areas of neighbouring countries. The project is co-financed by the European Regional Development Fund. HM accounts for 25 geological layers and its plane approximation step is 500 meters. HM have to be established, during 2010-2012, as the element of the Latvian Shared Environmental Information System. It is supported by the Latvian Environment, Geology and Meteorology Centre. HM will comprise geological and hydrogeological information provided by the centre. To ensure compatibility with models of other countries, the commercial program Groundwater Vistas is used for running HM. It contains software tools applied for groundwater modelling worldwide. For the establishment and calibration of HM, innovative methods are used: the map of the ground surface elevations (digital relief) serves as a boundary condition; the aeration zone is a formal aquitard; the actual geometry of HM may not be used in the initial phase of the model establishment. The model data will be used for regional evaluation of the groundwater flow distributions, especially, in areas bordering the neighbouring countries and the Baltic Sea. HM will provide data for establishment of local HM that are used for determination of the permissible productivity of well fields, for modelling contaminant migration and for evaluation of effectiveness of measures used for restoration of groundwater resources.*

Keywords: regional hydrogeological models, computer based modelling, MODFLOW

Introduction

The activity of Latvia in the surface water and groundwater resource management is defined by the Water Management Law (Latvijas Ūdens apsaimniekošanas likums, 2002) and by the subordinated regulations and orders of the Cabinet of Ministers. Latvia is implementing the aims laid down by the European Union (EU) Water Framework Directive (2000) for sustainable use of water resources. The Directive provides a unified procedure for the management of water resources in EU member countries:

- the use in conforming to natural laws the river catchment area principle; the territory of Latvia comprises four cross-border type river basins: those of Venta, Lielupe, Daugava and Gauja rivers;
- interdisciplinary approach to planning and its continuity; in Latvia three planning stages are foreseen: the years 2004- 2015, 2015- 2021 and 2021-2027.

At present, Latvia is in the first planning cycle. Some of its results are reflected in the document (Upju baseinu apgabalū raksturojums, 2005). The conditions of groundwater resources in Latvia, before it joined EU, are described in (I. Levins et al., 1998). In general, the groundwater resources in Latvia are in good condition. However, shallow groundwater is poorly protected from surface sources of pollution (waste dumps, territories of former military bases, oil product storage, agricultural activities, etc.). Incorrect and excessive use of groundwater has resulted in worsening of its quality (in Liepāja, sea water intrusion took place; in Jelgava, the quality of artesian groundwater is worsening, the well field Baltezers is endangered by economic activities in its vicinity, etc.).

Water management plans are drawn up and adjusted by the Latvian Environment, Geology and Meteorology Centre (LEGMC) upon assignment by the Ministry of Environmental Protection and Regional Development of the Republic of Latvia. The Centre has to establish and develop the shared environmental information system of Latvia that would also include water management.

The countries of the world: the USA (Mutz, Gan, 2002), Canada (Sykes et al., 2007), Russia (Spalvins et al., 2001); and of EU: Denmark (Muller-Wohlfein and Mielbs, 2007), the Netherlands (Snepvangers et al., 2007), Great Britain (Farell, 2007), Lithuania (Spalvins et al., 2010), etc. are developing hydrogeological models (HM) of country and its regions where, by means of computer modelling, the information necessary for the water management planning is obtained (distributions of groundwater heads, stratigraphic cuts, characteristics of water filtration for geological layers, directions and velocities of groundwater flows, spread and volume of contaminants in groundwater, etc.).

In 1996, Riga Technical University (RTU), upon assignment of the State Geological Survey established the regional HM REMO for the central part of Latvia (Spalvins et al., 1996a). The data of the model has been used by the university for obtaining many local HM (Spalvins et al., 1996b), (Spalvins, 1998), (Spalvins et al., 1999), (Spalvins et al., 2008a), (Spalvins et al., 2008b), (Spalvins et al., 2009a), (Spalvins et al., 2009b).

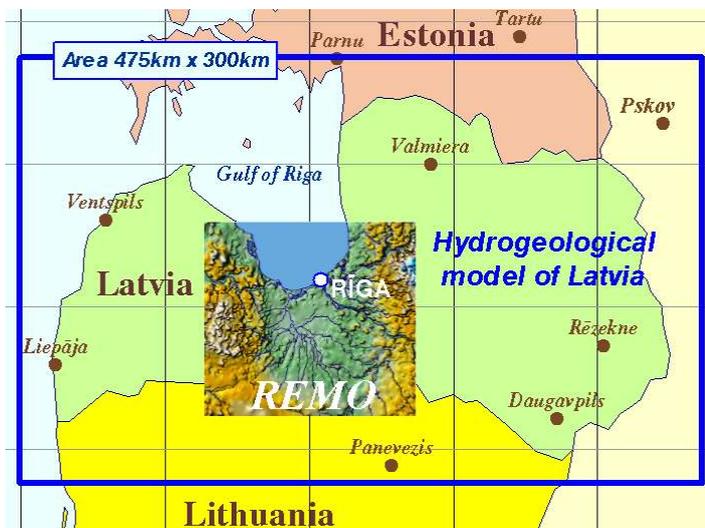


Fig. 1: Location of Latvia HM and REMO

At present, in the framework of the project co-financed by the European Regional Development Fund, RTU is developing HM for the whole territory of Latvia. Location of this model and REMO is shown in Fig. 1. HM of Latvia (LAMO) will be established as the element of the shared environmental information system of Latvia. LAMO will generalize geological and hydrogeological information accumulated by LEGMC. LAMO will be used for management of drinkable groundwater resources and for evaluating their recovery measures. To solve smaller scale problems, LAMO will serve as the data source for building more detailed local models. LAMO corresponds to requirements of the first planning stage of Latvia for the groundwater management. However, LAMO is open for its further development, as a tool to be used for the second stage.

Description of REMO and LAMO

LAMO covers the area of $475\text{km} \times 300\text{km} = 142500\text{km}^2$. Just like REMO, it will simulate the steady state average groundwater regimes for the area of active water exchange that is used in Latvia for drinkable water supply. The model is approximated by the spatial (3D) finite difference method; its plane approximation step is 500 meters; the spatial HM grid contains 25 planes (see Table 1); therefore, the grid consists of $951 \times 601 \times 25 = 14.86 \times 10^6$ nodes; the active groundwater zone is bedded by the regional Narva aquitard.

The REMO plane approximation step was 4000 metres. Its spatial grid contained 10 planes for aquifers, because the cruder semi 3D finite difference method was applied (aquitards were not presented by planes but only by the vertical links joining adjacent aquifers). The REMO grid contained $43 \times 40 \times 10 = 17200$ nodes. Although, the semi-3D scheme reduces the number of the HM planes nearly twofold, this scheme is not fully conformable with the commonly used software tools (MODPATH, MT3D) that are based on particle tracing. To avoid this drawback, the 3D scheme is applied to LAMO.

Table 1

LAMO vertical schematisation

HM plane z		Name of layer	Geological code	HM plane code	HM plane name	HM border code	Comments
1.		Relief	relh	relh	Relief	bHM	boundary condition
2.		Aeration zone	aer	aer	Aeration zone	bHM	formal aquitard
3.		Unconfined Quaternary	Q4-3	Q2	Quaternary Q2	Q2	
4.		Upper moraine	gQ3	gQ2z	Upper moraine	gQ2	
5.		Confined Quaternary or Jura	Q1-3 J		Quaternary Q1	Q1	includes volumes of J
6.		Lower moraine or Triass	gQ1-3 T	gQ1#z	Lower moraine	gQ1	includes volumes of T
7.		Perma Karbons Skerveles Ketleru	P2 C1 D3šķ D3ktl	D3ktl#	Ketleru	D3ktl	
8.		Ketleru	D3ktl	D3ktlz	Ketleru z	D3ktlz	uncertain boundary
9.		Zagares Svetes Tervetes Muru	D3žg D3sv D3tr D3mr	D3zg#	Zagare	D3mr	
10.		Akmenes	D3ak	D3akz	Akmene	D3ak	
11.		Akmenes Kursas Jonisku	D3ak D3krs D3jn	D3krs#	Kursa	D3jn	
12.		Elejas Amulas	D3el D3aml	D3el#z	Eleja	D3aml	
13.		Stipinu Katlesu Ogres Daugavas	D3stp D3ktl D3og D3dg	D3dg#	Daugava	D3dg	
14.		Daugavas Salaspils	D3dg D3slp	D3slp#z	Salaspils	D3slp	
15.		Plavinas	D3pl	D3pl	Plavinas	D3pl	
16.		Plavinas Amatas	D3pl D3am	D3am#z	Amata z	D3amz	uncertain boundary
17.		Amatas	D3am	D3am	Amata	D3am	
18.		Upper Gauja	D3gj2	D3gj2z	Upper Gauja z	D3gj2z	uncertain boundary
19.		Upper Gauja	D3gj2	D3gj2	Upper Gauja	D3gj2	
20.		Lower Gauja	D3gj1	D3gj1z	Lower Gauja z	D3gj1z	uncertain boundary
21.		Lower Gauja	D3gj1	D3gj1	Lower Gauja	D3gj1	
22.		Burtnieku	D2brt	D2brtz	Burtnieku z	D2brtz	
23.		Burtnieku Arikula	D2brt D2ar	D2ar#	Arikula	D2ar	
24.		Narvas Narvas Narvas	D2nr3 D2nr2 D2nr1	D2nr#z	Narva	bHM	borderline of HM
25.		Pernavas	D2prn	D2pr	Pernava		boundary condition

#- united aquifer, #z- united aquitard,



-aquitard

The whole REMO area ($168\text{km} \times 156\text{km} = 26208\text{km}^2$) was active. At present, LAMO consists of its active and passive zones. The active zone includes the land territory of Latvia and area of the Gulf of Riga that is covered by REMO (see Fig. 2.). The passive zone represents border areas of neighbouring countries.

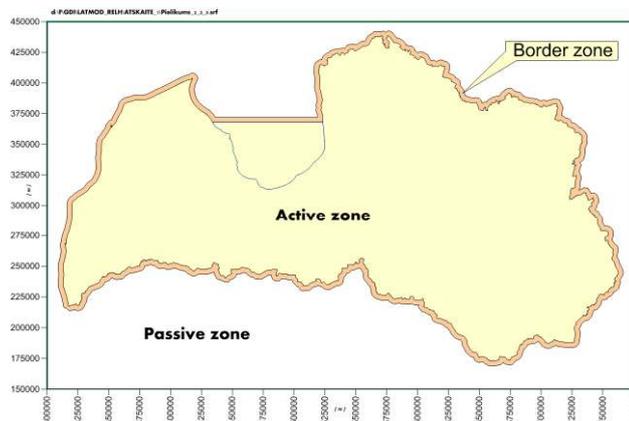


Fig.2. LAMO active and passive zones

However, LAMO is open for transboundary modelling projects. The neighbouring country provides data for activating the HM area involved. The active and passive zones are separated by 4 km wide border zone where piezometric boundary conditions for aquifers can be fixed.

For running REMO, an original modelling program was used. It was developed by RTU scientists. If RTU scientists did not participate in the project, the State Geological Survey would be incapable of supporting and using REMO. Unfortunately, the survey lost active interest in REMO (the decision was taken to use the Daugava River as the extra source of drinking water for Riga) and only RTU scientists had successfully used REMO, until now. To avoid the above mentioned difficulty, the commercial program “Groundwater Vistas” (GV) is used for running LAMO (Environmental Simulations, 2011). The program is being regularly updated (the GV-6 version is available). It contains software tools MODFLOW, MODPATH, MT3D that are applied for groundwater modelling worldwide. The GV system is generally used also in Latvia. Due to application of GV, results of LAMO will be available for public use in Latvia and the LAMO compatibility with HM of other countries will be more possible.

LAMO vertical schematization is presented in Table 1. For the planes 12-25, it coincides with the one of REMO. In REMO, instead of the planes 7-11, the united Farena aquifer (D3fm#) was used for the central part of Latvia. For LAMO, these five planes represent the geological layers of the South-West of Latvia.

In REMO and LAMO, the planes 1 and 2 are used, accordingly, as a place for fixing the relief deviation map as the piezometric boundary condition and as a formal aquitard that controls the infiltration flow distribution (Spalvins et al., 2011a). For more information, on these issues see section “Methods of HM Development”. In REMO, the Quaternary system was represented by two planes (unconfined Q_2 and the moraine gQ_{2z}). Four planes for this system are used in LAMO, because two extra layers are accounted (confined Q_1 , lower moraine gQ_{1z}). These two layers are of importance to the hilly areas of Latvia where the Quaternary system is thick. In LAMO, no separate layers are given for representation of the Jura and Triass systems. They are incorporated into the HM layers 5 and 6, accordingly, because their areas are insignificant (South-West of Latvia).

Most of geological layers, comprised by REMO and LAMO, are discontinuous (see also comments on Table 1). Discontinuity of the layers and their irregular geological borderlines cause serious problems for building elevation surfaces of the layers (Spalvins et al., 2011b).

Methods of HM Development

To describe development of HM, the mathematics of the 3D-steady state model must be introduced. By applying the 3D finite difference approximation, the xyz-grid of HM is built using ($h \times h \times m$)-sized blocks (h is the block plane size, m is the variable thickness of a geological layer). The model constitutes a rectangular p -tiered xy-layer system where p is the number of layers. Four vertical sides compose the shell of the HM grid. The relief (ground surface) and the lower side of the model are its geometrical top and bottom, respectively. The 3D-space volume enveloped by the boundary surfaces constitutes the body of HM. For the LAMO active part, its shell coincides with the border zone that separates HM active and passive parts. However, the GV system accounts for the whole body of HM.

The vector φ of the piezometric head is the numerical solution of the boundary field problem which is approximated in nodes of the HM grid by the following algebraic expression:

$$A\varphi = \beta - G\psi, \quad A = A_{xy} + A_z \quad (1)$$

where A is the symmetric sparse matrix of the geological environment which is presented by the xy -layer system containing horizontal (A_{xy} - transmissivity) and vertical (A_z - vertical hydraulic conductivity) elements of the HM grid; ψ - the boundary head vector: ψ_{rel} , ψ_{bot} , ψ_{sh} - subvectors on the HM top, bottom and shell, accordingly; G - the diagonal matrix (part of A) assembled by elements, linking the nodes where φ must be found with the ones where ψ is given; β - the boundary flow vector.

The elements a_{xy} , a_z of A_{xy} , A_z (or g_{xy} , g_z of G) are computed, as follows:

$$a_{xy} = k \times m, \quad a_z = \frac{h^2 \times k}{m}$$

$$m_i = z_{i-1} - z_i > 0, \quad i = 1, 2, \dots, p \quad (2)$$

where z_{i-1} , z_i are elevations, accordingly, of the top and bottom surfaces of the i -th geological layer; z_0 represents the ground surface elevation ψ_{rel} -map with the hydrographical network included; k , m are, accordingly, elements of digital m , k -maps of the computed layer thickness and permeability.

The set of z -maps describes the full geometry of LAMO. It is built incrementally: $z_0 \rightarrow z_1, \dots, z_p$ by keeping the thickness of the i -th layer $m_i > 0$. If in some areas, $m_i = 0$ then the i -th layer is discontinuous. To prevent the "division by zero", in the a_z calculation of (2), $m_i = 0$ must be replaced by $\varepsilon > 0$ (for HM, $\varepsilon = 0.02$ metres). In GV, only the z -maps serve as the initial geometrical ones. For REMO, the set of m -maps were used and, due to this reason, the model geometry was of lower quality than the geometry resulting from the z -maps.

Obtaining the right distribution for the infiltration flow β_{inf} on the HM top is a burdensome task. For REMO and LAMO, this task is considerably eased by using the ψ_{rel} -map as the boundary condition for heads. Then the flow $\beta_{inf} = \beta_{aer}$ passes through the aeration zone:

$$\beta_{aer} = G_{aer}(\psi_{rel} - \varphi_Q) \quad (3)$$

where φ_Q is the computed head (subvector of φ) for the first aquifer Q_2 ; G_{aer} (diagonal submatrix of G) contains the vertical ties g_{aer} of the aeration zone connecting ψ_{rel} with φ_Q . The expression (3) gives the standard result of HM, when a ψ -condition is applied. As a rule, even the first run of HM provides feasible results for β_{inf} .

The vertical links, g_{aer} of the diagonal matrix G_{aer} , are controlling the $\beta_{aer} = \beta_{inf}$ distribution. Values of g_{aer} depend on h^2 , k_{aer} and m_{aer} (formula (2)) where k_{aer} , m_{aer} are, respectively, the permeability and thickness of the aeration zone. Initially, k_{aer} and m_{aer} are unknown. In nature, $m_{aer} = \varphi_{rel} - \varphi_{Q2}$ if $\beta_{aer} > 0$ and it is the unsaturated part of the unconfined layer Q_2 . If $\beta_{aer} < 0$ then m_{aer} ceases to exist, because then $\beta_{aer} < 0$ is controlled by bed conductances of the hydrographical network. Formerly, these conductances were elements of G_{aer} . Just recently, the lines and areas of the network have been implemented as the "Rivers" and "Lakes" options of GV. (Spalvins et al., 2009b). This innovation will be used in LAMO. First, the following values of the unknown parameters of the aeration zone for LAMO will be tried: $m_{aer} = \varepsilon = 0.02$, $k_{aer} = 10^{-6}$ [m/day]. To avoid iterative changes of the HM geometry, $m_{aer} = \varepsilon$ must be kept constant, until the calibrated state of HM is achieved by adjusting the k_{aer} - distribution.

Therefore, for LAMO, only two real thicknesses m_{aer} and m_{Q2} must be restored, if necessary. It can be done by applying the "inverse" transformation of the calibrated $(k_{aer})_c$ and $(m_{Q2})_c$ -maps:

$$k_{aer} = (k_{aer})_c m_{aer} / \varepsilon, \quad k_{Q2} = (k_{aer})_c (m_{Q2})_c / m_{Q2}, \quad m_{Q2} = (m_{Q2})_c m_{aer}, \quad (4)$$

where $\varepsilon = 0.02$ and $(m_{Q2})_c$ are the thicknesses used during the HM calibration. The transformation results from formulas (2), because this operation does not change the calibrated values of the matrix A elements a_{xy} and a_z . On the much broader scale, this transformation has been applied for creating HM of the South-East Lithuania (Spalvins et al., 2010). This model was started and calibrated by using equal thicknesses $m = 1.0$ for all nine geological layers of HM (no z -maps were used, to run HM).

For geological layers, their geometrical thickness is $m \geq m_{ef}$. The effective thickness m_{ef} accounts for the fact that, not always, the layer permeability is isotropic. Aquifers and aquitards may include admixtures, accordingly, of low and high permeability. Because the HM geometry results in the thickness m -maps, the original k_{xy} , k_z -maps must be corrected, as follows:

$$(k_{xy})_c = k_{xy} \times C, \quad (k_z)_c = k_z \times C^{-1},$$

$$c_i = (m_{ef} \times m^{-1})_i \leq 1.0 \quad (5)$$

where $(k_{xy})_c$, $(k_z)_c$ are the corrected permeability values; C is the diagonal correction matrix which is obtained by interpolating borehole data on the xy -grid planes of HM; c_i – the i -th initial element of C given by a borehole. The algorithm (5) has been first used to create HM of a new well field (Spalvins et al., 2009a).

In REMO, the effective thicknesses m_{ef} were formed by changing the HM geometry when the m -maps were obtained. This method results in serious faults of the HM geometry. Due to this reason, for LAMO, the correction of (5) will be used.

Initial Data for Developing LAMO

Geological and hydrogeological data for developing LAMO were provided by LEGMC. Information regarding the ground relief of Latvia and its hydrographical network was taken from the Geospatial Information Agency of Latvia (GIAL).

The data provided by LEGMC in the digital form were, as follows:

- information carried by geological wells (stratigraphy of geological layers and their filtration characteristics (water permeability k);
- digital maps of some geological layer surfaces; the most important were two maps for the whole territory of Latvia: the subquaternary subQ surface (bottom of the Quaternary system; (plane $z=6$ of HM) and the bottom surface of the Narva aquitard (plane $z=24$ of HM);
- the set of borderlines for geological layers;
- arrangement and productivity of the groundwater extraction wells (information for the vector β of (1));
- data provided by monitoring wells where regular measurements of groundwater heads are done; the data are used for the HM calibration purposes and for obtaining values of the vector ψ of (1);
- other information, in the paper form, including the Geology Fund archive materials.

The information on geological wells, involve a high degree of uncertainty, as the arrangement of wells is irregular, their depth is different, their data, as a part of HM, have not been verified. The data contain essential errors (incorrect attachment to ground surface, erroneous plane coordinates, not all geological layers are mapped, etc.). The above mentioned errors may be detected and sometimes prevented only during the creation of HM. Gaps in information on wells can be partially prevented by examining materials from geological data archives where specialists have provided the analysis of hydrogeological situations. However, also archive materials are not always qualitative.

Information on the permeability k of geological layers is very incomplete even in respect to aquifers. The k -distribution for aquitards is unknown and it must be found by calibrating the model.

Obtaining the digital relief map ψ_{rel} of Latvia (scale 1:200000), as the most important item of LAMO was a rather difficult task, because the maps prepared by GIAL still did not account for the hydrographical network existence. In the materials (Slangens et al., 2010; Slangens et al., 2011) it is shown how the considerably improved ψ_{rel} map has been created (see Fig. 3). The map provides three types of information: a) the geometrical top surface $z=0$; b) the distributed piezometrical boundary condition ψ_{rel} ; c) the hydrographical network data (long line profiles of rivers and elevations of lakes) that are used by the options “Rivers” and “Lakes” of GV.

The $subQ$ surface is shown in Fig. 4. It was slightly corrected by RTU scientists when the thickness distribution of the Q system was obtained. No extra incisions into the $subQ$ surface were allowed. Due to this fact, some special corrections have been made for the surface $z=1$ plane. They are described in (Spalvins et al., 2011b).

The $D2nr$ bottom surface ($z=24$) is shown in Fig. 5. It has been accepted by RTU scientists without making any corrections in the map prepared by specialists of LEGMC.

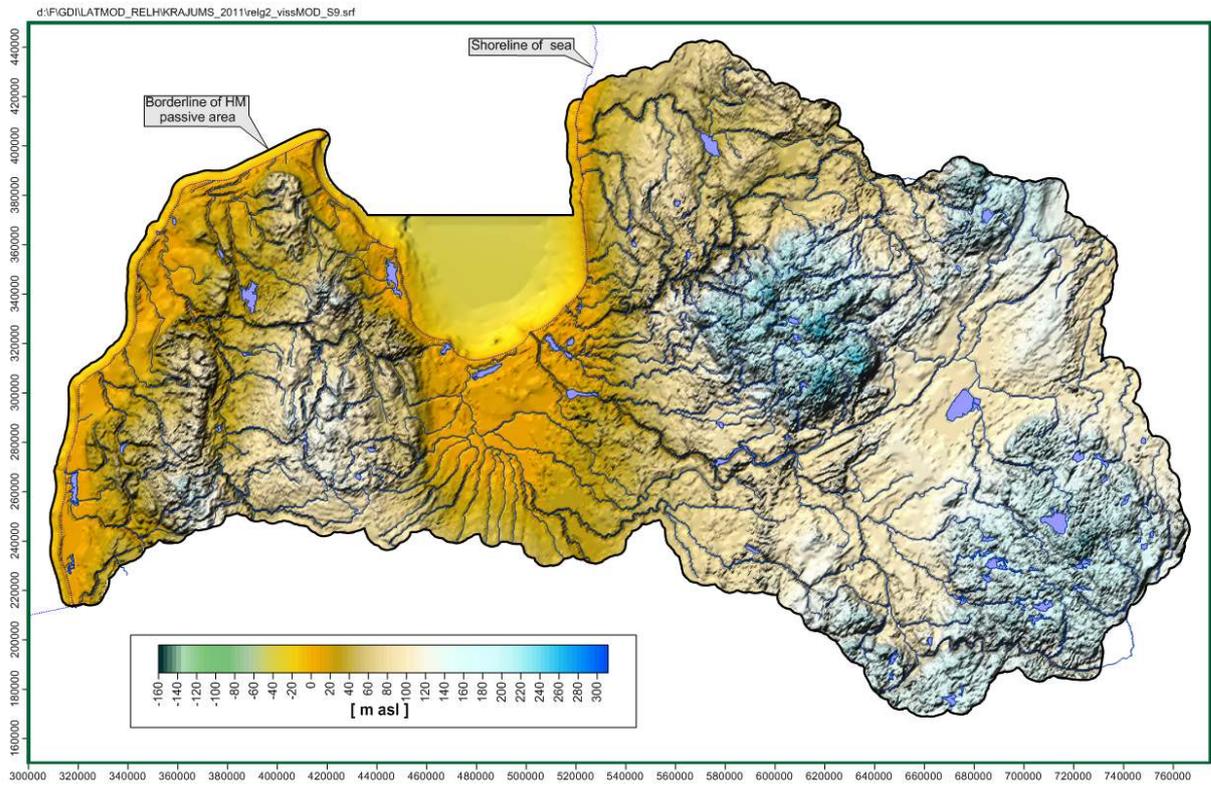


Fig. 3. The digital relief ψ_{rel} used in LAMO

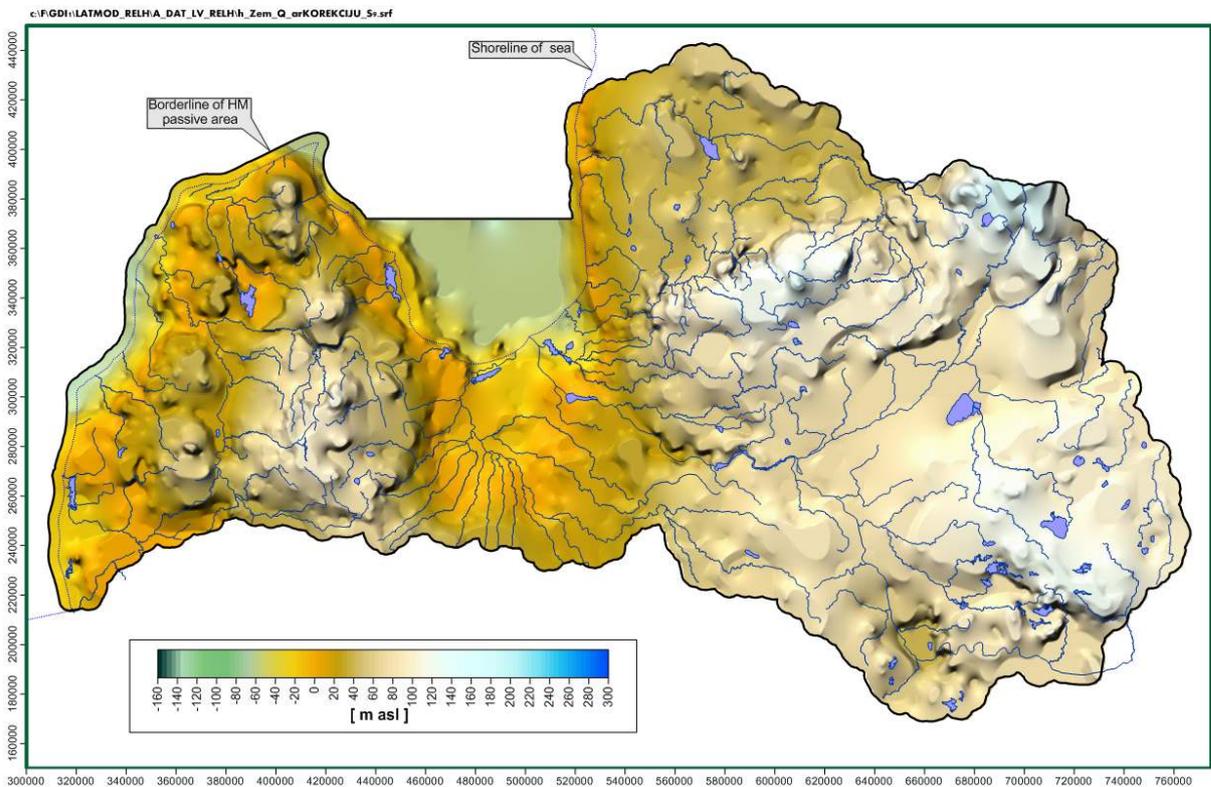


Fig. 4. The subquaternary surface used in LAMO

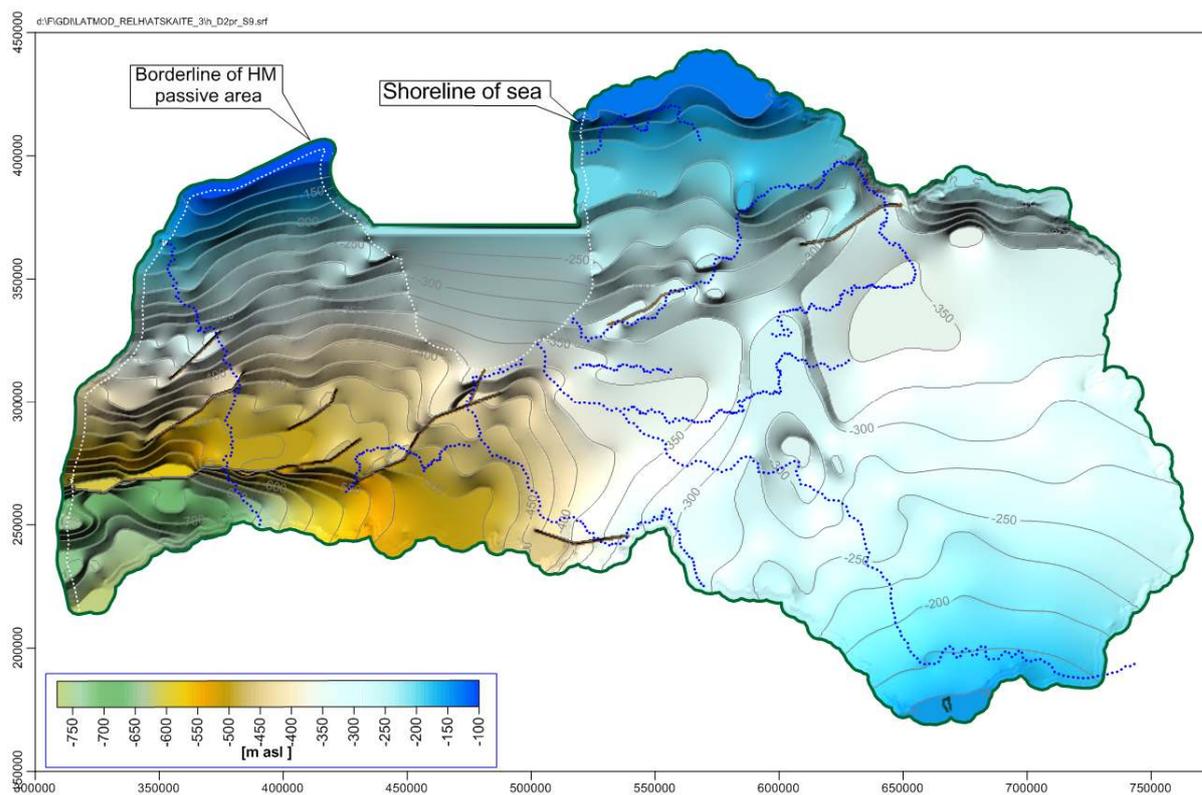


Fig.5. The bottom surface of the aquitard D2nr#

Stages of LAMO Development

Stages of the LAMO development are as follows:

- preparation of set of initial data;
- creation of the model digital map set;
- creation and calibration of the model.

The most time-consuming is the process of elaboration of the z -maps. To elaborate these maps, RTU scientists use the original GDI program (Spalvins et al., 2007; Spalvins et al., 2004) that mostly apply line-type data sources.

After all the necessary digital maps have been uploaded into the GV system, the model starts functioning and its calibration has to be accomplished.

Due to unavoidable limitations in the initial data, HM has no unique solution. Calibration of HM is a controlled iterative process involving the addition of complimentary data, until a HM of a required quality is obtained. The quality is checked and maintained by tracing calibration targets. The following targets are usually set:

- original data should not be contradicted by data generated by HM; for example, the ψ and φ distributions of (1) must reproduce observed head values, the matrix A must incorporate observed permeability and geometrical features of k , z -maps, etc.;
- within the HM body, groundwater flows should not reach unnaturally large values (infiltration flow, flows regarding the hydrological network, etc.);
- results of HM must confirm the real hydrogeological situation, because formal agreement between computed and observed target data does not assure correct simulation; unfortunately, automatic calibration tools can sometimes provide almost worthless results.

The first and second targets are formal components of HM, but the third target always requires subjective evaluation.

The calibration will never succeed if serious HM errors are present. Problems can include faults in data coordinate or values, mistakes in geological layer identification, mismatched reference data, unreliable boundary conditions or inadequate software.

Where initial data have not been previously used for modelling (most of data, to be used for LAMO, belong to these data, their role can be unclear and their validity may be questionable (especially, the stratigraphical data of boreholes).

However, to create and calibrate HM, RTU scientists are going to apply already tested sophisticated methods and software tools, in order to overcome possible problems regarding quality of initial data.

Conclusions

During two years (till 2012) scientists of Riga Technical University should establish the regional hydrogeological model of Latvia. The model will be applied as the element of the shared environmental information system. To create the model RTU scientists are going to use innovative methodology and software tools. The following main innovations will be used:

- the improved method of creating infiltration flow;
- the method for accounting for the effective thicknesses of geological layers;
- the method that enables not to use the real geometry of HM (at least, in the beginning);
- improved original software tools for interpolation of geological and geometrical data;
- the method enabling to find data needed to create the hydrological network of HM.

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INDUSTRIAL APPLICATION OF ICT

EFFECT OF THE INTERNATIONAL FINANCIAL CRISIS (2008-2011) ON ICT ADOPTION AND USE BY LATVIAN BUSINESSES

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Abstract: *As recently as December of 2010, experts have suggested that the international financial crisis has "changed everything." It has been anecdotally suggested that businesses that have survived the 2008-11 crisis have increased their adoption of and depth of use of ICT in response to new competitive demands. We tested the hypothesis that "nothing has changed during the crisis." To test the hypothesis we surveyed 97 MBA students. The students all worked as managers in companies operating in Latvia. The survey was in the form of a five point Likert scale and the questions were grouped into categories that reflected different functional or businesses areas that might have changed. The responses were coded for no change, some change, or significant change and compared in firms reporting high ICT use, medium use or low use. An Item Response Theory model was created by which to test the responses. Overall, there were no significant changes in use of ICT reported by Latvian firms. Intergroup (comparing high with medium or low for example) did show that high use groups reported significantly more changes than did low intensity use groups, but still the intensity of use did not change from 2008-2011. Generally, it can be stated that ICT use has changed very little in the time period 2008-2011. For all the variables the conclusion is that their importance was somewhat increased. The results showed that the high users of ICTs in general perceived greater increased opportunities from ICTs to respond to the challenges of the financial crisis. As the results are from managers in a cross-section of industries in Latvia, we can say that the general hypothesis is accepted. If we further accept that change is important this means that policy changes that would lead to adoption and more intense use are needed.*

Keywords: Adoption, ICT, International Financial Crisis, ICT Use.

Introduction

Over the last two decades, much of the developed world has been transformed by what are now termed Information and Communication Technologies (ICTs). These technologies made possible significant productivity gains in business (Gibbs et al., 2003; Kiiski et al., 2002) through enabling great changes in how processes are carried out, for example reducing labour costs, increasing proximity to customers and standardizing products and brands (Mahmood et al., 1991). This phenomenon however, was based on the needs present in large organizations typical of developed countries (Bonaccorsi et al., 2005; OECD, 2000). The benefits that companies in emerging economies can attain, where the opportunities based on economies of scale are less apparent, offered less evidence of productivity gains (Joseph, 2002; Roah, 1987; Roah, 1988; Strassman, 1997).

However, there is also research that shows that adopters (managers or others) to do not always behave in an objective manner. The model (Fig. 1) recently developed by one of the authors () demonstrates that decisions to adopt and use ICT are made in a consistent fashion by firms in Latvia. The model further demonstrates that the decision making process combines both objective component factors and managerial component factors. These factors interact and lead to decisions that reflect managers' reactions to both the managerial and external environments.

The overall objective of strategies to increase the likelihood of use of ICT has been to contribute to the diffusion and adoption of ICTs but little is understood of how specific circumstances of companies in developing countries need to be considered in order to take advantage of the benefits offered by ICTs (Bonaccorsi et al., 2005). This phenomenon is present in Latvia perhaps not in an absolute way, as clearly an infrastructure and use of ICTs are present to a considerable degree as the study shows. Nevertheless, the digital divide does exist in more subtle ways that are revealed by how much these ICTs are used and for what purposes. At the same time, the controversy regarding the effect of ICTs on productivity and economic growth signaled that there was a significant gap between strategies and policy statements and empirical practice (Alfaro et al., 2004; Ulmanis and Deniņš, 2011). In the context of the global financial crisis, this suggests a need to understand whether current strategies are either working or failing at encouraging companies in a struggling economy to use ICT and use it more deeply.

In the course of doing the extensive work done to create the adoption model, a question arose regarding whether the global financial crisis that began in 2008 had impacted the diffusion and use of ICT in firms in Latvia. The authors' hypothesis was that the crisis had not significantly impacted the diffusion of ICT in Latvian businesses. This paper presents the results of a survey done to determine whether the crisis has impacted the diffusion and use of ICT on/in businesses in Latvia.

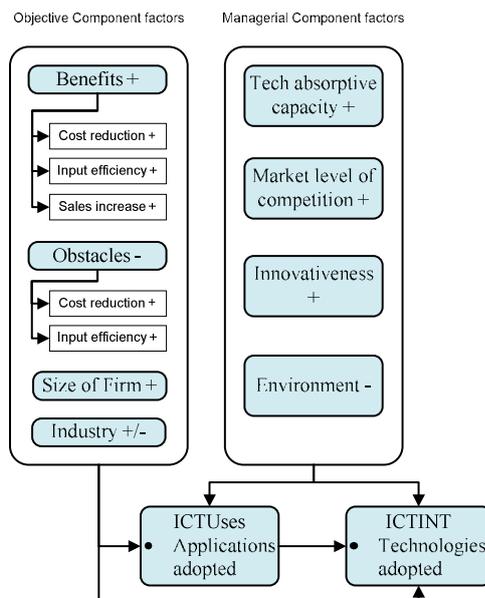


Fig.1. Adoption Model

Materials and Methods

In order to test the hypothesis that there has been no or little change in the use of ICT in Latvian businesses since 2008, a survey of managers was done. The managers were all MBA students taking summer classes during the summer of 2011 at RTU Riga Business School. The survey was distributed to 120 students and 97 completed surveys were returned. The surveys were coded into an Excel spreadsheet and subjected to statistical analysis using the SPSS package as discussed below.

The survey consisted of a total of 8 questions with sub-questions to understand the specific category of ICT being asked about. The first 5 questions asked about the firm's attitude toward ICT and its use and the other three were descriptive. They were:

1. The importance of ICT use (how it has changed);
2. How ICT efficiency benefit goals have changed;
3. How obstacle to investments in software and hardware have changed (at firm level);
4. How ICT absorption methods have changed.

The attitudinal questions asked about general attitudes about ICT and each was divided into items that asked about specific reasons or specific types of technology: For example the first general question was:

How has the importance of ICT in your business activity changed since the economic crisis beginning in 2008 in the following aspects of the work of the firm where you work?

The question was followed by items that asked about specific business areas:

1. In promoting competitiveness;
2. Overall efficiency;
3. Increasing market share;
4. Improving business processes;
5. Decreasing costs;
6. Improving collaboration;
7. Improving use of online processes;
8. Online HR process management and planning of online production and inventory management processes;
9. Increasing the number of customers in new markets;
10. Increasing the number of clients in existing markets.

The scale was:

1. Significantly decreased;
2. Decreased;
3. Unchanged;
4. Increased;
5. Increased significantly.

The descriptive information was tabulated. The attitudinal questions were grouped. The responses were coded for no change, some change, or significant change and compared in firms reporting high ICT use, medium use or low use. An Item Response Theory model () was created by which to test the responses.

Each item was first transformed as follows: no change is given a score of zero, increase or decrease a score of 1 and strong increase or decrease a score of 2. This approach recognizes that change, either increasing or decreasing use, matters - rather than having a decrease cancel out an increase and then claiming there is no change.

Results

As can be expected from MBA students, most (60) said that they were middle level managers. Of the rest, 11 each were high level and low level managers, with the other 15 having administrative or technical tasks. The largest proportion worked in financial services (29%), followed by 17.5% in services and 15% in ICT or communications. 36.1% of respondents worked in bigger (250 employees) firms and the rest were nearly equally distributed in smaller companies.

The final descriptive question asked about the general intensity/sophistication of use of ICT in the firm the respondent works in. The question characterized the use as Low (use email and internet), Medium (plus use of online purchasing and/or intranet) and High (use of sophisticated CRM tools such as SAP or Oracle). The largest fraction (46.4%) worked in firms using ICT in a sophisticated fashion and only 15% reported low sophistication. Table 1 below shows the results of the Item Response Theory model. Overall, there were no significant changes in use of ICT reported by Latvian firms. Intergroup (comparing high with medium or low for example) did show that high use groups reported significantly more changes than did low intensity use groups, but still the intensity of use did not change from 2008-2011. Generally, it can be stated that ICT use has changed very little in the time period 2008-2011. For all the variables that were consistent with the model previously validated, the conclusion is that their importance was somewhat increased. The results showed that the high users of ICTs in general perceived greater increased opportunities from ICTs to respond to the challenges of the financial crisis. Most importantly this lack of change is consistent whether the firms are large or small and whatever industry

Table 1.

Item Response Model results

Explanatory Variable	Overall		Low ICT Users		Medium ICT Users		High ICT users	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Change in market gain opportunities	3,31	,61	3,21	,59	3,23	,65	3,42	,57
Change in cost reduction opportunities	3,32	,59	3,17	,52	3,26	,56	3,43	,62
Change in efficiency gain opportunities	3,39	,49	3,22	,35	3,29	,43	3,54	,52
Change in employee learning attitude	3,14	,58	2,97	,61	3,16	,59	3,19	,54
Change in technology absorption capacity	3,10	,55	2,98	,69	3,08	,59	3,15	,46
Change in collaboration for innovation	3,36	,58	3,15	,32	3,36	,59	3,44	,61
Change in online suppliers & clients	3,35	,66	3,31	,55	3,09	,63	3,58	,62
Change in environment towards ICT use	3,30	,50	3,21	,43	3,16	,49	3,46	,48

Conclusions

The results of this survey of managers in Latvia demonstrate that businesses from a range of industries and sizes have not increased their use and intensity of use of ICT during the crisis time. While the financial crisis that began in 2008 has led to significant contraction in business and businesses, it seems that it has not led firms in Latvia to do one thing that has been shown to be connected with success- invest in the adoption and intense use of ICT. These results suggest that managers and owners could see that there is a clear strategic opening to increase their use of ICT and preempt competitors while the economy is still in crisis or stagnation.

From a policy perspective, the results suggest that policy aimed at increasing the adoption and diffusion of ICT in Latvian firms has not been successful. These results serve as a benchmark for Latvian policy makers (whether in government or in other public sector areas) in measuring whether policy has any objective benefits. As the lack of change is true in all industries and firm sizes observed, the results suggest that policy makers need to either find or create policies that are effective across a range of industries and firm sizes.

These results also reinforce the importance of the adoption model that was previously validated. The analysis proves that a more comprehensive link to growth and innovation is necessary to make ICTs adoption and usage

metrics matter. While conceptually it is easy to cast a general message of technology as some sort of panacea based on random examples, in practice, the very simple indexes used internationally to compare relative development, showed to lack any power to compare the qualitative impact of the use of ICTs

The value of ICTs for Latvia should reside mainly in developing new business processes that increase the productivity and scale of its internal market and enable it to participate in international value chains with more advanced ICT users in the region, as indeed has been the tendency in response to the financial crisis. If firms in Latvia continue to ignore the opportunities afforded by the adoption and intense use of ICT, they will likely lose the opportunity to become more generally competitive.

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EXPERIMENTAL RESEARCH OF FOAM GYPSUM DRYING PROCESS

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Abstract: *The theoretical model of porous materials drying process is developed. It is large importance of accurate modeling in order to bring together experimental results and theoretical prediction. A number of experimental investigations of drying process of different volume density foam gypsum samples are given. Theoretical model was tested using these experimental data. Model parameters are estimated. Dependence of these parameters on volume density is adequate physical processes.*

Keywords: drying process, porous materials, foam gypsum, moisture diffusion coefficient.

Introduction

Foam gypsum is a suitable material for different building constructive solutions (Skujans et al., 2007). According to the requirements for the technological process of foam gypsum, the initial moisture content should be very high (Iljins et al., 2009). The drying of these products is obligatory requirement to obtain material with sufficient mechanical and heat conductivity properties. In the case of porous materials drying is time and energy consuming process. Drying process is a complex phenomena with simultaneous mass and heat transfer mechanisms taking place. Understanding its physical phenomena is of great practical importance. There is a need for simple models verified by experimental data that will provide optimum conditions for drying. A complete drying profile generally consists of two drying stages – a constant drying speed period and falling drying speed period (Mujamdar, 1987). In first stage drying speed is determined not by the properties of sample material, but depends on temperature, relative humidity and flow speed of ambient air (Tang and Etzion, 2004; Dincer and Dost, 1995; Musielak and Kieca, 2009). In second stage drying speed is determined by the physical properties of the sample material. Now it decreases depending on the time and is lower than initial constant drying speed of the first stage.

The constant-rate and falling-rate stages are separated by critical point (Iljins et al., 2009) The critical moisture content is a significant design parameter since at this point the drying mechanism change from one controlled externally to one controlled internally.

One of most important material parameters in drying theory of capillary-porous materials is the moisture diffusion coefficient. In most cases moisture drying theoretical models are based on the solution of a simple diffusion equation (Fotzing, 2004; Jurendič et al., 2011; Kaya et al., 2010; Chemki and Zagruoba, 2005; Avci and Can, 1999). However, they cannot describe the changes of moisture in the material in time accurately enough. Limited data on moisture diffusion in porous materials are available in literature. Moisture diffusion coefficient experimentally determination was performed for wood material (Simpson, 1993; Fotsing, 2004), baby food (Jurendič and Tripalo, 2011), vegetables (Kaya at al., 2010), clay material (Chemkhi and Zagruoba, 2005). There is no data about moisture diffusion coefficient dependence on porous material volume density.

Materials and methods

The aim of this work was experimentally determine drying process parameters in porous material. In order to test the obtained theoretical results (Iljins et al., 2009), a range of foam gypsum samples were made with the different final density in the dry condition of approximately 270 - 1100 kg/m³ and the research on their drying at room temperature 20 - 22 °C and relative air humidity 30- 40%. The following description presents the physical data of one of the most typical sample. The moisture content of foam gypsum was calculated according to the following formula

$$W = \frac{m}{V}, \quad (1)$$

where m – water mass in the sample, kg; V – volume of foam gypsum sample, m³. Usually the initial moisture content is high $W = 200 - 350 \text{ kg/m}^3$ or (45 – 50%) in relation to a dry sample. Experimentally the drying speed of the sample is determined by the following formula

$$\phi = \frac{1}{S} \cdot \frac{\Delta m}{\Delta t}, \quad (2)$$

where ϕ – drying speed of the sample, kg/(m² s); Δm – change of mass, kg; Δt – interval of time, s; S – surface area of the sample, m².

According to our theoretical calculations, the drying time of the sample is inversely proportional to the thickness squared. Therefore, the thickness of the sample was chosen $d = 2 \text{ cm}$, so that the drying time would be within 1 week. All the surfaces of the sample, except the top surface through which the

moisture evaporates, are covered with a vapour barrier. During the process of drying the average moisture content in the sample was determined by weighing the sample with the scales manufactured by the company KERN, the maximum allowable weight of which is 16100.0 g, but sensitivity ± 0.2 g. The surface area of the sample was chosen 0.1 m^2 in order not to exceed the maximum allowable weight value. To check the temperature on sample surface and inside thermocouples were inserted. On the surface of sample heat flow sensors were replaced.

Experimentally when weighing the samples, the average moisture $\langle W \rangle$ was determined depending on time (fig. 1). Thus, the moisture experimental measurements depending on time should be theoretically compared with the integral (Iljins, et al., 2009):

$$\langle W(t) \rangle = \begin{cases} \frac{1}{d} \int_0^d W_I(t; z) dz = W_s - \frac{\phi \cdot t}{d}, & \text{if } t < t_{cr}; \\ \frac{1}{d} \int_0^d W_{II}(t; z) dz = W_0 + \frac{2}{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n A_n}{2n+1} \cdot \exp\left(-\frac{\pi^2 (2n+1)^2}{4d^2} D(t-t_{cr})\right), & \text{if } t > t_{cr}. \end{cases} \quad (3)$$

where W_s - initial moisture of the sample kg/m^3 ; t - drying time, s; D - diffusion coefficient, m^2/s . W_0 - equilibrium moisture kg/m^3 . In the course of time, the sample dries and after a certain time t_{cr} , when the first stage of drying period is completed, on the surface of the sample $z=d$, the moisture has reached the equilibrium moisture W_0 .

From this time on, the sample t_{cr} , has entered the second stage of drying.

Using this comparison, it is possible to calculate the unknown values W_{cr} , ϕ , D by means of the least square method (Iljins, et al., 2007).

Results and discussion

The experimental moisture measurements for different volume density samples were performed. In Fig. 1 typical drying curve is represented.

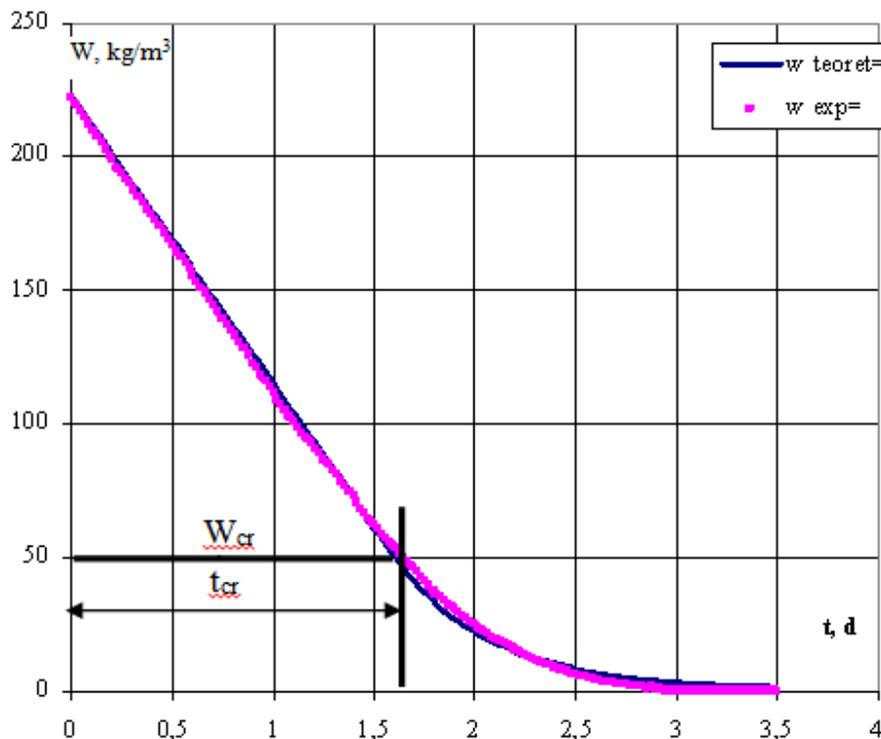


Fig.1. Theoretical and experimental comparison of the sample's average moisture depending on the drying time. Sample volume density was 311 kg/m^3 .

On the basis of experimental drying process data, we calculated theoretical model parameters that are summarized in the following table. It is worth to note that moisture diffusion coefficient in foam gypsum is the same order as in clay materials (Chemkhi and Zagruoba, 2005).

Table 1.

Calculated model parameters for foam gypsum samples with different volume density

ρ , kg/m ³	$D \cdot 10^9$ m ² /s	$\varphi \cdot 10^5$ kg/(m ² s)	W_{cr} kg/m ³
276	6,02	2,7	30
311	4,95	2,85	44,2
661	2,61	3,07	74

Conclusion

Drying model (Iljins, et al., 2009) physical aspects predicts that moisture diffusion coefficient decreases on increasing volume density. On the other hand drying speed should remain constant as it is determined by ambient air properties. Obtained results provide a satisfactory coincidence with the theoretical model predictions. It is necessary to provide experiment for different ambient air conditions – temperature and relative humidity.

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INCLUSIVE INFORMATION SOCIETY IN LATVIA

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Abstract: *There are several aspects which are critical for the successful formation of an inclusive information society – accessibility, skills and content. In this article these aspects are analyzed as well as the projects which have made their contribution in inclusive society in Latvia and which are carried out in collaboration between private and public sector. All these projects are important also in a sense that they decrease the digital gap between urban and rural areas in Latvia. One of these projects is “Father's Third Son” by means of which the Internet access was made available at all public libraries in Latvia, had librarians trained in digital skills and client oriented attitude as well as eContent was developed. Another project analysed in this article is Latvia @ World” which also was aimed to diminish the digital and social gaps in society by means of providing acquisition of digital skills for almost 100.000 members of disadvantaged groups. The third project is “Get Online week” which is a Europe-wide campaign to get new computer users online. More than 200 governmental, industry and municipal partners in 2010 were involved in organization of this campaign in Latvia, ensuring Latvia to be the most active of all of the European countries. In Latvia, we are ready in collaboration with private and public sector to contribute to Digital agenda goals and achieve that every citizen of Latvia is digitally literate.*

Keywords: information society, eInclusion, digital gap.

Introduction

In Latvia, similarly as in most European Union (EU) countries information society is fostered by a number of stakeholders representing different sectors: national government, local governments, non-governmental organizations and businesses.

All of them collaborate in order to achieve the main objectives of Information Society as well as the main objectives of Latvian eInclusion policy:

- to improve everyday life of individuals and communities,
- to promote participation of citizens in all aspects of information society,
- to overcome exclusion,
- to improve economic performance and cohesion,
- to improve education, employment, health care, social care and other opportunities,
- to reduce the gaps in the usage of information and communication technologies (ICT) between different groups of population.

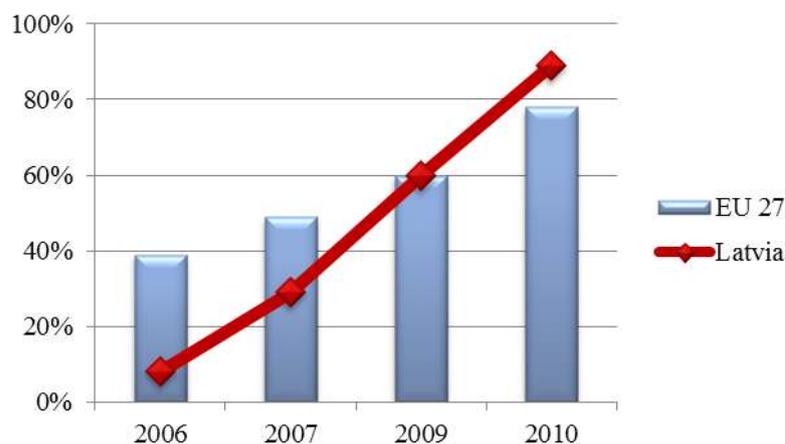
People are not motivated to learn how to use the Internet because there is a lack of awareness of the range of possibilities the Internet and eGovernment services can offer (Aerschot and Rodousakis, 2008). Therefore the critical aspects which should be fostered by all stakeholders are digital content, its accessibility and skills needed to use the digital content. By digital content understanding a wide range of various electronic services provided by government and businesses, digital information flows, electronic educational resources – if this content is created and developed then it should be available for every citizen and every business entity in the country. Access to the digital content is characterized by availability of the Internet and computers throughout the country. In order to use this digital content people need digital skills i.e. the basic skills of computer and the Internet usage.

Digital content

There is a strong focus on assessing to what extent government services are available online in Europe. This assessment is based on two main indicators: sophistication and full online availability of 20 basic public services of which 12 services are aimed at citizens and 8 – at businesses (Lőrincz et al., 2011).

The National Portal www.latvija.lv is the Point of Single Contact which provides Latvian eServices. The aim of the Portal is to provide people in Latvia and abroad with access to the Internet resources of Latvian state institutions. But the most important role of the portal is the centralized access to electronic services provided by various institutions.

Figure 1 shows the progress of eGovernment on-line availability for citizens in Latvia and 27 countries of European Union (EU 27).

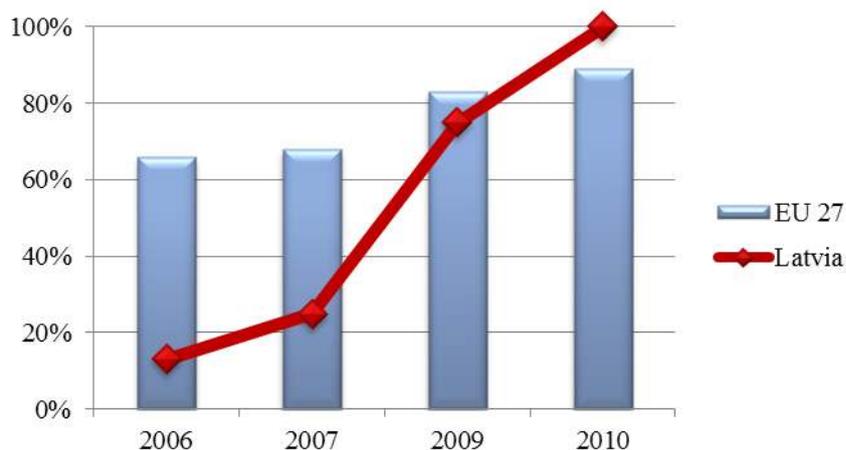


Source: the author's construction based on eGovernment benchmark report data.

Fig. 1. eGovernment on-line availability for citizens.

Figure 1 shows that in year 2006 there were only 8% of 12 basic eServices for citizens available on-line. In last five years Latvia has managed to ensure that in year 2010 these basic eServices were provided in 89 percentages which is higher than EU average. Today citizens in Latvia, for example, can get online declaration of income taxes (all declaration for civil servants are mandatory online), different public libraries services, enrolment in higher education establishments, announcement of moving, declaration of place of residence as well as health-related eServices.

Similar progress is achieved also in providing the basic eServices for businesses, shown in Figure 2.



Source: the author's construction based on eGovernment benchmark report data.

Fig. 2. eGovernment on-line availability for businesses.

There were only 13% of eServices for businesses provided electronically in year 2006, but in year 2010 all 8 basic eServices for businesses were already available on-line. Entrepreneurs of Latvia can collaborate with States Revenue Service thoroughly electronically – there is no need any more for document submission in paper format.

This progress was achieved not only due to the state policy, but also by means of Latvian IT companies which proficiently and actively participated in the process of state's service digitalization.

Latvia also has, for example, anchored the acceptance of electronic documents (signed with the secure eSignature and time-stamped when appropriate) in law. That is, according to the National Electronic Documents Law, electronic documents must be accepted by every public (state and municipal) institution. In addition, citizens and businesses can request an electronic reply from public administration.

There is a demand for public eServices in Latvia because people are active users of technologies in private sector – they are searching information about goods and services, they are seeking health related information as well as using services related to travel and accommodation. In last 7 years the number of Internet bank users has grown from one 3rd to more than two 3rds of all Internet users (see Table 1).

Table 1

Indicator	2004	2011
Finding information about goods or services	56.9	74.9
Using services related to travel and accommodation	28.5	35.8
Seeking health related information	23.0	54.2
Internet Banking	35.4	76.2

Source: Central Statistical Bureau of Latvia

Technologies are more and more persistent in our everyday life and consequently technologies more and more come also in communication with public sector.

Accessibility

The second aspect of successful development of inclusive information society is access to the Internet.

By analyzing the indicators of the Internet access availability and quality in Latvia it is evident that the quality of the Internet in Latvia is even higher than in average in Europe (see Table 2). At the same time Latvia is below the Europe's average number of households regarding the Internet access at home. Reasons for this situation are several. First of all there is insufficient Internet access coverage in rural areas in Latvia. The second reason is that not all households in Latvia have got computer at home.

Table 2

Indicator	Latvia	EU 27
Share of fixed broadband lines \geq 2 Mbps	96.4	88.0
Share of fixed broadband lines \geq 10 Mbps	45.4	42.2
3G coverage (as a % of total population), 2010	99.9	89.9
Households with access to the Internet at home	64	73

Source: Eurostat, Digital Scoreboard

Latvian public library network serves as the solution for this problem. Latvia is a small country where only 21 towns out of 77 have population higher than 10 000. However, there are 874 public libraries and most of them are in rural areas. In last years the role of libraries has significantly increased and libraries have greatly contributed in the improvement of information society in Latvia.

In last 5 years public libraries have faced transformation from traditional ways of libraries to modern technologies which nowadays is one of the reasons why people come to library.

As it is seen in Table 3 in the year 2006 only 13% of all public libraries provided Wireless Fiber (Wi-Fi) connectivity, besides all of those libraries were located in or near Riga – the capital of Latvia. Today people can get access to free Wi-Fi at all libraries or 24 hours a day near to every public library in Latvia.

Table 3

Indicator	2006	2011
Users' PCs per library	3.02	6.4
Wi-Fi access in public libraries	13%	100%
Internet users, % of population	46%	62.5%
Library as the only Internet access point, % of population	18%	20%

Source: State Agency *Kultūras informācijas sistēmas*

Percentage of inhabitants for whom library is the only access point to the Internet has increased from 18% in year 2006 to 20% in year 2011. Also the number of the Internet users has increased significantly – from 46% in year 2006 to 62.5% in year 2010. This clearly shows how important libraries are for providing equal access to information especially in case when economic situation was changing.

There is a good reason to look at public libraries as contributors to e-Inclusion processes in «before and after» mode. 2006 was the year when Global Libraries initiative of the Bill & Melinda Gates Foundation was started in collaboration with Latvian government and local authorities. The public library development project «Father's 3rd Son» was launched with its goal to facilitate better and proactive use of resources offered by free access to ICT and the Internet in libraries.

During this project all librarians were trained to use ICT as well as trained to help people work with computer, search for relevant information and use public or private sector eServices. These goals of the project greatly contributed to the development of Information Society in Latvia.

Digital skills

Since 1998 the Latvian Information and Communication Technology Association (LIKTA) has been taking care of the ICT Industry as well as about the development of Information Society and the development of digital

skills for everyone in Latvia. LIKTA is also an initiator and coordinator of eInclusion and eSkills development initiative Latvia@World, started in 2005. This initiative aims to diminish the digital and social gaps in society and raise eSkills as well as competitiveness of citizens, public organizations and small and medium enterprises.

Everyday activities of the association are focused on promoting the usage of eServices and facilitation of the development of new and useful content and services. Another activity is to provide opportunities for everyone to acquire ICT skills, regardless of gender, age or social status. Today more than 100.000 members of disadvantaged groups have acquired digital skills which greatly benefit for their everyday life.

One of the most important prerequisites of success of Latvia@World initiative is a partnership. The initiative is carried out in close co-operation with different partners – private donors and training centres, municipalities and local non-governmental organizations, libraries, state institutions and other. At the moment 31 training centres are operating in the network of Latvia@World throughout the whole country, covering also rural areas and small towns. A number of up-to-date highly valued training programs supported by online tools and other training materials are provided in these training centres.

Specific innovative training programs for basic computer and the Internet skills with ECDL certification, learning tool for people who have no or little experience of working with computers, as well as specialised training program for small and medium enterprises and micro-enterprise needs are developed within the project. There is also training program developed for families how to use computers for communications, family entertainment, etc.

The main principles in providing these trainings are as follows:

- cooperation with national partners;
- combination of classroom training with online skills assessment and e-learning;
- provision of clear Roadmap how to upgrade ICT competences.

The European “Get Online Week” in Latvia was organized and coordinated by LIKTA in cooperation with the Ministry of Environment Protection and Regional Development of Latvia. The aim of this event was to raise awareness of the importance of e-skills for citizens and small and medium enterprises, to encourage people who have never used computer and the Internet, and entrepreneurs to use and to involve in new eServices.

More than 41 000 people including 2900 of those who used computer and the Internet for the first time took part in various events in cities and rural regions all over Latvia. More than 200 partners were involved – ministries, public organizations, municipalities, ICT companies, libraries, schools etc. All together there were 709 events organized in “Get Online Week” for all kind of audiences.

For the first time within the framework of “Get Online Week 2011” Central Statistical Bureau gave the opportunity to take part in population Census 2011 via the Internet. This new eService was promoted by almost all regional partners and from March 1 – 5 was used by more than 170 000 citizens.

As the result of all these activities Latvia was the most active “European Get Online Week 2011” member country followed by Lithuania, Romania and Poland.

Analyzing the digital divide among world nations Latvia was characterised as ICT follower in Europe. This analysis was based on eGovernment Readiness Index as well as on telecommunication and ICT statistics about personal computers, the Internet users, telephone lines, mobile phones and broadband per 100 persons (Ayanso, Lertwachara, 2010). Nowadays all stakeholders collaborate in order Latvia to get an ICT leader in Europe.

Conclusion

In order to fully participate in society, people nowadays need competence and willingness to use ICT tools to access information and engage in social processes. In Latvia as well as in other EU countries the public library has become a bridge between people, knowledge and information. Existence of this bridge is particularly important in rural areas.

eGovernment services significantly change public sector relations with citizens and businesses. The majority of the 20 basic public services are now available online in Latvia. The main issue which still remains is that information technologies should serve so that all citizens can benefit from the usage of ICT.

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MODULAR MULTI-COMPONENT ACS WITH BUILT-IN ACTIVITY AND MEASUREMENT DATA STORAGE

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Abstract: *The paper describes the prototype of a modular multi-component ACMS (Automatic Control and Monitoring System). This prototype gives a possibility of simultaneous process monitoring and control by natively allowing logging the states of measurement and controlling actions to the local memory or remote database for further analysis. The prototype is a modular system consisting of several modules with distinctive functionality. These microcontroller-based modules, that can be interconnected using industry-standard RS485 and IEC-870 communication networks, are developed: digital I/O, pulse counting and measuring, relay, temperature measuring modules and central control module with SD memory card and Ethernet interface with TCP/IP networking. Besides of built-in process logging feature the advantages of the proposed ACMS over traditional programmable logic controllers are simple logic expressions based language where user without a prior knowledge in programming can create his own control algorithms; and a possibility to directly connect ZACwire interface devices, e.g., temperature sensors with digital output. This allows building cost-effective multi-point temperature monitoring and controlling systems.*

Keywords: ACMS, PLC, microcontroller.

Introduction

Industrial PLC's (Programmable Logic Controllers) are designed to be robust and reliable control units for use in harsh environments in the applications with high processing performance and safety requirements, where in the case of a malfunction there is a risk of damage to equipment or injury to personnel. These units can directly interface to commonly used (Bayindir, 2010) control system sensing components with pulse or analog voltage/current outputs as well as resistive sensors and thermocouples, actuators, e.g. relays and frequency converters and use industry-standard communication networks (Osadčuks and Galiņš, 2009). The PLCs are designed to be programmed by electrical and automation engineers, that are familiar with relay-based automation (Galiņš, 2008). Although the PLCs are also used outside industry environment to control processes in, e.g. agricultural facilities, Smart Houses, to control processes and collect data in scientific research projects in agriculture, food, forestry etc.; in many cases they are not suited to this purpose very well. The drawbacks of PLCs in such cases are relatively high cost of base system and expansion units, problems with interfacing to various types of sensors that are not commonly used in industry, relatively high power consumption for battery applications. Most types of PLC's do not contain built-in functionality for software activity, actuator and sensor data logging, which is one of the most important aspects for scientific experiments (S. Da'na, 2007).

On the other hand task-specific embedded systems could be used. In such cases, specialists with knowledge in embedded system design and development are needed, as well as a prolonged process of equipment testing which results in comparatively greater expenses (Bucur, 2010).

The aim of this work is to design a prototype of intermediate solution, which could be used to target various sensor measurement and simple automatic control applications. Emphasis is made on data logging of the system operation.

Materials and methods

The architecture of the proposed automatic control system is designed hierarchically similar to SCADA systems. In the hierarchical structure of the industrial automation (Кругляк, 2002) the proposed system goes along with segment and manufacturing automation level. Examined solution is modular and works using master - slave principle. One central master device is connected to the slave devices using high-speed digital data exchange network. Master performs functions of the controller of the process by executing the algorithm that has been set and stored in it, but slave devices are used for reading variables of the process and performing control actions. Master sends commands for execution or data requests, and the slave responds with the approval of the execution or with the requested information. In the current implementation several groups of slave devices equipment have been considered: temperature measurement, digital inputs reading, pulse counting and control of relay outputs.

Asynchronous communication is being used to exchange data between master device and slave devices and slave devices could be read at any time. Sequence diagram for transactions with a slave device in general case is shown in Fig. 1.

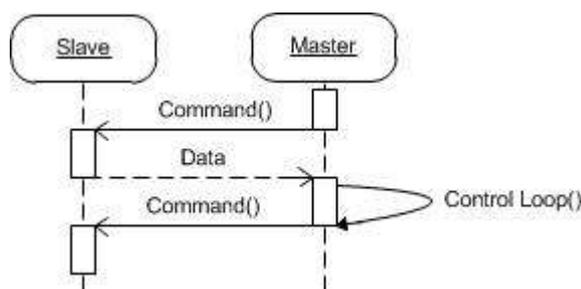


Fig. 1. Data exchange between master and slave devices in general case

For all types of devices in the general case the master-slave data exchange network initialization and data exchange procedure consists of the following steps.

1. The master contains a list of equipment of all known slaves. All physical devices within the network are identified by their unique MAC (Media Access Control) addresses. At the start of network initialization the master device successively dispatches test packets for each slave, if the result is a response it is considered that the machine is connected to a common network and is running.
2. The slave device default settings are sent after network initialization, such as a temperature sensor calibration values, the digital port mode or relay starting position, notice that the slave machine configuration can also be changed at any other moment later.
3. Then the slave devices are being pooled to get sensor reading data on the state of the process for use as the master control algorithm inputs.
4. Master device calculates a step of control loop and generates control action signals; the master logs actual measurements and the control signals data to a DB.
5. Control signals are then sent to the slave devices in a form of the commands and the cycle continues with the third point.
6. If slave does not provide answers to the master request in 300ms (in contrast to IEC-870 standard, where it depends on the communication baud rate) then the packet is sent again.

Discrete input block (pulse unit) is designed for reading of digital logic state and for counting status changes (pulses) at its inputs. The current prototype has eight inputs, which can be configured separately for either for logical level reading or pulse counting mode. The pulse counter at each input is 16 bit wide. This block can be used to count data from energy meters, flow meters, anemometers etc.

After master has configured operation mode of discrete input block port, data is exchanged in the following steps (see Fig. 2):

1. Digital input block reads the states of all the inputs and records them into transmission buffer, at the same time the state transition from the high logical level to the low at the specified input ports is fixed and corresponding port pulse count register is incremented.
2. When the master device transmits the reading request command, digital input block prepares a data packet and sends it to the master.
3. If the master has received the answer, it sends confirmation that the data is successfully received to discrete input block. After receipt of this package digital input block restores digital input status buffer and accumulated pulse value, if such a packet is not received, the discrete input unit continues to count pulse and at the next master request it sends a total count of pulses. Consequently, it provides integrity of transfer data and the digital input block will not count high to low transitions continuously, but only until the next master-slave transaction, thereby eliminating the need of back-up power supply or non-volatile memory and simplifying the system.
4. When the master device receives data from the digital input block, it can use the received data as input for control algorithm and also stores the data in a database.
5. If the master cannot read data from slave device until the pulse counters are overflowed, then in the next data packet there is error code encapsulated in it. When master device reads the packet, it is notified about data overflow.
6. The master can request new data.

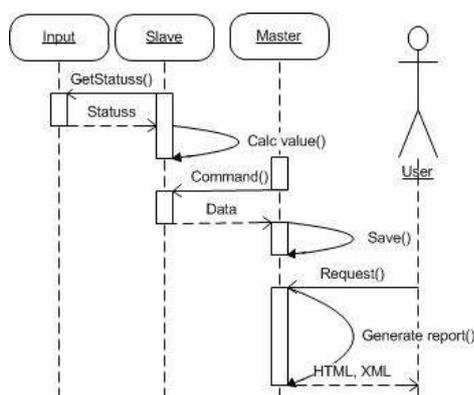


Fig. 2. Data exchange between master and digital input blocks

Temperature measurement block is intended to retrieve temperature data. In the current implementation to this unit can be connected up to 20 integral temperature sensors with digital output (ZACwire interface). All sensors can be read within 2 sec. After the master has configured which sensors to be read the temperature measurement in the slave is being carried out using following algorithm (see Fig. 3):

1. Cyclic reading of all temperature sensors.
2. When the request command is received from master device, temperature measurement block prepares data packet and sends it to the master.
3. When the master receives data from the temperature sensor unit, and stores them in a database and sends acknowledgement to the slave.
4. The master ser can request new data.

Sensor reading of the temperature-measuring unit is represented as a signed integer, but the master device converts it into a float type before saving into the database. Experimenting with the prototype equipment, the need of the sensor state determination arose, if measurement is not received due to some reason. Error codes that are applied on an individual digital output ZACwire sensor were introduced: no connection to the sensor (sensor response timeout), short between leads of a sensor, parity does not match and framing error (wrong bit type or count).

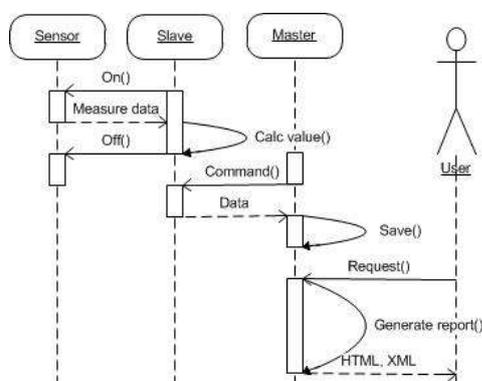


Fig. 3. Data exchange between the master, the temperature measuring unit and integrated temperature sensors

Relay block is provided as output device or actuator Fig. 4. The current implementation of a single block has 4 relays. Like other slave devices relay unit receives from the master the initial configuration (initial state of the relay, watchdog timer value and the default state of the relay) and operates using the following algorithm.

1. Waiting for the master commands which relay should be either turned on or turned off.
2. Receiving the master command (new relay state) setting the appropriate relays and transmitting current conditions back to the master.
3. If relay position command request is received, slave device returns current positions of all relays.
4. User can request new data.

Relay block has built-in safety mechanism, if there is a failure to receive data from the master device. In this case, user can set a watchdog timer and when no data received, the relay is set to default conditions so that control system would not produce emergency situations.

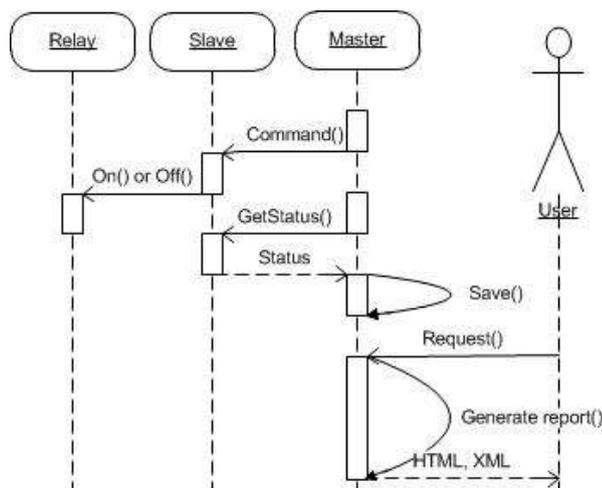


Fig. 4. Data exchange between master and relay block

Results and discussion

Based on the discussed theoretical control and monitoring aspects of the modular system, a prototype was developed. Equipment of the prototype, architecture and technological solutions that were used are shown schematically in Fig. 5.

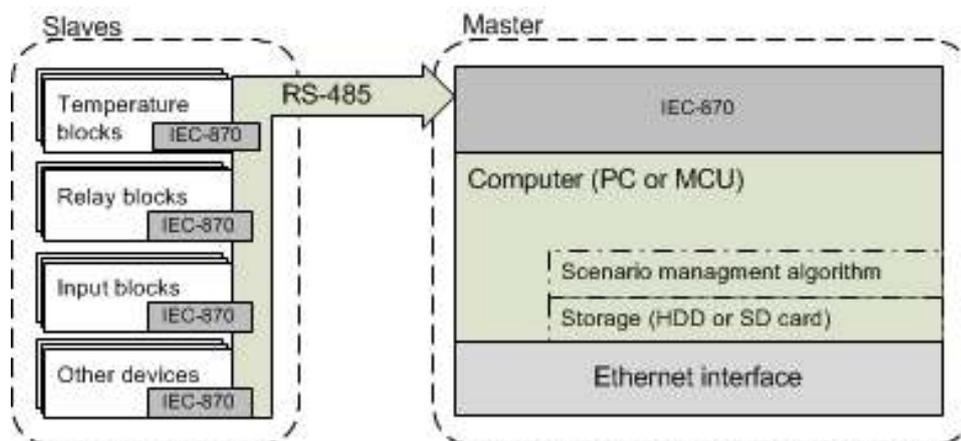


Fig. 5. Prototype equipment used in the circuit architecture and technological solutions

Communication is carried out via RS-485 physical interface, which can provide up to ~ 1 km long line of data at a rate of 9.6 kbod. IEC-870 protocol is used as OSI (Open Systems Interconnection model) model data link layer. The prototype currently has three device types: temperature measurement unit, relay unit and both digital input and pulse counting blocks in a single unit. Temperature unit works with TSIC506 integrated sensors with the ZACwire digital output. Up to 20 sensors can be connected to the unit and all sensors are pooled within 2 seconds. Relay block contains relays with single pole double throw 3A, 250V AC and 30V DC contact configuration. Pulse unit is able to count digital pulses and read the current input logical states (optically decoupled, max input pulse frequency is 10kHz). Arrangement of the prototype is shown in Fig. 6.

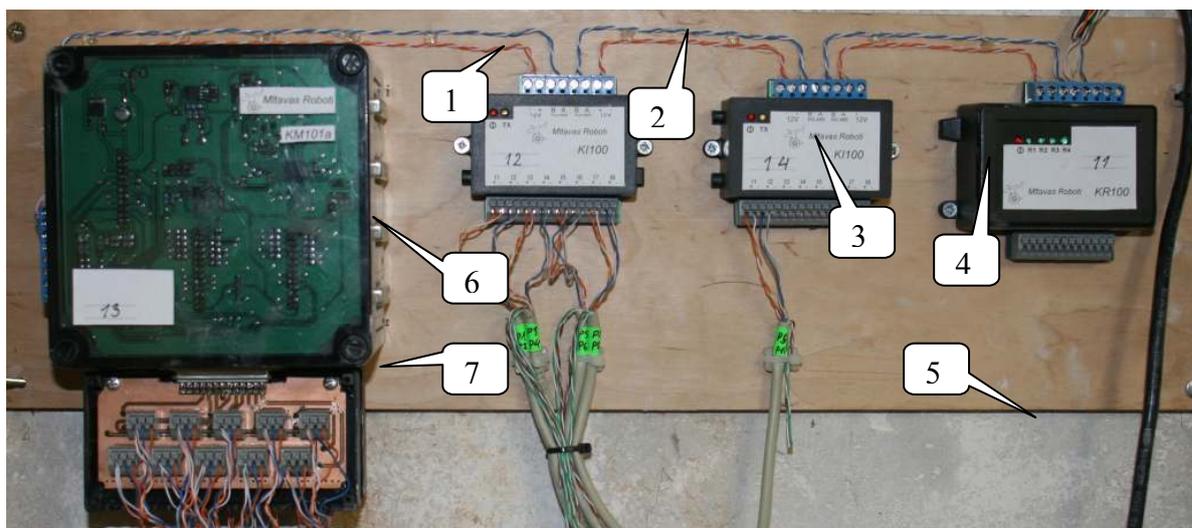


Fig. 6. Management system prototype:

1 - power supply (12V), 2 – RS485 interface, 3 - input block, 4 - relay block, 5 - RS485 to PC, 6 – temperature block, 7 - connection from TSIC506 sensors

Microcontroller-based device or PC can be used as the master. In the cases where there is an immediate need for reading data, such as a dynamic experiment and monitoring with the possibility to quickly change the control algorithm and its settings, PC can be chosen as a master device. Slave device is connected to the PC using USB <-> RS-485 or RS-232 <-> RS-485 interface. PC software has been developed which is capable of providing control algorithm execution, the retention of data in the database and viewing data in real time, and a control tool for user that ensures possibility to create dynamic algorithm. With this tool the user can create various logical conditions. Readings of the given sensors are used as inputs, relay contact states are outputs. Algorithm is composed of a list of the logical conditions and is carried out with user-defined cycle time (from 1 s to 1 h). At the same time the sensor data and the taken control actions are continuously stored in the database. As for example in Fig. 7 (1), condition is verified at which logical state is the input 0 and what is the temperature setpoint, as a result relay is set to ON position, see Fig. 7 (2).

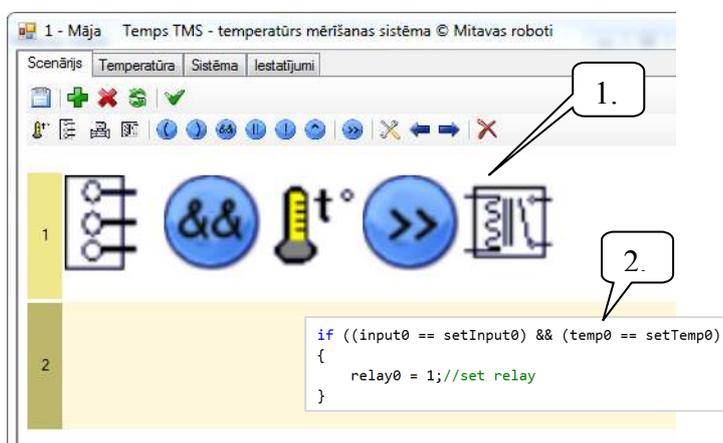


Fig. 7. One condition:

1 – Condition, 2 - interpretation of program code

By connecting PC to the Internet there is possibility to access the system remotely, using e.g. Remote Desktop to access the program online or read data from local data base server.

The other option as one can get sensor measurements from and send commands to slave devices is to use embedded control unit as a master, which is controlled by the MCU (Microcontroller Unit). MCU performs execution of control algorithm and communication with the rest of the equipment. SD memory cards are used for data storage; Ethernet interface provides access to the Internet. SD card also stores the logical conditions defined by the used (the control program), MCU reads them and executes cyclically. Temperature test run for 16 sensors is shown in Fig.8, 9. The control device runs an embedded WEB server and if it connected to the Internet then XML data file can be uploaded. This file consists of temperature, input, and output data.

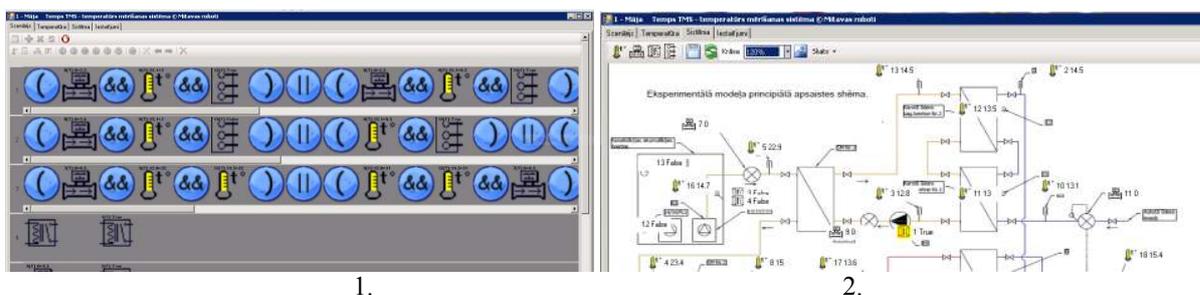


Fig. 8. PC master interface (form):
1 - the conditions, 2 - System overview

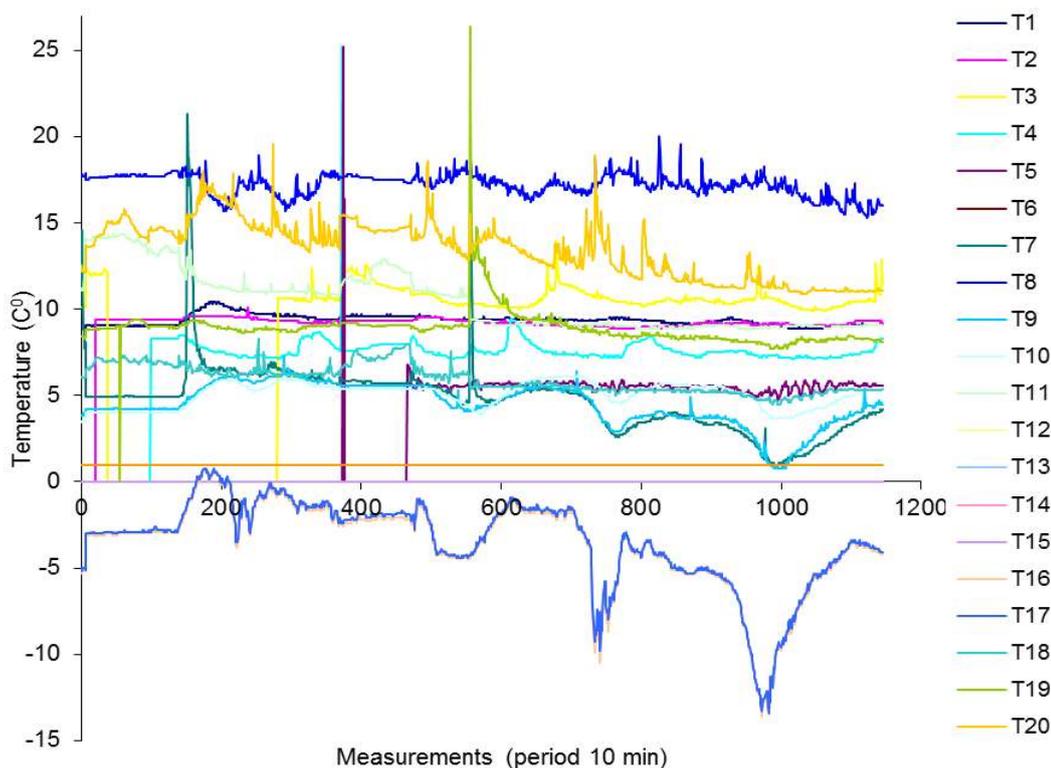


Fig. 9. 16 temperature sensor test run

Conclusions

By designing of system, which allows for automatic control and monitoring, it can be concluded that this type of control system can be used in various scientific experiments. The control system has a relay output, temperature and pulse reading blocks, as well as the control unit, which in this case is a personal computer or embedded WEB server. These blocks can be combined in a variety of combinations, making it easy to perceive the system configuration. Control algorithm can be easily composed according to the Boolean algebra principles.

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ROLE OF ICT IN PRACTICAL-ORIENTED EDUCATION OF AUTOMOTIVE ENTERPRISES SPECIALISTS

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Abstract: *There are features of the automobile profile specialists' information competence forming are considered in the article. The role of employers in professional order for specialists' preparation forming, forms of their interaction with educational institutions while maintenance of hi-tech and high technology manufactures problems decision by the highly skilled personnel, that is capable to use science and technologies achievements during formulated goals decision are mentioned. Besides, there are considered innovative approaches of forming informational competence while target preparing automobile profile specialists: maintained the content of informational competence as a base and as a component of professional competence, and also maintained its meaning for the solution of professional problems in life cycle of automotive engineering. As shown in the article, proposed approach in a combination to development and adoption of training individual programs under contracts with employers and undergoing of industrial practices on places of the future industrial activity will allow to reduce terms of adaptation of the specialist on a concrete workplace, will raise its competence both in professional sphere, and in the field of high technologies that will provide its competitiveness on a labor market*

Keywords: information, competence, target, preparing, plm-systems.

Introduction

Current state of educational system is characterized by increasing distance between loss of education quality and growing personnel's competence requirements which are caused by acceleration of technological progress and perfection of technologies. Discrepancy between subject matters and growing requirements of different social-practical situations defines the global crisis of higher education field which is underway against the background of worldwide trends, including wide distribution of education, its commercialization, and finally formation of informational society.

In such conditions the topical question is the looking for such directions of vocational educational system development which could provide for accordance of specialists graduation structure with labour-market requirements, and also could allow satisfying of the consumers' requirements to quality of graduating students' preparation. The purpose of domestic education modernization is to create the mechanism of educational system's sustainable development. At the same time as the main task of Russian educational policy it is possible to mark an assurance of contemporary quality of education based on conservation of its fundamental nature and accordance with relevant and perspective needs of individual, society and state.

The training of personnel for automotive branch is a topical question due to its rapid development. It is reflected in Strategy of motor industry development in Russian Federation for the period till 2020 year (Ministry of Industry and Trade of the Russian Federation, 2010) in which the discrepancy of graduating specialists quality with branch demands and is noted and the most efficient ways for taking the issue forward are marked: «... for the preparation of high quality experts which are able to ably solve assigned problems on working out and manufacture of modern and perspective production, it's necessary to teach them under the multilevel program of higher education including good fundamental preparation, sufficient skills in professional work during industrial, design, technological and pre-diploma practice».

It is possible to achieve accordance of graduates' quality with employers' requirements only by modification of educational system paradigm. Nowadays many researchers when consider the possibility of «education during the whole life» concept realization are citing the different mechanisms of providing with unified educational area. The hard is that educational system is enough inert. Thus, the educational cycle in several times, but in most cases even in several orders much more longer than the manufacturing one, so, considering that changes in manufacturing system under severe competition conditions happen more quickly than it is necessary for the specialist training, the educational system in it's own classical version will permanently run after the manufacturing one. If the measures to cardinal changes of both processes and specialists training approaches will be not taken then displeasure of employers will only increase.

One of the serious problems is the imbalance in skill-mix production professionals in vocational education at all levels with labor market needs. This applies both quantitative relations and qualitative characteristics of professionals. On the one hand, technological developments and new technologies contributes to economic well-being of society, on the other hand, they provide very serious problem of finding competent person who shall design, produce, maintain, new technology and use advanced technology. Because educational system has

different inertia, its development should outperform the economy and only in this case, trained professionals will be really in a great demand by production.

The target preparation of specialists for automotive enterprises

During the working travel to Khakassia president Dmitry Medvedev said that «... engineer is manufacturing-centric, piece and address product» and offered to businessmen to suggest to universities which specialists they really need (Komsomolskaya Pravda, 2011). Creation of the target preparation system is one of the possible ways to satisfy employers' requirements in highly skilled personnel in terms of dynamically developed economics.

For realizing the similar system of education it is necessary to use the innovative approach both to its construction, and to realization. Thus orientation to requirements of the employer and using of innovative technologies of education is the primary factor. In our opinion, it is possible, if at curricula of the expert preparation forming in a concrete direction maintain the principle of "consecutive accumulation of knowledge» and forming of competencies with the use of received skills. The conception of «target preparation» nowadays is determined by the new meaning: practically it means the specialists' preparation based on individual educational trajectory.

While analyzing the experience of universities in creation of integrated learning systems we can find out the unity of principles of coordination between universities and enterprises. It includes the curriculum and graduate works themes concordance, strengthening of practical-oriented systems by involving students into manufacturing process during the training, leading additional subjects into basic curriculum and development of additional curriculum containing relevant for enterprises subjects, attraction of leading experts of enterprises to conduct lessons and masterclasses and also to manage the course and graduate projects (Leskin et al., 2010, Orlov et al., 2009, Sobolev et al., 2005, Pimenov, 2010, Bureeva, 2011, Granichin et al., 2010, Korotkov, 2010).

Nowadays the automobile branch is one of the most dynamically developing branches where both the state of the economy and well-being of the whole nation is reflected. One of the whole factors defining dynamical development of the branch is the presence of the highly skilled personnel. The requirement of the highly skilled personnel is very high now. It is confirmed by the fact that one of eleven primary goals which are required to be solved within the frameworks of The strategy of Russian Federation's automobile industry development for the period till 2020 (Ministry of Industry and Trade of the Russian Federation, 2010) is the necessity of the perfection of «... automobile industry specialists' preparation's systems including new programs for a specialists' education creation according to the international standards».

In particular the acute problem of education for automotive branch is facing in Naberezhnye Chelny, for which KAMAZ, the leader of the Russian cargo motor industry, became an enterprise forming a company town, but not only for named town, also for Kama economic region of republic Tatarstan. Another one intensive developed large automobile concern – Sollers is located both in Naberezhnye Chelny and in a special economic zone "Alabuga".

Forming of HR potential which meet the requirements of the branch; development of new and modification of existent educational programs and programs of mid-career education to provide automotive branch by the personnel of a new type; development of the system of scientific-research, engineering and industrial personnel training for the purpose and tasks of automotive branch.

In «The strategy of Russian Federation's automobile industry development for the period till 2020» considered risks associated with restructuring and modernization of the automotive business, which may lead to increased social tensions. It states that «... it is possible to reduce these risks through effective implementation of development projects automotive clusters – supporting regional cluster initiatives - through the formation of coordinated programs with the companies targeted training and retraining». Thus, the formation of human resources, meets the needs of industry, development of new and modification of existing curricula and training programs for the automotive industry, a new type of personnel, development of training research, engineering and manufacturing skills for goals and objectives of the automotive industry – are the challenges included in the package of measures to create conditions for sustainable innovation in the automotive industry in Russia.

To staff the enterprises of Kama region's and Naberezhnye Chelny city's automobile branch the General cooperation treaty between Kama State Academy of Engineering and Economic (INEKA) and KAMAZ JSC was concluded in 7th June of 2008 whereupon a number of specialists target contract preparation treaties with KAMAZ JSC departments was concluded.

One of areas of cooperation is educational groups for target preparation forming. It assumes: from the side of the high school – solution of the organizational problems connected with presentations, interviews and competitive selections of students by departments and enterprises of KAMAZ, JSC; from the side of KAMAZ, JSC, - direct carrying out of the mentioned actions. As a rule, target audience are the students of 4-5 courses taking part in competitive selection from calculation of 3-4 persons on one place offered by the customer.

According to mentioned contracts INEKA has engaged the resource base forming (the laboratory equipment, the software, the literature) for realization of target contract preparation, and also the conditions for its realization support (fig. 1).

Target preparation is realized on the basis of the tripartite contract between high school, the enterprise and the student in which conditions of the specialist preparation, undergoing industrial and pregraduation practical training, job placements for the period of target preparation and after it ending, and also other details of relationship.

Under the organizations-customer's request INEKA develops schedules of educational process for target preparation of students, and also curricula of target preparation. The list of disciplines, volume of theoretical and practical training on each of them, studying terms are coordinated with customers and chairs which graduate students. To conduct the lessons under the curricula confirmed in a bilateral order both leading teachers of profile chairs of INEKA, and leading experts and production workers are involved. Such specialists develop working programs of disciplines in courses which are provided by curricula of target preparation.

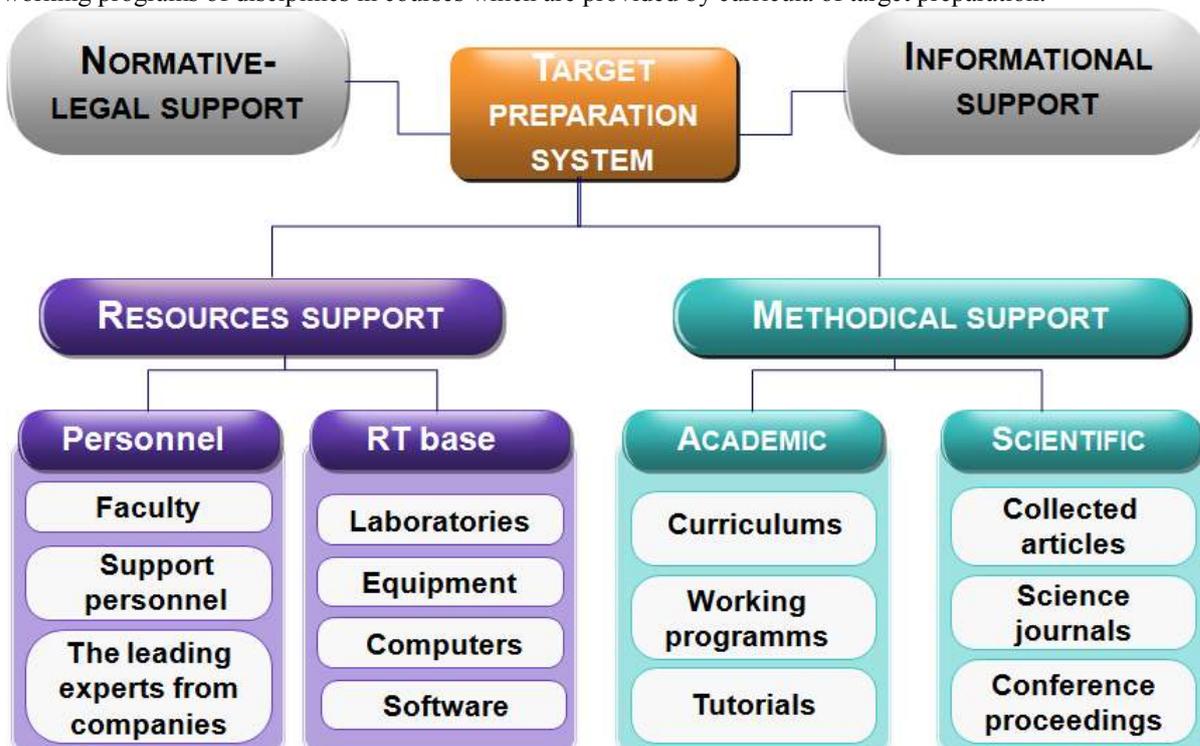


Fig. 1. The target preparation system support

IT-competence forming while training the specialists of automotive branch

The requirement for the experts that exploiting and serving the automotive technology, remains high. Expansion of a lineup and growth of cars modification number demands from experts in service high level of competencies, in particular these requirements are typical for the dealer-service network enterprises experts certificated under the standards of manufacturers. The requirement in engineering staff owning the modern methods of working out the design documentation and engineering analysis, and also in process engineers that are capable to work out innovative manufacturing technologies and renovation of products is still high.

The unique way in construction of effective system of professional training of the competitive expert – orientation of the educational institutions on requirements of a labor market and interaction with the customer. The competence-oriented formation, creation of a target preparation system – the singular way of employers requirements satisfaction in qualified personnel in the conditions of dynamically developing economy. The core is not that set of the information which graduate of educational institution has received and «has acquired», its ability to solve the supplied problems, using skills that they received.

For realizing the similar system of education it is necessary to use the innovative approach both to its construction, and to realization. Thus orientation to requirements of the employer and using of innovative technologies of education is the primary factor. In our opinion, it is possible, if at curricula of the expert preparation forming in a concrete direction maintain the principle of "consecutive accumulation of knowledge" and forming of competencies with the use of received skills.

In such a case the computer becomes the basic tool both for teacher and the trainee, and IT technologies becomes the technologies of work with the information in the course of training. As requirements of employers in our days assume knowledge of IT technologies, while training courses are constructing it is necessary to be guided by acquisition of skills by students of use of those software products and mathematical models which are used for the decision of the problems, similar themes which it will face in professional work, in our opinion. Competence of the specialist will be expressed in its ability to orient in all variety of the information, to choose

the necessary data, to analyze it and make relevant conclusions. At all stages of work with the information – gathering, processings, analysis –the software connected with specificity of branch and a concrete workplace is used.

IT technologies should become habitual toolkit for the decision of the problems connected with professional activity. In order to the student has been prepared for use of specialized software products while he is studying the special disciplines, he should possess a necessary minimum of knowledge and competences in the sphere of IT technologies. To ensure this it is offered to construct an educational program so that it met the requirements of tomorrow.

Considering the structure of informational competence, the majority of researchers consider that it assumes the ability to work with the computer technologies, to use modern software products, to involve means of information technologies for carrying out the mathematical calculations, processing the data of experiments, search of the necessary information, for business correspondence and communications, and also means rational activity in the field of development and use of the information technologies resources. Informational competence constitute, on the one hand, is a base (key), on the other hand, it is considered as an important component in structure of professional competence.

Base informational competence, being overprofessional, overobjective, includes uniform for all categories of users circle of questions in the field of base technical and computer facilities software, knowledge and experience in which the expert of any profile should possess. Informational competence as a component of the professional one includes a range of the specific questions corresponding to the level and the maintenance of computerization within the limits of the concrete professional environment, knowledge and experience in which the expert of the given profile should possess. Besides, it is supposed that the expert should be able to improve the knowledge and experience in professional and adjacent areas. Formation of the informational part of professional competence should be provided with a certain set of disciplines, educational situations and practices, simulating real professional tasks.

Informational competence as a component of professional competence of the automobile profile specialist is formed at studying of disciplines of a special cycle and inseparably connected with the subject-oriented information technology which is using to solve scientific research, design, industrial-technological and organizational-administrative problems. Thus, while studying the disciplines of a special cycle the orientation to a concrete kind of professional work is provided.

Realization of this principle in a practice assumes use of such bundled software which will be used by trainees in the conditions of real production. Thus, one of the INEKA automotive faculty's strategic targets is introduction in educational process of modern bundled software for scientific researches, visual designing and the engineering analysis. As the faculty has initially been organized for preparation of highly skilled engineering personnel for the automobile branch, its structure includes specialities which correlate practically with all stages of automotive engineering life cycle. While constructing the training courses for each speciality the proper program toolkit – from software of marketing researches and economic efficiency estimation to CALS-technologies for engineering analysis – is used at faculty (fig. 2).

Each specialist of automobile branch should be able to estimate efficiency of the enterprise activity and to predict demand for the product taking into account dynamics of market conditions. Thus, demands are made to graduates of our faculty on knowledge of bases of the automobile market segmentation, forecasting of demand for car sales, service and traffic volume, the competitive analysis, the analysis of efficiency of dealer-service networks. In this stage it is necessary to use the software which allows to carry out all above-stated kinds of the data analysis. For these purposes the KONSI software is used.

The main condition when preparing the automobile profile specialists is teaching to methods of visual designing and engineering analysis of automobile knots and units. Almost all of students of automobile profile specialities study bases of designing and calculation of automobile systems, calculations of dynamics and durability of products, methods of the engineering analysis and etc. The basic software product used in the field is Siemens NX, intended for development of mechanical and electromechanical systems of the car, engineering analysis of mechanical and electromechanical systems, etc.

The following class of software is used for designing and optimization both industrial systems, and service systems. On older courses students of automotive faculty design infrastructure and technological processes of the enterprises which produce the cars, facilitate service and transportations engaged. Modeling of real industrial systems allows not simply to teach bases of production and service systems functioning, but also to teach methods of optimization and management decision making in these systems (Karpov, Y.G., 2006).



Fig. 2. Use of modern information technology while preparing the automobile profile specialists

In the field of operation and service the software suites AnyLogic, Siemens Plant Simulation and Technomatix Jack are basic for studying. To solve practical problems of workplaces ergonomics definition at the automobile branch enterprises, comfortableness and ergonomics of a driver's place students study Siemens Technomatix Jack software. Siemens Plant Simulation allows to rapidly create realistic simulation models of dynamic warehousing and logistics operations, so it is an important part of learning process.

Such approach in a combination to development and adoption of training individual programs under contracts with employers and undergoing of industrial practices on places of the future industrial activity will allow to reduce terms of adaptation of the specialist on a concrete workplace, will raise its competence both in professional sphere, and in the field of high technologies that will provide its competitiveness on a labor market.

Results of application of the innovation approach to educational process

Considering sharp requirement for highly-skilled personnel for scientific and technical center (STC) and technological center (TC) of KAMAZ, JSC, since 2008 the preparation of specialists for the mentioned departments has been organized. Educational groups in demanded directions of preparation have been formed, curricula are made and coordinated, and working programs of disciplines are developed. Theoretical and practical training, carrying out of master classes by leading experts of STC and TC has been included in the training program. Students carried out course and degree projects on the themes coordinated with project manager - experts from the enterprise. Thus, in 2008 important in practice degree project connected with working out of methods of operational reliability of KAMAZ frames increase has been executed (fig. 3).

The students which training within target preparation, receive additional possibilities: use of the laboratory equipment, library fund of the technical literature, drawings, the technical, organizational-administrative and economic information of the enterprise-customer during all term of target preparation; participation in real scientific, technological, design workings outs while carrying out the course and degree projects and a possibility to begin work on them before the students trained under the usual program can do it, so far as they can get to know in advance the design object, learn it and collect and process a necessary material.

Level of progress of the students which are training within target preparation, as a rule, surpasses level of progress of the students trained under the usual program (fig. 4). It is connected with motivation growth to increase of professional competence and competitiveness, and also with works in real design groups over the decision of the assigned industrial problems. Leading experts of STC and TC are involved in degree designing

management, and also in working as a part of the State certification committee in the time of degree projects protection. A number of degree projects protection is spent directly at the enterprise.

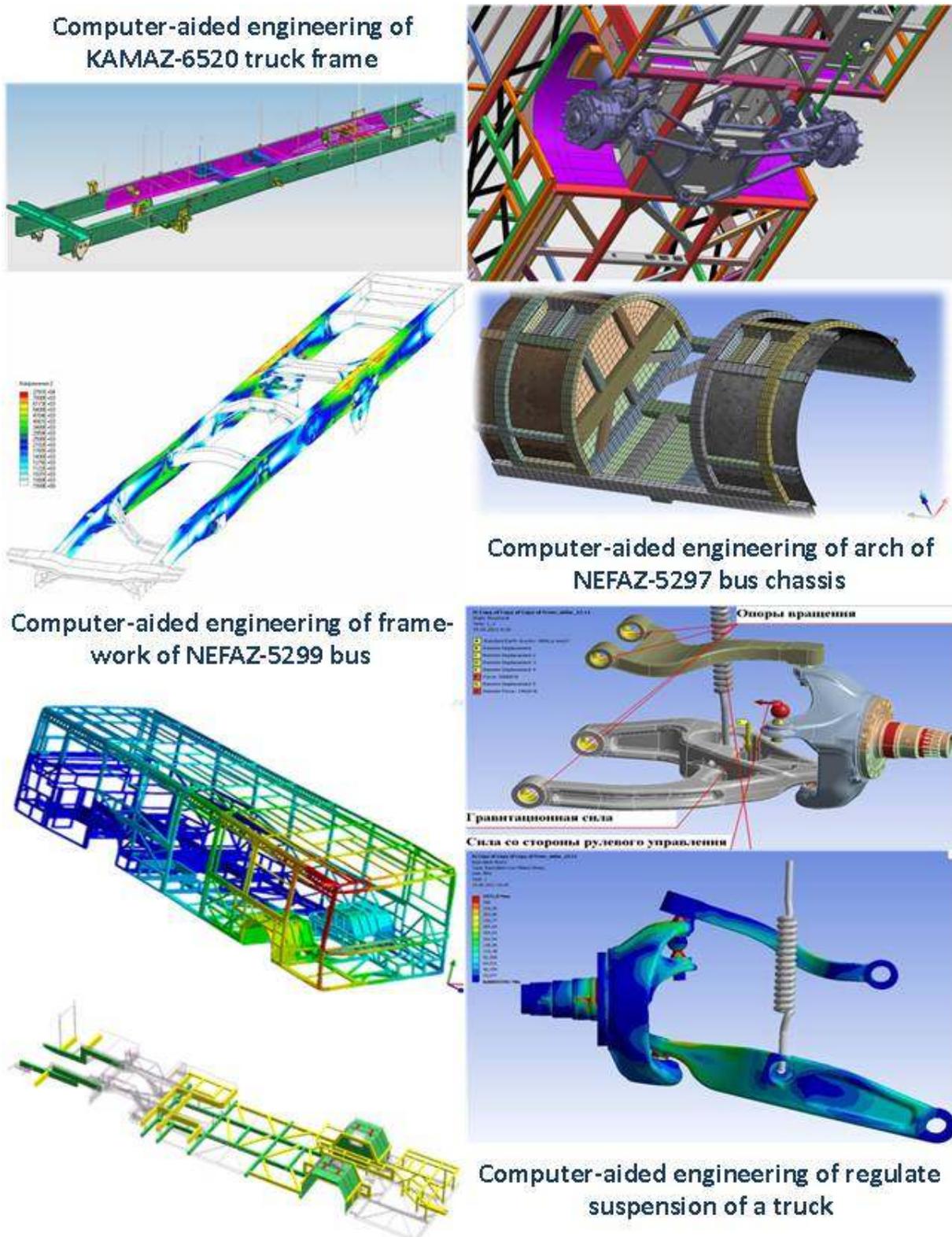


Fig. 3. Results of graduate project execution by the students which trained by the target preparation program with use of Siemens NX software

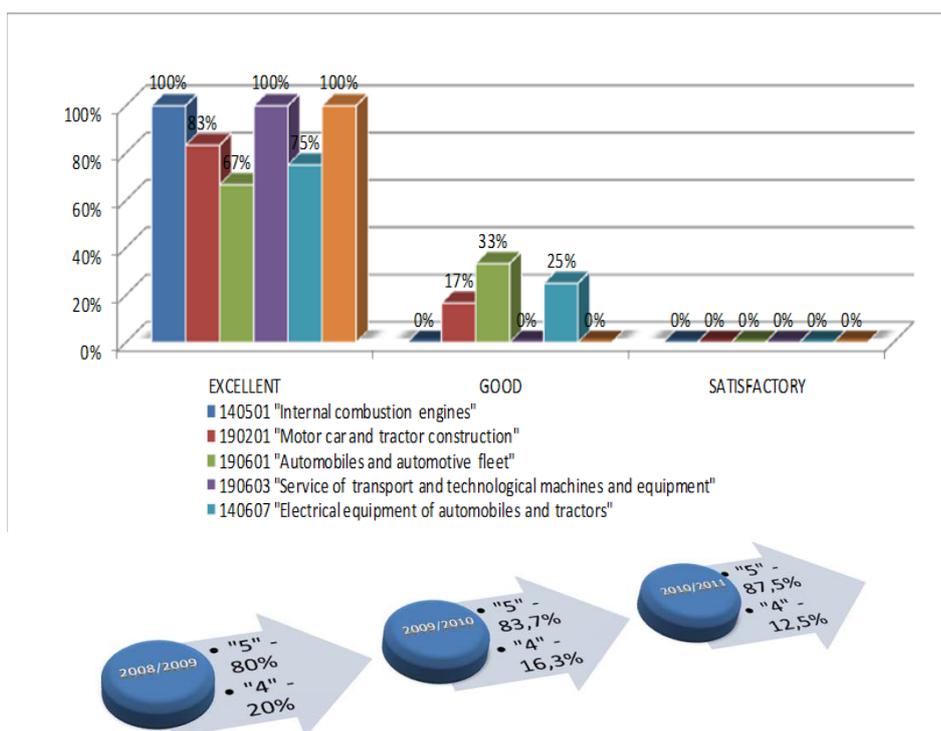


Рис. 4. Results of degree projects protection by students, having training within biennial target preparation (2008-2011 years)

Conclusion

Such organization of target preparation allows the enterprises to receive the competent specialists involved in production at a grade level that allows to consider own requirements to potential workers at training, and also to improve contents of the higher vocational training programs in conformity with changing requirements of innovative processes in technics and technology area.

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THE SELECTION OF THE ARCHITECTURE OF ELECTRONIC SERVICE CONSIDERING THE PROCESS FLOW

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Abstract: *The article discusses the basic steps of the electronic service design method using several languages, transformations between them and simulation. The inclusion of method which segments the process activity graph in these steps is evaluated. Merge requirements taking into account the process control flow are proposed to be implemented in the segmentation method so that could be used to solve problems concerning the selection of electronic service business process architecture. The solutions provided by this method can be interpreted as BPEL orchestrations, defining which activities could be implemented as web service calls. Using the proposed approach requirements can be defined in input data of segmentation method as well as during the execution of it. Possible solution of the implementation of requirements is also provided.*

Keywords: Quality driven attributes, Web services, Orchestration.

Introduction

E-services are common in information society nowadays, and even though they tend to become more and more accessible and varied, the problems that occur during the design phase of the service remain the same. These problems include, for example, questions on how to facilitate the creation of business process to the user with no specific programming skills, how to define the process in a way that creates the process description abstract but accurate enough at the same time, how to check the created model – to determine the weaknesses, perform the measurements based tuning, and others – for instance, designing the architecture of the process so that it conforms to various requirements. The design of architecture of the process may be influenced by multiple criteria – the requirements of performance, costs of development and maintenance, the reusability possibilities of the process or its parts and others. During the design phase of the process one should use an approach that allows the analysis of the process model designed and provides appropriate changes of the process structure, instead of modelling the process while trying to anticipate all possible requirements and restrictions – it would be easy enough with one criterion to comply with and almost impossible in case of five concurrent and conflicting criteria. Hence the prerequisite – the approach or methodology used during the design of the business process should allow to define various requirements and change the impact of these requirements on the process, thus providing effective way to model different process structures which implement the same functionality, but the possibility of the analysis and simulation of the business process model relies on the choice of the language used to describe the process.

Proposed approach

Existing business process modelling languages can be divided in two groups. The languages of the first group are favoured by the academic community, but rarely used in real-life solutions. These languages are based on Petri nets, process algebra; they have formal semantics, which allow the validation of the models described by these languages. The languages of the second group are used in real-life projects much more than in academic researches. BPEL, WSFL and WSCI are among these languages. These, so called business languages, often lack proper semantics, which could lead to debate on how to interpret the business models described by these languages. The availability of different implementations of these languages from different vendors does not facilitate the situation either, yet they are used much more, compared to seldom used models described by academic languages. If a situation arises when business process model described by business language needs to be validated using Petri nets, one must either abandon the validation or transform the process model to another model, described in academic language, for example YAWL. The authors propose reverse approach – first, a process is created using academic language. The design problems of the process model can then be solved by mathematical means. Second, the verified and updated model is transformed to model described in business language. The advantages of the approach described follows:

- If a model is created using academic language, it is more readable and maintainable than the model, which is a transformation result itself. It is also easier to perform analysis of untransformed model, because the transformation could lose some design information.
- Model, transformed to business language, is already validated and ready to be executed. Of course, the model must be double-checked to make sure if it needs any corrections. The alternatives of the

execution environment for the model are much more than the environments for academic languages; in addition to that, they have superior technical support.

The model of the business process can be changed and improved during the transition from one language to another – the approach proposed by authors consists of following phases (Fig. 1, dotted lines show that some phases may be omitted):

- The design of the business process using academic language;
- The validation and simulation of the business process model designed;
- Transformation of possibly improved model to primitive structure;
- The segmentation of primitive structure represented by graph using Quality Attributes Driven Web Services Design (QAD WS) method, developed by Zeiris (2009);
- The transformation of primitive structure (or its segmentation) to process using business language.

The purpose of this article is to examine the 4th phase of proposed approach – the usability of QAD WS method in this phase to generate multiple process structures corresponding to quality attributes given, and identify possible improvements of the method to ensure of its usefulness and efficiency during this phase.

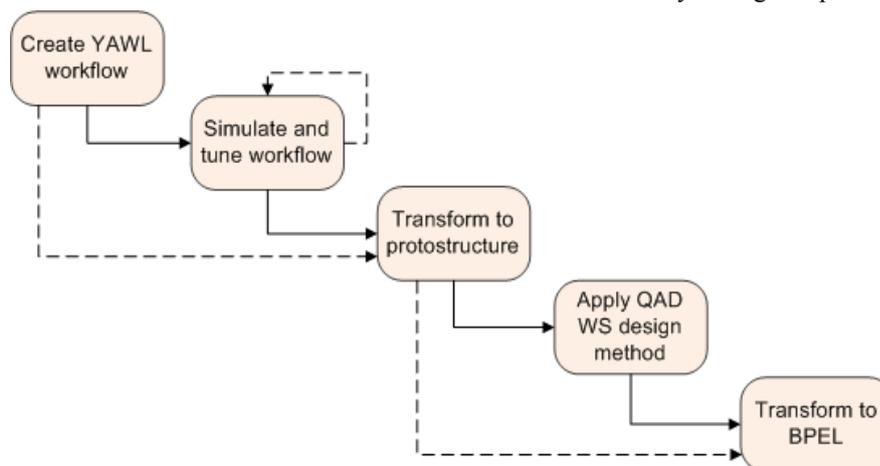


Fig. 1. The phases of proposed design approach

Similar approach is proposed by Pornudomthap and Vatanawood (2011): their solution is based on straightforward conversion of YAWL workflow to BPEL process. The approach proposed in this article allows transforming the workflow to any business process language and to simulate and optimize the process flow as well.

The first step is the design of the business process using academic language. The initial business process model is created during this phase. Designer should use only constructions supported by language chosen as a business language, i.e., avoid ‘goto’ workflow pattern if a business language selected is BPEL which does not support arbitrary loops. The workflow patterns supported by major business process languages are discussed by Havey (2005).

The second step consists of the simulation and tuning of business process model. Rozinat et al (2008) propose simulation which uses process design data, historical data about executed process instances from audit logs and state data of the running process instances from the execution environment. Data from all three sources are combined to create simulation model – design data are used to define the structure of the simulation model, historical data define simulation parameters, state data are used to initialize the simulation model.

Altering the simulation model allows to simulate different situations, for example, to omit certain activities or divert the process flow to other execution channels. Taking into account the state data of running process instances, it is possible to render the state of the system in near future and use the information to make decisions regarding the underlying business process.

The simulation of the workflow is carried out using process data mining framework ProM, proposed by van der Aalst et al. (2007). To create simulation model, following steps are performed:

- Workflow design, organizational and audit log data are imported from execution environment;
- According to imported data a new YAWL workflow model is created and state data are added;
- The new model is converted to Petri net;
- Resulting Petri net is exported to simulation execution environment CPN Tools as a colored Petri net – an approach proposed by Jensen et al (2007).

Stipravietis and Ziema (2011) have discussed the suitability of this simulation method to the process design approach in their work.

The third step provides the transformation to primitive structure. Primitive structure is simplified definition of business process control flow, although it can also be used to maintain the data flow. The primitive structure

serves as an intermediate between academic and business languages and can be used to create processes described by multiple languages, not only BPEL. The primitive structure may be changed and improved during this phase to facilitate the transition to target language, i.e., restructure its control flow in a way that it becomes well-formed and contains only patterns supported by BPEL. The creation of process primitive structure and its properties are discussed by Stipravietis and Ziema (2010).

The fourth step provides the segmentation of primitive structure using the Quality Attributes Driven Web Services Design (QAD WS) method which offers the segmentation of business process, represented as oriented graph. The segmentation result depends on process quality attributes selected by designer and their respective values. The result of this method is Pareto optimality set – the method returns the most suitable segmentations from all possible considering the quality attributes given.

The business language selected by authors and used in their proposed approach is BPEL, and using of QAD WS method on primitive structure would provide the possible structures of BPEL process – which parts of the process would belong to orchestration and which ones would be implemented as web service calls. Rosario et al (2006) also discuss the partitioning of Web services into orchestrations based on their QoS values, but their approach do not use multicriterial optimization – that approach is based on Petri nets and usage of statistical data.

The last phase of proposed approach is the transformation of primitive structure to business language process which results in the business process defined in business language. This process is not ready to be executed, but its structure corresponds to initial process model described by academic language and maintains its process flow. The transition from primitive structure to BPEL is proposed by Stipravietis and Ziema (2010).

The overview of QAD WS method

The QAD WS method perceives the business process as an oriented graph G , whose vertices corresponds to process activities, but edges between them represents the control flow. Using various quality attributes and the structure of graph G , QAD WS method solves multi-criteria optimization task, which results in the segmentation set of initial graph G : $G' = QAD(G)$. According to Zeiris and Ziema (2007), criteria used by the method are:

- Costs of development C ;
- Performance T ;
- Maintenance costs E ;
- Reusability R ;
- Integrity I .

The segmentation set G' consists of N most optimal solutions designer can choose from – in principle this method greatly reduces possible solutions of process architecture, thus aiding the designer.

The result of the 3rd phase of authors proposed approach is primitive structure – oriented graph P that corresponds to initial YAWL workflow, which could be used as an input graph G for QAD WS. Authors note that P is more complicated as G – in addition to process activities and links between them it also contains the process control flow.

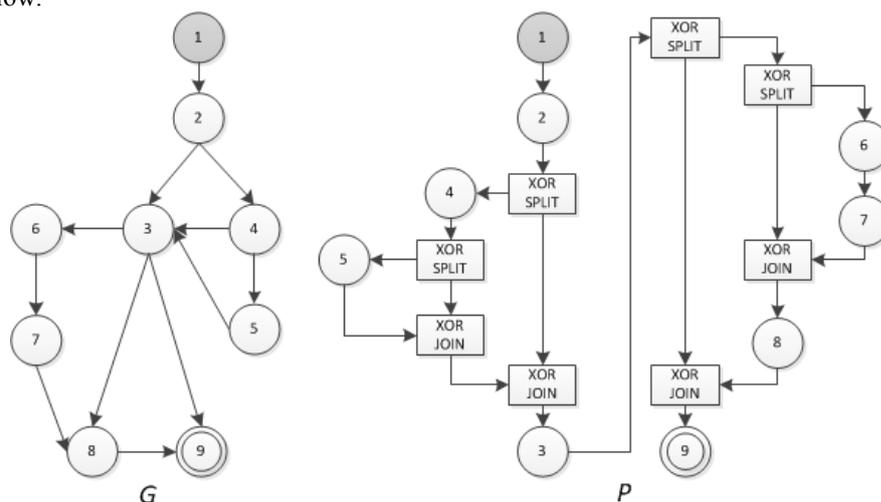


Fig. 2. Example – graphs G and P

Fig. 2 shows both graph G usable as QAD WS method input, and corresponding primitive structure graph P . Structure of both graphs are virtually identical, although P also contains control flow elements, in this case exclusive choices (XOR). Note that G does not define split types and therefore does not contain control flow information. Taking this into account, authors conclude that current implementation of QAD WS method provides results which does not preserve control flow logic of initial process.

This conclusion is confirmed by practical tests of QAD WS method – if one must find the segments of P taking into account only reusability, QAD WS method returns one solution, where all vertices of P form their own segment. In other words, QAD WS method propose that all activities must be implemented as web service calls, ignoring the fact that some activities does not perform any work but serve only as control flow providers. This solution is not only wrong but also illogical – how would one design a parallel flow in BPEL, if both start and end of it should be separate web service calls? The answer in this case should be either that entire parallel flow block is implemented as single web service call or that activities of each parallel branch are segmented at choice but the start and end belong to orchestration. The QAD WS method supports the concept of restriction, although current version provides only exclusive restrictions, i.e., activity A cannot be segmented with activity B. Hence the conclusion – in order to be properly used on selecting the process structure, the QAD WS method must support inclusive restrictions guaranteeing that start and end activities of some block N of graph P belong to one segment.

The improvements of QAD WS

Current implementation of QAD WS method processes both input and output data as graphs defined in XMI (XML Metadata Interchange). Restrictions (which vertices cannot appear in one segment) are defined during the method runtime. This approach allows changing dynamically the method parameters but cannot be used to define merging restrictions, and manual merge of control flow vertices can lead to erroneous results.

Authors propose to extend the restriction concept used in QAD WS. The restrictions are indices, describing segments – QAD WS should be able to merge vertices which have the same index. Let us define two types of restrictions – initialization and runtime restrictions. Initialization restrictions are defined in input data and are read-only during the method execution, but runtime restrictions are defined during the method execution and can be altered at will. Each type of restriction sets consists of merge restrictions and merge prohibitions:

$$I(G) = U_I(G) \cup J_I(G), W(G) = U_W(G) \cup J_W(G);$$

$I(G)$ – initialization restrictions, $W(G)$ – runtime restrictions, $U_x(G)$ – merge prohibitions, $J_x(G)$ – merge restrictions.

Both merge restrictions and prohibitions are mutually exclusive:

$$U_x(G) \cap J_x(G) = \emptyset$$

Initialization restrictions present in input graph G must be present in each segmented graph Γ :

$$\text{If } I(G) = U_I(G) \cup J_I(G), \text{ then } I(\Gamma) = U_I(\Gamma) \cup J_I(\Gamma) = I(G) \quad \forall \Gamma: \Gamma \in QAD(G)$$

Runtime restrictions cannot contradict with initialization restrictions, i.e., following condition must be true:

$$U_W(G) \cap J_I(G) = \emptyset \wedge J_W(G) \cap U_I(G) = \emptyset$$

If this condition is not true, QAD WS method must return empty result set.

Due to new restrictions, the upgraded QAD WS method must not yield results which contain overlapping segments.

Current implementation of QAD WS defines that no segment from result set has common vertices with other segments, i.e., if graph $\Gamma \in QAD(G)$ consists from segments S_1, S_2, \dots, S_n , then

$$S_i \cap S_j = \emptyset; S_i \in \Gamma, S_j \in \Gamma, i \neq j.$$

After the introduction of merge restrictions, the segments may contain one another but overlapping must still be avoided:

$$S_i \cap S_j = \emptyset \vee S_i \cap S_j = S_i \vee S_i \cap S_j = S_j; S_i \in \Gamma, S_j \in \Gamma, i \neq j$$

After defining the requirements for QAD WS improvements, authors propose a way to define them in input data. As mentioned before, QAD WS method receives, processes and returns data in XMI format. To define restrictions in XMI representation of graph, underlying XMI schema must be changed. A restriction is simply an index and is used as an attribute of vertex – to be able to define initialization restrictions, XMI schema fragment describing the vertex must contain optional attribute “Segment”. If this attribute is omitted, vertex can be merged in every possible segment (avoiding overlapping, of course). If this attribute has value, then all vertices with the same index value must be merged in the same segment.

The example below is a fragment from XMI formatted graph – it describes four vertices and their merge restrictions using the attribute “Segment”: Activity_1 and Activity_4 belongs to segment “1”, Activity_2 belongs to segment “2”, but Activity_3 has no restrictions – it can be merged both in segment “1” and segment “2”, as well as form its own segment.

```

<subvertex xmi:type="uml:State" xmi:id="Ub85d2fba-82dc-4761-9d8e - 9449884adfa6" xmi:uuid="b85d2fba-82dc-4761-9d8e - 9449884adfa6" name="Activity_1" Segment="1"/>
<subvertex xmi:type="uml:State" xmi:id="U4122a5e7-c725-4aa5-8486-e1ae5cc5c77b" xmi:uuid="4122a5e7-c725-4aa5-8486-e1ae5cc5c77b" name="Activity_2" Segment="2"/>
<subvertex xmi:type="uml:State" xmi:id="U8d7cf0ad-dc8a-4ddd-983b-c88b6aea44a4" xmi:uuid="8d7cf0ad-dc8a-4ddd-983b-c88b6aea44a4" name="Activity_3"/>
<subvertex xmi:type="uml:State" xmi:id="U5d900b52-cf99-4a84-bd5c-b66c927b2e9a" xmi:uuid="5d900b52-cf99-4a84-bd5c-b66c927b2e9a" name="Activity_4" Segment="1"/>

```

Presuming that activities are executed sequentially, QAD WS method offers three solutions of the example which conform to restriction requirements (Fig. 3).

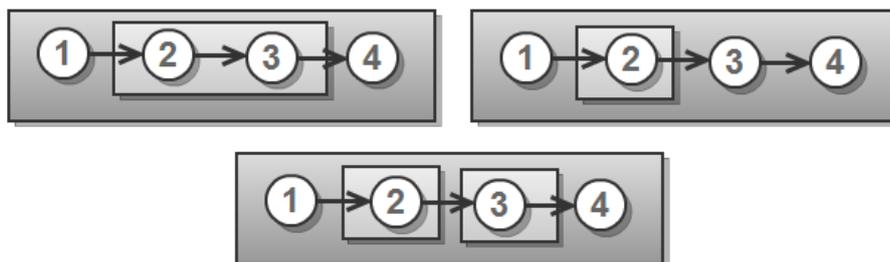


Fig. 3. QAD WS solutions of given example

Summary

During the design of electronic service systems one must take notice of various quality requirements of the implementation of the business process, for example, performance, reusability and others. The Quality Attributes Driven Web Services Design (QAD WS) method allows defining the impact of the said requirements. This method solves multi-criteria optimization task and offers Pareto optimality set. The authors have chosen this method as a part of their electronic services system design method and use it to prepare a business model for the transformation to the business language, in this case BPEL. The usage of BPEL lets the results of the QAD WS method be interpreted as different process orchestrations. Unfortunately the QAD WS method lacks the ability to preserve process control flow – this can lead to incorrect solutions.

Taking into account these shortcomings and improvements proposed, the authors set the tasks to improve the QAD WS method:

- Define XMI schema which allows to describe merge restrictions of a vertex;
- Implement the changes of the QAD WS method – it should be able to process and interpret the given initialization restrictions, i.e., from the process graph G and its initialization restriction set $I(G)$ it must produce the segmented graph $G' = T(G, I(G))$;
- During the processing of G' , following must be taken into account:
 - Runtime restrictions cannot contradict with initialization restrictions;
 - Partial overlapping of the segments is not acceptable;
 - The initialization restrictions must be preserved and be present in every resulting graph.

To select appropriate solution from the QAD WS Pareto optimality set, usually the non-automatic analysis methods are applied. Using various Web service selection approaches – the WS selection depending on data types used, as shown by Stipravietis and Zieme (2007) and the description of the process they implement, proposed by Stipravietis and Zieme (2008)– it is possible to further narrow down the solutions which must be processed manually.

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ICT IN EDUCATION

CURRICULA COMPARISON USING CONCEPT MAPS AND ONTOLOGIES

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Abstract: *Development of tools for automatic comparison of curricula is of special interest and importance in the context of creation of open and dynamic European educational area as they have potential to promote constructive and continuous improvement of study programmes of different educational institutions and their harmonization with requirements of the labor market and international trends in corresponding sectors of economy, which, in its turn, can raise quality of education in general and facilitate student mobility in particular. The authors of the paper have developed an approach that allows comparison of study programmes in automatic way by performing four steps: representation of curricula in the form of concept maps, transformation of the concept maps into ontologies, matching of the ontologies acquired, and visualization of comparison results. The paper presents the first two steps of the approach and discusses the main concepts (concept map and ontology), related works, a general structure of a concept map for a study programme, process for construction of a curriculum concept map, correspondence between elements of concept maps and entities of ontologies, as well as an algorithm for transformation of a concept map into an ontology. Illustrative figures are included in order to show the conceptual structure of concept maps for representation of curricula, a fragment of the created concept map, steps of the approach proposed, and an example of an ontology acquired. At the end of the paper, main activities of future work are specified paying attention to the last two steps of the approach: matching of ontologies and visualization of results.*

Keywords: concept map, ontology, curricula comparison.

Introduction

A number of changes in political, economical, social, and, particularly, educational sectors of the European Union (EU) have been fostered by several documents issued during the last fifteen years. However, the Lisbon Strategy (Lisbon, 2000) is one of the greatest impact because it has defined the further development course of the EU by stressing necessity to become the most competitive and dynamic knowledge-based economy in the world. In 2005, the Council of the EU emphasized that the Lisbon goals of competitiveness and economic growth can only be achieved if young people entering the labor market are properly equipped through qualitative education and training in line with the evolution of society (Council, 2005). Moreover, taking into account movement of the Europe towards open borders and free flow of labor force, it is worth to point out that easy adaptation of new specialists in different labor markets depends not only on the quality of curricula but also on wide opportunities for student mobility (Anohina and Grundspenkis, 2008). According to (Associates, 2001), student mobility and accompanying academic recognition are assumed to be necessary prerequisites for an open and dynamic European educational area that will aid European integration and labor market mobility. In such a context, in order to promote constructive and continuous improvements of study programmes of different educational institutions and to adjust them to requirements of the labor market and international trends in corresponding sectors, as well as to identify possibilities for student mobility it is necessary to harmonize curricula of universities across EU and to develop appropriate tools for comparison of study programmes. It is obvious that such tools must be based on some kind of curriculum mapping. The mapping process represents spatially the different components of the curriculum so that the whole picture and the relationships and connections between the parts are easily seen (Harden, 2001). Results of such comparison can be used in various ways, for example, for identification of possibilities for student mobility or lifelong education, creation of joint programmes, accreditation of new study programmes (interdisciplinary and based on best practices), etc.

The paper presents the first part of an approach intended for comparison of curricula on the basis of concept maps and ontologies. The approach proposed includes four main steps: construction of concept maps of curricula, transformation of the concept maps constructed into ontologies, matching of the ontologies acquired, and visualization of matching results. The paper is devoted to the first two mentioned steps. Concept maps allow visualization of the structure of a curriculum and facilitation of its perceiving by non-technical users, such as students looking for possibilities of mobility. Ontologies are used as an input for the matching tool which compares study programmes and displays results of comparison. The algorithm for transformation of concepts maps into ontologies is developed, as well.

The paper is organized as follows. First, definitions of main concepts used in the paper are given. After that, related works are considered and construction of a concept map for a study programme is described. Then, the approach to comparison of curricula is discussed specifying transformation of concept maps into ontologies. At the end of the paper conclusions and directions of future work are given.

Preliminaries

Concept mapping is a pedagogical tool developed by Novak in 1970s (Novak and Cañas, 2008) with the original aim to facilitate student learning by presenting key concepts in a knowledge domain and relations between them in a graphical way. Therefore, a concept map is a semi-formal knowledge representation tool visualized by a graph consisting of a finite, non-empty set of labeled nodes, which depict concepts, and a finite, non-empty set of arcs (directed or undirected), which express relations between pairs of concepts. Linking phrases can specify kinds of relations between concepts. A proposition - concept-relation-concept triple - is a semantic unit of concept maps. It is a meaningful statement about some object or event in a problem domain (Cañas, 2003). Regardless that initially concepts maps were developed for learning purposes, in this paper they are used for representation of a curriculum. That provides the following advantages:

- Concept maps offer a graphical illustration of a study programme and, therefore, facilitate perceiving of the structure of the curriculum which usually is given in textual or tabular format. This advantage is of great importance for non-technical users who are interested in comparison of study programmes, for example, students looking for possibilities of mobility or administration of an educational institution working on a joint study programme;
- The concept map of a curriculum can be easily developed because a study programme, as a rule, has the hierarchical structure of concepts with well-defined levels and the relation “part of” can be used as the main kind of relations between levels.

However, as it was mentioned before, concept maps offer only semi-formal representation, as their semantics is ill-defined and more formal notions are needed to provide fully automated processing of structures displaying curricula. Here it is necessary to note, that concepts maps are very similar to one of the formal knowledge representation schemes called ontologies (Graudina and Grundspenkis, 2008). It is easy enough to make transition from a concept map to an ontology (Graudina and Grundspenkis, 2011) and to use more advanced tools for analysis and matching. Nowadays, the term “ontology” is understood as a thesaurus and a taxonomy, as well as a more expressive knowledge representation schema with classes, their properties, individuals, and logical relations between them (Lassila and McGuinness, 2001). Ontologies have some structural similarity to concept maps, despite the fact that the ontology structure is much more expressive and more complex (Graudina, 2008; Graudina and Grundspenkis, 2008; Graudina and Grundspenkis, 2011). In the context of the paper, “ontology” is a knowledge representation schema formalized in OWL language (<http://www.w3.org/TR/owl-features/>).

Related works

Nowadays, concept maps are used not only for learning. A number of other application areas have been already explored, inter alia curriculum planning and organization. According to (Novak and Cañas, 2008), in curriculum planning, it is necessary to construct a global “macro map” showing the major ideas planned to present in a whole course, or in a whole curriculum, and also more specific “micro maps” to show knowledge structure for a very specific segment of the instructional program. In this direction, there are research studies concerning not only structuring of curriculum, but also analyzing relationships between subjects and competences (Riesco et al., 2008) and alignment of local curriculum with state standards (Heinze-Fry and Ludwig, 2006). However, comparison of study programmes on the basis of concept maps seems a quite new field, because no corresponding publications were found.

Traditionally, in the context of curricula, ontologies have been used for categorization of competences (Laborde et al., 2008), categorization and description of knowledge used in different study programmes (Chin et al., 2007; Cassel et al., 2008), construction of a study course and learning path, for example, (Kontopoulos et al., 2008; Chi, 2009). Despite this quite wide use of ontologies in area of curriculum and number of research in the field of ontology comparison, matching, and alignment (Ehrig, 2007; Euzenat and Shvaiko, 2007; Lin and Sandkuhl, 2008), there is no evidence that ontologies have been applied for comparison of study programmes. Moreover, taking into account progress in development of advanced ontology matching tools, transformation of concept maps (which do not have such tools, but provide intuitive visualization of a problem domain) into ontologies, is important in order to use ontology matching tools and methods for matching concept maps. Therefore, combination of ontology and concept map similarity (Graudina and Grundspenkis, 2008; Graudina and Grundspenkis, 2011) and already existing number of studies in ontology comparison makes background for research in this paper.

Concept maps and representation of curricula

Due to hierarchical nature of the structure of study programmes, a concept map of a curriculum can be divided into several levels:

- 1st - General level. It can consist at least of four main nodes. Three of them represent name of the educational institution, the name of the structural unit implementing the study programme, and the title of the study programme, accordingly. The last one labeled “Study programme” serves as a starting point

for comparison process of two study programmes. Moreover, it is possible to add more nodes representing educational institutions or structural units if the study programme is joint by its nature;

- 2nd - Level of study years presents duration of the study programme in terms of particular study years;
- 3rd - Level of semesters displays incorporation of particular semesters into study years;
- 4th - Level of major field. Sometimes study programmes, after mastering of some general courses, allow students to choose a particular major field, for example, software design, computer networks, and so on. Each major field typically includes different study courses;
- 5th - Level of course groups presents grouping of courses on the basis of students' freedom degree to choose them for studying. Examples of groups are compulsory courses, free electives, restricted electives, and so on;
- 6th - Level of course titles displays particular courses included in the study programme;
- 7th - Level of course topics presents specific topics forming a particular study course;
- 8th - Level of concept maps of particular topics.

The described structure of a concept map for a study programme is shown in Fig. 1. Here, the macro map is provided by levels starting from the general level and finishing with the level of course topics. In their turn, concept maps of particular topics represent micro maps.

It is necessary to note that for presentation of a specific study programme some levels can be omitted if the description of the study programme is not complete or some concepts are not applicable to the study programme at all, for example, major field. In order to be able to perform comparison of study programmes at least at a shallow level, three levels must be presented: general level, study years, and course titles.

The main linking phrase for relations between nodes at different levels is "part of" representing integration of particular parts into a whole: topics into courses, courses into groups of courses, groups of courses into major field and so on until inclusion of study years into the whole study programme. Unique linking phrases are "title" on the relation between the node "Study programme" and the node displaying the title of the study programme and "is implemented by" between "Study programme" and "Unit". At the levels of course titles and topics, the linking phrase "is a prerequisite" can be added to relations in order to show that one course/topic must be learnt before the other one or, in other words, knowledge from one course/topic are essential for understanding of another course/topic. The linking phrase "one of" can be used between levels of course groups and course titles if it is necessary to indicate that students can study only one course from a specific course group. At the eighth level, relations between nodes can be presented by any linking phrases because concepts of particular topics can be related in a variety of ways using not only standard linking phrases such as "is a", "part of", "has a value", but also any linguistic phrases.

Fig. 2 presents a fragment of a concept map developed for the study programme "Computer Systems" offered at Riga Technical University for students of the Faculty of Computer Science and Information Technology. Three levels are omitted in the concept map: major field, course topics, and topic concept maps.

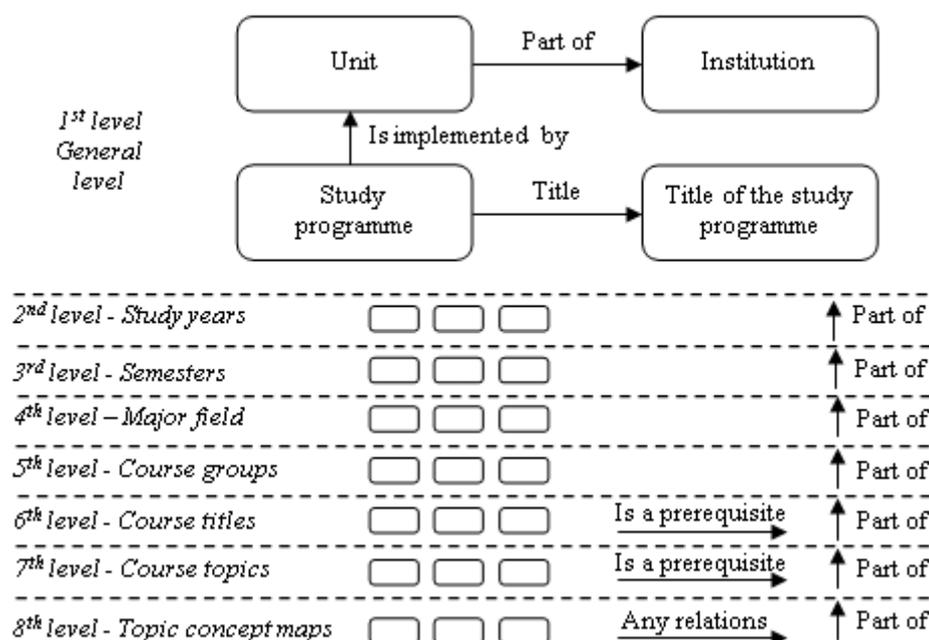


Fig. 1. Structure of a concept map for a study programme.

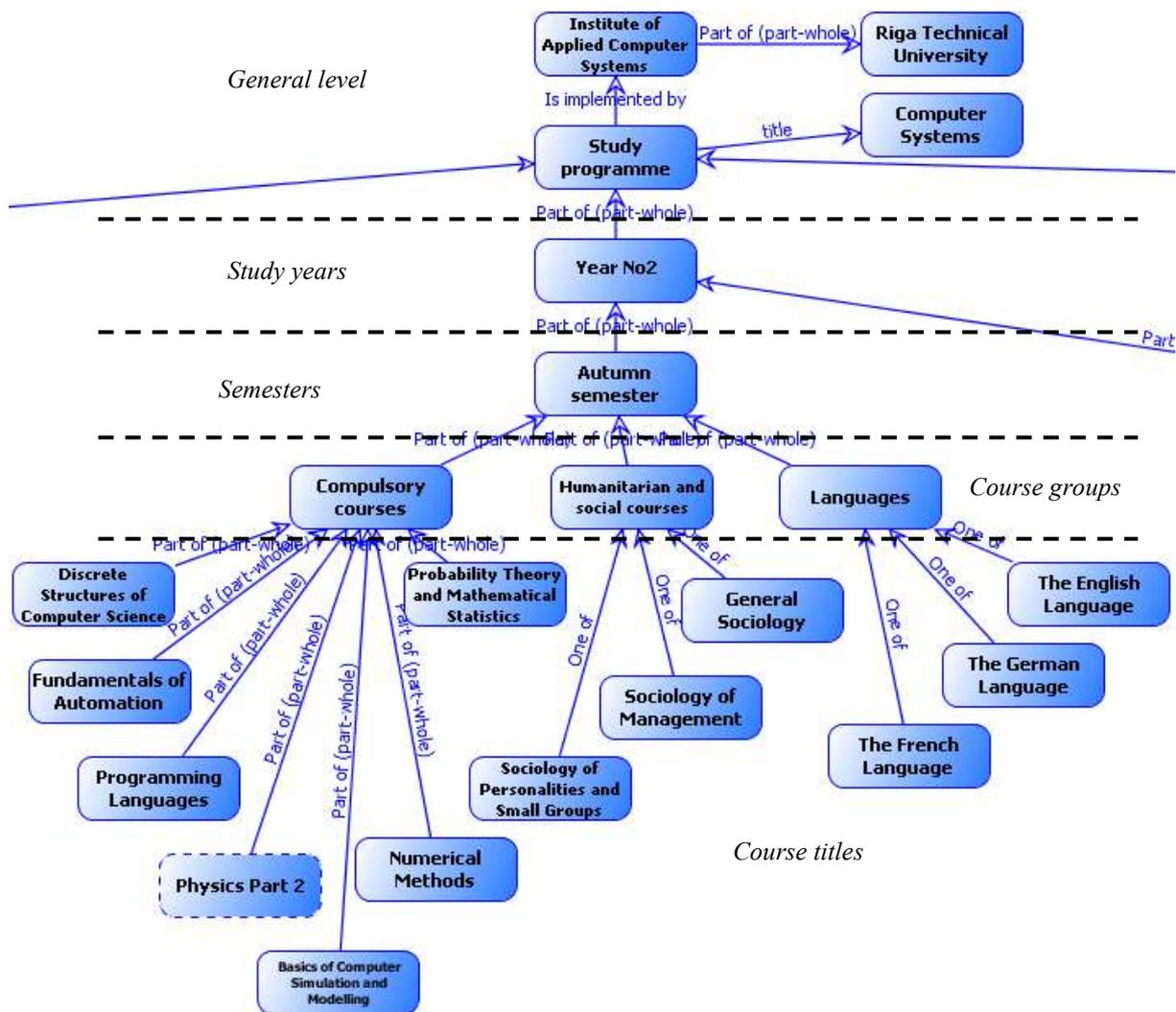


Fig. 2. A fragment of the concept map for the study programme “Computer Systems”.

In order to create a concept map for a study programme, the following steps must be realized:

- Acquire the description of a study programme;
- Identify the previously mentioned levels of the study programme;
- Start creation of the concept map with the general level incrementally adding nodes and relating them by relations with the linking phrase “part of” and going to the level of course topics;
- Identify “is a prerequisite” relations (if any);
- Create and add concept maps of topics.

Overview of the approach

Fig. 3 displays the overall approach proposed for comparison of study programmes on the basis of concept maps and ontologies. First of all, using the acquired descriptions of study programmes, concept maps are constructed. Secondly, the concept maps are transformed into ontologies. After that, comparison or, in other words, matching between the ontologies of the study programmes is performed and its results are visualized.

At the moment, the IKAS system (Anohina-Naumeica et al., 2011) is used for creation and transformation of concepts maps. In general, the mentioned system is intended for students’ knowledge assessment, but it can be used for other purposes, as well, for example, for creation of concept maps and their translation into XML format and/or ontology. The system provides icon- and drag-and-drop based graphical interface for creation of concept maps. For matching of ontologies, some ontology/schema matching tool must be used. The tool must satisfy the following minimal requirements:

- to accept ontology/schema inputs in XML or OWL format;
- to be able to discover mappings between ontologies;
- to provide visual representation of matching results for identification of related study programmes or making recommendations, for example, to a student, who is looking for possibilities of mobility.

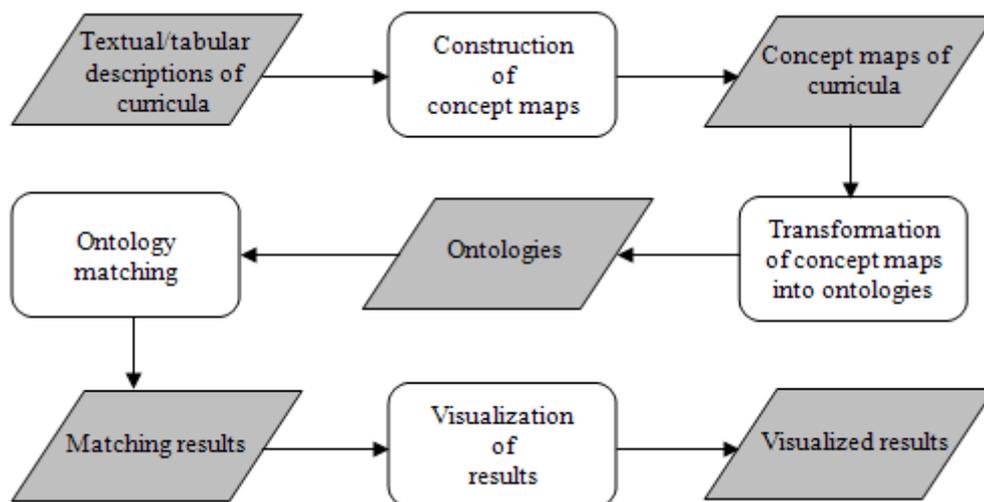


Fig. 3. The approach for comparison of study programmes.

Transformation of concept maps into ontologies

Correspondence between elements of the concept map and main elements/entities of OWL ontology is shown in Fig. 4. A concept in a concept map can correspond to a class, an instance, a datatype property and its value in the OWL ontology depending on a linking phrase which specifies a relation between two concepts. The linguistic and “part of” linking phrases agree to the object property in the ontology.

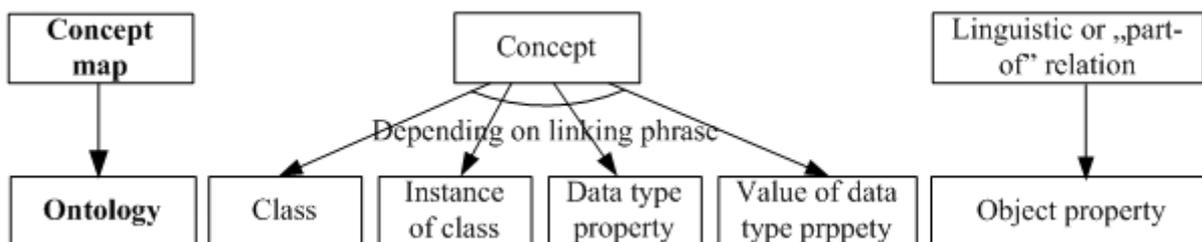


Fig. 4. Correspondence between elements of a concept map and entities of an ontology (Graudina and Grundspenkis, 2011).

The algorithm for transformation of a concept map into an ontology consists of seven steps (Graudina and Grundspenkis, 2011) during which all elements of the concept map are handled to determine their correspondence to ontology elements. In result, the appropriate ontology is constructed. The first six steps analyse linking phrases included in the concept map. As a result, types of related concepts are determined and according to them elements are added to the ontology. Step 7 finds synonyms for elements of the concept map because they are not defined directly with relations but are shown as additional information of concepts or linking phrases. The steps of the algorithm are the following:

- Step 1: Find all concepts related with hierarchic relations, where two classes are related with linking phrases “is a”, “is a subclass”, “is a subset”, “one of”;
- Step 2: Find all concepts related with instance relations, where a class is related to an instance with linking phrases “is an instance of”, “is an example of”;
- Step 3: Find all concepts related with property relations, where a class or an instance is related to a property with linking phrases “is characterised by”, “has a property”;
- Step 4: Find all concepts related with value relations, where a property is related to its value with the linking phrase “has a value”;
- Step 5: Find all concepts related with complement relations, where two classes are related with the linking phrase “not”;
- Step 6: Find all concepts related with “part of” or linguistic relations, where two classes are related with the linking phrase “part of” or any other linking phrase defined by a user;
- Step 7: Find all synonyms defined for concepts and linking phrases.

According to the determined pair of concepts in each step, appropriate OWL code is written (Graudina and Grundspenkis, 2011), for example, to define a relation between a concept and its property the following OWL code is used:

```

<owl:DatatypeProperty rdf:about="Property_name">
  <rdfs:domain rdf:resource="Concept_name"/>

```

```
</owl:DatatypeProperty>
```

In Fig. 5 a fragment of the concept map for the study programme and its corresponding ontology is shown where on the right side of the concept map the code for all “part of”, “is implemented by”, and “title” relations is given and on the left side definitions of ontology classes and hierarchy are provided.

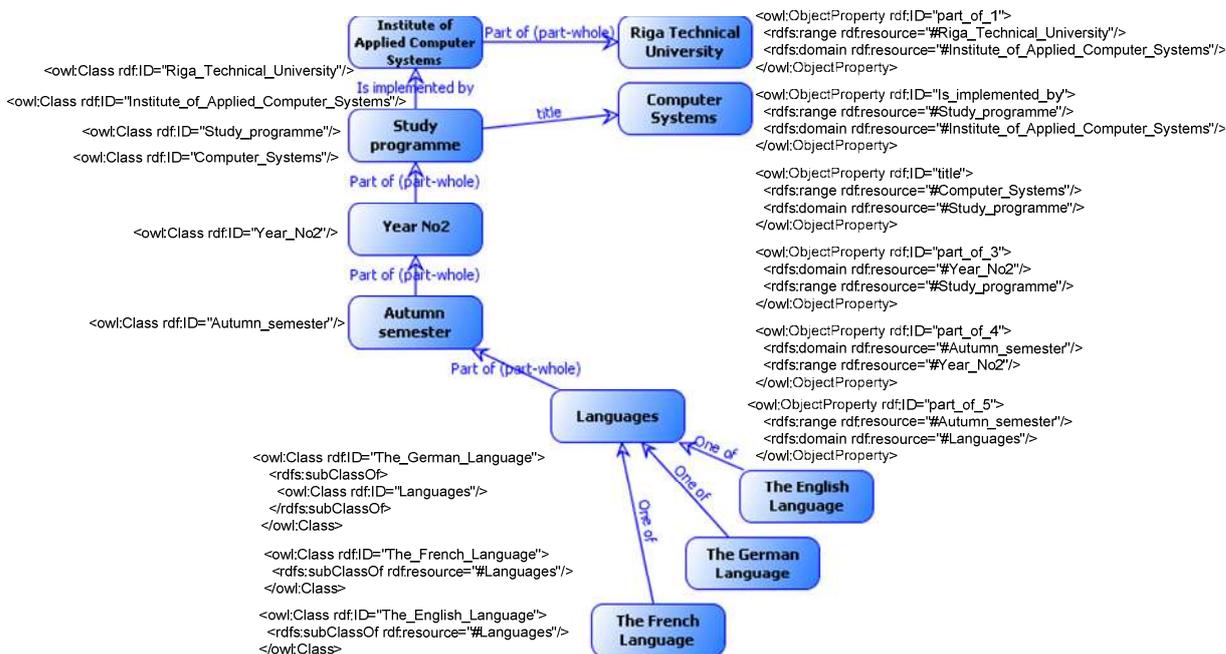


Fig. 5. A fragment of the concept map for the study programme and the corresponding ontology.

Before adding linguistic and “part of” linking phrases to ontology, pre-processing of them should be done. It is related to the fact that, on the one hand, there are no formal restrictions for usage of these relations in concept maps and, on the other hand, the same object property cannot link two pairs of different classes in the ontology. To handle such situations, indices are added to phrases. Situations when indices should be added are described below:

- Part-whole relations should be extended with indices which are equal to the number of the level of the structure of the study programme (see numbers of levels in Fig. 1). For example, for the relation at the first level the proposition will be like this “Institute of Applied Computer Systems – Part of₁ – Riga Technical University”. An exception is the eighth level which contains several concept maps for different topics, therefore there linking phrases should have not only the index coming from the number of the level but also the index of the use in the particular concept map, for instance, “part of_{8_3}” means that the linking phrase “part of” is used at eighth level in the third concept map;
- Relations with the phrases “is a prerequisite” also are double indexed: the first index denotes the level and the second one - each unique pair of related concepts;
- Also all other linguistic relations should be indexed if the same phrase relates different concepts and the source and the target of the relation is different.

Matchers used in ontology matching should be set up in such a way that they can identify that “part of₁” is different from “part of₂” despite very close syntactic similarity, because these linking phrases belong to two different levels of the concept map for a study programme.

Conclusions and future work

The paper focuses on the first two steps of the approach for automatic comparison of study programmes: representation of curricula in the form of concept maps and their transformation into ontologies. Concept maps are chosen as the main instrument for visualization of the structure of a curriculum as they consist only of labelled nodes and relations and facilitate perceiving of the structure of the curriculum for non-technical users who are interested in comparison of study programmes. Due to the fact that concept maps are semi-formal knowledge representation with ill-defined semantics and they do not have advanced tools for their comparison, ontologies are used as a main formalism for automatic processing of curricula.

At the moment, the mentioned steps are supported by the IKAS system allowing construction and transformation of concepts maps. However, the approach assumes the use of some matching tool for comparison of ontologies acquired from concept maps and providing possibilities for visualization of comparison results. Therefore, future activities include:

- Creation of a corpus of study programmes offered at different educational institutions across EU;

- Running an experiment on the created corpus of study programmes with aim to check feasibility and applicability of the approach proposed. For this purpose, an ontology matching tool must be used. At the moment, cooperation with researchers from LIRMM-Université Montpellier 2 and use of their tool WebSmatch is considered;
- Analysis of results acquired during the experiment.

In far future, possibility to use some existing categorizations at the level of topics, for example, the one from ACM for the curricula in computer science could be examined.

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DEVELOPMENT OF IMPROVED VERSION OF CORRESPONDENCE PROGRAMMING SCHOOL IN MOODLE

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Abstract: *The paper describes the existing training system NPS (Correspondence Programming school). Future needs of NPS are described in details, and analysis of them has also been made. Characteristics of user profiles and audience are defined (what students need to successfully use NPS), and teaching principles, along with registration options are described and analysed. NPS analysis and development of the transition to the new improved environment, and Moodle Training System Analysis and Integration are the main tasks of the research. In Master's thesis the research and analysis of Moodle features and facilities are made, and course improvement developed. New possible teaching tools have been researched (Virtual Programming). Specific attention was paid to the assessment of chart design, description of procedures, and various problems and weaknesses were analysed.*

Key words: NPS, Moodle, Training system.

Introduction

Distance education (Honeyman, 1993) dates to at least as early as 18th century when teachers were seeking students for lessons to be sent weekly. Usually an advertisement in a paper was used for that purpose.

Modern distance education initially relied on the development of postal services in the 19th century and has been practised at least since Isaac Pitman taught shorthand in Great Britain via correspondence in the 1840s (Greg Kearsley, 2005). The University of London claims to be the first university to offer distance learning degrees, establishing its External Programme in 1858. This program is now known as the University of London International Programmes and includes Postgraduate, Undergraduate and Diploma degrees created by colleges such as the London School of Economics, Royal Holloway and Goldsmiths.

In 1960-1970s United States universities started promoting methods other than the postal service to deliver distance education in America, which initially relied on radio and television broadcasts for much of its delivery. Shortly after, Europe followed United States example and there are now many similar institutions around the world, often with the name *Open University*.

The development of personal computers and the internet have made distance learning distribution easier and faster and have given rise to the 'virtual university, the entire educational offerings of which are conducted online. In 1996 Jones International University was launched and claims to be the first fully online (Larry Gold, 1999) university accredited by a regional accrediting association in the US.

Nowadays, there are many private and public, non-profit and for-profit institutions worldwide offering distance education courses from the most basic instruction through to the highest levels of degree and doctoral programs. Levels of accreditation vary: some of the institutions receive little outside oversight, and some may be fraudulent diploma mills.

In Latvia there are some institutions offering online tuition courses. Most of them are public and non-profit and usually were implemented to improve and ease current student studies or prepare future LLU students.

LLU NPS was available for many years and was recently converted and its improved version realised in Moodle.

Materials and methods

The whole idea of making NPS (*Correspondence Programming school*) was to provide free programming courses (C, Web programming, etc) mostly for high school students (basically to provide some basic programming education and to promote Latvian University of Agriculture), teachers (for skill improvement), but basically for anyone, including unemployed and elderly people.

NPS (*Correspondence Programming school*) is information technology toolset of procedures to help to ensure the information access for LLU workers and students any time and in any place with Internet connection.

NPS (*Correspondence Programming school*) basics can be described as following:

Administrator	User with rights to edit and update other users. Also controls user actions and system usage.
User	Identified person with rights to see, edit and update NPS information
User role	User rights, which allow users to be able to make different actions.
Learning tools	Learning tool files in standard formats.

Tests	Tests for students to check or to assess their knowledge, which are made according to SCORM, IMS and LRM standards.
Self tests	Tests for students to check or to assess their knowledge.
System	E-learning system
Right	Unique action allowed to users.

Registration in NPS consisted of three main parts: start phase (part where students registered themselves and filled in a form with information). Second phase is all about information storing in database for further access (information comes from forms that students filled in). In third phase administrator activates available courses to each of registered students. All participants were able to see courses they have registered to. After successfully completing the course, students were unregistered from it and lectures were no longer available.

Moodle is actually an acronym which stands for Modular Object-Oriented Dynamic Learning Environment (R.R.Danielson, 2008). It was developed by Martin Dougiamas. Moodle is at least a second-generation course management system, and includes a large number of features or so-called modules:

Overall design features:

- Based on a social constructionist learning pedagogy
- Offers a personal homepage listing all courses in which the learner is enrolled
- Based on the LAMP environment (Linux, Apache server, Mysql, Php)
- Assignment module:
 - due date, maximum grade, uploading feature, instructor feedback per assignment
- Chat module:
 - Synchronous communication, inclusion of profile pictures, attached URL's, images, etc.
- Choice module:
 - quick survey module allowing for class polls and student review of poll results
- Forum module:
 - many different types, subscription possible so that new posts are automatically forwarded via email, peer evaluation of student postings
- Journal module:
 - private instructor/student communication on course-related issues
- Quiz module:
 - instantly graded online quizzes
 - multiple choice, true/false, matching, random questions, numerical questions
- Resource module:
 - display of many different types of electronic content
- Survey module:
 - built-in surveys (COLLES, ATLAS)
 - student feedback of class data
- Workshop module:
 - online submission of workshop (example: lab) data
 - peer evaluation and evaluation of student's own grading reliability

Latvian University of Agriculture NPS is currently using Moodle features for e-learning purposes. The scheme (fig.1) displays current registration taking place in NPS improved version in Moodle. It consists of four major steps and three main actors (Student, NPS clerk and Administrator). At step 1 NPS clerk manages plan of studies for upcoming semester, usually before September 1st. In the meantime, all students who wish to participate in NPS e-learning systems register themselves by filling in a specific form (Word files). That is step two. In step three clerk manually registers *every* student in LLU LAIS learning system, according to plan of studies. In one hour, administrator receives list of students and activates their courses according to specific course code.

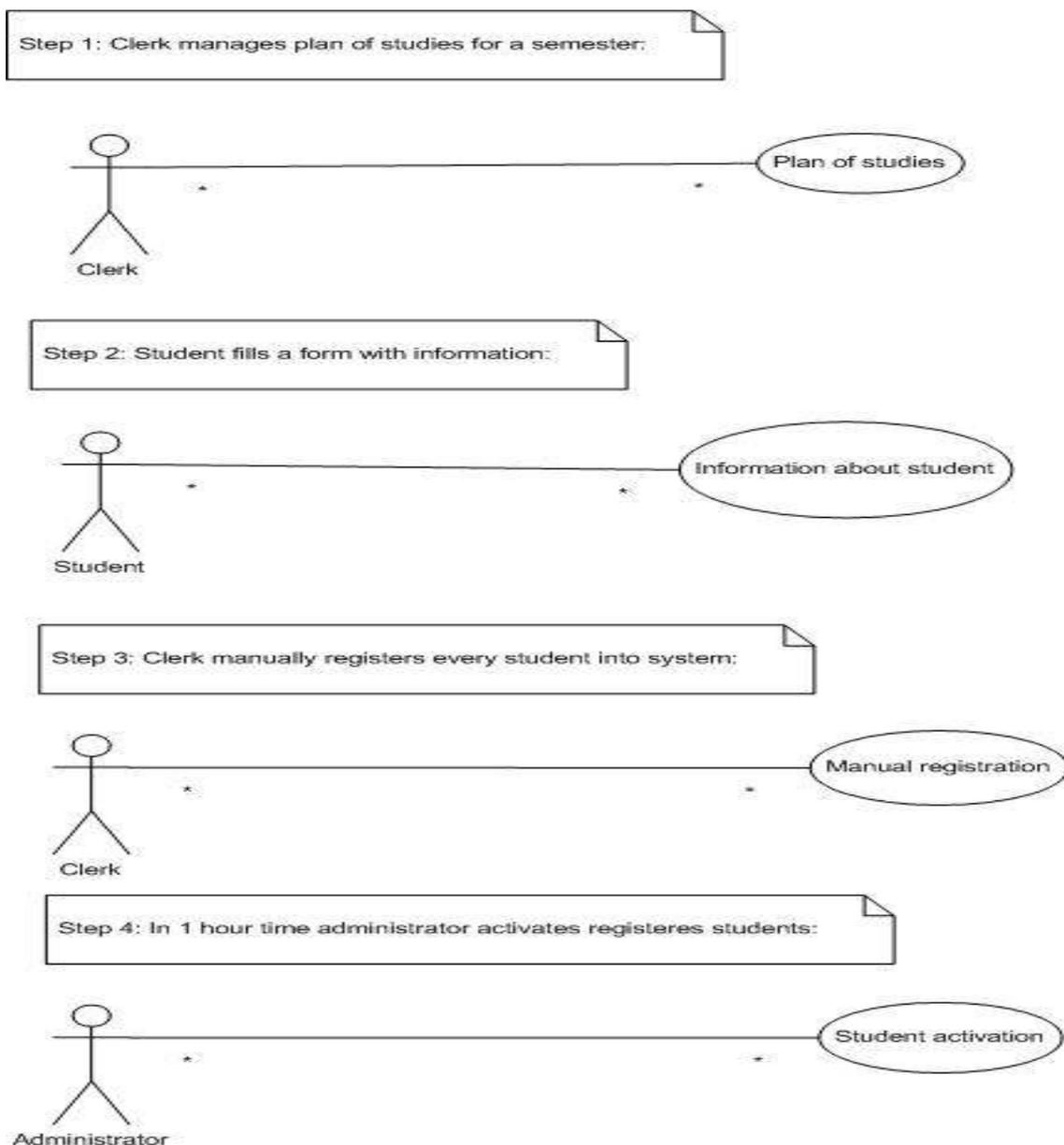


Fig. 1. NPS registration (Rozamascevs 2012)

Results and discussion

In current NPS system definite modules are used:

- Assignment module:
 - due date, maximum grade, uploading feature, instructor feedback per assignment
- Chat module:
 - Synchronous communication, inclusion of profile pictures, attached URL's, images, etc.
- Choice module:
 - quick survey module allowing for class polls and student review of poll results

Students download lectures and other materials uploaded by a teacher from a system. Those are mainly MS WORD files with theoretical part, examples and practical part (some exercises). Students' task is to complete those exercises, put them into one file and upload it back into system until a certain date.

Differences between Moodle system and previous NPS version:

- Students could not upload files with similar names, but they also could not see each other files.
- Communication between students and teachers was possible only through announcements and e-mails.
- Mark system was difficult.

The design of the WebVPL system (Alvin Chan, 2004), a *Webbased Virtual Programming Lab* for on-line distance learning was also described. The underlying setting is a collection of Lab server computers hosting

education and programming software. Students use personal computers at home to access over the Internet one of the Lab servers, which performs functions to accommodate various requests from the student such as software usage. The lab servers can be located in different buildings and even at different campuses.

WebVPL facilitates resource sharing among different schools and overcomes the limit of geographical distances. The design of the WebVPL system includes the user interface, agent-based client side functions, the structuring of Lab servers, the mechanisms to locate user requested software packages / services and to present various forms of data and information, and the interfaces to various education and programming software packages. Various implementation issues are analyzed.

Conclusions

NPS e-learning system was analyzed and administrating problems described along with registration features. Development of improved version of Correspondence programming school in Moodle was complete. Current NPS learning system features and registration aspects were described. Different Moodle modules for studying were researched and analyzed. Improvements were made in current Moodle data flow control and in data security administration.

Additional possible teaching tools were researched and analyzed (Virtual Programming). Also comparison was made between previous LLU e-learning system and improved Moodle version. Specific attention was paid to e-learning system weaknesses.

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E-ENVIRONMENT – ASSISTANT FOR PROFOUND KNOWLEDGE ACQUISITION

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Abstract: *The development and economic growth of any country depend on the level of its inhabitants' education and competences. It should be achieved that the skills and knowledge of the youth are developed from early childhood. Unfortunately, despite the new and improved study programmes the level of knowledge in schools of different levels does not only increase but even gets worse.*

One of the reasons is the huge amount of information which the youth has to acquire intensively as the result of which the memory is overloaded and is not continuous and stable.

There are several possibilities to change the situation and interest applicants to use the information; one of the possibilities is to create additional option for students to use e-environment during studies.

In the article there are analysed the test results of the secondary school leavers- new students in the study subject without comprehensive knowledge of which there cannot be imaginable either economists, or engineers, or specialists of many other fields, that is mathematics. There are analysed in Latvia non-published data from project SIBIS that characterize the situation in e-education in two directions: international internet lines as assistant in educational process and the use of electronic learning materials. While evaluating the survey results as well as the situation in Latvia there are sought solutions for this problem.

Key words: mathematics, studies, e-environment, pupils and students, e-materials, internet resources.

Introduction

Despite the guidelines for teaching mathematics in secondary schools and even in elementary schools are unitary, the teaching process is allowed to have certain deviations which most of the teachers also use. As the result, for example, during the teaching mathematics in form 3 there are taught separate elements of geometry of form 7 and 8 and even physics. Similar situation is also in other age groups thus the learning process of the schoolchildren is significantly enlarged and becomes complicated, but taking into account this huge amount of acquired information, the basic elements are mastered superficially that in its turn influences the quality of perception of the further learning process.

Using the resources of EU structure funds, groups of specialists after some period create new study programs with the best purpose to learn new subjects, but the results get worse from year to year due to both: the programs and the other adjacent conditions. In order to normalize the situation and the universities to get better and better prepared future students it is necessary to investigate carefully the changes in knowledge quality in the course of time, together with the general view of evaluated level of knowledge.

To accomplish this when starting the studies the 1st-year students in engineering sciences and social sciences for several years have been given the test in mathematics to test the basic knowledge. In the paper there is accomplished the research of the results and comparative analysis as well as searched for the possible solutions of the problems.

e-Environment is an integral part of the solutions.

The end of the 20th and the beginning of the 21st centuries is marked by new organizational form of the development of the society, i.e. information society. The main driving force of this society in all fields of activities becomes knowledge which is included into the range of economic values alongside with capital, technologies and man power. The man as the carrier and preserver of information and knowledge becomes the main factor of economic growth and creation of values (Bikse, 2000)

In modern education due to the influence of fast technology development and process of globalization there take place different changes, including changes based on information communication technologies (ICT) in its turn which includes the creation of self supporting learning and teaching environment. Taking into account the youth's interest in the latest technologies and their wide application and possibilities, one of the solutions for expanding the applicants' knowledge and viewpoint is the use of materials in e-environment and internet network when reading the material or communicating with lecturers and peers both in Latvia and abroad.

Materials and methods

With the purpose to examine the level of mathematics skills background including ICT application there was carried out the test for the 1st-year students of the University of Latvia (LU) and Riga Technical University (RTU). In the test there participated 250 LU students and 125 RTU students. The results were analysed.

Results and discussion

The development and economic growth of any country depend on the level of its inhabitants' education and competences. In order to achieve that, the skills and knowledge of the youth should be developed from early childhood.

Active inclusion of knowledge in the economic model changes the whole range of economic cardinal postulates as the result of what material product turns into intellectual product (Karnitis, 2004)

Unfortunately, despite the new and improved study programmes the level of knowledge in schools of different levels does not only increase but even gets worse.

In the secondary school during the lessons of mathematics the pupils in most cases are prepared for the final examinations which are compulsory only from 2009. Thus the aim of teaching mathematics in the secondary school is to prepare the pupils for the final examinations but this is very short-sighted act.

More than 80% of secondary school graduates continue studies in the universities. During the first year of studies except some specialities there is taught 'higher mathematics', 'mathematics for economists', 'mathematics for engineering sciences', etc., and during the next semesters there are a lot of subjects in studying of which there is required the knowledge of mathematics on the secondary school level.

Already in the first tests it is obvious that applicants lack necessary basic knowledge (in spite of additional consultations the number of which, however, is limited), while during the initial test of secondary school knowledge examination fail on average 80-90% which is simply disruptive result. When investigating the mistakes, they mostly are based on basic topics which ought to be mastered in secondary school, sometimes even in elementary school.

Hereto it should be recognized that the results are declining from year to year.

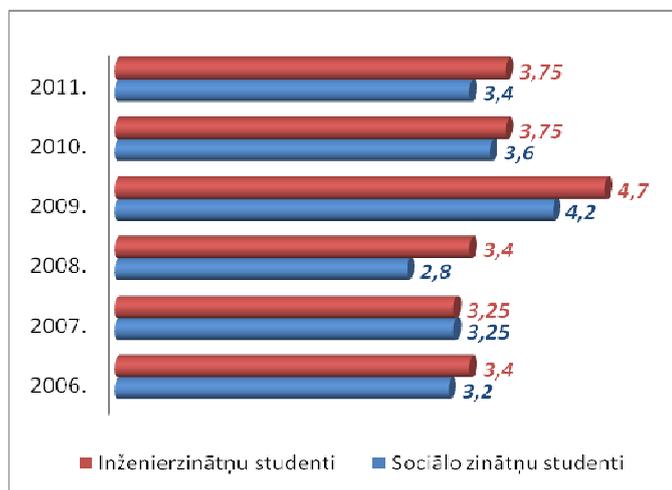


Fig. 1. The average evaluation of mathematics tests of students of social sciences and engineering sciences in 2006- 2011:

(Source: tests of 1st-year students of the two largest universities of Latvia, carried out by the author)

As it is seen in Figure 1, the dynamics of the results is equivalent in the period from 2006 – 2008 then it rapidly changes in 2009 when was renovated the compulsory centralised examination, however, the further results declined again because the number of mathematics lessons both in elementary and in secondary education is not sufficient. Although in each new study program version, which currently are changing often enough (the previous has not expired the experimental period of testing when the next one is applied), the amount of material to cover and the level of complexity rise, in addition besides mathematics the situation is similar in other subjects as well, thus sustainable knowledge is influenced also by overload.

As the youth is prepared mainly for the final examinations, but not so much for the further wider use of knowledge, the defined levels of the final examinations (A level is the highest possible, and D the lowest successful level) and the results of mathematics basic test differ significantly. To demonstrate it there are shown the results of September, 2011 in Figure 2.

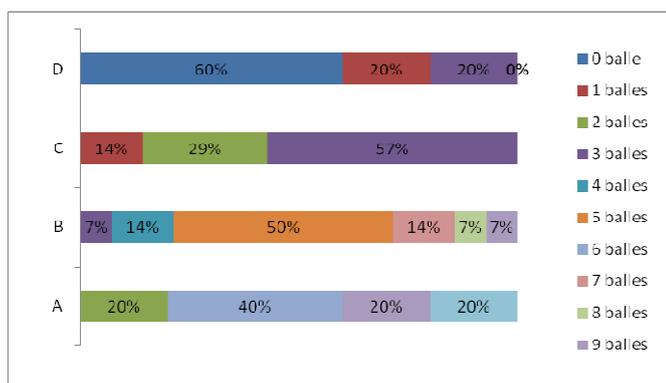


Fig. 2. The evaluation of mathematics tests of students of social sciences and engineering sciences in grades and the acquired level at the centralized secondary school examination in 2011.

(Source: the results of the tests and centralized examinations of the fresh-1st-year students of the two largest universities of Latvia, carried out by the author.)

To solve these problems that are not only interfering the studying process of the applicants at the university but also are causing extra duties for the lecturers during the lectures partly repeating the topics from secondary school program, giving additional consultations and organizing several tests on repeated topics. As a result the possibilities to discuss more essential topics during the lectures, consultations and seminars are decreasing, namely to evaluate and analyse different processes and relationships connected with the chosen speciality using the mathematics methods.

To ensure that schoolchildren/ students learn to find in internet the necessary information, learn to work with it and use as additional learning aids, there should be found the solution on the government level to cover these expenses for the educational institutions fully, definitely attracting extra means from EU finances for education.

At present one of the possible solutions is: in addition to studies at school pupils using their own initiative improve their knowledge with the help of e-learning, for example, in homepages www.uzdevumi.lv or www.dzm.lv. Also in this field the attitude of the youth and their possibilities are different.

The man as a carrier and preserver of information and knowledge becomes the main factor of economic growth and creation of values (Bikse, 2000)

However, the technologies have potentially big, but not always used, role in the field of learning and teaching. Several international research works show that relatively little research is done to explore the information communication technology (ICT) aspects in the education. In Latvia wider research on ICT application in education are not carried out at all. Thus it could be favourable to carry out a survey about ICT application in education: summary on international topicalities as well as the analysis of the situation in Latvia.

Evaluating the up to date research, summarizing the approaches described in scientific literature and personal experience there can be distinguished two important e-environment application functions in education:

1. the creation of ICT supported learning and teaching environment;
2. the use of ICT in administration and management.

One of the ways of ICT supported learning and teaching environment creation is the development of e-education possibilities. If by the term e-learning we understand specially organized studies/ training where ICT are used (applied) and which could be used in different forms of acquisition of education both in full-time studies, and in distance learning, in formal and in informal education, then e-education involve wide range of activities: from the application of effective digital resources and learning technologies in the auditoriums to improvement of personal learning experience through individual approach to these resources, ensuring individuals with modern and exciting possibility to realize their academic and creative potential at their adequate time and pace and fostering effective lifelong education.

Since 2000 the Central Statistical Bureau carries out surveys about the level of computerization and the use of information technologies of enterprises, institutions and organizations. As the statistical surveys do not include all factors for information society assessment, within the framework of information society technologies program there was established the project SIBIS (Statistical Indicators Benchmarking the Information Society) for the assessment of information society, which is the only project for overall assessment of information society in European Union (EU).

Within the framework of the international project SIBIS+ in Latvia there was carried out the survey including following 5 topics: telecommunications and approach, social incorporation, education, work, employment and knowledge, and e-administration. In the survey there participated in total 1006 inhabitants of Latvia out of which 32.4% from Riga region, 23.1% from Kurzeme, 13.6% from Zemgale, 14.7% from Vidzeme and 16.2% from Latgale. This division was chosen based on both the definite area of the territory and the density of population in it.

In the given research there are analysed unpublished data of the project SIBIS Latvia which characterize e-education in two ways:

- International internet lines as helper in the process of education;
- The use of electronic training materials.

Analysing the survey data there was revealed the following situation: in Latvia in general international internet lines as the help in educational process are used by 16.3% respondents.

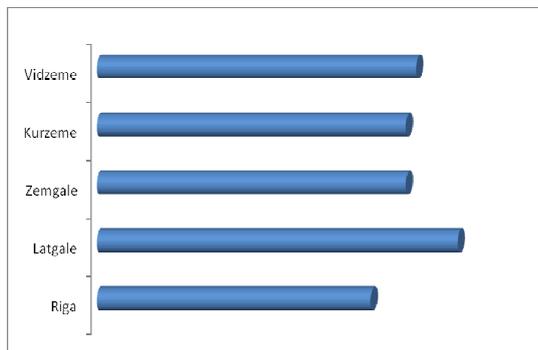


Fig. 3. **The density of respondents who use international internet lines in the studying process**
(Source: Picture created by the author using the unpublished data of the project SIBIS Latvia)

Analysing the survey results according to the regions of Latvia (Fig. 3), the international internet lines are used most in Latgale – 17.4% of respondents and in Vidzeme - 15.4%, and the least in Riga region – only 13.2%. In Zemgale and in Kurzeme there is equal amount of respondents – 14.9% which use the international internet lines.

Obviously in the field of education there are not specially actualized, promoted and practiced the possibilities of international internet for the acquisition, processing and exchange of information. It means that there should be aggravated the problem. The limited use of international internet lines in the field of education could be connected with the problems of language acquisition on the level of comprehensive schools. Besides there become actual also problems connected with the use of internet – among the youth the literary and scientific language becomes incomprehensible and strange for the learners.

In the field of further education the use of international internet could ease the mastering of different studying programs, especially those that are not offered by higher educational institutions of Latvia, and thus also to prepare for such programs. This type of education could be implemented in the realization of vocational education, interest education, and lifelong learning.

If e-learning is charged service then how safe it is that it is real training not malicious action with the aim to defraud financial means. How safe it is to send over internet own made assignments (homework, practical works, tests, etc.)

Different situation is in the field of the use of electronic materials, for example, different tests, assignments, etc. In Latvia 37.7% respondents use materials electronically. Radical differences in this field are observed in Riga region and in Zemgale region if compared to the total situation in Latvia and in Kurzeme, Vidzeme, Latgale (most of the respondents are students).

As it is seen in Fig. 4, in Latgale and Zemgale respondents use materials electronically in equal shares - 41.3% and 40.8% respectively. The least materials electronically are used in Vidzeme, only 30.9%. Also in Kurzeme the share is not radically bigger – only 31.1% of respondents. Less than in Zemgale, but more than in Vidzeme and Kurzeme materials electronically are used in Riga region – 40.2%. Such situation can be explained by the fact that most educational institutions: comprehensive, vocational, secondary special educational institutions, higher educational institutions both in the number of establishments and the students are situated in Riga region (it should be taken into account that many students come from different regions) and in Zemgale. So the use of materials electronically and internet possibilities in general in these regions is objective necessity.

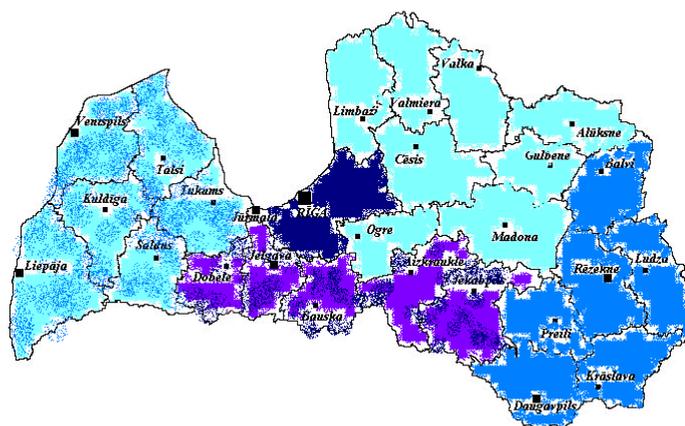


Fig. 4. The density of respondents who use electronic learning and communication resources in the learning process: (Source: Picture created by the author using the unpublished data of the project SIBIS Latvia)

The use of electronic materials has its advantages and disadvantages.

It should be mentioned that in order not to mislead pupils, students, their parents, teachers and lecturers the information ought to be updated in the homepages. The question arises how to solve the problem with extra costs for the educational institution.

Researching the analysed data (factors influencing the results) with the help of econometric methods, it is obvious that the factors that have positively influenced the use of electronic learning and communication resources in the studying process could be foreseen earlier (the data obtained using the category regression), and they are: the age, skills to find the needed information in the internet, as well as certainty that the internet is the main type of information acquisition. When using the category regression in the analysis of the survey data it revealed that the main negatively influencing factors for the use of e-learning materials are connected with the working conditions of the person and the attitude towards the person – tense atmosphere at school, the length of the study day, dissatisfaction with existing training and lack of interest in learning. Increase of value by 0.04 units for any of these negatively influencing factors, the other factors remaining constant, the use of electronic materials and communication resources decreases by 0.009 units. The influence of these factors has been estimated with credibility up to 99%.

As the factors have various measurements, the coefficients of the regression equation are not comparable thus it is not possible to determine which of them influence the resulting characteristics more and which less. In order to use the regression coefficients for this purpose, coefficients were modified with the help of ‘CATREG – Regression for Categorical Data’ (variables were standardized).

It is important to use the computer, the internet and different e-materials not only after classes but also at school, when teachers work with both, the whole class, the groups and individually. However, not all teachers are ready for that. Before introducing any new technology into classrooms, teachers must be able to justify its contribution. In order to use ICT constructively, educators may have to use technology when it helps them do their good work better. Moreover, no teacher or classroom exists in isolation. Implementing technology is an issue for the entire educational institution. For example, the advent of network technologies and access to the Internet in educational institutions has brought attention to the need for learning organisation-wide technology planning. Thus, many organizations in recent times have changed their working culture to embrace such ideas as group working and self-management teams. The purchase of classroom computers and presentation equipment does not guarantee the effective integration of technology into teaching and learning. Classroom management strategies, facilities design, and long-range technology planning are equally necessary to realise technology's potential for education. Classroom design allows the educators to plan classroom layout and technology resources for the effective integration of computer Technologies into a university. Planning considerations offer guidelines for long-range planning that seek to equip and empower teachers for technology-enhanced instruction. (Vintere, Majinovska, 2009.)

At present the demand is growing in the labour market for highly qualified employees who can quickly find the necessary information in the latest scientific achievements, modern technologies and materials that concern their field. Dynamic development processes significantly influence the necessary professional qualification of specialists stressing the need for continuous education, professional growth and social mobility. The qualification of professions and the necessary competence are changing. The fast development of technologies determines the need to over- specialize at different age. The introduction and use of information communication technologies in education can serve as strategic tool for completion of the set objectives. Therefore very important is the development of e-education possibilities. The most significant benefit from the integration of

ICT in education is that for the applicants there are created qualitative new conditions for the study process as well as for their further education and professional performance. Of course, it is clear that the problems of education system cannot be solved only by introducing new technologies in the study process. The main value is not of that how the students use ICT but of that how the use of information communication technologies foster the quality of education. (Vintere, 2006)

However, in addition to the above mentioned the use of electronic materials has the following problems:

- When studying in elementary school, and partly also in secondary school, pupils have not worked out such a degree of responsibility that in spite of the overload at school, they could initiate by themselves additional studying if for that is not expected any evaluation at school;
- Part of the offered materials are on very low level;
- Predominantly these materials, tests or exams are for a fee;
- To master, for example, materials from homepage www.dzm.lv (natural sciences and mathematics) it is necessary to install additional computer program which is again for a fee, and there are problems to get it, etc.

The solutions for such problems are many and various; unfortunately, taking into account the economic situation in the country most them cannot be implemented at present.

Conclusions

Despite the complications both financial and moral, to approach the favourable result in the field of youth knowledge, at first it is necessary to carry out the following activities that do not demand large funds:

- organize intensive cooperation between the school teachers and university staff in connection to teaching mathematics, physics, and other subjects;
- summarize necessary basic skills for mastering mathematics and other subjects of programs connected with other fields in LU, RTU and LLU;
- improve the mathematics themes of the secondary school course, deepening the training in the fields that are the most necessary when studying at the universities in the fields of humanitarian, social, or exact sciences or specialities connected with medicine; for the more complete preparation the future applicants dividing the pupils in the groups according to their interests;
- organize optional lessons or after-lesson groups where pupils are helped to master better the themes in definite subjects that are necessary when entering the next educational institution;
- improve e-communication possibilities between applicants and teachers;
- find the possibility for the schoolchildren to use fully the home page www.dzm.lv (without additional investment), as well as offer other sites.

Despite the situation in the country in the fields of e-education and communication is promising due to state's policy which fosters the provision of computers and Internet connection in all schools as well as provision of the corresponding infrastructure in all territory of Latvia, it should be remarked that failure to use possibilities provided by information communication technologies or lack of skills to use them, can cause the so-called 'digital exclusion', which create the risk of failure to join social and economic processes. To foster the principle of provision of equal possibilities for all population there should be created the possibilities of the use of ICT and the possibilities to development skills of the use of ICT.

The main benefit of successful ICT application in education including full e-education development is that there are created qualitatively new conditions for students/schoolchildren in the studying/ learning process as well as for their further education and professional performance.

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EFFECTIVENESS OF IMPLEMENTATION OF ONLINE LESSONS ON THE BASE OF SERVER'S REMOTE CONTROL

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Abstract: *Technological tools and practical experience of distance lessons devoted to mastering of software product by non-IT professionals are described. For provision of distance lessons two independent channels were simultaneously used: one for video-audio conference providing teacher-student communications and second one for teaching-methodological link providing delivery of teacher's presentation, show of software execution and control over student's working with the software. The main focus is stressed on realization of teaching-methodological link. This link is realized as virtual computer with two remote control sets - one on teacher's side and another one on student's side. Three approaches are discussed for creation of mentioned above virtual computer - a) remote control to participant's computer (were considered and compared both alternatives - remote access to teacher's and remote access to student's computer); b) usage of special software like TeamViewer; c) management of remote server session from both teacher's and student's sides. As the most appropriate solution a server session management is argued. The proposed technological solution was implemented for remote training of teachers (non-IT professionals) of the usage of course management system Moodle. After completeness of remote training course participating teachers (as professionals in education issues) made an evaluation of considered solutions by filling in the questionnaires. In general, pilot implementation of proposed technological solution shows its practical viability and applicability.*

Keywords: Distance teaching, remote control, collaboration.

Introduction

During the training of specific software usage to potential users it is necessary to give an insight into the software in the form of lectures as well as showing of specific operations with given software interface (single manipulations, particular sequences of manipulations, etc.). In the case of distance learning the teacher-student collaboration (hereinafter by the teacher is meant any educator - teacher, lecturer, instructor, academic, professor, etc.; by student hereinafter is meant any trainee) must be sufficiently convenient (Jekabsons et al., 2010). For lectures the following should be provided:

- student-teacher visual communication, where the student sees the teacher and teacher sees student. This type of communication stimulates the most appropriate speed of presentation, helps to maintain student interest and so on;
- student-teacher audio communication. Teacher's voice delivering a lecture, students' questions and discussions;
- presentation of course materials, usually using a computer. There may be various types of presentations (Power Point, Word, execution of specific software, etc).

During practicum (hands-on training) in addition to the items listed above also should be provided means (tools) for teacher-student collaboration for completion tasks using software environment. It is necessary to note that in the case of classroom's lessons the teacher has the opportunity to observe student's work at the computer and have the opportunity to advise the student directly on the base of seen on the screen, including showing of particular necessary manipulations.

Description of the solution

Implementing four European Social Fund projects in Latvia (Lavendels et al., 2005; Lavendels et al., 2008a; Lavendels et al., 2008b; Agency, 2010) we pointed out two parallel channels operating in co-operation (Fig. 1.):

- channel for audio and video transmission. Audio communication for teacher's voice, students' questions, discussions and the video communication for broadcasting of teacher's image to audience and auditorium image to teacher;
- channel for presentation of course materials and for collaboration (presentation of slides, demonstrations of practical manipulations, monitoring of students performance during completeness of assigned tasks, analysis of student's work and individual student assistance).

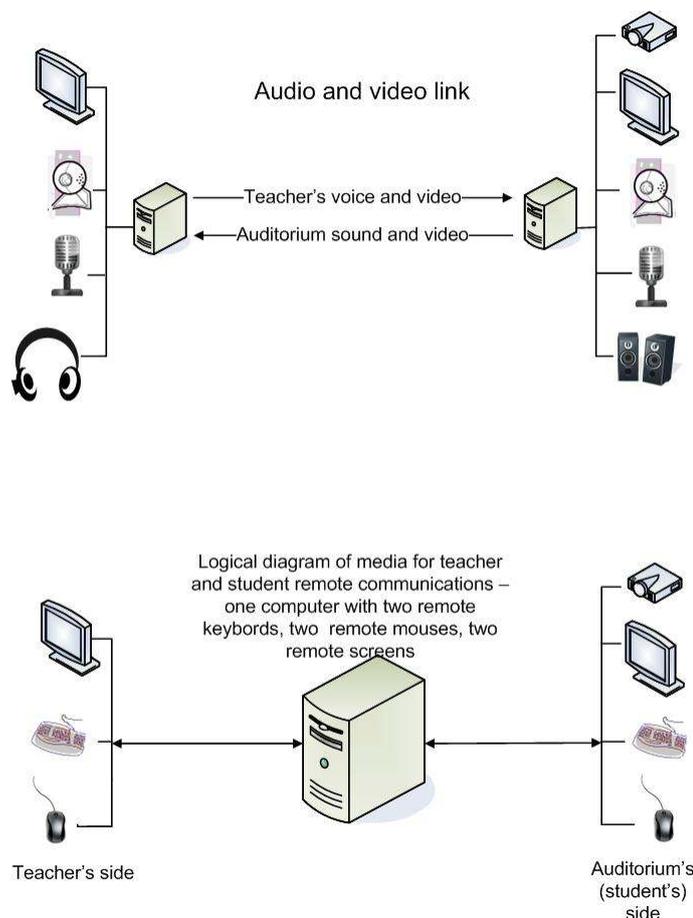


Fig. 1. Schematic diagram of Teacher-Student collaboration.

Voice and video channel could be realized by the use of Internet communication tools such as Skype (Unuth, 2011). Channel for presentation of course materials and for cooperation (actually for application sharing – working with the same instantiation of software product) could be realized by different means of cooperation on the Internet. On the logical level this channel is realized as an imaginary (virtual) computer, hereinafter called as "cooperative computer", which has two controls: one on the remote teacher's side and one on the remote student's side (bottom part of Fig. 1). Depending on the type of lessons - lecture in one auditorium, simultaneous lecture in several auditoriums, software demonstration, student's control, consultation, etc. – channel for presentation of course materials could be realized by a variety of different means, giving to the channel a slightly different properties.

Below are described our implementations that were used for distance teaching and learning of different target groups.

Examples of practical implementation of distance learning means

Examples of implementations for provision of remote lectures and remote hands-on training are described below.

Simultaneous lecture in several classrooms

The simplest means for lecture for a number of audiences at the same time could be Skype in "screen sharing" mode in combination with "High Speed Conferencing Service" (Krauklis et al., 2007).

Simultaneous lecture in a number of audiences can be provided using separate channels for audio and video transmission (teacher's voice and image) and channel broadcasting lecture's presentations. In this case, the presentation material (e.g. power point presentation) is posted on the server during the lectures. An audience connects to the server and lecture's presentation is projected on the screen.

However in such solution the teacher cannot see particular student's work with the program, therefore interactive collaboration between teacher and student is actually lost. As a consequence, for distant hand-on training such approach does not work.

Usage of PC remote control

For providing common work of teacher and student on the same software unit (program) on the base of remotely controlled computer, there are two possibilities:

- take-over control of student's computer;
- take-over student's terminal session on a server (How, 2011).

Remote Control of Student's PC

Taking-over control of student's computer has the following shortcoming – the screen of the computer is seen either by the student (normal work) or by the teacher (remote control). It means that the teacher can correct the mistakes the student has made, but the student does not see this process. At the same time, when the student is working with the program, the teacher does not see what the student is doing.

Remote control of Server's session

More complicated, but at the same time more efficient alternative is taking-over student's terminal session on a server (Fig. 2). In this case, necessary working environment is created in the following order:

- at first student starts a remote terminal session on a server;
- then teacher (having the required access rights) takes-over control of the student's session.

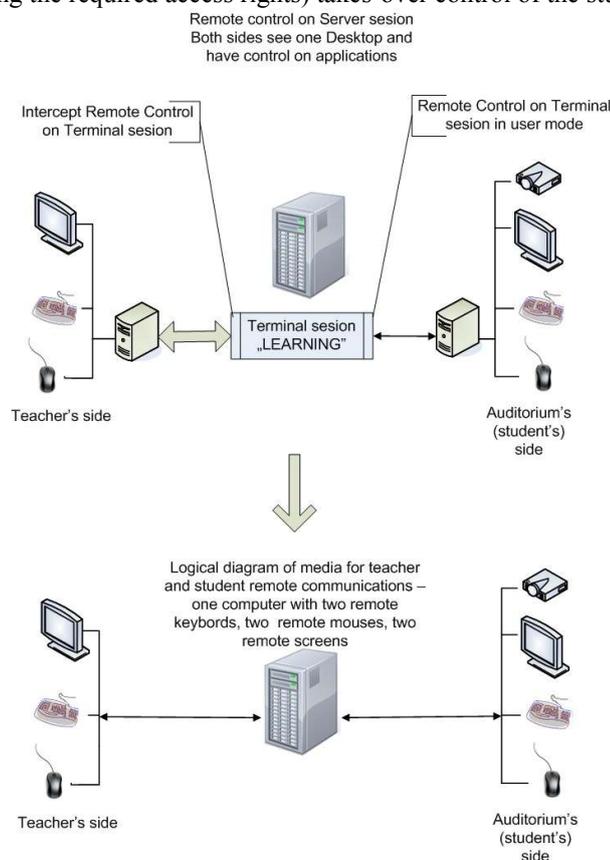


Fig. 2. Topological and logical diagrams when taking-over student's terminal session.

This way, both student and teacher see the same session's screen (desktop of the server and all applications running on the server). Both sides are able to control the process and the mouse pointer is being seen all the time for both sides.

The approach described here provides possibilities for two people to be working at the same computer. And in the remote learning, it is very important because basically, there are no essential difficulties to arrange video conference for a teacher and a listener, but it is much more important to provide to both these participants working at the same application and being able to correct student's mistakes and to show good practice of using the software.

It is necessary to note that application of what both student and teacher are working is executed on the server. This means that all programs and data required are to be accessible from the server. Practically this means that the teacher has beforehand to deploy on the server all necessary programs and data. Work on the server is potentially dangerous in term of computer viruses, so the right of user-student has to be limited till minimally required.

It is necessary to note also that the suggested approach is useful for giving a lecture as well as for arranging hands-on training. During the lecture projector could be connected to the student's computer and the presentation could be watched by everyone in the classroom. The interchange of audio information is being done by using Skype and, if available, Skype is used for video call. In this case, the teacher can watch the audience, and the audience sees its teacher. For hands-on training or consultations (tutorials), from the audience's side just a single student is working at the "cooperative computer" and the teacher is interacting just with him.

Advantages of solution

This approach does not require installation of additional software on trainee's computer. This enables potential users of remote lectures easily try out a new kind of lessons. Approach can be applied also to train skilled users, especially when working with data placed on the server.

Disadvantages of solution

It is necessary to note that applying this approach all programs and data must be deployed on the server in advance.

For less qualified student it could be quite difficult to understand its place in a rather sophisticated environment. Trainee's computer may have different properties than installation on the server, so there might be differences in further execution of the same being studied program directly on a trainee's computer.

Example of implementation

We implemented this approach in training course for secondary schools teachers mastering MOODLE environment (Agency, 2010). It should be noted that our trainees were not specialists in the area of information technologies - these were teachers of biology, economics, mathematics, literature, culturology, history. Moreover, most of them had no experience with computerized tools for online communication. We worked with five groups of trainees - each group of 10 persons (by 5 teachers from 2 schools). Lessons were conducted from Riga to seven cities in Latvia. It is important that group of trainees had already been familiar, so immediately can communicate and help each other.

For arranging of remote lessons we had been used MS Windows 2003 Server on which studying system MOODLE was installed. Lessons are always held from Riga – from different places, depending on the teacher. Trainees during the lessons were in computer classes of participating schools in 7 other cities.

The teacher always uses just one computer on which both Skype videoconferencing and remote session on the server were running. Sometimes it was a computer with two monitors (separately for MOODLE and Skype), sometimes with one – combining both windows.

To the trainee's physical computer were connected projector, speakers and microphone. On this computer also were running both remote server's session and Skype video conference. Thus trainees simultaneously watch on one wall screen both teacher's video and window with running MOODLE. Listening to the teacher and watching running MOODLE trainees in parallel performing on their computers the same operations as teacher. If necessary they ask teacher's advice, using classroom microphone.

The teacher, in turn, watching what is happening in the auditorium could regulate the speed of lecture and level of necessary details. With each group 5 remote lessons were held, each of one and a half hours duration.

Assessment

To assess the acceptability of this approach after the end of the course surveys of trainees was conducted. In a survey have been participated 33 secondary school teachers whose were trained using virtual remote sessions platform. Some results of the survey are given in table 1.

Table 1

Results of the survey of virtual classes participants

	Yes (%)	50/50 (%)	No (%)
Does the quality of teaching material's video image was sufficient?	80	13	7
Does the cursor and its movement was always visible on the screen?	79		21
Do the movements of cursor and teacher's voice were always synchronized?	78		22
Does the quality of sound (teacher's voice) was adequate?	67		33
Is it necessary to see video images of teacher during the lesson?	79	6	15
Did you feel discomfort on the presence of video camera in the classroom?	3	6	91
Was the teacher able to regulate temp of training lesson?	91	6	3
Does the temp of virtual lesson must be slower than on classroom's lesson?	50	25	25
Does the duration of virtual lesson must be shorter than in classroom?	21	58	21
Does it necessary to have a moderator in the remote auditorium during virtual lesson?	91	6	3

Does it necessary to demonstrate teaching materials directly on the learner's screen instead of projection to the wall's screen?	29	16	55
Do you see usefulness of virtual classes in your subject areas (non-it)?	69	23	8
Do you want to conduct by yourself virtual lesson on your subject?	33	12	65
Are you in general satisfied with such environment and method of virtual lesson?	84	10	6

In addition, views of respondents regarding duration of virtual lesson is given in table 2.

Table 2

Desired length of the virtual lesson				
	30 minutes	40 minutes	60 minutes	90 minutes
Frequency of responses	15%	54%	23%	8%

At the same time, the minimal, maximal and optimal numbers of trainees in the audience during virtual lessons are presented in Figure 3.

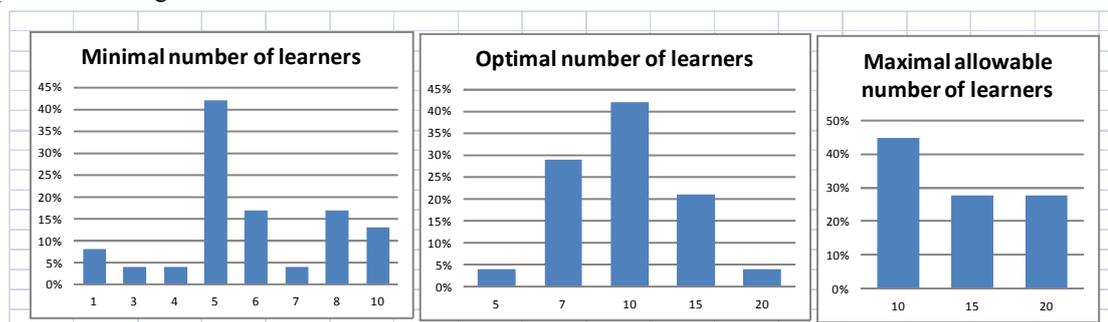


Fig. 3. Frequency of responses regarding the size of the audience for virtual lessons.

Brief analysis of presented results show the following (Lavendels et al., 2011):

- For audience it is important to see the video of lecturer;
- Approach provides sufficient technical quality, even in places with rather low speed of Internet connection;
- Despite two parallel channel sessions, it was provided synchronization of video conference and running of "learning computer";
- During virtual lessons, trainees very often consult with colleagues;
- Realized environment can provide for teacher ability to adapt to the audience;
- Despite of rather high interest, only 30% of the participants wanted to try themselves as teacher in such online lessons.

Conclusions

1. Trainees gladly accepted such form of training. For a person with a minimum experience in the field IT isn't a problem to run virtual remote session.
2. There is no need to use two computers at each of the sides to carry out remote sessions – combining two screens on one monitor provides sufficient technical quality. In addition, this quality does not depend on the location of the teacher during lessons.
It is very important that the participants were mutually friendly and sociable. Within each group, it is desirable to have one leader, which assumes the functions of communication with the remote teacher.
3. There is an assumption that one and a half hours is the maximum appropriate time for remote lessons, after this time trainees dramatically lose their concentration.

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HETEROGENEOUS TOOL KIT FOR REAL-TIME EDUTAINMENT

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Abstract: In today's world, digital technology is taking over our lives more and more including education and entertainment. In both fields situations occurs when someone needs to control or coordinate tasks in different locations to be performed just in time. There exists certain amount of modus operandi characterized by various levels of complexity that tries to solve this issue. During state-of-the-art research authors found a lack of simple solutions that could be easily adapted for specific user requirements while still suitable for wide area of needs. In this paper we describe our experience taken from developing of hardware and software tool kit suitable for education or entertainment event staging and management where real time user-assigned task control or task reassignment is required. Hardware part includes embedded device that performs SRD interface control and configured information output. Development of this part was done with energy economy in mind to ensure the utmost possible autonomous operation of device. Software part is lightweight web based application that can be accessed by event organizers and participants using HTML-enabled Internet browser from PC or smartphone. Mobile phone's built-in camera and matrix bar code interface can be used as an option for access to the system or execution of specific tasks. Over the course of last 5 years tool kit has been progressively implemented in hardware and software prototypes that found multiple applications in various "Autoliste" and "CDT" organized events.

Keywords: game based learning, mobility, distributed systems, embedded hardware and software.

Introduction

In today's world, digital technology is taking over our lives more and more including education and entertainment. Both fields quite frequently encounter situations when someone needs to control or coordinate tasks in different locations to be performed just in time, sometimes with limited resources in mind. There exists multiple ways with various levels of complexity how such issues can be solved.

Authors gradually performed research and development of tool kit for edutainment over the course of last 5 years to accommodate requirements of event organizers like "Autoliste" and "CDT". Research results described in this paper isn't the final version rather it's a milestone.

History of education, entertainment and sporting events that involves orienteering dates back to end of 19th century when orienteering was the part of military training and later evolved into civilian sport. Initially it's required only a map and a compass to aid crossing of unknown land on foot. Car orienteering's concept is similar to traditional orienteering and it's initially evolved from rally and used map to navigate along unfamiliar roads. One of the pioneers in the context of car orienteering in Latvia is "Autoliste" that started to organize such events in 2001. As time progressed participants became more technology hungry and events started to evolve from simple car orienteering to more complex tasks that required more resources to control them and evaluate end results. Therefore authors of this paper and persons that are closely involved in "Autoliste" operations chose to move to new more robust solution to avoid common pitfalls for entertainment and sporting events that involves results that can be evaluated, like:

- It's resource consuming to print and prepare multiple orienteering checkpoints that needs to be placed in exact locations in very short time before the event to avoid information leakage to participants – same applies for printing of various materials required for event, like control cards, maps, road books etc.;
- It's also time consuming to use photos as method of authorizing checkpoints due to huge amount of visual data that aren't structured and needs to be processed by human that results in errors that can lead to incorrect and delayed event results;
- Usage of traditional orienteering equipment for checkpoints is limited due to that they are suitable for registering fact of visit of checkpoint, but still event organizers requires additional method of task delivery to participants.

Therefore authors developed their own solution with simple yet robust web application as its user interface and controlling system and micro-controller based embedded device as checkpoint.

The paper is structured as follows. In Section 2 we describe our system architecture, its hardware and software components. Section 3 describes some use cases of our system; Section 4 briefly touches on related work and Section 5 concludes and summarizes our work and sketches further prospects.

System Architecture

Architecture of authors proposed solution is presented in Figure 1 that displays all components of the system and outlines specific research goals covered by this paper.

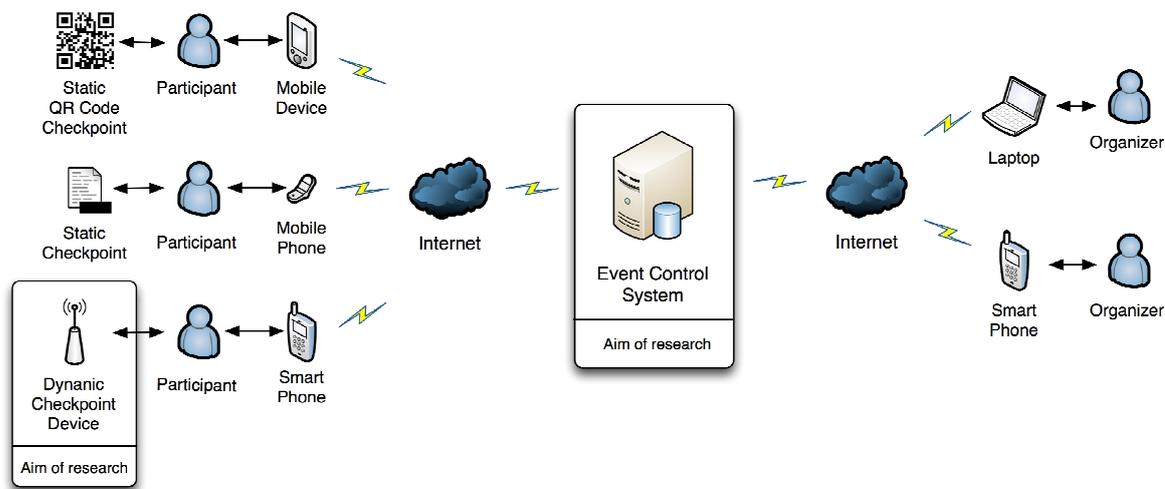


Fig. 1. Overall system architecture with outlined research goals

Hardware

Design and development of the hardware part was carried out with the aim to create a solution characterized by inexpensive development and maintenance costs, simple end-user interface as well as low energy consumption. Therefore, following list of technical requirements was chosen as a basis for embedded checkpoint device:

- Device should be able to use a Short Range Devices (ERC, 2011) radio transmitter operating in FM broadcasting band as end-user interface;
- Device should be able to perform its operation according pre-programmed timetable using as reference Real-Time Clock (RTC);
- Device should be able to store certain amount of data used for transmission to end-users according pre-programmed timetable;
- Device should be able to operate autonomously without battery replacement at least 350 hours (approximately two weeks).

One of the ways for inexpensive design of embedded electronic devices is usage of open source electronics prototyping platform. In our case Arduino platform and its board Arduino Pro (Arduino, 2008) was selected due its popularity and relative low hardware component costs as well as support from MansOS operating system (Strazdins, 2010; MansOS 2012) developed in cooperation between Institute of Electronics and Computer Science and University of Latvia. Checkpoint device's main board prototype is shown in Figure 2 and is based on ATmega328P (Atmel Corporation, 2011) microcontroller with external 8 MHz oscillator. To ensure connectivity to PC for firmware upload and configuration device uses Universal Serial Bus (USB) through FTDI chip based cable or board that is connected to device when required. That helps to reduce amount of components required and decrease energy consumption. To facilitate firmware upload microcontroller is programmed using appropriate boot loader software.

Short Range Devices radio operating in FM broadcasting band was selected as end-user interface due widespread usage of corresponding receiving devices. Capable receivers are installed in almost all passenger vehicles and portable receivers can be purchased for less than 5 EUR. A lot of mobile phones and smart-phones among other functionality can act as FM broadcasting band receivers, too. Data transmission through selected end-user interface was performed using Morse code. This choice was motivated by relatively simple software development and a smart additional task for end-users of embedded checkpoint device.

Short Range Devices radio transmitter was designed, using as basis device developed by Burak Incepinar (Incepinar, 2001). Modifications include programmable transmitter power supply commutation as well as modulation with programmable Morse code signal instead the audio signal from microphone. Another option was usage of ready-made transmitter module such as NS73M (Niigata Seimitsu, 2006). This option was not chosen due relative higher costs and interface complexity as well as relatively lowly requirements for transmitting frequency accuracy and transmitting power for this particular solution. During later research phase were discovered solution (Domburg, 2012) that needs even less components and is fully microcontroller based, except it's not fully stable and powerful, and has limited time of operation due to frequent modification of microcontroller's internal RC oscillator's calibration registers and their deterioration. As well authors have

considered AM based transmitter (Arduino Forum, 2007), but dropped the idea because of unpopular for nowadays transmission band and modulation type used and therefore – decreasing of the availability of suitable end-user receivers.

To ensure a proper begin and end of the operation of the checkpoint device just in time as well as changes of the transmitted content according pre-programmed timetable the device contains a RTC chip PCF8593 (NXP B.V., 2010). Communication with this circuit is performed using I2C interface.

To ensure a sufficient amount of non-volatile memory to store specific content transmitted to end-users the device contains an I2C Serial EEPROM chip AT24C64C (Atmel Corporation, 2008). The size of the EEPROM used in this device – 64 KB - was selected to provide space for 2048 4 to 8 digit long checkpoint codes that can be changed from 1 to 30 times per hour providing from 68 up to 2048 hours long continuous operation time if device is equipped with large enough batteries.

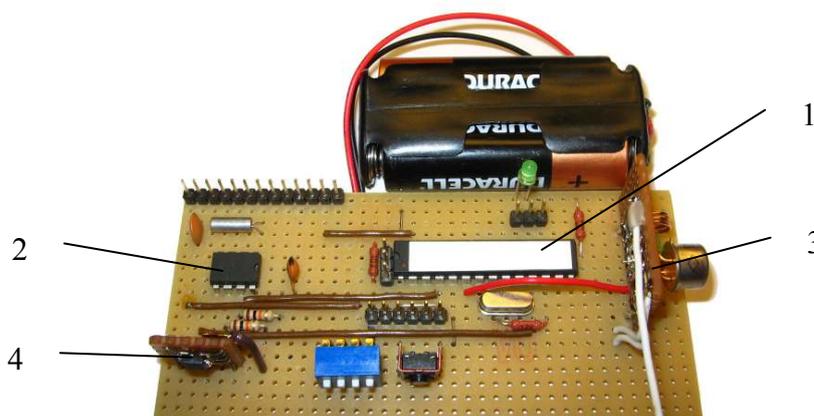


Fig. 2. Main board of embedded checkpoint device: 1 – microcontroller, 2 – RTC chip, 3 – FM transmitter board, 4 – EEPROM chip

Energy consumption of the developed embedded checkpoint device is determined by energy consumption of separate components as well as their duty cycles. Measurements of energy consumption during different operation modes are presented in Table 1. Analysis of these data revealed that embedded checkpoint device in standard situation can operate autonomously up to 536 hours or more than three weeks (Table 2) using two Alkaline AA batteries with typical capacity of 2000 mAh.

Table 1

Embedded checkpoint device’s energy consumption during different operation modes

Mode	Consumption, mW
Sleep	0,89
Configuration (FM transmitter OFF)	11,23
Active (FM transmitter ON)	15,12

Table 2

Autonomous operation time using different checkpoint code lengths and 8 sec sleeping between two subsequent code transmissions

Checkpoint code length, digits	Code transmission time, sec	Consumption per hour, mWh	Autonomous operation time, hours (days)
4	18	10,74	536 (22)
6	27	11,87	485 (20)
8	36	12,53	460 (19)

Device firmware was designed with robustness in mind so that later for its operation is enough to have computer equipped with USB port and Serial terminal program. To configure device, first you need to switch on the configuration mode using hardware switch found on it and then through the terminal perform configuration tasks according to requirements of event where its going to be used. All configuration commands are numeric and have similar data entry format (1). Length of command and parameters in total are limited to by Atmega328P serial buffer size that is 128 bytes. After command has been processed on device user receives OK or NOK (Not OK) message preceded by command number used. NOK message usually means that command had invalid format or invalid parameters or microcontroller didn’t fully read serial buffer. Configuration mode can be used to read back configured parameters stored in microcontroller’s internal 1KB large EEPROM memory as well as codes stored in external EEPROM chip using the same data entry format (1) as for configuration.

$$A * B[*C] \# \quad (1)$$

where A – Command, numeric;
 B – First parameter, numeric, depending on command;
 C – Optionally second parameter, numeric, depending on command;
 $*$ – Divider of arguments;
 $\#$ – End of command.

Software

Design and development of the software part - Event Control System (ECS) - was carried out with the aim both to reduce administrative effort required by organizers and to provide dynamic environment for participants. Additionally the following non-functional requirements were taken into account:

- Software users might be mobile;
- Software should be available on demand;
- No specific hardware should be required.

To meet these requirements ECS was implemented as lightweight web application with both WAP 2.0 and full HTML support. That covers most mobile and smartphones currently in use, which is of particular interest for outdoor events in rural areas, where other computing and communication devices might not be readily available. ECS addresses the following aspects of event organization:

- Task definition;
- Participant registration;
- Control of checkpoint placement and activation;
- Task assignment to participants;
- Task progress tracking;
- Task result evaluation;
- GPS track analysis;
- Traceable communication between organizers and participants.

Task definition in structured format is essential for event control automation. For this purpose data structure shown in Figure 3 was used in ECS. It consists of three parts where first one is task that is uniquely identifiable and contains some description. Task may be related to particular location defined by GPS coordinates, as well it may be available for limited time duration. There is at least one question in a task and it is also uniquely identifiable and contains some description. There is at least one answer for a question – again it is identifiable and contains description. Each answer variant has been assigned a value. Participant's result for answering particular question is determined depending on verification algorithm. Answers to some questions are required to complete task. Minimal rate of answered questions may be required to complete task. Overall task value within event may be balanced via coefficient.

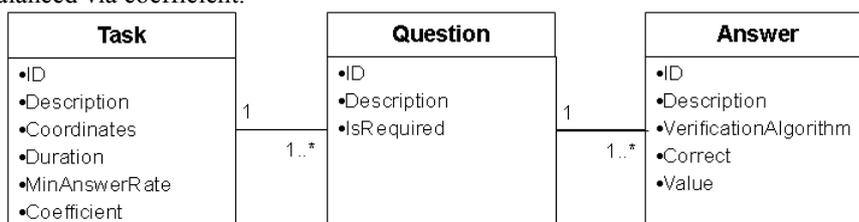


Fig. 3. Task data structure

Particular data structure along with answer verification algorithms of string match and numeric difference has been sufficient to define rather different types of tasks e.g.:

- Orienteering checkpoint authorization by entering code - task with GPS coordinates, 1 required question with 1 answer that is verified by exact string match;
- Timed test - task with duration and minimal rate of answered questions, i.e., 30 questions with 4 answers each that are verified by exact string match;
- Estimation of distance between two objects - task result is calculated as numeric difference between participant answer and correct answer.

Both data structure and list of available verification algorithms may be extended as new types of events and tasks are designed for ECS.

Task assignment to participants via ECS allows for fine-grained control over which tasks are available for which participants at which moment of time irrespective of organizers' current location, that could strain their resources otherwise. It is of particular interest for events that span large territories and have many participants e.g. car orienteering. Some event design patterns that benefit from this approach are as follows:

- Making task available for participant at particular moment of time irrespective of location e.g. controlled mass start from multiple locations;

- Making task available based on participant performance so far e.g. multistage event, where next stage becomes available after predefined quota of previous stage has been completed;
- Assigning task for participant based on overall event state e.g. to facilitate even participant distribution in event area.

Task description in ECS may be any content that can be delivered via web browser - text, images, multimedia files - as shown in Figure 4. In case of mobile phone as client device available software and screen resolution had to be considered. To accommodate for potentially weak mobile network signal and therefore slow network speed, e.g., in forest or valley, typical transferred data amount for 1 request / response was reduced below 10 KB.

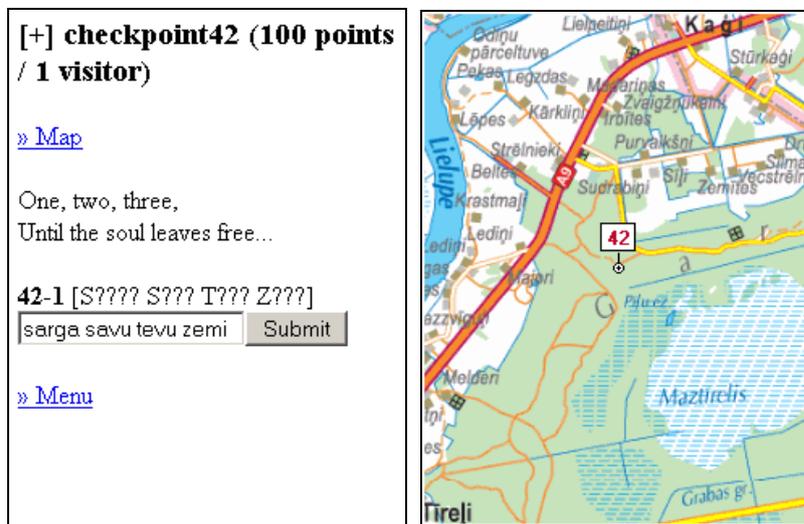


Fig. 4. Task in ECS

Task progress tracking and result evaluation are performed in ECS in real time - as soon participant registers an answer to a question, result for particular question is determined and completion status of corresponding task is evaluated. These data are immediately available to organizers, which allows them to monitor both task execution process and participant performance and take corrective actions if required e.g. in case of task description errors or cheating. Depending on event rules and task type some of these data are available to participants as well.

Several input methods have been evaluated in ECS to optimize answer registration on mobile phones:

- Selection from predefined answer variants. There is low amount of input errors. Screen resolution is a technical limiting factor. Question format is a task definition-limiting factor.
- Text input. There are various input errors. They can be resolved to some extent by:
 - Predefining input format;
 - Limiting input length;
 - Normalizing received input - ignoring case, diacritics, special characters;
 - Giving limited number of hints in case of wrong input.
- Quick Response code. Most mobile phones currently in use have built-in camera. In combination with corresponding software this allows with one key press to retrieve URL, which registers answer, from QR code and open it in web browser. However there are some technical limiting factors. There is multitude of QR code recognition software, browser software and mobile phone combinations available, thus organizers' are neither able to test for, nor consult participants in case of component integration problems. Additionally QR code recognition is rather dependant on lighting conditions, background colour and size e.g. this method is not well suited for a night event.

Automated result evaluation in real time allows usage of more complex algorithms, e.g., dynamic task value coefficient within event based on number of participants that completed it, and immediate result publishing irrespective of number of participants.

Result evaluation may include participant GPS track analysis. After finish of event participants themselves or organizers can upload their track in GPX format to ECS and its performs analysis of the following aspects:

- Maximum speed. There are road speed limits to be abided. If speed calculated by timestamp and coordinates from track exceeds predefined speed for predefined period, corresponding incident is registered for each occurrence and disciplinary action against offending participant may be taken. GPS tracks recorded on typical devices are approximated - there are less points on straight fragments and more in turns. Usually timestamps are given with second precision. This leads to several problems. On straight fragments slight curves are ignored, which reduces distance and slightly increases calculated speed. In turns points may be registered every second, which leads to undefined actual time span anywhere between 1 to 2 seconds and has significant impact on calculated speed. To accommodate

these measurement errors and reduce false positives minimum time span to be analyzed is defined and rather conservative predefined speed and period parameters are used e.g.:

- Time span of at least 10 seconds, which should reduce timestamp error below 10%;
- Predefined speed of at least 100 km/h for road speed limit of 90 km/h;
- Predefined period of 60 seconds, which should indicate speeding, but exclude temporary acceleration e.g. during overtaking.

Besides extremely high speed indicates data integrity problem - coordinates of subsequent track points are too far away e.g. because of GPS receiver error or because of data tampering.

- Checkpoint authorization. Task may be considered completed if participant has visited area within predefined distance of checkpoint. An event design pattern that benefits from this approach are virtual checkpoints that are defined as coordinates and participants equipped with GPS receiver have to visit them. Speed within checkpoint area may be used as indicator for data tampering e.g. if checkpoint is reachable only by foot, it is reasonable to expect that participant speed in checkpoint area will not exceed 15 km/h.

Additionally GPS data may be used to provide dynamic visual representation of event. In case of ECS it means event replay with participant position display on Google Maps and intermediate results as shown in Figure 5. It is of interest for organizers to evaluate event design and it is of interest for participants to compare themselves with competitors.

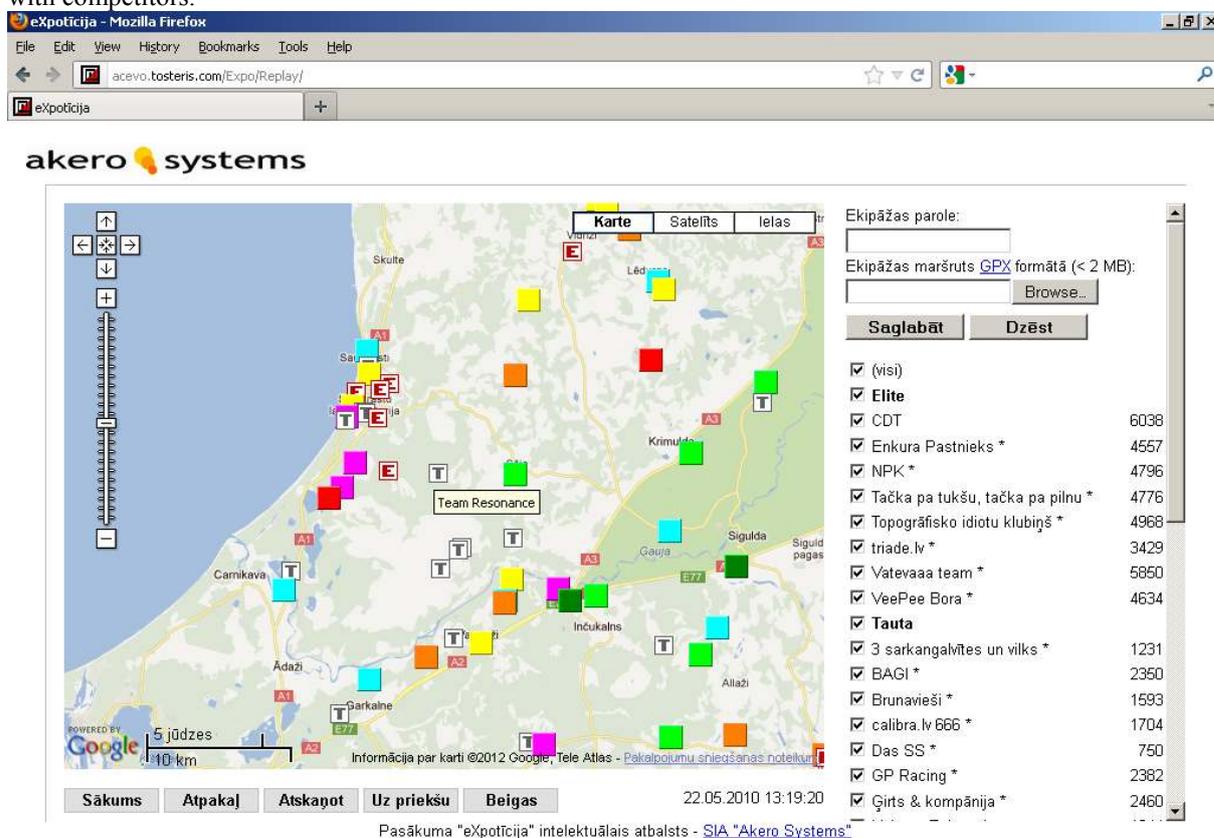


Fig. 5. Event replay in ECS

Communication support in ECS is implemented as messages with individual or group scope that are registered in system and delivered to addressees via e-mail to SMS text messages. In communication from organizers to participants this provides cost and time efficient means to distribute information to large audience. In communication from participants to organizers this provides means to allocate organizer resources for incident resolution on need-to basis without taking a risk of too few or too many appointed contacts.

Evaluation

Several prototypes of the tool kit were evaluated in various stages of research and development in multiple events organized by "Autoliste" and "CDT" over the course of last 5 years. Most of the events were designed based on search of the shortest path in predefined graph algorithm. Some parts of latest events were based on project ideas covered by Bekker et.al. (Bekker, 2010).

First deployment of ECS was in September 2007 in "Autoliste" organized event "AutoChase: Descent" and it was based only on SMS text message exchange between event participants and organizers for registration of

checkpoints found and receiving next tasks to perform. Lesson learned from this deployment – you couldn't rely on mobile operator's SMS system with public SMS sending functionality because it has no correlation with any prioritization algorithms meaning that Message 2 can be received before Message 1.

After fiasco with SMS system authors decided to move ECS development to the system described in Section 2.2 resulting in multiple successful deployments starting from May 2008 and ending on September 2011.

In May 2011 "Autoliste" organized event for its 10-year anniversary during which some of participants were not playing fair game – before start of the event they visited some static checkpoints with the aim to get checkpoint codes therefore gaining advantage over others. That led to disqualification of respective participants and authors decided that system must be improved using embedded checkpoint device which should be small and therefore can be well hidden, turned on only after start of the event and turned off at the end – and all before-mentioned operations should be done autonomously. Also this approach would lead to more precise timing of registered events because prior to such improvement participants could gather multiple checkpoint codes and enter them into ECS all at once. That led to situations when organizers weren't able to determine exact time when participants really visited each checkpoint. Due to usage of embedded checkpoint device's transmitted dynamic code that is later entered into ECS it is possible to determine at least exact time frame when participant visited particular checkpoint leading to more flatten event time scale.

After 3 months of development device described in Section 2.1 was ready and tested by 20 participant teams in September 2011 during "Autoliste" organized event.

In total tool kit was evaluated in 17 events that included:

- 1 event with embedded checkpoint device (static checkpoints were used, too);
- 1 event with only QR code based checkpoints;
- 3 events where participant's submitted GPS track were evaluated;
- 2 events where participants were required to track organizer car that was moving around event's region, and after receiving new task from them find one or more static checkpoints;
- 10 events with only static checkpoints.

Related Work

While performing research and development of the tool kit authors evaluated related work in the field of outdoor and indoor game based learning and activities. Mostly all related work that covered ideas similar to ones described in this paper was intended for children learning experience while ones described in this paper are mainly evaluated in grown-ups environment. Conjunctive thread for related work found and most "Autoliste" and "CDT" organized events are that they (even before employing ECS system) are based on story that ties together various subtasks into one big task similar to ideas described by Verhaegh et.al. (Verhaegh, 2006) except – for grown-ups.

Facer et.al. (Facer, 2004) describes study that explores mobile technologies used in direct interaction with environment and other participants and it can be combined with principles of engagement and self-motivation amongst 11 and 12 years old children. Ideas covered in this work are similar to concept that uses "Autoliste" and "CDT" in their events – competition increases engagement and results in powerful and enjoyable learning and gaming experience.

In some works (Magielse, 2009; Bekker, 2010) were described specific devices created for gaming experience – due to their specialization for children all of them had an impact on audio-visual experience that correlates with Morse code employed in our system. One of recent papers that were found (de Vasconcelos Campos, 2011) described full computer system on participants to fully track, command and control them. For organizers it gives the opportunity to real-time tracking of participant and easily changing their tasks depending on situation.

As commercial analogue to embedded device with limited possibilities can be named Garmin Chirp (Garmin, 2010) – it works together only with Garmin GPS devices and can be used only to point user to exact location therefore requiring additional channel of information passing to participants.

Due to popularity of ECS system in "Autoliste" events, there already exists a clone of it – Xelluc SVS (Makatana, 2011) that currently has been used in 1 event – "Makatana", but event organizers are planning to use it again. Main difference between systems is that in Xelluc SVS have been incorporated "The Settlers of Catan" rules and skipped a lot of features from original ECS system – except visual look.

Conclusions and Future Work

In this paper authors have presented their experiences from designing and developing of heterogeneous tool kit for education and entertainment that consists of software and hardware parts. They have developed and field-tested software system for event organization and management and developed prototype of a microcontroller based embedded checkpoint device with Real-Time Clock for precise timing and EEPROM memory for code storage.

The future work includes further development of software system to adopt it for wider use of event types. Also, embedded device must developed further into next stage where every participant instead of using their mobile phone will have their own device with built-in 2.4GHz transceiver module that will be able to communicate

directly with checkpoint device and with other participants devices. That will enable organizers to adapt tasks more dynamically. Participant devices then can be used as data transportation devices or data mules to transport data gathered by checkpoints and from other participants to some predefined data harvesting point therefore eliminating need for intensive use of GSM network as data transport and saving on event organization costs. From research point of view participant interactions can be analyzed to get social patterns of participants. Due to recent decrease of electronics component pricing authors plan that participant devices will be equipped with GPS modules and data gathered from them can be analyzed to find participant behaviour, shortest path search in predefined environment performed by human and comparison with calculated results (Sadilek, 2010).

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SCREEN RECORDER SOFTWARE OPPORTUNITIES FOR LEARNING MATERIALS DEVELOPMENT

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Abstract: Screen recorder software is a program that captures the user desktop activities and records anything on the computer screen, including the entire desktop, windows, menus, cursor, and video with sound. Screen recorder software allows creating video for learning or demonstration of computer software. Available freeware products are Freez Screen Video Capture, Camstudio and others. Examples of commercial software are Camtasia Studio, All Capture, Instant Demo Screen Recorder BB Flash Back, BSR Screen Recorder4, etc. Using these programs it is possible to create training materials that can be used by anyone without of on-site training session attendance. To easier understand the study material, it is possible to use various forms of data presentation and interactive multimedia materials. From the one side, such material preparation requires considerable time, as well as specific skills, but from the other side, it allows to show practical examples in a better manner. It is possible to place materials developed with screen recording software for a particular course in the e-learning system of Latvia University of Agriculture. Many of the study courses in Faculty of Information Technology (Latvia University of Agriculture) are associated with teaching of application software. Therefore in this study screen recorder software Blueberry Flash Back Pro is discussed for use to create video training materials for open source program GIMP (GNU Image Manipulation Program) learning, also interactive training material developed for the course "Computer graphics" with Blueberry Flash Back Pro software is tested.

Keywords: software, learning, materials.

Introduction

Increasing importance of new forms of learning such as self-study and distance learning is emerging in recent years. These forms of learning are characterized with limited or non-existent communication with a teacher. Consequently, this way of learning increases the role of Internet, CD-ROMs and other auxiliary materials to enhance knowledge acquiring through the content of study course. Distance learning materials also promote information sharing and students self-learning. In the 19th century, German scientist H. Ebbinghaus investigated human memory and effectiveness of different teaching approaches. He discovered that studied materials most rapidly are forgotten right after learning occurs, and this process slows down over time. One of the H. Ebbinghaus finding shows that a person forget more than half of the study material in an hour after study without using any tools or techniques to support information acquisition (Fig. 1).

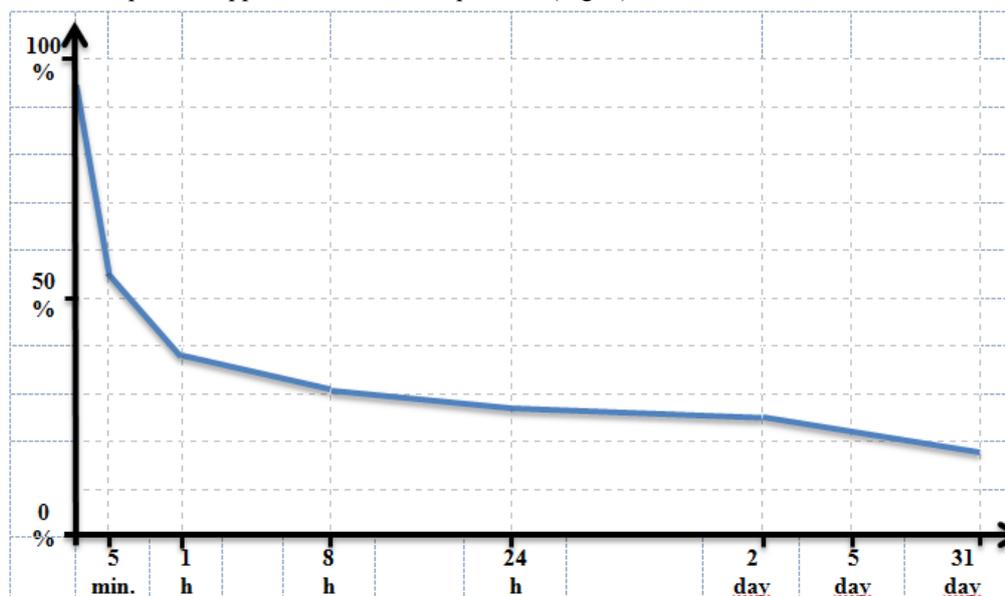


Fig. 1. Memory of the quantity of residual information against time (Urdze T., 2010)

Gathering of information comes to people through visual, acoustic and tactile channels. Various studies have shown that a person perceives and remembers 10 % of information by reading, 20 % by listening or watching, 30 % by listening and watching, 50 % by discussion and almost 75 % by doing practical exercises (Fig. 2).

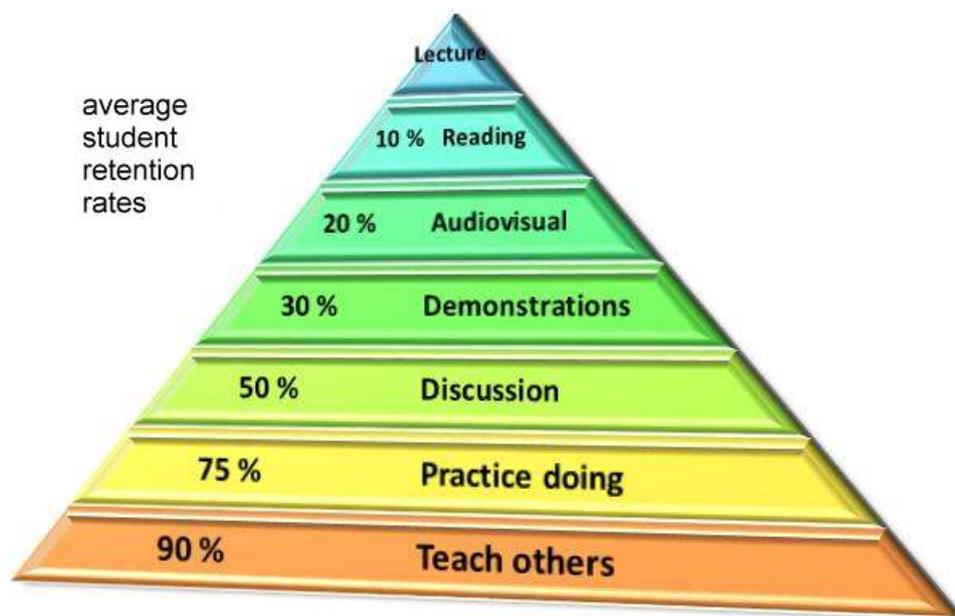


Fig. 2. **Learning Pyramid** (National Training Laboratories, Bethel, Maine)

The use of information technology tools significantly enhances the acquiring of teaching material, and it becomes possible to increase the complexity of the tasks given to students. Screen recording software is valuable for preparation of digital learning materials. By using this software, it is possible to record every screen activity on a computer monitor and save them in image, audio, video, and animation formats. Special effects, offered by software developers, can be valuable to fix user's attention to the particular locations, as well as to form explanations with text or voice comments. There is a wide range of screen recording software available: ranging from free (mostly open source) packages (Freez Screen Video Capture, CamStudio etc.) to partly free, shareware and fully commercial packages (Camtasia Studio, All Capture, Instant Demo Screen Recorder, BB Flash Back, BSR Screen Recorder 4 etc.). These programs help to create learning materials that can be used by anyone without the attendance of on-site training session.

Latvia University of Agriculture (LUA) has the e-learning system. This system is recommended as highly suitable for students who are studying individually; therefore it becomes essential to develop visually attractive training materials for easy caching. Using screen recording software, existing training materials in the different kinds of presentation format can be supplemented with video material. Such type of learning material in LUA is not widely accessible because its preparation requires considerable time as well as specific skills. However, these materials are considered as favourable to originate or improve knowledge by watching excellent demonstration of practical examples during learning.

Materials and methods

The first studies of screen recording software in the Department of Computer systems, Faculty of Information Technology (LUA) was done in 2009 during computer science bachelor thesis framework with objective to develop practical examples that can be used in Adobe Photoshop teaching (Kikiņova, 2009). In 2010, another thesis was written with the aim to provide teaching staff with details about screen recording software for preparing of digital learning materials (Čugurovs, 2010). During the research, both free and commercial software were analyzed. The software analysis was guided by seven criteria: complexity of recording, possibilities of intuitive editing, possibilities to use special effects, the existence of the interactive area, information export options, audio, sound and video quality. Results of the research showed that the most appropriate program for video tutorials and other educational material development could be Blueberry Software Professional company product Flash Back. Flash Back was practically used in other bachelor work (Kūliņš, 2011) to develop training materials for the study course "Computer graphics".

Blueberry Flash Back

Blueberry (BB) Flash Back is a leading screen recording program for Windows, but it is a commercial product that costs 200 USD (BB Flash Back Online Store). After registration, thirty days trial version is available. There are 3 editions of BB Flash Back: Express, Standard and Professional.

Express edition allows to record screen, sound and webcam, share recordings online and save them as AVI and Flash movies. Standard edition adds annotation and Windows Media and QuickTime exporting. Professional edition includes all options from other editions, adds audio and video editing, executable file export, zoom and pan effects. The software has user friendly interface and easily editable video and audio tracks with a time scale (Fig. 3). It is possible to record commentary while the screen is recording or after that, as well as to add text, images and sounds to annotate the movie.

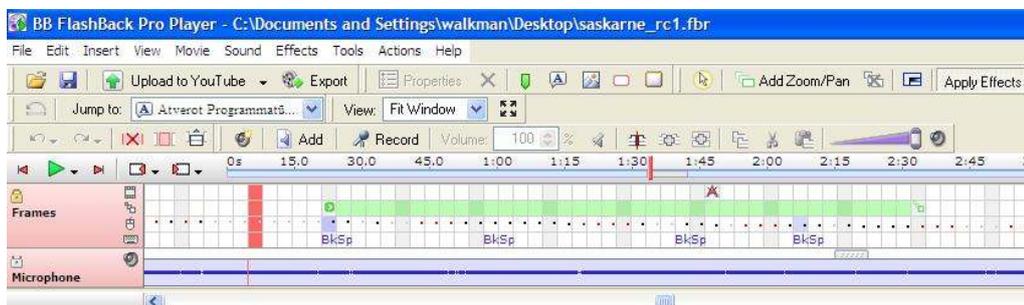


Fig. 3. BB Flash Back Pro video processing

BB Flash Back Pro is compatible with the latest operating systems like Windows Vista and Windows 7. Minimum requirements of the system are:

- Processor: 500 Mhz required, 1Ghz recommended.
- Memory: 256 Mb required, 512Mb recommended.
- Display: 800x600.
- Video Card: 8 Mb memory required, 64 Mb recommended.
- Approximately 50MB of hard disk space for application files.

Video recording

BB Flash Back Pro software provide high-quality video recording, without significant affecting of the computer performance. Video recordings could be supplemented with comments on what is happening on the screen by using a microphone or other audio equipment. The software provides extensive support for file size and quality selection, and export of files in different video formats: Flash, QuickTime, AVI and Windows Media Video.

Video Editing

Screen records can be improved by creating text boxes with comments, making certain fields brighter, inserting images and interactive buttons. Comments can be customized according to specific requirements for message managing and imposing fade-in / out effects (Fig. 4).



Fig. 4. Text boxes with comments

The possibilities of zooming allow to user make focus on any particular part of learning material (Fig. 5).



Fig. 5. Possibilities of zooming

Processing of records includes a feature, which correct errors occurred during screen recording. It is the possibility to insert or remove pauses at a particular moment. During the processing of video, user is able to safely do experiments because undo / redo features allow cancelling of activity.

Interactive learning material

The study course “Computer graphics” includes learning of freeware GIMP (GNU Image Manipulation Program). In order to improve training materials of the study course, videos were created by using screen recording software Flash Back Professional. Beside to traditional learning materials, students were provided with interactive tutorials. For evaluation of study material students were asked to use grading scale from 1 (lowest value) to 5 (highest value). Survey sample size involved 42 students of 2010/2011 and 2011/2012 academic year. The main questions in checklist were:

- Is the study material suitable for self-study?
- Is the study material understandable?
- Is the study material easy to use?

Results and discussion

Data summarizing from questionnaires shows that 43 % of respondents consider prepared interactive training material as well suited for self-study (value 4). 29 % of respondents consider this material as medium suitable for self-study (value 3), while 21 % of respondents find it remarkably suited for self-study (highest ranking value 5). Only 7 % of respondents are not satisfied (value 2) with the study material. None of respondents selects the lowest-rated response (Fig. 6).

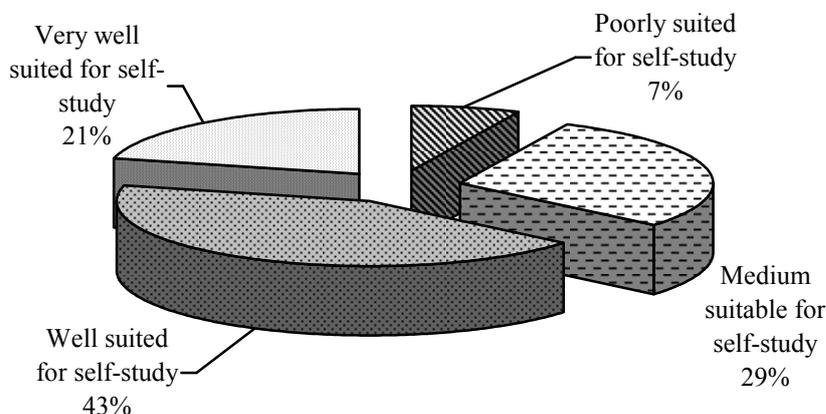


Fig. 6. The training material suitability for self-study

Responses to question about how easy is to use the interactive learning material show that 50 % of respondents rate it as easy to use (value 4), while 29 % of respondents rate it as particularly easy to use (value 5). 21 % of respondents believe that training material is moderate friendly (value 3) to user. None of the respondents selects lowest rating values as 1 or 2 (Fig. 7).

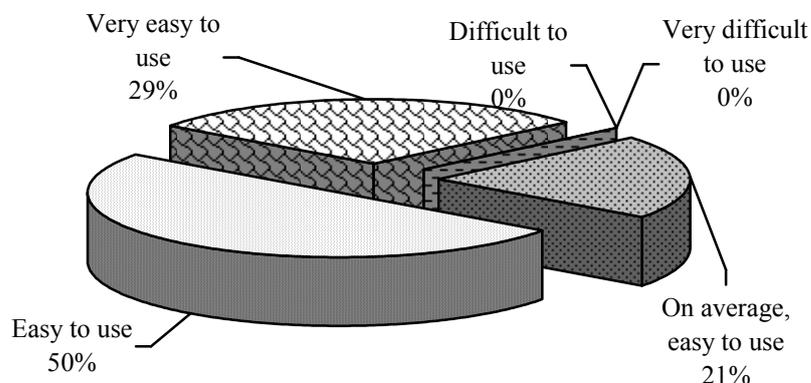


Fig. 7. Simplicity to use the learning material

Personal interest is one of the most powerful driving forces in cognitive processes. Therefore, survey includes question to find out if the learning process with interactive tools application is attractive for students. Remarkable proportion of respondents describe interactive training process as particularly interesting or

interesting, respectively 36 % of respondents select value 5 and 36 % of respondents select value 4. 14 % of respondents believe that the training process is moderately interesting (value 3), and the same number of respondents answer that such learning process is not interesting for them (value 2). None of the respondents selects the lowest rating value (Fig. 8).

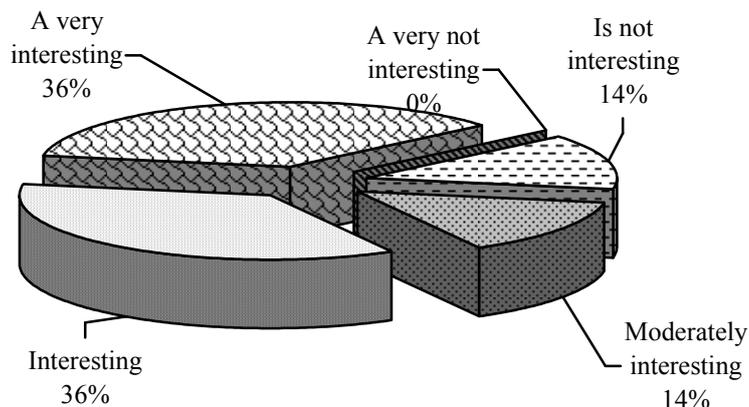


Fig. 8. Student's personal interest in the study process

Respondents were also asked to evaluate how easy is to use the training material. Data analysis results show that 50 % of respondents say the training material as has been understood (value 4), whereas 29 % of respondents describe training material as almost understandable (value 3), but for 21 % of respondents, it is well understandable (value 5). None of the respondents selects lowest rating values as 1 or 2 (Fig. 9).

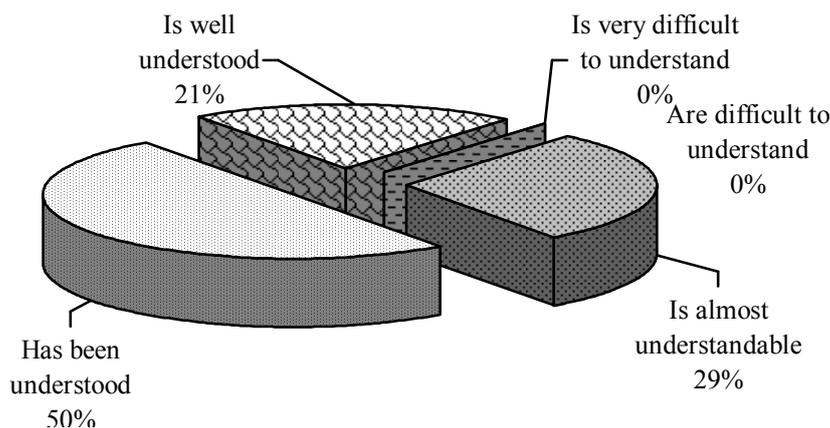


Fig. 9. Student's understanding of the study material

Finally, the survey shows the training type opportunities for other software learning. 50 % of respondents prefer interactive learning for other software study. 27 % of respondents give preference to learning with video training. 9 % percent of respondents wish to learn other software by using the text books. 5 % of respondents highlight the audio training opportunities.

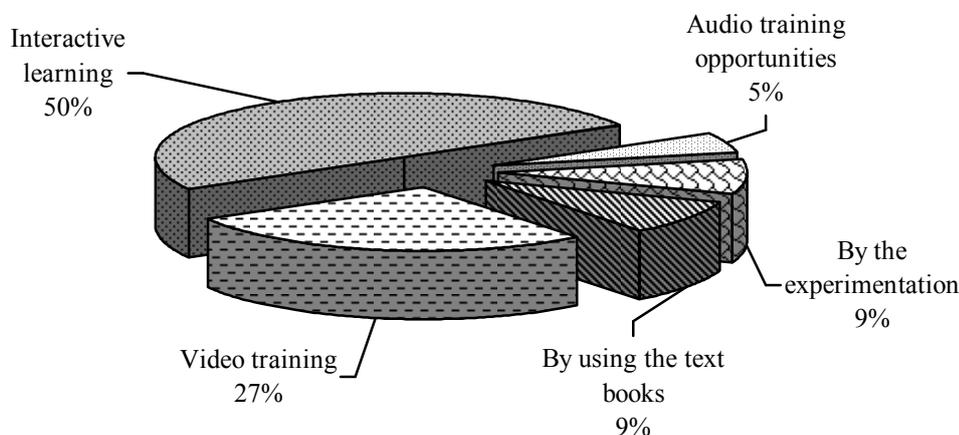


Fig. 10. Preference of training material type for other software learning

It is important to note that respondents emphasise exploring of the interactive learning tool for GIMP software learning as interesting process and well suited for self-study. It allows concluding that similar materials could be successfully prepared for other software teaching.

Conclusion

1. Screen recording software BB Flash Back Pro is suitable for Faculty of Information Technology study courses material improvement with videos or interactive video learning materials.
2. BB Flash Back Pro is easy to use software that allows preparing of e-learning materials in more productive manner thanks to user friendly graphical interface.
3. Process of interactive training material preparing with BB Flash Back Pro is time-consuming. Each frame with visual information, as well as areas suitable for effect or interactive element adding should be carefully reviewed.

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ICT IN AGRICULTURE

APPLICATION OF BEE HIVE TEMPERATURE MEASUREMENTS FOR RECOGNITION OF BEE COLONY STATE

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Abstract: *Rapid improvements in modern temperature measurement systems and information technologies overall led to a possibility for temperature data to be used to monitor individual biological objects within the whole biological system. Beekeeping is one of the agricultural sub directions where information technologies and precision agriculture methods can be used too. In the field of beekeeping temperature measurement system can be adapted for the individual bee hive monitoring and maintenance, substituting the traditional monitoring methods. The main objective of bee hives temperature measurements is to monitor and control bee behavior and activity using an individual access to objects. Bee hive temperature measurements can provide beekeeper with continuous, real time data about the state of the bee colony. The main activity parameter for bee colonies is temperature, higher the temperature more active is bees. Based on this parameter beekeepers can make important conclusions and if needed perform some additional actions. Mainly monitoring the bee colony temperature is needed to find out if colony is started the brood rearing process and in case of need to slow down this process, because too early start can lead to the death of the whole colony. Based on author achieved measurement results during the passive wintering period, while bees are kept in the specific wintering building, it can be concluded that it is possible to precisely find out the date, when the bee colony died and find out the dates of the potential start of the brood rearing process.*

Keywords: temperature measurements; state recognition; bee colony monitoring.

Introduction

Bee hive temperature measurements can be used to understand and to monitor the honey bee colony activity and changes in it behavior. Many researches were connected with the bee hive temperature measurements and various researches using the available information and sensing technologies tried to complete the measurement task. Mainly bee colony temperature were monitored while bee hives were placed outside in open environment, but our research and this paper is concentrated on bee colony state recognition during the passive wintering period, while bee hives are kept in closed environment in special bee wintering building. In our case we artificially made the needed external environment with constant air temperature.

Activity and behavior features of bees have been as investigation object for many researches, starting from far 1926 when W.E.Dunham measured temperature inside one bee hive using 8 thermometers. Using this thermometers bee hive temperature was measured each hour. As a result graph of average bee hive temperatures were obtained (Dunham, 1926). Already at that time it was concluded, that air temperature affects the bee activity much more than other environmental parameters, such as humidity and gas composition. Also from that measurements, were obtained data that showed, that in active brood rearing state bee colony temperature increases till 30°C.

One more research were made in Rumania in 2004, when hive temperature changes, humidity and dew point were registered using the three digital sensors. Research aim was to develop information system for real time parameter monitoring. Monitoring task was to find out adverse effects on bees and to develop preventive methods (Vornicu and Olah, 2004).

Scientifically valuable research took place in Riga, Latvia in 2000, when E.Stalidzans developed the bee hive temperature monitoring system. The aim of that system was to monitor hive temperature changes during the whole year to determine the start and end dates of the bee activity states (Stalidzans et al., 2002).

One more interesting research was made in Jelgava, Latvia in 2008, when J.Meitalovs developed bee hive humidity and temperature measurement system for determination of honey bee pre swarming condition. System consists of temperature and humidity sensors network, control application and video monitoring module (Meitalovs et al., 2009).

Paper author have made bee hive temperatures measurements with main aim to determine honeybee colony developmental stage and to understand if temperature changes really corresponds to the changes of the bee colony activity state. Main feature of this research is that during the measurements bee hives were kept in artificially made environment (wintering building).

Bee wintering buildings practically in Latvia are not used. Observations in "Vecbebru" beekeeping technical college shown, that heated wintering building in Latvia are not economically beneficial (Ārgalis et al., 1970). But in Canada these special buildings are successfully applied (Furgala and McCutcheon, 1992; Fingler and Small, 1982).

With the development of wintering building installation technologies, the main aspect goes to microclimate regulation and control (Fingler and Small, 1982). A rational building construction and installation calculation for Latvia region also is made (Kristapsons et al., 1996).

Looking at such building application worldwide, it can be concluded that they are used in such climatic conditions, where winters are especially harsh, where bee wintering in open air ends with very high percent of dead bees. But very low temperatures are only the one factor, another one is often temperature changes from plus to minus degree. This can be seen also in Latvia climate region.

Recognition of the bee colony state

Author proposed model of the bee colony activity state recognition is demonstrated in Fig. 1:

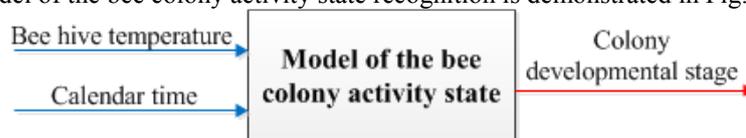


Fig. 1. Model of the bee colony activity state recognition

This model can be used during the whole bee colony life cycle, but information that can be mined from temperatures data differs from calendar time. It means, for example, that same data in summer and in winter shows different information.

During the passive wintering process based on temperature data it is possible to distinguish three bee colony activity states (see Fig.2):

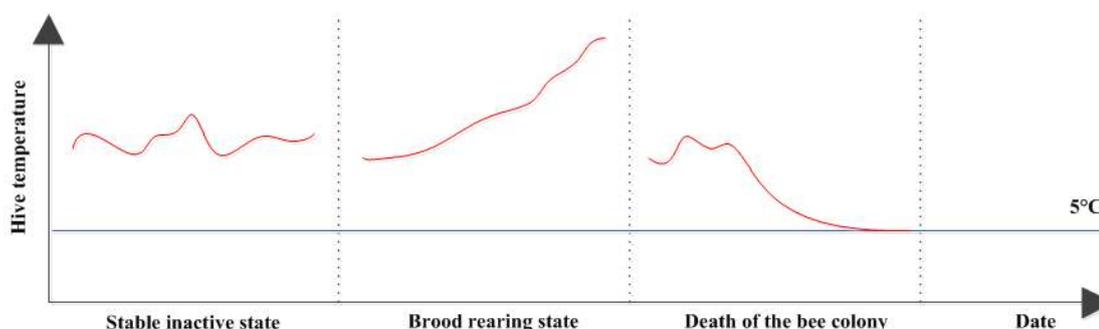


Fig. 2. Three honey bee colony developmental stages during the wintering process

Based on temperature data it is possible to conclude if the bee colony is in a passive/inactive state, if the brood rearing process has started and if the bee colony is still alive. This information is very useful for the beekeeper, because it is needed to monitor the brood rearing process, and if this process has started too early it is needed to slow down or stop this process. Premature start of bee breeding in the winter can cause high energy consumption of the bee colony that, in turn, can lead to a possible death of that colony. That is the main risk factor during the wintering in the special building.

Experiment configuration

The main microclimate parameter for bees is temperature. Temperature is an important factor that influences the start of brood rearing in the winter (Seeley, 1985; Mattila, 2001; Mobus, 1998).

Main feature of author research is that during the measurements the bee hives were kept in artificially created environment with controlled microclimate. Bee hives were placed in special wintering building, where an automated control system was used to keep inside temperature at a constant level. According to the literature and practical investigations, desired temperature band for bees during the winter is between 3°C and 8°C (Jeskov, 1983). When the temperature is outside of this band the food consumption of bees increases (Fig. 3).

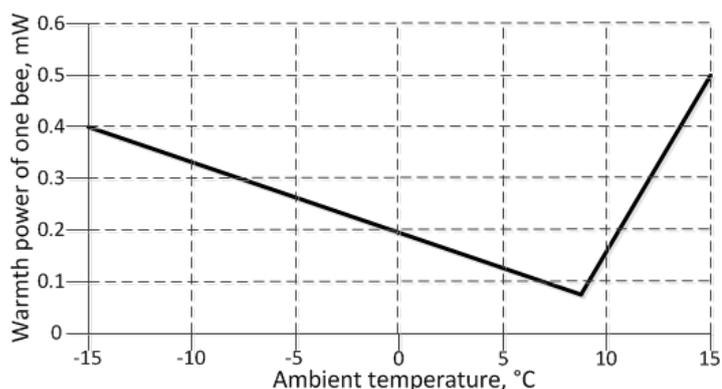


Fig. 3. **Dependence of bee warmth power from ambient temperature (Jeskov, 1983)**

The honey bee wintering building is a building sized 6,25m×4,00m×2,40m made of sandwich panels with wall thickness of 80 mm and the roof thickness of 100 mm (Osadcuks and Stalidzans, 2008) (Fig. 4.):



Fig. 4. **Honey bee wintering building**

To control the building temperature it is needed to develop automatized control system. In author case building temperature control was accomplished by a PLC device (Siemens S7-200 controller with CPU 224XP). PLC is a digital computer used for automation of electromechanical processes and is designed for multiple input and output arrangements. PLC controlled other needed equipment in the wintering building. The controlled equipment were: air recirculation fan for homogenizing the air and its temperature inside the building, cooling ventilator system, fresh air fan and electrical duct heater (Zacepins et al., 2010).

The main task of the system is to control the temperature changes in the wintering building. Inner temperature is measured, using the Siemens Sitrans TF2 sensor. Duct heater is functioning using the PLC integral PID algorithm. The air is heated till the target temperature is reached. PLC user program is written using the Ladder Diagram programming language (Zacepins et al., 2010).

Author did practical experiments obtaining the bee hive temperature measurements in closed environment created in the wintering building. In this building up to 30 bee hives were placed. Each hive was equipped with small digital temperature sensor (Fig.5). All sensors were sequentially connected with Temp08 interface device, while it was connected with the end PC using the COM port. All data from the sensors were transmitted to the PC database (Zacepins et al., 2011).



Fig. 5. **Developed bee hive temperature measurement system in wintering building**

When developing such temperature measurement systems one of the main aspects is to choose the right sensor and sensing technology. In our case it was possible to use both wireless and wired solutions. Wireless solution is a modern one, but it is needed to evaluate also other factors. For example in author situation system had to work up to 4 month without maintenance and it was hard to find wireless sensors with so high battery capacity. Author have developed wired temperature measurement system. Small ds18s20 sensors were used for temperature measurements. These small sensors were soldered to a small plate, granting wire connection. Then sensors were sequentially connected one with another using the 1-wire network protocol. 1 wire protocol was developed by Dallas Semiconductors Company. With such network it is possible to connect different types of devices and sensors. Classic 1-wire network connection scheme is shown in Fig. 6:

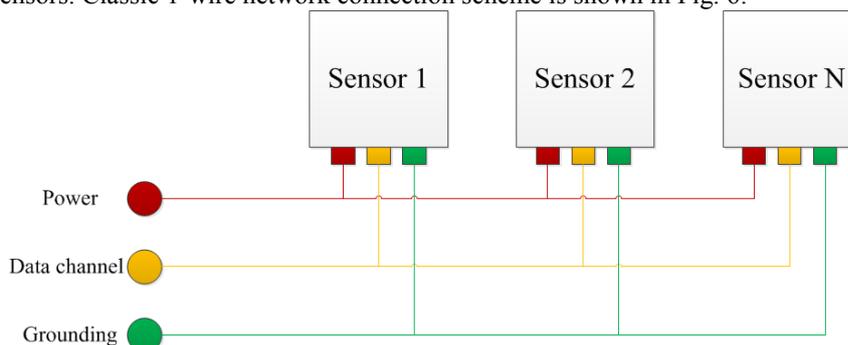


Fig.6. **Classic 1-wire network connection scheme**

1-wire system allows to use almost unlimited count of sensors, allows to decrease cable length, exclude the impact of the line length to precision of the result (Baums et al., 2004).

When developing large 1-wire systems it is important to create the network correctly already during the design stage, otherwise some problems can occur during the data harvesting process.

For data saving and analysis all sensors were connected to the special interface device Temp 08, which transmitted all the data to the end device (PC).

Results and Discussion

Author experimental temperature measurement system consisted of 34 sensors, where 30 sensors were placed into the bee hives, 2 sensors measured inside temperature of the wintering building and 2 sensors – the outside air temperature.

During the data analysis stage, when all temperature data were summarized in MS Excel using the pivot tables and pivot charts author received many temperature data curves that were almost ideally reduplicated proposed model of the bee colony activity state. Analyzing the achieved measurements author founded examples for each bee colony activity stage.

Three graphs (Fig. 7, Fig. 8, Fig. 9.), demonstrates examples of practical results with some single bee colony activities.

Figure 7 demonstrates situation when a whole bee colony died. This conclusion can be made at the point when honey bee hive temperature sharply decreases and converges with external air temperature. Unfortunately for the beekeeper, it is not possible to predict that bee colony will die – it is only possible to conclude the fact when the colony is already dead. To someone this information seems to be unnecessary, but making survey to Latvian

beekeepers they approved, that knowing the count of dead colonies during the winter is useful. It can help to prepare and to predict economic situation, which is likely to appear in summer.

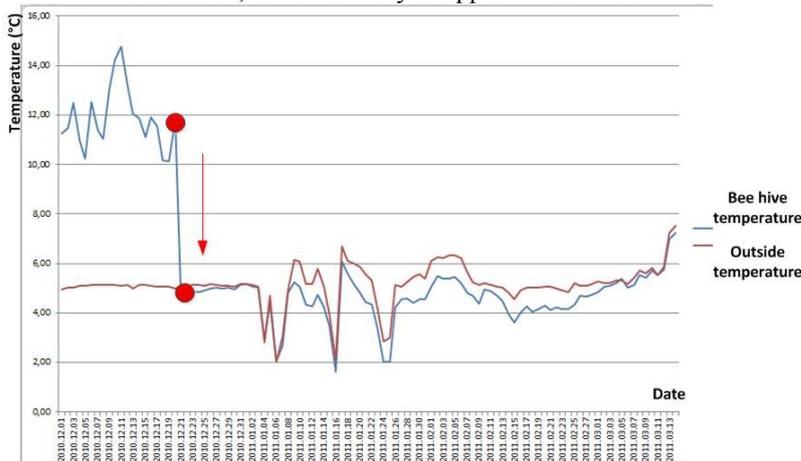


Fig. 7. Dead of the bee colony

Figure 8 demonstrates situation when bee colony were in passive state. This conclusion can be made when honey bee hive temperature is not fluctuating. In this state the bee colony food consumption is optimal.



Fig. 8. Passive state of the bee colony

Figure 9 demonstrates situation when bee colony were in brood rearing state. This conclusion can be made when honey bee hive temperature is starting to increase. For the beekeeper it is very important to find out when the brood rearing process starts and if it is needed to slow down this process.

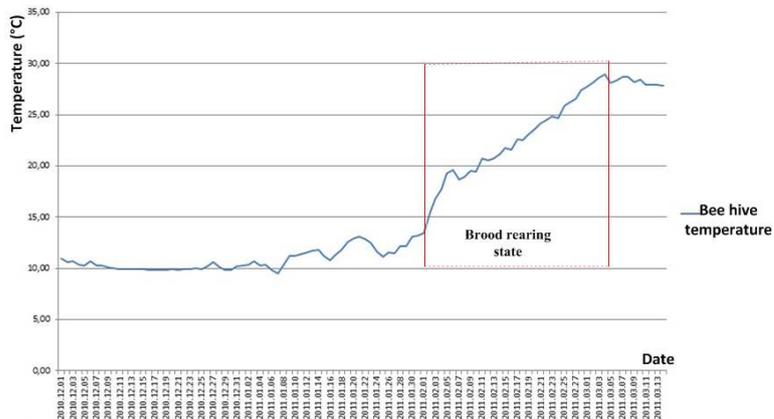


Fig. 9. Brood rearing state of the bee colony

Conclusions

Bee hive temperature measurements offer possibility of collecting data about bee activity and behavior in a continuous, real time and automatic way. But of course while monitoring bee colony processes it is not possible to fully replace the beekeeper "eyes", it remains as an important end decision maker.

Author have made temperature measurements to monitor the activity of bees inside each individual hive during the passive indoor wintering period in a closed environment as it is honeybee wintering building, where it is possible to grant stable and convenient microclimate conditions for bees. In passive wintering period it is important to mark such events as the death of the bee colony and have up to the date information about the state of the brood rearing process. The process of intensive brood rearing leads to the increased consumption of food and to the waste of energy. As a result, the whole bee colony can die. The rapid increase of temperature is a signal of a potential start of intensive brood rearing.

Practical results showed that it is possible to obtain the needed information during the temperature measurement process with high precision.

The developed temperature measurement system can be used also in other agricultural fields where it is needed to make some precise decisions based on temperature data.

Acknowledgment

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AUTONOMOUS PRECISION AGRICULTURAL DYNAMIC COMPLEX SYSTEM

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Abstract : For the spade works in precision agriculture more often the robots are being used instead of men. Therefore there is need for unified standard to manage the robots, to create software level plans and communication environment modules. The new unified standard would be made on basis of agroXML updated standard. The Robotic Multiagent system robots work is depending on sustainable Software Multiagent system software plan. In the article Software Multiagents system and Robotic Multiagent system components and their cooperation ability and tasks are reviewed. Precision Agriculture Dynamic Complex System main task would be long term planning and communication management between Robotic Multiagent system and Software Multiagent system is reviewed. This would be an innovative solution to combine both Multiagent systems into one common system.

Keywords: Precision agriculture, multiagent system, complex system, schema.

Introduction

In little more than a decade, precision agriculture has emerged from a concept to production-scale, multiple-task operations implemented on a field-by-field basis. As precision agriculture is developing new necessities to develop technologies arise. One on main issues is to hand over the precision agriculture decision making to software to analyze data quicker and more precisely and reach better result in shorter term. By using Multi agents' qualities such as autonomous deliberation, planning and communication, Robotic Multiagent system (RMAS) and Software Multiagent system (SMAS) may solve autonomously the delegated tasks with different methods that are reviewed in the articles and are presented by authors as a schema. The cooperation of both Multiagents would be promoted by the Precision Agriculture Dynamic Complex System (PADCS), which main task would be long term planning and communication management between RMAS and SMAS is reviewed. This would be an innovative solution to combine both Multiagents systems into on common system.

Precision agricultural tools

Precision agriculture needs information as digital crop maps with underlining database in which stores attribute data in different layers, which consist of different crop information like weed management, precision water management, nutrient management, crop diseases management, parasites management and many more (Shrinivasan, 2006). Each of this information is stored at different layer. Layer can be used to for additional data storage, retrieval, queries execution for analyses. Analysis is used for decision making to increase crop productivity. This is done by precision agricultural dynamic complex system (PADCS) help which is in this paper is described as schema in results.

Global Positioning System (GPS) is used to get accuracy from trilateration process for agricultural machinery. Agricultural machinery (AM) catch the coded signal from several satellites and in AM built GPS unit receives that and recalculates latitude and longitude. With this technology agricultural machinery knows crop field dimensions accuracy from several centimeters to 3 m (Tiangang, 2004).

For data calculations, storage, manipulations, decision making is need for *computational device* like computers, microcontrollers and many different auxiliaries for systems demands and performance goal (Shrinivasan, 2006).

Data is important component of PADCS functionality it contains every necessary information about crop, AM (statuses, learning, financial calculations, environment, planning and many other information). Data in PADCS have many different standards and interpretations (binary, XML, different communication standards, Java, GIS, analog type and different other kinds) (Yoshida et al., 2008).

PADCS can work with *reference maps* (geographical are graphical representation), choropleth maps (illustrates attribute data values in colored polygons, line and points), isoline maps (illustrates data as contoured maps). All maps are viewed and made for GIS software (Chen et al., 2010). Maps are used for analyses and for decision making processes (Base, 2006).

PADCS use analog and digital *communication systems* to communicate between Multiagent systems and their agent components. These communication systems could be internet, wireless, sensor networks, GPS signaling, local communication systems as Bluetooth, GSM network and different new technologies. Basic communication language needs to be considered as improved agroXML language based standard (Doluschitz, 2009).

Multiagent system

Multiagent system could be described as homogeneous system (property of a team of agents whose members are exactly the same both in the hardware and in the control software) and heterogeneous system (property of a team of agents whose members have a difference either in the hardware devices or in the software control procedures). In Multiagent - system must easily achieve robustness, in acceptable time period make deliberation processes and calculate the agents behavior plan as also provide the learning processes using historical information about Multiagents system behavior and influencing environment. (Pentjušs et al., 2011; Wooldridge, 2009).

RMAS system components could be stationary or mobile devices (agricultural machinery) and often made as homogeneous systems architecture. RMAS system uses reactive deliberations processes and has only execution and data mining functionality for soil fields.

SMAS system components could be software systems which are located on some server, computer or different calculating machine. On computer should be installed operation system like UNIX, Windows, Linux (Stallings, 2009) or similar, to provide necessary SMAS functionality.

All Multiagent systems (RMAS and SMAS) should have potential work on JAVA based environment (Bruegge, 2009).

Precision agricultural dynamic complex system

Dynamic complex system involves numerous interacting agents whose aggregate behaviors are to be understood. Such aggregate activity is nonlinear, hence it cannot simply be derived from summation of individual components behavior.

Close relationships between RMAS and SMAS components in PADCS, may be the reason, when failure in one in these components can lead to cascading failures which may lead to catastrophic consequences on the PADCS system functionality. It can be difficult to determine the boundaries of a PADCS complex system. It works in stochastic dynamic continuous and open environment where boundaries are unlimited (difficult to determine boundaries).

PADCS is an open system, which continuously interacts with its environment. The historical records of a PADCS may be important for future changing, learning algorithms and deliberation processes. Because PADCS is dynamical system, it could change its functionality over time, and prior states may have an influence on present states (complex systems have a memory). The RMAS and SMAS components each of them are multi-agent systems where leader role takes PADCS. RMAS and SMAS are different kind of sophisticated system, which have very different goals and functioning systems (Complex systems may be nested). PADCS coupling rules, the dynamic network of a complex system small-world or scale-free networks, where can be found many local structured interactions and a smaller number of inter-area connections (dynamic network of multiplicity).

PADCS exhibit behaviors that are emergent, minor systems basic processes of behavioral outcomes and activities may be significantly affecting PADCS as whole (produces emergent behaviors). Small changes in PADCS, RMAS and SMAS system interaction may cause a large effect, a proportional effect, or even no effect at all. In linear systems, effect is always directly proportional to cause.

Relationships contain feedback loops (relationships are non-linear). Relationships contain negative (damping) and positive (amplifying) feedback loops in PADCS (Bar -Yam, 2003).

Results and discussions

Precision agriculture consists of several different computational processes like GIS – geographic information system, different types of digital maps, many statistics based on collected digital maps data, GPS for coordination of vehicles movements, robotized field machinery, arable information data base, different type agents properties, knowledge, deliberation mechanisms, communications and decisions database, finances calculation block, mobile homogeneous agents refueling, raw materials storage base. These computational processes together forms autonomous precision agricultural complex system based on multi-agents technology (Shrinivasan, 2006). RMAS and SMAS technologies is PADCS system components, which allows for us to add more modules to this system as technologies grow and new researches would be found.

Robotic multiagent system

RMAS *Information agent* - it should have functionality like: information collection from robotic agents, making deliberation process, learning, calculations of financial projections and providing access to SMAS interface. Information agent should have following concepts: (Fig.1 a).

1. Persistence - information agent must have its own threads and schedules. It can start and shut down them having no impact on other types of agents. Have access to scheduler / database where stored information about environment agents, scheduling actions.
2. Social ability – makes interaction with environmental agents collecting requirements, needs, dimensions, and deciding of decisions for actions of robotic agents. Information agent provides an interface for other agents with internal RMAS and external services of PADCS.

3. Activeness - information agent don't demonstrate activeness behavior. It is a stationary located agent in environment.
4. Reactivity - information agent acts like governor agent for other agent types by taking requests and providing all necessary deliberation processes. Have no mobility opportunities.

Environmental agent – is spatial agent, where is stored crop area processing actions, spatial information, results of financial projects and statuses. It should act like information manager from robotic agent and information agent. Environmental agent tries to coordinate conflicting processes between different robotic agents, get and operate with rules that restrict possible settings for environment parameters and provide data about environmental agent environment formation. Environmental agent should have following concepts: (Fig.1 a).

1. Persistence - environmental agent must have its own threads and schedules. It can start and shut down them having no impact on other types of agents.
2. Social ability - environmental agent interacts with robotic agent to acquire stored crop field data and require raw information via sensors. Acquired data and selections, requirement and identity environmental agent sends to information agent, but information agents send them to environmental agent as calculation results.
3. Activeness - environmental agent goal - directed behavior goal is to make crop field information calculations and raw obtained data storage.
4. Reactivity - environmental agent collects environment formation and results of financial projection data via Robotic agents and information agent calculations results, responds to changes that occur in it by sending messages robotic agents.

Robotic agent - it is autonomous agricultural machine, which makes crop field cultivation, via sensors acquires crop field information, and provide with it environmental agent and then it gets information agent. Robotic agents operate with information agents made decisions of future robotic agent's behavior. Robotic agent should have following concepts: (Fig.1 a).

1. Persistence - robotic agent has its own threads and schedules, and them can start and shut down by self or information agent based on made planning and deliberation calculations.
2. Social ability - robotic agent collects crop field environmental information and provides with that environment agent and information agent. Robotic agent acquires environment formation via sensors. Robotic agents goal based behavior is calculated and controlled by information agent.
3. Activeness - robotic agent has reactive behavior for crop field cultivation processes. It is mobile agricultural autonomous machine.
4. Reactivity - robotic agent perceives current environment via environmental agent and takes a respond to environmental change using information agent calculating obtained raw crop field environmental data.

Software multiagent system

Applications (Fig. 1 c) are important models in SMAS. GIS agent is used for attribute data collection, visual representation and analyses. With Multiagent - system approach and deliberation algorithms for calculating equilibriums for individual SMAS agents there should be following concepts (Fig 1 c):

1. Data interpretation – GIS data interpretation is made through data storage systems like local SQL database or public accessible database of stored farmer's crop land data. Information could be like different GIS useable maps and different type of models for prediction and background processes for data integration from publically accessible data storage places.
2. Data collections – GPS systems provides positioning information for crop field and crop field dimensions. Through RMAS information agent with PADCS systems approval information pass to SMAS GIS agent where it verify that. Sensing technologies like remote sensing systems (aerial photo, Satellite imagery), proximal sensing (in field soil sensors, in field crop sensors) are used to get real time information for RMAS environmental agents planning and deliberation process as attribute data. Local database information which use background processes for data collection also provides with some real time necessary information. For data collection process can be used different communication technologies like wireless, Ethernet, sensor networks, Bluetooth communication between Robotic agents, GSM network for bigger crop fields.

GIS (Fig. 1 c) system is used to get accuracy on crop field treatment and different type analyses and financial benefits calculations. For RMAS environmental agent GIS provided information is very important for deliberation and planning processes, which controls robotic agents reactive behavior for crop land treatment should have following concepts (Fig 1 c):

1. Data interpretation – GPS data interpretation is made through RMAS robotic agents who pass this data to RMAS environmental agents. Data is stored in database and provides SMAS GIS agent with that, if PADCS system approves that. Can be used local positioning systems on crop field as GPS system. Data is interpreted by SMAS GIS agent as different maps, models. GIS systems data main goal is to make an accuracy of analyses, deliberation, planning and financial calculation processes.

2. Data collections – GPS systems which use RMAS robotic agents to calculate positioning on crop field and crop field dimensions. Through RMAS information agent with PADCS systems approval information pass to SMAS GIS agent where it verify that.

Application components (Fig. 1 c) is used to store specified information about crop field data or even make additional deliberation or planning or calculation processes, data storage or new improvement models functionality verification and they should have following concepts (Fig 1 c):

1. Data interpretation – is necessary only for RMAS and PADCS. Graphical interpretation is not necessary. Can be used data storage system, computational software, different tools and improvement technologies what can appear on future.
2. Data collections – Application components can use wide range of communication technologies to communicate with other agents provide new data or make additional calculations with new type data increasing PADCS system efficiency.

PADCS (Fig. 1 b) is complex system collaborates with two Multiagent systems RMAS and SMAS. It provides interface between them two and has main goal is to control between these two Multiagent systems information flow and make comparison on both deliberation, planning and goal – based behavior to increase efficiency of crop field treatment and getting better financial aspects. Makes interface between complex system and human to inform status what is happening in PADCS. Human have opportunity to make changes in plans and PADCS tries to implement these changes in system activity.

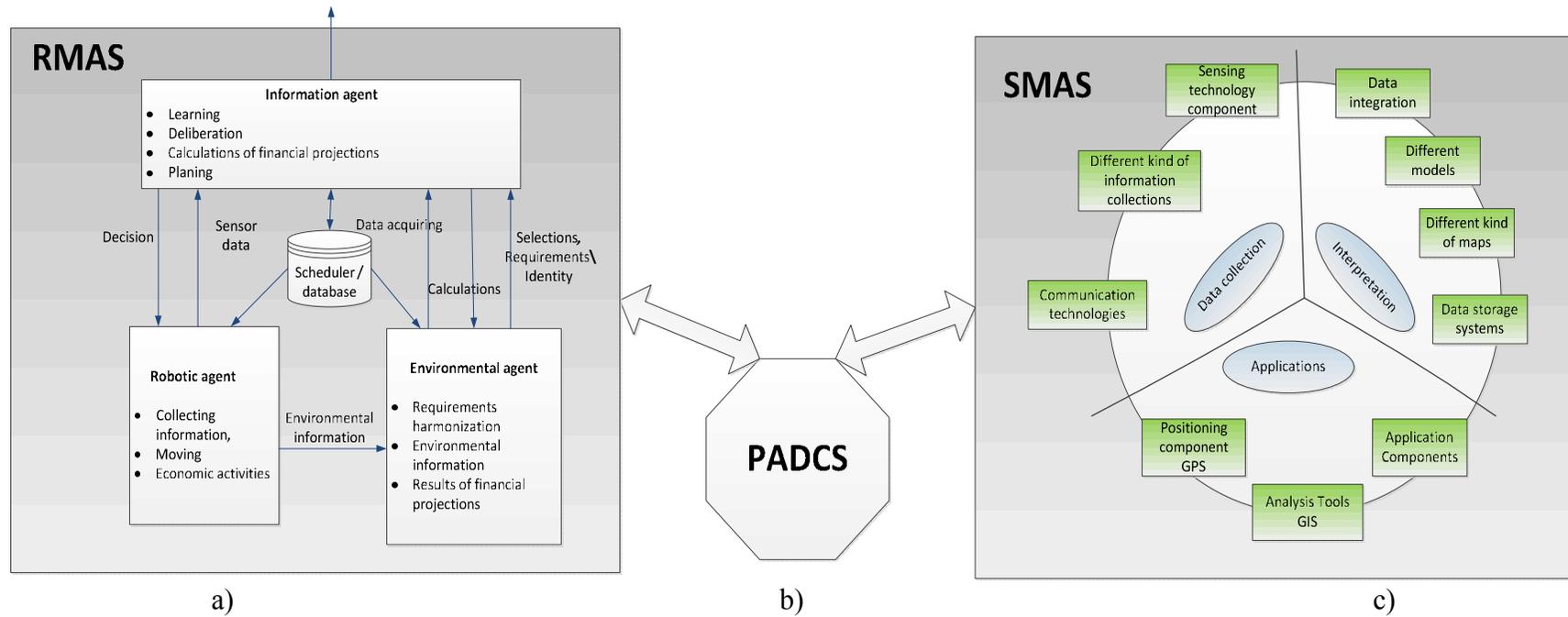


Figure 1. Precision Agricultural Dynamic Complex System

Conclusions

PADCS schema must be used for further research in agent's simulation tools, on decision making mechanisms creation, on RMAS prototype, SMAS prototype, XML communication based system, on learning mechanism creation, on preferences learning and decision making in conflict resolutions.

Implementing PADCS in real farm makes agriculture process as autonomous process, where robots can do their duty without human interactions, planning, deliberation, calculations and analyses is made by PADCS. Only human system interaction is made by human interface where it can find out PADCS status, plans and change each model goal-based behavior changing PADCS plans.

Deliberation, planning and calculation algorithms must be researched and tested on PADCS system, to increase its efficiency and time consumption in these processes.

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DEVELOPMENT OF GREENHOUSE MICROCLIMATE CONTROL SYSTEM PROTOTYPE

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Abstract: The aim of the paper is to develop Matlab Simulink model that is substantiated by mathematical methods, in order to carry out further investigations of the climate control in the greenhouse and elaboration of a practical solution. Greenhouse environment is complex and it is necessary to understand greenhouse environment to create advanced models to describe nature processes and ensure effective crop production process. Our research is dedicated to convergence of mathematics, modeling and programming. Inaccuracy in system building methods, methodics and methodology can lead into more expensive system building and unreasonably difficult system maintenance. It is necessary to use structured methodics that have been developed by other researchers and field professionals. This research is not limited by greenhouse, nature processes is the same in different applications the same mathematical methods can be applied to describe similar differential equations of the processes. Author's recent studies in operating systems field show that such system can have client – server model utilizing innovations in hardware and software development. (Campi, N., Bauer, K., 2009) In the future such system can be integrated into a cluster with bio-diesel plant, ethanol still, methane biogas digester to improve efficiency and production of bio-gas and bio-diesel, co-generation unit to improve energy efficiency and plasma arc waste disposal to decrease environment pollution. Some ideas to build greenhouse system can be borrowed from smart house systems. (Goodwin S., 2010) Hardware interfaces and data transmission protocols are the same. One of the proposals for an ultimate goal is to build cloud system which can be accessed from anywhere on the planet to control production processes in the factory facilities.

Keywords: Microclimate, Matlab, Control system, SCADA

Introduction

In system building certain levels exists as shown in fig.1. The lowest is the statistics and analysis, main objective of this process is to gather data from sensor network and analyze it. On process recognition stage using data from previous level we can make one or another decision on how to control heat, humidity or light process using programmable logic controller or personal computer or custom electronic solution. When it is done we can model our solution in Matlab or other alternative. And finally mathematical model can be optimized to gain better output results. The quantity of the quality information increases in each level. Nowadays science mostly is datacenter-science, scientist summarize theory, carry out experiments and simulate results. Using process data exploration and data mining (data obtained from instruments, simulated results and data collected from sensor networks). (Stalidzāns and Osadcuks, 2008) Also if we want Latvian agriculture to be able to compete for market share it is necessary to provide economically verifiable product at the lowest cost possible and the quantity is giving huge impact on the output revenue and market coverage. Such manufacturing production systems are the necessary part of modern rural development in giving sustainable and predictable profit ground for businesses. Synergy of Economics, Information technology, Automation can give boost for Latvian economics. In cooperation with other professionals options can be varied for example minimized pollution from production processes or minimized energy consumption with maximized production output from greenhouse production plants. So before modeling data sensor network must be deployed and result must be summarized in database for data further analysis.

In our opinion modeling can be divided into three stages:

1. Conceptual model
2. Control system model
3. Numerical process model

• Conceptual model

This is the entry level of modeling on that stage scientist must have perception of the control process physics. Figure 2 shows greenhouse control system functional model input data, output data and external perturbations. It was assumed that the heat exchange process interfere with gas to gain more accurate greenhouse model. It is also necessary to control CO₂ emission and consumption for biological process monitoring. Conceptual model represents 'concepts' (entities) and relationships between them. Conceptual model can be developed using various notations, such as UML or object-modeling technique (OMT) for object and their relation modeling. Also UML model enables to generate source code this option can be very useful in system development.

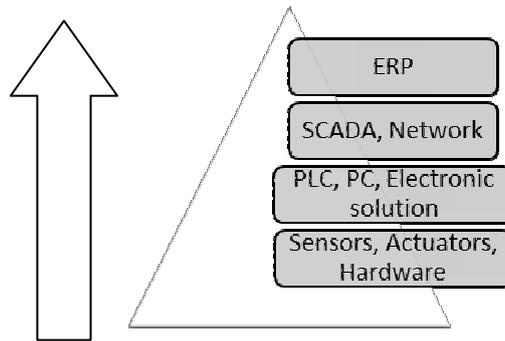


Fig.1. System building methods

Classic model for computer integrated manufacturing typically splits the control and monitoring functions of an automation system into 4 discrete levels.

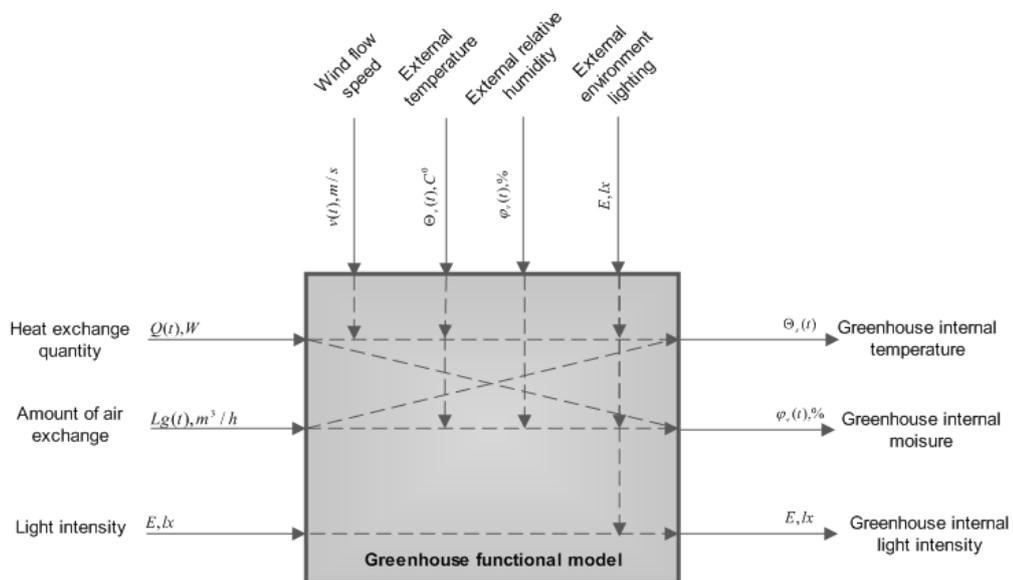


Fig.2. Greenhouse control system functional model

Greenhouse model is based on classic model for computer integrated manufacturing and as system gets more sophisticated it is often difficult to fault it and find time of the fault. Because of that fact system building must be structured it can decrease solving problem time and finding working solution.

- Control system model

This is the second level of modeling which introduces control system concept substantiated by mathematical calculations. It is classical control system with the feedback link. Processes are controlled by the PID and PI controllers.

Heat model

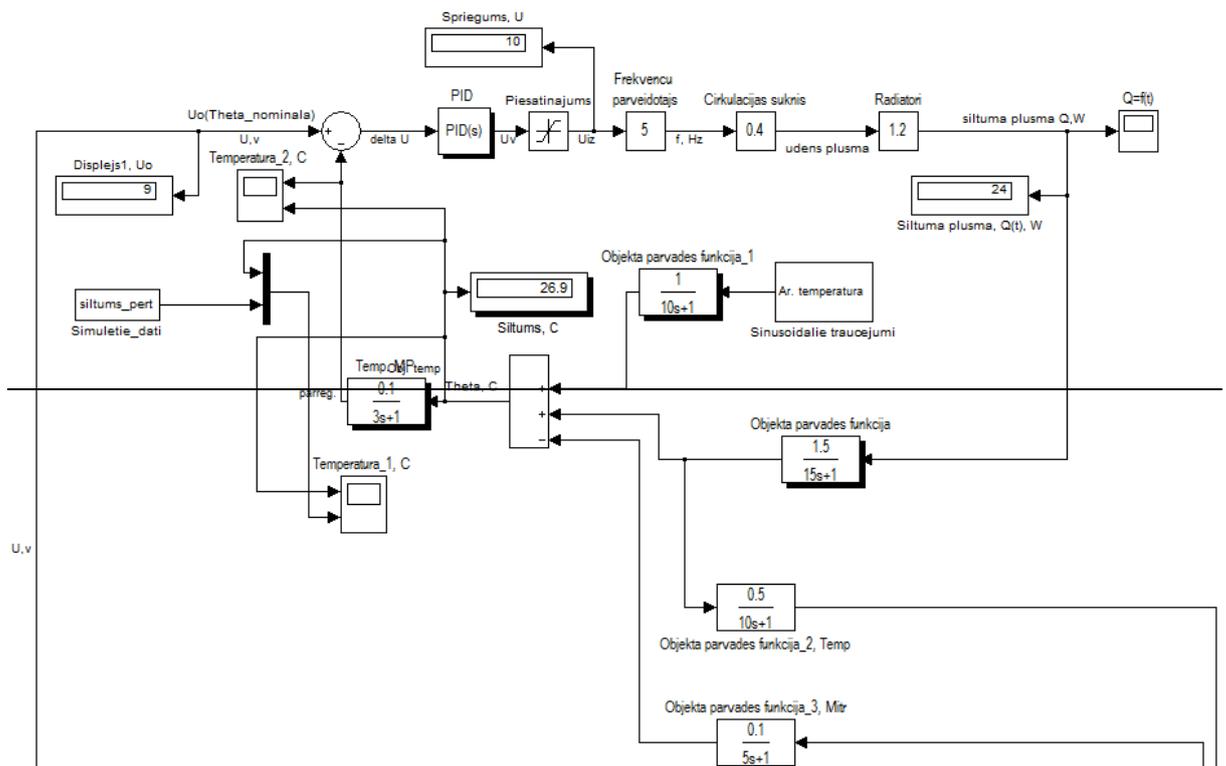


Fig.3. Control system heat process modeling

Heat process involves PID electronic execution hardware, frequency converter and circulation pump and heater system. It is the main heat process execution equipment. Heat feedback link equipment is process measurement sensors, monitoring server and software. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse air temperature $\theta_{\text{fakt}} = 26^{\circ}\text{C}$;
- Static error $\varepsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Humidity model

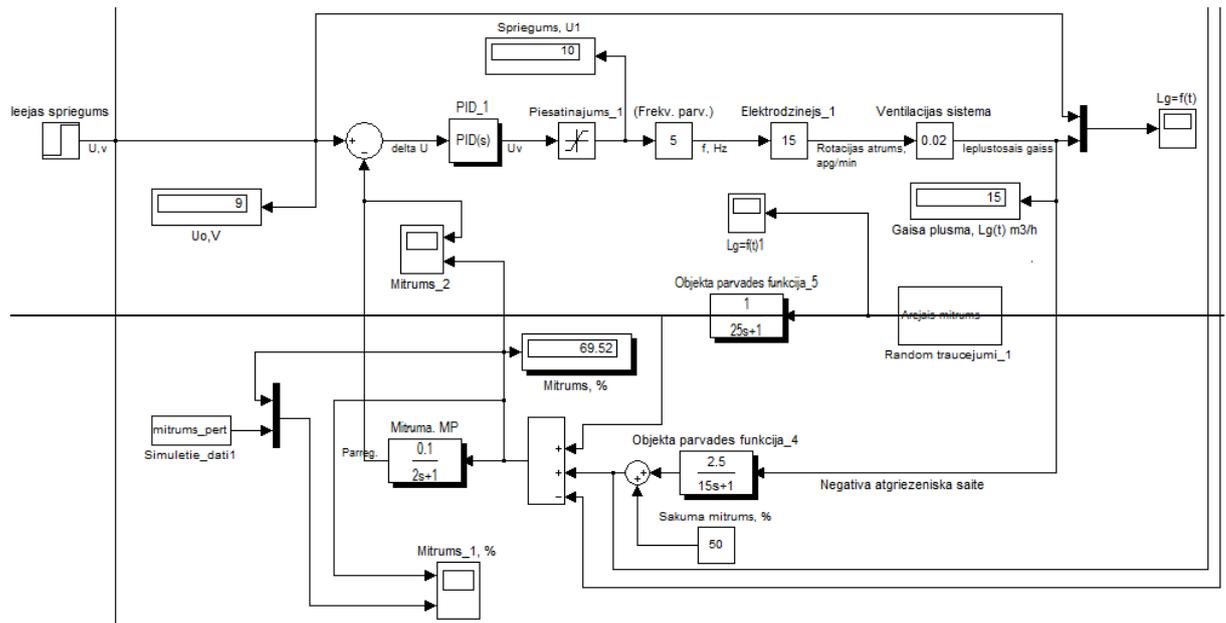


Fig.4. Control system humidity process modeling

Humidity process involves PID controller, frequency converter and motor and ventilation shaft system. It is the main process equipment. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse humidity level $\varphi_{izkš} = 70\%$;
- Static error $\epsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Light control model

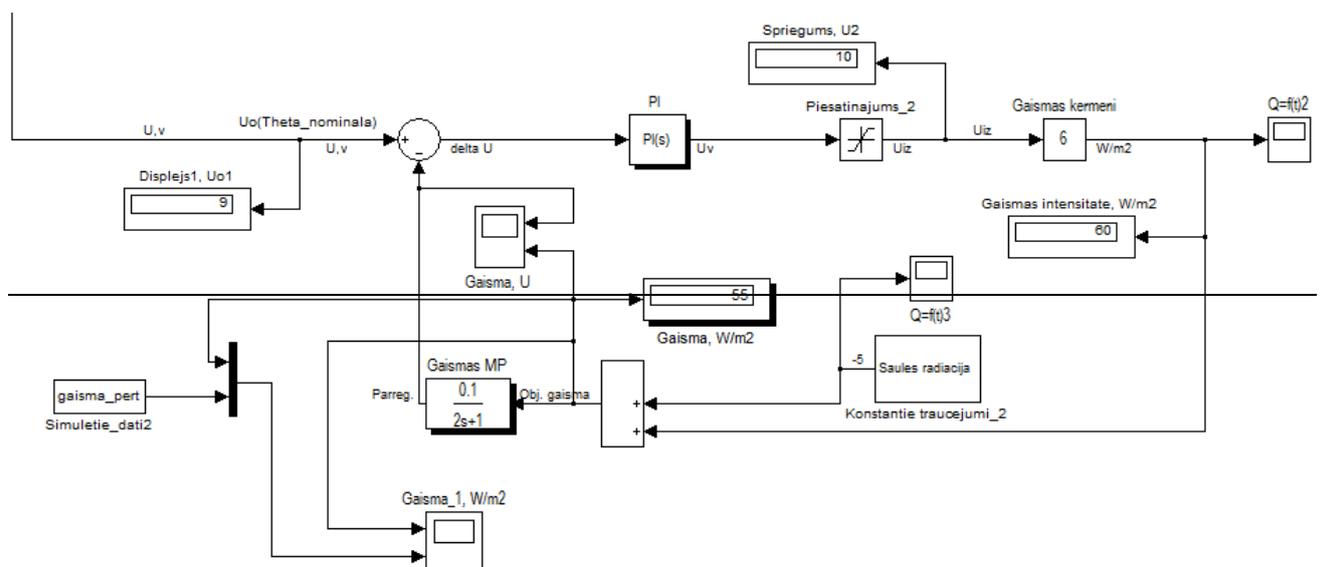


Fig.5. Control system light process modeling

Light control process involves PI controller, frequency converter and light panels. It is the main process equipment. (Šnīders, 2008)

Automation system quality indicators:

- Greenhouse artificial light intensity $E_c = 55 W * m^{-2}$

- Static error $\varepsilon \leq \pm 10\%$;
- Maximal allowed over regulation level $\sigma \leq \pm 10\%$;

Heat and humidity processes are not linear processes exception is light and regulation appropriate for process control is the PID controller. For light control we choose PI controller especially for light attenuation in the greenhouse. System also should make CO₂ emission and consumption evaluation to prevent errors in biological process to maximize productivity. CO₂ concentration decrease or increase in air can be as a signal for other process correction. CO₂ impact on biological process is complex as if carbon dioxide concentration is too high plants cannot cool themselves and humidity will decrease and temperature will increase slowing down plant development process. If carbon dioxide concentration decreases again plants will not develop properly slowing down vegetation process. (Stalidzāns and Osadčuks, 2008)

- Numerical process model

This is most complicated level of the modeling because of mathematics complexity in real-time world equations that describes processes. We can model differential equation of the process but to fully understand for example gas motion in the greenhouse we have to use Navier–Stokes equations, those arise from applying Newton's second law to fluid motion, together with the assumption that the fluid stress is the sum of a diffusing viscous term (proportional to the gradient of velocity), plus a pressure term. This differential equation system describes fluid and gas motion in Newton physics world.

With Fourier method or d'Alembert method heat differential equation can be solved to show changes that occur during the process. Maxwell's equations are the set of partial differential equations with Lorentz force, form foundation of electrodynamics, optics and electronic circuits. Those problems mostly can be solved with Matlab software. (Seibold, 2009)

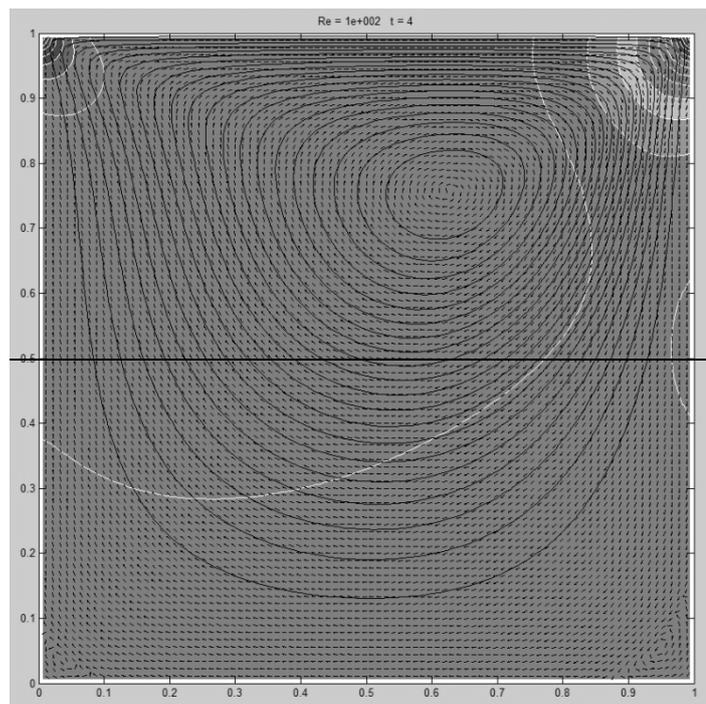


Fig.6. Matlab model representation of Navier–Stokes equations (Seibold B., 2009)

Materials and Methods

System building levels have been shown in Figure 7. To build system we should start with electronic circuit logic and sensors to gather data. Next is the data transmission protocols can be used. C-Bus, X10 or TCP/IP, such system require deep knowledge of Assembler, C and Java or C# and MySQL programming languages. To control low level electronics it is mostly C programming and interface programming mostly done in C# for Windows platform and Java for Linux. Also using MonoDevelop in Linux C# programs can be developed. Such system should have server-client method using for example Ubuntu Linux which is mostly stable platform for further development.

Windows or Linux platform choice will play important role on the tools available for further system development. Nowadays trend for information technologies is the cloud computing this is the typical server-

client system which utilizes benefits of remote access through TCP/IP protocol to controlled system. Application server can be installed on Ubuntu Linux with secure access to the service using openssl library. This is representing operating system level. On the system and electronics level electronic system must be developed to communicate with higher level. It is Linux based problem solving approach which is open source and requires knowledge of Java and C and electronics and MySQL.

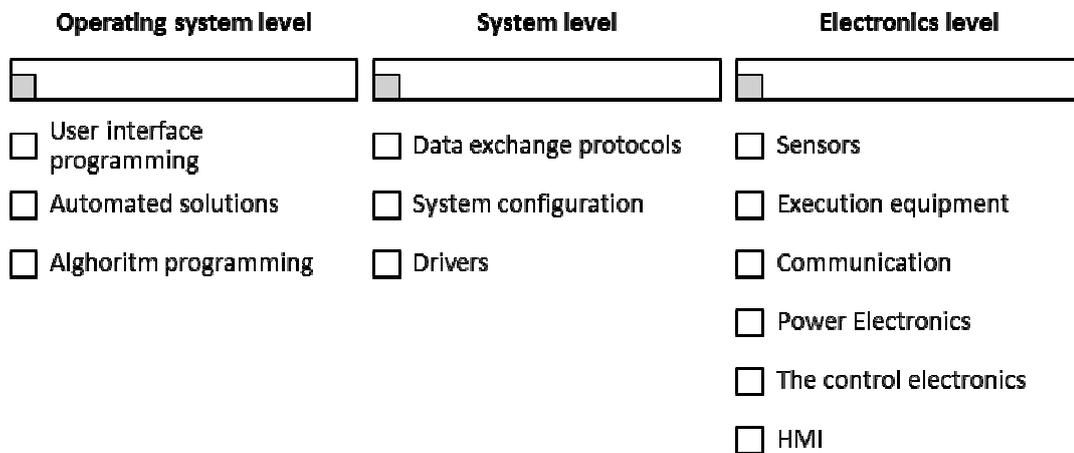


Fig.7. Control system level classification

Siemens Corporation offers Totally Integrated Automation suite for controlling factory machinery. It is another good solution for tasks automation. This problem solving approach requires knowledge of ladder logic, statement list or functional block diagram language and good knowledge of TIA environment for HMI development. This is Windows based automation concept for serious engineering projects because of high costs of Siemens equipment. It is necessary to calculate system and maintenance cost to evaluate economic gain from the project.

International experience of such system building is different Siemens is one of leading automation technology supplier. On other hand many promising open source technologies emerge for automation tasks for example Open Scada or MatPLC for Linux. One interesting project is the RTAI (Real Time Application Interface) which enables Linux kernel to execute applications with strict timing constraints this is critical to real time systems executing commands in real world environment. One of the common issues is the necessity of usage of standardized hardware because of that industrial pc usage is becoming trend.

Future possibilities of control system building (maybe autonomous systems, agent based systems) on horizon emerge adaptive control with neural networks and evolutionary algorithm concepts. For now presented system is the classic variant of PID and PI with the feedback link. (Komasilovs and Stalidzāns, 2010)

One more important topic is the model validation and verification it is important to be sure that the model is accurate representation of the real system. Validation is usually achieved through the calibration of the model; it is an iterative process of comparing the model to actual system behavior. It is utilized in the comparison of the conceptual model to the computer representation that implements that conception.

Results and Discussion

The greenhouse effective floor surface is 160 m² (7500mm x 20000mm) and height in along the longest side of the building 2500 mm and height at the top 3700 mm. The building has a metal backbone and white plastic wall coating with thickness of 4mm. On one sides of the greenhouse there is a plastic door 1000 mm x 2000 mm with additional insulation, on other side of greenhouse is the gates with physical parameters of 5000 mm x 2500 mm also with additional insulation.

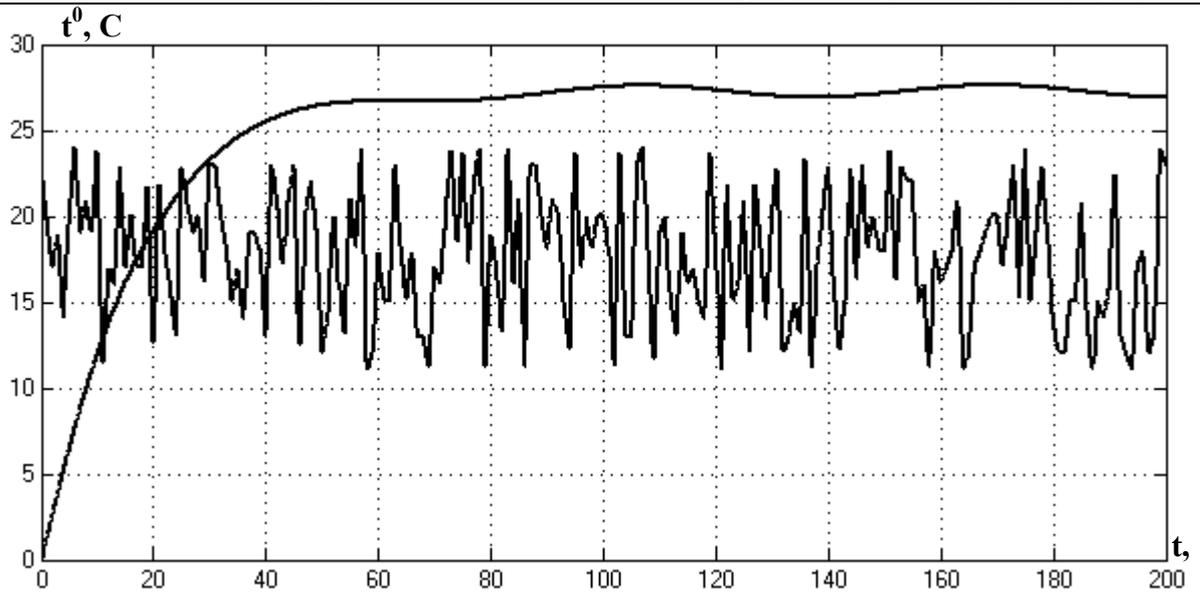


Fig.8. Temperature change during the day and internal greenhouse temperature, $\Theta_s(t)$

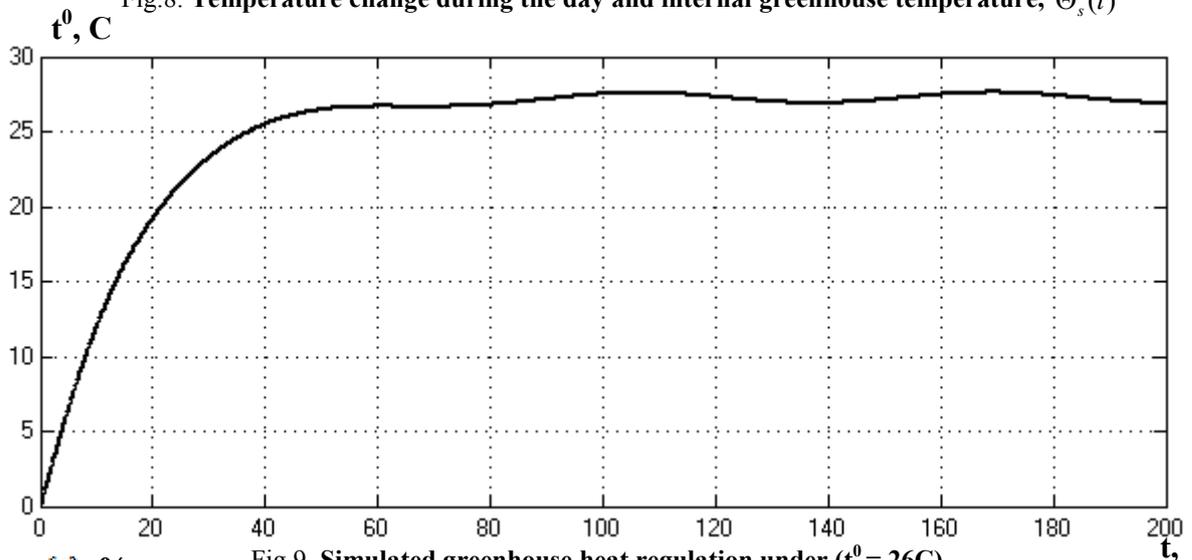


Fig.9. Simulated greenhouse heat regulation under ($t^0 = 26C$)

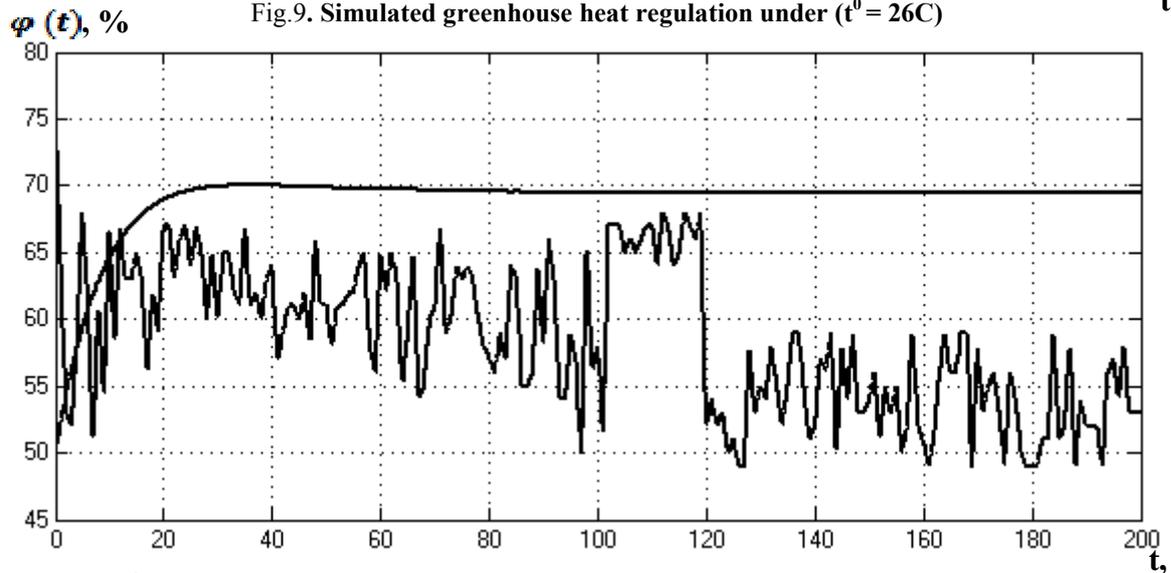


Fig.10. Humidity change during the day and internal greenhouse humidity, $\varphi_v(t),\%$

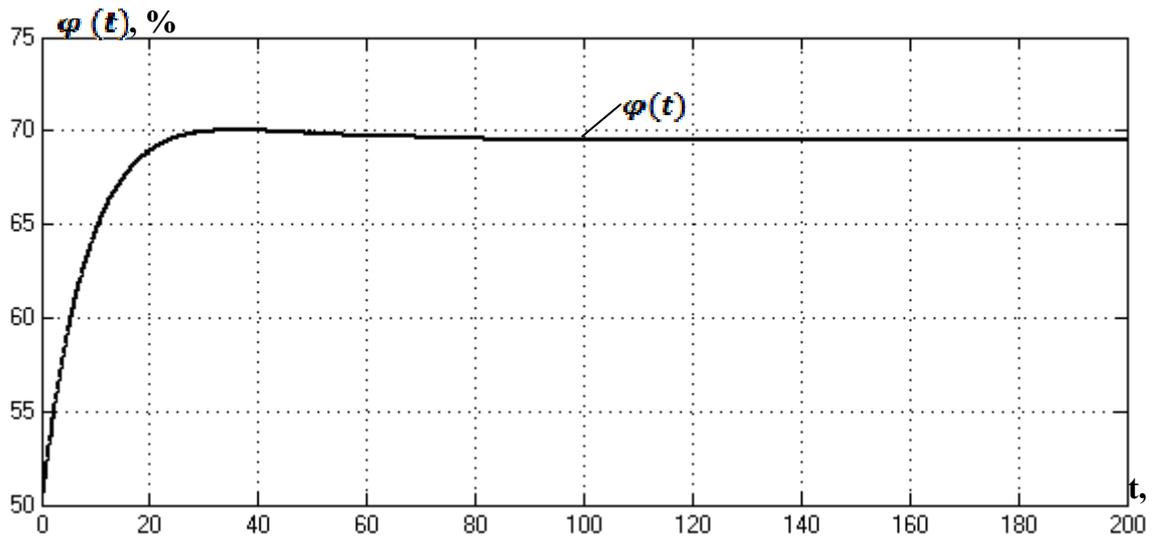


Fig.11. Simulated greenhouse humidity regulation for model with feedback under ($Lg=70\%$)

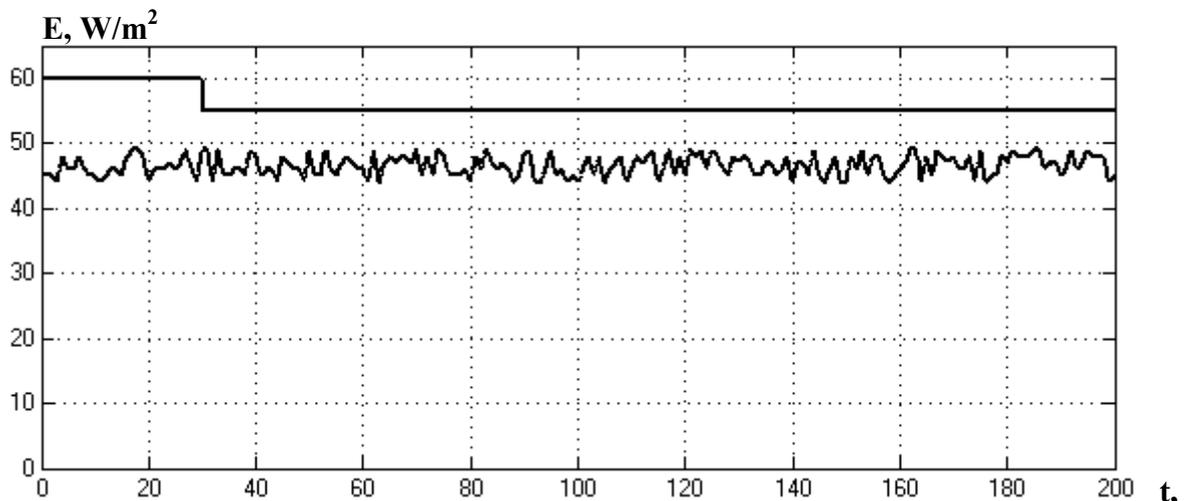


Fig.12. External light intensity change during the day and internal greenhouse lighting, $E(t), W * m^{-2}$

Conclusion

Based on the information gathered during the work and experience gained, it can be concluded that the control problems can be found in different fields of human activity. They are associated with different process research in machines and living organisms. An automatic control system with feedback control signal is formed according to the output variable values. Information about the object state through feedback into the control unit at the inlet, where, after appropriate modifications to the system is compared to the input size. Comparison of the resulting signal (error signal) is used to form devolved signal according to algorithm (enhanced, integrated, differentiated) impact. Control system is trying to reduce the output size of the deviation and return the object to the default condition.

The main advantage of systems with feedback is the ability to set the output variable, regardless of changes in the size of the bias caused by the underlying causes, which may not always be measured. System accuracy is significantly higher than in the compensation principle method.

The Lerner and Ziegler-Nicholas criteria for the regulator algorithm choices are appropriate. Using the PI and PID system shows good results in the bias compensation. On the feedback is returned set element change, and then compared with the necessary element value if it is corresponding to necessary value. Depending on whether it meets or does not meet the voltage is supplied.

Acknowledgements

We Mihails Andrejevs and Vitālijs Osadčuks are thankful to Andris Šnīders for his guidance in model development process.

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EVALUATION OF RENEWABLE ENERGY EFFICIENCY OF GALEGA BIOMASS

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Abstract: *The objective of this study was to quantify the environmental sustainable and renewable energy of fodder galega (*Galega orientalis* Lam.) at different growth stages and during vegetation period. Field trials carried out at the Research Station of Aleksandras Stulginskis University on a sandy moraine humic horizon of Calcary-Epithypogleyic Luvisol (LVg-p-w-cc). Galega crop is notable for its longevity, high overwintering peculiarities and heavy yield. Fodder galega ensure 60 - 75 t ha⁻¹ green mass, 15 - 17 t ha⁻¹ hay, 14.79 t ha⁻¹ dray matter and 0.3 - 0.7 t ha⁻¹ seed. Galega growing season lasts a long time, from early spring until late autumn. Depending on meteorological conditions its vegetation finishes in the end of October – beginning of November. Thus fodder galega is high valuable as suitable supplement for green conveyer. Galega production is characterized by low fertilizer and pesticide requirements making it a relatively benign crop environmentally. Content of crude fiber and dry matter increases with the stages of plant development and the best energy value of green mass is received in case of galega harvesting in the flowering stage. Maturation of the crop increase in crude fibre content up to 285 g kg⁻¹ DM, thus reducing their digestibility, but increasing energetic value output to 10.79 MJ kg⁻¹. Therefore long-term fodder galega can be used as energetic plant producing sufficient biomass yield with high energetic value. Three-cut system at plant flowering stage guaranteed to obtain a heavy biomass yield with higher energy content. Moreover, this undemanding plant can be linked to exploited in abandoned areas of biomass production and thereby protect these areas from forest overgrowth.*

Keywords: sustainable environment, renewable energy, galega, biomass, energetic value.

Introduction

Inevitability of exhaustion of fossil fuels is becoming increasingly intensive, efforts are on to find and use substitute forms of energy. K. Hubbert, a geologist for the US geological survey, was discussing how fuels, specifically oil and coal, will come into and go out of use, e.g. oil might even peak out before 2050 (Calvin, 1978). Search of renewable energy sources has a global importance target to conserve and clear environment (Franzese et al., 2009; Hellegers et al., 2008). Energy sources partly correspond to the energy forms. Gross Energy Requirement focuses on fossil fuel use and is capable to support the development of more efficient use of commercial energy. Renewable energy resources mainly addressed for environmental aspects of sustainable development decreasing CO₂ emission and present alternative solution of fossil fuels usage (Stoeglehner, Narodoslowsky, 2009). Fossil carbon stocks originate existed millions of years ago, but could be consume during some centuries. A substitution of this energy sources with energetic crops becomes a real plot of land consuming bioproductive capacity (Kalita, 2008). This might cause some different problems: environmental pressures, social and economic consequences because of rising food prices. One of the reasons named is the production of renewable energy sources as a new competing use of bio-capacity, which adds to food production, production of industrial raw materials etc. Food versus renewable energy sources and biofuel aspect are broadly discussed in general publications (Demirbas, 2007; Hellegers et al., 2008; Catic and Rujnic-Sokele, 2008).

EC proposed three aims for 2020 in EU climate and energy package (EC, 2009): reducing greenhouse gas emissions by 20 %; improving energy efficiency by 20 %; and generating 20 % of energy consumption from renewable energy. Consequently, EU has committed to obtain 20 % of its energy from renewable sources by 2020 (Beurskens, Hekkenberg, 2011). An analysis of the 27 EU Member State action plans shows that renewable energy output has projected to grow by 6 % per year on average. Wind power, solar electricity and biofuels have foreseen to contribute with the highest growth rates. If all Member States follow the trajectory outlined in their plans, the EU will exceed its 20 % renewable energy target by 0.7 percentage points. Total renewable energy production increase projected from 99 million tonnes of oil equivalent (M toe) in 2005 to 245 M toe in 2020 corresponding to an average annual growth rate of 6 % (MEMO/11/54).

In National Renewable Energy Action Plan (NREAP) biomass present the main source of renewable energy, which total share was 16% during 2010 in Lithuania. Biomass heat target contributes the largest part, e.g. ½ of this energy. Remain part (~5%) produced from bioethanol, biodiesel, hydropower, solar energy, wind power. Biomass heat will make up the biggest proportion (¾) of renewable energy production, and is the fastest growing element between 2005 and 2020 in Lithuania REAP. Total share of bioethanol, biodiesel, hydropower, solar energy, wind power has projected to increase and compose ¼ of total renewable energy in 2020. To approach this question from an ecological perspective means to be mainly addressed the environmental aspects of

sustainable development identifying bioproductivity and potential to produce a certain amount of energy of field crops (Dodić et al., 2011; Lewandowski et al., 2000; Stolarski et al., 2011; Franzese et al., 2009).

In this paper biomass, yield and energetic value of fodder galega (*Galega orientalis* Lam.) evaluated during vegetation period at different growth stages in order to mitigate impact of human-dominated production processes and to provide performance and environmental sustainability (Baležentienė et al., 2003). This plant might be considered as renewable energy source due to its valuable agro biological peculiarities, namely good adaptability to growth conditions, intensive vegetative propagation and longevity (it can grow 15 and more years in the same plot), high productivity (60 - 75 t ha⁻¹ green mass, 15 - 17 t ha⁻¹ hay, 14.79 t ha⁻¹ dry matter and 0.3 - 0.7 t ha⁻¹ seed) (Baležentienė, 2003; Balezentiene, 2008). Consequently, to biological properties, galega might use for ecological proposes: to improve soil fertility by accumulating nitrogen, enriching with organic matter and increasing the amount of humus, to decrease soil permeability, to protect against soil erosion and for soil preservation (Baležentienė, 2000). As energetic plant fodder galega should be regarded for producing heavy yield with high content of dry material, especially at flowering-seed maturity stages (Adamovics, 2000; Balezentiene, Mikulioniene, 2006; Jasinkas et al., 2008; Golušin and Munitlak-Ivanović, 2009). Delayed harvest of galega have resulted increasing of dry materials due to increasing cellulose content and diminishing of feed materials synthesis (Chamberlain and Wilkinson, 1996; Braun et al., 2005).

The main object of this research is to assess galega, as novel energy crop, ability to provide environmental sustainable and renewable energy source at different growth stages and during vegetation in total.

Materials and Methods

Galega has sown in 3 terms (the 1st ten-day period of May and 15 and 30 day later) at the Research Station of Lithuanian University of Agriculture (Balezentiene et al., 2003). The trials were set on a sandy moraine humic horizon of *Calcary-Epihypogleyic Luvisol*, LVg-p-w-cc (FAO/UNESCO, 1997). Soil agrochemical analyses have done at Agrochemical Research Centre of the Lithuanian Institute of Agriculture accordingly to these methods: pH evaluated potentiometric, humus percentage by Tyurin, total nitrogen by Kjeldahl, content of available P₂O₅ and K₂O by acetone-lactate (A-L) analysis, hydrolytic acidity by Kapen and sum of saturated bases by Kapen-Gilkovich. Soil pH_{KCl} rated between 7.0–7.1, P and K content – 18.2 and 21.3 mg 100 g⁻¹ respectively (Table 1). Background fertilising P₆₀ and K₆₀ have applied only in autumn. The three cuttings have done annually at the beginning of the grasses flowering stage. Chemical composition of green mass has determined by NIRS.

Examined dry matter (DM), crude lipid (CL) crude fibre (CF), crude protein (CP) were assayed accordingly Weender forage analytical methods in 'Tempus' laboratory of Lithuanian Agricultural University (Nauman, Baasler, 1983). Element concentrations in DM were analysed using near-infrared reflectance (NIR) spectroscopy (PSCO/ISI IBM-PC 4250; Pacific Scientific, USA) according to the database of research plants.

Table 1.

Soil agrochemical characteristic						
pH	Humus, %	Total N, %	Available P ₂ O ₅ , mg/100 g ⁻¹	Available K ₂ O, mg/100 g ⁻¹	Hydrolytic soil acidity, mg eq/100 g ⁻¹	Sum of saturated bases, mg eq/100 g ⁻¹
7.1	3.05	0.172	18.2	21.3	1.8	17.9

Energetic value of biomass (EV, MJ kg⁻¹) of examined forage grass calculated by a standard formula (LST 1986:2007; Madlener et al., 2009; Franzese et al., 2009; Carter et al., 2008) on a basis of plant species biomass chemical analysis, which has presented by Baležentienė (2004) and Baležentienė, Mikulionienė (2006):

$$EV = 14.07 + 0.0206 \times CL - 0.0147 \times CF - 0.0114 \times CP;$$

Means: CL- crude lipid g kg⁻¹; CF- crude fibre g kg⁻¹; CP- crude protein g kg⁻¹.

Additionally, level of data statistical significance was calculated using computer programme ANOVA for analyses of correlation and variance. The least significant difference (LSD) index was used to evaluate significant differences (p<0.05) between the studied crop yields, chemical composition and energetic value.

Results and Discussion

Though galega has a long continuous period of vegetative growth, nonetheless active vegetation starts depending on meteorological conditions, usually on the beginning of April. Galega seed mature within 98–102 day (Table 2). The ability to mature seeds is an important characteristic of galega. This peculiarity to mature seed assures species propagation and is important for plant spread in new territories. Moreover, this undemanding plant can be linked to exploited in abandoned areas of biomass production and thereby protect these areas from forest overgrowth. As confirmed by tests data, galega produce high biomass without fertilizer and pesticide thus making a relatively environmentally sustainable crop (Baležentienė et al., 2003). Therefore, employment of galega biomass as energy source should help to alleviate the scarcity of petroleum products and create healthy environment.

Table 2.

Average duration of vegetative growth stages of fodder galega

Beginning of vegetation	Tillering	Bud phase	Flowering	Seed maturity	Duration of development	LSD ₀₅
04 08 - 12	04 07-05 09	05 10-05 25	05 25-06 20	07 18-08 15	98 - 102	11

Early sowing positively influenced initial growth because galega has long germination period and slow development. The 1st sowing term guarantee sufficient soil moisture for seed germination and seedlings growth due to better meteorological and environmental conditions (Šlepetys, 2008). Therefore, the densest stand and the heaviest biomass yield formed in this treatment in the next year as compared with stands of later sowing terms (Table 3). Decrease of soil moisture, temperature fluctuation, and increase of weed number and slow initial galega development of later sowing term conditioned forming of non-closed and sparse stand that might disappear after winter.

Table 3.

Galega' energetic value and yielding response on sowing time

Sowing data	Winter hardness, %	Crop density, un. m ⁻²	Height of plants at flowering, cm	DM, t ha ⁻¹	EV, MJ kg ⁻¹
1 st 10-day period of Ma	90.6	137	127	14.79	10.72
After 15 d.	88.0	110	116	12.19	9.95
After 15 d.	73.5	73	103	11.66	8.76
LSD ₀₅	9.12	17.6	9.91	1.02	1.04

Due to intensive vegetative propagation, GM and DM yield of galega increase year by year. Nonetheless, the maximal tillering and GM yield formed only in the 3rd year after sowing have obtained. Significantly the heaviest DM yield (14.79 t ha⁻¹) obtained in earliest sowing treatment. Differences of biomass energetic value were determined significant only between the 1st (10.72 MJ kg⁻¹) and the 3rd (8.76 MJ kg⁻¹) treatments (Table 3). Thus early sowing terms are the most preferable to obtain heavier DM yield with bigger energetic output. The term of later sowing is not suitable due to decline of DM yield and energetic value.

Assayed chemical composition data confirmed that galega is productive and valuable fodder crop due to sufficient CP content (Table 4). Rate of GM and DM yield, digestible materials and VE ranged accordingly growth stage and cuttings. In agreement with references (Jasinskas et al., 2008; Kalita, 2008), plant maturity increase content of CF, therefore DM and EV galega. As data of chemical analysis testify, fibre content increased during plant vegetation and development period CF content was 210.8-246.2 g kg⁻¹ at tillering – budding, and increased up to 258.0 g kg⁻¹ at flowering stage in I harvesting. The same decrease of main indices of biomass chemical composition has observed in subsequent II and III harvestings, thus changing energetic value of biomass.

Table 4.

Chemical composition (g kg⁻¹ DM) and energetic value of fodder galega biomass in different development stages and harvesting

Growth stage	CP	CF	CA	CL	P	K	Ca	EV, MJ kg ⁻¹
1 st harvesting								
Tillering	267.0	210.8	109.5	29.9	5.9	15	8.9	7.69
Budding	247.5	246.2	98.3	26.7	4.4	10.8	7.7	8.64
Beginning of flowering	226.4	258.8	79.2	24.6	4.0	9.1	6.8	9.73
Complete flowering	189.9	285	70.3	21.5	3.5	8.3	5.9	10.79
LSD ₀₅	10.3	12.1	8.79	3.41	0.47	1.01	0.92	1.03
2 nd harvesting								
Tillering	233.7	252.9	80.6	25.1	4.2	9.5	7.1	9.36
Budding	234.0	252.1	80.0	25.2	4.0	9.4	7.2	9.38
Beginning of flowering	234.4	251.5	80.9	25.3	4.1	9.3	6.9	9.41
Complete flowering	234.6	250.8	81.0	25.4	3.5	9.1	6.9	9.45
LSD ₀₅	9.87	11.4	7.01	0.19	0.04	0.12	0.14	0.91
3 rd harvesting								
Tillering	239.1	247.5	84.3	25.9	4.2	9.3	7.4	8.69
Budding	229.0	248.7	84.0	24.3	4.0	8.9	7.1	9.31
Beginning of flowering	220.2	248.9	83.1	21.7	3.9	8.7	7.0	9.43
Complete flowering	219.7	251.0	80.1	21.0	3.7	8.5	7.0	9.61
LSD ₀₅	9.02	9.11	2.97	2.61	0.45	0.11	0.10	0.87

As Braun et al. (2005) referred, maturation of the grass leads to growing content of cellulose and lignin, contrary to diminishing of others components such as minerals, digestible proteins etc. in biomass. Therefore, harvesting time of fodder galega for energy production must be no earlier than flowering end (Zaltauskas et al., 2001). Whereas water content also reduced in biomass while plant aged, thus plant became more suitable for energy

purposes. Obtained investigation data of chemical analysis showed that biomass of matured fodder galega is most suitable for biofuel utilisation. Moreover, during the 1st cut it has observed that growth stage had a greater impact than that of the harvest time on chemical composition (Fig. 1). Thus, insignificant changes of such energetically important index as crude fibre content have observed in the 2nd and 3rd harvests of fodder galega.

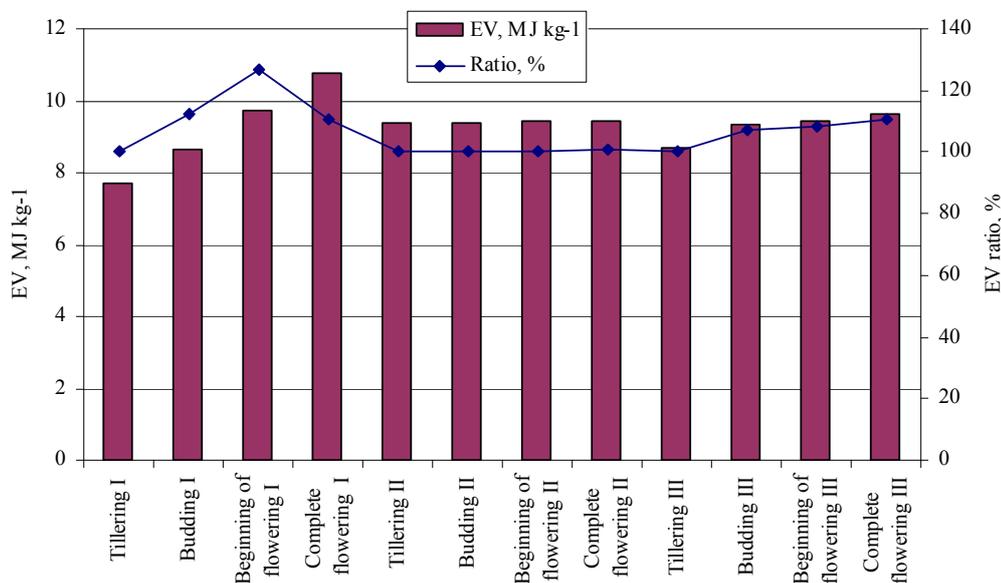


Fig.1. Energetic value (EV) and its ratio at different growth stages and cuts of fodder galega

It could also be assumed, that galega regrow well enough when three cut systems has been applied at plants flowering stage during the growing season. The higher the number of cuts has not tested because plants have not supermaturated. It should be note that the slowest atoll regeneration observed after the second harvest, when both plant and environmental resources reduced in our agroclimatic conditions.

Conclusions

Exhaustion of fossil fuels resource leads to approaching for maximizing findings of renewable sources of biomass productivity. Increasing bio-crude content with quality product should be adopted which will help to alleviate the scarcity of petroleum products as well as create healthy environment. In this study fodder galega (*Galega orientalis*) is provided as one of energetical plant species for solving this problem in Lithuania. As long-term field test data showed, galega development duration (98 days) in full compliance with the Central Lithuanian agroclimatic conditions: plants are fully mature and managed to produce sufficient seed yield. Seed production is important galega bio-peculiarity in order to distribute this legume species in Lithuania. Early spring seed drilling is best, since that time is the most favourable temperature and moisture conditions for seed germination and plant development, therefore resulting in thickest (137 shoots m⁻²) and productive (12.79 t ha⁻¹ DM) crop. In order to obtain a higher galega green mass yield with higher energy content, three-cut system at plant flowering stage recommended. Galega first cut grass is a high nutritive value when cut at tillering or early flowering stages. Maturation of the crop increase in crude fibre content up to 285 g kg⁻¹ DM, thus reducing their digestibility, but increasing to 10.79 MJ kg⁻¹ energetic value input. Therefore long-term fodder galega might be used as an energetic plant producing sufficient biomass yield with high energetic value.

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FUZZY TOPSIS METHOD APPLIED FOR EVALUATION OF MITIGATION STRATEGIES FOR GREENHOUSE GAS EMISSIONS FROM ABANDONED GRASSLAND

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Abstract: Most agricultural area lies under permanent grasslands (3488 M ha, or 69%). Grasslands and fertilized areas occupy about 20% of the Earth's land surface generating considerable GHG emissions and increasing global climate change. Grassland compose 1.2 M ha, or 50 % of agricultural lands in Lithuania. Accounting for GHG emission of grassland ecosystems may be important to evaluate and interpret measurements of fluxes at regional and ecosystem levels. Therefore biosphere-atmosphere interactions were investigated on a clay loam topsoil over silt loam (Calc(ar)i-Endohypogleyic Luvisol) in different managed grassland ecosystems of Training farm of Lithuanian University of Agriculture in 2009 within the frame of the European Projects COST.

Objective of this investigation was to determine impact of fertilizers, their rates and combinations on GHG emission and productivity of abandoned semi-natural sward and cultural pasture. GHG emission measurements were run in June-September, when meteorological conditions were optimal for intensive plant and soil biota physiological processes, in absence of frosts stress.

Gradual decline of GHG fluxes was observed during vegetation, in accordance with decreasing supply of environmental components encompassing organical substrates, fertilizers, activity of microorganisms, as well as their interaction with humidity and temperature (HTC ranged from 2.0 to 0.9). There was strong correlation observed between mean N_2O , CO_2 and CH_4 emission during vegetation period on the one hand, and NPK ($r=0.9$, 0.8 and 0.9) with monomial nitrogen fertilizers ($r=0.8$ and 0.6) on the other. The fuzzy multi-criteria decision making method TOPSIS was applied when choosing the best compromise fertilizing regime. Therefore appropriate fertilizing rate for supporting soil fertility and low emissions rate should not to exceed $N_{60}P_{40}K_{50}$.

Keywords: emissions, fuzzy TOPSIS, sustainability, grassland, fertilizing

Introduction

Human-inflicted greenhouse gas emissions affect the global temperature (IPCC, 2007). United Nations has summarized greenhouse gas (GHG) annual increase of 0.4 (CO_2); 0.6 (N_2O) and 0.25 % (CH_4). Therefore it is actual to reduce this main agent of climate change, i.e. GHG emissions in agricultural sector as well as in others activities. Grasslands (3488 M ha, or 69 %) occupy a large segment of global agricultural land (5023 M ha), consequently, measurement and prediction of GHG emissions from these ecosystems are of great importance (FAOSTAT, 2006). Furthermore, amount and composition of covering plant species impact considerably total GHG emission in grassland ecosystems (Raivonen et al., 2009). In Central Lithuania, like in other parts of central Europe, abandoned grasslands situated near woodlands are overgrown by shrubs and trees (Dzwonko and Loster, 2007). An increase in tree and shrub cover results in a decrease of the number and cover of grassland species and may lead to their local extinction within decades. Domestic political-economical circumstances have meant, that about 50% of grasslands (former pasture or arable land) have been abandoned and has been turning into natural habitats/climatic ecosystems during the last two decades in Lithuania (Balezentiene et al., 2010). In order to maintain soil fertility and imminent growing up with shrubs and trees, these abandoned, differently anthropogenized plots needs to apply extensive management, e.g. sustainable fertilizing, grazing, etc. (Vries et al., 2002) However, rising fertilizer use contributed to a number of environmental problems including an increase of GHG emissions (Groenigen et al., 2004; Lehuger et al., 2010). Moreover intensive recycling and often high rates of applied mineral fertilizers is expected to be significant pathway for contribution to share of global anthropogenic GHG emission share from agro sector (IPCC, 2007; Johnson et al., 2007). Therefore assessment of effects of various fertilizing rates and techniques on the gaseous emissions from abandoned grasslands should be based on research data (Kammann et al., 2008). Otherwise, agro ecosystems are represented by complex of multidimensional components thus making their evaluation and management rather complicated. Hence their evaluations require appropriate analysis techniques including mathematical methods (Balezentis et al., 2010). In order to address this context, it is necessary to move away from the assessment methods that have traditionally predominated in agro ecosystems management.

Multiple criteria decision making (MCDM) methods are aimed at choosing the best alternative from finite set of alternatives with respect to certain objectives represented by respective criteria (Linkov et al. 2006; Lynam et al. 2007). More specifically, Roy (2005) presented the following pattern of MCDM problematique: 1) α choosing problem – choosing the best alternative; 2) β sorting problem – classifying alternatives into relatively

homogenous groups; 3) γ ranking problem – ranking alternatives from best to worst; 4) δ describing problem – describing alternatives in terms of their peculiarities and features. A rather extensive overview of MCDM methods was offered by Guitouni and Martel (1998).

Nowadays many phenomena cannot be defined in crisp terms; hence the fuzzy number theory developed by Zadeh (1965) enables to deal with uncertainty. Complex environmental problems can therefore be analyzed on a basis of fuzzy logics (Krohling and Campanharo, 2011; Pappas, 2010). Consequently, many MCDM methods have been extended into the fuzzy environment. Consider, for example, the Analytic Hierarchy Process (AHP) proposed by Saaty (1987) and extended into fuzzy environment (van Laarhoven, Pedrycz, 1983; Leung, Cao 2000); the simple additive weight (SAW) method (MacCrimmon 1968) updated with fuzzy numbers theory (Chou et al. 2008); Technique for the Order Preference by Similarity to Ideal Solution (TOPSIS) introduced by Hwang and Yoon (1981) and updated with fuzzy numbers theory (Krohling and Campanharo, 2011); method of Complex Proportional Assessment (COPRAS) (Zavadskas et al., 1994) improved by applying fuzzy number technique (Zavadskas, Antuchevičienė 2007); ARAS method introduced by Zavadskas and Turskis (2010) and extended with grey and triangular fuzzy number. This study will be based on application of the fuzzy TOPSIS method further extended for group decision making (Krohling and Campanharo, 2011).

Accordingly, the article is organized into the following way. Methods section presents the basics of the fuzzy logics as well as fuzzy TOPSIS method. The multi-criteria evaluation according to the described method is offered in Methods.

This study encompasses integrated assessment of sustainable management of abandoned grasslands aimed at proper management of fertilizer application methods leading to reduction of GHG emissions in the fertilized abandoned grasslands in Lithuania. The main aim of this investigation was to compare the impact of a single as well as multiple fertilizers on long-living biogenic greenhouse gas (CO_2 , N_2O and CH_4) emissions and to evaluate optimal fertilizing schemes in semi natural sward. Fertilizing risk management was evaluated applying fuzzy TOPSIS method.

Materials and Methods

The measurements were conducted on two sites: abandoned for more than 20 years grassland and intensively managed cultural pasture have been situated at Aleksandras Stulginskis University ($54^\circ52' \text{ N}$, $23^\circ50' \text{ E}$), Kaunas district, during vegetation period of 2009. The site is located in 5-6 hardiness zone (Peel et al., 2007) of temperate climate (C) with moderate warm summer and moderate cold winter (Lithuanian climate, 2007). Mean annual temperature ranges between $5.5\text{-}7.5^\circ\text{C}$ with annual precipitation of 670 mm. Total solar radiation inflow amounts 3600 MJ m^{-2} in Lithuania. The site soil was clay loam topsoil over silt loam (*Calc(ar)i-Endohypogleyic Luvisol*; FAO/UNESCO, 1997). Humus horizon was 25 cm deep.

The N (ammonium saltpetre 34.4% N) and NPK (ammonium saltpetre 34.4% N + granulated superphosphate 19% P_2O_5 + potassium chloride 60 % K_2O) application scheme of 9 treatments of semi natural sward (>20yrs abandoned former sown sward): Control (0); N_{60} ; N_{120} ; N_{180} ; N_{240} ; $\text{N}_{180}\text{P}_{120}$; $\text{N}_{180}\text{K}_{150}$; $\text{N}_{60}\text{P}_{40}\text{K}_{50}$; $\text{N}_{180}\text{P}_{120}\text{K}_{150}$. P and K were applied before plant vegetation in early spring, N fertilizer was applied two times: end of April and after 1st cut (beginning of July) in all grasslands. Fresh mass (FM) weighting ($\text{g } 0.2 \text{ m}^{-2}$ per treatment) and drying (105°C) were used to determine grassland productivity (g m^{-2}) and obtain dry mass (DM, %). Grassland botanical composition was determined on harvested vegetation.

GHG (CO_2 , N_2O and CH_4) emissions were monitored by the static chamber method (Hutchison, Livingston, 1993) using opaque circular chambers (0.05 m^3), with 6 replicates per treatment. Cylindrical steel collar (20 cm high and 43 cm diameter) were inserted into the soil to a depth of 6 cm. Two collars and chambers were placed in each treatment. The collar frames remained in the soil and were open to the atmosphere between samplings, except when removed for tillage and sowing. During the measurements the chambers were closed with an airtight lid simultaneously in all treatments. Chamber air was sampled 3 times in one hour interval period. Gas fluxes were measured on 4 different dates in grasslands.

The measurements were carried out 2 or 3 weeks after fertilizer application every month between June and September in absence of frost stress. The gas samples were analyzed in the laboratory by infrared gas analyzer (MGA3000) calibrated separately for each gas using ML-800 gas standard (2 atm). Gas samples were analyzed on the same day evaluating volume concentrations (ppm) of trace gases. Daily net exchange ($\text{mg h}^{-1} \text{ m}^{-2}$) of CO_2 , CH_4 and N_2O in agro ecosystem was calculated by integrating the 60-minute fluxes determined by the meteorological measurements over each day.

Thermal and irrigation conditions during vegetation period were characterized by sum of monthly precipitation (Pr) and active air temperature (T) ($>10^\circ\text{C}$), accordingly to commonly used in Europe G. Selianinov (1928) hydrothermal coefficient (HTK) (Coufal, 1987). High rates of hydrothermal coefficient (HTC=2.0 and 4.0) indicated moisture abundance in June and August, but it was optimal in July (HTC=1.6), and too dry (HTK=0.9) in September 2009.

In order to evaluate the most optimal management way of agro ecosystems the fuzzy set theory and fuzzy TOPSIS for group decision making were applied. Zadeh (1965) introduced the use of fuzzy set theory when

dealing with problems involving fuzzy phenomena. Noteworthy, fuzzy sets and fuzzy logic are powerful mathematical tools for modelling uncertain systems. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or non-membership, while fuzzy sets allow partial membership. The theoretical fundamentals of fuzzy set theory are overviewed by Chen (2000).

In a universe of discourse X , a fuzzy subset \tilde{A} of X is defined with a membership function $\mu_{\tilde{A}}(x)$ which maps each element $x \in X$ to a real number in the interval $[0; 1]$. The function value of $\mu_{\tilde{A}}(x)$ resembles the grade of membership of x in \tilde{A} . The higher the value of $\mu_{\tilde{A}}(x)$, the higher the degree of membership of x in \tilde{A} (Keufmann and Gupta, 1991). Noteworthy, in this study any variable with tilde will denote a fuzzy number.

A fuzzy number \tilde{A} is described as a subset of real number whose membership function $\mu_{\tilde{A}}(x)$ is a continuous mapping from the real line \mathfrak{R} to a closed interval $[0; 1]$, which has the following characteristics: 1) $\mu_{\tilde{A}}(x) = 0$, for all $x \in (-\infty; a] \cup [c; \infty)$; 2) $\mu_{\tilde{A}}(x)$ is strictly increasing in $[a; b]$ and strictly decreasing in $[d; c]$; 3) $\mu_{\tilde{A}}(x) = 1$, for all $x \in [b; d]$, where a, b, d , and c are real numbers, and $-\infty < a \leq b \leq d \leq c < \infty$. When $b = d$ a fuzzy number \tilde{A} is called a triangular fuzzy number represented by a triplet (a, b, c) .

Triangular fuzzy numbers will therefore be used in this study to characterize the alternatives. The membership function $\mu_{\tilde{A}}(x)$ is thus defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a, \\ \frac{x-a}{b-a}, & a \leq x \leq b, \\ \frac{x-c}{b-c}, & b \leq x \leq c, \\ 0, & x > c. \end{cases} \quad (1)$$

In addition, the parameters a, b , and c in (1) can be considered as indicating respectively the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event (Torlak *et al.*, 2011).

Let \tilde{A} and \tilde{B} be two positive fuzzy numbers (Liang, Ding 2003). Hence, the main algebraic operations of any two positive fuzzy numbers $\tilde{A} = (a, b, c)$ and $\tilde{B} = (d, e, f)$ can be defined in the following way (Zavadskas, Antuchevičienė 2007): Addition \oplus :

$$\tilde{A} \oplus \tilde{B} = (a, b, c) \oplus (d, e, f) = (a+d, b+e, c+f); \quad (2)$$

$$\text{Subtraction } ! : \tilde{A} ! \tilde{B} = (a, b, c) ! (d, e, f) = (a-d, b-e, c-f); \quad (3)$$

$$\text{Multiplication } \otimes : \tilde{A} \otimes \tilde{B} = (a, b, c) \otimes (d, e, f) = (a \times d, b \times e, c \times f) \quad (4)$$

$$\text{Division } \% : \tilde{A} \% \tilde{B} = (a, b, c) \% (d, e, f) = (a \setminus f, b \setminus e, c \setminus d). \quad (5)$$

The vertex method will be applied to measure the distance between two fuzzy numbers. Let $\tilde{A} = (a, b, c)$ and $\tilde{B} = (d, e, f)$ be two triangular fuzzy numbers. Then, the vertex method can be applied to measure the distance between these two fuzzy numbers:

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a-d)^2 + (b-e)^2 + (c-f)^2]}. \quad (6)$$

Fuzzy numbers can be applied in two ways when forming the response matrix of alternatives on objectives. First, fuzzy numbers can represent the values of linguistic variables (Zadeh 1975) when deciding either on the importance of criteria or performing qualitative evaluation of alternatives. For the latter purpose Chen (2000) describes the following fuzzy numbers identifying values of linguistic variables from scale Very poor to Very good: Very poor – (0, 0, 1); Poor – (0, 1, 3); Medium poor – (1, 3, 5); Fair – (3, 5, 7); Medium good – (5, 7, 9); Good – (7, 9, 10); Very good – (9, 10, 10). Second, the fuzzy numbers can represent monetary (quantitative) terms. It can be done either through direct input of certain fuzzy numbers into the response matrix or by aggregation of raw data (e. g. time series). For example, if there are costs “approximately equal to \$200” estimated, the sum can be represented by triangular fuzzy number (190, 200, 210). Moreover, the fuzzy numbers can embody expected rate of growth. For example, if there is level of unemployment of 5 per cent with expected growth of 10 per cent, a triangular fuzzy number (5, 5.5, 6.1) can summarize these characteristics. Similarly, crisp number x with uncertainty of 5 per cent can be represented by a fuzzy number $(0.95x, x, 1.05x)$. As for time series data, a fuzzy number can represent the dynamics of certain indicator during past t periods:

$$(\bar{x}(a_t) - 0.5s(a_t), \bar{x}(a_t), \bar{x}(a_t) + 0.5s(a_t)), \quad (7)$$

where $\bar{x}(a_l)$ and $s(a_l)$ stand for mean and standard deviation of certain indicator respectively. Krohling and Campanharo (2011) developed the following procedure for fuzzy group decision making. First of all, we have a group decision makers $G = \{M_1, M_2, \dots, M_L\}$. This group can encompass various stakeholders interested in the analyzed phenomenon. Each of them is assigned with coefficient of significance $\alpha_l \in [0,1]$, where $l=1,2,\dots,L$, such that $\sum_{l=1}^L \alpha_l = 1$. Moreover, each of the decision-makers is attributed with appropriate significance vector $W^l = (w_1^l, w_2^l, \dots, w_n^l)$, $l=1,2,\dots,L$ with n being the number of criteria. The coefficients of significance can be obtained by applying AHP method (Dagdeviren et al., 2009), entropy method (Huang, 2008), ameliorated nominal group or Delphi methods (Brauers and Zavadskas, 2010). The initial decision matrix $\tilde{P} = \tilde{p}_{ij} = (p_{ij1}, p_{ij2}, p_{ij3})$ is formed with $i=1,2,\dots,m$ being the number of alternatives and $j=1,2,\dots,n$ being the number of criteria respectively. Consequently, the initial matrix is normalized by applying the following procedure:

$$p_{ij1}^* = \frac{p_{ij1}}{\sqrt{\sum_{i=1}^m p_{ij1}}}; p_{ij2}^* = \frac{p_{ij2}}{\sqrt{\sum_{i=1}^m p_{ij2}}}; p_{ij3}^* = \frac{p_{ij3}}{\sqrt{\sum_{i=1}^m p_{ij3}}}; \forall i, j \quad (8)$$

As a result, the normalized matrix \tilde{P}^* is formed. Consequently, the weighted normalized decision matrix for each decision maker is calculated:

$${}^l\tilde{P}^* = \begin{pmatrix} w_1^l \tilde{p}_{11}^* & \dots & w_j^l \tilde{p}_{1j}^* & \dots & w_n^l \tilde{p}_{1n}^* \\ \vdots & & \vdots & & \vdots \\ w_1^l \tilde{p}_{i1}^* & \dots & w_j^l \tilde{p}_{ij}^* & \dots & w_n^l \tilde{p}_{in}^* \\ \vdots & & \vdots & & \vdots \\ w_1^l \tilde{p}_{m1}^* & \dots & w_j^l \tilde{p}_{mj}^* & \dots & w_n^l \tilde{p}_{mn}^* \end{pmatrix}, \forall l \quad (9)$$

with $l=1,2,\dots,L$ being the number of decision makers. L decision matrixes are therefore formed. The positive ideal solution ${}^lA^+$ as well as negative ideal solution ${}^lA^-$ are found for each decision maker:

$${}^lA^+ = ({}^l p_1^+, {}^l p_2^+, \dots, {}^l p_n^+), \forall l, \quad (10)$$

$${}^lA^- = ({}^l p_1^-, {}^l p_2^-, \dots, {}^l p_n^-), \forall l, \quad (11)$$

where

$${}^l p_j^+ = (\max_i {}^l \tilde{p}_{ij}^*, j \in J_1; \min_i {}^l \tilde{p}_{ij}^*, j \in J_2), \quad (12)$$

$${}^l p_j^- = (\min_i {}^l \tilde{p}_{ij}^*, j \in J_1; \max_i {}^l \tilde{p}_{ij}^*, j \in J_2), \quad (13)$$

with J_1 and J_2 being sets of benefit and cost criteria respectively. Then Eq. (6) is employed in order to obtain the distances of each alternative from the positive ideal solution for the l -th decision maker:

$${}^l d_i^+ = \sum_{j=1}^n d({}^l \tilde{p}_{ij}^*; {}^l \tilde{p}_j^+), \forall i, l \quad (14)$$

Similarly, the distances from the negative ideal solution are calculated in the following way:

$${}^l d_i^- = \sum_{j=1}^n d({}^l \tilde{p}_{ij}^*; {}^l \tilde{p}_j^-), \forall i, l \quad (15)$$

Finally, the relative proximity of the i -th alternative to the positive ideal solution for the l -th decision maker is found:

$${}^l c_i = \frac{{}^l d_i^-}{{}^l d_i^- + {}^l d_i^+}, \forall i, l \quad (16)$$

The higher the value of ${}^l c_i$, the more proximate the i -th alternative is to the positive ideal solution for the l -th decision maker. These results are summarized in the weighted relative-proximity matrix $C = c_{il} = {}^l c_i \cdot \alpha_l$, for $i=1,2,\dots,m; l=1,2,\dots,L$, and further processed with traditional TOPSIS method. In this case, the positive ideal and the negative ideal solutions denoted respectively as A^+ and A^- are identified in the following way:

$$A^+ = (c_1^+, c_2^+, \dots, c_l^+) = (m \max_i c_{i1}, m \max_i c_{i2}, \dots, m \max_i c_{il}) \quad (17)$$

$$A^- = (c_1^-, c_2^-, \dots, c_l^-) = (m \min_i c_{i1}, m \min_i c_{i2}, \dots, m \min_i c_{il}) \quad (18)$$

The n -dimensional Euclidean distance method is then applied to measure the distances of each alternative from the positive-ideal solution and the negative-ideal solution:

$$S_i^+ = \sqrt{\sum_{l=1}^L (c_{il} - c_l^+)^2}, \text{ for } i = 1, 2, \dots, m, \quad (19)$$

$$S_i^- = \sqrt{\sum_{j=1}^l (c_{ij} - c_i^-)^2}, \text{ for } i = 1, 2, \dots, m, \quad (20)$$

with c_i^+ and c_i^- being obtained from Eq. (17) and Eq. (18) respectively. Finally, the relative similarity to the positive-ideal solution is calculated (proximity to positive and remoteness to negative values):

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad (21)$$

where $C_i \in [0;1]$ with $i = 1, 2, \dots, m$. The best alternative can therefore be found according to the preference order of C_i .

Results and Discussion

Basically, the process of decision making is composed of decision makers, alternatives and criteria. In this study, there will be three approaches defined, each representing specific stakeholders. The investigated fertilizing regimes represent the alternatives. Finally, here two groups of criteria are considered, namely GHG emissions (cost criteria) and yield indicators (benefit criteria). CO₂, CH₄, and N₂O emissions were evaluated at certain periods during the investigation period. Hence the mean volumes as well as standard deviations of these emissions were estimated and turned into fuzzy numbers according to Eq. (7). The remaining indicators of fresh mass (g m⁻²), dry mass (g m⁻²), and part (%) of grass (G) + legume (L) found in the harvest were translated into fuzzy numbers with 5 % uncertainty. Table 1 summarizes the initial decision matrix.

Three approaches were considered in the analysis, namely those of farmers, environmental agencies, and holistic one. These three approaches can be perceived as three decision makers. Farmers seek to maximize the output of production, hence the importance of yield criteria is stressed. Environmental agencies seek to mitigate the pollution, and hence pay most of attention for minimizing the GHG emissions in stands. The holistic approach considers each of criteria equally important. Three significance vectors W^l were therefore formed (Table 2). Moreover, two scenarios were defined: the first one pays the most of attention to farmers' needs, whereas the second considers all the three approaches equally important. Hence, two significance vectors α were formed. By changing the importance weights of the decision makers (ecologic, agro economic and holistic) and choosing two scenarios (I and II), automatically one alters the preferences and the calculation of the impact of the alternatives, which, in turn, may modify the ranking of the alternatives. Consequently, the initial decision matrix was normalized according to Eq. (9). The positive as well as negative ideal solutions were hence found by employing Eq. (10) and Eq. (11).

Table 1.

Initial decision matrix \tilde{P} .

Variables	CO ₂ , ppm	CH ₄ , ppb	N ₂ O, ppm	FM, g m ⁻²	DM, g m ⁻²	G+L
	MIN	MIN	MIN	MAX	MAX	MAX
Control	122.871; 192.45; 262.029	0.03; 0.036; 0.043	1.225; 1.526; 1.827	909.625; 957.5; 1005.375	180.69; 190.2; 199.71	66.5; 70; 73.5
N ₆₀	531.92; 790.236; 1048.551	0.028; 0.04; 0.052	1.456; 1.774; 2.092	847.875; 892.5; 937.125	193.61; 203.8; 213.99	50.35; 53; 55.65
N ₁₂₀	637.635; 724.534; 811.433	0.02; 0.025; 0.03	1.742; 1.863; 1.984	952.375; 1002.5; 1052.625	223.345; 235.1; 246.855	71.25; 75; 78.75
N ₂₄₀	766.697; 874.506; 982.316	0.027; 0.032; 0.037	1.895; 2.28; 2.665	1444; 1520; 1596	182.97; 192.6; 202.23	66.5; 70; 73.5
N ₁₈₀ P ₁₂₀	592.775; 643.457; 694.14	0.03; 0.038; 0.045	1.33; 1.586; 1.843	1615; 1700; 1785	366.89; 386.2; 405.51	85.5; 90; 94.5
N ₁₈₀ K ₁₅₀	983.428; 1261.542; 1539.656	0.03; 0.038; 0.045	1.693; 2.521; 3.349	1287.25; 1355; 1422.75	325.09; 342.2; 359.31	76; 80; 84
N ₆₀ P ₄₀ K ₅₀	1057.368; 1499.019; 1940.67	0.036; 0.045; 0.054	2.414; 2.694; 2.974	78880.4; 83032; 87183.6	470.725; 495.5; 520.275	85.5; 90; 94.5
N ₁₈₀ P ₁₂₀ K ₁₅₀	632.263; 879.987; 1127.71	0.032; 0.034; 0.036	1.093; 1.889; 2.686	2869; 3020; 3171	786.315; 827.7; 869.085	92.15; 97; 101.85

Table 2.

Coefficients of significance given to criteria according to different approaches and those for approaches under different scenarios.

Scenario I	Scenario II	Approaches	CO ₂ , ppm	CH ₄ , ppb	N ₂ O, ppm	FM, g m ⁻²	DM, g m ⁻²	G+L
			MIN	MIN	MIN	MAX	MAX	MAX
0.5	0.33	Agro economic	0.08	0.08	0.08	0.25	0.25	0.25
0.25	0.33	Environmental agencies	0.25	0.25	0.25	0.08	0.08	0.08
0.25	0.33	Holistic	0.17	0.17	0.17	0.17	0.17	0.17

The calculations of distances of each alternative from these solutions, according to Eq. (14) and Eq. (15), enabled to apply Eq. (16) and thus evaluate the relative proximity of each alternative to the positive ideal solution with respect to each of approaches. The results are visualized in Fig. 1.

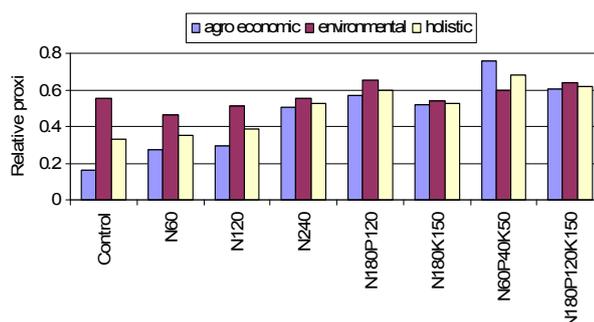


Fig.1. Fuzzy evaluation of grassland fertilizing according to different approaches

As we can see, the most promising fertilizing alternative according to both agro economic and holistic approaches is that of N₆₀P₄₀K₅₀. However, N₁₈₀P₁₂₀ is the most preferable one in the view of environmental agencies' approach due to the lowest emission rates.

The two scenarios with different importance of the three approaches (i. e. groups of stakeholders; see Table 2) were evaluated by employing Eqs. (16)–(21) (Triantaphyllou, 2000). The results are presented in Fig. 2. The results suggest the existing convergence in choosing the best alternative: fertilizing rate N₆₀P₄₀K₅₀ is the most suitable according to both of scenarios. That could be explained by low fertilizer assimilation capacity of plant species established in semi natural grassland. Indeed it is more attractive for stakeholders of agro economic approach due to sufficient FM and DM yield. According to the both scenarios, N₁₈₀P₁₂₀K₁₅₀ could be considered the second-best option, which, in turn, is more attractive for the remaining stakeholders. This high fertilizer rate determined not only the highest yield of grasslands, but also the biggest GHG fluxes and management expenses. Therefore this treatment could be chosen in some circumstances, when seeking high productivity in short time etc.

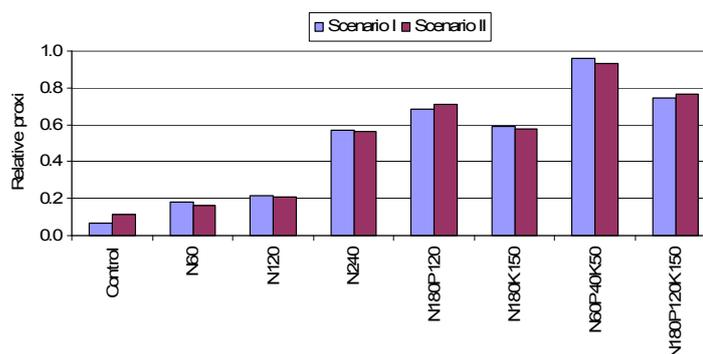


Fig.2. Summarized evaluation of grassland fertilizing according to different scenarios

Conclusions

In this study fuzzy TOPSIS method for group decision making to tackle multicriteria decision problems affected by uncertainty and taking into account the preferences of the decision makers was successfully applied. This method allows finding the best alternative of abandoned grassland amelioration by the way of fertilizing and thus ensuring both mitigation of GHG emissions and maximization yield indices. For this case study, we used 7 fertilizing ratios (and Control), three decision approaches (ecologic, agro economic and holistic) and two

scenarios (I and II) to illustrate the method. The results suggest the existing convergence in choosing the best alternative: fertilizing rate $N_{60}P_{40}K_{50}$ is the most suitable according to both of scenarios with respect to all decision approaches.

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IMPROVEMENT RECOMMENDATION DEVELOPMENT AND RESEARCH OF FARM (LUA RTF) „VECAUCE” AGRICULTURE INFORMATION SYSTEM

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Abstract: *The article describes the „Vecauce” information system of the Latvian University of Agriculture, Research and Training farm (LUA RTF). The need for up-to-date information has been analyzed. Specific attention has been paid to technologies which data acquisition source is connected to central data-processing site. Also, the data flow between branches and data-processing site has been discussed. The availability of information and its security problems and the data flow and data management at data-processing site have been analyzed. As well, the database access has been inspected and suggestions have been described and developed for the integrated systems development. Suggestions for communication technology choice have been developed. Information security guidelines for working with data have been created.*

Keywords: information technology, information systems, data management

Introduction

Internet use around the world has been growing rapidly. Internet access is a service that provides access to the global system of interconnected computer networks as the Internet. Information and communications technology is almost everywhere and it is a key tool for transmitting information nowadays. The Research and Training farm “Vecauce” have a common data-processing site that is based in the accounting center. Data are collected in the control journals during the month and then at the end of month those journals are taken to the data-processing site. There they are entered in the database. All other branches and its offices are not positioned near the main accounting center, which is the reason why such control journals are required. The problem is that no one of those branch offices has a computer that is connected to the data-processing site. In order to do that, Local Area Network with central system must be established.

Materials and methods

Research has been made that Research and Training farm “Vecauce” needs to develop its infrastructure and modernize branch offices with workstations (computers). It is required because, at the given moment, reports from all around the branches are written on in the journals that are made from paper and then carried to central data processing site (Fig. 1). This fact gives us a new set of problems, including data loss. Data loss is very serious problem. Also data can be very easily destroyed or falsified, stolen or tempered with. This discovery was made by having a discussion with senior accountant at Research and Training farm “Vecauce”. Careful branch office inspection suggests that branch offices must be equipped with workstations in order to input data electronically. But workstation without network connection is just an advanced calculator, which in this case is no use, because there are data-processing site and data would have to be carried and imported to the database. Disconnected workstation suggestion of course would lower the risk of some problems like, security and data loss over the network (conditional). Main problem still remains - up-to-date data. This problem is easily solved with network connection that connects distant workstations to database.

For analyze were chosen multiple network connection types and technologies. One of the possible network connection types are dial-up. Dial-up Internet access is a form of Internet access that uses the facilities of the telephone network to establish a dialed connection to an Internet service provider (ISP) via telephone lines. Places where telephone access is available, dial-up remains useful. Dial-up is often the only choice available for remote areas, where broadband installations are not present due to low population density, and high infrastructure cost (Woodford, 2011).

Other possible way to connect a designated place to the internet is a satellite internet connection. Satellite internet access is internet access provided with the help of satellites, and the service can be provided world-wide. All geostationary satellite communications, compared to ground-based communication, experience high latency due to the signal having to travel 35,786 km (22,236 mi) to a satellite in geostationary orbit and back to Earth again. It takes a radio signal about 250 milliseconds (ms), or about a quarter of a second, to travel to the satellite and back to the ground even if all other signaling delays could be eliminated. For an internet packet, that delay is doubled before a reply is received. This gives u a typical one-way connection latency of 500–700 ms from the user to the ISP, or about 1,000–1,400 ms latency for data packet to travel back to the user also known as total round-trip time (RTT).

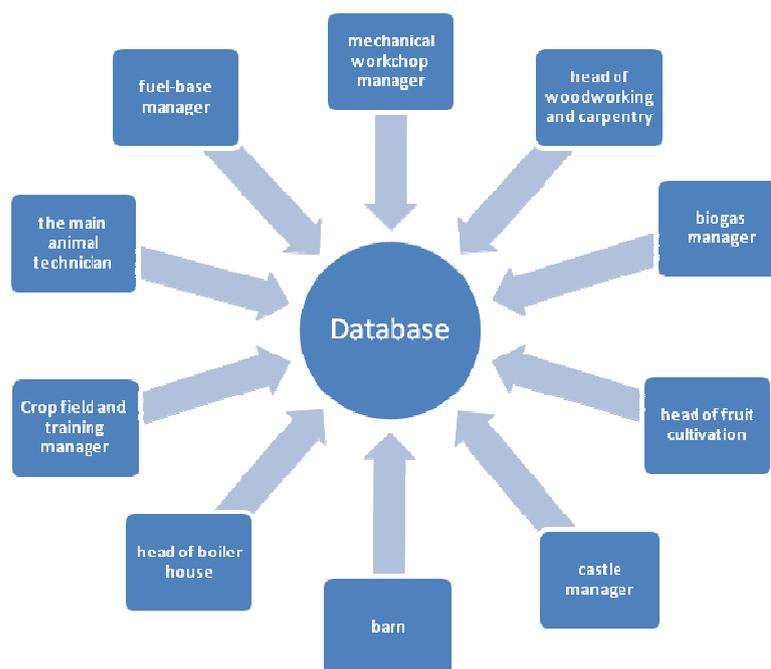


Fig. 1. **Branch distribution** (Varslavans, 2012).

Next possible way to connect the internet or make Local Area Network is the power lines solution. Power line communication or power line carrier (PLC), also known as power line digital subscriber line (PDSL), mains communication, power line telecom (PLT), power line networking (PLN), or broadband over power lines (BPL). Those are systems for carrying data on a conductor also used for electric power transmission that way network can be established without additional wires (Sheldon, 2001). Electrical power is transmitted over long distances using high voltage transmission lines, distributed over medium voltages and used inside buildings at lower voltage.

Cellular broadband connection is one of possible ways how a remote workstation can be connected to the network. This network connection is very mobile and can be used almost anywhere where is cellular network coverage

Wireless Network is widely used all over the world because it's mobile and fast and most of portable devices are equipped with Wi-Fi transmitter-receiver unit. Wi-Fi is a mechanism that allows devices to exchange data wirelessly over a computer network. A device enabled with Wi-Fi, such as video game console, tablet, personal computer or any other device, can connect to a network via a wireless network access point.

Workstation itself should be running at least windows XP or newer version and should be connected to the network in order to access database. Workstation must be equipped with UPS for emergency case or power failure. Program itself has low hardware requirements comparing to nowadays technology achievements as described in Table 1.

Table 1

Hardware requirements	
Hardware	Minimal requirements
Case	Not specified
Processor	At least Pentium IV 3.0Ghz
Hard drive	200 GB or more
Video card	Nvidia GeForce 6200 250Mb RAM or equivalent
Motherboard	Not specified
Memory	1 GB
Network card	At least 10 Mb/s
CD/DVD drive	Not specified
Keyboard/mouse	Not specified
PSU	With surge protection
Monitor	Not specified

Results and discussion

Network connectivity could be established through many technologies, some of them require internet connection, and some of them don't. Ones that require internet are cheaper and more easy to use because of the very distant branch office location around the main data center. Internet is required to connect those distant branch workstations to main database simply because it is more easy and faster than developing LAN at the start. Although LAN would pay off in very long period. Since there is no twisted-pair (10BaseT) or coax (10Base2) going from or to the workstations, it requires that other type of internet connection is established (Catanzarite, 2001).

Dial-up Internet connection is first internet connection available to public and it is as old as it is simple and slow, with the modern modems the speed varies from 20kbit/s to 56kbit/s. Factors that affect speed is phone line noise and quality of the modem. Sometimes connection speed may be lower than 20kbit/s because of the "noisy" environment, like electrified fence or high voltage lines or any other place that generates electromagnetic field. Other negative thing is a high latency that dial-up have, which might create problems in data input (if program is latency sensitive). When a computer dial into the Internet, what is actually happening is using a modem and telephone line to make a semi-permanent connection into another computer network. When a computer dials in, it sends digital information through the telephone line to a modem at your Internet service provider (ISP). Once the modem is talking to the ISP's modem, computer can use the ISP's computer to access other network resources. Dial-up requires time to establish a telephone connection (up to several seconds, depending on the location). When connection is established performing handshaking for protocol synchronization is needed before data transfers can take place. Dial-up access is a transient connection, because either the user, ISP or phone company will terminate the connection. Internet service providers usually set a limit on connection duration to allow sharing of resources (phone call, etc.), and will disconnect the user—requiring reconnection and causing delays associated with it. Only thing is, if there is no phone line there is no dial-up. Prices are as follows fee for establishing a connection 0.0244 LVL and every 0.0244 LVL for every minute that user spends connected.

If Satellite connection is chosen, then the latency problems occur and if program is latency sensitive then this is a very bad solution. The higher the satellite the higher the latency and this is much more than most dial-up users experience at typically 150–300ms total latency. However Medium Earth orbit (MEO) and low Earth orbit (LEO) satellites do not have such great delays. The problem with data transfer rate is that Satellite communications are affected by moisture and various forms of precipitation (such as rain or snow) in the signal path between end users or ground stations and the satellite being utilized (Maral et al., 2011). Total Expenses that are required to organize internet connection with satellites is 450 LVL starter kit that includes satellite dish and transmitter receiver and additional 17 LVL monthly subscription, but that is cheapest option.

Power line communication or power line carrier (PLC), on the other side is rather new technology and not widely used in Latvia. Most PLC technologies are limited to one set of wires (such as indoors wiring within a single building). Different data rates are used in different situations. Speed can be affected by power usage and interference. Typically transformers prevent propagating the signal due to their operating principles, which requires multiple technologies to form larger networks. But there is greater risk of data security problems, because power lines are going from pole to pole and everyone can access them if they have determination. In this case data could be easy stolen or altered. But there is solution for that- Virtual Private Network if network involves internet connection or data encryption if it is just Local Area Network. As mentioned above authors did not find any companies supporting this technology in Latvia, however it can be acquired from foreign countries. Price is approximately 150 USD for a package that includes two outlets for both ends of the communication. That is only for single power network. To create larger network there is required other technologies that of course rises the exploitation fee.

Cellular network is available almost everywhere, however weather plays a role in network speed that is available at any given moment. There are lots of network standards that can be used, such as GPRS, 3G, WiMAX, LTE, Flash-OFDM, IPW, iBurst UMTS/HSPA, EV-DO. However most of them refer to EVDO, GSM, EDGE, and HSPDA/HSUPA/HSPA. Such systems use the mobile phone infrastructure, and some of them even actually share spectrum with voice calls, which of course have higher priority (Hallberg, 2009). Problem with this cellular broadband connection solution is the coverage the mobile phone network can provide. In many areas it is not possible to achieve the maximum speeds due to mobile data coverage limitations. In addition there are issues with connectivity, network capacity, mobile network operator's overall inexperience with data traffic and application quality. The further the users are from the transmitter, in this case the mobile phone tower, the slower and less qualitative the connection is. Price is dependent on the amount send and varies depending operator. Prices are as follows 500Mb- 5 LVL, 20 GB- 20 LVL or 0.03 LVL per Mb.

Wi-Fi as network solution is good in low range situations, but here we have longer distances that have to be connected. Wi-Fi networks range is limited by the antenna type, transmission power, environment and the location that it's used in. Access points have a range of approximately 20 meters indoors with stock antenna using point-to-multipoint arrangement and using 802.11b or 802.11g protocol. Point-to-multipoint would be

useful if the branch workstations are near, which in this case are not true (J.Muller, 2003). That's why mostly in outdoors everyone uses point-to-point arrangements and directional antennas. By using directional antenna there is way to transmit data over 10 km or more. Directional antenna or beam antenna is an antenna that radiates greater power in one or more directions. This gives improved performance on transmit and receive and reduced interference from unwanted sources. Using this antenna there is much bigger power consumption. However between antennas there must be clear line of sight, even soft vegetation can affect or dampen signal (Greene, 2008). Also changes to software must be made, because the signal has to travel longer distances and that takes longer time. Due to earth's curving geographical shape there is a limited range. Regarding price directional antennas price ranges from 60 to 200 LVL plus every extra equipment about the same price.

Since data travels from one branch to data-processing site, it is essential, that data are entered as soon as they appear so that other branches can use that information and act accordingly. It is suggested that data input is one person duty, thus involving less security problems and data errors. Input operators should have only limited database access adjacent to his jurisdiction. As the communication technology choice is chosen Wi-Fi technology with directional antenna in places where line of sight is available. For the places where no line of sight is available there are two suggestions - cellular network connection or dial-up. Data should be handled by not more than 4 persons that work in branch and are responsible for data, also computer security measures has to be taken to lower the security risk. Virtual Private Network should be used for connection and also data encryption techniques to guarantee traveling data security.

Conclusion

Before selecting network connection for branches, a good understanding of networking is required. Some networking solutions for Research and Training farm "Vecauce" require internet connection, but some only require LAN. In this work had reviewed network connection types and why it is needed to connect branch offices to network, based on the given data and office location in nature. It also reveals that no single technology could be applied for all branches, because some branches are closer and some are further away from data-processing site. One technology can be applied for some branches but for other branches the technology can't be applied, because of a numerous factors that impact network capability to function properly. During the research were found out that there is a lot of way how a network connection could be established between two distant places. Also that Research and Training farm "Vecauce" farm needs workstations at branch offices so that data can be inputted as soon as they appear, and also some data security related problems would be resolved. Also data handling guidelines have been created.

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INFLUENCE OF FORMING PRESSURE OF SAMPLES MADE OF THE MIXTURE OF UNBURNT CLAY AND SAPROPEL ON THERMOPHYSICAL PROPERTIES

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Abstract: *The article deals with the dependencies of density of samples made of pure clayey soil, sapropel and clayey soil mixture on formation pressure; it also deals with the dependency of heat conductivity and absorption capacity of samples made of clayey soil with 20% additives of sapropel on formation pressure and absolute humidity of samples. It has been established that density of dry samples increases when formation pressure is enhanced. Density of samples made of pure clayey soil increases more than of samples made of clayey soil and sapropel mixture. The dependence of heat conductivity in samples, formed at 26 – 40 MPa on absolute humidity, is linear, whereas, in samples, formed at less than 26 MPa, is nonlinear. The dependence of absorptive power on formation pressure belongs on the duration of samples keeping over water. Linear regressive analysis of investigation data has been fulfilled using a packet of statistical programmes SPSS-15. It is established that absolute humidity of samples and formation pressure are statistically significant (Sig.>0,001), and humidity of samples during measurements is more important to heat conductivity than formation pressure (Beta values are equal to 0,781 and -0,528 respectively).*

Keywords: Clay, sapropel, heat conductivity, density, absorption

Introduction

The mixture of sapropel and clayey soil is perspective substance in producing building materials (Brakš, 1971; Biriasov et al., 1987; Garliauskas et al., 2004; Katkevičius et al., 1998; Lopotko et al., 1985; Mandeikytė, 1997; Žvironaitė, 1997; Kurzo, 2005). Building materials made from these mixtures have unique properties dependable on the conditions of production and percentage composition of mixture. Lots of authors investigated the properties of sapropel mixtures with various additives (Gurklienė et al., 2004; Gurskis et al., 1996, 1998, 1999, 2000, 2004; Iljins et al., 2005; Navickas et al., 2005).

The purpose of the work is to investigate the dependencies of density, heat conductivity and absorption capacity on formation pressure in samples made of sapropel and clayey soil mixture. The samples were formed from easily melting clayey soil found in Kaunas Šatijai clay quarry. The clay was remilled additionally before making. It had particles: if their measurements were from 2 mm to 0,063 mm, they made 0,3 %, 63 – 2 μm – 32,3%, less than 2 μm – 67,4%. The samples were formed from 22 % absolute humidity mass, which was made of 20 % sapropel and 80% clayey soil. The pH of used sapropel was 5,7, and its dry mass was only 6,46 %. Organic substances in a dry mass made 91,03%. The samples were pressed by hydraulic press ПГ-100 (Kasperiuonaitė et al., 2010). The samples were formed using 7 – 40 MPa pressure in an indoor temperature. The samples, after taking them from forms, were dried at indoor temperature till constant mass appears. The process of desiccation was continued in a thermostat at 105°C also to a constant mass. Further, the samples were cooled in a hermetic vessel to a constant thickness. The density and volume of samples was established applying Archimedes's principle; heat conductivity was measured up by conductivity gauge FOX200, and absorptive power was established according the methods that were described above (Kasperiuonaitė et al., 2009).

Results of research

The dependence of density of samples made of dry clayey soil and samples made of clayey soil and sapropel mixture on formation pressure is given in Fig.1 below.

It can be observed, that density, enhancing formation pressure, increases both in dry samples made of pure clayey soil and in samples made of mixture of clayey soil and sapropel. However, true to form, density values of samples made of pure clayey soil are larger than of samples made of sapropel and clayey soil mixture. The dependence of density of samples made of pure clayey soil on formation pressure is more expressed than of samples made of sapropel and clayey soil. Besides, the samples made of pure clayey soil were formed of formation mass having 9% of absolute humidity. Absolute humidity of formation mass determines the density of a sample (Iljins et al., 2005), therefore, it is impossible to compare the above mentioned dependences, however, it is obviously seen that the additive of sapropel lessens density. Sapropel as an additive enhances scattering of experimental points as it is calculated using trend lines and the coefficients of their determination. The dependence of the samples formed using 7 - 40 MPa pressures on absolute humidity of samples is presented in Fig.2.

It can be observed from the above mentioned results that heat conductivity of samples increases when formation pressure enhances. Absolute humidity of samples also increases heat conductivity, however, as it can be seen,

the run of the growth depends on sample formation pressure. From pointed trend lines we see that when there are similar coefficients R^2 , samples formed at 40 – 26 MPa pressure, the dependence of heat conductivity λ on absolute humidity of samples W can be describes using linear function $\lambda = aW + b$, and samples formed using pressure less than 26 MPa have the dependence described by a polynomial $\lambda = aW^2 + bW + c$. After calculating trend lines and choosing only such trend lines that have coefficients R^2 larger than 0,99, we can explain the above mentioned experimental dependencies in a following way: the larger sample formation pressure, the closer particles of substance are and they form capillaries of less diameter. When sample formation pressure is equal to the range from 40 MPa to 26 MPa, humidity existing in the capillaries of samples moves towards surface according to additional pressure and heat conductivity decreases in a linear way. Heat transport from particle to particle, diffusions together with secret heat transport and radiation mechanism function here. Capillaries having unequal diameters are usually formed in samples formed using pressure less than 26 MPa.

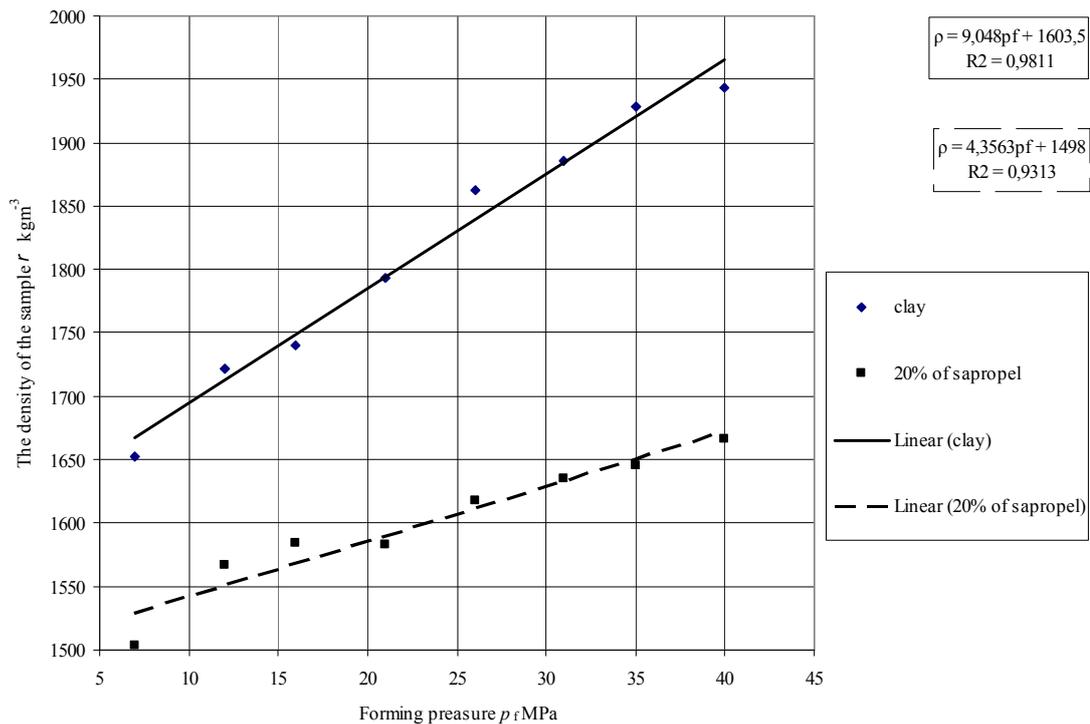


Fig.1. The dependence of density of samples on sample formation pressure

- ◆ ————— Experimental points and trend lines of samples made of pure clayey soil
- - - - - - Experimental points and trend lines of samples made of clayey soil with 20%

Capillary water fills them not fully; air–water vapour plugs are formed and they impede water vapour diffusion as well as prevent capillary water to move towards surface. Therefore, heat transfer decreases according to diffusion and secret heat transfers in samples that have been formed using pressure less than 26 MPa. Comparing dry samples and samples having 8% of absolute humidity formed using 7 and 40 MPa pressure, the difference of heat conductivity between humid and dry samples shows that heat conductivity in humid samples is larger in 36% than id dry samples. After processing the dependencies of heat conductivity by programme SPSS15, it is established that absolute humidity of samples in a process of measurements and formation pressure are statistically significant (Sig.>0,001), and humidity of samples to the average of heat conductivity is more important than sample formation pressure (Table 1, Beta values are equal to 0,781 and -0,528 respectively).

Table 1.

Results of linear regressive analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	0,504	0,007		74,631	0,000
	W , %	0,015	0,001	0,781	28,495	0,000
	p_f , MPa	-0,008	0,000	-0,528	-19,246	0,000

Applying unstandardized coefficients, we get a linear equation of regression to prognose the average of heat conductivity λ in samples:

$$\lambda = 0,504 + 0,015W - 0,008p_f, \tag{1}$$

here W – humidity of samples during measurements in %; p_f – sample formation pressure MPa.

The dependence of sample absorption capability on sample formation pressure is presented in Fig.3. It can be seen that absorption capability ambiguously depends on sample formation pressure. In the beginning of the process (in a period of two days) absorption capability is inversely proportional to sample formation pressure. After three days of experiments absolute humidity in samples, formed using 7 and 40 MPa, becomes equal.

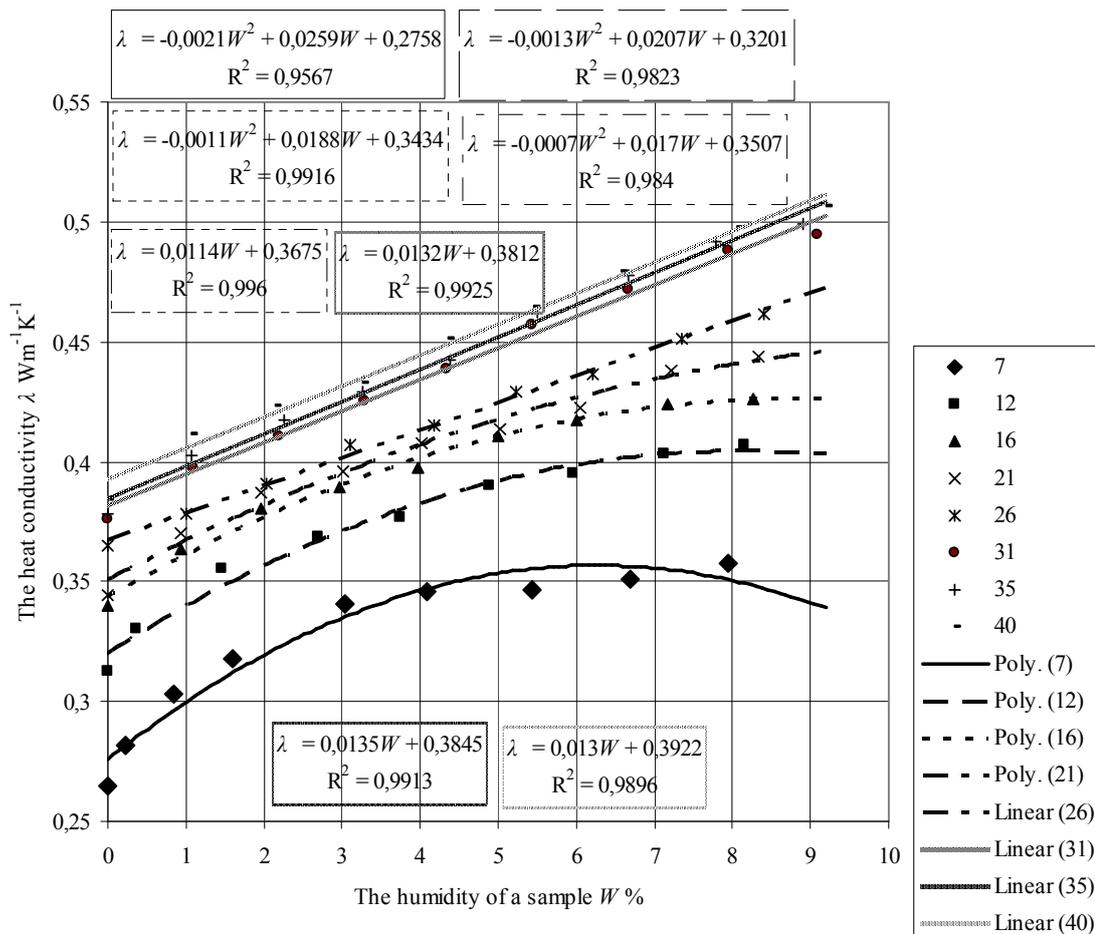


Fig.2. The dependence of heat conductivity on absolute humidity of samples formed at 7 – 40 MPa formation pressure. Ratings at points and trend lines show formation pressure MPa of samples

After keeping samples over water for 9 days, it was established that absorption capability in samples, formed using 7 – 25 MPa, does not almost depend, and maximum absorption can be noticed in samples, which are formed using 30 – 40 MPa. The fact can be explained in the same way as in heat conductivity case. When

sample formation pressure increases, the diameter of capillaries enhances too. Therefore, in the beginning of absorption on account of diffusion water vapour transfer is quicker in samples formed using less pressure. The thinner a capillary is, the earlier water column forms in it, because the smaller the diameter of a capillary is, the larger concentration of nucleus forms. Scilicet, absorption of water vapour takes place in the samples in two modes: water vapour diffusion in capillaries and moving of formed water column in a capillary.

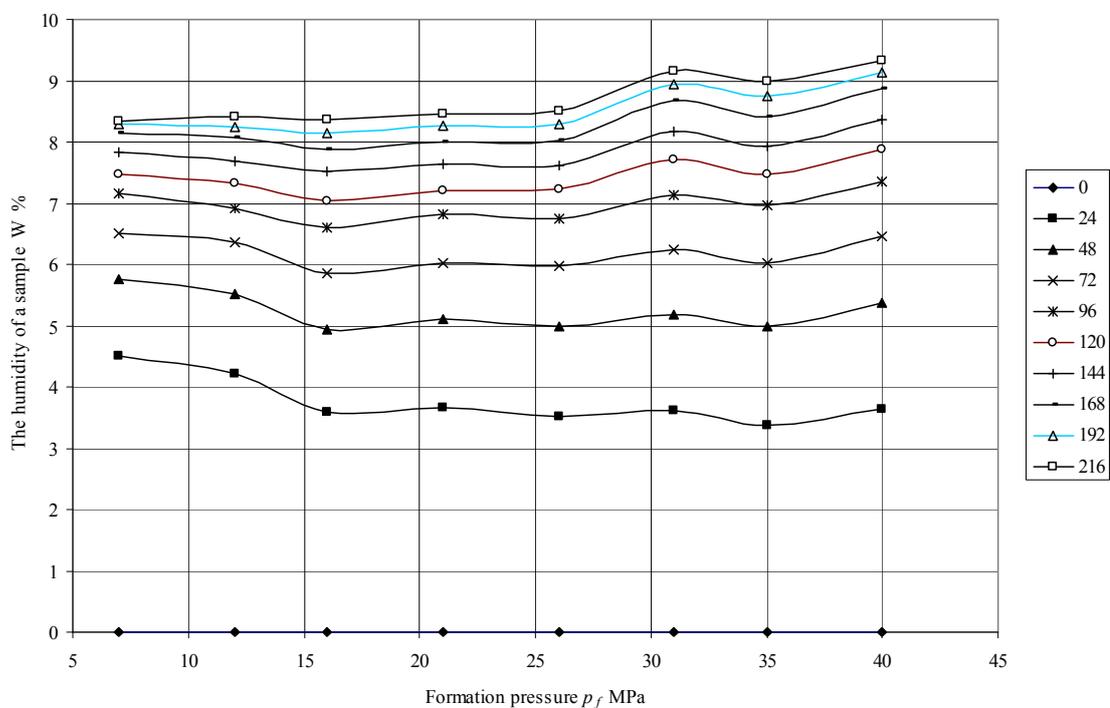


Fig.3. The dependence of sample absorption capability on sample formation pressure in various terms of keeping samples over water. Ratings at experimental points correspond to sample keeping term in hours

Conclusions

1. The density of samples made of clayey soil and of clayey soil with 20% of sapropel additives has linear dependence on sample formation pressure (coefficients of determination are 0,9811 and 0,9813 respectively).
2. Linear dependence (formation pressure is 40 – 26 MPa) and nonlinear dependence (formation pressure is less than 26 MPa) are observed in the dependencies of heat conductivity on sample formation pressure.
3. Humidity of samples while measuring is more important to the average of heat conductivity than sample formation pressure (standardized coefficients 0,781 and -0,528 respectively).
4. During two primary days the capacity of absorption was larger in samples made using small formation pressure, and later the capacity of absorption is larger in samples made using the largest pressure (30 – 40 MPa).

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INFLUENCE OF PERCENTAGE IN THE MIXTURE OF SAPROPEL AND UNBURNT CLAY ON THERMOPHYSICAL PROPERTIES OF SAMPLES

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Abstract: *The dependence of thermo physical properties of samples formed at 21 MPa from clayey soil and sapropel mixture having 22% of absolute humidity on the amount of sapropel. It is established that when the amount of sapropel changes in samples from 8 to 20%, the density, heat conductivity and absorptive power in samples are inversely proportional to the amount of sapropel. After fulfilling experimental data of linear regressive analysis it has been established that the amount of sapropel has greater influence on the average of density (Beta=-0,794) than humidity of samples (Beta=0,528); humidity in samples has greater influence on the average of heat conductivity (Beta=0,819) than the amount of sapropel (Beta=-0,485); and the duration of sample keeping over the water has larger influence on the average of sample humidity (Beta=0,902) than the amount of sapropel (Beta=-0,313).*

Keywords: Clay, sapropel, heat conductivity, density, absorption

Introduction

Since long-ago local materials were used to build shelters. Clayey soil (further – clay) was one of used materials. It was used to form the walls and other elements of a building. It was proved that properties of clay samples had been determined by formation pressure and absolute humidity of both formation mass and samples at the date of the establishment of characteristics (Garliauskas et al., 2004; Gurklienė et al., 2004; Kasperiuonaitė et al., 2005, 2006, 2009). The properties of unburnt clay were influenced by various additives (Gurskis et al., 1996), Lithuanian lake silt – sapropel was one of them (Gurskis et al., 1998, 1999, 2000, 2004; Iljins et al., 2005; Navickas et al., 2005). The results of the investigation showed that heat conductivity, capacity of water vapour absorption and strength bending and compressing the samples depended on the amount and quantity of sapropel. However, the works did not deal with the problem how formation pressure and absolute humidity of formation mass influence the properties of samples. Later the influence of the amount of organic sapropel (1%, 2% and 4%) on heat conductivity, density and absorptive power of samples forming them from formation mass having 7% of humidity at the pressure from 10 MPa to 40 MPa (Kasperiuonaitė et al., 2009, 2010; Iljins et al., 2009). It was also established that increasing the formation pressure from 10 to 40 MPa the density of samples enhanced; increasing the amount of sapropel from 0 to 2% density and heat conductivity in dry samples decrease; further increasing the amount of sapropel to 4%, the above mentioned properties did not change. When samples were moistened, their heat conductivity increased. After fulfilling linear regressive analysis it was established that the largest influence on the average of heat conductivity had the humidity of samples and the least influence had sample formation pressure, whereas, sample formation pressure has larger influence on the average of density than the amount of sapropel.

The purpose of the work is to investigate the dependencies of density, heat conductivity and absorptive power of samples made of sapropel and clay mixture on the amount of sapropel in them (8%- 20%) when sample formation pressure is constant (21 MPa). The samples were formed from easily melting clayey soil from Šatijai clay quarry near Kaunas. Before production the clay had been ground and particles: from 2 to 0,063 mm amounted to 0,3 %, 63 – 2 μm – 32,3%, and less than 2 μm – 67,4%. The samples were formed from mass having 22 % of absolute humidity; the amount of sapropel varied from 8% to 20%. The used sapropel had pH equal to 5,7, and its dry mass amounted to 6,46 %. Organic materials in dry mass were equal to 91,03%. Other materials were: N – 27653 mg/kg, P – 540 mg/kg, K – 464 mg/kg, Cd – 0,8 mg/kg, Cr – 4,63 mg/kg, Ni – 8,60 mg/kg, Pb – 11,3, Cu – 9,73 mg/kg, Zn – 94,0 mg/kg. Granulometric composition of sapropel was as follows: particles with diameter from 2000 to 63 μm amounted to 75,6 %, and 63 – 2 μm - 14,1%, less than 2 μm – 10,3%. The samples were pressed by hydraulic press ПГ-100 using 21 MPa pressure in indoor temperature (Kasperiuonaitė et al., 2010). The samples taken from a form were desiccated at indoor temperature to constant mass. After that they were put into a thermostat and also desiccated at 105°C till constant mass was reached. Later the samples were cooled at in hermetic vessels to 20 °C. The surface of cooled samples was polished to fixed thickness. The density and volume of samples was established applying Archimedes's principle; heat conductivity was measured up by conductivity gauge FOX200, and absorptive power was established according the methods that were described above (Kasperiuonaitė et al., 2009).

Results of research

The dependence of density ρ of dry samples made of the mass having 22% of absolute humidity and formed at 21 MPa pressure on the amount of sapropel x is given in Fig.1 below. It can be observed that when the amount of sapropel increases from 8 to 20%, the density of samples lessens. The density increases when humidity in samples increases too. The results of linear regressive analysis of the dependencies of sample density on sample humidity are presented in Table 1. 124 experimental points have been used for the analysis. Determination coefficient of a model $R^2=0,979$ shows that 97,9% of sample density dispersion can be explained by the model of linear regression.

From the results presented in Table 1 we can observe that the amount of sapropel and humidity in a sample are statistically significant to the prognosis of average density of a sample ($p<0,001$) (Navickas et al., 2005). The equation of average density prognosis is got applying the meanings of non-standardized coefficients B in Table 1.

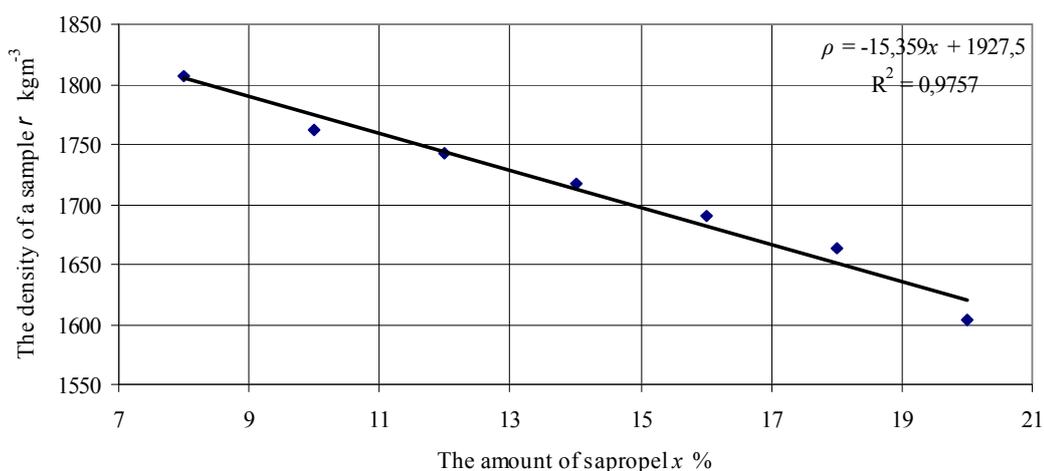


Fig.1 The dependence of density on the amount of sapropel in a sample

Table 1.

The influence of sapropel amount and humidity of a sample on the average of density

Factors	Coefficients	Non-standardized Coefficients B	Standardized Coefficients Beta	p
Constant		1934,702		0,000
The amount of sapropel, %		-15,890	-0,794	0,000
The humidity of a sample, %		13,657	0,528	0,000

$$\rho = 1934,702 - 15,890x + 13,657W,$$

here ρ – density of a sample kgm⁻³;

x - amount of sapropel %;

W - humidity of a sample %.

It can be observed that when the amount of sapropel increases in 1 %, the density of a sample lessens in 15,89 kgm⁻³, whereas, when the amount of sample humidity increases in 1%, the density increases 13,657 kgm⁻³. According to the meanings of standardized coefficients it can be concluded that the amount of sapropel on the average of sample density (Beta=-0,794) has larger influence than the humidity of a sample (Beta=0,528).

Figure 2 presents the dependencies of heat conductivity in samples on the humidity of samples when samples have different amount of sapropel. Values of trend lines coefficient R^2 are larger than 0,99 and it shows great reliability of the results. It can be seen that when the amount of sapropel in dry samples increases, heat conductivity lessens. After calculating maximal values of trend lines, it was received that a sample having 8% of sapropel additive would get maximal value of heat conductivity when humidity of sample is 11,2%. Increasing the amount of sapropel in a sample the value of above mentioned maximum sample humidity W_{max} increases and becomes the largest ($W_{max}=16,7\%$) when the amount of sapropel reaches 14%, whereas, when the amount of sapropel are 12 and 16% they are close (16,1 and 16,2% respectively). Continuing to enlarge the amount of

sapropel, W_{\max} lessens.

After fulfilling linear regressive analyses on the dependencies of heat conductivity on density, absolute humidity and the amount of sapropel in samples, it has been received that the density of a sample is statistically insignificant to the prognosis of heat conductivity average. Final results of linear regressive analysis are presented in Table 2. From the data given in the table it can be noticed that the amount of sapropel and humidity in a sample is statistically significant to the average of heat conductivity ($p < 0,001$). Using the values of non-standardized coefficients, we can write the equation of prognosis of the average of heat conductivity:

$$\lambda = 0,492 - 0,007x + 0,015W, \quad (2)$$

here λ – heat conductivity of a sample $\text{WK}^{-1}\text{m}^{-1}$.

It can be seen that when the amount of sapropel increases in 1% heat conductivity of a sample lessens in 0,007 $\text{W}/(\text{mK})$, whereas, when humidity increases in 1%, its heat conductivity increases in 0,015 $\text{Wm}^{-1}\text{K}^{-1}$.

The coefficient of determination of a model is $R^2=0,948$. It proves that the model of linear regression can explain 94,8% of heat conductivity dispersion. Comparing standardized coefficients we can draw a conclusion that humidity of samples has larger influence heat conductivity (Beta=0,819) than the amount of sapropel (Beta=-0,485).

The results of the investigation of absorptive power are presented in Fig.3. It can be observed that when the amount of sapropel increases, absorptive power in samples lessens.

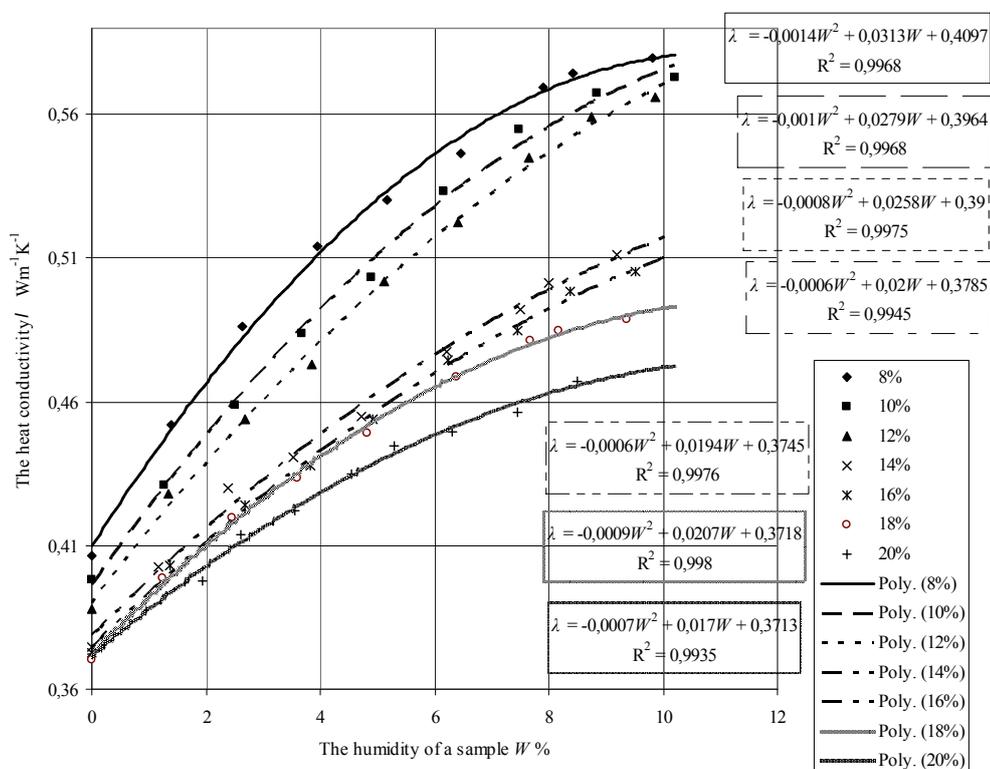


Fig.2. The dependence of heat conductivity on the humidity of a sample when the amount of sapropel in a sample amounts to 8, 10, 12, 14, 16, 18 and 20%: 8% - 8% sapropel, 10% - 10% sapropel, 12% -12% sapropel, 14% -14% sapropel, 14% - 14% sapropel, 16% - 16% sapropel, 18% - 18% sapropel, 20% - 20% sapropel. (8%), (10%), (12%), (14%), (16%), (18%), (20%) –trend lines, calculated according to the dependencies of the second degree polynomials 8%, 10%, 12%, 14%, 16%, 18%, 20% respectively

Table 2.

The influence of the amount of sapropel and humidity of a sample on the average of heat conductivity

Factors	Coefficients	Non-standardized Coefficients B	Standardized Coefficients Beta	p
Constant		0,492		0,000
The amount of sapropel x, %		-0,007	-0,485	0,000
The humidity of a sample W, %		0,015	0,819	0,000

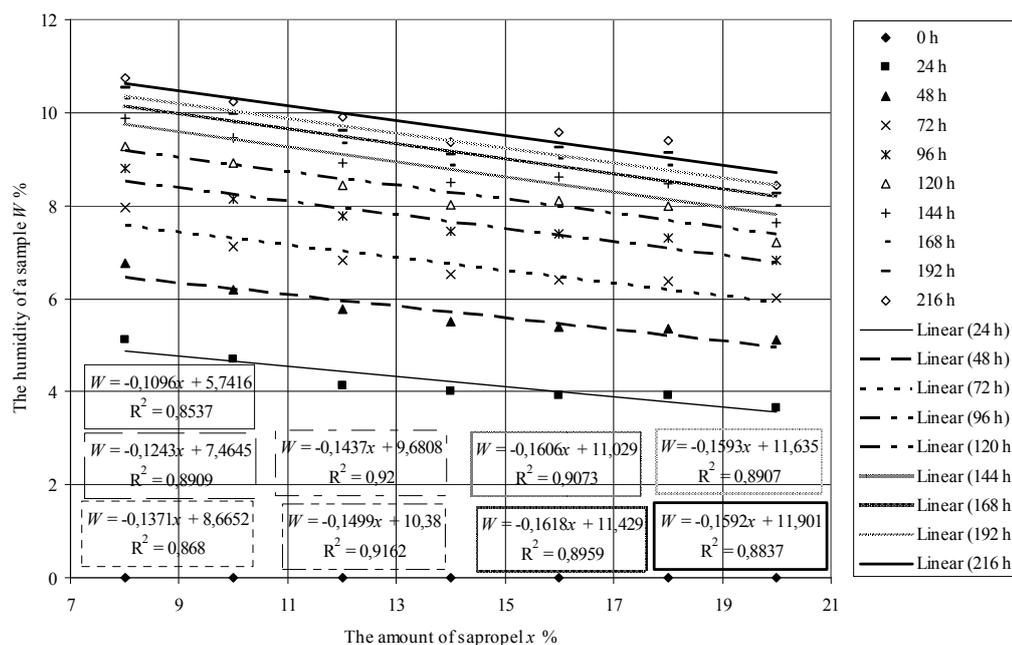


Fig.3. The dependence of absolute humidity of samples on the amount of sapropel when the duration of samples being over water is different. Numbers at symbols mean duration of samples being over water in hours

It can be explained that the larger amount of sapropel is, the greatest part of capillaries is recovered by sapropel particles and absorptive power lessens. The results of linear regressive analysis of the data are presented in Table 3.

Table 3.

The influence of sapropel amount and the duration of samples being over water on the average of sample humidity

Factors	Coefficients	Non-standardized Coefficients B	Standardized Coefficients Beta	<i>p</i>
Constant		6,532		0,000
Time, h		0,027	0,902	0,000
The amount of sapropel, %		-0,145	-0,313	0,000

The equation of the prognosis of sample average humidity is as follows:

$$W = 6,532 + 0,027t - 0,145x, \quad (3)$$

here t – duration of sample being over water in h .

It can be seen that the duration of sample being over water t and the amount of sapropel x in a sample are statistically significant to the average of sample humidity ($p < 0,001$). The duration of sample being over water has larger influence on the average of humidity (Beta=0,902) than the amount of sapropel (Beta=-0,313).

Conclusions

1. The amount of sapropel in samples formed using 21 MPa pressure and having 8-20 per cent of sapropel has larger influence on the average of density (Beta=-0,794) than humidity of samples (Beta=0,528).
2. Humidity in samples formed using 21 MPa pressure and having 8 – 20 per cent of sapropel has larger influence on the average of heat conductivity (Beta=0,819) than the amount of sapropel (Beta=-0,485).
3. Duration of sample keeping over the water has larger influence on the average of sample humidity (Beta=0,902) than the amount of sapropel (Beta=-0,313).

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MEASUREMENT OF PHYSICAL INDICES IN IN DIFFERENTLY MANAGED ARGO ECOSYSTEMS

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Abstract: *The assessment of multiple physical parameters (temperature and humidity of atmosphere and soil, gas concentration, soil solidity, wind velocity, greenhouse gas emissions) is necessary to improve knowledge about management of agro ecosystems. The approach is based on the local measurement and comparing the impact of environment physical indices on agro ecosystems productivity at crop habitat scale. The study was conducted in semi natural grassland (54°52' N, 23°50' E) at Training Farm of Lithuanian University of Agriculture in 2009 and in intensive grassland at conventional farm (Kalvarija distr., 54°28' N, 23°38' E) in 2011 respectively. The data have been collected in a real time using digital sensors of the humidity, pressure, gas concentration, solar intensity, wind speed and temperature. All the dependencies of the various physical data were valuated according to the plant growth. Data were obtained in cultural grasslands with different fertilizer application and in crop fields of different geographical location. The experimental data confirm that the average meteorological data obtained from the State Meteorology Stations are quite preliminary and cannot be unambiguously considered as the environmental factors on the wide area of vegetation with different soil. The picked data set should be used when analyzing ecological drivers on the fluctuation of the climate. Measurement of properties that affect fluid storage and transport, such as macro porosity, provided soil quality indices that helped in recommending suitable soil management systems.*

Keywords: physical indices, measuring methods, ecosystem, spatial variation

Introduction

Cropland amounts to about 12% of the earth's surface (Verma et al., 2005), thus interaction of plants within their physical surroundings is one of the most important concepts within Environmental Science. During the changes of the ecosystem, concerning of the household practice, the rise has born to find others new methods to investigate the environment of the plants. These investigations would optimally let us to evaluate the abiotic environment of plants, namely soil humidity, temperature, solar intensity, atmospheric pressure and others factors. Generally, soil temperature and soil moisture are considered the most influential environmental factors controlling soil respiration. These factors interact to affect the productivity of terrestrial ecosystems and the decomposition rate of soil organic matter, thereby driving the temporal variation of soil respiration (Wiseman and Seiler, 2004). Soil respiration, which originates from autotrophic root respiration and heterotrophic microbial respiration in the rhizosphere and the bulk soil, provides the main carbon efflux from terrestrial ecosystems to the atmosphere and is therefore an important component of the global carbon balance (IPCC, 1996; Soil gas exchange, which originates from autotrophic root respiration and heterotrophic microbial respiration in the rhizosphere and the bulk soil, provides different effluxes from terrestrial ecosystems to the atmosphere and is therefore an important component of the global climate balance (IPCC, 1996). Human-inflicted greenhouse gas emissions affect the global temperature (IPCC, 2007). Indeed, the United Nations has summarized greenhouse gas (GHG) annual increase of 0.4% for CO₂, 0.6 for N₂O, and 0.25 % for CH₄. Therefore it is actual to reduce this important agent of climate change, namely GHG emissions from agricultural sector. However, there is a surprising lack of knowledge on the precise functional roles played by multiple abiotic factors on plant and soil organisms (Park et al., 2003; Han et al., 2007). Generally, soil temperature and soil moisture are considered the most influential environmental factors controlling soil respiration and other metabolic processes. These factors interact to affect the productivity of terrestrial ecosystems and the decomposition rate of soil organic matter, thereby driving the temporal variation of soil respiration (Wiseman, Seiler, 2004). Soil respiration also exhibits high levels of spatial heterogeneity, especially across small spatial scales in forest, grassland and farmland ecosystem at different time scales (Maestre, Cortina, 2003). In order to accurately estimate abiotic conditions in target ecosystems, we must be able to account for small-scale spatial variation in ambient (both air and soil) peculiarities (Adachi et al., 2005). Methods in quantifying spatial variation in soil and air peculiarities are limited and proved to be in small scale (Rayment, Jarvis, 2000). The heterogeneity of vegetation coverage, root distribution, major environmental factors and soil properties contributes to the spatial variation of soil (Tang, Baldocchi, 2005).

This paper reports preliminary results from a project designed to investigate the field scale interactions between the productivity of plant-soil biota ecosystem and environment physical indices (ambient and soil temperature, soil compactness, humidity, greenhouse gas (GHG) emission, etc.). The approach is based on the local measurement and comparing the impact of environment physical indices on agro ecosystems productivity at crop

habitat scale. Moreover, the study was aimed at evaluation effects of site-specific environmental factors (climate and soil) and compare with those of State Meteorological Station (Kaunas, Kalvarija distr.).

Materials and Methods

Biosphere-atmosphere interactions were investigated on a light deeply carbonate washed light loam soil (*Bathihypogleyi-Calc(ar)ic Luvisol*) (FAO/UNESCO, 1997) in semi natural grassland (54°52' N, 23°50' E) at Training farm of Lithuanian University of Agriculture in 2009, in grassland and crops at conventional farm (Kalvarija distr., 54°28' N, 23°38' E) in 2011 respectively. Humus horizon was 25 cm deep. Physical measurements of abiotic parameters were run in June, when meteorological conditions were optimal for intensive plant and soil biota physiological processes, in absence of frosts stress. The nearest neighbors are situated 2-3 km and 250 m away from the study sites at conventional farm and semi natural grassland of Lithuanian University of Agriculture respectively. The vegetation of the site semi natural grassland developed on a neutral soil which has been cultivated in the past, i.e. more than 20 years ago. Investigations were completed during active vegetation period at June. The plants height was 15-20 cm in both cases. Fresh mass (FM) weighting and drying (105°C) was used to obtaining dry mass (DM, %) and grassland productivity (g m⁻²).

Air temperature and humidity were measured by mobile air station Meteo Multi, Campbell (sensor FMA510, humidity sensor PS 2174), UVA radiation by Almemo FLAGB, Radiometer CNR2, soil density by Compaction meter SC 900, Campbell, soil temperature by CM 107, soil humidity by sensor Hydrosense CS-620. GHG emissions, namely CO₂ (mg h⁻¹ m⁻²) and N₂O (µg h⁻¹ m⁻²) were assessed by closed chamber method (Hutchinson, Livingston, 1993). Air samples were analyzed by using MGA3000, CEA Instruments. Results were obtained in 5 sites of each study field (n=10) and processed with Excel and Data Studio. The inter-dependency and correlation of solar intensity, temperature of environment, pressure, and wind speed, soil density were investigated. The air temperature and humidity results were collected evaluating change of the humidity, temperature etc. in the time of dry period. The data of the State Meteorological Station have been compared with measurement results for respective periods (i. e. days) and sites of the experiment. Results were evaluated statistically by using package Statistica program ANOVA. The confidence limits of the data were based on Student's theoretical criterion at the level of statistical significance p<0.05.

Results and Discussion

The 5 experimental sites have been chosen (Fig. 1), which were in many different places of the relief in the semi natural grassland, handing different humidity and density of the soil. The investigations of the soil density have shown that the structure of the measured soil is very different depending on the relief and depth. Diverse results of soil density measurements were recorded at different sites of semi natural and intensive grassland ecosystems (Fig. 1 -2).

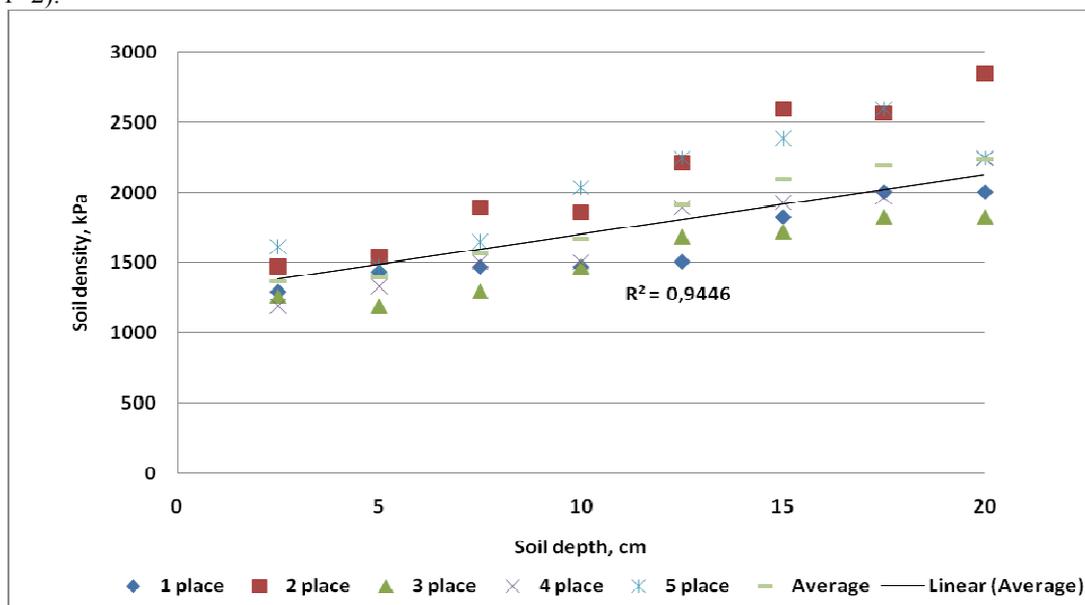


Fig.1. Soil density measurements in semi natural grassland (54°52' N, 23°50' E)

Soil density varied differently depending on experimental site and significantly depend ($r=0.9$) on soil depth (Fig. 1). Therefore more favorable aeration and growth conditions for plant root might be considered in the layer of 0-10 cm, where the main root mass is arranged. When it was compared soils of different land management types, lower soil density of 0-10 cm layer was observed in grassland of conventional farming than that of

abandoned semi natural grassland (Figs1, 2). Consequently, more relevant plant growth conditions could be considered soil of conventional farming due to applied higher cultivation technology.

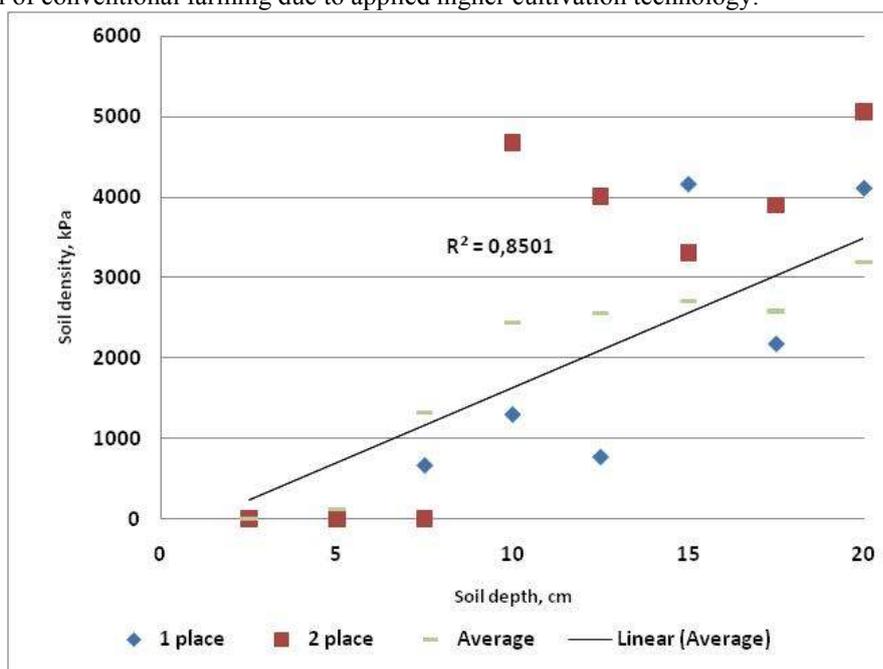


Fig.2. Soil density measurements in conventional farm grassland ecosystems (54°28' N, 23°38' E)

Compared grassland ecosystems, differing in the degree of anthropogenization level and abiotic factors, the least yield of fresh mass (892.5-1520.0 g m⁻²) and dry material (12.7-23.6 %) were obtained in semi natural grassland as compared with those of intensive grassland (Table 1). Intensive fertilizing and optimal botanical composition (47% *Poaceae* and 50% legume) possible could be a reason of higher productivity of intensive grassland.

Table 1.

Yield and botanical composition of semi natural (1-5 site) and intensive grassland (IG)

Site	FM, g m ⁻²	DM, %	Botanical composition, %		
			<i>Poaceae</i>	<i>Fabaceae</i>	Forbes
1	957.5	19.9	35	35	30
2	892.5	22.8	50	3	47
3	1002.5	23.5	75	0	25
4	1102.0	23.6	71	0	29
5	1520.0	12.7	70	0	30
IG	3020.0	27.4	47	50	3
LSD ₀₅	87.55	0.6	1.04	0.53	1.18

One can see the total increase of the soil density against the depth. Indeed, that is logical. Measurements of soil humidity in the same 8 different places verified non homogeneous increasing of density at the same time, and then the depth of the measuring is increasing also.

The highest humidity alteration (ca. 35 %) was observed in sites 1, 2, 4, and 5 (Fig. 1). Noteworthy, these measurements are directly correlating to investigations of the soil density, shown in Fig. 2. In the last (others-at 2011 years) measuring sites moisture was about 5% that emerges a higher soil density (Fig. 2).

When analyzing environment influencing change of plants, investigations of humidity, solar intensity, temperature, wind speed and absolute air pressure were considered. The data of these measurements are presented in Figures 3-7.

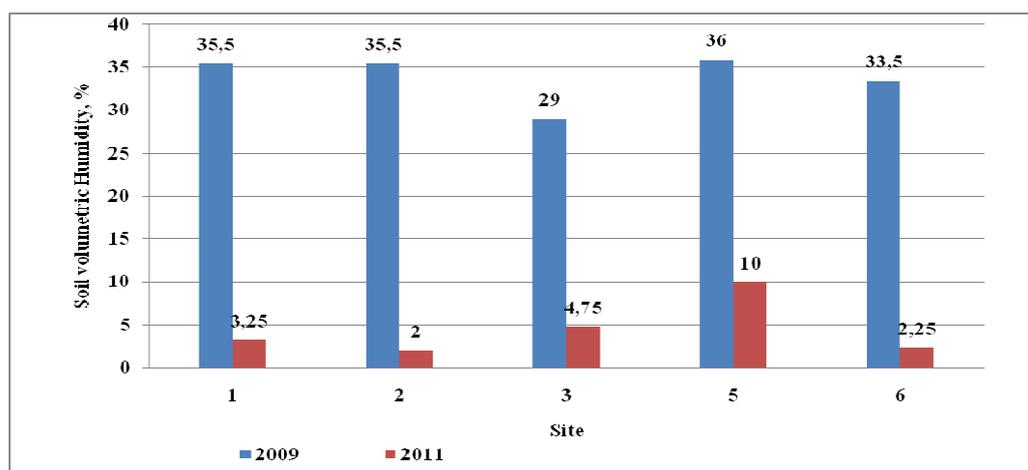


Fig.3. Soil humidity measurements in 2009 and 2011

When lacking rain, the soil humidity (Fig. 3) was changed in dependence on the relief and soil density. This correlation between soil humidity and density is very important for plant growth and productivity (Han et al., 2007). In the sites, where soil density was observed the highest, but humidity was the lowest, the plant height was for 5 – 7 cm less. That shows that plant state directly depended on soil humidity and density.

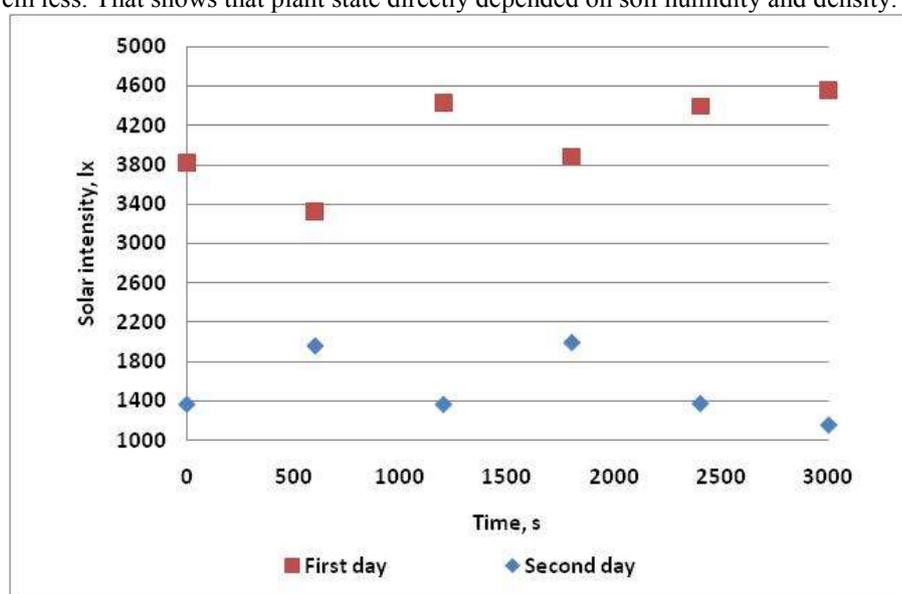


Fig.4. Solar intensity in 2009

As we see, the ambient temperature directly depends on the weather temperature and solar intensity (Fig. 4). The experimental measurement has been arranged during dry period of the day in 12-14 a.m. The medium ambient temperature was 23-27 °C in the first day and 28-23 °C in the second day in the grassland site (Fig. 5). Nonetheless, the different air temperature of 18.9 °C and 21.8 °C was measured in the same days at the Kaunas Meteorology Station (in 2009). Therefore ambient measurements (temperature, precipitation etc.) are more precise in case they are performed at the experimental site, if compared to those obtained at Meteorology Station located some 500 m away. Air humidity ranged between 58-59% in the 1st day and between 38-49% in the 2nd day when measured at the site.

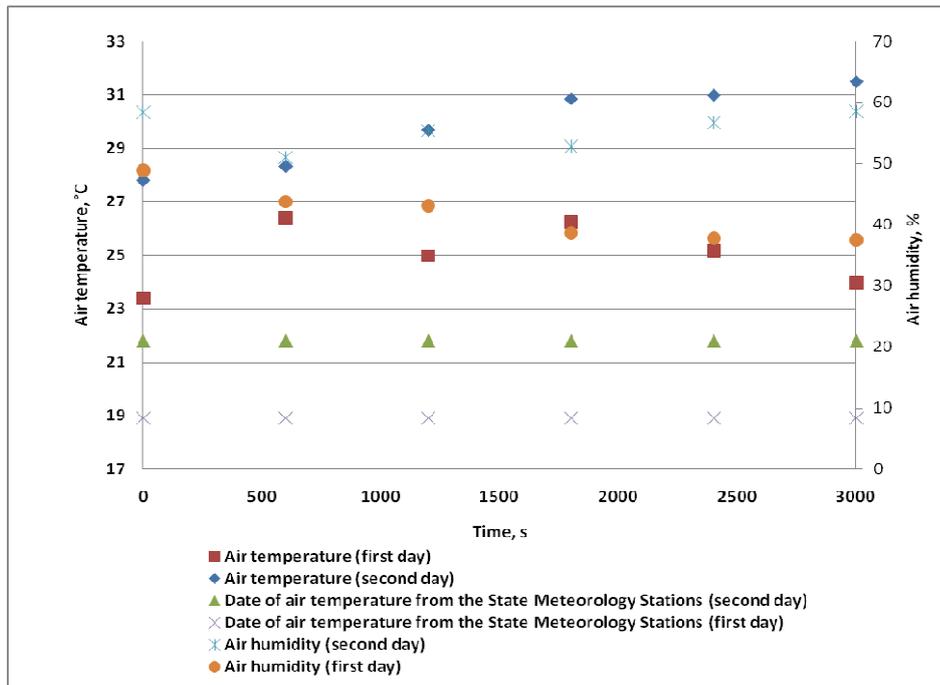


Fig.5. Air temperature and humidity in 2009

The same tendency has observed in the next experimental site situated in Lazdijai district in 2011 (Fig. 6). Air temperature ranged between 28 and 29.1 °C in the experimental field. While it was 22.5 °C obtained from the nearest Kalvarija Meteorology Station. The average soil temperature was 17.5 °C (in 2009) and 19.3 °C (in 2011), during the experiment. The average soil temperature was 18.2 °C (in 2009) and 18.5 °C (in 2011) obtained data from the State Meteorology Stations.

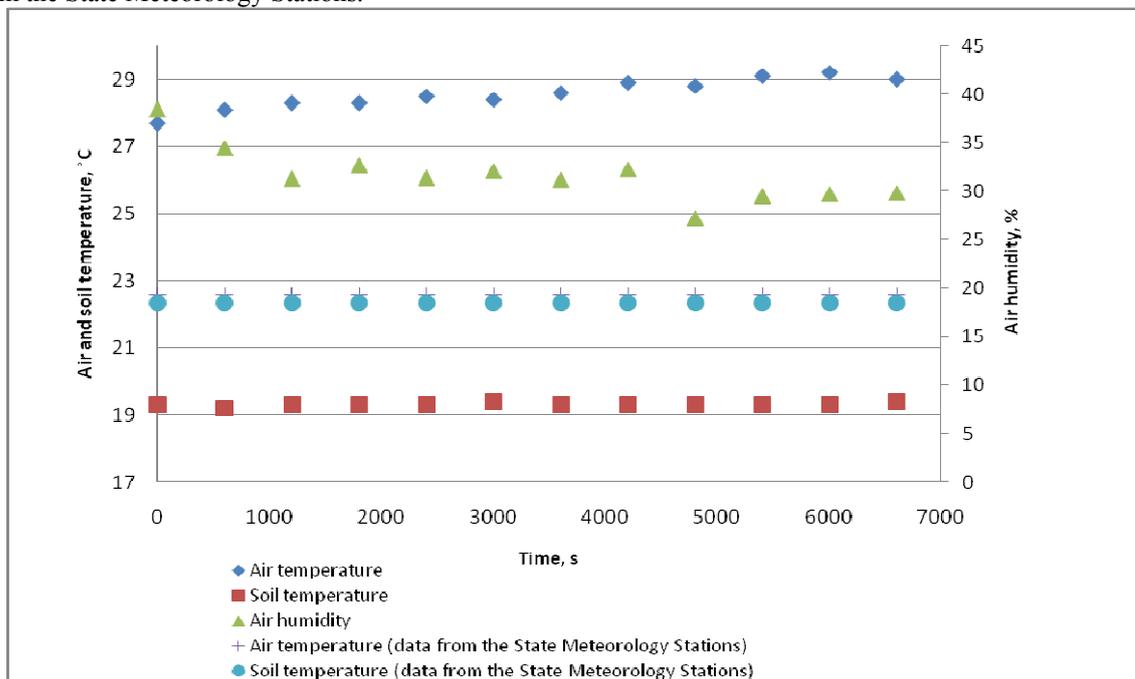


Fig.6. Air and soil humidity and temperature in 2011

The wind direction was changing between 75 and 130 degree to N (Fig. 7). Wind speed approximately ranged between 2.0 and 4.5 m s⁻¹ respectively in 2011.

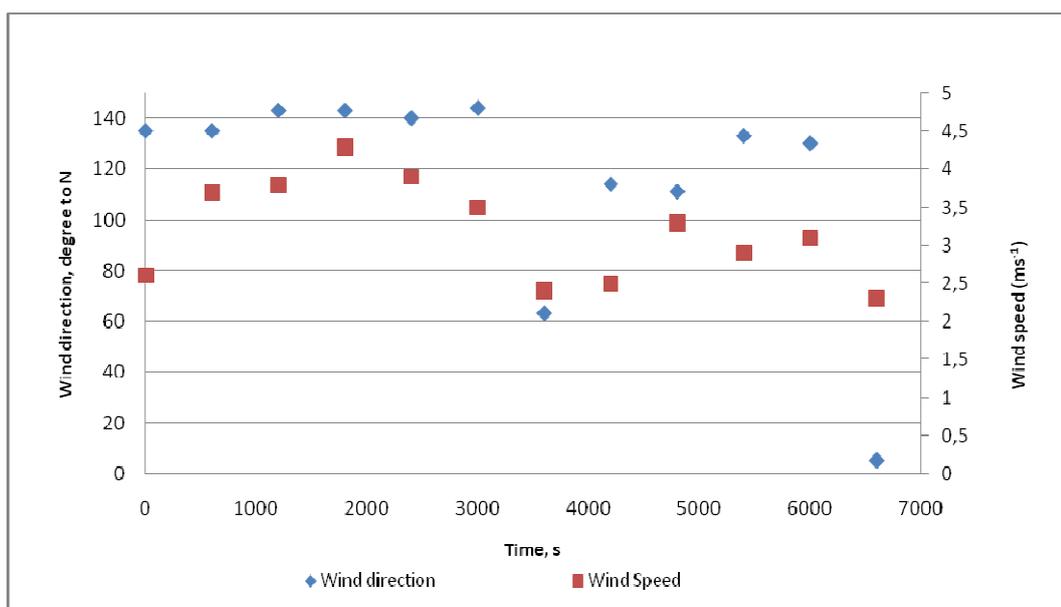


Fig.7. Wind speed and direction in 2011

Crops differed in emitted GHG emissions (Fig. 8). Determination of the most sustainable management practice, generally of fertilizer application, plays an important role in minimizing the residual soil nitrate (Lindborg et al., 2008). Such a reduction, in turn, helps to mitigate the risk of excessive N₂O emissions. On the other hand this practice helps to reduce the confusion over the role of fertilizer N on the total GHGs emission from the cropping ecosystem.

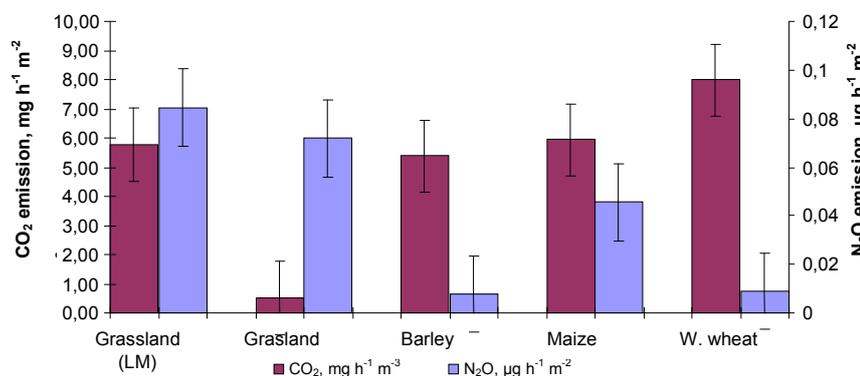


Fig.8. GHG emissions from different crops in 2011 (LM-applied liquid manure; MF-applied mineral fertilizers, w. wheat- winter wheat; mean±SE, p<0.05)

Conclusions

During the time of plant active vegetation period, the abiotic environment indices which have covered have a great importance on crops biomass. Influence of physical factors in local agro environment gives us to understand rating of physical data complexes over time, not only in plant surrounding (air, and soil), but also it gives as an information about influence of field management measures (soil preparation, structure, fertilization etc.). Experimental data of this study confirmed that for thorough analysis of agro environment impact on plants would be not limited data getting from State Meteorological Stations, lying in distance of 10 to 15 km. The best way would be to use these data only as a bearing or commendatory. We have to notice that data of the environment factors in agro ecosystems must be collected in separate site rather obtained from centralized Stations.

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SAD: WIRELESS SENSOR NETWORK SYSTEM FOR MICROCLIMATE MONITORING IN PRECISION AGRICULTURE

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Abstract: *Accurate and easily accessible microclimate data coming from a broad range of locations is useful for both for agricultural scientists researching the effects of various environmental parameters on orchard, and for agriculture practitioners willing to increase yield quantity and quality from their plantations.*

We present SAD: a wireless sensor network (WSN) system designed for this very purpose – collecting microclimate data in precision agriculture. We describe the hardware solution we have specifically designed for this application – SADmote, a WSN device for microclimate monitoring –, and the software we have created and adapted, which includes MansOS, an operating system for WSN motes. However, the main focus point of this paper is on two pilot sensor network deployments carried out in the orchard of Latvia State Institute of Fruit-Growing. The first pilot sensor network was deployed in 2009, used 8 motes, and harvested data for a month; the second deployment took place in 2011, used 17 motes (12 of them custom-made) and lasted for one and a half month. We discuss and analyse this real-world WSN experience in the context of our future plans. We believe the lessons learned will be useful for a broader WSN community.

Keywords: environmental monitoring, precision agriculture, sensor networks, real-world experience

Introduction

Microclimate factors have tremendous influence on fruit plant yield quantity and quality. In past, these factors were largely unmanageable, but that has changed with the proliferation of protective covers for fruit species (such as sweet cherries, strawberries and raspberries), precise watering systems, and other precision agriculture technologies. In the modern orchard, microclimate can be controlled and changed, for example, by using covers, the fruits can be protected from rain and hail, which can damage and in some cases destroy the yield. On the other hand, the cover itself can have a negative influence on the yield – it not only protects the plants and helps to establish optimal moisture conditions, but also reduces the amount of sunlight that plants receive, and is beneficial for development of pathogens and pests.

It is essential to have a high-quality microclimate monitoring solution in place to fully exploit the options offered by such a microclimate control system, register its own effects, and to provide a near real-time alarm signal in case some of parameters reach values dangerous either for the yield or the plants themselves. Wireless sensor networks is a technology that naturally fits in this role, and as such have been frequently used in precision agriculture (Baggio, 2005) and environmental monitoring (Selavo et al, 2007) applications.

In SAD project we experimentally evaluate suitability of wireless sensor networks for microclimate (light, temperature, humidity) monitoring in precision agriculture. This task is carried out in collaboration with Latvia State Institute of Fruit-Growing (LSIFG), as part of a greater precision agriculture research project “Development and adaptation of innovative risk reducing technologies for fruit and berry growing in conditions of Latvia”. Informal name of the project is “Sensors in Fruit Garden”, which has the Latvian abbreviation “SAD”. We note the excellent suitability of this name for our project, as in Russian “sad” means “orchard”.

For this application we have designed our of hardware solution – SADmote (Elsts et al, 2012a) and adapted our own mote software – WSN operating system MansOS (Strazdins et al, 2010), and supporting tools, for example, web interface for data access. The objective of this paper is to describe the experiences and lessons learned from our two pilot sensor network deployments. We analyse these experiences and use them to as a basis for future plans and perspectives. The chronology of our deployments is outlined in Table 1.

Table 1

Chronology of SAD WSN deployments

Date	Activity
The first deployment (2009)	
17.08.2009	Eight Tmote Sky motes and their supporting infrastructure (outdoor router) deployed
25.08.2009	Network inspection and maintenance operations
15.09.2009	Network is taken down
The second deployment (2011)	
12.08.2011	Partial deployment of the supporting infrastructure (server software, indoor router, roof antenna). One SADmote placed in raspberry tunnel. Due to troubles with an outdoor router further network deployment was delayed.
19.09.2011	Second sensor network deployed: twelve SADmotest with sensors, five Waspmotest, one outdoor router. WiFi link with the router in LSIFG building established. Multi-hop 802.15.4 link between the remote part of the orchard and base-station mote established.
07.10.2011	Network inspection and maintenance operations
02.11.2011	Network is taken down

Our first deployment

Our pilot research experiment used eight Tmote Sky sensor devices (Fig. 1) with built-in sensors for humidity, total solar radiation, and photo-synthetically active radiation. The experiment took place in LSIFG orchard (Dobele, Latvia) and lasted for almost a month (from August 17th until September 15th, 2009).

The WSN was deployed in apple trees close to a weather station. In total, two trees were covered; one had four motes, the other one three. Initially we had one more mote, but it turned out to be useless, because it failed to function from batteries as power source – a frequent problem for used Tmote Sky motes. The eight mote was programmed with base station software and attached through USB port to a WiFi router (we used MikroTik RB411U) mounted on weather station's pole. The range of the network was restricted to areas close to the weather station, because no multihop routing was implemented in our software at that time, and the router needed a constant power source, which was available only at weather station.

Our initial plan was to establish a WiFi link between the router and LSIFG building. However, it failed, because the default omni antenna on the router tuned out to be not powerful enough. As a consequence, the router had to locally store data from the network. In total, sensor readings about 661 hours were collected – 405061 measurements done at 20 second intervals.

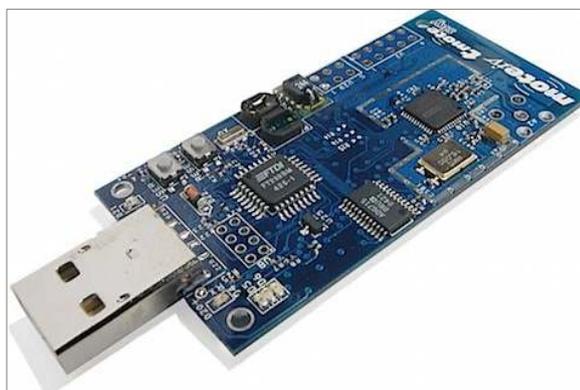


Fig. 1. Tmote Sky with on-board light and humidity sensors

The lessons learned include:

- the default Tmote Sky sensors should be replaced with something more suitable for the task;
- data should be stored locally on motes as a backup;
- sensor reading frequency should be the minimum necessary for the application; the large amount of readings collected was unnecessary, energy-inefficient, and created some problems for agro-scientists who tried to process them later;
- radio links should be planned carefully; directional antennas should be used if possible;
- software support for multi-hop networking is necessary.

The main problem of this deployment was the quality of the data. Apparently the default light sensors located on Tmote Sky are not suitable for agricultural monitoring due to their limited dynamic range. During sunlight the sensors become saturated, yielding inaccurate data about the amount of radiation received by the plants. Even if

the dynamic range could be fixed by attaching a dimming filter to the sensors, the sensitivity and precision they provide with 12-bit ADC might not be sufficient for research-grade data. Furthermore, the light wavelength sensitivity curve of the photo-synthetically active radiation sensors was different from the actual plant response. As for the humidity measurements, the SHT11 sensor had sufficient precision, but it was located on-board, inside the protective enclosure, and therefore measured the humidity in the box, which could be very different from the actual humidity conditions in the garden.

Another problem was data loss due to unstable radio links. Even though the remotest of the motes were no further than ten meters away from the base station, a significant proportion of the packets still was lost. Packet delivery failures are frequently encountered in WSN (Srinivasan et al, 2006) and ought to be taken in account as one of design considerations. Therefore, we came to conclusion that all data should be stored on the mote itself whenever possible, regardless whether they were already sent out to the network. An SD card or a larger external flash chip would be useful for this purpose; the flash on Tmote Sky has only 1MB storage capacity and could run out of space in longer-term deployments.

Our second deployment

Taking into account the experience with Tmote Sky and software in the first deployment, for second deployment we created our own hardware design – SADmote (Elsts et al, 2012a) and extended our software, which includes both WSN operating system MansOS and software designed specifically for this application, such as a web interface for accessing sensor readings.

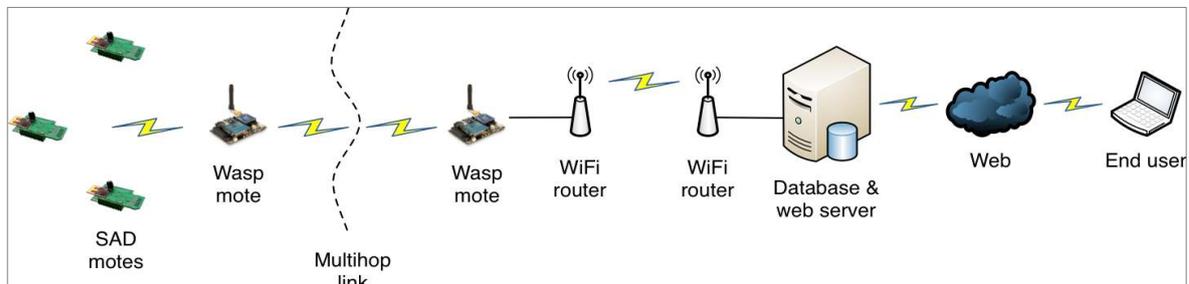


Fig. 2. The conceptual architecture of the network.

Network architecture. A hierarchical two tier sensor network was used (Fig. 2, 3). Tier one consisted of SADmotes, which functioned as data sources. Tier two was formed by Wasp motes, which acted as network coordinators for the SADmotes, and forwarded data towards the base station. Static routing was used (preconfigured next-hops), as only a single path to sink was possible.

Wasp motes were used for data forwarding as they had more powerful batteries (6600 mAh rechargeable versus ~2800 mAh of AA batteries used by SADmotes), and featured more powerful radio modules with external antennas. The Wasp motes were placed approximately four meters above ground. In this way, a network with four intermediate hops was formed. Total distance covered by this sensor network was 600m. Wasp motes were located in 150-200m intervals from each other. Between some Wasp motes there were clear lines of sight, while other links were partially blocked by some trees. The last of the motes was attached to a wireless router through USB port, and functioned as a data sink for the network. The router, which was located on weather station's mast, read data from serial port, stored the data locally and forwarded them to a server in LSIFG building via a Wi-Fi link. Directional antennas with 17dBi gain (Interline INT-PAN-17/24-HV) were used in both ends of the link. One of the antennas was located on the mast, next to the router, the other on LSIFG building's roof.



Fig. 3. The structure and location of the network⁶. The points in the middle mark Wasp mote locations.

SAD hardware design. We decided to create our own custom hardware solution, because it is the option that offers maximal flexibility, while being cost-effective, robust, and energy-efficient. These benefits were made possible because application-specific design allows to minimize the number of electronic components. The alternative solutions, such as electronic dataloggers and commercial off-the-shelf (COTS) motes fitted with application-specific sensors each have their own drawbacks. Compared to electronic dataloggers, a network formed by WSN motes allows online access of the data, removing the need for human operator and manual collection of the data, which is extremely labour intensive process. Compared to COTS devices, SADmote is more cost-effective and flexible, as well as have lower estimated long-term energy consumption (Elsts et al, 2012a).

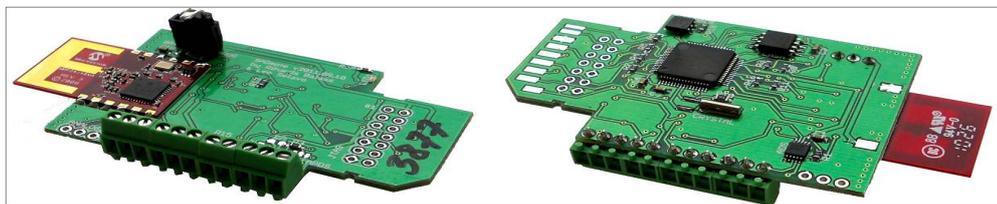


Fig. 4. SADmote v02, front and back views

The SADmote (Fig. 4) is built on a two-layer printed circuit board and features ultra-low energy consumption MCU MSP430F1611. The MCU was selected as a true-and-tried design choice (also used on Tmote SKy), and because our software already had support for it. As for the radio, we selected Microchip's MRF24J40MA radio module (2.4-3.6V operational voltage, 18 / 22mA Tx/Rx current consumption, -94dBm sensitivity). Even though the chip used in this module (MRF24J40) has slightly worse characteristics than, for example, CC2420 transceiver chip used by Tmote Sky (2.1-3.6V, 18.8 / 17.4mA, -95dBm), we chose it. The reasons: first, we lacked the experience to build our own radio module; second, other available radio modules (e.g. Amber

6 Full map and exact location of the network is available at <http://tinyurl.com/5szy3jd>

Wireless AMB2720) were approximately two times more expensive. MRF24J40MA also has the benefit that it can easily be replaced by other modules from the same manufacturer, such as MRF24J40MB-I, which features higher Tx power, or MRF24WB0MB, which has external antenna connector – these options would be useful for construction of a second-tier, longer haul network.

SADmote also has AT25DF161 flash chip (2MB storage size), ADS111x 16-bit ADC chip (with one or two analog inputs), and DS2401P+ unique serial number chip, which is useful for automatic generation of a network address and unique identification of a mote. SADmote can be powered either from a programming board (also custom-built for this project) or two AA batteries.

External sensor boards can be attached to SADmote through expansion interface (analog and digital ports). A light sensor board was developed, specifically, two versions of it – one features Intersil ISL29003 sensor, the other Avago Technologies APDS9300. Both are controlled through digital I2C interface. The other sensors experimentally tested include SHT75 humidity and temperature sensor (digital interface) and a high-precision solar radiation sensor SQ-110 (analog interface). Other sensors can be attached to SADmote as well, as soon as they are available – for example, soil humidity and temperature sensors, air chemical content sensors etc.

Our tests show that in active mode SADmote has energy consumption comparable to Tmote Sky (7.5mW versus 6.9-8.4mW); when radio is also turned on, then efficiency is slightly worse (76.5mW versus 63.9mW). However, in sleep mode SADmote showed much better energy efficiency (90.0 μ W versus 210 μ W). Since this mode is the one used most of the time in real-world sensor deployments, such a feature enables to create longer-living sensor networks by using SADmote than would be possible by using its competitors. SADmote has radio communication range comparable to Tmote Sky: reliable line-of-sight links can be established in 150 meter distance and more.

The design of SADmote has gone through multiple revisions. The second version is the one we used for this deployment. The third version is in development at the moment.

SAD software design. There were multiple software instances we had to design for the SAD use case:

- software on SADmotest (a MansOS application);
- software on Waspmotest (a C++ application using Waspmote API and libraries);
- software on the router and on server (command line C++ applications);
- graphical user interface (a PHP web server application).

MansOS operating system was used to program SADmotest, which were used as data sources. MansOS has multiple advanced features (MansOS, 2012) that are useful in the context of this application:

- Simple and easy-to-learn API. One of our research goals is to construct a WSN OS that is relatively easy to use for beginners. Existing WSN operating systems have extremely steep learning curve; we hope to improve the situation by offering an OS that uses programming paradigms familiar to every system-programmer, such as coding in plain C and UNIX-like abstractions.
- Over-the-air reprogramming. MansOS allows to reprogram a mote without physical access. For this purpose, the built-in network management protocol is used. Partial reprogramming is also possible. IN this fashion, bugs can be fixed and new features added seamlessly and simultaneously to whole network.
- Networking stack. MansOS has built-in networking stack, which features a simple CSMA (Carrier Sense Multiple Access) MAC protocol with optional acknowledgements. They can be turned on to make data delivery more reliable. It also features a distance-vector routing protocol with built-in time synchronization. On top of these mechanisms, UNIX-like sockets are implemented.
- Simple and robust multithreading. MansOS supports preemptive multithreading. As opposed to other WSN operating systems such as TinysOS or Contiki, MansOS can continue to function even if the user has included an infinite loop in his code, because kernel code can continue its execution in a separate thread.

As for Waspmotest, which functioned as data forwarders and the base station, we used Waspmote IDE and API to construct the respective applications. Since support for multi-hop networking was necessary, the MansOS routing protocol was ported to Waspmotest and included in their software.

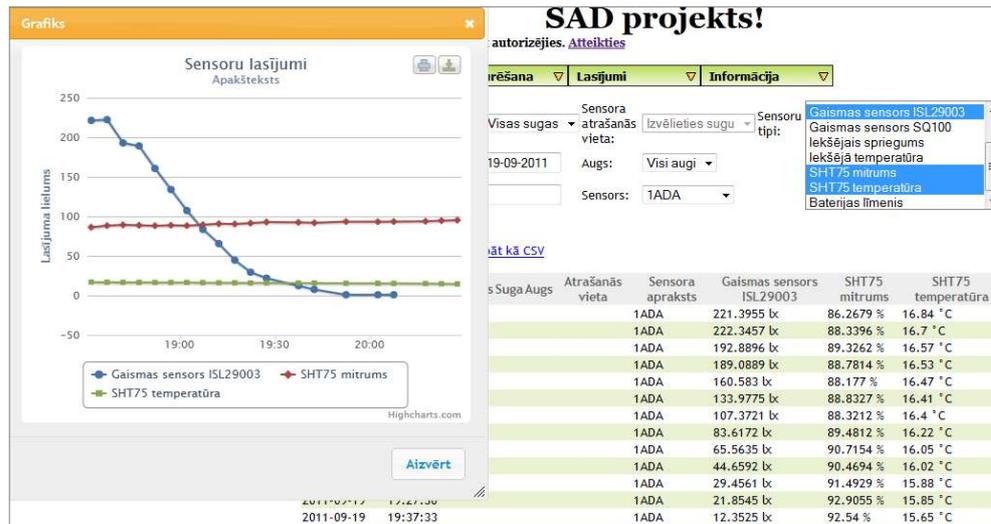


Fig. 5. SAD web interface: table view

Once the readings have reached the router nearby the weather station, they have to be encapsulated in IP packets and sent over a WiFi link to the server. For this purpose, we constructed two C++ command line programs. One was running on the router, read data from router's serial port (to which a Waspote base station was attached), stored the readings locally, and functioned as a TCP server. The second C++ application was running on the server and functioned as a TCP client. It tried to establish a connection to the router and receive data from it. Once received, the data were parsed, checked for consistency, and stored in a database.

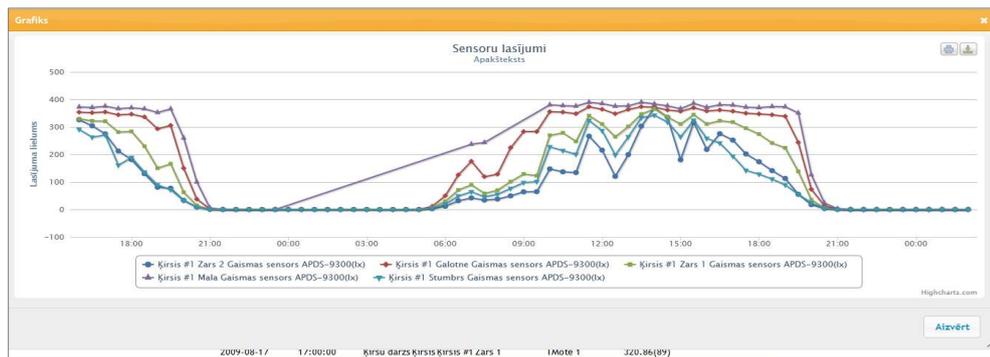


Fig. 6. SAD web interface: graphical view

Afterwards the data could be accessed using a browser through a web interface (Fig. 5, 6, 7) we have developed. It allows scientists to access the data from anywhere in the world, provided sufficient authorization is granted. The web interface was developed taking in account feedback given by domain scientists; the objective was to make it intuitive to use even for non-technical users. For example, by using on-line graphical reports generation (Fig. 6), users can receive intuitive visual feedback on data. By using integrated Google maps feature (Fig. 7), every mote's position in the orchard can be seen on map once its precise coordinates have been entered. We tested the web interface with sensor readings gathered in 2009 to ensure it is working properly even in conjunction with large datasets.



Fig. 7. SAD web interface: map view

Results. Twelve SADmotes were placed in the orchard: two in a strawberry plantation, nine in a nearby raspberry plantation, and one next to the weather station. The motes were programmed to read sensors with five minute interval, send the readings to radio and store in external flash, as well as receive time synchronization information from the router through the forwarding tier (i.e. Wasmotes). After the SADmotes were turned on and the Wasmotes installed, some data initially was received in the server. Our multihop network was working – the approach we used apparently was feasible! This was an important positive conclusion. Unfortunately, the stream of the data reaching the server was small at the start and ceased altogether only after approximately two days. Only about a hundred readings were recorded in the server. By reading on-line debugging information from the network, we discovered that Wasmotes, including the base station, are frequently rebooting. After a few days the intermediate Wasmotes become completely unreachable, likely because of battery depletion.

In October 7th we performed network maintenance operations: SADmotes had their batteries exchanged and were reprogrammed. It turns out that all but two of the SADmotes also had hanged soon after installation and had stored only a few records in their flash memories. One mote was still working and had collected ~5000 records, the other had stopped after collecting ~2000. One of the raspberry motes was not functioning anymore and could not be reprogrammed; it was removed from the field at that point.

The second stage of the experiment was more successful. The eight reprogrammed motes become more stable (the new software version disabled radio communication). From these motes five were still running at the end of the experiment (2nd November, close to 26 days total for this period). One had stopped worked recently before the end, and one had stopped working half-way the experiment; their SHT75 sensors were damaged due to corrosion. The remaining one was displaced and probably mishandled by field workers. The results are shown in Table 2. The collected sensor readings at the moment are analysed by LSIFG scientists.

We conclude that we need to protect the external sensor boards better in future, as many of the motes outside of the agricultural cover had visible corrosion damage. A protective lacquer covering was used to cover the sensor boards in this time, but apparently it is insufficient for local outdoor conditions.

Table 2

Results of the second stage of the second deployment

Mote	Location	Number of readings	Sensors*	Under cover?	Ending battery voltage	Notes
0x0DD4	Strawberries	83	APDS, SQ-110	yes	0.73V	Was not reprogrammed
0x5F7C	Strawberries	106	APDS, SQ-110	no	2.1V	Was not reprogrammed, sensors appear to be damaged
0x68D6	Raspberries	6847	ISL	variable**	2.65V	Sensors appear to be a little damaged
0x1AD A	Raspberries	7483	ISL, SQ-110	variable**	2.63V	
0x1B81	Raspberries	7258	APDS, SQ-110	variable**	2.81V	Sensors appear to be damaged
0x727B	Raspberries	80	APDS, SQ-110	variable**	2.1V	Sensors appear to be damaged, mote had been moved

* All motes (except 0x7376) had SHT75 humidity and temperature sensors.

* * Initially under cover, which was removed at later point of time

0x77CE	Raspberries	22	APDS, SQ-110	variable **	2.12V	Was not reprogrammed, sensors appear to be heavily damaged
0x6B89	Raspberries	7470	APDS	no	2.85V	
0x0079	Raspberries	7480	ISL, SQ-110	no	2.65V	Sensors appear to be a little damaged
0x7376	Raspberries	11210	APDS, SQ-110	no	2.77V	No humidity sensor, light sensors appear to be a little damaged; mote had been rebooting multiple times
0x0CD0	Next to the weather station	1967	ISL	no	2.05V	Sensors appear to be heavily damaged
Total		50006				

Analysis and future perspectives

Extending the radio range. High number of intermediate hops has the drawbacks of both decreased packet delivery rate and higher energy consumption. Taking this in account, one of our future objectives is to reduce the number of intermediate hops needed, by increasing motes' radio range and radio link stability. We see a number of ways how it could be achieved:

- Place repeater motes higher above ground. For this purpose, some of the higher trees located in the orchard, large poles or small towers placed there could be used. However, due to elevated ground in the middle of the testing site, a single line-of-sight radio link reaching the farthest parts of the orchard does not appear to be feasible, at least not without mayor investments in tower construction.
- Use directional antennas for some of the intermediate hops, or at least for the base station placed next to the router. The motes in the middle would benefit from dual-beam antennas. Taking in account that the forwarding path is not always a straight line, the beams of the antenna should be apart not for 180 degrees, but a deployment-specific number of degrees. The construction of such antennas is an interesting engineering challenge in itself.
- Use lower radio frequencies. Sub-1GHz electromagnetic waves are not absorbed by foliage and other small obstacles as much as 2.4GHz waves, as they have longer wavelengths. For example, assuming a 200m distance between radio receivers, 100m of foliage within the line-of-sight path, and using Weissenberg's modified exponential decay model (Seybold, 2005) we can calculate path loss using the formula: $Loss(dB) = 1.33 F^{0.284} d_f^{0.588}$, where F is frequency in GHz, and d_f is foliage depth in meters. The resulting loss is 25.73 dB for 2.450 GHz, and 19.16 dB for 0.868 GHz – a 6.57 dB difference.

In future, we decided to combine all these options, and go for sub-1GHz radio transceiver, use directional antennas on forwarder motes, and, whenever the means allows, put them higher, above the foliage.

Avoiding a single point-of-failure. Having a single forwarding path in the network means that a single failed node can cause the data to no longer be accessible online. As our experience with failing Wasmotes shows, this problem should be taken in account for network design considerations. Fault-tolerance is especially important if sensor readings are used to generate alerts, or to activate orchard watering or other control systems. The solutions are:

- Place repeater motes more frequently, so that each mote can see not only the nearest neighbour in both directions, but one or two next neighbours as well. In this case, the path is still functional even if some of the motes fail, but then we have to cope with the previously described drawbacks of having too many repeater motes, as well as more radio collisions.
- Construct two parallel forwarding paths. To avoid interference, non-intersecting radio channels should be used. This is a robust solution, although relatively expensive and labour-intensive to set up, as twice as many motes and mounting locations are required. It would benefit from an advanced multi-path routing protocol, which would provide a kind of load-balancing, thus increasing the lifetime of the motes by decreasing their energy expenditure.

Unit testing each component. Before the deployment we performed unit testing on each mote by uploading a specifically designed MansOS SAD testing application and checking whether all the components are working. Specifically, the software checked light and humidity sensor output, radio transmission and reception, writing in and reading from external flash, and other hardware components on SADmote. In the deployment we learned both the value of these tests and that our testing was incomplete. It turned out that most of the motes deployed were unable to enter low-power (“sleep”) modes correctly. We cannot know whether all of them had this defect initially; in any case, when testing afterwards, only one from all of the motes deployed was able to enter this mode. Since energy consumption in active mode is dramatically higher than consumption in sleep mode (current draw is 2.5 mA in active mode versus tens of *microampers* in sleep mode), and a normally functioning mote ought to spend most of the time in this sleep mode (as much as 99.9%, the measurement and data transmission takes approximately 0.3 seconds and is performed once in every five minutes), the consequences on long-term energy efficiency are dramatic. These test deployments were too short, but a quick calculation shows that the

motes would certainly fail in a deployment that would last at least for two months. Assuming battery capacity 2800 mAh, operating voltage of 3.0V, and average current consumption of 2.8mA (active mode with the occasional radio packet transmission and reception), we get 1000 hour lifetime from a pair of batteries, which corresponds to approximately 41 days. Consequently in the future we will extend our unit testing with low-power mode testing.

System level testing. Unit testing is useful, but not sufficient to discover all the problems that can manifest themselves only in real-world settings. We encountered both some problems that could be discovered by more careful system level testing in-house, and some that apparently could not.

First, we note the failure of the Libelium Meshlium router after trying to reconfigure it. We tested the router with a base station attached in our lab. It was able to successfully communicate with our server and store sensor readings in database. However, we used static, factory-preset IP address for the router. As soon as we brought the router to the field location and tried to reconfigure it to function as a DHCP client (which required rebooting it), the router stopped working and was not able to start up successfully anymore. It was partially our fault because of our lack of experience with handling Meshlium routers, but as a result we had to send the router for warranty repair back to the manufacturer, which took almost two months, re-engineer the WiFi part of the network and use a MikroTik router instead, which significantly delayed our deployment.

Second, some of the SADmotes exhibited tendency to hang when radio was actively used. We had not encountered this problem in our in-house testing because we usually tested transmit and receive modes separately, but this problem manifests itself only when packet transmissions are mixed packet receptions, which are common in real-world settings. To work around this problem for now, we disabled radio driver for the second part of the deployment and gathered data only in the flash. Taking in account that the forwarding motes at that point of time were not functioning in any case, it was the optimal solution. The long term solution is to change radio chip – SADmote v03 is going to feature a radio module based on CC1101 transceiver chip by Texas Instruments. We have good experience with TI chips in other projects.

Another problem that we suspect was triggered by radio packet reception is the constant rebooting of Waspotes. It is possible that our Waspote software had some errors, but we note that we used the examples provided by Libelium as the basis of our code. Because of this problem, the forwarding path was never reliable and completely stopped working after only a few days. The motes also soon ran out of batteries. As we had no replacement batteries available for Waspotes, we left the dead motes intact until the removal of the rest of the network. In the future we plan to avoid using the current version of Libelium products (Waspote and Meshlium) in production networks altogether.

Mechanisms for run time control and assurance. Domain scientists, having no previous WSN experience, no programming skills and lack of intent to setup complicated development environments on their computers, require an intuitive visual feedback on the way network functions. Current version of SADmote features a single LED, initially intended for debugging purposes. As it turns out, LEDs are useful for run-time assurance as well. In the end of our experiment some of the motes apparently had frozen when trying to read their humidity sensors, which were damaged because of their incomplete protection from precipitation. Since our software turned the LED on during the sensor reading period, we could quickly tell which motes are not functioning anymore at the end of the deployment – their LED was constantly on. The domain scientists suggested extending this approach and use multiple LEDs, each corresponding to a specific sensor. For example, the mote could have red, green and blue LEDs, and each of these was associated with a specific sensor. Glowing red LED would mean that light sensor has failed; blue LED: humidity sensor, and so on.

Run-time reprogramming. MansOS supports over-the-air reprogramming; however, this feature is in experimental status. We did not include it in these initial tests, as firstly, we did not want to compromise the initial deployment of our sensor network by software bugs, and secondly, have a stable minimal base of the software tested in field conditions, which to use as a benchmark for later tests, when more features will be added and the unavoidable software bugs start to creep out.

However, this deployment convinced us about the necessity of such a feature even in medium size networks. At the first inspection of the network (7th October, 2011) we discovered that the motes are not functioning correctly and need to be updated. Afterwards some of them were reprogrammed. Reprogramming a mote meant that it should be not only physically accessed, but also taken out of the box, attached to the programmer which is in turn attached to a laptop, and so on. As a consequence, reprogramming just nine motes (eight successfully, one could not be programmed at that time) took two hours (from 18:00 till 20:00 that evening). Even if this procedure took just five minutes for each mote, a network from 66 motes (our target size for the next deployment) would require more than five hours for a single person to reprogram! Hence, support for reprogramming the motes in a non-interactive mode without physical access is essential.

Usability aspects of WSN applications. Even more, reprogramming the motes – updating software versions, reconfiguring sensor reading frequency and other parameters – should be easy enough for agro-scientists to do on their own, without the help of computer professionals. To facilitate this, at the moment we are working on a WSN domain-specific programming language and environment for domain scientists and novice programmers:

Sensor Application Development Language or SEAL (Elsts et al, 2012b). The observation behind SEAL is that even though the low-level details of WSN are swarming with complexities, a broad class of WSN applications are conceptually simple – they can be described either as sense-and-send or event detection. SEAL decouples the low-level networking and hardware details present in sensor networks from application logic, thus reducing the complexity visible to the user. SEAL was evaluated positively on the target audiences: agriculture scientists and on computer science students with no WSN programming experience. Specifically, four agriculture scientists from LSIFG were asked to program the same solution using the SEAL GUI. After initial help with installation and setup, all were able to complete this assignment on their own or using only discussions with colleagues. Such a result would be unthinkable with C, where they would have to battle with issues such as C pointer semantics and memory alignment.

Closing the control loop. A natural extension of the SAD WSN design is to close the control loop and use the network not only to monitor the microclimate, but also to control the watering and other systems in the field. So far this has not been a typical use of sensor networks due to the experimental status and perceived instability of this technology, although some projects with positive real-world experience exist (Cerriotti et al, 2011). We consider such an extension to be a future research goal. The first step in implementation of such a system would be an alarm signal in case some microclimate parameters reach critical values. Such an extension would still require a human operator in the loop, but would provide a significant assistance in detection of such critical events, for example, frost.

Conclusion and future plans

The design of a WSN system is an iterative and incremental process. Deploying a sensor network which can consist of tens of motes is a significant engineering challenge, being ridden with unexpected problems (Langendoen et al, 2006). Nevertheless, our two pilot deployments were able to gather some data that will be useful to agriculture scientists.

Deploying wireless sensor networks is still a global research problem. We hope that the lessons we have learned will be useful to other prospective WSN designers and users, either in precision agriculture or in other areas, and will serve to advance the research boundaries in this area. To the best of our knowledge, this is the first time a WSN is used in Latvia for this application, therefore, our work helps by discovering the specific local conditions and adapting WSN technologies to them.

Still, first and foremost, by enhancing our experience and WSN deployment know-how, these pilot deployments are useful to ourselves. Using this experience, we plan to continue SAD project and to deploy a network from 66 motes in the spring of 2012. We expect the network to last for all the vegetation season (from April until October) and serve as a helpful, interactive tool for domain scientists. Closing the loop and integrating the WSN with orchard control systems is a more ambitious goal. We leave it as the research objective for the next year, the final for the SAD project.

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INFORMATION TECHNOLOGY IN BIOLOGY

ALGORITHM DEVELOPMENT OF STRUCTURE FOR DYNAMIC COMPUTER MODEL OF BIOCHEMICAL NETWORKS

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Abstract: *Comparatively new research area known as systems biology widely uses engineering approaches to develop mathematical models of metabolic networks. Behind all that systems biology aims to use white box modelling approach and perform in silico experiments to explore behaviour of elements of target system. Both dynamic and static or structure type modelling approaches are successfully used in systems biology. Stochastic and deterministic approaches of dynamic modelling could be the most common methods used in this area. Nevertheless dynamic and structure type also known as genome scale reconstruction models have common mathematical representation of structure. Structure of dynamic models are smaller scale but with a positive tendency to extend. With increase in a scale of dynamic model development of structure become more and more complicated. Therefore research work discussed in this article presents a methodological strategy represented in a form of algorithm to develop a good quality structure of large scale dynamic models of metabolic networks. Methodology offered in this paper merges together methodology used in genome scale reconstruction models and dynamic models. Also algorithm covers a use of newly emerged software tools to analyze quality of structure developed for dynamic models.*

Keywords: Algorithm, Dynamic model, Stoichiometric model, Metabolism.

Introduction

An information technology has a wide use in different areas of science and industry because of its computational power of data analysis. Necessarily computational power is also used in different subfields of biology, e.g., statistical analysis of in vivo or in vitro experimental data. Development of computational power encouraged use of methods of engineering in a field of biology. As a result emerged new research areas like bioinformatics and systems biology. Bioinformatics and systems biology has different tasks and goals therefore also use of engineering methods differ. Bioinformatics deals with algorithms, databases, artificial intelligence, software engineering, data mining and image processing (Kingsford and Salzberg, 2008; Nikkila et al., 2002; Noble, 2006; Pal, 2006; Sternberg et al., 1994) whereas systems biology concentrates on mathematical modelling of particular process of biological system. Well known engineering approaches like white box, grey box, black box, dynamic or static modelling approaches are used in systems biology.

Systems biology has changed the way of understanding of biology. Hans Westerhoff (2009) highlights that systems biology is the science that aims to understand how biological function that is absent from macromolecules in isolation, arise when they are components in the system. Also Hiroaki Kitano (2002) pays attention to understanding of systems-level in biology. A system-level understanding of a biological system can be derived from insight into for key properties: 1. Systems structure; 2 System dynamics; 3. The control methods and 4. The design method. In this paper we will concentrate on the systems structure which is mentioned as the first and perhaps the most important property of the biological system.

Also mathematical modelling of biological system starts by defining the structure of the system. The scale of structure of model depends on process of interest and modelling approach. However there are limitations of the scale of model. Network of metabolic reconstructions can be reconstructed as far as it is known. Oleg Demin and Igor Goryanin (2009) point out that it is possible to model only for biological systems that we can observe with the help of experimental techniques. Many high-throughput experimental technologies have been developed in the last ten years that have enabled full genomic sequences to be obtained (Covert et al., 2001). Also development of microarray technology has widened understanding of system and interactions of system elements. Microarrays are one of the latest breakthroughs in experimental molecular biology, which allow monitoring of gene expression for tens of thousands of genes in parallel and are already producing huge amounts of valuable data (Brazma and Vilo, 2000). Simultaneously there has been almost explosive development in dynamic modelling of metabolic networks. Already in 2010 BioModels Database offered 249 curated and 224 non-curated models which were freely available for public access (Li et al., 2010).

Mathematical representation of structure is common for both dynamic and static or genome scale reconstruction models. Despite that dynamic models are significantly smaller in scale. Genome scale reconstruction models have been developed for microorganisms in a whole level of cell size e.g. compartmentalized model of *Saccharomyces cerevisiae* (Duarte et al., 2004; Nookaew et al., 2008; Forster et al., 2003). Even more researchers are working on entire genome scale reconstruction model of human (Duarte et al., 2006). Comparatively dynamic models do not reach even size of single cell. Nevertheless there is a tendency of

quantitative kinetic models to increase in a scale and complexity (Li et al., 2010). Markus Covert (2001) draw attention to the fact that for detailed dynamic model building to succeed on a whole-genome scale, much progress must be made in estimating kinetic parameters of enzymes, either from first principles or by correlation to known properties of similar enzymes.

Predictive models for cells or whole organisms can be regarded as the keystones of systems biology, ultimately providing scientific explanations of the biological systems in health and disease and assisting in the identification of therapeutic targets with the promise of molecular medicine and on the long run, personalised medicine (Riel, 2006). Therefore development of large scale dynamic models has a great perspective.

Aim of this paper is to describe development methodology of structure of large scale kinetic model in a form of algorithm. Methodology offered in this paper merges together methodology used in genome scale reconstruction models and dynamic models.

Materials and methods

Methodology described in this paper concentrates on static part of dynamic model of metabolic network. Static part or structure development is described solely for deterministic approach of dynamic modeling and it is extraneous to stochastic modeling approach. Also principle of white box modeling approach is used to describe development of structure.

Development of dynamic model of metabolic network consists of several steps. The first step is to identify problem and specify space of interest. None of models can be built without experimental results therefore databases (e.g., KEGG, BRENDA, REACTOME), research articles and lab experiments should be studied. The third step is to formulate hypothesis about model performance. When hypothesis is defined then structure of the model can be built. If static part of the model is finished then it should be converted into stoichiometric matrix. After that follows verification of the static model. The resulting static model can be used separately as independent model to analyze different properties of the system, e.g., steady states. However, only definition of rate equations and ordinary differential equations will exclusively grant dynamic properties to the model. Finally model should be simulated and validated. Complete methodology which represents development of dynamic model of metabolic network is presented in a Fig.1. Methodology is presented in a form of algorithm and consists of 19 steps.

Algorithm presented above has been used as the main methodological procedure to achieve good quality dynamic model of metabolic network. However the main attention in research work has been paid to methodology which describes generation of components and interactions that affect the system. To describe components and interactions in a dedicated manner, methodology used in genome scale reconstruction models have been used as source material to develop algorithm of structure of large scale dynamic model.

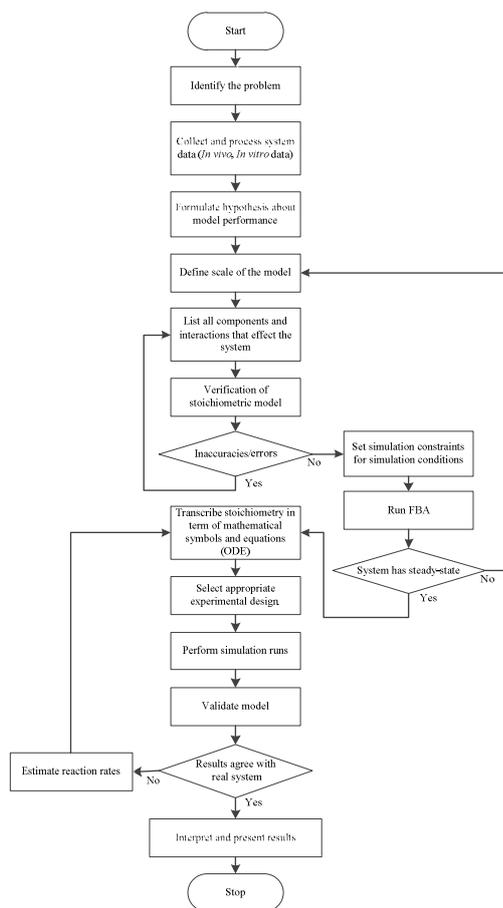


Fig.1. Main steps of dynamic metabolic model development.

Results and discussion

In a case if research problem is defined and purpose of the model is found then one can develop static part of dynamic model. That is known as “pathway reconstruction” (Demin and Goryanin, 2009). Methodology offered in this work is presented in a form of algorithm. It consists of four main steps: (1) assemble draft network, (2) refine draft network, (3) draw map and (4) validate network. All four steps are crucial to develop good quality structure of the dynamic model. Nevertheless the main attention has been paid to step which displays refinement of draft network. Altogether the main and sub steps result in a 64 step algorithm.

Draft network assembling lists candidate components of the system and interactions between components. Assembling is based on genome annotation. Also databases like KEGG (Kanehisa et al., 2012) and Reactome (Joshi-Tope et al., 2005) can be useful to create draft network. Draft network is only rough copy of possible structure of dynamic model. In a next step it should be refined.

Refinement of draft network is a complex process and each interaction of the system should be checked manually (Demin and Goryanin, 2009). Refinement should be based on organism specific literature, databases and experiment studies. However, preference should be given to organism specific databases if such exist. Such databases exist for a few organisms like SGD (Cherry et al., 2012) for *Saccharomyces cerevisiae* and EcoCyc (Keseler et al., 2011.) for *Escherichia coli*. During this stage all components (metabolites) or pools of components that affect the system should be listed. Also decision should be made what to include in a model and what to exclude. Interactions between these components and all modulations by which components affect the system should be created. Attention should be paid also to decision which exchange reactions and extracellular and intracellular metabolites include in a model and which exclude. As a rule of thumb, one tries to define a system in such a way that number of interactions within the system is maximized and the number of interactions between a system and its environment is minimized (Voit, 2000). Finally decision should be made which metabolites are dependent and which independent variables. Usually intracellular metabolites are dependent variables but extracellular and dead end metabolites are independent variables. Sophisticated and detailed development methodology of structure of large scale kinetic model in a form of algorithm is presented in a Fig. 2. A protocol for generating a high-quality genome-scale metabolic reconstruction presented by Ines Thiele and Bernhard Palsson (2010) is used as a source material to develop algorithm of structure of large scale dynamic model.

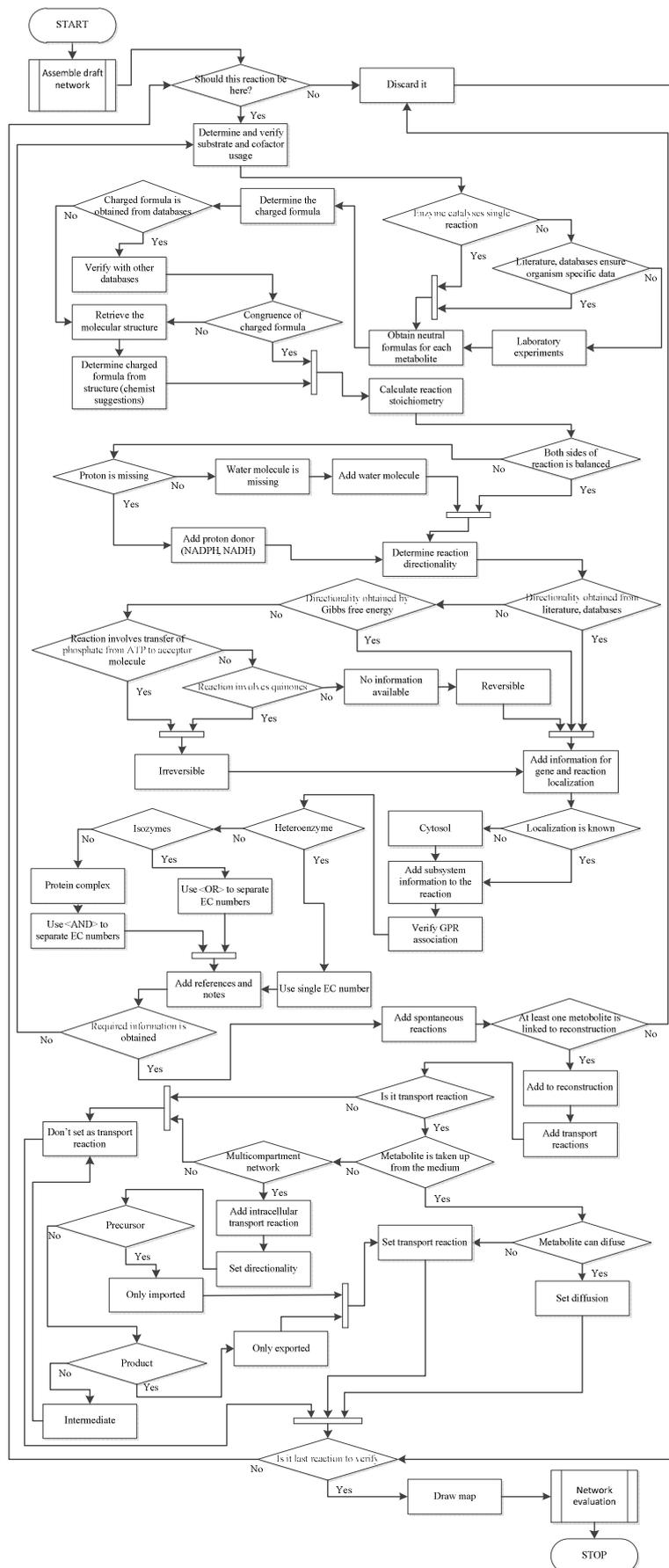


Fig.2. Methodology for structure development of dynamic model.

When refinement of draft network is finished it can be visualized graphically. Result of graphical representation is biochemical map. Different software tools can be used to create biochemical map but CellDesigner (Funahashi

et al., 2003) could be the most popular one. A map may depict the chemical structures of all metabolites which are involved in a model. Graphical representation has several advantages. It allows seeing static part of the dynamic model as entire system and allows detection of interactions between system components. Also it can be used to validate quality of the static model, e.g., detection of gaps.

The final stage in development of static part of dynamic model is to validate reconstructed network. As a result of increase of kinetic model in a scale it could be wise to develop reconstruction of network in a spreadsheet, as it is described by Ines Thiele and Bernhard Palsson (2010). That will facilitate validation of reconstruction and will enable application of very useful tools like ModeRator (available at <http://sourceforge.net/projects/moderator/>) and Paint4Net (Kostromins and Stalidzans, 2012) (available at http://www.biosystems.lv/index.php?option=com_content&view=category&layout=blog&id=65&Itemid=86).

Use of ModeRator will allow catching out for duplicate reactions and duplicate metabolites if such exist. Each system element or metabolite should have a source and sink or at least participate in one of reaction (Demin and Goryanin, 2009). Use of Paint4Net will allow analysing wholeness of reconstructed network. Connectivity of single reaction or metabolite to network can be visualised by Paint4Net therefore gaps and dead and metabolites easily can be found. As result of validation network should include all interactions connecting all known entities (Demin and Goryanin, 2009).

If static part of the model is finished then it can be used separately as independent model. Before that constraints should be added to the network. Nathan Price (2004) describes proper methodology how to apply constraints to the network. Static model can be used to run Flux Balance Analysis (FBA) and steady state analysis if proper constraints are applied to the model. However, only definition of rate equations and ordinary differential equations will grant dynamic properties to the model.

Conclusion

Methodology presented in this work can be used to develop good quality static part of large scale dynamic model. Also the same rules presented in sub steps of draft network refinement can apply to small scale dynamic models. For example, to describe gene-protein-reaction association, reaction directionality, to make right decision on transport reactions, etc. No information exist that up to now development methodology of static part of dynamic model is presented in a form of algorithm in a scientific literature. To improve applicability of the algorithm research work should be continued to develop validation algorithm of static part of dynamic model in a sophisticated and detailed manner.

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ALGORITHM OF GENOME-SCALE METABOLIC ENGINEERING IMPLEMENTATION

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Abstract: *Systems biology is a rapidly growing field that is based on building and validating in silico models of biological systems using a wealth of experimental data. These models can be applied to generate novel, testable and often quantitative predictions of cellular behavior (Becker et al., 2007). Building these models is required stoichiometric model analysis, followed by the addition of dynamic model parameters. To make it easier to resolve this task is necessary to develop an algorithm that will facilitate the metabolic engineering problems solution. The algorithm describes the metabolic engineering task progress from stoichiometric analysis of the dynamic parameters of the addition and analysis. In generating these models need stoichiometric model analysis, followed by the addition of dynamic model parameters. For an easier to resolve this task is necessary to develop an algorithm that will facilitate the metabolic engineering solutions to the task.*

Keywords: Stoichiometric analysis, model analysis, algorithm.

Introduction

To be able to study the system is the need to model the entire biological system dynamic behaviour, but the system is large and the whole system create a dynamic model is a complex and long process. Therefore, one of the options are: create a system stoichiometric model and then, part of a system that describes the problem of the creation a dynamic model. Optimized dynamic model results of a full model stoichiometric to verify whether such a solution is possible and analyze system behavior with the new data. The exact models for the could provide opportunities for biologists find out how one or more system components and variable changes may affect the entire system as a whole. Algorithm describes the genome scale computer modelling the methodology of the analysis and improvement of metabolic engineering solutions without using the modified organism experimental data. Algorithm's describes the genome scale structural model and process scale models of the dynamic interaction.

Description of the algorithm

Algorithm describes the genome scale computer modeling the methodology of the analysis and improvement of metabolic engineering solutions without using the modified organism experimental data. Algorithm describes the genome scale structural model and process scale models of the dynamic interaction (Fig. 2).

Step 1. Building Stoichiometric model. Create stoichiometric model of biological systems that describe salient problem (Palsson, 2009; Odzina et al., 2010; Odzina et al, 2011). Stoichiometric model create using a protocol for generating a high-quality genome-scale metabolic reconstruction. The protocol describes the procedure necessary to reconstruct metabolic networks intended to be used for computational modeling, including the constraint-based reconstruction and analysis (COBRA). This protocol describes in detail the process to generate metabolic reconstructions applicable for representatives of all domains of life (Thiele and Palson, 2010). To create stoichiometric model need using a protocol two first step (Fig.1): Draft reconstruction and Refinement of reconstruction.

Step 2. Analysis of Stoichiometric model (Matlab COBRA toolbox). A limited number of software tools and packages are available (freely and commercially), which aim at assisting and facilitating the reconstruction process. Stoichiometric analysis make using *Matlab COBRA toolbox*. *Matlab COBRA toolbox* is software that silico metabolic network reconstruction of the creation and use of various methods of analysis. All metabolites and reactions data must be with every specific requirement with regard to the software methods of analysis. A variety of tools have been developed to facilitate simulations and to handle the models like COBRA toolbox (http://gcrp.ucsd.edu/Downloads/Cobra_Toolbox). Tool called COBRA toolbox (Kauffman et al., 2003; Reed and Palsson, 2003) include implementations of many of the commonly used forms of constraint-based analysis such as flux balance analysis (FBA) (Orth et al, 2010), gene deletions, flux variability analysis, sampling, and batch simulations together with tools to read in and manipulate constraint-based models (Rahmanian et al., 2009). Authors find it useful to perform model integrity check before importing models into COBRA toolbox. Model Comparator (Rove et al., 2012) and ModeRator (Mednis et al., 2012) allow quick identification of duplicate reactions and missing metabolites. Analysing models stoichiometric, we are interested in possible stationery positions, flow values, limiting the reaction of flow, if you are the target function. Prior to model's analysis, it lay so that it can handle the *Matlab COBRA tollbox*, this process description "A protocol for generating a high-quality genome-scale metabolic reconstruction" the third step (Thiele and Palsson, 2010). After the preparation of the analysis shall be carried out by the Step 4 of the protocol (Fig. 1). After the step 2. of the checks carried out, shall ascertain whether systems stoichiometric model is possible steady state (***Is obtained***

corresponding steady state of the experimental data (reference sources)). If it not steady state, then need perform corrections of stoichiometric model (**Step 3. Adding / correction the stoichiometric model**). Check reactions in data bases, for example: KEGG (<http://www.genome.jp/kegg/>), BRENDA (<http://www.brenda-enzymes.info/>), Transport DB (<http://www.membranetransport.org/>), PubChem (<http://pubchem.ncbi.nlm.nih.gov/>), Transport Classification Database (<http://www.tcdb.org/>), the model seed (http://blog.theseed.org/model_seed/). After adding and corrections execute algorithm's step 2 and repeated all analysis.

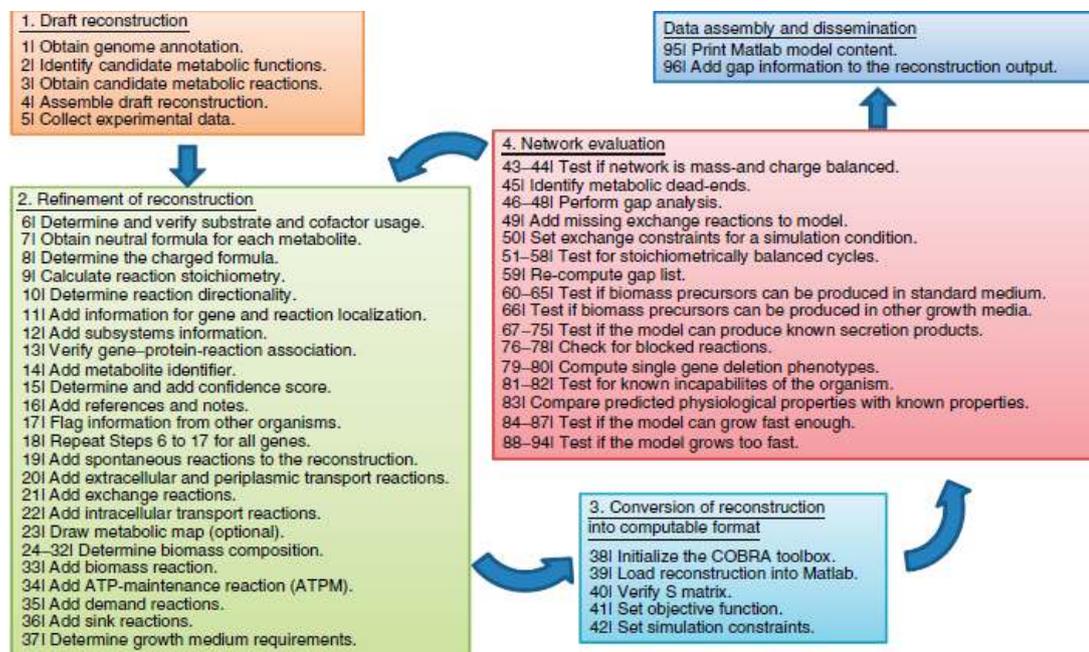


Fig.1. Steps of protocols to creating stoichiometric model (Thiele and Palsson, 2010)

Step 4. Addition complementary reactions to stoichiometric model. Where, after checks are carried out in Step 2 is reached steady state, to the satisfaction of the experimental data, which is taken from the literature sources, then you can add system stoichiometric model with the reactions, which wants to add to achieve a goal (Modify). Stoichiometric model is added to the reactions and reagents.

Step 5. Analysis of Stoichiometric model (COBRA). A modified stoichiometric models analysis (Step 2) how shall also analyse the constraining the reactions of the target function (shadow price) (Palsson, 2009). The analysis of shadow prices and reduced costs, which are associated with the LP solution, can be of great help to identify metabolites or reactions that limit the rate of biomass (<http://www.copasi.org/tiki-index.php?page=UserManual&structure=DocumentationNew>). If steady state after the analysis is not possible, then returns to the stoichiometric model addition, because you might need to add additional events added to the already reactions that the model could work.

To analysis can also use the programs Paint4Net. The „Paint4Net” is an open source extension developed for the „COBRA Toolbox” in „MATLAB” scripting language for visualization of stoichiometric models of metabolism. Both flexible visualization and information on reaction and metabolite data can be reached using „Paint4Net”. „Paint4Net” functionality can be used to: (1) get lists of involved metabolites and dead end metabolites of the visualized part of the network, (2) exclude (filter) particular metabolites from representation, (3) find isolated parts of a network and (4) find running cycles when all the substrates are cut down (Kostromins and Stalidzans, 2012).

Step 6. Create dynamic model of variable process. If after analysis model has reached steady state, only could not be verified, in the absence of experimental data modified system, you can create a dynamic process model of interesting process. Dynamic model can create several software. One of software is COPASI. COPASI is a software application for simulation and analysis of biochemical networks and their dynamics. COPASI is a stand-alone program that supports models in the SBML standard and can simulate their behavior using ODEs or Gillespie's stochastic simulation algorithm; arbitrary discrete events can be included in such simulations. COPASI carries out several analyses of the network and its dynamics and has extensive support for parameter estimation and optimization. (Hoops et al., 2006) COPASI provides means to visualize data in customizable plots, histograms and animations of network diagrams. Systems Biology Markup Language (SBML) is a modular language, with a core comprising a complete format that can be used alone. SBML is oriented towards representing biochemical networks common in research on a number of topics, including cell signaling pathways, metabolic pathways, biochemical reactions, gene regulation, and many others (Hucka, 2003).

The meaning of each component: *Unit definition*: A name for a unit used in the expression of quantities in a model. *Compartment*: A container of finite volume for substances. In SBML Level 1, a compartment is primarily a topological structure with a volume but no geometric qualities. *Species*: A substance or entity that takes part in a reaction. *Reaction*: A statement describing some transformation, transport or binding process that can change the amount of one or more species. For example, a reaction may describe how certain entities (reactants) are transformed into certain other entities (products). Reactions have associated rate laws describing how quickly they take place. *Parameters*: A quantity that has a symbolic name. Dynamic model have initial concentrations and kinetic parameters: the equation contains rate of reaction (V_{max} , V_{maxf} , V_{maxr}), affinity constant (K_{mS} , K_{mP}), inhibition constant (K_i), concentrations of metabolites (for example: ATP, ADP). This information search of databases from references source. *Rule*: In SBML, a mathematical expression that is added to the differential equations constructed from the set of reactions and can be used to set parameter values, establish constraints between quantities, etc. (<http://www.copasi.org/tiki-index.php?page=UserManual&structure=DocumentationNew>) (Hoops et al., 2006)

Step 7. Finding the best stationary state. Time Course Calculation. With the time course simulation, you can calculate the trajectory for the species in your model over a given time interval. There are different methods to calculate such trajectories and depending on your model, one or several of them may be appropriate to do a time course simulation of your model. COPASI supports three different methodologies to calculate a trajectory. The first method is to do a deterministic time course simulation of your model using the LSODA (Petzold, 1983) algorithm. For systems with small particle numbers, it is sometimes better to do a stochastic simulation rather than a deterministic one. COPASI supports a method for the stochastic calculation of time series, which is called stochastic and uses the next reaction method described by Gibson and Bruck (Gibson and Bruck, 2000) Since the deterministic simulation is inappropriate for some systems but on the other hand, the stochastic simulation is too time consuming, there are some methods that try to combine the advantages of both deterministic and stochastic simulation. Most of those methods are termed hybrid methods. COPASI also includes such a hybrid method which in some systems where deterministic simulation would lead to incorrect results will give the correct time series but is still computationally less demanding than a pure stochastic simulation (<http://www.copasi.org/tiki-index.php?page=UserManual&structure=DocumentationNew>).

Step 8. Analysis of stability. If model have stationary state, then make Steady State Calculation. The best technically feasible stationary state should be found taking into account the dynamic parameters of both the cellular dynamics and industrial control system. The steady state is the state in which the state variables of the model, e.g. the species concentrations do not change in time. Mathematically this is expressed by setting the differential equations that describe the time evolution of the metabolic system to zero. This forms a system of algebraic non-linear equations. To solve them, COPASI can use a series of strategies using more than one numerical method. All calculations are done based on particle numbers and particle number rates rather than concentrations internally. The reduced model is used. The Jacobian (which is used in the Newton method and when eigenvalues of the Jacobian are requested) is calculated using finite differences. The Eigenvalues of the Jacobian are calculated using LAPACK (<http://www.copasi.org/tiki-index.php?page=UserManual&structure=DocumentationNew>) (Hoops, 2004).

Step 9. Prevention of Instability. Necessary to prevent instability. Are to be checked for all parameters, the reactions equations. Added to the reaction, to complement the process and ensure stability.

Step 10. Adding dynamic model results in to stoichiometric model and make analysis of Stoichiometric model. Add modified stoichiometric model the flow of values of dynamic models. Or with these values can be to ensure of modified stoichiometric model stable stationary process adjuvants. If modification stoichiometric model have steady state with this new parameters then can make modification of organisms in laboratory. But if modification stoichiometric model does not produce the results you want then return to step 7 and search the other best steady-state.

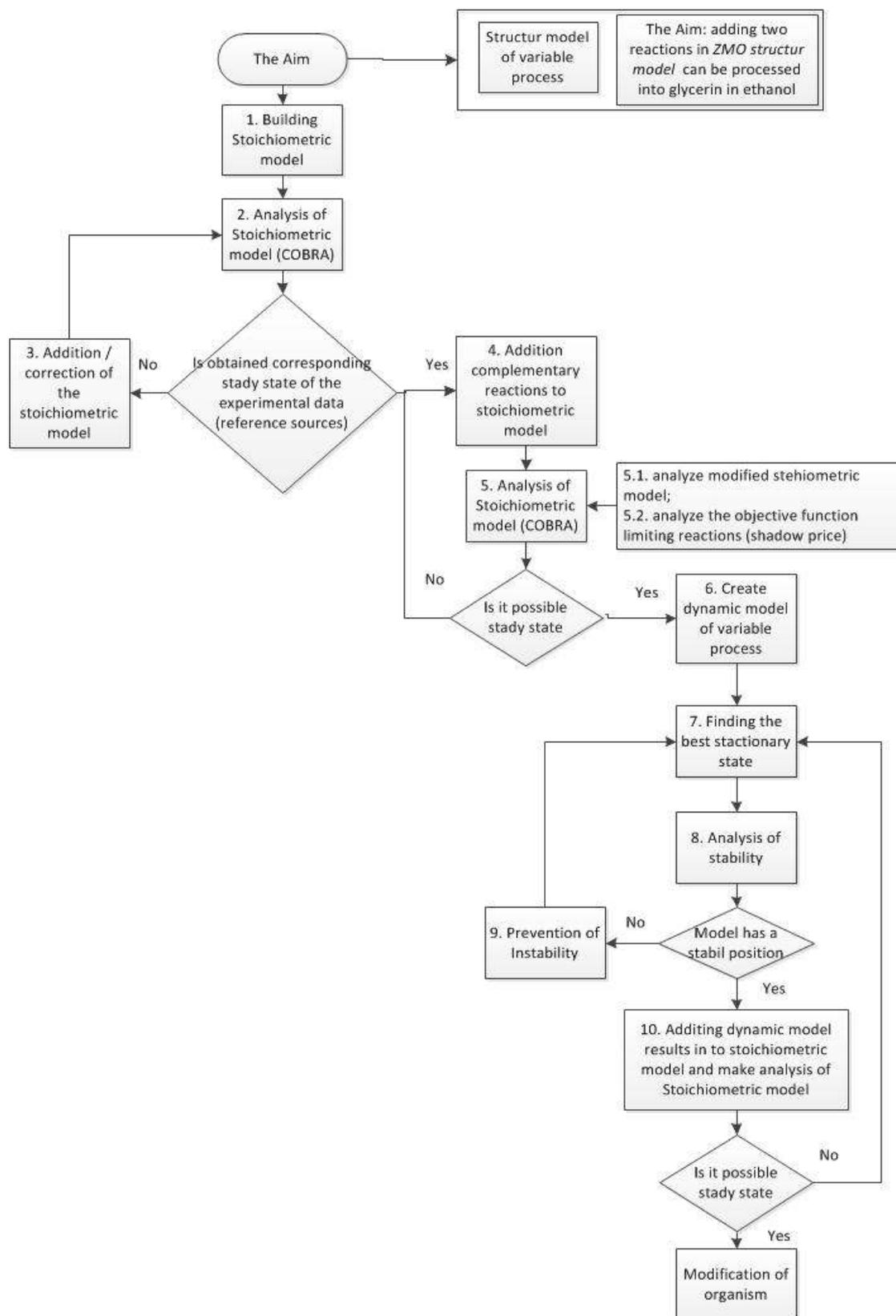


Fig. 2. Genome-scale metabolic engineering analysis solution algorithm

Conclusion

Algorithm describes the genome scale computer modelling the methodology of the analysis and improvement of metabolic engineering solutions without using the modified organism experimental data. Algorithm describes the genome scale structural model and process scale models of the dynamic interaction. Algorithm consists of 10 steps.

One of systems biology industry's the problem is that it can not directly know the way of the biological systems in the molecular level. Consequently, it is necessary to carry out the modelling of biological systems. The application of the method is able to address the biological tasks in the molecular level, allows you to make modifications and verify or may be the solution. Modelling to simulate modified organism behaviour. Developed the method can be used in medicine, metabolic engineering tasks ecological problems, environmental problems, etc.

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ALTFLUXES: COBRA TOOLBOX EXTENSION FOR FLUX VARIABILITY ANALYSIS OF STOICHIOMETRIC MODELS OF METABOLISM

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Abstract: *The size and number of available constraint-based genome scale metabolic reconstructions and models is rapidly growing. Flux Balance Analysis (FBA) is an important analysis for these models to investigate possible steady state conditions for particular constraints sets in the models. FBA is based on linear algebra and it returns only one feasible set of distribution of fluxes. In the model there is possible infinite number of unique solutions depending on constraints set in the model. The COBRA Toolbox is a powerful tool with expanding functionality for analysis of stoichiometric models. The COBRA Toolbox offers the function to calculate alternative flux rates for each reaction in the model, however there is a lack of visual representation of the obtained results. Therefore the AltFluxes extension for the COBRA Toolbox is developed to visualize the flux variability results in the graph. The AltFluxes represents the numerical results in more transparent structure in the MATLAB command window as well. Moreover, proposed function returns not only alternative fluxes for each reaction in the model, but the sets of the other fluxes of reactions in the extreme flux rates of corresponding reaction. The function AltFluxes is written in the MATLAB scripting language ensuring the cross-platform approach. It is an open source software under the GPL v3 license and available at <http://www.biosystems.lv/altfluxes>.*

Keywords: flux variability, COBRA Toolbox, stoichiometric model, FBA, MATLAB.

Introduction

There are several modeling approaches (Boolean networks (Lahdesmaki et al, 2006), Bayesian networks (Lahdesmaki et al, 2006) Time Petri Nets (Koch et al, 2005), Constraints-based stoichiometric models (Price et al, 2003), Dynamic models (Anesiadis et al, 2008), Neural models (Ławryńczuk, 2008) etc.) to investigate and simulate metabolism of biological organisms in silico. Each approach has advantages and disadvantages, and it serves for different purposes. Constraints-based stoichiometric models have got a high popularity in the field of metabolic engineering. Moreover metabolic network reconstructions have become an integral part of studying the metabolism of target organism (Thiele and Palsson, 2010). Constraint-based reconstruction and analysis approach is one of the beginning steps before dynamic modeling, where kinetic parameters are taken into account.

A rapidly growing and improving tool - the COBRA Toolbox (Schellenberger et al, 2011) is powerful software specially developed for wide range of simulation and analysis of the metabolic engineering tasks in the MATLAB environment (<http://www.mathworks.com>). There are already implemented a lot of algorithms to process on the constraint-based models for model debugging and analysis purposes (network gap filling, ¹³C analysis, metabolic engineering, omics-guided analysis etc.). One of the key function in the metabolic engineering and so in the COBRA Toolbox is flux balance analysis (FBA) that shows if model is able to produce the products of interest according to objective function at steady state (Orth et al., 2010). The calculations are accomplished by linear programming and there are possible three result cases: (1) zero solutions, (2) one unique solution and (3) infinite number of feasible solutions, however FBA is able to return only one set of reactions fluxes. To check the uniqueness of distribution of fluxes it is necessary to perform flux variability analysis (FVA) which can find alternative solutions for the constrained solution space (Schellenberger et al, 2011).

Despite the wide functionality of the COBRA Toolbox, it still has a lack of user friendly interface that nowadays becomes to play a big role among almost any program user, especially for biologists. The *Paint4Net* toolbox is available for visualization of stoichiometric models of metabolism (Kostromins and Stalidzans, 2012). It is possible to see FBA results, however it does not visualize FVA results. Therefore the *AltFluxes* - extension for the COBRA Toolbox has been developed to deliver FVA functionality in combination with user friendly result representation and usage simplicity.

The *AltFluxes* returns FVA results in the MATLAB command window in form of four columns (Reaction name, Min flux, Max flux, Detailed view) and creates color graphs with flux rates of reactions. Furthermore the *AltFluxes* checks the model constraints and signalizes about potential mistake in case of equal lower and upper bound rates of a particular reaction that causes the limitation of solution space and could exclude the best FVA result.

Materials and methods

The COBRA Toolbox works in MATLAB that is already a long time one of the most popular engineering environments. A big advantage of MATLAB is platform independency, so the *AltFluxes* can be run on any platform where MATLAB is working. The *AltFluxes* is written in the MATLAB scripting language as open source software under the GPL v3 license.

The execution of the *AltFluxes* function is very easy with only two arguments: a stoichiometric model and a list of reactions for FVA, that could be as well as few or even all reactions that are present in the model. Before execution of the *AltFluxes* function it is necessary to set known constraints from literature and practical experiments or simulations in silico.

The first step *AltFluxes* do after execution is the reaction presence check, where it goes through the list of reactions of interest and checks if each reaction is present in the model. In case of absence of any reaction the calculations are stopped and informative message appears in the MATLAB command window. In case of uninterrupted calculation the *AltFluxes* stores all nonzero coefficients of the objective function in the temporary list and changes coefficients in the model to zeroes. The next step is the cycle through the list of reactions of interest, where the *AltFluxes* (1) changes the coefficient of the objective function of reaction of interest to one, (2) performs two optimizations with “min” and “max” flags of the COBRA Toolbox internal function *optimizeCbModel* and (3) set the coefficient of the objective function back to zero (see Fig.1).

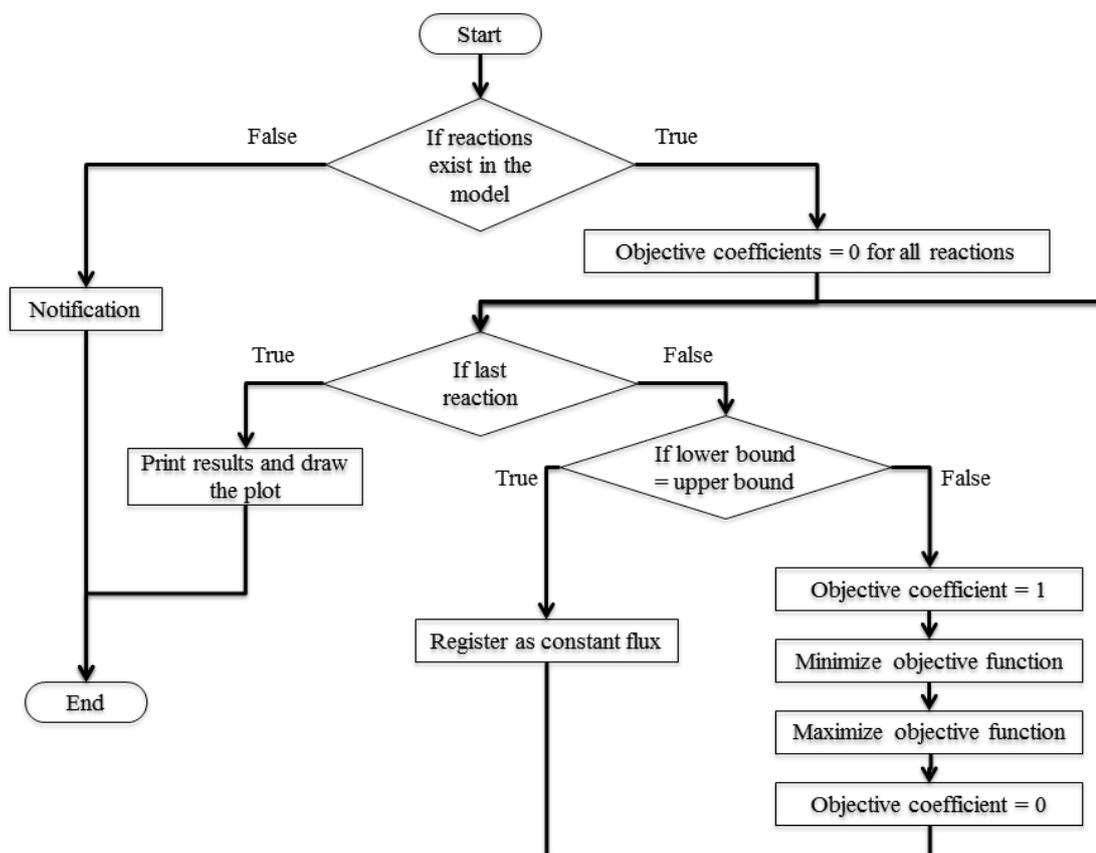


Fig. 1. The algorithm of the *AltFluxes*.

For those reactions where lower and upper bounds are equal the *AltFluxes* specially signals in the MATLAB command window as constant flux rates in the model (see Fig.2).

```

'R74'      [      0]      [      0]      {2x2 cell}
'R75'      'Const 0'      'Const 0'      []
'R76'      [      0]      [     40]      {2x2 cell}
'R77'      [      0]      [      0]      {2x2 cell}
'R78'      [      0]      [      0]      {2x2 cell}
'R79'      [      0]      [      0]      {2x2 cell}
'R80'      [      0]      [      0]      {2x2 cell}
'R81'      [      0]      [      0]      {2x2 cell}
'R82'      'Const 0'      'Const 0'      []
'R83'      [      0]      [     80]      {2x2 cell}
'R84'      [      0]      [     80]      {2x2 cell}
'R85'      [      0]      [      0]      {2x2 cell}
'R86'      [      0]      [      0]      {2x2 cell}
'R87'      [      0]      [     40]      {2x2 cell}
'R88'      [      0]      [     20]      {2x2 cell}
'R89'      [      0]      [     40]      {2x2 cell}
'R90'      [     -40]      [      0]      {2x2 cell}
'R91'      'Const 0'      'Const 0'      []

```

Fig. 2. Fragment of the result of the *AltFluxes* function with constant flux rates. Reactions *R75*, *R82* and *R91* are marked as constant with 0 flux rates set in the model.

The *AltFluxes* returns the FVA result in the MATLAB command window (see Fig. 2 and Fig. 3) and stores it in the MATLAB workspace as a variable for further analysis.

```

'Reaction Name'      'Min flux'      'Max flux'      'Detailed view'
'glyc12'             [      0]      [      0]      {2x2 cell}
'glyc21'             [      0]      [     40]      {2x2 cell}
'carb12'             [      0]      [      0]      {2x2 cell}
'ed2'                [    -1000]      [     1000]      {2x2 cell}
'g6pd'               [    -1000]      [     1000]      {2x2 cell}
'ed3'                [      0]      [ 40.0000]      {2x2 cell}
'ed1'                [      0]      [     40]      {2x2 cell}
'R035'               [      0]      [      0]      {2x2 cell}
'ppp4'               [      0]      [      0]      {2x2 cell}
'ppp3'               [      0]      [      0]      {2x2 cell}
'carb2'              [      0]      [      0]      {2x2 cell}
'R040'               [      0]      [      0]      {2x2 cell}
'ppp5'               [      0]      [     40]      {2x2 cell}
'glyc3'              [      0]      [     40]      {2x2 cell}
'glyc1'              [      0]      [     40]      {2x2 cell}
'glyc4'              [     -40]      [      0]      {2x2 cell}
'glyc7'              [     -40]      [      0]      {2x2 cell}
'glyc23'             [      0]      [     40]      {2x2 cell}
'glyc14'             [     -40]      [      0]      {2x2 cell}
'pyr_dec'            [      0]      [     80]      {2x2 cell}
'ed5'                [      0]      [ 80.0000]      {2x2 cell}
'Alcohol14'         [     -80]      [      0]      {2x2 cell}
'acet_dehy'         [    -1000]      [     1000]      {2x2 cell}
'acet_dehyh'        [    -1000]      [     1000]      {2x2 cell}
'acet_dehyE'        [     -80]      [      0]      {2x2 cell}

```

Fig. 3. Fragment of the result of the *AltFluxes* function in the MATLAB command window. The result is formed in four columns: Reaction Name, Min flux, Max flux and Detailed view.

The column “*Detailed view*” in the structure of the variable contains FBA results for extreme points (min and max) of every reaction of interest, however it can be again only one feasible flux distribution set from infinity (see Fig. 4).

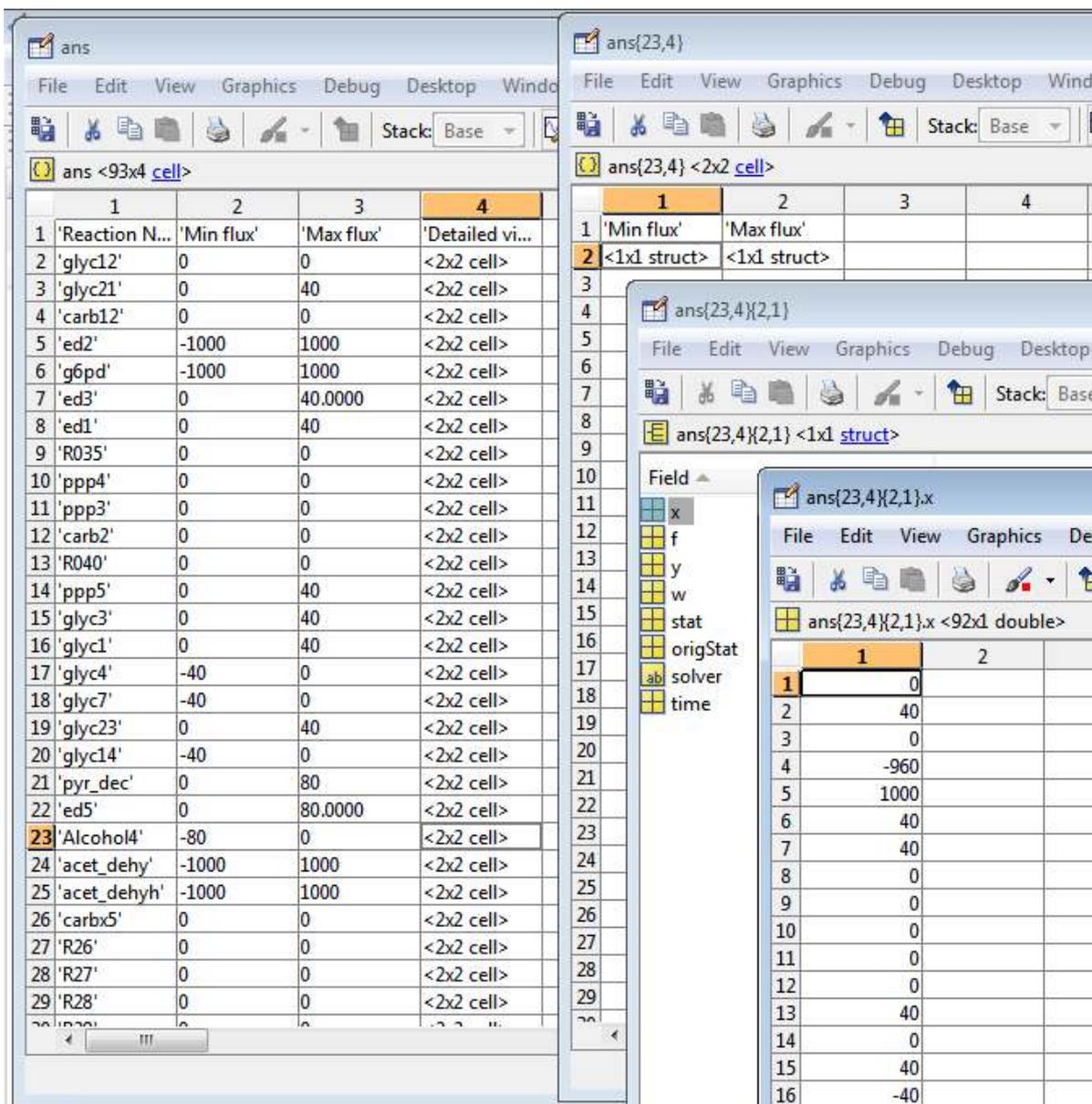


Fig. 4. The column “Detailed view” expanded for reaction *glyc12*. Flux distribution for extreme value of “Min flux” is expanded.

In addition the *AltFluxes* generates the visual graphs where reactions are split by 30 per graph in case of large number of reactions of interest in the model. The example of *AltFluxes* visual results are shown in Figure 5, where the model of the central metabolism of bacteria *Zymomonas mobilis* is taken as study case. The spreadsheet file of the model can be found at http://www.biosystems.lv/altfluxes/sample_files.

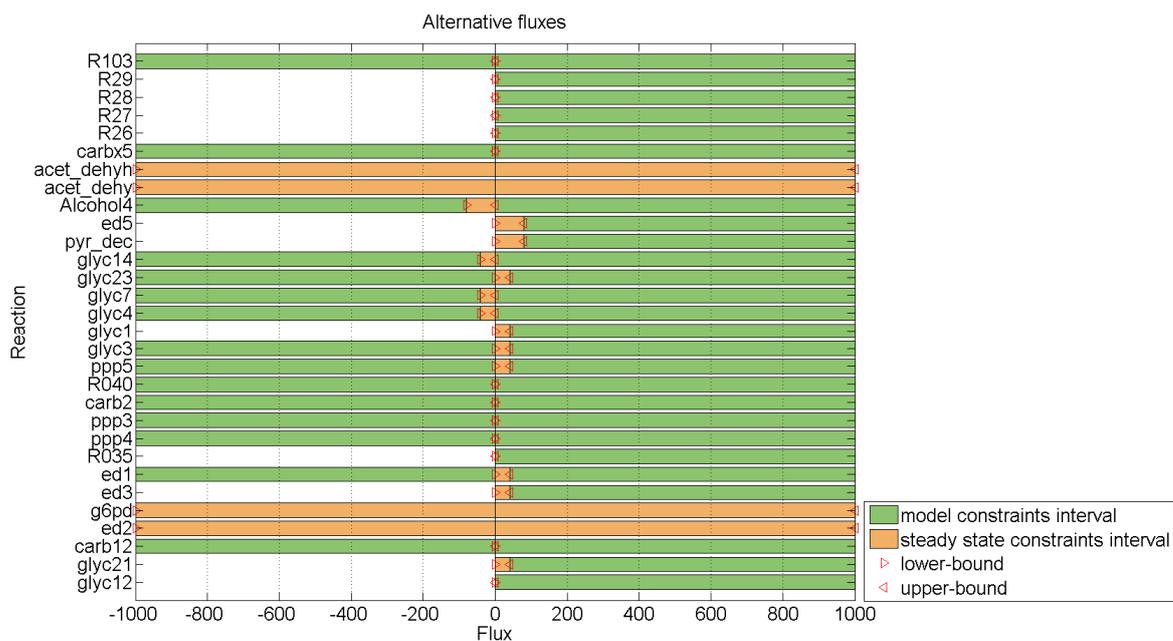


Fig. 5. Part of the result of the *AltFluxes* function. The first 30 of 92 total reactions in the model. The *AltFluxes* argument is set to perform FVA to all reaction in the model. The intervals of the constraints of the model are represented as green bars. The feasible steady state constraints intervals calculated by the *AltFluxes* function are represented as orange bars with triangles in extreme points of intervals.

Results and discussion

According to the *AltFluxes* the example model contains three constant flux reactions, where constraints are set to zero (see Fig. 2) that is definitely limiting the metabolism and possible solution space. However such constraints can be used to simulate gene knockouts (Orth et al., 2010) as well. Another case is constant nonzero flux rates. Although it can be a right approach for fixing particular flux rates of reactions of interest (Orth et al., 2010, supplementary tutorial), still it is worth to check if they are not a bottleneck reactions in the model.

Some reactions in the model can use tight interval or even single value for flux rates at steady state (see Fig. 5), but there are several reactions, which are running full speed as well. Later analysis has shown that clusters of high flux reactions actually are stoichiometrically balanced cycles (Thiele and Palsson, 2010), which are running even, when all substrates are cut down.

Useful information, which can be taken in to account in the future in the *AltFluxes*, is shadow prices and reduced costs (Orth et al., 2010, supplementary tutorial). Shadow prices are derivative of the objective function respecting to the exchange flux of a metabolite, and it shows how much the addition of particular metabolite will change the objective value. Reduced costs are the derivatives of the objective function respecting to an internal reaction with zero flux rate, showing how much each particular reaction affects the objective.

Conclusion

AltFluxes – the COBRA Toolbox extension for FVA of stoichiometric models of metabolism is developed. It is the open source product and it's functionality can be easily extended in the MATLAB scripting language. By default the COBRA Toolbox offers to perform FVA, but user must execute two separate functions (*fluxVariability*, *printLabeledData*) to get structured FVA results in the MATLAB command window, while the *AltFluxes* with it's function delivers FVA results not only in the MATLAB command window, but in graphical format as well in order to facilitate the analysis and debugging of the model of the target organism. In addition the *AltFluxes* returns the distribution of FBA fluxes for each extreme point of the reactions of interest. The *AltFluxes* functionality helps to identify potentially limiting reactions, where lower and upper bounds are equal in the model, by indicating them as constant rate reactions. Graphical representation of the constraints intervals of the model and FVA constraints intervals at steady state allows comparing them and determine potentially limiting flux bounds in the model as well as find stoichiometrically balances cycles running in the model without any substrates.

Acknowledgements

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APPLICATION OF FUNCTIONAL STATE MODELLING APPROACH FOR YEAST *SACCHAROMYCES CEREVISIAE* BATCH FERMENTATION STATE ESTIMATION

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Abstract: *Bioprocess requirements for monitoring, control and identification of process states are increasing to optimize performance and time to avoid disruption that may affect the success of the yeast *Saccharomyces cerevisiae* fermentation process. Continuous estimation of bioprocess state during fermentation requires to use accurate mathematical model and parameters that can describe the actual state of the yeast growth during the fermentation.*

*Application of functional state modelling approach for the mathematical modelling of batch yeast *Saccharomyces cerevisiae* CEN.PK haploid fermentations is presented. Main advantage of the functional state modelling approach against global model with complex structure is that the parameters of each local model can be estimated separately from the other local models parameters. Functional modelling approach also makes it easier to perform model simulation and parameter estimation as compared to the complex global model. Obtained experimental data from yeast batch fermentations shows sufficiently good match with the curves simulated using functional state model.*

Keywords: Bioprocess modelling, batch fermentation, state estimation.

Introduction

The yeast *Saccharomyces cerevisiae* is one of the most relevant microorganisms in the biotechnology industry. It has been used intensively for the production of single cell protein (SCP) for human and animal consumption, and ethanol for alcoholic drink and transport fuel usage from fermentable sugar. In view of increasing importance of ethanol, as an alternative source for chemicals and liquid fuel, a great deal of research interest in ethanol fermentation has been generated (Hunag et al., 2011; Kumoro et al., 2009).

It is valuable to accurately monitor and control biotechnological process (Mednis et al., 2010) to produce the target product (ethanol) for the highest quality and more profitable. For more accurate control it is useful to apply a metabolic model of the yeast in the bioprocess control algorithm that can provide the essential information about ongoing intracellular activities of the bioprocess (Viļums, 2011).

Continuous evaluation of process parameters during the cultivation is a need for a fermentation mathematical model that can simulate the process. The progress of the process can be adequately predicted in a timely manner. Bioreactor control program using the developed model on the basis can handle actuators to stabilize and maintain the progress of the process in the optimal mode. Models cannot only explain and reproduce observed behavior but also predict the evolution of the process. Models are useful for the estimation of parameters and variables. If the anomaly is detected in the functioning process then control system based on model can act on the process to steer and control its variables to the suitable state.

Mostly for bioprocess modeling are used global process models (Nagy, 2007; Renard et al., 2006). The main disadvantage of such approach is the complex model structure and the large number of model parameters, which complicates the model simulation and parameter estimation. The functional state modeling approach is alternative concept of process modeling. In functional state the process is described by local model, which is valid in actual state only. A set of local model together with function state equations can be used to describe, monitor and control the yeast growth process. Several authors have already showed benefits of this approach for more accurate and detailed process modeling (Hristozov et al., 2005; Pencheva and Hristozov, 2005; Pencheva et al., 2004; Roeva et al., 2007; Roeva et al., 2006).

This article aims to demonstrate the functional modeling approach benefits of yeast batch fermentation process modeling to use it as base for yeast growth state estimation. This approach in case of good model and experimental data coincide can be used not only for process predictions but also for fermenter control to stabilize process early enough.

Materials and methods

1. Batch fermentation

The organism used in this study was *Saccharomyces cerevisiae* CEN.PK haploid. 2 litre of production medium was prepared according to the requirements of *S. cerevisiae*, containing glucose 20.0 gL⁻¹, peptone “Biolife” 20 gL⁻¹, yeast extract “Sifin” 10 gL⁻¹. The medium was sterilized in autoclave for 30 min at 110 °C. At the

beginning of fermentations initial OD was 0.20 – 0.25. The batch fermentations were carried out in a stirred tank fermenter (BTC EDF 5.3.1.), with a working volume of 4.5 litres. Temperature was controlled at 30.0 ± 0.2 °C, pH level at 5.5 ± 0.5 , dissolved oxygen partial pressure at 60 ± 5 %. Agitation was ensured with two “rushton” style impellers at 600 rpm and airflow was ensured to 3 slpm. 10 ml of sample were taken every 1.5 hours for the entire fermentation cycle, which was terminated after 9.5 hours. Yeast biomass growth was evaluated by spectrophotometric measurements at 600 nm in a *Helios Epsilon* UV-visible spectrophotometer. The concentration of glucose was determined used glucose measurement device *Accu-Chek Active*. The concentration of ethanol in the medium was determined by liquid chromatography (HPLC).

The pre-culture of the yeast *Saccharomyces cerevisiae* CEN.PK haploid was developed by inoculating 100 ml partially defined medium containing glucose, yeast extract, salts and trace elements with 0,15 ml of frozen culture at 37 °C in shaker flasks. 2 L of initial batch culture for fermentation was derived by inoculating overnight 100 ml (14 – 16 h, OD=2.2 – 2.7) flask pre-culture in batch medium. Dry pellets of *S. cerevisiae* were used for inoculation in yeast fermentations directly to batch medium with initial biomass concentrations of ~4 g/L.

2. Fermentation modeling

Dynamic mass balances are the traditional chemical engineering approach to state estimation in bioreactors. Approach uses dynamic balances at the reactor scale and reasonable assumption regarding the regulatory structure of the organism. Making accurate measurements of bioreactor process variables, the possibility of using mass balance models has a high chance of success (Komives and Parker, 2003).

The rates of cell growth, glucose consumption, ethanol production, oxygen concentration and volume are described for all functional states with mass balance equations as follows:

$$\frac{dX}{dt} = \mu X \quad (1)$$

$$\frac{dS}{dt} = -q_S X \quad (2)$$

$$\frac{dE}{dt} = q_E X \quad (3)$$

$$\frac{dO}{dt} = -q_O X + k_L a (O^* - O) \quad (4)$$

$$\frac{dV}{dt} = F_A + F_B + F_{ANT} - F_{SMP} - F_E - F_C \quad (5)$$

where X - the concentration of biomass, g·L⁻¹;
 μ - specific cell growth rate, h⁻¹;
 S - concentration of substrate (glucose), g·L⁻¹;
 q_S - specific substrate consumption rate, h⁻¹;
 E - ethanol concentration, g·L⁻¹;
 q_E - specific ethanol production rate, h⁻¹;
 O - oxygen solubility, g·L⁻¹;
 q_O - specific oxygen consumption rate, h⁻¹;
 $k_L a$ - volumetric oxygen transfer coefficient, h⁻¹;
 O^* - maximal solubility of oxygen, g·L⁻¹;
 V - volume, L;
 F_A - acid consumption rate, L·h⁻¹;
 F_B - base consumption rate, L·h⁻¹;
 F_{ANT} - antifoam consumption rate, L·h⁻¹;
 F_{SMP} - sampling rate, L·h⁻¹;
 F_E - evaporation rate, L·h⁻¹];
 F_C - carbon loss rate, L·h⁻¹.

A substrate such as glucose is consumed by yeast to produce a number of carbon intermediates as well as to provide energy. The yeast then utilizes the carbon intermediates to synthesize a new cell material. If the sugar concentration in the broth in an aerobic yeast growth process exceeds a certain level, called the critical sugar mass concentration (S_{crit}), a part of the sugar is metabolized in ethanol. In the case of batch cultivation S_{crit} is assumed to be zero. A critical level of dissolved oxygen concentration for yeast growth process is assumed to be 18%. The whole yeast growth process can be divided into at least five functional states in batch and fed-batch cultures (Pencheva et al., 2004; Roeva et al., 2006).

In the case of batch cultivation two phases are identified (Fig. 1.):

1. The first functional state (I) is called *the first ethanol production state*. The process is defined to be in this state when the sugar mass concentration is above the critical level and there is sufficient dissolved oxygen. In this state ethanol is produced.
2. The second functional state (II) is called the *ethanol consumption state*. The process is defined to be in this state when ethanol is available but there is no sugar in the broth, and the dissolved oxygen concentration is above the critical level. Ethanol is the only carbon source for yeast growth.

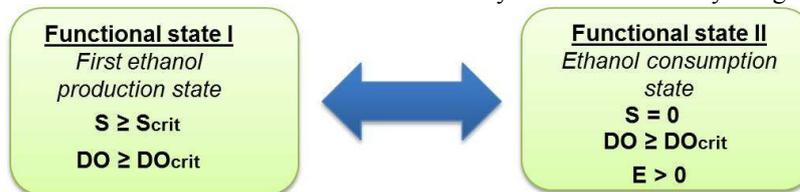


Fig. 1. Identified functional states of the yeast batch cultivation

(Roeva et al., 2006) assume that in principal, the functional state (I) can appear in all batch, fed-batch, and continuous yeast growth processes. The functional state (II) normally appears only in batch culture. A yeast growth process switches from one functional state to another like a state machine or automation familiar in computer science. Parameter functions of the local models in the states (I) and (II) are presented in Table 1.

After entering state II yeast cell begin to synthesize the enzymes for gluconeogenesis so that cells can utilize ethanol as the carbon-source for growth. This causes a lag in the yeast growth. The lag term for functional state can be calculated by equation (1).

Table 1

Parameter functions of the local models (Tania Pencheva et al., 2004)

Parameter functions	State I	State II
μ	$\mu_1 \frac{S}{S + k_S}$	$\mu_2 \frac{E}{E + k_E} \eta$
q_S	$\mu_1 \frac{S}{S + k_S} Y_{SX}$	0
q_E	$\mu_1 \frac{S}{S + k_S} Y_{ES}$	$-\mu_2 \frac{E}{E + k_E} Y_{EX} \eta$
q_O	$\mu_1 \frac{S}{S + k_S} Y_{OX}$	$\mu_2 \frac{E}{E + k_E} Y_{OE} \eta$

where μ_i – maximum specific growth rates, h⁻¹;
 k_S, k_E – saturation constants, g·L⁻¹;
 $Y_{SX}, Y_{ES}, Y_{EX}, Y_{OX}, Y_{OE}$ – yield coefficients, g·g⁻¹;
 η – lag term, h.

$$\eta = 1 - \exp\left(-\frac{t - t_m}{t_1}\right) \quad (1)$$

where t – the current process time, h;
 t_m – time point of involving in lag phase, h;
 t_1 – the length of lag phase, g·g⁻¹.

Results and discussion

The functional state model of yeast batch process was developed in MATLAB environment. The model consists of script M-Files and experimental data CSV files. Experimental data obtained from two batch fermentations of yeast *Saccharomyces cerevisiae* CEN.PK haploid. The experimental data contains on-line measurements of pO₂. Off-line data include measurements of biomass, substrate (glucose) and ethanol.

The first batch experiment measured and model simulated curves are presented in the Fig 2.

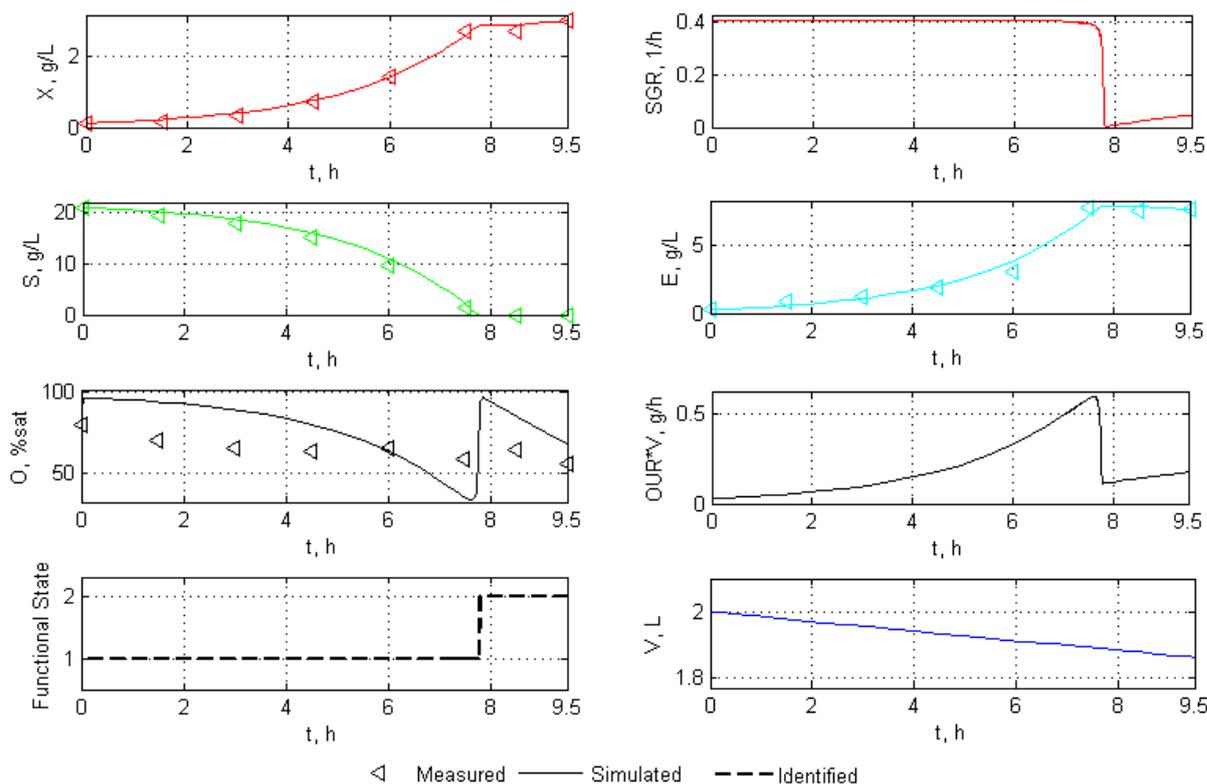


Fig. 2. 1st Batch fermentation measured, model simulated and identified curves

The process was carried out in 9.5 hours. Model simulated curves X (biomass), S (substrate), E (ethanol) shows good accordance with a measured experimental data. The actual functional state is identified automatically from actual substrate and dissolved oxygen saturation concentration. The functional state plot (Fig. 2) shows that switching between the 1st to the 2nd functional state is approximately at 7.8 process hour. Then substrate concentration has reached the critical value. The estimated model parameters can be seen in Table 2.

Table 2

1st batch experiment estimated values of functional state parameters

Parameters of State I	Estimated value	Parameters of State II	Estimated value
μ_{max1}	0.41	μ_{max2}	0.158
K_S	0.0714	K_E	0.181
Y_{SX}	7.7	Y_{EX}	2.07
Y_{ES}	2.8	Y_{OE}	0.9
Y_{OX}	0.25	t_l	3.7
k_{La}	55	t_m	7.8
-	-	k_{La}	55

The second batch experiment measured and model simulated curves are presented in the Fig 3. The process was carried out in 11.5 hours. Model simulated curves X, S, E shows good accordance to a measured experimental data. The actual functional state is identified automatically from actual substrate and dissolved oxygen saturation concentration. The functional state plot (Fig. 3) shows that switching from the 1st to the 2nd functional state didn't occur because process substrate and dissolved oxygen concentration was all the process time above critical values.

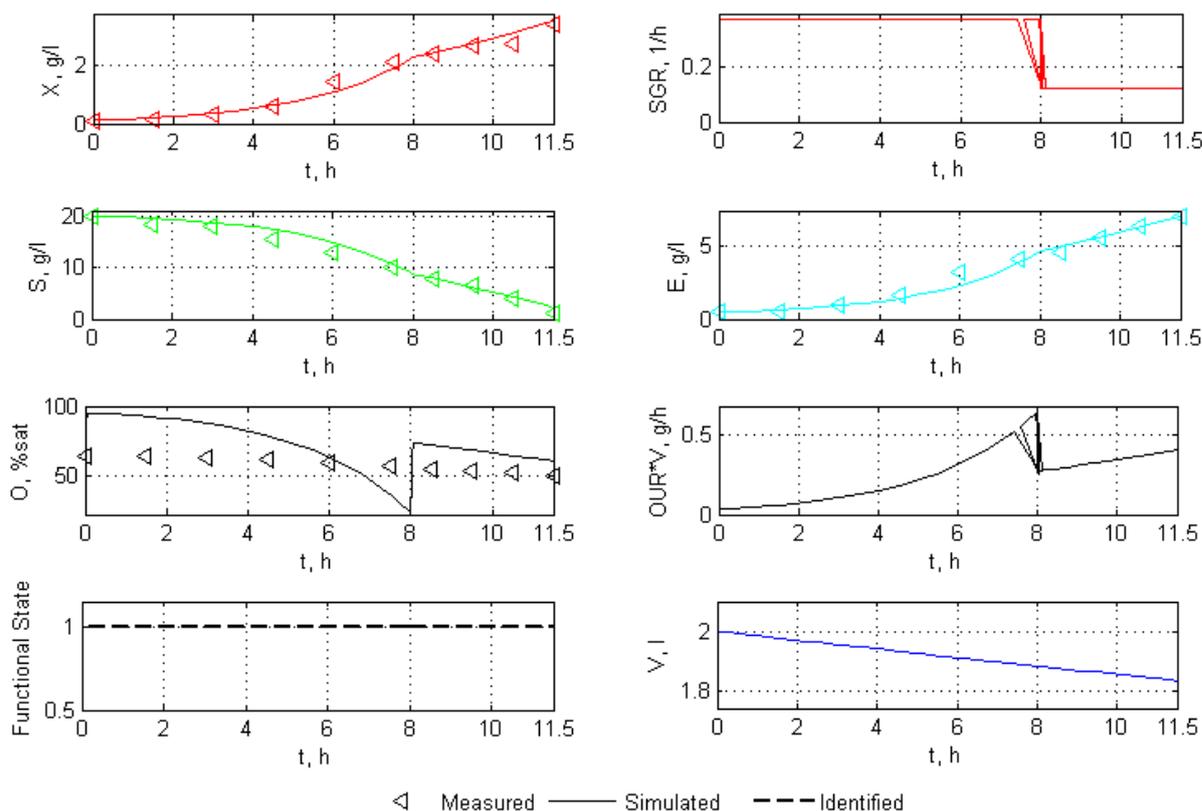


Fig. 3. 2nd batch fermentation measured, model simulated and identified curves

Parameters of the actual functional state were manually estimated by changing parameter value to reach the best experimental data and model simulated curve consistency. The estimated model parameters are shown in Table 3. The 2nd mumax coefficients were estimated in the 1st functional state. Beginning of the process effective growing was observed and mumax value was estimated 0.376 but after the 8th hour the growing was decreased and was estimated mumax value 0.125. Other parameters were similar to the 1st batch process (see Fig 2.).

Table 3

2nd batch experiment estimated values of functional state parameters

Parameters of State I	Estimated value
mumax_{11}	0.376
mumax_{12}	0.125
K_S	0.0714
Y_{SX}	5.15
Y_{ES}	1.9
Y_{OX}	0.35
k_{La}	55

Conclusion

The application of the functional state modeling approach for two yeast batch fermentations modeling were presented in this paper. This approach shows good benefits for using it as base for the yeast batch fermentation model based control system development. The yeast growth functional state estimation is valuable to find out appropriate parameters that can adequately describe the actual physiological state of yeast growth process. Model simulated curves for X (biomass), S (substrate) and E (ethanol) showed good accordance to measured experimental and model simulated data for both batch fermentations. The greater deviation from measured and model simulated curves was observed with dissolved oxygen partial pressure value due to problems to identify a correct mass transfer coefficient value and functional state parameters. The functional state modelling approach parameters for actual functional state were manually estimated by changing parameter value to reach the best experimental data and model simulated curve consistency. In future is planned to improve yeast batch fermentation model with automatic functional state parameter estimation.

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BIOCHEMICAL NETWORKS COMPARISON TOOL

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Abstract: *In genome-size model (reconstruction) case, each model may contain several hundreds of reagents and reactions. To be semantically comparable and then merged, biochemical network models require strict standardization. Unfortunately, the standardization of biochemical substances is not solved, therefore comparison of models made by different authors is not a trivial task, because the names of reagents and reactions often have synonyms. Without a computerized algorithm, comparison of models is time consuming process. In this paper a model is viewed as two interrelated mathematical sets. An algorithm to compare two stoichiometric models and application example is presented.*

Keywords: stoichiometric models, comparison, tool

Introduction

The genome-size models are available in different formats. Mostly it is SBML (System Biology Markup Language) file format. The SBML enables the model use of multiple software tools without having to rewrite models to tools inner format. Also, these models can be easily published and shared to other researchers to different software environment (Andrew Finney, Michael Hucka, 2003). Still the comparison of models is complicated as the standardization of substances and reactions is not a completed task. It is possible to compare structures of models visually (Kostromins and Stalidzans, 2012) or parameters of the structure (Rubina and Stalidzans, 2010). Still that is not enough to compare the scope of models or join the models as equal metabolites and reactions have to be recognized for that purpose.

To read, write and manipulate with SBML models, the LibSBML application programming interface (API) library is available. The LibSBML API supports different SBML levels and versions. LibSBML is written in C++ and provides language bindings for Common Lisp, Java, Python, Perl, MATLAB and Octave, and includes many features that facilitates adoption and use of both SBML and the library. Developers can embed LibSBML in their applications, saving themselves the work of implementing their own SBML parsing, manipulation, and validation software (Benjamin et al., 2008).

The BiGG database is systematized biochemically, genetically and genomically structured knowledgebase of metabolic reconstructions. In BiGG database models do not contains gaps or incorrect annotations, preventing errors in model predictions. The BiGG knowledgebase is designed to work with COBRA toolbox (Schellenberger et al. 2011).

BiGG two main functions are content browsing and exporting whole reconstructions as SBML files, which are specifically designed to work with Matlab COBRA toolbox and System Biology Research Tool. Using COBRA toolbox, the SBML file exported from BiGG database may be imported as a network data structure into Matlab (Schellenberger et al., 2010).

The COBRA toolbox allows predictive computations of both steady-state and dynamic optimal growth behavior, the effects of gene deletions, comprehensive robustness analyses, sampling the range of possible cellular metabolic states and the determination of network modules. Functions enabling these calculations are included in the toolbox, allowing a user to input a genome-scale metabolic model distributed in SBML format (Beker et al., 2007).

COBRA toolbox can import models in various formats, including SBML, but the Excel spreadsheet with defined columns is preferred.

COBRA compatible model comparison using web based tool ModeRator has been described by Mednis et al, 2012.

To show application of the algorithm, the model comparison software prototype has been developed. The software comparison process overview is shown in Figure 1. Comparison software supports model file format (.xls) of COBRA toolbox. COBRA Excel file of model contains one sheet of information about all reactions and another sheet about all metabolites that are used in these reactions. Columns have specific order and each of them contains specific information. To compare reactions, the necessary columns are used – abbreviation, description, reaction and E.C number column. From metabolites sheet, abbreviation, descriptions and chemical formulas are used.

Materials and methods

Reactions and metabolites can be defined as lists, but to simplify mathematical notation, further they are viewed as sets.

Each model contains of 2 mathematical sets R and M (1):

$$\text{Model} = \text{MO} = \{R, M\} \quad (1)$$

Where set R contains all model reactions (2), but set M contains all metabolites (3):

$$R = \{r_i | i = 1..m\} \quad (2)$$

$$M = \{m_i | i = 1..r\} \quad (3)$$

Each reaction can contain from one to several reactants S and products P :

$$S = \{S_1, S_2, \dots, S_i\} \quad (4)$$

$$P = \{P_1, P_2, \dots, P_i\} \quad (5)$$

All model reactants (6) and products (7) are elements that includes in set M :

$$\forall S_i \in M \quad (6)$$

$$\forall P_i \in M \quad (7)$$

Two models can be described following:

$$\text{Model 1} = \text{MO}_1 = \{R_1, M_1\} \quad (8)$$

$$\text{Model 2} = \text{MO}_2 = \{R_2, M_2\} \quad (9)$$

Two models can be compared by following coherence:

$$\text{If } \forall r_i \in \text{MO}_1 \text{ and } \forall r_j \in \text{MO}_2 \text{ then } r_i \perp r_j \Rightarrow \text{MO}_1 \perp \text{MO}_2$$

Formulation of the problem:

1. are all models equal
2. does all models have the same reactions
3. are two reactions equal

An algorithm has been developed for two models comparison. It has 4 steps:

1. In the first step each reaction metabolite abbreviations are replaced by its chemical formula. This process has been done to all model reactions. In this step H, H₂O and another user defined metabolites are removed.
2. Each model reaction is divided into two parts – left and right formula parts. The reaction parts are divided by “<=>” or “->” symbols.
3. All model M₁ reactions are compared with M₂ reactions:
 - If metabolites count between two reactions is different, automatically those are not equal.
 - Each M₁ reaction left side metabolites are compared with M₂ left side metabolites. The same is done with the right reaction side metabolites.
 - Reactions are compared by E.C numbers. If reaction R_a E.C numbers are equal to reaction R_b ones then E.C numbers are considered as equal. Also if one of those reactions doesn't have an E.C number, those are supposed to be equal.
4. Duplicate reactions in the same model are found by comparing reactions abbreviations – a reaction abbreviation is compared to all other reactions abbreviation.

To test algorithm application, two COBRA file format models of *Zymomonas mobilis* bacteria are used:

- test model A which is based on Singapore reconstruction (Widiastuti et al., 2011).
- test model B which is based on Korea models reconstruction (Lee et al., 2010).

Test model one contains 747 reactions and 601 metabolites, but test model two contains 600 reactions and 614 metabolites, although both models represent the same bacteria.

To compare these models, the developed model comparison software prototype ModelComparator is used.

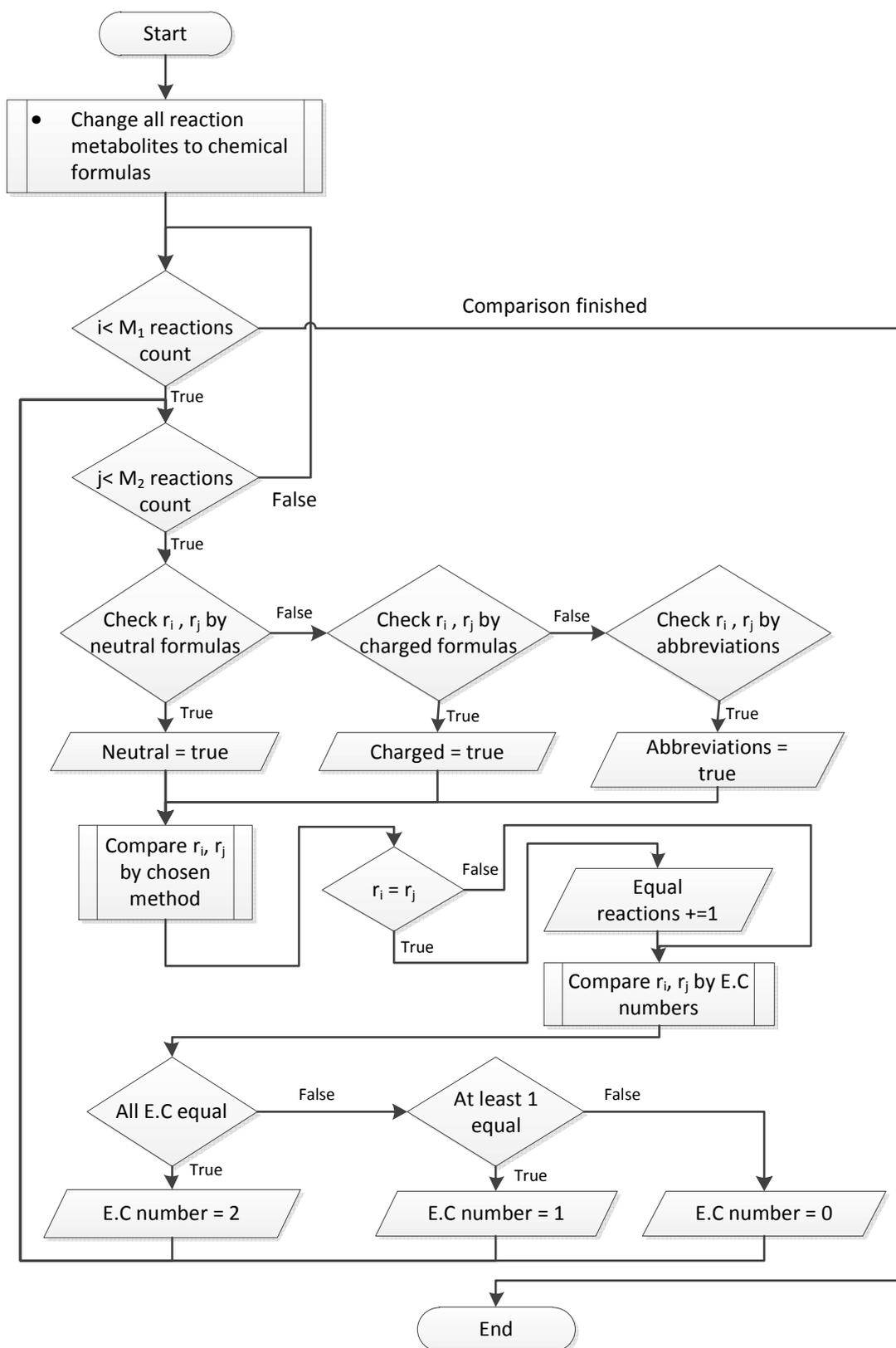


Fig.1. Two model comparison process in developed comparison software prototype.

Results and discussion

The comparison software prototype resulted that test model A has 33.20% (comparing by neutral formulas) equal reactions with test model A Table 2. Using default option to remove all H₂O and H metabolites from reactions the ModelComparator results more equal reactions Table 2 than performing comparison without that option Table 1:

Table 1

Test models comparison summary

	By charged formulas	By neutral formulas	By abbreviation
Equal reaction overriding E.C number	111	189	0
Equal reactions by E.C number	83	122	0
At least 1 equal E.C	3	10	0
Reversed reactions	36	79	0
Equality %	14,86 %	25,30 %	0 %

Table 2

Test models comparison summary – H₂O, H ignored

	By charged formulas	By neutral formulas	By abbreviation
Equal reaction overriding E.C number	139	248	0
Equal reactions by E.C number	107	174	0
At least 1 equal E.C	3	11	0
Reversed reactions	36	79	0
Equality %	18,61 %	33,20 %	0 %

Comparing by abbreviation the result is 0 %, because one of models doesn't have correct abbreviations.

After comparison is accomplished, the Model comparator results various data about models (Fig.2):

- List of all equal reactions, where detailed information between two reactions is available. The reactions with E.C numbers and chemical formulas or abbreviations have highlighted row in green color.
- Additionally, the Model Comparator shows if reaction is reversed (in "=" column).
- List of all duplicate reactions in the same model.
- List of all model metabolites.
- Two models comparison summary is available.

The screenshot shows the Model Comparator software interface. At the top, there are two model selection boxes: 'modelFilev1.xls' (600 reactions, 614 metabolites) and 'ZMO_Sing.xls' (747 reactions, 701 metabolites). A 'Compare' button is visible, along with radio buttons for 'Abbreviation', 'Neutral reactions', and 'Charged reactions'. Below this, a table displays the comparison results for 11 reactions. The table has columns for 'Nr', 'Abbreviation', 'Description', 'Reaction', '=', 'Abbreviation', 'Description', and 'Reaction'. The reactions are listed with their corresponding descriptions and chemical formulas. A legend at the bottom explains the symbols used in the table: a double-headed arrow for 'equal reaction', a single-headed arrow for 'reversible reaction', a crossed arrow for 'crossed reaction', a green box for 'equal by E.C numbers', and a yellow box for 'partly equal by E.C numbers'.

Nr	Abbreviation	Description	Reaction	=	Abbreviation	Description	Reaction
1	R001	glucose-6-phosp...	G6P -> bDG6P	↔	env7	104	man6p -> f6p
2	R002	glucose-6-phosp...	G6P -> F6P	↔	env7	104	man6p -> f6p
3	R003	glucose-6-phosp...	bDG6P -> F6P	↔	env7	104	man6p -> f6p
4	R004	glucokinase	GLC + ATP -> G6P + ADP	↔	carb12	79	atp + fru -> adp + f6p
5	R005	aldose 1-epimerase	bDGLC -> GLC	↔	T001	564	glc-D_e -> glc-D
6	R005	aldose 1-epimerase	bDGLC -> GLC	↔	T159	692	fru_e -> fru
7	R011	phosphoglycerat...	3PG -> 2PG	↔	glyc7	335	2pg -> 3pg
8	R018	pyruvate decarbo...	PYR -> ACAL + CO2	=	glyc22	329	pyr -> acald + co2
9	R020	phosphoglycerom...	G6P -> G1P	↔	env7	104	man6p -> f6p
10	R021	glucokinase	bDGLC + ATP -> bDG6P + ADP	=	carb12	79	atp + fru -> adp + f6p
11	R022	citrate synthase	ACCOA + OA -> COA + CIT	=	tca12	131	oaa + accoa + h2o -> cit + coa

Fig.2. The ModelComparator user interface.

Information about two model comparison summary is available (Fig.3). The similarity between two models is shown in percents. The quick way to obtain similarity between second to first models, the switch button is available.

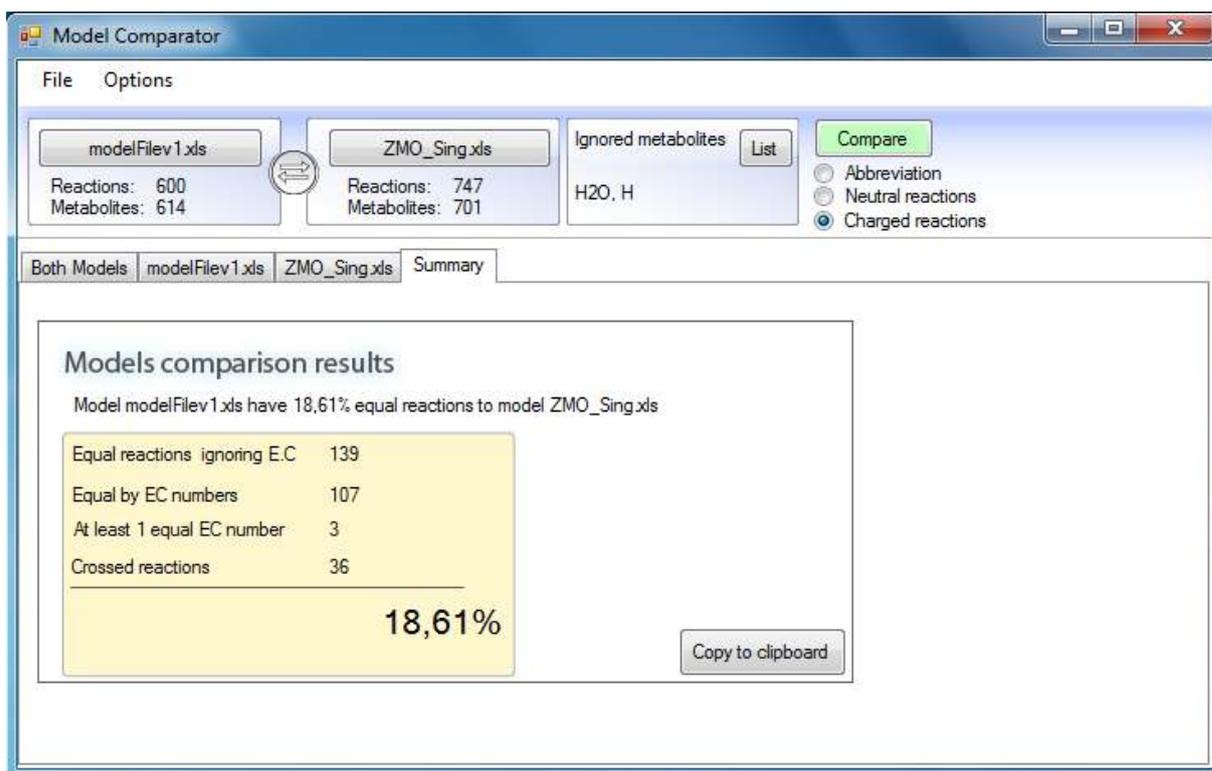


Fig.3. Two models comparison summary results in ModelComparator.

Conclusion

ModelComparator is desktop application that allows comparison of COBRA compatible models in *.xls* file format by comparing reactions and involved metabolites. ModelComparator has been tested on two representative genome-scale models of *Zymomonas Mobilis*. The obtained results shows that equalizing all reactions by removing water and hydrogen improves the comparison results. The use of reactants chemical formula as a mapping layer involves the risk of isomers, which can be overcome by additional E.C. numbers check.

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CORUNNER: MULTIPLE OPTIMIZATION RUN MANAGER FOR COPASI SOFTWARE

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Abstract: *Numerical optimization based design tasks of dynamic models of biochemical networks mainly are solved using global stochastic optimization methods which can deliver relatively quick improvement of the objective function in short time but it cannot guarantee finding of optimal solution. In case of large models or complicated dynamics the question about appropriate duration of optimization runs become important question in case of necessity to analyze high number of combinations of adjustable parameters. This task becomes even more complex if the optimal solution has to fulfil the steady state condition which is typical in case of biotechnological applications of design tasks as steady state precondition rejects many combinations of adjustable parameter values thus making the optimization slower.*

Duration of one optimization run therefore can take time up to several days or weeks for one combination of adjustable parameters which make the procedure inefficient. Application of parallel optimization runs is proposed to reduce the stochastic impact of a single optimization run.

A software CoRunner is developed to apply parallel runs automatically collaborating with software COPASI for automation of optimization procedure. In case of necessity the dynamics of parallel optimization runs, which are stored in form of COPASI reports, can be visualized with software ConvAn for detailed analysis of optimization performance. CoRunner automatically stops the optimization in case of consensus of all the parallel optimization runs and returns COPASI model with the set of best values of adjustable parameters found.

Keywords: biochemical networks, stochastic numerical optimization, parameter estimation, design task, convergence dynamics.

Introduction

The mission of systems biology and synthetic biology in metabolic engineering tasks (Mendes and Kell, 1998) is to facilitate the development of new bioprocesses by the help of *in silico* procedures thus reducing the amount of necessary biological experiments which are more costly both in terms of time and resources. Important class of tasks is the optimization of the model in the allowed space of adjustable parameters is the optimization that can be used both in parameter estimation and design tasks (Moles et al., 2003).

Dynamic models give detailed quantitative information about the influence of many parameters of the network like kinetic parameters of reactions and concentrations of reactants (Stelling, 2004). The most typical approach to representing biochemical networks is through a set of coupled deterministic ordinary differential equations intended to describe the network and the production and consumption rates for the individual species involved in the network (Balsa-Canto et al., 2010). The expected increase of the size of dynamic models (Jamshidi and Palsson, 2008) will facilitate their application generally and in optimization tasks in particular.

Mostly the numerical optimization methods are used in optimization tasks of biochemical networks. They can be divided in local and global optimum seeking methods (Balsa-Canto et al., 2008; Mendes and Kell, 1998). Usually the global optimization methods are used to avoid stagnation of the solution in local minimum. There are two classes of global numerical optimization methods: deterministic ones and the stochastic ones. The advantage of some of deterministic methods is the guaranteed reach of global optima for the price of unknown computation time (Banga, 2008; Moles et al., 2003). Therefore, the stochastic global optimization methods are the most popular in optimization tasks of biochemical networks due to their universality and relatively fast convergence to the global optima close value (Banga, 2008; Moles et al., 2003).

The convergence of global stochastic optimization methods is analyzed in case of parameter estimation tasks (Baker et al., 2010; Balsa-Canto et al., 2010; Balsa-Canto et al., 2008; Mendes and Kell, 1998; Moles et al., 2003) while less research is found on convergence in case of design optimization tasks where the properties of metabolic pathways are changed with the aim of enhancing the production of some metabolite of interest (Mendes and Kell, 1998; Moles et al., 2003). Condor COPASI project can be mentioned as a case where parallel optimization runs are applied using web interface (<http://code.google.com/p/condor-copasi/>). Variable convergence speed and stagnation at non optimal values are mentioned as critical in design problems of biochemical networks (Mozga and Stalidzans, 2011b; Mozga and Stalidzans, 2011c) where even relatively small number (5-15) of adjustable parameters of the model cause hundreds or thousands of combinations to be explored. High variability of convergence speed is reported also by Nikolaev: optimization runs can last from minutes up to 90 hours (Nikolaev, 2010). Software ConvAn (Kostromins et al., 2012) is proposed for statistical analysis of convergence dynamics is proposed to analyze and compare different settings of optimization tasks. The combinatorial explosion of adjustable parameter sets force to look for efficient approaches to reduce

necessary time either by rejecting some combinations of adjustable parameters or by reducing the optimization time.

Therefore an automatic termination of optimization run would be of advantage to spend exactly the necessary time for particular model, criteria, set of parameters and optimization method. We propose to use a desktop application software that collaborates with COPASI command line version (Hoops et al., 2006) initiating parallel optimization runs and terminates the optimization automatically when a termination criteria is satisfied.

As set of criteria is proposed to stop a set of optimization runs when it is assessed that no major improvements are expected. The first criteria is the consensus of parallel optimization runs which indicate that all the parallel optimization runs have converged via different trajectories to the same solution indicating also good performance of the optimization method (Mozga and Stalidzans, 2011b; Mozga and Stalidzans, 2011c; Mozga et al., 2011). The second criterion is the end of pre-set maximal duration of optimization runs in case if no consensus is reached.

Use of these criteria's for automatic termination of optimization runs reduce the length of optimization experiment by more intensive use of computational resources due to parallel optimization runs.

Software description

Software development and compatibility

CoRunner works on machines running Windows XP, Vista or 7 and Microsoft .NET Framework version 3.5 (available on <http://www.microsoft.com/net>). To avoid unexpected errors set point as your decimal separator that means that user must check under Regional Setting in Windows OS if decimal separator is point.

CoRunner installation package contains Copasi SE (command line version of Copasi) 3.5. Build version optimization tool files.

Collaboration with COPASI and ConvAn

CoRunner needs the Copasi file for execution. Copasi file must have fully configured all parameters for optimization task and checked check box for executable in optimization task must be checked. Software works fine for both of optimizations types (minimization or maximization). Please give the most attention to optimization report configuration: separator must be "tab"; in body tab first must be the time value and second the criteria (for example best value); software will ignore header configuration but it's recommended to leave this section empty; also strongly recommended to leave footer configuration empty otherwise it may cause an error. CoRunner will generate the name for report file automatically, so it's not necessarily to set name of report file.

When all optimizations are done Copasi generated report files are suitable to perform convergence analyse using ConvAn software (Kostromins et al., 2012).

Functionality of CoRunner

First of all it's necessary to fetch the Copasi file (*.cps), to do so use yellow folder button and select file you need. When it's done in text box next "Path to Copasi file:" label will appear path to your selected Copasi file.

That's enough to run program with default settings. Press the "Go!" button and the program will start 5 parallel runs and criteria checking. All report files will be stored in "tmp" sub directory of CoRunner installation directory. While program is running on form will appear inscription: "Program is RUNNING!"

Program cycles label indicates how many minutes program is running.

CoRunner's parameters configuration is described below.

First is "Number of parallel optimization runs" this value means how many runs and report files will be created and executed. It's suggested to set this value not more than one less as total count of CPU core on machine.

"Waiting for first increase of criteria value" – time in minutes that given to all parallel optimizations to reach at least one first criteria change. This option is significant for models that have a risk don't reach any possible criteria value.

"Consensus criteria" this configuration indicates maximum offset of best criteria (in percentage).

"Consensus delay time" when criteria consensus is reached and not changed during this amount of time all optimizations will be stopped.

"Maximal duration of optimization" is the maximal time for all optimizations to reach the consensus. If consensus didn't reach during this amount of time CoRunner will consider that optimizations aren't perspective or there is a stagnation and stop all of optimizations automatically in preselected time.

"Keep new Copasi files" if this check box is checked then after stopping all of optimizations CoRunner will create new Copasi files for all optimizations. This option is suggested when "update model" is checked in source Copasi file.

Last configuration parameter is check box - "Insert last criteria value before stopping". If this value is checked then before stopping optimization best value for each optimization will be inserted in report file at stopping time.

This option is suggested if further report files will be used in ConvAn for analyses.

CoRunner software and manual available at Tibit home page (<http://tibit.lv/corunner/>)

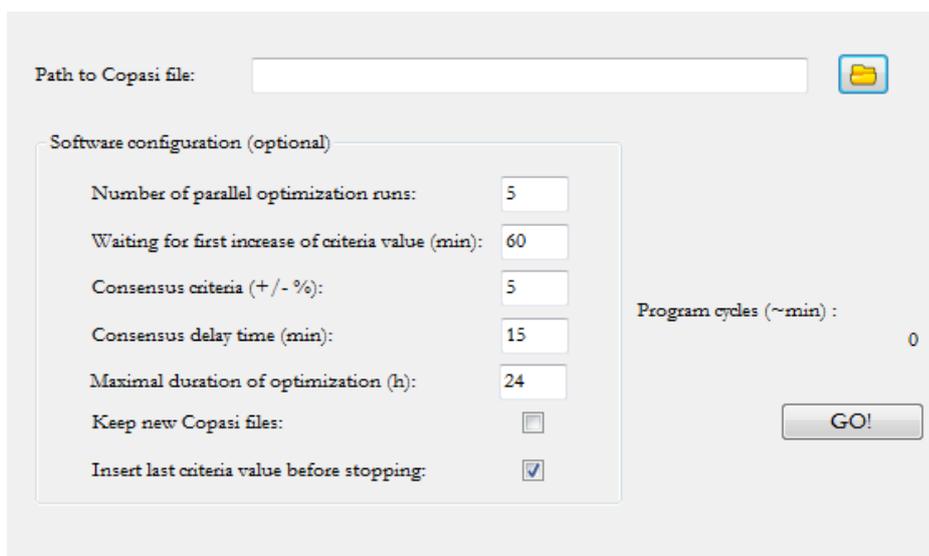


Fig. 1. User interface of CoRunner

Applications

Several cases of results of CoRunner applications are demonstrated. The figures are generated by the software ConvAn using data from report files created by CoRunner.

Case of good performance of optimization can be seen in the Figure 2 and Figure 3. In both cases the optimization is stopped when all the runs reach consensus (best values are within 3% area). It can be seen that the number of parallel runs (5 runs in Figure 2 and 10 runs in Figure 3.) in this particular case does not influence the descriptive statistics of parallel runs. Still the optimization length in case of ten reactions (Fig.3) was almost two times longer.

Stagnation of optimization method (Fig.4) is very important case as optimization results have to be interpreted very carefully (Mozga and Stalidzans, 2011a; Mozga and Stalidzans, 2011b; I Mozga et al., 2011) as stagnation indicate that particular optimization method is not well suited to the particular model or optimization task. Therefore even the best value of the parallel optimization runs may not be the best possible value of objective function (I Mozga and Stalidzans, 2011c).

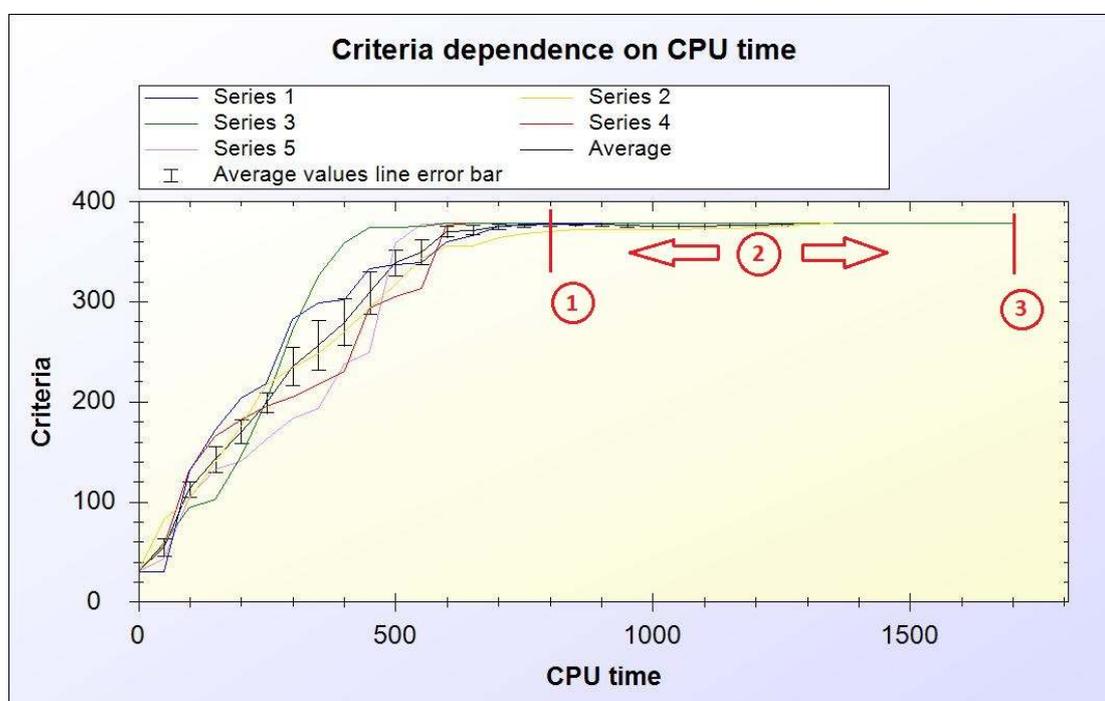


Fig. 2. Consensus case when all the five optimization runs have reached the consensus range

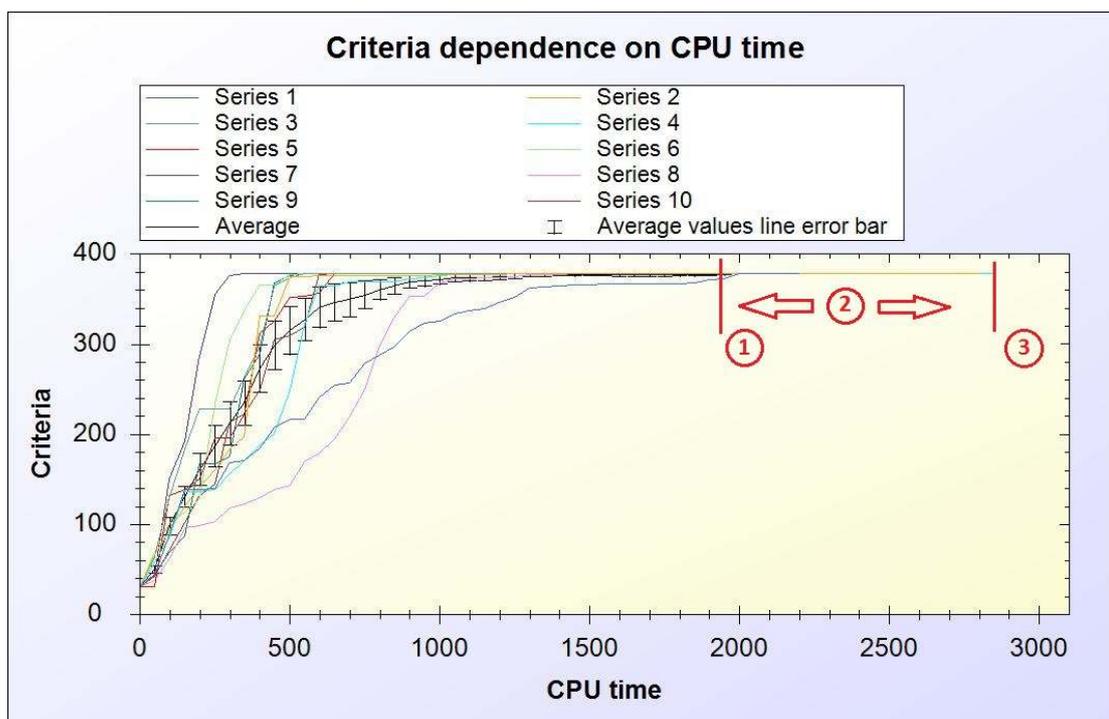


Fig. 3. Consensus case when all the ten optimization runs have reached the consensus range

Consensus case when all the five (Fig. 2) and all the ten (Fig. 3) optimization runs have reached the consensus range (1 – best values of all runs lie within 3% consensus range; 2 – preset consensus delay time (15min or 900s); 3 – all optimization auto stop after reaching consensus and passing the consensus delay time). Error bars represent standard deviation.

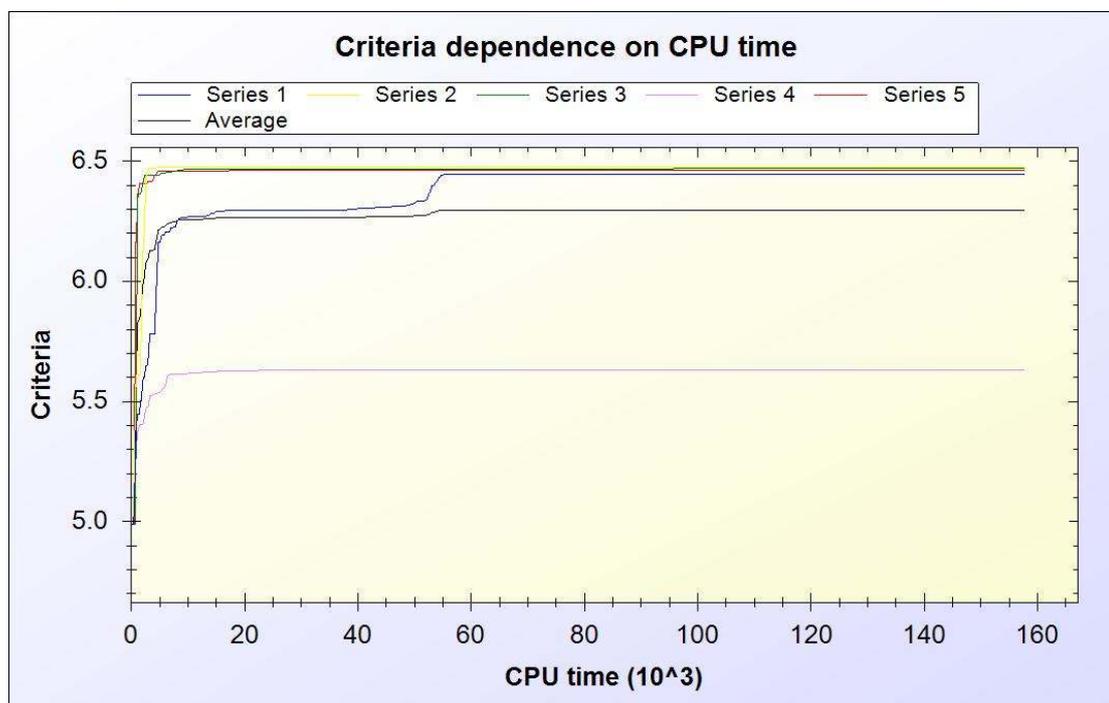


Fig. 4. Stagnation example when different optimization runs stagnate at different values long time

Conclusion

Optimization based design tasks of dynamic models of biochemical networks mainly are solved using global stochastic optimization methods which can deliver relatively quick improvement of the objective function in short time but it cannot guarantee finding of optimal solution.

Application of number of parallel optimization runs is proposed to shorten the optimization time and detect failure of optimization method. A software CoRunner is developed to apply this method automatically

collaborating with software COPASI for automation of optimization procedure. In case of necessity the dynamics of parallel optimization runs can be visualized with software ConvAn for detailed analysis of optimization performance.

Suitability of optimization method for particular model and optimization task setting can be confirmed in case of convergence of all optimization runs to a consensus value. Stagnation of at least one optimization run indicates that method is not well suited for particular task.

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EVOLUTION OF ALTERNATIVE CONTROL LOOPS OF BIOLOGICAL SYSTEMS

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Abstract: *Biological systems are complex, difficult, open, nonlinear and self-regulated, self-organized living systems. Such systems are known to be considerably robust to environmental changes and genetic perturbations. It is possible due observed property called robustness. Robustness is a fundamental feature of complex systems that allows them to maintain its functions despite external and internal perturbations. The main mechanism that ensures the robustness of a system is a system control that consists of negative and positive feedback. Presence of feedback is the important party of control in biological systems. The deviations of object from the target state by the means of feedback loops form the control action which brings the system back to the target state. A complete understanding of network robustness and their evolution requires that the biochemical network topological singularities, functional and dynamic changes that are caused by perturbations, are explored. For achievement this issue computational modeling is required. In this manuscript we explore scientific literature with a goal to characterize the robustness and the prime system control mechanism (feedback mechanism) that ensure it, to indicate and analyze existing network growth models of their evolution.*

Keywords: biological systems, robustness, feedback, biochemical network, network structure, network growth models, Boolean network model, modeling of evolution, systems biology.

Introduction

Biological systems are complex, difficult, open, nonlinear and, in some cases, independent living systems such as cell, animal and human. They have requirements, purposes and aspiration to satisfy them, and facilities to choose and change the behaviour depending on circumstances or conditions (see Fig.1.). Since long time many researchers aim to find the methods how to control biological system. In most cases the main goal of control is to cope with the illnesses and complex diseases or industrial biotechnology tasks (for example, reception of the maximum quantity of ethanol).

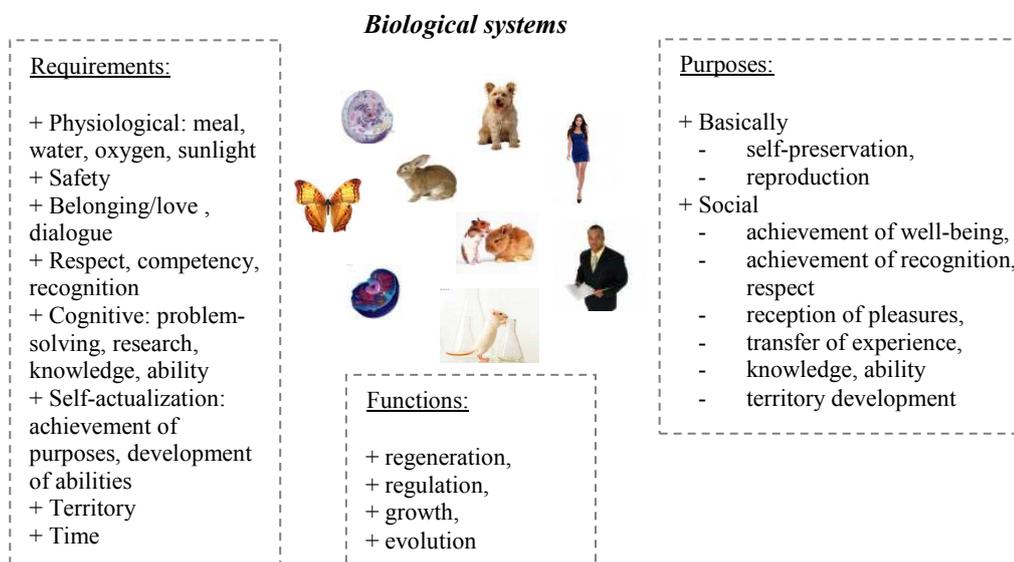


Fig.1. Requirements of biological systems.

Defining all possible requirements of biological systems that are mentioned on figure, in attention Maslow's hierarchy of human needs (Maslow, 1943) has been accepted.

From the social viewpoint it is much easier to induce on action the biological system by influence on behaviour and consciousness. For example, the main task in this case is not to admit the disease and to carry out preventive actions. Le Chatelier's principle (Kay, 2000) means that if to have possibility to change internal and external environment of the biological system these actions will provoke its some behavior directed on elimination of undesirable influence or on preservation if the influence is desirable.

From the biological viewpoint it is much more difficult while the biological systems have a set of many states, are self-organized and are known to be considerably robust (Kwon et al., 2007, Kitano, 2004, Barabasi et al., 2004) to environmental changes. In this case the main task of control is first, to understand the basically building, underlying and existence principles of biological system, and second, to learn to “switch” and maintain the system in necessary state.

Biological systems are self-organized systems as operating factors of such system arise in her. Therefore control in biological systems is self-control, regulation processes – self-regulation processes.

Control is process of system streamlining according to changes in the external and internal environment for the purpose of counteraction to disorganization factors. This process is carried out by means of the elements which are a part of the system. Control is function of the organized systems, providing performance of following tasks:

- preservation of certain system structure;
- maintenance of a mode of system activity;
- realization of the purpose of system activity by a certain rule (algorithm).

These control tasks dare by means of regulation. Regulation is directed on maintenance homeostasis, caused by ability of biological systems to develop reactions in reply to changes of environment parameters which exclude or reduce to a minimum the consequences of these changes. Regulation is function of the operating systems, providing performance of following tasks:

- maintenance of a constancy of adjustable size at some certain level;
- change of adjustable variable under the set law (program regulation);
- change of adjustable size according to a course of some external process (watching regulation) (USTUA, 2002).

The important party of control in biological systems is presence of feedback. Without feedback self-control and self-regulation processes are impossible (USTUA, 2002). Feedback and biological regulation are two sides of the same coin, reflecting the need of the biological system - particularly living cell - to deal with changing environments, to generate cell to cell heterogeneity and to optimize cellular metabolism to a given external condition (Krishna et al., 2007).

Robustness and feedback

Many complex systems are known to be considerably robust to environmental changes (Kwon et al., 2007, Kitano, 2004, Barabasi et al., 2004). It is a key feature of system, which refers to the system’s ability to respond to changes in the external conditions or internal organization while maintaining relatively normal behavior (Barabasi et al., 2004).

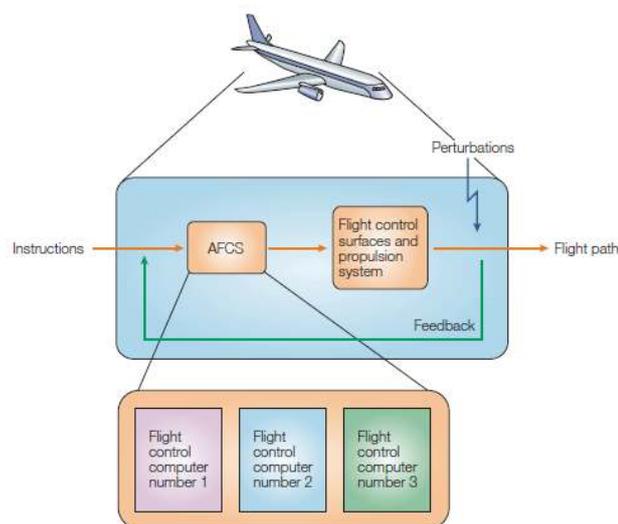


Fig.2. Airplane as robustness explanation example.
(Kitano, 2004)

The commercial passenger airplane (see Fig.2.) is one of the best examples that describe the concept of robustness. Many modern airplanes have an automatic flight control system (AFCS) that maintains a flight path (direction, altitude and velocity of flight) against perturbations in atmospheric conditions. This can be accomplished by a feedback control in which deviations from the defined flight path are automatically corrected. AFCS is the crucial component that allows the robust maintenance of the flight path by controlling the airplane’s flight-control surfaces (rudder, elevator, flaps, aileron, etc) and the propulsion system (engines). AFCS is generally composed of three modules with the same functions, thereby creating redundancy, although each is designed differently (heterogeneity) to avoid a common mode failure. Three computers are modular, so that

failure in one module does not affect the functions of other parts of the system. This type of mechanism is implemented using digital technologies that decouple low-level voltages from digital signal (ON/OFF of pulses), thereby preventing noise from influencing its functions. Although this is a simplified explanation of the actual system, the concept applies to details of the basic system as much as it does to the more complex systems. Although there are differences between man-made systems and biological systems, the similarities are overwhelming. Fundamentally, robustness is the basic organizational principle of evolving dynamic systems, be it through evolution, competition, a market niche or society (Kitano, 2004).

As argue Kitano, robustness is a ubiquitously observed property of biological systems and fundamental feature of complex systems that allows a system to maintain its functions despite external and internal perturbations, to be evolvable against environmental and genetic perturbations. This is a phenomenon that cannot be understood by looking at the individual components (Kitano, 2004). Robustness is attained by several underlying principles that are universal to both biological organisms and sophisticated engineering systems. There are trades-offs between robustness, fragility, resources demands and performance which explain system behavior, including patterns of failure, and provide a possible framework for how biological systems have evolved and been organized (Kitano, 2004). Kitano note, that in some cases, such as cancer, disease state establishes its own robustness against therapeutic interventions. Understanding robustness and its intrinsic properties will provide a more profound understanding of biological systems, their anomalies, complex diseases, countermeasures and a guiding's principles for therapy design (Kitano, 2004).

The mechanisms that ensure the robustness of a system are: *system control*, *alternative (or fail-safe) mechanisms*, *modularity* and *decoupling*, but these mechanisms need to be organized into coherent architecture to be effective at the level of the organism. The prime mechanism for coping with environmental perturbations is the *system control* that consists of *negative* and *positive feedback* to attain a robust dynamic response and many biological subsystems use the combinations of these systems control (Kitano, 2004).

The principle of feedback is one of main principles of self-control and self-organizing of biological systems. By means of feedback deviations of object from the set condition (state) form operating influences which result an object condition (state) in the set. Feedback is a return influence of process results on its course (USTUA, 2002). From the viewpoint of network structure feedback is organized on *feedback loops*. Feedback loop is closed simple cycle (Kwon et al., 2007, Barabasi et al, 2004) of any length (Hallinan et al., 2006) with the set of nodes where the nodes are not revisited except the starting and ending nodes (see Fig.3.).

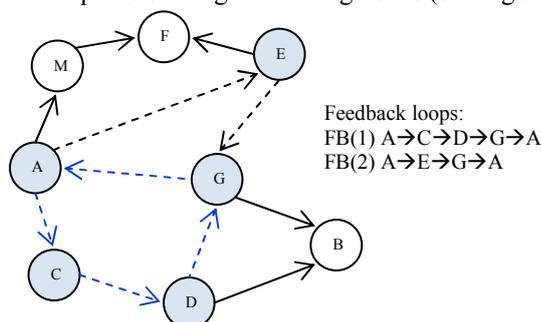


Fig.3. **Feedback loop.**
(Rubina et al., 2010)

Negative feedback. Negative feedback promotes restoration of an initial condition of system. They provide stability of system functions, their stability to external influences and are the basic mechanism of energetic and metabolic balance in biological systems, control of population's number, self-control of evolutionary process (USTUA, 2002). Systems involving negative feedback loops tend to settle to a steady state, which may be stable or unstable (Hallinan et al., 2005).

Positive feedback. Positive feedback by means of process results strengthens it. Positive feedback with draws system all further from an initial condition and strengthen the processes of ability to live. They play a special role for growth and development. On the basis of positive feedback mechanisms self-organizing at all levels begins. In a consequence on positive feedback mechanisms then imposes restrictions of negative feedback (USTUA, 2002). Positive feedback loops promote multistationarity. It is the existence of a number of different stable states. For example, multistationarity is fundamental to the development of bistable switches in regulatory networks, in which there are two stable states, between which the system can be moved by an external stimulus. Bistable switches are essentially a memory for the cell, since the state in which it finds itself is dependent upon the history of the system (Hallinan et al., 2005).

Positive feedback contributes to robustness by amplifying the stimuli, often producing bistability, so that the activation level of a downstream pathway can be clearly distinguished from non-stimulated states, and so that these states can be maintained (Kitano, 2004).

The most studied examples of robust adaptation is the bacterial chemotaxis. It uses negative feedback to attain the perfect adaptation that allows chemotaxis to occur in response to a wide range of stimuli even if network topologies are not the same. Krishna with colleagues indicates that a key part of overall system of molecular regulation is the interface between the genetic and the metabolic network. A motif that occurs very often at this interface is a negative feedback loop used to regulate the level of the signal molecules (Krishna et al., 2007). Feedback controls sometimes compensate for changes in rate constants of interactions within the network and changes in the initial state of the network. A computational study of the cell cycle demonstrated that removing some genes does not necessarily block the cell cycle; it might only make it more fragile against perturbations (Kitano, 2004).

Robustness and alternative control loops

Kwon and colleagues have verified hypothesis on the relationship between feedback loops and the robustness of a network by employing Boolean network models. They have examined robustness with respect to the initial state mutations, update rule mutations, and the number of coupled feedback loops (see Fig.4.) of a network during evolution. They found that there is a strong positive correlation between the number of coupled feedback loops and the robustness of a network. Their simulations showed that the networks involved by preferential attachment (by preferential attachment a node is more likely to connect to a node with a high degree) are more robust and produce more coupled feedback loops (Kim et al., 2008) than the random networks. For example, it was found that three distinct feedback loops responsible for genetic regulation, mRNA attenuation, and enzyme inhibition that regulate tryptophan concentrations in *Escherichia coli*. The complex regulatory network formed by the feedback loops induces a rapid and stable response, while being robust against uncertainties (Venkatesh et al, 2004, Kwon et al., 2007).

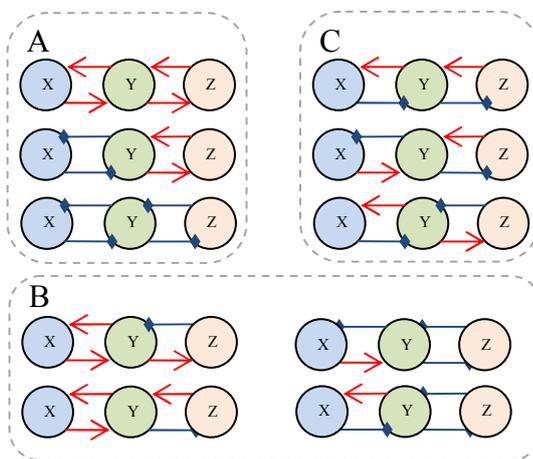


Fig.4. Network motifs of coupled feedback loops.

(A) Positive-Positive structures. (B) Positive-Negative structures. (C) Negative-Negative structures. (Kim et al., 2008).

Robustness can be enhanced if there are multiple means to achieve a specific function, because failure of one of them can be rescued by others by *alternative (or fail-safe) mechanisms*. The existence of alternative mechanisms at the system-component level allows regulatory feedback to remain intact despite mutations. It is usually attained by having multiple heterogeneous components and modules with overlapping functions. This concept encompasses redundancy, overlapping function and diversity, as the differing degrees of similarity between the various alternative means that are available. Redundancy generally refers to a situation in which several identical, or similar, components (or modules) can replace each other when another component fails. Diversity, or heterogeneity, represents the other extreme, whereby a specific function can be attained by different means available in a population of heterogeneous components (Kitano 2004).

A complete understanding of network robustness requires that the functional and dynamic changes that are caused by perturbations are explored. In a cellular network, each node has a slightly different cellular function and therefore the effect of a perturbation cannot depend on the node's degree only. The activity of the various metabolic reactions or regulatory interactions differs widely; some are highly active under most growth conditions, other switch on only under environmental circumstances. Therefore, an ultimate description of cellular networks requires that both the intensity (strength) and the temporal aspects of the interactions are considered. As Barabasi with colleagues have note and indicate that there are hot links in metabolic and genetic networks, in many non-biological networks to, and their activity following a wide distribution. For example, the biochemical activity in both the metabolic and genetic networks is dominated by several "hot links" that represent high activity interactions that are embedded into web of less active interactions (Barabasi et al., 2004).

To explore biochemical networks computational network models, these modeling, simulation and analysis are needed.

Alternatives in networks and evolution

Biological systems components and their interaction can be present in network form. From the viewpoint of biochemical network architecture, main ingredients of biological system are molecules, interactions, pathways and networks. A biological system can be viewed to be formed conceptually from individual molecules, to pairwise interactions, to local structures (including network motifs, molecules, pathways, subnetworks) and eventually to global biomolecular networks (Zhang, 2009). Biomolecular networks allow visualizing and describing of intracellular molecular interactions of cellular system by using available metabolic and gene regulation experimental data (Zhang, 2009), as well as representation of many biochemical processes such as metabolism, gene regulation, signal transduction (Zhenjun et al, 2005).

There is a growing interest in understanding the principles of biochemical network evolution, such as protein-protein interaction, signaling, metabolic, gene regulatory networks, and many network growth models have been proposed to investigate this issue (Kwon et al., 2007). Meanwhile, there have been various studies on the topological properties of biochemical networks, and one prominent result is about the scale-free property (Barabasi et al., 2004, Kwon et al., 2007). The main singularity of scale-free networks is that most number of their nodes has only a few links, but few nodes called hubs have a very large number of links. In this regard, finding a network growth model that can produce a scale-free network has become an issue (Kwon et al., 2007). Network of different types can be distinguished by their degree distributions. Scale-free network has a power-law degree distribution, $P(k) \sim k^{-\gamma}$, indicating that a few hubs (highly connected nodes) bind numerous small nodes, while they are playing a significant role in the network. The structure and dynamics of these networks are independent of the network size as measured by the number of nodes. For example, protein-protein interaction networks have the features of a scale-free network, while most proteins participate in only a few interactions, while a small set of hubs participate in dozens of interactions. This type of network has a characteristic property known as the “small-world effect”, which states that any two nodes can be connected via short path of a few links. Although the small-world effect is a property of random networks such as internet, scientific collaboration networks, metabolic networks, the path length in scale-free networks is much shorter than that predicted by the small-world effect. Therefore, scale-free networks are “ultra-small” (Zhang, 2009).

At most cases, biochemical networks are scale-free. Barabasi with colleagues (Barabasi et al., 2004) exploring scale-free networks have indicated two types of network robustness: topological robustness and functional and dynamical (Alon et al., 1999) robustness. Similar to both robustness types are selective: whereas some important parameters remain unchanged under perturbations, others vary widely. For example, scale-free networks do not have a critical threshold for disintegration – they are amazingly robust against accidental failure (Albert et al., 2000, Vázquez et al., 2003): even if 80% of randomly selected nodes fail, the remaining 20% still form a compact cluster with a path connecting any two nodes. This is because random failure affects mainly the numerous small degree nodes, the absence of which doesn't disrupt the network integrity (Albert et al., 2000). The second example is the adaptation time or steady-state behavior in chemotaxis show strong variations in response to changes in protein concentrations (Barabasi et al., 2004, Alon et al., 1999).

For the last century and years have been created many network growth models such as random growing models, duplication-mutation models, random static network models, aging vertex network models, small-world network models, random Boolean network models, mathematical models by using differential equations. We can call them of network evolution models or network evolutionary models. All this called network models are related to the scale-free networks, except small-world network model and tie basic algorithms of network growth to a real biological basis, naturally reproducing the scale-free network architecture. Such network is more robust to random failure. This is because random failure affects mainly the numerous small degree nodes, the absence of which doesn't disrupt the network integrity (Albert et al., 2000).

All this network models are created to reconstruct and explore biochemical networks *in silico* on theoretical underground with a goal to establish and identify different network properties and singularities, to interpret the received results concerning real systems and if it is possible to test and convinced *in vivo*.

The duplication-mutation models suggest that network growth occurs through the duplication of an existing node and mutation of links by deleting an existing link or adding a new link running the growth procedure many times (Vázquez et al., 2003, Sole et al., 2002, Kwon et al., 2007). This model leaves aside many finer details of the genetic evolution that lies behind the duplication and divergence process (Vázquez et al., 2003).

Vázquez et al. have translated the evolution of the Protein Interaction Networks into a growing network model. The model aims only to capture the most basic factors affecting the topological evolution of the network. It can be consider each node of the network as the protein expressed by a gene. After gene duplication, both expressed proteins will have the same interactions. This corresponds to the addition of a new node in the network with links pointing to the neighbors of its ancestor. Eventually, some of the common links will be removed because of the divergence process. Vázquez et al. have formalized this process by defining an evolving network in which, at each time step, a node is added according to the duplication and divergence rules by using parameters p and q . In

this model, each node in the network represents a protein that is expressed by a gene, and the network grows as follows. At each time step, one selects a random node – call it node i – and carries out two steps in sequence. First step includes duplication. In association with node i , a new node i' enters the network and is linked to the same nodes to which i is linked. This reflects the idea that the new protein, the result of duplication, is identical to the old protein; hence, it interacts with other proteins in the very same way. Also, with some probability p , a link is added between i and i' to account for the possibility that these two (identical) proteins also interact. At the next step comes divergence. Mutations in the genes associated with i and i' will gradually produce differences in these proteins, altering their interactions. The model accounts for this divergence by considering in turn all the proteins j to which i and i' are linked, selecting one of these at random, and removing it with probability q (Vázquez et al., 2003).

In the random growing models network growth occurs through the adding of new node and random k links to it where k is the initial number of neighbors of incoming node. In a random static network models a new node is added and new undirected link is randomly added with probability δ between two uniformly at random chosen vertices (Callaway et al., 2001, Kwon et al., 2007). This process is repeated by many time steps. Callaway et al. have concluded that grown graphs, however randomly they are constructed, are fundamentally different from their static random graph counterparts. These dramatic differences between grown and static random graphs stem from a positive correlation between the degrees of connected vertices in the grown graph - older vertices tend to have higher degree, and to link with other high-degree vertices, merely by virtue of their age (Callaway et al., 2001).

Aging vertex network model based on a finite memory of the nodes (Klemm et al., 2002). In aging vertex network models the probability of producing new edges decrease with the age of network node (Kwon et al., 2007).

The small-world network models based on an interpretation between regular ring lattices and randomly connected graphs (Watts et al., 1998, Kwon et al., 2007). In this model each edge with probability q is deleted and a new edge is added for a random node.

Boolean network model (Kaufmann, 1969, Shmulevich et al., 2002, Shmulevich et al., 2002, Chaves et al., 2005, Steggle et al., 2006, Paszek, 2007, Morris et al., 2010) is a popular type of network models. They consist $G(V, F)$ of a set of nodes $V=(x_1, x_2, \dots, x_n)$, directed links between them and of a list of Boolean functions $F=(f_1, f_2, \dots, f_n)$. In boolean models each variable $x_i \in \{0, 1\}$, $i=1, 2, \dots, n$ can only attain two values (0/1 or on/off). For example, these values represent whether a gene is being expressed, or the concentration of a protein is above a certain threshold, at time t (Sontag et al., 2007). The nodes are assumed to have binary activation, being either on or off at any given time step (Hallinan et al., 2005). Each directed edge can be characterized as either an inhibition or an activation (Sontag et al., 2007). The behavior of each network node x_i is described by Boolean function f_i based on its inputs.

Above mentioned models for a network growth basis take only two types of mutations – gene duplication (whole genome duplication, locally confined gene duplication, retrotransposition) and loss (Yamada et al., 2009), which are the most important drivers of network evolution. Gene duplication implies the addition of a network node and also the addition of links. With the loss of a gene not only the node but also all associated links are lost. But there are many other types of genetic mutations that can influence the process of network evolution. They do not modify a gene as whole, but modify a gene or its regulation in a way that results in link addition or loss. These genetic changes can be point mutations, insertions or deletions, or mutations that affect the regulation of the gene (Yamada et al., 2009). As Yamada with colleague note by investigating metabolic and protein interaction networks the evolution of network nodes and links is coupled to the genetic material of a cell, but the links can change over time even if nodes are unaffected, the rewiring of links can occur without gene duplication and link changes might occur more frequently than node changes. There are plenty of genetic mechanisms that can easily lead to the link addition or deletion. Apart from point of mutations, alternative splicing and domain accretion, inversion, shuffling and duplication are other means for the fast acquisition or loss of links. But the quantification of link changes remains difficult, while requires sufficient network data in several species, which are slowly emerging, whereas network nodes can be studied just by genome comparison. Combinations of these can even occur, whereby forming the link is under positive selection (Yamada et al., 2009).

Conclusion

The prime singularity and phenomena of biological systems is their robustness that allows a system to maintain its functions despite external and internal perturbations, to be evolvable against environmental and genetic perturbations.

The prime mechanism for coping with environmental perturbations is the *system control* that consists of *negative* and *positive feedback* to attain a robust dynamic response and many biological subsystems use the combinations of these systems control (Kitano, 2004). Negative feedback promote restoration of an initial condition of system, but positive - withdraws system all further from an initial condition and strengthen the processes of ability to live (USTUA, 2002). Positive feedback loops promote multistationarity; that is the existence of a number of different

stable states. Several authors believe that the analysis of network feedback loops is not just the best but the only way in which complex networks can be analyzed (Hallinan et al., 2005).

There exist many different models, which researchers can use for modeling and exploring of biochemical networks. The popular type of network growth models is Boolean network model.

The basis of every model is the structure of examined biochemical network. It means that every model first of all is structural model. Structural model characterize and provide information of the connectivity (topology) of the interactions involved in a cellular process that described biochemical network. Identifying topological features in networks such as node degree, degree distribution, feedback loops is an important part of understanding the relationship between network structure and functions of their subunits.

Structural analysis of biochemical networks contributes to a deeper understanding of network-wide interdependencies, causal relationships, and basic functional capabilities. Some insights into the dynamic properties can nevertheless often be obtained, because fundamental properties of the dynamic behavior are often governed by the network structure (Klamt et al, 2006).

Development of alternative control loops during evolution of biological networks is one of the necessary preconditions of robustness of biological systems.

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FEATURE SELECTION FOR BIOINFORMATICS DATA SETS – IS IT RECOMMENDED?

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Abstract: *This article studies the impact of feature selection methods on the results of bioinformatics data classification. The success of data preparation using preprocessing techniques determines the positive result of classification. The bioinformatics data have a specific property – they have a large number of attributes (up to tens of thousands) and a comparably small number of records (few hundred or less). Thereby the attribute selection can increase the speed of classification results computation without losing in accuracy.*

This study examines A Fast Correlation-based Filter Solution that is especially suited for data of high dimensionality as the data used in bioinformatics. This approach is compared with various other attribute selection methods to validate its suitability. The article also investigates the changes of the classification results appearing when the feature selection is applied compared to the results obtained with the full data sets. The data sets used in the experiments are real biomedical cancer data sets provided by Latvian Biomedical Study and Research Center holding information about breast cancer, prostate cancer, gastric cancer, gastric intestinal disease and healthy donor samples and other eighteen popular and in literature used data sets. The experiments implement three classification algorithms – Fuzzy Unordered Rule induction algorithm, JRIP and RIDOR algorithms, which induce rules in If-Then form. To interpret the classification results more accurately, the experiments were executed using data sets that are often used in popular researches worldwide. The article ends with conclusions and the answer to the question whether attribute selection is recommended for bioinformatics data sets.

Keywords: classification, bioinformatics data, feature selection

Introduction

Bioinformatics data have their own specifics – a very large number of attributes and a small number of records. This makes working with classification algorithms to induce classification rules a very resource intensive process, because an algorithm has to be trained on a very large and complex data set. To decrease the number of attributes, feature selection techniques are used. They select only the attributes that are relevant for classification. This study assesses, whether this type of methods have perspective use in these particular complex, multidimensional data like bioinformatics data. This article uses 22 bioinformatics data sets – 18 used in literature, publicly available sets and 4 presented by Latvian Biomedical Research and Study Centre that were obtained in LATVIA – BELORUS Co-operation programme in Science and Engineering within the project «Development of a complex of intelligent methods and medical and biological data processing algorithms for oncology disease diagnostics improvement». Feature selection uses a perspective method intended for data with high dimensionality called Fast Correlation Based Filter solution (Yu and Liu, 2003). Three other feature subspace search methods that are available in *Weka* library are used for comparison – Linear Forward Selection, Greedy Stepwise Selection and Genetic Search that are combined with corresponding evaluation methods – Symmetrical Uncertainty Attribute Set Evaluation (used with Fast Correlation Based Filter search) and Consistency Subset Evaluation (with Linear Forward Selection, Genetic Search and Greedy Stepwise Selection). To compare the results of feature selection techniques, three If-Then rule-based classification algorithms were used: RIDOR (Brian, 1995), JRIP (Cohen, 1995) and FURIA (Hühn, 2009). The results were analyzed to find an answer to a question – is the use of feature selection techniques recommended for bioinformatics data sets. Feature selection strengths are the following: they help to avoid overfitting and improve model performance; provide faster and more cost-effective models and allow gaining a deeper insight into the underlying processes that generated the data (Saeys, 2007). Feature selection techniques differ from each other in the way they incorporate search in the added space of feature subsets in the model selection. In the classical context, feature selection techniques can be divided into three categories based on the way search and classification model are connected: filter methods, wrapper methods and embedded methods (Saeys, 2007). Filter techniques assess the relevance of features by looking only at the intrinsic properties of the data. Wrapper methods embed the model hypothesis search within the feature subset search. In embedded technologies, the search for an optimal subset of features is built into the classifier construction (Saeys, 2007). This study continues the previous research of the authors concerning the use of FURIA algorithm for the analysis of bioinformatics data (Gasparovica, 2011b) and the influence of membership functions on the processing of multidimensional data (Gasparovica, 2011a).

Materials and methods

1. Feature selection methods

A fast correlation-based filter (FCBF) was created in 2003 (Yu and Liu, 2003), it is available in *Weka* library and is meant for data with high dimensionality. This technique can effectively remove both irrelevant and redundant features and is less costly in computation than other algorithms. It is based on predominant correlation and relies on characteristics of the training data to select features without involving any learning algorithm. That is also the reason it does not involve resource-costly computations and is efficient for large data sets.

Fast Correlation Based Filter algorithm consists of two parts. In the first part it calculates the symmetrical uncertainty value for each feature, selects relevant features into the subset of relevant features based on the predefined threshold, and orders them in descending order according to their symmetrical uncertainty values.

In the second part, it further processes the ordered subset of relevant features to remove redundant features and only keeps predominant ones among all the selected relevant features.

<pre> input: S(F_1, F_2, \dots, F_n, C) // a training data set δ // a predefined threshold output: S_{best} // an optimal subset begin for $i=1$ to N do begin calculate $SU_{i,c}$ for F_i; if ($SU_{i,c} \geq \delta$) append F_i to S_{list}; end; order S_{list} in descending $SU_{i,c}$ value; $F_p = \text{getFirstElement}(S_{list})$; do begin $F_q = \text{getNextElement}(S_{list}, F_p)$; </pre>	<pre> if ($F_q \neq \text{NULL}$) do begin $F_q = F_q$; if ($SU_{p,q} \geq SU_{q,c}$) remove F_q from S_{list}; $F_q = \text{getNextElement}(S_{list}, F_q)$; else $F_q = \text{getNextElement}(S_{list}, F_q)$; end until ($F_q == \text{NULL}$); $F_p = \text{getNextElement}(S_{list}, F_p)$; end until ($F_q == \text{NULL}$); $S_{best} = S_{list}$; end; </pre>
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Fig. 2. **FCBF algorithm** (Yu and Liu, 2003)

Comparative evaluation is implemented using another three searching methods available in *Weka* software – Linear Forward Selection, Greedy Stepwise and Genetic Search, which were combined with the corresponding evaluation methods – Symmetrical Uncertainty Attribute Set Evaluation (with Fast Correlation Based Filter search), Consistency Subset Evaluation (with Linear Forward Selection, Genetic Search and Greedy Stepwise).

2. Classification methods

2.1. RIDOR

Ripple-Down Rule learner (Brian, 1995) generates a default rule; then it finds exceptions for the default rule with the least (weighted) error rate and iteratively progresses with exception search for each exception until the corresponding subsets are pure. The exceptions are a set of rules that predict classes other than the default; they form a tree-like structure. The exceptions are generated using IREP.

2.2. JRIP

This is a version of RIPPER (Repeated Incremental Pruning to Produce Error Reduction) algorithm in *Weka* (Hall, 2009). RIPPER was proposed in 1995 as an improvement to IREP algorithm by Cohen (Cohen, 1995). While working on the improvements (a new metric for guiding its pruning phase; technique for rule optimization and a new stopping condition) Cohen identified the problems of previously used rule induction algorithms – inability to effectively analyze data with high dimensionality and noise.

This algorithm is based on rule induction with reduced error pruning (REP), a very common and effective technique used in decision tree algorithms. In REP that is used for rule induction algorithms, the training data is split into a growing set and a pruning set. First, an initial rule set is formed that overfits the growing set. This large rule set is then repeatedly simplified by applying one of pruning operators (like deleting any single condition or any single rule). At each stage of simplification, an operation is chosen that yields the greatest reduction of error on a separate pruning set. Pruning ends when the application of any pruning operator increases error on the pruning set. The experiments implement the version of RIPPER, JRIP that is included into *Weka* library; a scheme of the algorithm is shown below.

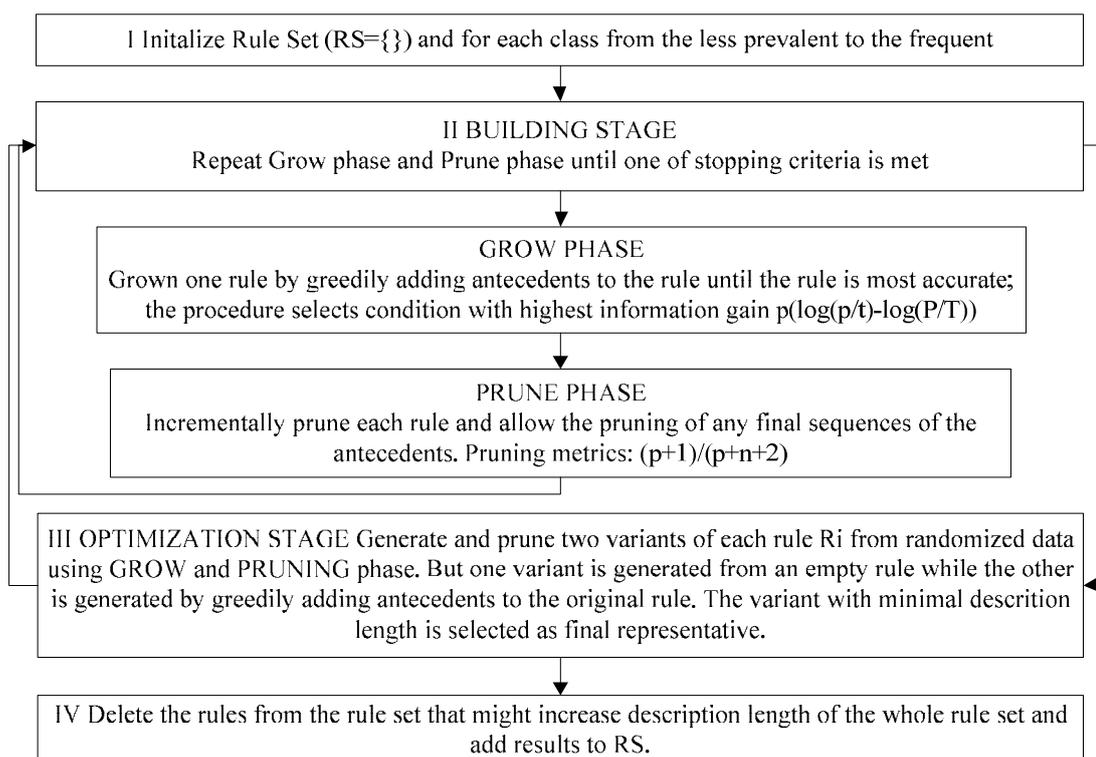


Fig. 3. JRIP algorithm

2.3. FURIA

This algorithm was proposed by Hühn and Hüllermeier in 2009 (Hühn, 2009). It is an improvement of the RIPPER algorithm (Cohen, 1995) that uses a modified RIPPER algorithm as a basis. A simplified scheme is shown in Fig. 4. FURIA learns fuzzy rules and unordered rule set. The algorithm induces rules for each class separately using the “one class – other classes” dividing strategy.

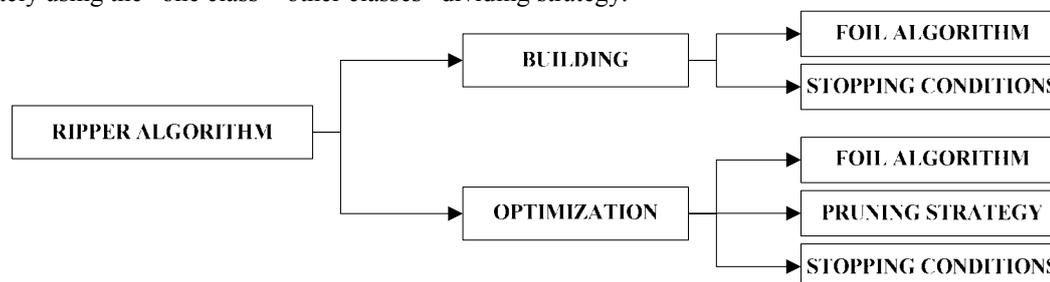


Fig. 4. FURIA (modified RIPPER algorithm)

When the classifier is trained using one class, other classes are not considered. This helps to achieve a state when there is not one main rule and the sequence of classes in the training process is irrelevant. However, this approach also has its shortcomings – if a record is equally covered by rules of two classes, certainty factor has to be calculated. The main improvements of the RIPPER algorithm affect pruning modifications (see Fig. 4, building phase). However, the main strength of this algorithm is the rule stretching method solving the pressing problem that new records that should be classified could be outside the space covered by the previously induced rules. The representation of fuzzy rules is also advanced; essentially, a fuzzy rule is obtained through replacing intervals by fuzzy intervals, namely fuzzy sets with trapezoidal membership function.

3. Prediction accuracy

Classification is the allocation of objects to predefined groups. It can be generally divided into three steps – training, testing and classification of new data. Training data serves to build a classification model that is afterwards tested and can later be used to classify new data. In this study the classification (prediction) accuracy is the accuracy of the obtained If-Then classification rules to assign the correct class to a new record that has not been included into training set. The accuracy is measured using the confusion matrix, that is an $n \times n$ matrix where n is the number of classes. The columns represent the class labels allocated by classifier and the rows correspond to the actual classes. The confusion matrix for two-class problem is shown in Table 1.

Table 1

		Predicted class	
		Yes	No
Actual class	Yes	$f_{++} (TP)$	$f_{+-} (FN)$
	No	$f_{-+} (FP)$	$f_{--} (TN)$
Overall accuracy		$AC = \frac{TP + TN}{TP + FN + FP + TN}$	
Overall classification error		$ER = 1 - AC$	

The matrix is filled with classification results – either correct or misclassified according to classes. The true positive rate (TP) shoe the number of the positive records that were classified as positive, the false negative rate (FN) shows the number of positive records that were misclassified (assigned the negative label), the false positive rate (FP) shows the number of negative records that were misclassified (assigned the positive label), the true negative (TN) rate shows the number of negative records that were classified correctly (assigned the negative label). To assess the accuracy of the obtained classifier, the overall accuracy (AC) is used (see Table 1). It can be calculated by dividing the number of correctly classified records by the number of records in the used test data set. Similarly the overall classification error(ER) can be calculated as presented in Table 1 (Tan et al., 2006).

4. Used data sets

The study uses 22 data sets – 18 popular data sets mentioned in literature (see Table 2): DLBCL data set (Shipp et al., 2002) - diffuse large B-cell lymphomas (DLBCL) and follicular lymphomas (FL); GSE412 - childhood acute lymphoblastic leukemia data set (Cheok et al., 2003); GSE2191 - acute myeloid leukemia prognosis after treatment (Yagi et al., 2003); GSE349_350 - breast cancer treatment response (Chang et al., 2003); GSE3726 - breast & colon cancer gene expressions (Chowdary et al., 2006); GSE89 - bladder cancer gene expressions, (Dyrskjot et al., 2003).

Table 2

Used data sets			
Name	Diagnostic classes	Number of genes	Number of samples
DLBCL	Diffuse large B-cell lymphoma (DLBCL): 58 ex.	7070	77
	Follicular lymphoma (FL): 19 ex.		
GSE412 (childhood ALL data set)	Before therapy (before Th): 50 ex.	8280	110
	After therapy (after Th): 60 ex.		
GSE412 (childhood ALL data set)	Mercaptopurine alone (MP): 13 ex.	8280	60
	High-dose methotrexate (HDMTX): 21 ex.		
	Mercaptopurine and low - dose methotrexate (LDMTX_MP): 16 ex.		
	Mercaptopurine and high - dose methotrexate (HDMTX_MP): 10 ex.		
GSE2191 (AML prognosis)	Remission (remission): 28 ex.	12625	54
	Relapse (relapse): 26 ex.		
GSE349_350 (Breast cancer)	Resistant to docetaxel treatment (resistant): 14 ex.	12625	24
	Sensitive to docetaxel treatment (sensitive): 10 ex.		
GSE3726 (breast & colon cancer)	Breast cancer (breast): 31 ex.	22283	52
	Colon cancer (colon): 21 ex.		
GSE89 (bladder cancer)	Tumor stage T2-T4 (T2+): 10 ex.	5724	40
	Tumor stage Ta (Ta): 19 ex.		
	Tumor stage T1 (T1): 11 ex.		
GSE2535 (CML treatment)	Non-responder to imatinib treatment (Non-Responder):	12625	28
	Responder to imatinib treatment (Responder): 16 ex.		
GSE967 (childhood	Ewing's sarcoma (EWS): 11 ex.	9945	23

Name	Diagnostic classes	Number of genes	Number of samples
tumors)	Rhabdomyosarcoma (RMS): 12 ex.		
GSE967 (childhood tumors)	Ewing's sarcoma (EWS): 11 ex.	9945	23
	Embryonal rhabdomyosarcoma (eRMS): 3 ex.		
	Alveolar rhabdomyosarcoma (aRMS): 9 ex.		
GSE2685 (gastric cancer)	Normal gastric tissue (Normal): 8 ex.	4522	30
	Diffuse gastric tumor (Diffuse): 5 ex.		
	Intestinal gastric tumor (Intestinal): 17 ex.		
GSE2685 (gastric cancer)	Normal gastric tissue (Normal): 8 ex.	4522	30
	Advanced gastric cancer tissue (Tumor): 22 ex.		
GSE1577 (lymphoma & leukemia)	T-cell lymphoblastic lymphoma (T-LL): 9 ex.	15434	19
	T-cell acute lymphoblastic leukemia (T-ALL): 10 ex.		
GSE1577 (lymphoma & leukemia)	T-cell lymphoblastic lymphoma (T-LL): 9 ex.	15434	29
	T-cell acute lymphoblastic leukemia (T-ALL): 10 ex.		
	B-cell acute lymphoblastic leukemia (B-ALL): 10 ex.		
GSE1987 (lung cancer)	Squamous cell carcinoma (Squamous): 17 ex.	10541	34
	Adenocarcinoma (Adenocarcinoma): 8 ex.		
	Normal lung tissue (Normal): 9 ex.		
GSE468 (medulloblastoma)	Metastatic medulloblastoma (Met): 10 ex.	1465	23
	Non-metastatic medulloblastoma (NonMet): 13 ex.		
GSE2443 (prostate cancer)	Androgen dependent tumor (dependent): 10 ex.	12627	20
	Androgen - independent tumor (independent): 10 ex.		
Braintumor	Medulloblastoma (medulloblastoma): 10 ex.	7129	40
	Malignant glioma (glioma): 10 ex.		
	Rhabdoid tumor (RhabdoidTu): 10 ex.		
	Normal cerebellum (Normal): 4 ex.		
	Primitive neuroectodermal tumor (PNET): 6 ex.		

GSE2535 - chronic myeloid leukemia treatment response (Crossman et al., 2005); GSE967- childhood tumors - Ewing's sarcoma (EWS), embryonal and alveolar rhabdomyosarcoma (eRMS and aRMS) gene expression (Baer et al., 2004); GSE2685 - diffuse and intestinal gastric cancer gene expressions (Hippo et al., 2002); GSE1577 - lymphoma & leukemia (T-ALL, T-LL and B-ALL) gene expressions (Raetz et al., 2006); GSE1987 - lung cancer (Dehan et al., 2007).

Table 3

Data sets provided by BMC

Class name	Number of samples by class	Number of genes	Number of samples
Breast cancer (BrCa)	Breast cancer (BrCa): 13 examples	1229	168
	Healthy donor (HD): 155 examples		
Gastric cancer (GaCa)	Gastric cancer (GaCa): 173 examples		328
	Healthy donor (HD): 155 examples		
Prostate cancer (PrCa)	Prostate cancer (PrCa): 52 examples		207
	Healthy donor (HD): 155 examples		
Gastric intestinal disease (GIS)	Gastric intestinal disease (GIS): 126 examples		281
	Healthy donor (HD): 155 examples		

GSE468 - metastatic (Met) or non-metastatic (NonMet) medulloblastoma gene expressions (MacDonald et al., 2001); GSE2443 - prostate cancer gene expressions (Best et al., 2005); Braintumor (Pomeroy et al., 2002) - distinguishes between different embryonal tumors of the central nervous system on the basis of DNA expression signatures. The popular data sets are provided by University of Ljubljana, Faculty of Computer and Information Science Bioinformatics Laboratory on their home page (University of Ljubljana, 2012). All popular data sets

characterize gene expression data, but the data provided by the Latvian Biomedical Research and Study Centre characterize antibody display data. The four data sets used in experiments, that were provided by Latvian Biomedical Research and Study Centre (see GSE2535 - chronic myeloid leukemia treatment response (Crossman et al., 2005); GSE967- childhood tumors - Ewing's sarcoma (EWS), embryonal and alveolar rhabdomyosarcoma (eRMS and aRMS) gene expression (Baer et al., 2004); GSE2685 - diffuse and intestinal gastric cancer gene expressions (Hippo et al., 2002); GSE1577 - lymphoma & leukemia (T-ALL, T-LL and B-ALL) gene expressions (Raetz et al., 2006); GSE1987 - lung cancer (Dehan et al., 2007).

Table 3) are as follows: Breast cancer and healthy donor data set; Gastric cancer and healthy donor data set; Prostate cancer and healthy donor data set and Gastric intestinal disease and healthy donor data set (Gasparovica, 2011a, 2011b).

Results and discussion

Initially all 22 full data sets without any modifications were classified using the algorithms employed in this study – RIDOR, JRIP, FURIA (using 10-fold cross validation to eliminate the impact on classification accuracy by the combination of unfavourable test and training set combination). Classification accuracy is the ratio between correctly classified records, using the generated If-Then rules, and the number of records in the data set. The results are summed up in Table 4. It shows that FURIA has the best results because out of 22 cases, it has the best accuracy in 11 data sets and reaches three best tied results where two or three algorithms have equal performance results. JRIP has five best results and three tied bests, whereas RIDOR has only three best results and one tied result. If the numbers of rules are compared, it is equal or very similar for JRIP and RIDOR algorithms, and FURIA algorithm has larger sets of rules. The computation time is also longer for FURIA algorithm as compared to JRIP and RIDOR algorithms.

Table 4

Results of classification using full data sets

Name	RIDOR			JRIP			FURIA		
	1	2	3	1	2	3	1	2	3
DLBCL	3	1.25	72.7273	3	4.5	85.7143	4	6.27	77.9221
GSE412 (childhood ALL data set – 2cl.)	3	4.07	78.1818	4	7.53	82.7273	5	15.14	85.4545
GSE412 (childhood ALL data set – 4cl.)	6	3.69	33.3333	4	5.66	45.0000	7	13.38	45.0000
GSE2191 (AML prognosis)	2	2.33	57.4074	3	4.13	61.1111	4	7.81	48.1481
GSE349_350 (Breast cancer)	2	0.84	58.3333	2	0.81	70.8333	2	1.47	75.0000
GSE3726 (breast & colon cancer)	2	1.99	90.3846	3	4.63	94.2308	2	10.09	92.3077
GSE89 (bladder cancer)	3	1.1	70.0000	3	1.5	55.0000	3	2.13	67.5000
GSE2535 (CML treatment)	2	0.74	57.1429	1	1.23	64.2857	4	2.69	53.5714
GSE967 (childhood tumors – 2cl.)	2	1.14	78.2609	2	0.66	52.1739	2	1.03	69.5652
GSE967 (childhood tumors – 3cl.)	3	1.56	39.1304	2	1.13	60.8696	2	1.81	52.1739
GSE2685 (gastric cancer -3cl.)	2	0.22	90.0000	2	0.33	90.0000	2	0.67	93.3333
GSE2685 (gastric cancer – 2cl.)	2	0.47	46.6667	3	0.8	63.3333	3	1.2	73.3333
GSE1577 (lymphoma & leukemia – 2cl.)	2	0.52	84.2105	2	0.66	89.4737	2	1.38	89.4737
GSE1577 (lymphoma & leukemia – 3cl.)	3	1.58	96.5517	3	1.59	86.2069	3	3.97	65.5172
GSE1987 (lung cancer)	3	2.19	79.4118	3	1.31	79.4118	4	3.83	79.4118
GSE468 (medulloblastoma)	1	0.06	60.8696	2	0.17	47.8261	3	0.22	65.2174
GSE2443 (prostate cancer)	2	0.45	70.0000	2	0.66	60.0000	2	1.53	85.0000
Braintumor	6	2.5	55.0000	5	3.41	57.5000	5	4.72	65.0000
Breast cancer (BrCa)	3	0.39	91.0714	2	1.45	90.4762	5	2.19	92.8571
Gastric cancer (GaCa)	4	2.78	54.878	3	5.34	53.6585	3	21.64	61.5854
Prostate cancer (PrCa)	3	0.88	85.5072	4	1.91	79.7101	7	4.27	89.372
Gastric intestinal disease (GIS)	1	0.99	53.7367	2	2.28	54.8043	18	16.89	55.1601

1 – Number of Rules, 2 – Time in seconds, 3 – Accuracy

Then feature selection was implemented using four different methods – Fast Correlation Based Filter solution and three other search methods available in Weka software for comparison – Linear Forward Selection, Greedy Stepwise and Genetic Search, which were combined with corresponding evaluation methods –Symmetrical Uncertainty Attribute Set Evaluation (with Fast Correlation Based Filter search), Consistency Subset Evaluation (with Linear Forward Selection, Genetic Search and Greedy Stepwise Selection).

Table 5

Name	Number of genes	Number of genes after feature selection			
		FCBFS	Genetic search	Linear	Stepwise
DLBCL	7070	74	162	5	5
GSE412 (childhood ALL data set – 2cl.)	8280	34	242	4	4
GSE412 (childhood ALL data set -4cl.)	8280	19	242	8	8
GSE2191 (AML prognosis)	12625	54	435	6	5
GSE349_350 (Breast cancer)	12625	2	2849	2	2
GSE3726 (breast & colon cancer)	22283	37	765	3	3
GSE89 (bladder cancer)	5724	48	74	4	3
GSE2535 (CML treatment)	12625	33	2849	3	3
GSE967 (childhood tumors – 2cl.)	9945	2	180	2	2
GSE967 (childhood tumors – 3cl.)	9945	28	135	3	3
GSE2685 (gastric cancer -3cl.)	4522	2	12	2	2
GSE2685 (gastric cancer – 2cl.)	4522	25	489	3	3
GSE1577 (lymphoma & leukemia – 2cl.)	15434	2	1430	2	2
GSE1577 (lymphoma & leukemia – 3cl.)	15434	53	1430	3	3
GSE1987 (lung cancer)	10541	41	849	3	3
GSE468 (medulloblastoma)	1465	20	245	3	3
GSE2443 (prostate cancer)	12627	2	748	2	2
Braintumor	7129	67	163	5	4
Breast cancer (BrCa)	1229	22	40	3	3
Gastric cancer (GaCa)	1229	7	326	22	19
Prostate cancer (PrCa)	1229	28	40	6	6
Gastric intestinal disease (GIS)	1229	7	343	22	19

Feature selection results – the initial numbers of attributes and the decrease in the attribute set size using each of the methods are shown in Table 5. It can be seen that the most data set results indicate an important decrease in the number of attributes to up to 18 times, significantly decreasing the time and complexity of computations. After performing the attribute selection using all four methods, the experiments were carried out using all three classification algorithms used in this study.

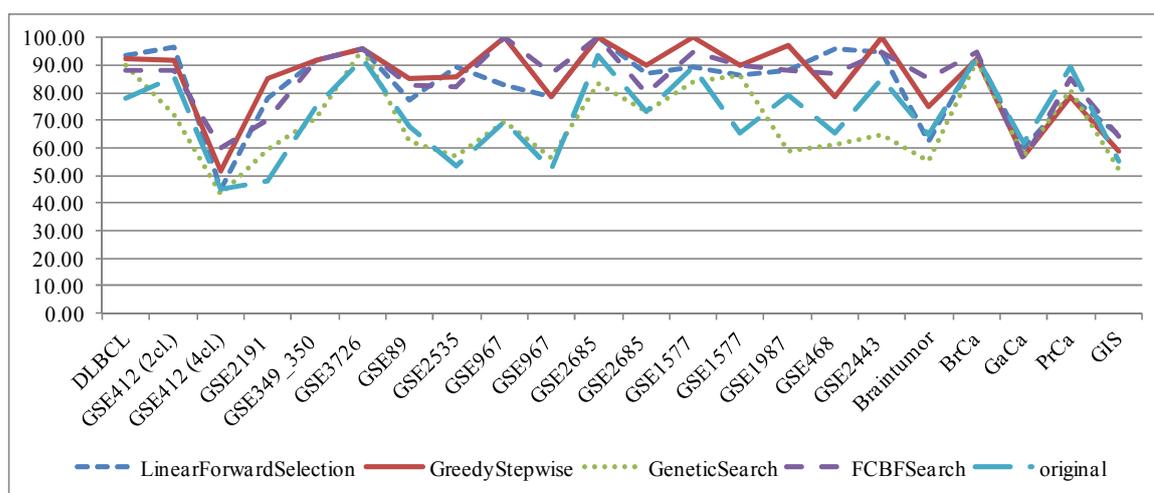


Fig. 5. Classification accuracy of FURIA algorithm, comparing four feature selection methods and the original data set dimensionality

The results of classification accuracy using FURIA can be seen in Fig. 5. It is obvious that the classification results of full data sets (original) are one of the worst, whereas the best results are achieved when attribute

selection is performed using Greedy Stepwise and FCBF Search, which indicates that the use of FCBF is suitable for the complex and multidimensional data of bioinformatics.

Classification results of all three classification methods with all of the four studied feature selection methods are given in Table 6. After comparing all 22 data set classification results with and without feature selection, it can be seen that in 21 cases out of 22 the best classification result (higher classification accuracy) is obtained when feature selection is applied. Therefore it can be concluded that classification results after feature selection do not decrease but even increase, which makes this preprocessing step a recommendation when working with complex bioinformatics data.

Table 6

Results of classification accuracy with future selections methods

Name	LinearForwardSelection			GreedyStepwise			GeneticSearch			FCBFSearch		
	Ridor	Jrip	FURIA	Ridor	Jrip	FURIA	Ridor	Jrip	FURIA	Ridor	Jrip	FURIA
	Accuracy											
DLBCL	87.01	90.91	93.51	89.61	90.91	92.21	87.01	88.31	89.61	83.12	85.71	88.31
GSE412 (2cl.)	97.27	94.55	96.36	88.18	92.73	91.82	75.45	72.73	71.82	85.45	90.00	88.18
GSE412 (4cl.)	51.67	58.33	45.00	50.00	55.00	51.67	45.00	50.00	43.33	48.33	45.00	60.00
...												
GSE468	86.96	86.61	95.65	73.91	78.26	78.26	65.22	60.87	60.87	73.91	69.57	86.96
GSE2443	95.00	95.00	95.00	100.00	90.00	100.00	60.00	50.00	65.00	95.00	95.00	95.00
Brain tumor	60.00	72.50	62.50	70.00	62.50	75.00	57.50	57.50	55.00	77.50	67.50	85.00
BrCa	94.05	93.45	93.45	92.26	92.26	92.26	91.67	89.88	91.67	92.26	92.26	94.64
GaCa	61.28	54.27	60.06	56.40	47.87	56.71	54.88	55.49	56.71	58.23	50.30	55.79
PrCa	91.30	78.74	78.26	90.82	75.85	78.74	79.23	76.81	80.68	80.19	77.78	85.02
GIS	56.58	64.77	64.77	55.57	59.43	58.72	54.09	52.31	52.31	53.38	64.06	64.41

Classification results of one feature selection method using all three algorithms studied in this research are shown in Fig. 6. There are no sharp differences in the results of these rule-based classification algorithms but FURIA achieves better classification accuracy. These results compare the changes in classification results when the applying rules obtained by different algorithms and carrying out classification using them.

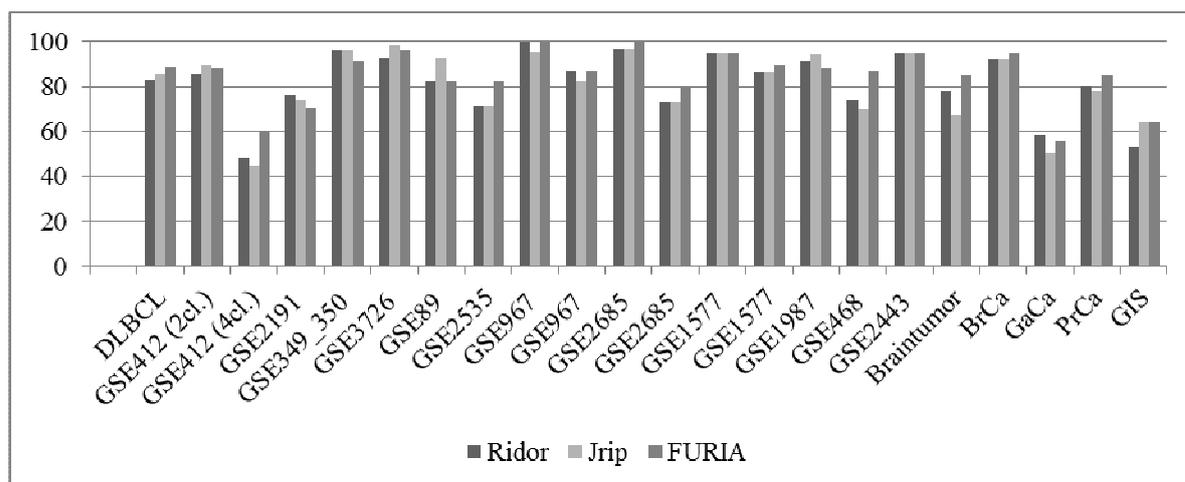


Fig. 6. Classification accuracy with FCBF search future selection method

Conclusions

For the full data sets without any modifications, FURIA showed the best classification results, because out of 22 data sets, it achieves the best results in 11 of them and has three tied best results, when two or three algorithms had the same classification accuracy.

When attribute selection was applied using four different methods – Fast Correlation Based Filter solution, Linear Forward Selection, Greedy Stepwise, Genetic Search, the attribute set of the largest data set decreased 18 times, which significantly decreases the time and complexity of computations.

After attribute selection using all four methods, experiments using three classification algorithms were carried out, which indicated that the results of the original data set classification were one of the worst, but the best results were achieved using attribute selection with Greedy Stepwise and FCBF Search, therefore using FCBF is beneficial for the complex and multidimensional bioinformatics data.

When classification results of all 22 data sets before and after feature selection were compared, in 21 cases out of 22 the reduced data sets provided better classification results (higher classification accuracy). This fact indicates that classification results after applying feature selection methods improve.

Rule induction methods like FURIA are not frequently used in bioinformatics but their strengths like short and easy to comprehend If-Then rules, than can predict the class of the record using few attributes because of the use of fuzzy techniques can help biologists to look at the classification problem from a slightly different angle and conduct research; if these attributes are successfully used in classification, maybe they should be included in some separate research.

The research of four feature selection methods (Fast Correlation Based Filter solution, Linear Forward Selection, Greedy Stepwise selection and Genetic Search) and three classification algorithms (RIDOR, JRIP and FURIA) using 22 real bioinformatics data sets shows that the use of feature selection in bioinformatics data is recommended and can be used as data preprocessing technique.

Acknowledgements

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GENETIC ALGORITHM FOR RANDOM TREE GENERATION IN BIOINFORMATICS DATA

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Abstract: *In the last few decades the progress in medical technology has made it possible to analyze biologic material like DNA, protein profiles and antibody displays. But it has also created new challenges in data analysis related to processing of high-dimensional data. One of the significant tasks in bioinformatics is finding diagnostic rules in biomedical data, that can be solved using data mining techniques like classification, which has to be highly accurate. But there is an issue related to the bioinformatics data called 'the curse of dimensionality' because the data have very high dimensionality and relatively few records that not only influences the classification accuracy but also makes the classification process very costly calculation-wise. Many dimensionality reduction methods hinder the interpretation of classifiers ergo there is a necessity for scalable methods like Decision trees that have a built-in dimensionality reduction algorithms that need only the variables that are used in the classifier. And the other issue (calculation costs) can be tackled by using random subspace methods. Both of these possible solutions are combined in the proposed approach that uses Genetic Algorithm to implement the random subspace selection and search for the best solutions while building a Random Decision tree, that can be used to find diagnostic signatures in biomedical data. This article gives information about the method as well as examines its performance in comparison with other classification methods using bioinformatics data (antibody phage display data with more than 1000 attributes and few hundred records).*

Keywords: bioinformatics, classification, data mining, genetic algorithm, random tree.

Introduction

The modern technologies of biology and medicine use genes and proteins to discriminate between patient conditions (e.g. affected or healthy) and monitor the response to treatments. One of the problems with these technologies is that most of the genes and proteins are not studied enough to identify their functions and features, therefore the laboratories test many genes and proteins having data with very high dimensionality and little knowledge to analyze them or interpret the results. This problem is approached by statistical and data mining experts trying to find informative features, their inter-relationships and connection to patient conditions. One of the issues of these methods is the 'curse of dimensionality' or *Hughes effect* (Hughes, 1968), meaning the data sets have too many (thousands) features and only some of them are significant. This leads to long computation times and overfitting the data by choosing the wrong features.

This study proposes a new algorithm that tackles these problems in several approaches. One of those is the use of decision tree based classifiers (derived from Quinlan, 1986) that show the most significant features and their hierarchical relationships. These models are also easy to comprehend and explain to biologists or medical staff. Another approach is using only subsets of the whole feature sets and growing the tree classifier to a predefined size (binary tree in three levels in this case) to avoid overfitting.

The tree model in the proposed algorithm is generated using genetic algorithm (Goldberg, 1989), which is implemented to find the most informative and accurate decision tree possible considering the randomly chosen subspace.

This article is composed as follows: Section 2 describes the methods that serve as a basis for the proposed algorithm and the algorithm itself; Section 3 gives a short insight in the specifics of the used data and experimental setup; Section 4 analyzes the obtained results; the last section of the article offers conclusions.

Methods

This section gives short descriptions of data mining methods that serve as a basis for the proposed method of Random decision tree generation using Genetic algorithm; such as Genetic algorithms, Decision tree classifiers and Random subspace method. Then the proposed method is described in detail.

Genetic algorithms

Genetic algorithms are a widely used technique to find optimal solutions to a function or a problem, whose solution is an object that can be encoded into a string called chromosome. A chromosome consists of genes that represent parts or properties of the object, e.g. if a chromosome represents a decision tree, its nodes (the attributes that are used for the split of data set) can be encoded as chromosomes. A predefined number of chromosomes make up a population that is further processed by the genetic algorithm.

Then the algorithm uses operators that are adapted from genetics – selection, crossover and mutation. Selection is used to copy or import the best members of a population into the next population. Crossover is used to produce new offspring (chromosomes) from the genes that are held by the existing members of the populations by swapping a part of the genetic material of two parent chromosomes. Mutation is an operator that changes a random gene to a different value; it is used to ensure that the solutions found by the algorithm are not stuck at a local optimum.

Each member of the population is evaluated at the end of each iteration using a fitness function, e.g. in the case of the search for the most accurate decision tree, the fitness function value represents the accuracy of each tree in a population. Then a new population is formed from elite chromosomes, chromosomes from the old population, children chromosomes produced by the crossover operator and the mutated individuals. If the algorithm does not reach the stopping criterion (usually a maximum number of iterations or iterations that do not produce improved fitness of individual chromosomes or population), it continues by implementing the aforementioned operators again and forming a new population until the stopping criterion is met. For more information on genetic algorithms see (Goldberg, 1989).

Decision tree classifiers

Decision tree classifiers use the recursive partitioning approach to iteratively split the data set objects into smaller groups based on their descriptive attribute values until a class can be assigned to the subgroup. The methodology of decision tree classifiers was first introduced by Breiman et al. (Breiman et al., 1984), when the authors introduced classification and regression trees, and J. R. Quinlan (Quinlan, 1986), when he first introduced his algorithm ID3. After numerous modifications presented by other authors, an improved version of ID3 algorithm called C4.5 (Quinlan, 1993) is still one of the most widely used in data mining.

At every split (also at beginning at the root node) an algorithm chooses the attribute that would gain the ‘cleanest’ subsets after splitting. It is mostly measured by changes in entropy before and after the split. ID3 uses the Information gain criterion, which is also called Kullback-Leibler divergence (Kullback and Leibler, 1951), to evaluate splitting attribute and threshold. Let C be the class attribute with values $\{c_1, c_2, \dots, c_n\}$ and A an attribute with values $\{a_1, a_2, \dots, a_k\}$, then $H(C)$ is the entropy of the class attribute, and $H(C|A)$ is the conditional entropy that shows entropy of C if state of attribute A is known; and Information gain of splitting using attribute A is calculated as shown in Equation (1).

$$I(C, A) = H(C) - H(C|A) \quad (1)$$

The entropy of attribute C is calculated as shown in Equation (2), in decision tree classifier induction the entropy used in calculations is usually Shannon entropy (Shannon, 1948), which is basically information content that is missed when the value of an attribute is not known.

$$H(C) = -\sum_{i=1}^n P(C = c_i) \log_2(P(C = c_i)) \quad (2)$$

where $P(C=c_n)$ – the relative frequency of class value c_n .

And the conditional entropy of C if the value of attribute A is known $H(C|A)$ is calculated as shown in Equation (3).

$$H(C|A) = -\sum_{j=1}^k P(A = a_j) H(C|A = a_j) \quad (3)$$

Information gain favors attribute with higher number of values. To avoid that, gain ratio can be used in the improved version of C4.5. This criterion penalizes a large number of attribute values by dividing Information gain with entropy of the attribute itself as shown in Equation (4).

$$IG(C, A) = \frac{I(C, A)}{H(A)} \quad (4)$$

After a tree is grown by consecutively splitting the data subsets gained in the previous splits, the tree is pruned to avoid overfitting and tested on data previously unseen to the classifier to evaluate its accuracy.

Feature subspace

Considering the large attribute space, some technique of dimensionality reduction must be applied. Whereas the attributes analyzed in bioinformatics data (like genes, proteins and anti-bodies) are not fully studied and their interrelations and meanings are not fully understood, the heuristic dimensionality reduction methods would not

be applicable. There are also some dimensionality reduction approaches in data mining that can be applied to unknown data but they all have their shortcomings.

Feature selection methods discriminate between informative features that make up variable signatures of the classes present in data set and features that hold little or no relevant information for class recognition. But the drawback of this approach is sometimes questionable nature of the selected attribute subsets because they can hold redundant features and may overfit small data samples. And once an attribute is eliminated from the predictive set, it is lost for all future analysis. The choice of the proper feature selection or evaluation method is also intuitive and in most cases only the approach of tries and misses can determine the most efficient one. But this process is very slow and it is not robust because the results mostly depend on the specific features of data sets.

There are also dimensionality reduction techniques that do not lose the information contained in the existing features but combine several features into one resulting in a data set consisting of fewer attributes. But this approach is not only computationally costly considering the large dimensionality of the initial data set but also makes interpretability nearly impossible because instead of working with biomedical variables that are conceptually clear to experts who will work with the resulting models it works with conceptual variables that have close to no meaning for experts of the area.

Considering the aforementioned drawbacks of other methods, it is obvious that the preferable dimensionality reduction approach should make the reduction reversible and preserve the concepts of the field where the data stem from to ensure the interpretability. One such approach is sometimes used in classifier ensemble construction and it is called Random subspace method. The idea is to work with a randomly chosen subspace of the attribute space while constructing a classifier, then the subspace is changed and another classifier is constructed. In the end there is a classifier ensemble, whose outputs are combined in a unified output. This idea is used in the proposed method when searching for the most appropriate classification tree using Genetic algorithms.

The proposed method

Random decision trees generated by Genetic algorithm have a structure of seven nodes that are arranged in binary splits from the root node. The tree structure is shown in Fig. 1. These nodes are represented in chromosomes of the genetic algorithm – each chromosome represents a classifier.

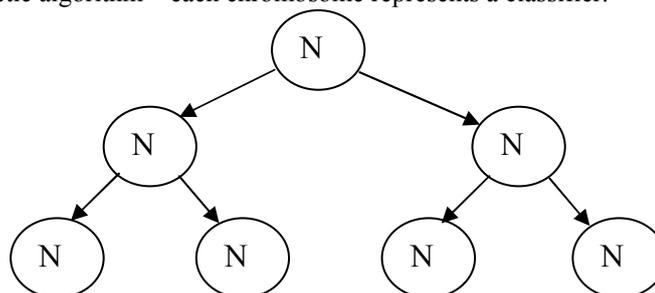


Fig. 1. Tree structure of the generated decision trees.

To implement the random subspace approach, each of the nodes can be selected from a random subset of the attribute space. This ensures that the tree will not be overfitted considering the small number of records in a data set and the classification algorithm will be fast. Also the use of the Genetic algorithm ensures that the precision of this algorithm will be better than that of a regular Random tree classifier because the algorithm finds the most accurate tree in the corresponding subset of data.

The Genetic algorithm used in the proposed algorithm implements elitism by copying the best chromosome to the next generation; crossover is implemented using one-point crossover for two pairs of randomly selected chromosomes. The experiments during the working process showed that the algorithm tends to converge to populations with very similar individuals, therefore, to ensure genetic diversity of the population, a part of it is always replaced with randomly generated individuals. The algorithm is depicted in Fig. 2. After each chromosome is created, the algorithm gradually finds the splitting threshold for each node based on the Information Gain (Kullback-Leibler divergence) measure.

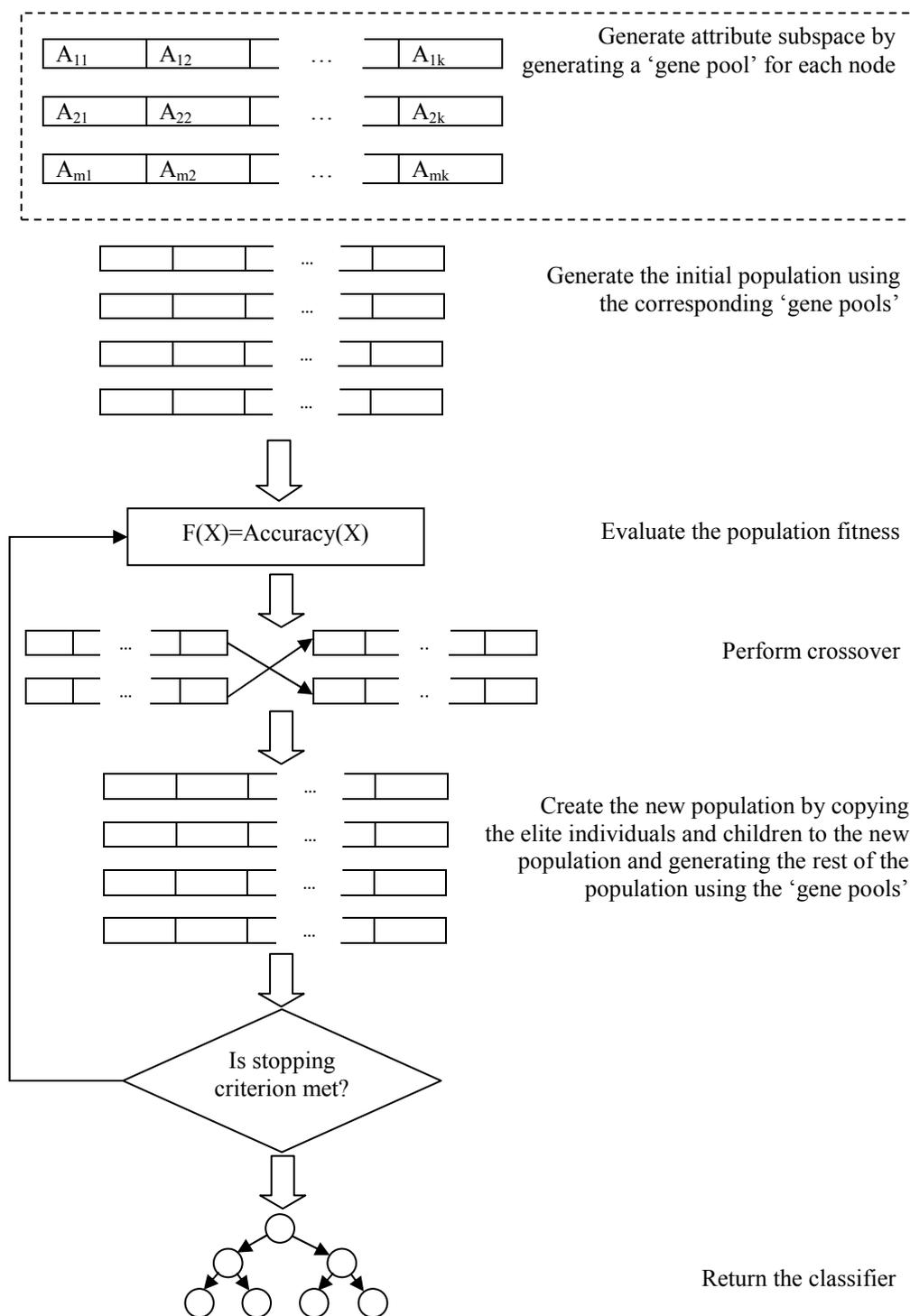


Fig. 2. The algorithm generating Random decision trees using Genetic algorithm.

The stopping criterion used in the algorithm is based on the gene probability of each gene in the 'gene pool' – at the beginning each gene in the 'gene pool' is assigned probability 0.5 and in each iteration the genes that make up the best tree (with the highest fitness function value) have their probability increased. The algorithm stops when in each pool there is a gene with probability 0.9 – these are the genes that are the best candidates for splitting in each node.

Experimental setup

The data used in this study were provided by Latvian Biomedical Research and Study Centre and describe the autoantibody panels of patients and healthy donors. The diseases examined in this case are breast cancer (the data set is referred to as 'Br' for short in the following text), gastric cancer ('Ga' in the following text), gastrointestinal inflammatory disease ('GIS' in the following text), melanoma ('Mel' in the following text) and

prostate cancer ('Pr' in the following text). Each of the sets consists of 1229 autoantibody expression levels and one target class (type of the disease or healthy).

The experiments are carried out using each of the five data sets, that are pre-processed by replacing missing values and then classified using one of three methods: the proposed Random trees generated by Genetic algorithm, classical Random tree algorithm and the popular decision tree construction algorithm C4.5. To evaluate the results, each classification is assessed using 10-fold cross-validation except breast cancer data set because it had rather few records (60 records with 13 breast cancer patient data and 47 healthy donor data) and therefore it was decided to use 6-fold cross-validation on this set for all of the used methods.

Results and Discussion

The results of the experiments show a significant improvement in classifier accuracy in all data sets. The experimental results were analyzed in two cross-sections – the accuracy of discrimination between classes and the classifier size. The results are shown in Table 1.

Table 1

Data set	RT-GA	Random tree		C4.5	
		Accuracy	Size	Accuracy	Size
Breast c.	98,33	90,00	192	95,00	9
Gastric c.	76,25	56,71	203	59,76	53
GIS	78,93	54,80	173	55,16	47
Melanoma	87,06	59,77	227	67,06	31
Prostate c.	87,50	72,46	111	72,46	21

The tree sizes (number of nodes in the decision tree) generated by algorithms Random tree and C4.5 shown in Table 1 are much larger than the predefined seven node maximum in the GA-generated Random trees and still they perform worse than the classifiers generated by the proposed method. This points to the tendency to overfit the training data while learning the classifiers by other algorithms; and these classifiers perform worse on test data because they are looking for models that fit the specific instances in the training set instead of features and relationships that point to the disease.

Although the breast cancer data set was the smallest considering the number of records, all classification methods showed the best accuracies in it. GA-generated random trees showed a 98,33% accuracy across 6 folds of cross-validation. The results in five folds of cross-validation showed 100% accuracy and 90% accuracy in one of the runs (see Fig. 3 for accuracy fluctuations across different runs in cross-validation in all data sets), which is a high result and it means that only one of the instances was misclassified in six runs. Other classification algorithms also showed an accuracy of 90 or more percent but were behind the GA-RT algorithm with 90% accuracy for classic Random tree algorithm and 95% for C4.5.

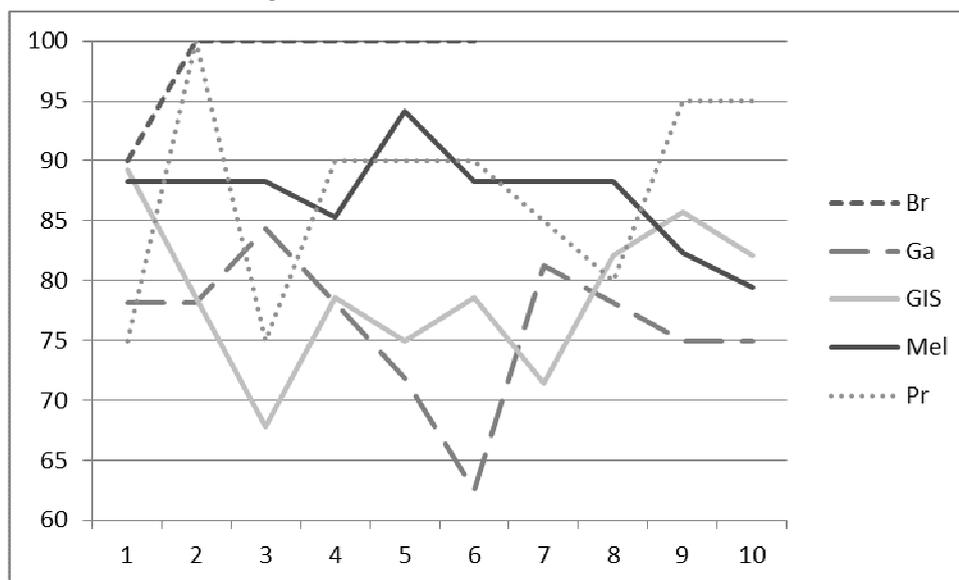


Fig. 3. GA-RT classification accuracy in all folds of cross-validation.

In the gastric cancer data set all of the methods showed worse accuracies. Classic methods showed results under 60%, which can be explained by the complex nature of the data and class (disease) description (features and their connections), this also facilitated overfitting and the classifiers were rather large compared to other data sets. The

GA-generated Random trees were much smaller (7 nodes compared to 203 or 53 nodes in other methods) and showed a much better result (76,25% accuracy). A similar situation is with gastro-intestinal inflammatory disease data set, where disease descriptions could vary based on the specifics of the particular disease. But the results show that there are common features to all diseases because the GA-RT method shows a much better accuracy (78,93%) than other two methods that settled at around 55%.

A slightly better situation for all methods was with melanoma data set but also here GA-RT method showed significantly better results and surpassed the accuracy of Random trees (59,77%) and C4.5 (67,06%) by more than 20% achieving 87,06% accuracy.

The gap between GA-RT and other methods was smaller in prostate cancer set but it still remained the most accurate method (87,50%). Random trees and C4.5 methods performed at the same level of 72,46% accuracy but significantly differed in the tree sizes – Random tree classifier consisted of 111 nodes (the smallest tree for this method in all of the used data sets), whereas C4.5 classifier held only 21 nodes. Overall there is a trend that smaller classifiers performed better (were more accurate) due to the overfitting of large trees.

Conclusion

The article presents a new way of building Random classification trees that has experimentally shown its potential in working with data arrays with high dimensionality and a comparably small number of records, which can be used in omics data analysis. The accuracy of the method significantly surpasses that of other popular decision tree methods, when tested on autoantibody panel data.

One of the cutbacks of the proposed method is its low stability in different cases (robustness) but it is planned to deal with this issue by expanding the method to ensembles of random decision tree classifiers that would use voting to determine the class of a new instance. This would also solve the problem with ‘bad’ subspaces – if a significant feature is not included into gene pools of one tree, it would possibly be included in at least one of the other trees of an ensemble, which would preserve the encoded information for use in classification process.

An evident trend in the experiment results was the poor performance of large tree classifiers. Smaller classifiers yielded better efficacy because large classifiers tend to be fitted to match the training data and do not always capture the true nature of the disease properties.

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MODELING AND DESIGN TOOLS FOR SYNTHETIC BIOLOGY

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Abstract: *The aim of this paper is to review several computational tools for application in synthetic biology. Recently developed computational tools, for instance, for gap-filling, orphan reaction searching, metabolic engineering, pathway analysing, gene engineering, metabolic reconstruction and others, were reviewed and their functionality was described. Some tools have similar functionality and some tools can be used for different tasks. Tools for comparison were chosen from the most cited scientific literature.*

Keywords: synthetic biology, software tools, modeling and design tools.

Introduction

Synthetic biology brings together engineers and biologists to design and build novel biomolecular components, networks and pathways, and to use these constructs to rewire and reprogram organisms (Khalil and Collins, 2010). It is an extension of the biotechnologies that focuses on the design of new organisms not found in nature from a set of pre-characterized biological component (Gendrault et al., 2011).

Major application domains of synthetic biology apply to the medical field and environment, e.g. drugs synthesis, therapeutics, biosensing, biofuel production, pharmaceutical, biomaterials production and chemical production life understanding improvement (Khalil and Collins, 2010, Tepper and Shlomi, 2010, Gendrault et al., 2011)

Synthetic biology can be used to learn more about how natural living systems work. One way how to test our current understanding of biological system is to build an instance of the system in accordance with our current understanding of the system. Mathematical modeling plays an important and often indispensable role in synthetic biology because it serves as a crucial link between the concept and realization of a biological circuit. (Zheng and Sriram, 2010). Using models of biological systems instead of real systems and experiments is cheaper and does not require specific resources (Gendrault et al., 2011, Wiechert, 2002). Modeling is a tool to optimize the design of modified organism according to objective function. It is possible to use different computational tools for engineering approach in design and modeling (Macdonald et al., 2011).

In recent years, numerous computational tools have been developed, especially in the field of systems biology, and many of them have potential applications for synthetic biology (Marchisio et al., 2009). Several attempts have been made to describe synthetic biology software (Macdonald et al., 2011, Marchisio and Stelling, 2009, Orth and Palsson, 2010, Rubina and Stalidzans, 2010).

This article is devoted to the different groups of modeling software from the point of view of non-biologist. Below are shown some of these tools that can be used in different research processes, e.g. gene design tools, flux balance analysis, gap-filling, dynamic analysis. In different research fields of synthetic biology many processes are connected to each other, but each of them has its own purpose. In this paper are shown some of these processes.

Gene design tools

One of the first stages of metabolic network analysis is gene circuit design. Genetic regulatory circuits are the genes and gene products that are involved in the response to a signal or functional clusters of genes that impact each other's expression. These circuits can be modeled *in silico* to predict the dynamics of a genetic system. Understanding of genetic regulatory circuits is a key in the field of synthetic biology, where disparate genetic elements are combined to produce novel biological functions (Richardson et al., 2010).

GeneDesign is a set of web applications that provides public access to a nucleotide manipulation pipeline for synthetic biology. The server is public and freely accessible, and the source is available for download under the New BSD License. In the functionality of GeneDesign were added several algorithms and modules, were updated the restriction enzyme library, were added batch processing capabilities and several command line modules. GeneDesign was originally developed as an in-house project to automate the design of oligonucleotides for the construction of individual synthetic genes. The most popular modules are building block design, reverse translation and restriction site addition (Richardson et al., 2010).

GenoCAD is an application to design protein expression vectors, artificial gene networks and other genetic constructs composed of multiple functional blocks called genetic parts. GenoCAD automatically derives the construct sequence from its comprehensive libraries of genetic parts. GenoCAD includes design rules describing how parts should be combined in genetic constructs. These rules are used to build a wizard that guides users through the process of designing complex genetic constructs and artificial gene networks. GenoCAD facilitates the design of artificial DNA sequences in different ways. GenoCAD includes a flexible system to manage libraries of public and user-defined genetic parts and it relies on formal design strategies to guide both novice

and experienced users in the design of structurally valid constructs for various biological applications (Czar et al., 2009).

ProMoT was originally designed for the computer-aided modeling of chemical processes as well as for the implementation of libraries that contain reusable modeling. ProMoT enables the use of object-oriented modeling techniques including encapsulation, aggregation, and inheritance. In ProMoT, dynamic models are built by aggregating structural and behavioral modeling entities, which in ProMoT are organized as an object-oriented class hierarchy with multiple inheritances. ProMoT supports models based on differential algebraic equation systems and on a logical modeling formalism. Modeling in ProMoT is subdivided into several steps which are associated to different components. ProMoT provides a special modeling language as well as a graphical user interface (GUI) for interactive modeling (Mirschel et al., 2009).

TinkerCell is a synthetic biology computer-aided design (CAD) tool for visually constructing and analyzing biological networks. The visual interface alone does not have any analysis capabilities. The analyses are performed by third-party libraries and modules that interface with TinkerCell. Numerous functions are available in TinkerCell for analyzing a constructed model, including deterministic and stochastic simulation algorithms, metabolic control analysis, structural analysis, flux-balance analysis, one-dimensional and two-dimensional steady state analysis, and centrality measurements. This software supports SBOL standard (Chandran et al., 2009).

Gene Designer is a stand-alone software for fast and easy design of synthetic DNA segments. Software allows adding, editing and combining genetic elements such as promoters, open reading frames and tags through an intuitive drag-and-drop graphic interface and a hierarchical DNA/Protein object map. Using advanced optimization algorithms, open reading frames within the DNA construct can readily be codon optimized for protein expression in any host organism. GeneDesigner also includes features such as real-time sliding calculator of oligonucleotide annealing temperatures, sequencing primer generator, tools for avoidance or inclusion of restriction sites, and options to maximize or minimize sequence identity to a reference (Villalobos et al., 2006).

Databases

All necessary information for genetic modeling, microorganism reconstruction and optimization can be taken from specific databases. Below is given description of a few databases that are useful for a metabolic reconstruction.

Kyoto Encyclopedia of Genes and Genomes (KEGG): This is a bioinformatics database containing information on genes, proteins, reactions and pathways. The organisms section is divided into eukaryotes and prokaryotes, encompasses many organisms for which gene and DNA information can be searched by typing in the enzyme of choice. This resource can be extremely useful when building the association between metabolism enzymes, reactions and genes (Ogata et al., 1999).

BioCyc and MetaCyc: BioCyc is a collection of 1690 pathway/genome databases (Nov 2011). Each database in the BioCyc collection describes the genome and metabolic pathways of a single organism. For example, Additionally, MetaCyc, an encyclopedia of experimentally defined metabolic pathways and enzymes, contains 1790 pathways from more than 2216 different organisms and 8800 metabolic reactions in Nov 2011 (Caspi et al., 2008).

metaTIGER: is a collection of metabolic profiles and phylogenomic information on a taxonomically diverse range of eukaryotes. Phylogenomic information is provided by 2,257 large phylogenetic trees which can be interactively explored. High-throughput tree analysis can also be carried out to identify trees of interest, e.g. trees containing horizontal gene transfers. metaTIGER also provides novel facilities for viewing and comparing the metabolic profiles (Whitaker et al., 2009).

BRENDA: A comprehensive enzyme database, BRENDA, allows you to search for an enzyme by name or EC number. You can also search for an organism and find all the relevant enzyme information. Moreover, when an enzyme search is carried out, BRENDA provides a list of all organisms containing the particular enzyme of interest (Schomburg et al., 2002).

Model SEED: This is an online resource for the analysis, comparison, and reconstruction of genome-scale metabolic models. Users can submit genome sequences to the RAST annotation system, and the resulting annotation can be automatically piped into the Model SEED to produce a draft metabolic model. The Model SEED automatically constructs a network of metabolic reactions, gene-protein-reaction associations for each reaction, and a biomass composition reaction for each genome to produce a model of microbial metabolism that can be simulated using Flux Balance Analysis (Henry et al., 2010).

BioBrick standard biological parts are DNA sequences of defined structure and function; they share a common interface and are designed to be composed and incorporated into living cells to construct new biological systems. BioBrick parts represent an effort to introduce the engineering principles of abstraction and standardization into synthetic biology (Shetty et al., 2008).

Gap-filling tools

Even the most complete models are not perfect, however, they all contain gaps or missing information. There are two types of missing information in metabolic network reconstructions. The first type is gaps in a network, places where a reaction that consumes or produces a metabolite is missing, creating a dead-end. The second type is orphan reactions. These are reactions that are known to exist, but it is not yet known which gene or genes code for their enzymes. Both types of gaps are the result of our incomplete knowledge of the metabolism of an organism (Orth et al., 2010). Gap-filling methods can thus be used to improve metabolic network models while simultaneously leading to discovery of new metabolic gene functions.

MetaRoute is a computational method to search for relevant routes between a source and a product in metabolic networks. Its speed allows the method to be used in a web interface for interactive navigation through genome scale networks and local network visualization. The underlying approach is based on graph-theory and the basic algorithm uses atom mapping rules and path weighting schemes to search for relevant paths in a directed graph representing the metabolic network. Precalculated atom mapping rules are incorporated into both the graph representation and the path finding algorithm to ensure calculation and to enforce biochemical constraints. To this end, the weighted path search is constrained to only trace feasible paths transferring atoms from the user-specified source to the product metabolite. The underlying data stems from the Biological Network Database (BNDB) and is based on data from KEGG (Blum et al., 2008).

BNICE - algorithm developed to identify all biochemical reactions that could realistically link two metabolites. In this algorithm, molecules are represented as bond- electron matrices (BEMs) and reactions are represented by matrix addition. It is possible to model the activity of an enzyme catalyzed reaction occurring with alternative substrates by adding the same reaction matrix to different BEMs, resulting in different product BEMs from each one. BNICE iteratively searches for all possible pathways of chemical transformations from one metabolite to another, offering gap-filling hypotheses (Hatzimanikatis et al., 2005).

GapFind and **GapFill** were developed in attempt to minimize the total number of gaps in a metabolic network model. GapFind is a mixed-integer linear programming (MILP) algorithm that can identify every gap in a network by identifying blocked metabolites, that is, those that cannot be produced or consumed at steady-state under any conditions. Although it may be easy to identify some gaps by inspection of network or pathway maps, certain unusual model structures such as cycles can lead to non-intuitive sets of blocked metabolites. GapFill is another MILP algorithm, and its objective is to minimize the total number of gaps by reversing the directionality of existing reactions, adding new reactions, adding transport reactions for blocked metabolites, or adding intracellular transport reactions between compartments for multi-compartment models (Kumar et al., 2009).

SMILEY -with a constraint-based metabolic network model, flux balance analysis can be used to simulate the growth of microbial organisms on different substrates, including many different carbon and nitrogen sources. When an *in vivo* experiment shows that an organism can grow on a certain substrate but the model predicts that it cannot, the model is likely missing one or more of the reactions required to consume the substrate. SMILEY was created to predict which reactions are likely missing from a network when the model predicts no growth but experiment indicates growth. SMILEY uses MILP to attempt to identify a flux distribution that leads to growth on the substrate of interest while minimizing the total number of reactions added from a universal database of reactions. It thus predicts which reactions should be added to the model parsimoniously, adding the smallest number of reactions necessary to reconcile *in silico* and *in vivo* growth predictions (Reed et al., 2006).

GrowMatch - this algorithm uses experimentally determined gene essentiality data to identify incorrect model predictions. GrowMatch attempts to correct two types of disagreements differently, when the model predicts growth but an experiment shows that the organism cannot grow with this gene knockout and when the model predicts no growth but an experiment shows that growth is possible. GrowMatch then uses the three single compartment methods from GapFill (reversing reaction directions, adding reactions from a database, or adding transport reactions) to attempt to correct the model (Kumar et al., 2009).

OMNI - is another MILP-based algorithm that compares *in silico* predictions to experimental measurements in an attempt to improve a constraint-based model. In this case, OMNI uses measured metabolic flux data. OMNI compares experimentally measured fluxes to fluxes predicted by flux balance analysis, and then attempts to minimize the total difference between measured and predicted fluxes by adding or removing reactions while maintaining a predicted growth rate above a defined minimum. Because it can remove reactions as well as add them, it can be used to remove reactions corresponding to poorly annotated genes if they do not match the experimental data (Herrgård et al., 2006).

PathoLogic is a program for automatically constructing metabolic networks from annotated genomes. It uses EC numbers, Gene Ontology terms, or annotated gene names to map reactions to genes, and then assembles the reactions into pathways by comparing the reactions to the reference database MetaCyc and adding any missing reactions. After performing these steps, however, many of the reactions in the new pathways may be orphans. Pathologic includes a PHFiller program that attempts to identify the genes associated with these reactions (Karp et al., 2002).

ADOMETA is a bioinformatics framework that combines analysis of gene co-expression, phylogenetic profiles, chromosomal clustering and protein fusions has been developed. The genes in an organism with unknown functions and genes with known functions as well, can be compared to the genes in the local metabolic network surrounding an orphan reaction using different types of functional association evidence. Genes that are close to each other in a metabolic network are more likely to have similar co-expression profiles, phylogenetic profiles, and so forth. In **ADOMETA**, the genes in an organism are compared to the surrounding genes using different methods, and the different association scores are combined. The products of the highest scoring genes are the most likely to catalyze the orphan reaction (Kharchenko et al., 2006).

Flux balance analysis (FBA) tools

FBA is a mathematical method for analyzing metabolism and distribution of fluxes in large metabolic networks. Flux-balance analysis based on linear optimization is widely used to compute metabolic fluxes in large metabolic networks and gains increasingly importance in network structural analysis. Thus, a computational tool flexible enough to realize a wide variety of FBA algorithms and able to handle batch series of flux-balance optimizations is of great benefit (Hoppe et al., 2011). The first FBA applications relied on the steady-state assumption and biomass maximization only. Several software solutions for FBA are currently available.

COBRA is a constraint-based reconstruction and analysis toolbox, a software package running in the Matlab environment, which allows for quantitative prediction of cellular behavior using a constraint-based approach. Specifically, this software allows predictive computations of both steady-state and dynamic optimal growth behavior, the effects of gene deletions, comprehensive robustness analyses, sampling the range of possible cellular metabolic states and the determination of network modules. Functions enabling these calculations are included in the toolbox, allowing user to input a genome-scale metabolic model distributed in SBML format and perform these calculations with just a few lines of code. The results are predictions of cellular behavior that have been verified as accurate in a growing body of research (Becker et al., 2007).

OptFlux covers an even larger range of flux optimization methods accessible through a graphical user interface. It is an easy-to-use solution well suited for biotechnologists with lesser interest in the algorithmic details (I. Rocha et al., 2010).

FASIMU offers the first available implementation of thermodynamic feasibility as a quickly computable MILP, is flexible in the choice of objective functions and constraints, and allows for batch processing of heterogeneous computations and automatic evaluation of the solutions and visualization of the computed fluxes (Hoppe et al., 2011).

FluxAnalyzer is a package for MATLAB and facilitates integrated pathway and flux analysis for metabolic networks within a graphical user interface. Arbitrary metabolic network models can be composed by instances of four types of network elements (Klamt et al., 2003).

FAME is a web-based modeling tool that combines the tasks of creating, editing, running, and analyzing/visualizing stoichiometric models into a single program. Analysis results can be automatically superimposed on familiar KEGG-like maps. FAME allows users to either upload their own preexisting model, or to build a new model based on the information in KEGG. When building from scratch, it is possible to select a subset of pathways from KEGG, foregoing the inclusion of unnecessary reactions that may be present in existing genome-scale reconstructions (Boele et al., 2012).

Optimization of pathways

Sometimes it is necessary to modify metabolic network to achieve better result by additions and deletions of reaction in the network. It can be used also for flows optimization in the pathways.

OptORF is a bi-level optimization problem which identifies the optimal metabolic and regulatory gene deletions as well as gene over expressions that maximize biochemical production at the maximum cellular growth under transcriptional regulatory constraints. The inner problem of OptORF, which is a linear programming problem, maximizes growth under the given gene deletions and regulatory states that are determined by the constraints of the outer problem. OptORF is formulated as a single level MILP by replacing the inner maximization problem with its optimality conditions as constraints (Kim et al., 2010).

OptForce procedure identifies all possible engineering interventions by classifying reactions in the metabolic model depending upon whether their flux values must increase, decrease or become equal to zero to meet a pre-specified overproduction target. This leads to the identification of a sufficient and non-redundant set of fluxes that must change to meet a pre-specified overproduction target. Starting with this set we subsequently extract a minimal set of fluxes that must actively be forced through genetic manipulations to ensure that all fluxes in the network are consistent with the overproduction objective (Ranganathan et al., 2010).

OptKnock computational framework is introduced for suggesting gene deletion strategies leading to the overproduction of chemicals or biochemical. This is accomplished by ensuring that a drain towards growth resources must be accompanied, due to stoichiometry, by the production of a desired product. Computational results for gene deletions are in good agreement with mutant strains published in the literature. While some of the suggested deletion strategies are straightforward and involve eliminating competing reaction pathways, many

others suggest complex and nonintuitive mechanisms of compensating for the removed functionalities (Burgard et al., 2003).

OptStrain computational framework is aimed at guiding pathway modifications, through reaction additions and deletions, of microbial networks for the overproduction of targeted compounds. These compounds may range from electrons or hydrogen in biofuel cell and environmental applications to complex drug precursor molecules. OptStrain provides a useful tool to aid microbial strain design and, more importantly, it establishes an integrated framework to accommodate future modeling developments (Pharkya et al., 2004).

Tools for metabolic network dynamic modeling

Having identified the key components of the system, reacting entities and topology, one needs to design the biochemical structure of the model. Genome-scale metabolic network reconstructions are built from all of the known metabolic reactions and genes in a target organism. Reconstructions are useful because they can be converted into constraint-based models, allowing practical calculations and simulations to be performed.

CellDesigner is a graphical editor for biological networks, into which existing models in SBML format can be imported and modified. Notes can also be added and mathematical equations entered for the different interactions. Substrates, products and modifiers can be added either directly by drawing and setting the appropriate connections on the canvas or by entering them in the corresponding lists. Information about the graphical layout is stored in a CellDesigner - specific format in the annotation elements of the newly created SBML file. While CellDesigner is mainly an editor, it has some built-in deterministic integration capability features, based on third party solvers. Using SBML as its native format CellDesigner generates models that can be used by the whole family of SBML aware tools (Funahashi et al., 2003).

COPASI is a software application for simulation and analysis of biochemical networks and their dynamics, creating and solving mathematical models of biological processes such as metabolic networks, cell-signaling pathways, regulatory networks, infectious diseases, and many others. COPASI includes features to define models of biological processes, simulate and analyze these models, generate analysis reports, and import/export models in SBML format. COPASI carries out several analyses of the network and its dynamics and has extensive support for parameter estimation and optimization. COPASI provides means to visualize data in customizable plots, histograms and animations of network diagrams (Hoops et al., 2006).

AMIGO is a toolbox which facilitates parametric identification by means of advanced numerical techniques which cover the full iterative identification procedure putting especial emphasis on robust methods for parameter estimation and practical identifiability analyses, plus flexible capabilities for optimal experimental design. The toolbox offers several dynamic simulation tasks to solve system dynamics under given values of model unknowns and given experimental schemes, run sensitivity analysis and rank of parameters, parameter estimation allows for multi-experiment fitting of local and global unknowns, the toolbox can solve the optimal sequential-parallel experimental design problem as a truly general optimal control problem (Balsa-Canto and Banga, 2011).

Conclusion

There are many and varied modeling and design tools for synthetic biology. That is why authors have shown only a fraction of all possible software tools and possible application areas. Many of these tools are connected and can be used to solve problems together as COPASI and CellDesigner for example. Some of the tools have similar functionality, e.g., Cobra and FAME offers similar computational procedures, so each user can select the most appropriate software for solving synthetic biology problems.

Some of all tools, described above, are web based applications, some – desktop applications that are not available for all users. Some tools are freely available for academic purpose, but there are also tools which work under other software, like Matlab, which needs license. There are many different databases that are useful for researcher in the field of synthetic biology. Each database is developed with a specific goal and collects specific information. Reconstruction models of microorganisms are not perfect and may contain errors. There can be used a gap filling software which can improve metabolic network models. For each type of problem it is necessary to choose correct software tool to achieve better results. It depends on many aspects of research field and possible employment of these tools.

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PROCESS OF GENETIC MODIFICATION OF MICROORGANISMS FROM THE POINT OF VIEW OF THE SOFTWARE ENGINEERING

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Abstract: *Genetically modification of organisms using approaches of systems and synthetic biology becomes very popular in recent years. Implementing genes from one organism to another or creating synthetic genes is useful in many fields to create products that are necessary for people. Also it is possible to use genes or devices to get new functions of organisms which not occur in the nature. Also this science uses approaches of engineering to create modified organisms. In this paper is shown modified organisms development process from the point of view of a software engineer. Also it focuses on the usage of modeling techniques in this process creation of a prototype of system.*

Keywords: synthetic biology, systems biology, genetically modified organisms, modeling software tools

Introduction

Genetically modified organisms engineering has received considerable attention in recent years for enabling the production of chemicals and novel functionality achievement. A genetically modified organism (GMO) is referred to as a living organism whose genome has been modified by the introduction of a gene able to express an additional protein that confers new characteristics (Mannelli et al., 2003).

Industrial genetically modified microorganisms, such as *Escherichia coli*, have been extensively used in major industrial processes including food, chemicals, pharmaceuticals and environment (Kizer et al., 2008; Lee et al., 2008; Shams Yazdani and Gonzalez, 2008; Trinh and Srienc, 2009). The microbial metabolism transforms feeding substrates into a wide variety of cellular products, many of which are materials for industrial and commercial purposes. Standard industrial operations have been developed to cultivate microbial cells in a controlled growth environment (Wang and Hatzimanikatis, 2006, W.-C. Lee and Huang, 2000)

There are many steps in creating genetically modified organisms. The main steps that be distributed to the following steps: design, fabrication, integration and testing. First step - target of modification should be defined – getting of new functions, new product production or utilization of some substrate. Different possible options of organisms where such a target can be implemented and possible sources of functional parts should be examined. That can be one of the most time-consuming processes and the result of it will affect the next steps.

This process can be viewed from the point of view of software engineering. We can assume that a cell is a computer, genome is an operating system and additional gene is a program (Andrianantoandro et al., 2006). In this case it is possible to use software engineering approach to program new function or to implement genetic modification into organism. Reprogramming a cell involves the creation of synthetic biological components by adding, removing, or changing genes and proteins. That means that software engineering methods, e.g. specification, design, modeling, implementation, validation, can be used during genetically modified organisms production (Andrianantoandro et al., 2006). For example, a waterfall model can be used for this purpose (See Fig.1). The waterfall model is a sequential design process, often used in software development processes, in which progress is as flowing steadily downwards through the phases of development process (Wescon, 1970). After each step it is possible to return to previous step and to make correction to improve results. Also in the end of the process in is necessary to compare the achieved result with specification. Modeling tasks can be performed and we can assume that modeling is prototyping of a real organism.

As a result, design of synthetic biological systems has become an iterative process of modeling, construction, and experimental testing that continues until a system achieves the desired behavior. There can be found a possible problem – a mistake in one of the previous steps cannot be found at once and can cause possible troubles in the next steps. To reduce the possibility of such problem it is possible to use a technical journal where it is necessary to make documentations about all the changes in the development process.

The aim of this paper is to the show process of implementation of genetically modification into microorganism from the point of view of a computer scientist.

Modeling tasks in GMO production

It is important to predict behavior of systems using modeling in the phase when they are under development and therefore cannot be examined experimentally (Stepina and Stalidzans, 2010). The process begins with the abstract design and specification of devices, modules, or organisms, and is often guided by mathematical models where parameters of organisms and devices are described. However, such initial attempts rarely yield fully functional implementations due to incomplete biological information (Andrianantoandro et al., 2006). It is possible to create the model in many ways, e.g. at genome level or at metabolic network level. There are

different software tools for it. For genome level modeling such tools as Tinkercell, Genocad, Genedesigner and others can be used. That can help understand how a modified gene should work, is it possible to make such modification and are the correct genes chosen.

Various computational methods are based on constraint-based modeling, which allows to predict the effect of genetic manipulations on cellular metabolism considering a genome- scale metabolic network (Tepper and Shlomi, 2010). For constraint-based metabolic network modeling can be used tools like Cobra, Copasi, Metatool and many others. They can be used on different levels of modeling - stoichiometry, dynamic modeling, and elementary mode analysis. This is the level of metabolic reconstruction of the whole organism or a part of it. Using these methods it is possible to understand how organisms will work after modification, will metabolic network supply all necessary compounds and how metabolic kinetics works and how much possible metabolic pathways are presented. Each of these methods employs an optimization problem that searches for a specific genetic manipulation that would lead to a possible metabolic flux distribution, which maximizes the production rate of a chemical of interest (Tepper and Shlomi, 2010).

After genome level modeling is complete, next step is inserting genes or chemical reactions that represent these genes into metabolic network model (Fig. 1). Metabolic network model or metabolic reconstruction model shows all possible chemical reaction in the organism or in the part of organism. If this model is developed in sufficient level and satisfies defined criteria, there can be implemented new functionality. If the model shows that there are some gaps in the network, different tools can be used to predict possible compounds and reactions that can be implemented into model, e.g. GapFill, OptKnock. That allows simplifying the model - deleting unnecessary reactions, removing deadends and cycles in the network, getting better flow through chemical network. In the end that brings a list of reactions which can be removed and which can be inserted into organism and a list of corresponding genes.

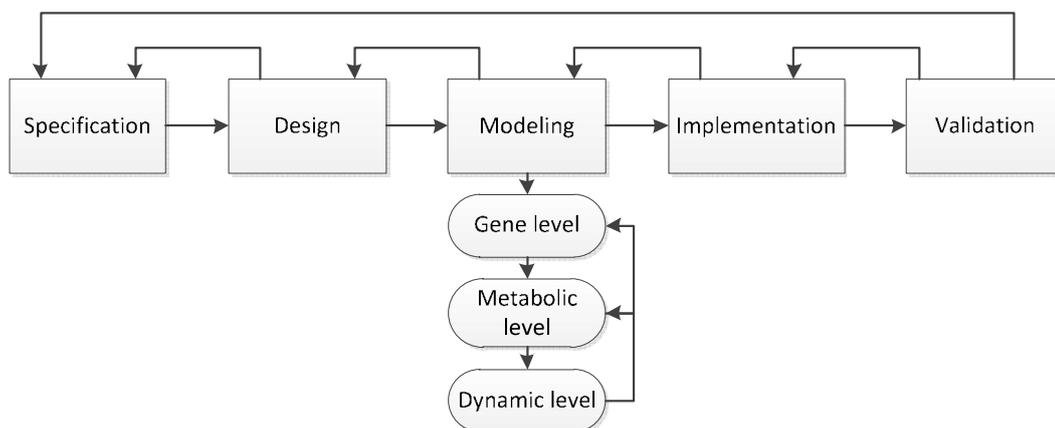


Figure 1. Iterations of GMO development process

When all necessary modifications in metabolic network are completed it is possible to make dynamic analysis of kinetic parameters of the organism. During dynamic analysis parameters estimation and optimization are made. It can show how modified organisms can behave in time scale and return data of compounds concentrations. Also it is possible to achieve necessary parameters of reactions speed and enzymes concentrations. After each modeling step it is possible to return to the previous step to improve the model.

When all parameters are obtained it is possible to make biological experiment in the lab based on the achieved data. After the modification all modified organisms are separated from unmodified. That can be done using additional markers. After that it is possible to make an analysis of microorganisms – do the planned function according specification or not. That gives back experimental data that can be used in optimization. All data can be used to make modeling process and modification process until the best result will be achieved. It depends on quality of the model and accuracy of biological modification.

Next step is validation or testing of the organism to compare it with a specification. If there are some differences in the specification and the real organisms that mean that there are some errors in others steps of the process. It is possible to make experiments with modified organism in flask at first to understand how organisms behave under specific conditions and then make cultivation in a bioreactor to test industrial production. Results between experiments in flask and bioreactor may vary because of different parameters of the environment. It is a good practice to make a design of the experiment before starting a cultivation (Tye, 2004). That can help cover all possible parameters and reduce the count of physical experiments. Also during cultivation processes the model of the process can help check how microorganisms behave under given conditions. Such model can take into account all parameters of the process and recognize the differences between the planned processes and a real one. If physical process matches with data from the model it can be assumed that the modification of the organism is made successfully.

During each start of modeling process it is necessary to mark start parameters and in the end to mark end parameters to get information about changes. Also the result of model should be marked. In case when many models are running in the same time, e.g. for optimization or parameter estimation processes, parameters of each running model should be marked. This approach can help track changes in each model and the obtained results. Data exchange format should be taken into account between different software because at this step gaps in data can occur, even if one data standard, e.g. SBML, is used. During a physical experiment even when it is happening according to the protocol, each parameter of the process should be noted so it would be possible to repeat this experiment in the future.

It is also possible to implement cost calculation for modification into the model. If the quality of the final result and costs of the modification process is satisfying, real experiment can be started. If in the beginning of the process prediction is that it cannot return investments, it is desirable to think about making this kind of research project. If the goal of the project is to get profit but the model of all processes shows that it is not possible, it is needed to examine all the aspects of the project and make some changes in it or decline it.

Conclusions

Genetically modified organisms production is an interactive process where can be used many approaches from software engineering. Steps of software development can be performed to create new functionality of microorganisms in the similar way how new software extends functionality of the computer. Also computer modeling can be performing to create the model or prototype of organisms to see how it should work.

Computational modeling in metabolic engineering has traditionally been used to guide experimental attempts by predict the effect of genetic modifications on metabolism. Modeling involves the prediction of genetic manipulations that would lead to optimized microbial strains, maximizing the production rate for chemicals of interest (Tepper and Shlomi, 2010). From an engineering perspective, mathematical modeling is one of the most successful scientific tools available for this task. Starting with the modeling process for a given complex system the aim of the model should be specified. Rational design based on mathematical models improves system behavior during new system development (Andrianantoandro et al., 2006). The development of large models must be supported by tools that help keeping track of all the structural assumptions and enzyme kinetic terms in the model (Wiechert, 2002).

Each change in data during modeling process should be carefully documented. Also process of data transfer from one step to another should be documented. All, even small, changes in the process should be taken into account, e.g. which parameters are changed in the model during each launch and when it was made, what are the results of these changes. That can help to analyze results of changes and understand which changes are excess and minimize their count doing only needed of them. That can reduce time consuming and reduce costs of the process. The journal of changes should be accessible for all participants of the process- modeler, genetics, and biologists. Also that can help find errors in the process and avoid them.

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THE CONCEPT OF METABOLIC ENGINEERING SOFTWARE TOOL

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Abstract: *Computational tools are indispensable for any modern engineering disciplines. With synthetic biology as a new scientific field, it clearly needs computational tools to help in design and modeling process. Many algorithms and tools were developed for synthetic organisms engineering. The generation of novel metabolic pathways involves compounds that exist in biological databases and compounds that are suggested by special algorithms. As a result a model with a list of all necessary changes will be obtained. There is presented a concept of data flows and a workflow of a system that can realize such functionality as stoichiometric and elementary modes analysis, optimization and novel biochemical network dynamic analysis.*

Keywords: software tool, metabolic engineering

Introduction

Over the last few years a number of methods and algorithms have been proposed for the analysis and generation of possible pathways for the production of a product from given set of starting substrates using a set of known biochemical reactions and compounds (Blum and Kohlbacher 2008; Heath et al. 2010; Finley et al. 2009; Wang et al., 2006) They are used to discover orphan reactions and enzymes, for gap-filling in metabolic pathways, new pathways generation and other functions. The generation of pathways involves compounds that exist in biological databases, as well as compounds, suggesting novel biochemical routes for these compounds. But such algorithms usually do not allow implementing the result into existing models of organism and making stoichiometric and dynamic analysis of whole organism model. Also not always it is shown, genes from which organism are used to create the metabolic pathway.

Therefore it is necessary to develop the methodology and the software package that allows creating necessary metabolic reaction list to produce a product from a substrate. It should show which minimal set of reactions should be implemented into the organisms to achieve the necessary result based on different constrains and rules, i.e. present substrates, substrate expenses, reaction rates, potential revenue etc. (Carbonell et al., 2012). Important item is the production rate of a substrate which determines the economic feasibility of industrial process (Mozga and Stalidzans, 2011a; Lee et al., 2008). The aim is to develop concept of a system that will have wide functionality, e. g. specified format support for metabolic networks definition, searching of specific chemical reactions to convert a substrate into a product, possible reaction implementation in the metabolic network, constraint based analysis (economic factors, available substrates, specific organism etc.), possibility to knockout specific reactions, conversation options to different model notations, stoichiometric and dynamic analysis, using of common notation for reactions, automatic parameter estimation from online data bases.

At this moment there are many tools that have partly similar functionality to the described tool concept. But usually they have only some specific functionality and returned data sometimes is hard to use in other tools. The problem is that not all tools use one specific data format, for example SBML (Hucka et al. 2003) or SBOL (Rodriguez et al. 2009). In addition data processing can take long time in case of using of different software, e.g., Metaroute (Blum and Kohlbacher, 2008), Copasi (Hoops et al., 2006), Cobra (Becker et al., 2007) etc. The main goal of described tool is to allow user easily work with data and models, make corrections and search data to receive necessary result.

Architecture of the system

In order to perform given tasks, it is important to choose the correct architecture and functional modules of the system. The choice of the optimal architecture in the future will allow making changes and expanding the system with additional functional modules. Also, the module type system allows changing of the structure of the system. The system will consist of different modules or plugins (Figure 1). Each of them will respond for additional functionality. It will be possible to add or delete plugins or modules to expand the functionality of the system.

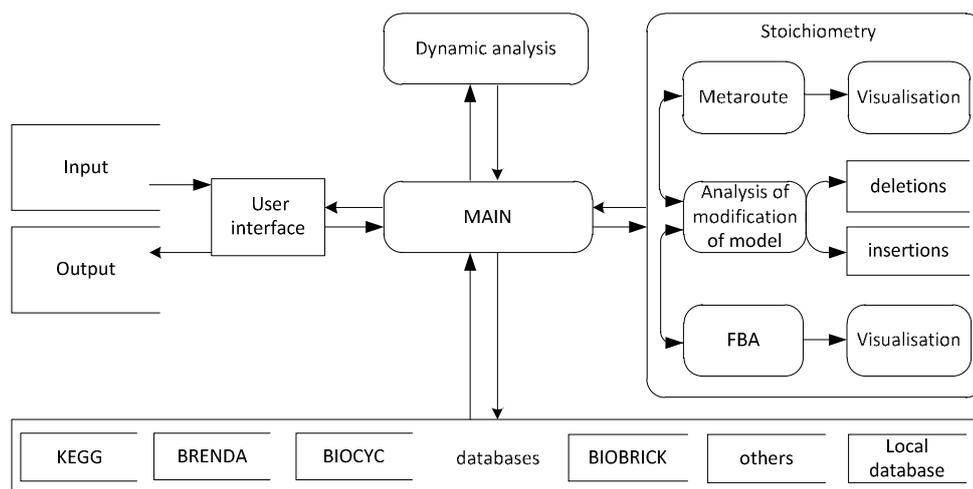


Fig. 1. Structure of the system.

The main notations for metabolic network model description are SBML (Hucka et al., 2003), SBOL (Rodriguez et al., 2009). It is necessary to develop separate algorithms for automatic model converting to one notation. For the user it is possible to input metabolic networks in different formats. It is possible for the user to choose the output format of metabolic network.

The main system module is responsible for all processes in the system – it provides connections with databases, reads and process data, and returns it in optimized format. It controls metabolic pathway search, stoichiometric analysis, modifications of the metabolic network, calculates flux balance analysis depending on parameters of the system, provides dynamic analysis and returns output result to the user. Main module can launch different other applications, for example Matlab to launch Cobra toolbox for FBA (Becker et al., 2007) or Paint4Net for visualization of the metabolic network.

It is possible to use separate software modules. Each component of the system should be like a separate module that can be installed or uninstalled from the system. It allows changing software components easily, it will not be necessary to change all source code. It will be possible to develop other necessary modules and add them to the system, i.e. integration with other software tools. For integration with other tool additional modules can be developed.

User interface will allow users to input data and parameters of metabolic network. Also it will allow choosing output parameters of modeling results. It will visualize modeling process and its results and show all the pathways in the system and control parameters. It will be WEB UI with client – server architecture. Users can open web interface and work with the system via Internet. It will be also possible to get a local version of the system, to install it on a local server. It should be configured for local database and Internet connection.

Communication with databases

Main functionality is separated to different parts. The first part is connection to databases using web services and APIs from databases (e.g. WSDL or SOAP). It is possible to receive information about reactions, metabolites, pathways and others. Connection to each database should be made separately to provide system safety in case of error in connection. Each database stores different type of information and it is useful to use different databases to get complete information, e.g. KEGG is a bioinformatics database containing information on genes, proteins, reactions, and pathways (Ogata et al., 1999), BRENDA is a comprehensive enzyme database (I. Schomburg et al., 2002), BioCyc is a collection of pathways and genomes databases, MetaCyc is an encyclopedia of experimentally defined metabolic pathways and enzymes that contains pathways from different organisms and metabolic reactions (Caspi et al., 2008).

To work with each database additional data class should be used to convert information from different database to one data format. That can allow to separate data reading and processing logic from other functionality of the system. To reduce data from data bases reading time it will be possible to cache data in local database, if this data is not being used for some time. Some information can be stored in the local database for a long time if this data is used often. That can allow reducing count of requests into database. The local database can be developed using different engines, e.g. the most popular free engines MySQL, Postgres, Firebird, MS SQL Express.

It is necessary to go through many steps to analyze metabolic network – find pathways from substrate metabolites to products depending on input parameters, model optimization, flux balance analysis and dynamic analysis (Palsson et al., 2003). Metabolic pathways analyzing module searches metabolic pathways from substrate to product based on input parameters included specific reaction and search results. There it is possible to choose specific microorganisms where algorithm should search for pathways (Blum and Kohlbacher, 2008b).

Performance of stoichiometric and dynamic analysis

During previous step the best pathway between product and substrate is chosen. The next step is optimization of the metabolic network. In this step new pathways are inserted into the metabolic network. It is possible to use additional algorithms to optimize metabolic network, i.e. to identify the optimal metabolic and regulatory gene deletions as well as gene over expressions that maximize biochemical production at the maximum cellular growth under transcriptional regulatory constraints (Burgard et al., 2003; Kim et al., 2010; Ranganathan et al., 2010).

The next step is FBA. One of these steps is flux balance analysis for analyzing the flow of metabolites through a metabolic network. Flux-balance analysis based on linear optimization is widely used to compute metabolic fluxes in large metabolic networks and gains increasingly importance in network curation and structural analysis. There are many algorithms and tools for flux balance analysis (e.g. Cobra, OptFlux, FluxAnalyzer and others (Becker et al., 2007; I. Rocha et al., 2010; Klamt et al., 2003)).

Different types of visualization can be used for metabolic network visualization – all metabolic network, selected pathway, selected reaction or metabolite depending on user selection. Also it will be possible to export graphical information for external software, e.g. Graphviz or Paint4Net (Kostromins et al., 2012b). Selecting each element of metabolic network will make additional windows open with detailed information about the selected element. In the future it is planned to enable the deletion of reactions or pathways in graphical way during visualization of all metabolic networks or their part.

For a dynamic analysis software tool Copasi can be used – ready metabolic model after stoichiometric analysis in SBML format can be exported to Copasi. It is possible to use Copasi in two ways – using user interface and in batch mode (Hoops et al., 2006). In this system batch mode can be used to launch analysis in background mode and receive only the results. Using the UI of system it will be possible to change parameters of the dynamic analysis. COPASI can be used both for parameter estimation and optimization of dynamic model. Software ConvAn (Kostromins et al., 2012a) can be used to rationalize the time resources needed for optimization (Mozga and Stalidzans, 2011b). After the analysis of dynamic properties the output result can be returned to the user.

The output is an ideal metabolic network model in the format that chooses the user and the list of reactions and genes that should be added and deleted from the microorganism. It will be possible to save imported metabolic networks into the local database. It allows to use preceding results in the future work.

Conclusions

The concept of a software tool for biochemical network analysis and modeling is presented. This software tool can be useful in many research fields and it allows achieving the necessary results using limited number of tools. There are many different tools but usually they use different data format and cannot exchange results without adaptation. The described tool should implement possibilities to convert different data formats.

The concept of the described system is developed and possible realization components are discussed. Were shown functionality and algorithms that should be implemented in this system. In this paper were shown possible fields of use for such system.

The system is in a development stage and different models of the system are developed. Next steps are to connect all functionality in a common system. The novelty of such system is that in input parameters economic factors can be used, e.g. expenses of substrates and products, organism modification costs etc. That will allow researcher to find possible options for modification of microorganism and to predict results in the form of a model. It allows to decide in the early stage of modification project if it can bring in a profit and will this project be successful or not.

Acknowledgments

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ICT IN AGROMETRICS STUDIES

E-COURSE: WEB-RESOURCE FOR ON-LINE SUPPORT OF IT-STUDENTS STUDYING ENGLISH LANGUAGE

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Abstract: *The web-resource for on-line study of English language that was specially developed to meet needs of undergraduate students of IT-specialties is presented in this article. The structure of the web-resource and the specificity of both the development and the use of the e-Course are discussed as well.*

Keywords: ICT in education, web-resource, blended learning, teaching of English.

Introduction

The level of English language skills becomes more and more crucial for employability of graduates of technical universities in Ukraine, especially for graduates of IT-specialties. This tendency explains by the rise of a number of IT-companies working in Ukraine for European and American customers. To ensure effective work of software developers' teams with English-speaking customers, IT-companies hire software engineers, testers and developers taking into account not only their professional skills, but also English skills. This demand of modern IT-labour market leads to rise of motivation of IT-students to learn English language.

At the same time the majority of first-year students of Bachelor programs in IT area has insufficient level of English. This is because these students are internally aimed at studying mathematics, programming and technical subjects, but they aren't interested much in studying humanitarian disciplines, including foreign languages.

Moreover, not all students studied English language in a school. Ukrainian schools provide teaching of the wide range of foreign languages: German, French, Spanish, etc. However English language is a standard de-facto for the area of IT. All the documentation on a developed software application is presented in English usually. So, to get at least basic level of English, while studying in a university, is important for those IT-students who didn't learn English in a school. The task for university teachers of English is to help IT-students in developing their English language skills in order to meet the demands of labour market.

To support IT-students in enhancement of their level of English skills, the special web-resource “e-Course” (<http://english.eec.kpi.ua>) has been developed at the Faculty of Applied Mathematics of the National Technical University of Ukraine “Kyiv Polytechnic Institute” (NTUU “KPI”). The e-Course of English allows students to have access to teaching materials, listen to dialogs, watch video in English, perform exercises and test own knowledge. It is suitable for IT-students, whether they are preparing for the examination or aiming to improve and extend their English for personal or professional reasons.

E-Course Structure

Since the e-Course (<http://english.eec.kpi.ua>) is designed to meet the needs of the students of the Faculty of Applied Mathematics of NTUU “KPI”, it includes modules related to the following profession-oriented subjects: Discrete Mathematics, Programming, Multimedia in Computer Systems, Information Security and Cryptography, Computer Systems. However modules for other subjects can be easily added into this web-resource.

Each of the 25 units in the e-Course is based on different topics of profession-oriented subjects and contains exercises and activities that concentrate on different skills, helping students to revise and consolidate what they already know and to develop and extend their knowledge further.

The functionality of the e-Course (fig. 1) includes:

- Units and modules creation and update;
- Timetable modification;
- Vocabulary creation and update;
- Students' groups management;
- Users' profiles management;
- Tests automatic check-up;
- News creation and update;
- Video lessons download.

The content of the e-Course is accessible for registered users only. All registered users belong to one of the following groups:

1. Students;
2. Teachers;

3. Administrators.

Different categories of users have access to different content and functionality.

Students are allowed to access to lessons modules, video lessons, vocabulary, timetable and their own profiles with personal data and test results.



Fig. 1. E-Course: a home web-page (<http://english.eec.kpi.ua>).

Teachers have access to the wide range of web-pages in edit mode, including web-pages of lessons modules, video lessons, vocabulary, timetable as well as to groups list, students’ test results and their own profiles with personal data.

Administrators have rights to access all web-pages. Usually only one administrator is necessary to manage this web-resource.

E-Course Development Specificity

The developed web-resource for English language learning and self-testing is a web-site. The application structure corresponds to a web-recourse structure shown in fig. 2.

The server script language PHP (Reiersøl et.al., 2007) and CodeIgniter (Upton, 2007) framework were used for the development of the server side.

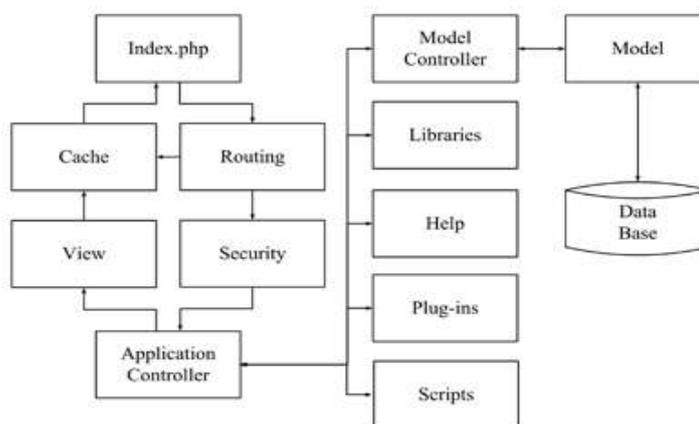


Fig. 2. A web-resource structure.

The framework CodeIgniter includes the most of necessary libraries for the work with files, emailing, check-up of data forms, sessions support, work with images, etc. This framework also has easy expandable architecture and allows connection of own libraries and plug-ins. The main specificity of the framework CodeIgniter is compliance with design architecture “Model-View-Controller” (MVC). This architecture provides separation of the data model, user interface and control logic into three different components in order to minimize influence of modifications in one of the components to the rest of the system. The model objects perform loading and storing data in relational database as well as they realize the business-logic. The view creates user interface for visualization of the data received from the controller. It also passes user’s requests for data processing into the controller. The controller is a main component responsible for interaction with a user. The controller gets necessary data from the model and prepares them for visualization as well as stores data received from a user

into the model. The purpose of the MVC template is a flexible design of software that simplifies further changes and modifications as well as gives a possibility of reuse of some software components.

HTML was used for visualization of the results of the application work. HTML code is interpreting by a browser and visualizing as a document in a form convenient for a user.

The Cascading Style Sheets (CSS) technology was used for forming of the documents view. It allows to define elements of web-pages design.

The script programming language Javascript and the library JQuery is used to solve tasks related to dynamic change of web-pages content. JavaScript is used as an embedded language for software access to objects of HTML documents as well as a language of scenarios for adding of web-pages interaction. The library jQuery focuses on JavaScript and HTML interaction and helps to get the access to any element of HTML-document easy, refer to attributes and elements content, manipulate with them, add graphical effects as well as it helps to send data from a browser to a server and back without refreshing a web-page by a uses.

There are no pre-requirements for the use of the developed web-resource, only the access to Internet is necessary. The e-Course is compatible with all widely-used browsers (MS Internet Explorer, Mozilla Firefox, Opera, Google Chrome). Informational security of the system is realized by means of access rights separation.

Work with e-Course

Users' registration process is organized in the following way. An administrator registers teachers only. When a university course of English starts, students have to register themselves using a link "Registration" at the home page of the e-Course (<http://english.eec.kpi.ua>). Their records are saved in the system, but require confirmation by teacher to avoid false registrations. Once a teacher has confirmed records of an academic group, students can begin to use the e-Course.

The functionality of the e-Course was designed in such a way to do work in this environment easy for English teachers who usually aren't much experienced PC users. Main actions assigned to teachers in the e-Course are:

- Creation and modification of lessons;
- Creation and modification of vocabulary;
- Creation and modification of news (notices for students);
- Confirmation of students' registration;
- Confirmation of the results of tests automatic check-up.

A lesson editing web-page (fig. 3) has intuitive user interface. A template is used for lessons creation. The following main types of assignments are predefined in the template:

1. Vocabulary and grammar in use;
2. Reading comprehension;
3. Writing an essay.

A teacher sets correct answers in a lesson unit for those assignments, which can be checked in automatic way ("Vocabulary and grammar in use" and "Reading comprehension"). An essay can't be checked automatically.

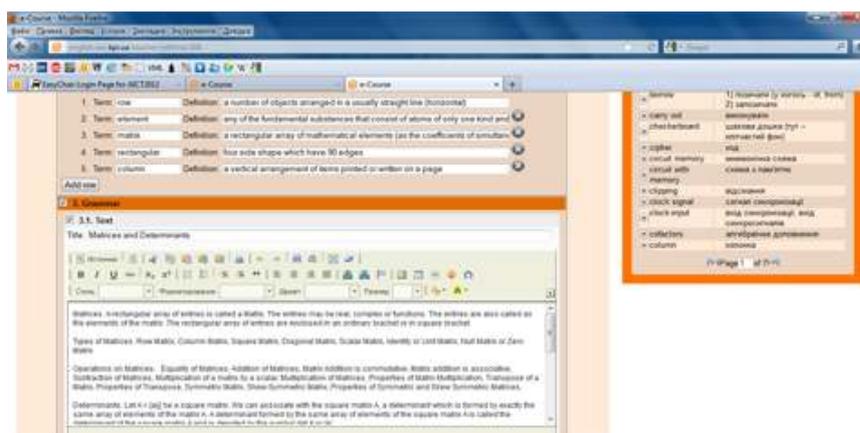


Fig. 3. E-Course: a web-page of a lesson editing.

To support students with better feedback, a teacher monitors the results of the tests automatic check-up and confirms their correctness. Once this confirmation has been done the result of a student's test becomes available in a profile of this student. The student can see only own results, but the teacher has access to all the records of the students' group. To systematize students' results each teacher has the possibility to look through the tables with students' grades ordered by academic groups as well as the results of exercises fulfillment by each student separately.

Video lessons allow to widen the range of available types of assignments. A video lesson is a .flv file that can be easily uploaded from a disk of a teacher's PC into the server. Each video lesson can be followed by any necessary text (comments, questions, assignments, etc.).

News is accessible for all visitors of this web-resource. This was done intentionally, because students are too lazy sometimes to login daily into the system for checking whether new teacher's notices are available.

Discussion of e-Course

The e-Course should be discussed from two points of view:

1. As an application developed by students;
2. As a web-resource developed for students.

From the first point of view the e-Course is a Diploma project fulfilled by two students, who study computer engineering. They developed the functionality of the web-resource built as a client-server application. However, some other students also took part in this project. Five students were involved into the web-pages content makeup and design. Two students were responsible for the creation of audio files for the vocabulary. As the result of this collaborative work all the students obtained positive experience of team work.

From the second point of view the e-Course is an effective tool for on-line teachers' support of educational process. It can be used for blended learning as an additional component of students' unsupervised work. The term "Blended Learning" means the combination of e-learning and face-to-face learning. Many researchers consider blended learning as a good alternative to a "pure" e-learning (Bersin, 2004; Bonk et.al., 2006; Sulema, 2004; Sulema, 2006). In particular Bersin (Bersin, 2004) gives the recommendations on the possible models of blended learning; Bonk and Graham (Bonk et.al., 2006) gives examples of good practices on blended learning application. Thus, the e-Course can be especially useful for students who study by correspondence.

The first practical experience of the e-Course use has shown that the most popular feature of this web-resource among different groups of students is the vocabulary, because it can be used not only for the assignments fulfillment, but also for translation of the wide range of technical texts in IT area.

The most important feature of the e-Course consists in the following: it has been designed as a framework that allows easy transition to other languages. Thus, it can be modified into the e-Course of German, French or any other foreign language. The only limitation is that the structure of the lesson template is predefined.

Conclusion

The developed web-resource provides undergraduate students of IT-specialties with on-line support of their English studies. The functionality of the e-Course allows to add new modules and in this way adapt it to specificity of other technical specialities. In particular the vocabulary can be modified in order to cover other professional areas. The e-Course can be also modified for study of other languages. Moreover, the e-Course can be considered as an example of positive experience of students' team work.

Acknowledgements

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IMPLEMENTING THE PRACTICAL APPLICATION OF MATHEMATICS IN E-LEARNING USING MULTI-DOMAIN PROBLEM SOLVING

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Abstract: *Organizing study process in mathematics, we face two major problems. First, engineers do not apply directly the problem solving skills of higher mathematics. Usually the problem is defined, mathematical equations are created, IT software is used for calculations and problem solving. This means that students need skills to use IT programs as well as knowledge of mathematics, to understand software operations. Second, studying higher mathematics, students get an insufficient idea of its usability. This means that it is necessary to include the use of mathematics in the study process. The purpose of this paper is to find the way how to organize the self-directed study of mathematics' practical application based on didactic approach and e-learning features.. As practical example for self-directed study organization we chose Moodle computerized learning system (CMS), which is one of the main teaching tools in Latvia University of Agriculture. Moodle has two main tools for problem solution mentioned before – the glossary auto-linking filter and the lesson module. Combination of these tools can improve usability of mathematics in specific subjects and students' knowledge about mathematical operations in their learning subject.*

Keywords: mathematical application, self-directed learning, e-learning

Introduction

Mathematics studies have both a direct and indirect impact on the development of outcomes necessary for university graduates. First, Mathematics serves as a tool for solving and calculating various problems. But much greater is indirect impact of mathematics which provides the other outcomes such as development of skills to formulate and solve problems. Competencies of the future specialist, which are connected to his/her future working area, are also established:

1. Practical implementation (technical specialist).
2. Theoretical perception (engineer-integrator).
3. Creativity and novelty (engineer-performer of the changes). (ABET, 2006)

The results of the research regarding employers' opinion about importance of mathematics studies in higher education show that studying higher mathematics students get an insufficient idea of its usability. Therefore, organization of the mathematics study process is very import. Two main problems hamper improvement of the mathematics study process at university:

1. The number of ECTS has been reduced in mathematics and there is no time to solve practical mathematical tasks;
2. Teachers of mathematics as nonprofessionals are supposed to explain technical concepts which have been taken out of the context and therefore they are not easy understandable for students.

Implementation of the practical application of mathematics in the study course can be done using e-learning tools for self-directed study process organization. The purpose of this paper is to attract the attention to the potential of auto-linking mechanism which allows select proper information resources automatically from knowledge repository. Auto-linking is the mechanism that determines automatically which libraries to link while building C or C++ programs. Inspired by this idea we wanted to implement auto-linking feature in multi-domain problem solving.

Materials and methods

Mathematics studies have both a direct and indirect impact on the development of the necessary outcomes. First, Mathematics serves as a tool for solving and calculating various problems. But much greater is the role of indirect impact of Mathematics which provides such outcomes like formulate and solve problems. For developing the ability to solve problems it is necessary: 1) the knowledge; 2) the ability to formulate a problem in cognitive sphere; 3) the ability to construct the solution of a problem; 4) the ability to apply a constructive solution of a problem to the real situation. In mathematics study process the skills are trained to directly apply the formal rules, which are sometimes quite abstract and complex, demanding to choose exactly that one which is necessary from the long list of known rules to complete the task, to build a sequence of applicable regulations. (Zeidmane, 2011). Organizing study process in mathematics, we face two major problems. First, specialists in manufacturing do not apply directly the skills of solving problems of higher mathematics. Usually the problem is defined, Mathematical equations are created, but IT software is used for calculations. This means that students need skills to use IT programs as well as knowledge of mathematics, to ensure understanding of what IT

programs do. Second, studying higher mathematics, students get an insufficient idea of its usability. This means that it is necessary to include the use of mathematics in the study process.

In order to satisfy the above-mentioned problems in mathematics, in accordance with the requirements of the Bologna process, the mathematics curriculum must be developed in compliance with the credit-module system. The term "**module**" in the Longman Dictionary of Contemporary English is explained as one of the units that a course of study has been divided into, each of which can be studied separately. The objective of a study module is to provide definite knowledge and skills which are realized integrating separately differentiated study modules.

Study modules contain certain information, they are mutually coordinated (have an entrance and exit) and they are coordinated with professional and didactic tasks (Zeidmane and Vintere, 2009).

In the authors' opinion it is necessary to form modules for separate study subjects by elements and approaches. Therefore the course of mathematics was designed according to **study module** principle (Zeidmane, 2003). For realizing separate subject syllabus development we can divide the study process into STUDY FORMS modules, for realizing cognitive development we can divide the study process into STUDY CONTENT modules. In order to optimize the study process in mathematics the following should be observed which can be seen in Figure 1:

1. The course should be divided into separate themes ("The **TITLE**"), the sequence of which is appropriate to the logic of the given science;
2. The goal of this module **BACKGROUND KNOWLEDGE** is to indicate, which questions should be known in order to follow the solution of the scheme successfully. Thus this module is structured into *methods, concepts, and regularities*;

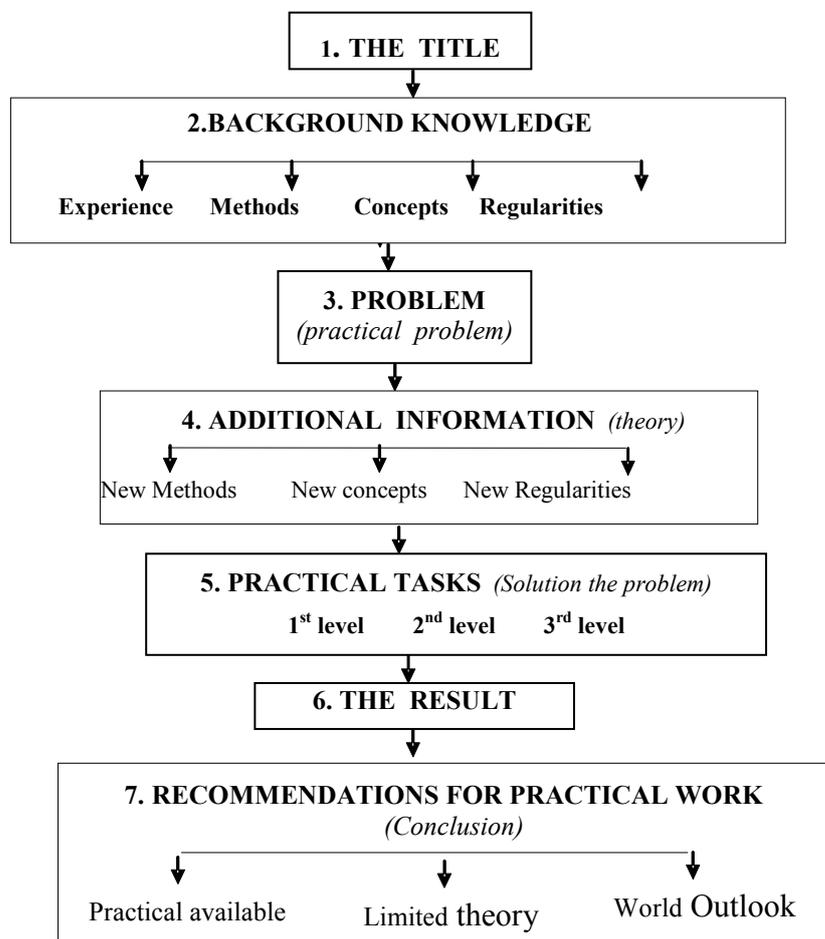


Fig. 1. Structural scheme of study matter modules

3. In the module PROBLEM it is important to formulate the problem, including: 1) motivation, why this problem exists or why it is not sufficient with background knowledge to acquire the given theme; 2) concise and clear formulation of the problem, so that the module theme solution could solve this problem.

4. The module ADDITIONAL INFORMATION is considered as the continuation of the module BACKGROUND KNOWLEDGE. If the questions included in BACKGROUND KNOWLEDGE can't comply with the solution, then there is necessity to study new methods or come to an agreement about new concepts. This module contains also regularities, which are not learned before, but which will be necessary for the solution.
5. The module PRACTICAL TASKS as a logic solution of regularities is presented which is based on the background knowledge and additional information and that leads to the solution of the problem. It is very important divide task solving process in separate tasks.
6. The module THE RESULT is necessary to review a theme solution once more, shortly formulating concepts and laws, and classifying them according to causal relationship or analogy, thus encouraging the process of memorizing;
7. The perception of an individual is always selective and everyone in his/ her lifetime has created the evaluation criteria, according to which all new information is classified into significant, less significant and negligible. Consequently, the module RECOMMENDATIONS FOR PRACTICAL WORK or conclusion is considered to be of great importance.

Two major problems create obstacles in the implementation of the mathematical studies of the above mentioned modules: 1) The number of ECTS has been reduced in mathematics and there is no time to solve practical mathematical tasks; 2) Teachers of mathematics as nonprofessionals are supposed to explain technical concepts which has been taken out of the context and therefore they are not easy understandable for students. The solution will be to design the e-study materials which consist of the practical mathematics tasks and insert links to relevant explanations of terms.

Learning nowadays is connected with different information technologies. E-learning is one of modern approaches in education field. The introduction of e-studies in the higher educational establishments does not mean only the creation of data basis which provides access to materials (Kellner, 2001). It also requires the organization of new teaching forms as well as a new way of assessing the acquired level of knowledge. E-learning gives opportunity to follow up every student, his/her abilities, requirements and deliver to him/her only the information he/she wants. In fact, combined teaching is used in the studies – work in the lecture-room is combined with the work on e-learning website. In such case, students can benefit from e-learning technologies and interact with teacher or other students. E-learning part brings adaptive ability in exercises. Thus with planning, e-learning can customize given content to each student with no further action required by the teacher, but the same time can improve outcomes of learning process. That makes online learning more effective and gives extra advantage in face to face learning. For using e-learning materials, students have to obtain the skills of self-directed studies, which raise students' responsibility for the learning process and promote the ability to acquire knowledge, skills and abilities independently. Students take part in the setting the study aim themselves, they plan the acquisition of the theme, create presentations, as well as evaluate their own work and then agree about the final assessment with teachers and their colleges. Teacher only marks the "cognition steps" in this process.

In order to raise the student's accountability for the study process and facilitate the ability for independent learning it is of a paramount importance to create intrinsic environment for self-motivated studies. The students themselves are involved in setting their objectives, plan the study process, presentations, as well as evaluate their work and together with course mentors and lecturers agree on the final assessment. (Lamb, 2008). Consequently, the self-motivated studies are defined as the student's active participation in the creation of the study plan, as well as in the acquisition of knowledge and skills, and the assessment of their own results. (Gibbon, 2009). Students are more aware of the study process and the expected results; they have greater self-evaluation skills, determination, intrinsic motivation and responsibility. Everyone has to be able to analyze his/her own input in the creation of the process and determine his/her own stumbling blocks which blocked the way for the development.

E-learning is learning (self-education, study) through electronic teaching tool, books, textbooks, that can be distributed in various ways and the educated can obtain study materials and information also by means of new information and communication technologies. At the same time, it is based on voluntary approach, consciousness, responsibility and ambitions of an individual student who is self-responsible for the selection of his study materials, the way he/she studies, his/her specialization as well as the search for possibilities of obtaining a certificate for his/her knowledge. He/she himself/herself states (programmes) the goals of his education and adapts them to his/her needs, conditions, life rhythm and lifestyle. This form of education plays an important role in life-long education process, e-learning can be also a part of an organized form of study (education, learning), for example, distance learning as well as attendance form of study. (Čerņajeva S., Zeidmane, 2010).

Consequently, **self-directed** studies are students' active involvement and participation in the planning of the syllabus of the studies, acquisition of the knowledge and abilities and in the assessment of their own results. It requires greater understanding about the learning process, prospective results, self-evaluation abilities, determination, self-motivation, self-responsibility and self-movement. Each student must be able to analyze

his/her own yield in the creation of the work and determine their "stumbling blocks", which had been holding back from making progress in the studies.

The purpose of this paper is to find the way how to organize the self-directed study of mathematics' practical application based on didactic approach and e-learning features. To achieve this goal we chose Moodle computerized learning system (CMS), which is one of the largest e-learning systems (Lahins and Ezis, 2010) and Latvia University of Agriculture use this system as e-learning tool since September 2010. Moodle has two meanings, first of all it is Modular Object-Oriented Dynamic Learning Environment, and secondly, the word Moodle symbolizes lazily meandering through something that often leads to creativity. Moodle was created from teachers from teachers and its community has grown to two hundred millions of users. This community gives real power to create new features to Moodle and has translated it to more than 70 languages. Moodle has two main tools for problem's solution mentioned before – glossary auto-linking filter and lesson module, shown in Figure 2.

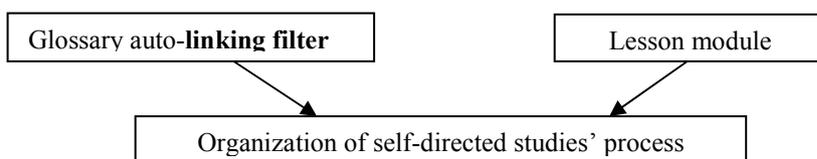


Fig. 2. The introduction of e-learning in the study process of the higher educational establishments

The Glossary activity is one of the Moodle features which can store a list of definitions for specific terms, it is like a vocabulary. Moodle's glossary can be used like a regular vocabulary, but there is extra possibility to link terms in text with Moodle's glossary. Glossary auto-linking filter is creating links to glossary activity entry where the word or phrase of the glossary entry is used within the same course in which glossary is located (Glossary auto-linking filter, 2011). When this setting is turned on, whenever a word from a Glossary appears in the course, it is highlighted in gray. Clicking on the word brings up a pop-up window containing the word's Glossary entry. Glossary also allows implementation of specific terms in the particular area in a practical task. Becoming an expert in specific area, like construction or software development, specialists are using terms by practitioners and experts in that area. Each Moodle has its own set of glossaries, and teacher can ask students to edit these terms and make extra activity for them. Teacher can edit and change every entry if students do some mistakes. The lesson module presents a series of HTML pages to the student who is usually asked to make some sort of choice underneath the content area (Lesson module, 2011). Each page of lesson module can have a button or a question at the bottom of the page, the next page in module depends on the answer or choice of student. The choice will send them to a specific page in the Lesson. In a Lesson page's simplest form, the student can select a continue button at the bottom of the page, which will send them to the next page in the Lesson. There is a hidden potential in this module that makes it much more interesting than it at first appears. It is possible to take advantage of the ability of each step to link to any other page, what is usable in several scenario simulations. This is not the case of this research, but could be a possible topic for next research activities.

Results and discussion

Organization of self-directed studies' process has been used to provide practical application of mathematics. For understanding practical application of mathematics it is necessary to have additional knowledge in specific terms and regularities. Often students need to refresh knowledge in mathematics. Therefore for creation of data basis with corresponding information resources we created a glossary with multi-domain terms and regularities in specific fields and mathematics in Moodle. This is just one of the Moodle feature filters, which provide extra possibilities for teachers. Filters are enabled by Moodle administrator and provide possibility to build in materials multimedia players, convert mathematical expressions or other features. This is great possibility for teachers to reduce their work but improve result of learning outcomes.

the Lesson module with scenario based steps and links to created glossary has been made for successful organization of self-directed studies, so that students can independently solve the problems using knowledge in mathematics. (See Figure 3).

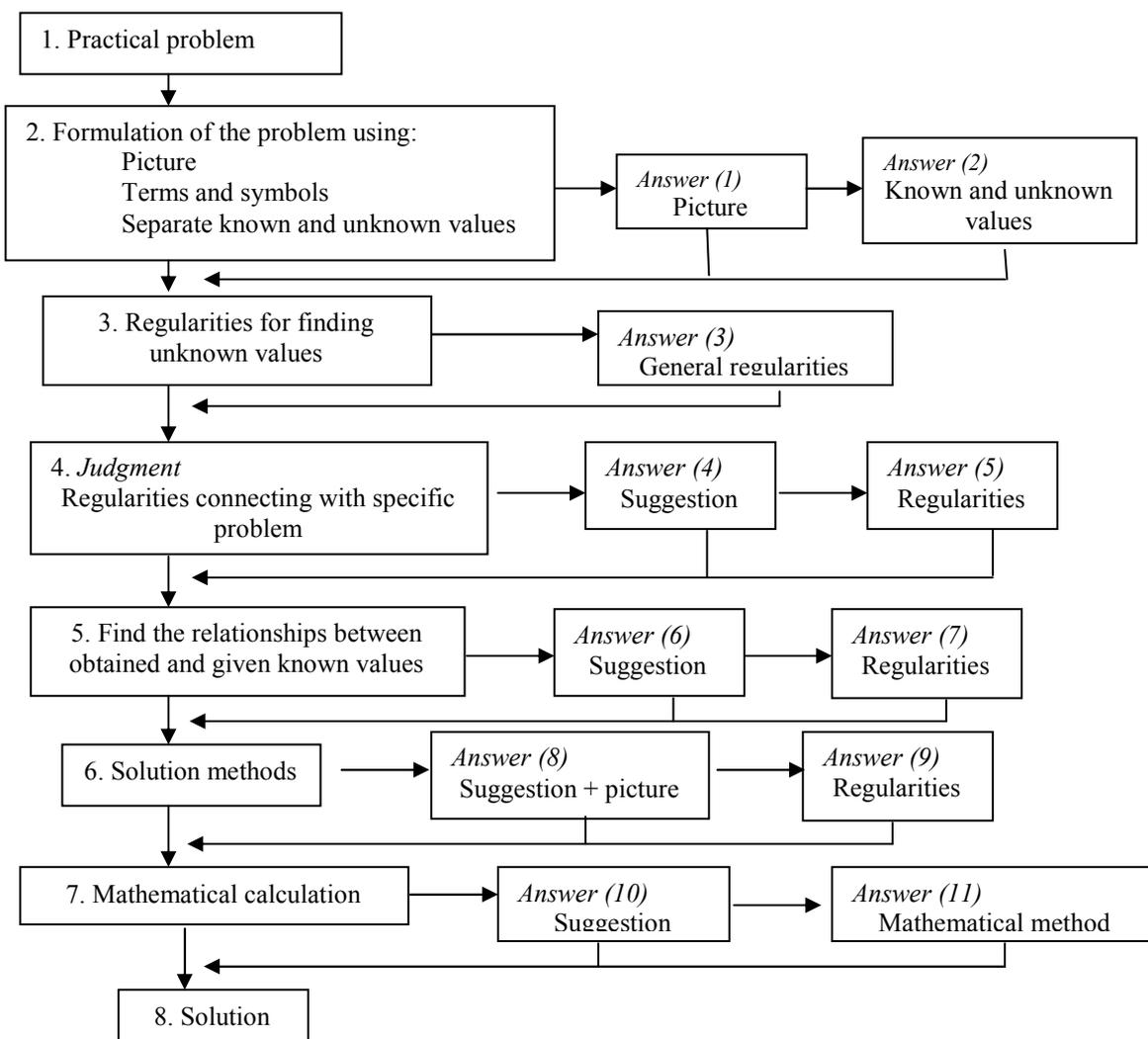


Fig. 3. Framework for organization of practical problem solving in mathematics

At first, students receive a practical problem from which they must express picture and task related values. If he/she has a problem to solve this step, he/she can get answer for each step separately. Each term that is related with specific area is linked with Moodle vocabulary. Such linked explanation can contain also links to other entries of glossary. The problem must be formulated by picture, terms and symbols and the known values must be separated from the unknown values. After problem formulation students have to express regularities for unknown values, respectively, the help with an included answer can be received. In this step just general regularities are expressed, but as regards the problem specific regularities, students must judge independently, again there is some problem for this solution, extra answers (Answer 4 and 5) can be received. When regularities are obtained, it is necessary to choose a correct solution method, for any case students have access to Answer 6, where correct mathematical method is given. Then it is necessary to find out relationship between the obtained and the given known value, extra regularities (Answer 7..n) are given for extra support. Next mathematical calculation follows giving problem solution for students, again this solution is given step by step to provide better explanation of calculation process; the mathematical calculation is supported by suggestions and mathematical methods to provide better explanation of the calculation process.

As a practical example the lesson activity exercise screenshots from Moodle e-learning environment of Latvia University of Agriculture is provided, where the student has to calculate the work which has to be done to sink cylindrical pudding below the water, which half sunken is floating in the water. This exercise is related to mathematics and physics, terms from physics are linked with Moodle glossary, but mathematical calculations and "cognition steps" are provided with lesson activity. In this case we did not give any questions in these steps, but just provided practical application steps in the exercise calculation. Because of the limits of publication we illustrate the main steps of practical task without extra answers and suggestions, see Figure 4:

Task

1. Practical problem

Calculate the work, which have to be done, to sink cylindrical pudding below the water, which is half-sunken floating in the water. Cylinder height H , cross-sectional area S , the water density ρ (cylinder symmetry axis is vertical)

Begin calculation

First step

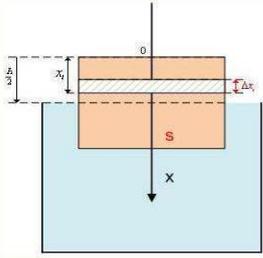
2. Formulation of the problem

For problem formulation you need to:

- Draw picture
- Set Terms and Symbols
- Seperate known and unknown values

Answer (1) Back to the task

Known and unknown values



Known:

- H - cylinder height
- S - Cross - sectional area
- ρ (ro) - water density

Unknown:

- $A = ?$ - work

Answer Back to task

Judgment

Making work for sinking cylindrical pudding below the water, must overcome the force of Archimedes (buoyancy) $F = F_A$

express force of Archimedes

Next

Expressed work

$$A = F_A \cdot x = m_{disp} \cdot g \cdot x$$

Next step

Relationships between obtained and given known values

Find relationships between obtained and given values

Known:	Unknown:
H - cylinder height	$A = ?$ - work
S - Cross - sectional area	
ρ (ro) - water density	

Answer Back to values

Suggestion 1

$$A = \rho \cdot S \cdot H_{disp} \cdot g \cdot x$$

choses $x_i = H_{disp}$ to the Ox axis

Next step

Suggestion 10

Final Solution:

$$A = \frac{\rho S g \cdot H^2}{8}$$

Turpinat

Fig. 4. Practical example of problem solving in mathematics

Conclusion

This paper presents the way how to organize the self-directed study of mathematics' practical application based on didactic approach and e-learning features. Nowadays is great possibility to use several IT software solutions for specific problem solving, but it is necessary keep student's competencies about operations which is included in such task solving. Students have to obtain the skills of self-directed studies, which raise students' responsibility for the learning process and promote the ability to acquire knowledge. E-learning is one of the best solutions to improve student's possibilities to organize their study process. As a practical example of e-learning possibilities we used Moodle system. We provided model glossary and lesson modules for practical applications of mathematics in problem solving. Model provided in Figure 3 allows students to engage applications of mathematics in practical examples and link them with particular study area. Such model brings extra benefits to teachers, allowing them just mark the "cognition steps" in this process and allow students organize the learning process by themselves.

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INTEGRATION OF SOME RATIONAL AND IRRATIONAL FUNCTIONS USING SOFTWARE “MATHCAD”

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Abstract: One of the most important classes of elementary functions, whose integrals can be found in comparatively simple way and always are elementary functions, are rational functions. Except for a few very special cases, currently we have no way to find the integral of a general rational function. In practicality, the method we shall develop is long and cumbersome, but the most important thing is that, in general, it will work. Before we start with the integration, we need to develop a method of reducing a rational function called the method of partial fractions. For evaluating some particular types of irrational functions our endeavour will be to arrive at a rational function through an appropriate substitution. We motivate our actions with the examples. Mathcad is one of popular computer algebra system. Math software and technology are helpful aide in teaching of Maths. Although for most problems we meet in teaching of Math it is enough to use computation ability, in certain cases the program function becomes necessary and very helpful.

Keywords: rational functions, irrational functions, integration, software “Mathcad”.

Introduction

Mathcad is studied in the course of higher mathematics. The most important in the course is to consider more complicated themes, for example, multiple integrals or differential equations. It is quite simple operation in Mathcad “find the indefinite integral symbolically”. So usually students consider only the indefinite integral symbol and few examples about this part of higher mathematics.

The lecturer does not have enough time for explanation about possibilities to evaluate the indefinite integral in Mathcad. More time usually spend to speak about definite integrals and multiple integrals. If we consider multiple integrals or solve differential equations we have indefinite integrals which Mathcad cannot calculate or solutions are complicated, for example, using special functions.

Integration of rational functions.

A rational function is a function which is the quotient of two polynomials. Any rational function (a ratio of polynomials) $\frac{P_n(x)}{P_m(x)}$ by expressing it as sum of polynomial $Q(x)$ and partial fractions

$$\frac{A}{x+a} + \frac{B}{(x+a)^k} + \frac{Ax+B}{x^2+px+q} + \frac{Ax+B}{(x^2+px+q)^k}$$

Consider integrals of the type $\int \frac{P(x)}{x^2+px+q} dx$ where $P(x)$ is a polynomial, $p, q \in \mathbb{R}$. If the degree of the polynomial $P(x)$ is greater than 1, the division of $P(x)$ by x^2+px+q results in a polynomial $Q(x)$ and a polynomial $ax+b$, as the remainder. Consequently $\frac{P(x)}{x^2+px+q} = Q(x) + \frac{ax+b}{x^2+px+q}$.

The integration of the polynomial $Q(x)$ does not present any difficulties and hence the problem reduces to integrating a fraction $\frac{ax+b}{x^2+px+q}$, if $a^2 + b^2 \neq 0$.

If $x^2+px+q = (x-x_1)(x-x_2)$, where x_1 and x_2 are two different real numbers, then there exist real constants A and B such that $\frac{ax+b}{x^2+px+q} = \frac{A}{x-x_1} + \frac{B}{x-x_2}$, what is useful for integration. Unknown constants A and B are found by “the method of indefinite coefficients”.

Example 1. Calculate $\int \frac{1}{x^2+px+q} dx$, where $p, q \in \mathbb{R}$.

We consider the case, that the polynomial x^2+px+q has a double root or is positive on an interval. Using software “Mathcad” for calculating this examples students have not problem with solutions. The result is given in easy to use form.

$$\int \frac{1}{x^2+2x+1} dx \rightarrow -\frac{1}{x+1}$$

or

$$\int \frac{1}{x^2 + 4x + 8} dx \rightarrow \frac{\operatorname{atan}\left(\frac{x}{2} + 1\right)}{2}$$

Remark. Remember that the computer algorithm might simplify expressions different from what we are used to. Also, it does not give the integration constant "+C".

If the polynomial $x^2 + px + q = (x - x_1)(x - x_2)$, where x_1 and x_2 are two different real numbers, then there exist real constants A and B such that $\frac{ax+b}{x^2+px+q} = \frac{A}{x-x_1} + \frac{B}{x-x_2}$, what is useful for integration. It is important for student to know about integration methods "the method of indefinite coefficients".

Example 2. Calculate the indefinite integral $\int \frac{dx}{x^2 - 3x + 2}$.

The polynomial $x^2 - 3x + 2$ has two different roots $x_1 = 1$, $x_2 = 2$ (both the real numbers). The result Mathcad gives is

$$\int \frac{1}{x^2 - 3x + 2} dx \rightarrow -2 \cdot \operatorname{atanh}(2x - 3)$$

The integration result has inverse hyperbolic tangent. This result is difficult for understanding for students. Almost all students do not know about the inverse hyperbolic tangent.

This rational function $\frac{1}{x^2 - 3x + 2}$ we can be written in the form of the partial fractions decomposition and then integrate new expressions. The result is easier to understand for students and to continue work with multiple integrals or differential equations.

$$\int \frac{dx}{x^2 - 3x + 2} = \int \left(\frac{1}{x-2} - \frac{1}{x-1} \right) dx = \ln|x-2| - \ln|x-1| + C$$

The similar result we give from Mathcad result using the formula

$$\operatorname{arctanh} x = \frac{1}{2} \ln \left| \frac{x+1}{x-1} \right|,$$

$$-2 \operatorname{arctanh} |2x-3| = -\ln \left| \frac{2x-2}{2x-4} \right| = -\ln \left| \frac{x-1}{x-2} \right| = \ln|x-2| - \ln|x-1|$$

These transformations require additional knowledge for students.

Using Mathcad functions (simplify, expand, factor, parfrac etc.) sometimes we can get the better result.

$$\int \frac{1}{x^2 - 3x + 2} dx \rightarrow -2 \cdot \operatorname{atanh}(2x - 3) \text{ simplify } \rightarrow \ln(4 - 2x) - \ln(2x - 2)$$

Working with Mathcad students can at first find a partial fractions decomposition for a given rational function (the Mathcad function parfrac) and then evaluate indefinite integrals.

$$f(x) := \frac{1}{x^2 - 3x + 2} \text{ parfrac } \rightarrow \frac{1}{x-2} - \frac{1}{x-1}$$

$$\int f(x) dx \rightarrow \ln(x-2) - \ln(x-1)$$

Example 3. Calculate the indefinite integral $\int \frac{x dx}{x^2 + x + 1}$.

The result Mathcad gives is

$$\int \frac{x}{x^2 + x + 1} dx \rightarrow \frac{\ln \left[\left(x + \frac{1}{2} \right)^2 + \frac{3}{4} \right]}{2} - \frac{\sqrt{3} \cdot \left[2 \cdot \operatorname{atan} \left[\frac{2 \cdot \sqrt{3} \cdot \left(x + \frac{1}{2} \right)}{3} \right] - \pi \right]}{6}$$

In this examples it is difficult to understand for students the inverse hyperbolic tangent and $-\pi$ as a part of constant C .

The examples were with polynomial with 2nd degree, in the similar way can calculate the indefinite integrals of rational functions $\int \frac{P(x)}{R(x)} dx$ where $P(x), R(x)$ are the polynomials in x .

Example 4. Calculate the indefinite integral $\int \frac{11x^3 - 107x + 108}{x^4 + x^3 - 30x^2 + 76x - 56} dx$.

If students integrate rational function as given in Mathcad it takes more time to get the result.

$$\int \frac{11x^3 - 107x + 108}{x^4 + x^3 - 30x^2 + 76x - 56} dx \rightarrow 7 \cdot \ln(x - 2) + 4 \cdot \ln(x + 7) - \frac{3 \cdot x - 7}{x^2 - 4x + 4}$$

The similar result can get faster if at first students use the method of partial fractions and then integrate these fractions.

$$f(x) := \frac{11x^3 - 107x + 108}{x^4 + x^3 - 30x^2 + 76x - 56} \text{ parfrac} \rightarrow \frac{7}{x - 2} + \frac{3}{(x - 2)^2} - \frac{2}{(x - 2)^3} + \frac{4}{x + 7}$$

$$\int f(x) dx \rightarrow 7 \cdot \ln(x - 2) + 4 \cdot \ln(x + 7) - \frac{3 \cdot x - 7}{x^2 - 4x + 4}$$

Integration of irrational functions.

The task of integrating functions gets tougher if the given function is an irrational one, that is, it is not of the form $\frac{P(x)}{R(x)}$. For evaluating some particular types of irrational functions our endeavour will be to arrive at a rational function through an appropriate substitution.

Integration of functions containing only fractional powers of x . In this case we put $x = t^m$, where m is the lowest common multiple of the denominators of powers of x . This substitution reduces the function to a rational function of t .

Example 5. Calculate the indefinite integral $\int \frac{1}{\sqrt{x} + \sqrt[3]{x}} dx$.

Using Mathcad sometimes it is important to write $\sqrt[3]{x}$ in the form $x^{\frac{1}{3}}$. In this example Mathcad does not give the result

$$\int \frac{1}{\sqrt{x} + \sqrt[3]{x}} dx \rightarrow \int \frac{1}{\sqrt{x} + x^{\frac{1}{3}}} dx \quad \text{OR} \quad \int \frac{1}{\sqrt{x} + x^{\frac{1}{3}}} dx \rightarrow \int \frac{1}{\sqrt{x} + x^{\frac{1}{3}}} dx$$

To calculate the indefinite integral $\int \frac{1}{\sqrt{x} + \sqrt[3]{x}} dx$ students can use the substitution. It is important to choose correct substitution. Partially students can do this using Mathcad:

$$f(x) := \frac{1}{\sqrt{x} + \sqrt[3]{x}} \quad \text{Substitution: } x = t^6$$

$$y(t) := f(x) \text{ substitute, } \sqrt{x} = t^3, \sqrt[3]{x} = t^2 \rightarrow \frac{1}{t^2 \cdot (t + 1)}$$

$$dy(t) := \frac{d}{dt} t^6 \text{ simplify} \rightarrow 6 \cdot t^5$$

$$h(t) := y(t) \cdot dy(t) \rightarrow \frac{6 \cdot t^3}{t + 1}$$

$$\text{rezl}(t) := \int h(t) dt \rightarrow \frac{3 \cdot t^4 \cdot \text{hypergeom}(1, 4, 5, -t)}{2}$$

On the one hand the integration result contains the hypergeometric function. This result is difficult for understanding for students. On the other hand the resulting function $h(t)$ is a rational function of t and for this function students can use the method of partial fractions and then integrate these fractions. Then the result is given in easy to use form:

$$\begin{aligned}
 h1(t) &:= h(t) \text{ parfrac} \rightarrow 6 \cdot t^2 - 6 \cdot t - \frac{6}{t+1} + 6 \\
 rez2(t) &:= \int h1(t) dt \rightarrow 6 \cdot t - 6 \cdot \ln(t+1) - 3 \cdot t^2 + 2 \cdot t^3 \\
 rez(x) &:= rez2(t) \text{ substitute, } t = \sqrt[6]{x} \rightarrow 2 \cdot \sqrt{x} - 6 \cdot \ln\left(x^{\frac{1}{6}} + 1\right) - 3 \cdot x^{\frac{1}{3}} + 6 \cdot x^{\frac{1}{6}}
 \end{aligned}$$

Integration of $\frac{1}{(x+1)\sqrt{ax^2+bx+c}}$ is used the substitution $x+1 = \frac{1}{t}$, and then simplify the expression.

Example 6. Calculate the indefinite integral $\int \frac{1}{(x+1)\sqrt{x^2+4x+2}} dx$.

In this example Mathcad also does not show the result if the students want to write as given

$$\int \frac{1}{(x+1)\sqrt{x^2+4x+2}} dx \rightarrow \int \frac{1}{(x+1)\sqrt{x^2+4x+2}} dx$$

Having applied the additional knowledge about substitution students can use Mathcad possibility for getting resulting function $h(t)$:

$$\begin{aligned}
 f(x) &:= \frac{1}{(x+1)\sqrt{x^2+4x+2}} && \text{Substitution: } x+1 = \frac{1}{t} \\
 a(t) &:= x+1 = \frac{1}{t} \text{ solve, } x \rightarrow \frac{1}{t} - 1 && b(x) := x+1 = \frac{1}{t} \text{ solve, } t \rightarrow \frac{1}{x+1} \\
 y(t) &:= f(x) \text{ substitute, } x = \frac{1}{t} - 1 \rightarrow \frac{t}{\sqrt{2t-t^2+1}} \\
 dy(t) &:= \frac{d}{dt} a(t) \rightarrow -\frac{1}{t^2} \\
 h(t) &:= y(t) \cdot dy(t) \rightarrow -\frac{1}{t \sqrt{2t-t^2+1}} \\
 \int h(t) dt &\rightarrow -\int \frac{\frac{1}{t}}{\sqrt{\frac{2}{t} + \frac{1}{t^2} - 1}} dt
 \end{aligned}$$

Mathcad could not simplify it fully. If student having applied knowledge about the expression $h(t)$ transformation then the Mathcad get the integration result

$$\text{result1}(t) := \int \frac{-1}{\sqrt{2t - t^2 + 1}} dt \rightarrow -\text{asin}\left[\frac{1}{5} \cdot \sqrt{5} \cdot (t - 2)\right]$$

$$\text{result}(x) := \text{result1}(t) \text{ substitute, } t = b(x) \rightarrow -\text{asin}\left[\frac{\sqrt{5} \cdot (2 \cdot x + 1)}{5 \cdot x + 5}\right]$$

Conclusion

Software “Mathcad” is very convenient for computing integrals of rational or irrational functions. Integration of an elementary function not always leads to an elementary function. As shown in examples there exist elementary functions whose integrals are inexpressible in terms of elementary functions without substitution.

The method of partial fractions is used not only for finding integrals, but also for analyzing linear differential systems like resonant circuits and feedbackcontrol systems (electrical or mechanical engineering).

For receiving results in Mathcad in convenient form students are required theoretical knowledge about integration of some rational and irrational functions.

The lecturer can suggest to students to use other software: “Matlab”, “Mathematica”, but these software are more complicated and require more time for obtaining skills for work.

Software “Mathcad” advantage is the possibility easy and quickly write the received results.

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SELECTING A COMPUTER PACKAGE FOR TEACHING BASIC STATISTICS COURSE

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Abstract: *An introductory statistics course usually consists of descriptive statistics and doing different graphs, testing hypothesis, regression analysis and analysis of variance. Nowadays there are many computer packages for statistics calculations that can be used in teaching statistics. This article tries to compare and examine different packages (i.e. Excel, Minitab, R and Statistica), and to find a package that is the easiest to use for the students. It seems that Excel is the most straightforward to use for a basic statistics course, but is it the best choice? Today, the computer package R has developed to a level that makes it quite easy to use and understand for the students.*

Keywords: basic course of statistics, teaching statistics, statistics packages

Introduction

Nowadays a lot of data is collected but it will be beneficial only when one can analyse it. That is why an introductory statistics course is being taught for many different specialities at the university. This course consists of descriptive statistics, drawing different graphs, testing hypothesis (χ^2 -test, F-test, t-test), regression analysis and analysis of variance. In this paper, the same tasks have been solved with different computer packages, i.e. MS Excel, Minitab, Statistica and R.

The choice of a computer package depends on its cost too. To use Statistica, annual licence fee has to be paid. For example, it costs €170 for one computer place, but we have 30 computers in the computer rooms, therefore, the total amount will be very high. Already now, every computer in our university has MS Office package installed to make use of its various functions. As Excel has Data Analysis procedures, statistics can be taught easily. But is it the best choice for students to understand statistics? I do not think so. I would recommend using the free software package R, instead.

The home pages of three of the companies introduce their package as follows:

“R is a collaborative project with many contributors. This is a free software environment for statistical computing and graphics,” (<http://www.r-project.org/>).

“Minitab Inc. delivers software and services for quality improvement and statistics education. For more than 35 years, thousands of distinguished organizations in more than 100 countries have turned to Minitab for tools that help quality initiatives yield bottom-line benefits. Businesses trust Minitab® Statistical Software to analyze their data, and more than 4,000 colleges and universities use it to teach statistics,” (<http://www.minitab.com>)

“StatSoft, Inc. was founded in 1984 and is now one of the largest global providers of analytic software worldwide. StatSoft is also the largest manufacturer of enterprise-wide quality control and improvement software systems in the world, and the only company capable of supporting its QC products worldwide, with wholly owned subsidiaries in all major markets (StatSoft has 23 full-service offices, on all continents), and its software is available in more than 10 languages,” (<http://www.statsoft.com>).

In this analysis descriptive statistics are computed, a histogram is made, one regression model is found and a dispersion analysis task is solved. To do all this Estonian data about worms, which has been collected from 1996 to 2008, is used.

Analysis

In MS Excel package, Data Analysis procedures are needed to compute statistical values or many different Excel functions can be used separately for every value or for every test. The other packages (i.e. Minitab, R and Statistica) are made especially for statistics analysis and all the above-mentioned tasks can be found under Statistics from the main menu. The majority of the collected data is in Excel format and all these packages support Excel format. For students the most problematic thing is to transform Excel data to R data, they forget the right parameters that are needed for dragging. Before the commands from the console alone could be used but now R package has R Commander that makes the communication with package quite easy because it has similar dialog boxes to Statistica's or Minitab's. In Minitab, there arises another important problem with data. In Estonia we use commas to separate decimals but the package uses full stops instead. The data transformation from Excel to Minitab is not easy with every value. For example, when using in Excel the command “replace” the value 12,3 will change to a date value 12th March, not 12.3.

Descriptive statistics

The statistics course starts with the introduction to different variables, where their type is being clarified. For every variable type, a frequency distribution is composed, and for a numerical variable, descriptive statistics (See Table 1) is computed and composed to a histogram. With all packages it is possible to calculate statistics directly. In Excel prior calculations are needed (to determine class limits) to make a histogram (See Fig. 4), while the other packages do not need any calculations. The histogram will be displayed with the results of the normality test (See Figure 2). With Excel, calculations are needed also before it is possible to say whether the variable's distribution is normal, or not. When the frequency distribution is an empirical distribution then it is necessary to calculate theoretical distribution and after that to do a χ^2 -test with the Excel function Chitest.

Table 1.

Descriptive statistics with MS Excel

<i>Acal</i>	
Mean	65,97269
Standard Error	2,730206
Median	50,65
Mode	0
Standard Deviation	61,41446
Sample Variance	3771,736
Kurtosis	6,219454
Skewness	2,013158
Range	432
Minimum	0
Maximum	432
Sum	33382,18
Count	506
Confidence Level(95,0%)	5,36396

Excel's descriptive statistics procedure calculates all descriptive statistics at the time (See Table 1). With Minitab, Statistica and R only the basic descriptive statistics are calculated (See Table 2). However, when using the advanced button one can calculate the rest of the descriptive statistics as well.

Table 2.

Descriptive statistic with Statistica

Variable	Descriptive Statistics (Spreadsheet11)				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
Acal	506	65,97269	0,00	432,0000	61,41446

With one command in Minitab and Statistica one can get everything- statistics, histogram and also the result of the normality test- together (

Fig. 6, Fig. 7). Based on these graphs, it is very good to write the characterisation of the distribution of the variables which is the main purpose of descriptive statistics.

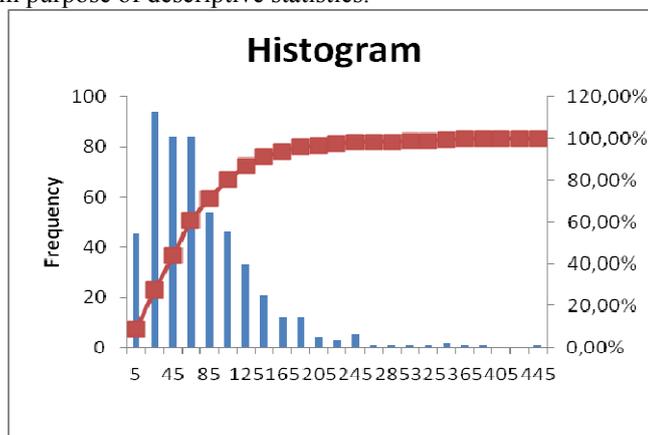


Fig. 4. Histogram in MS Excel

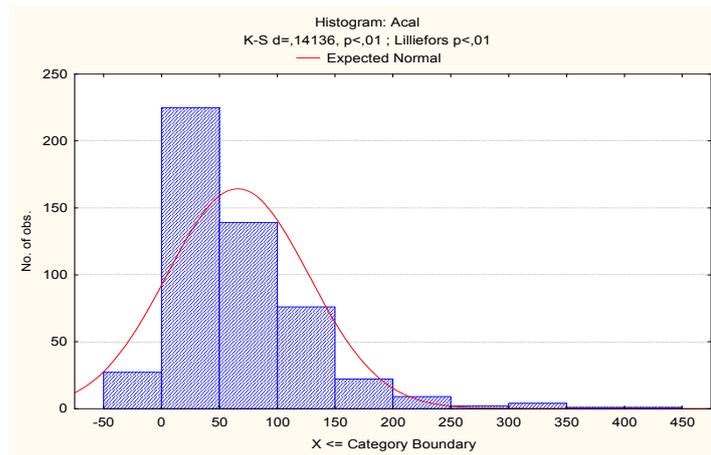


Fig. 5. Histogram and normality test result with Statistica

Descriptive Statistics

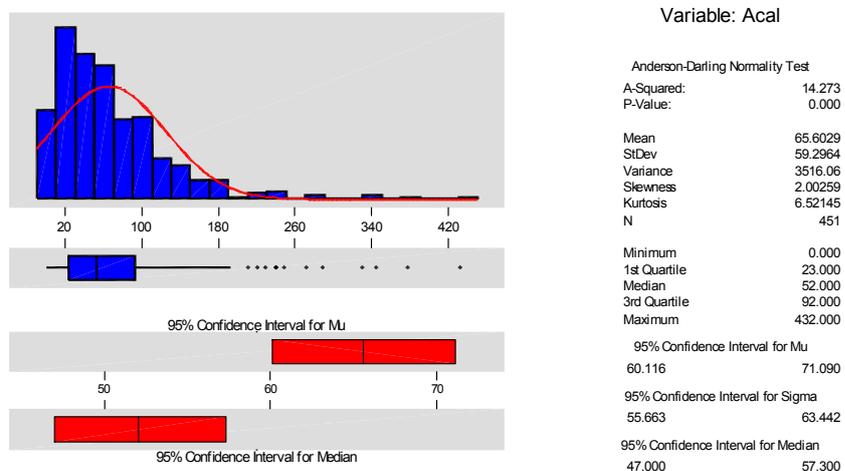


Fig. 6. Descriptive statistics, histogram and normality test in Minitab

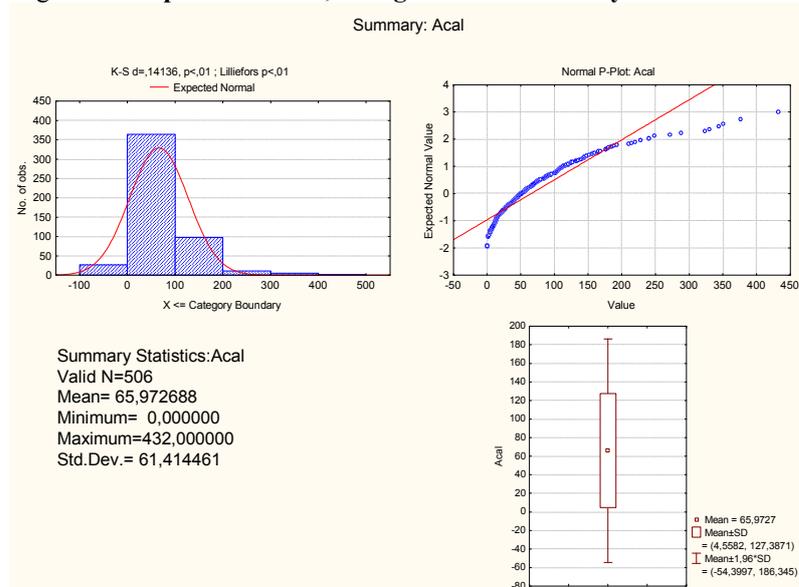


Fig. 7. Descriptive statistics, histogram and normality test with Staistica

Regression analysis

In many statistics analysis, it is needed to compose a regression model to show how two or more different variables depend on one another. In this paper, a multiple regression model is used (See Table 3). Composing a regression model with these different packages follows a similar pattern. Though, there is a problem with Excel:

data has to be revised to detect any missing data, and in that case, the whole row has to be deleted. The other packages leave out the rows which include missing values automatically.

Table 3.

Multiple regression output in Excel

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple R	0,278257
R Square	0,077427
Adjusted R Square	0,068528
Standard Error	62,80579
Observations	315

ANOVA

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	102956,1	34318,71	8,700248	1,47E-05
Residual	311	1226760	3944,567		
Total	314	1329717			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95,0%</i>	<i>Upper 95,0%</i>
Intercept	159,5726	27,08229	5,892137	9,9E-09	106,2849	212,8603	106,2849	212,8603
aasta	0,290375	0,092385	3,143107	0,001833	0,108597	0,472153	0,108597	0,472153
pH	-14,6307	4,215994	-3,47028	0,000593	-22,9262	-6,3352	-22,9262	-6,3352
N	-7,65796	3,703614	-2,0677	0,039495	-14,9453	-0,37065	-14,9453	-0,37065

Table 4.

Multiple regression analysis output with package R.

```
lm(formula = Acal ~ aasta + N + pH, data = uss)
Residuals:
  Min    1Q  Median    3Q   Max
-108.23 -41.27 -15.18  25.32  342.55
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 159.54541  27.08217   5.891 9.96e-09 ***
aasta        0.29040   0.09239   3.143 0.001832 **
N           -7.66363   3.71348  -2.064 0.039873 *
pH          -14.62675   4.21604  -3.469 0.000595 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 62.81 on 311 degrees of freedom
Multiple R-squared:  0.07738,    Adjusted R-squared:  0.06848
F-statistic: 8.694 on 3 and 311 DF,  p-value: 1.481e-05
```

As you can see on both outputs (See Table 3, Table 4), it is possible to read the same model with the same value of R² but the model building in package R is much easier and clearer.

Analysis of variance

When finding mean differences (See Fig. 8) with analysis of variance (ANOVA) it is necessary to check before ANOVA procedure whether the variances of different groups are equal. In Excel, there is not a test to check this important option. In the other packages, Bartlett's test or Levene's test can be used to detect whether the variances are homogeneous or heterogeneous. As a result of using the ANOVA procedure one can determine

whether there are differences between the means of different groups, but it is impossible to say. In Excel there is not any test to verify that. Although it is possible to calculate the confidence intervals for every group, it is very time-consuming. In the other packages, Tukey test can be used to determine which groups' means are different. MS Excel does not complete the analysis of variance task, and therefore, is inappropriate for that.

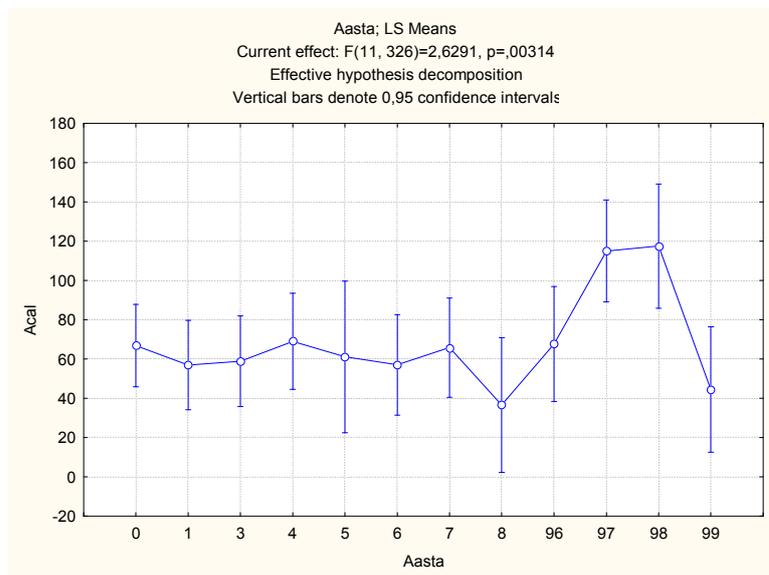


Fig. 8. Acal mean differences in different years, used package Statistica

Conclusions

When comparing these four different packages, Statistica is the best because no problems were detected. It is very user-friendly and it has many great possibilities. Minitab has also a wide selection of possibilities, but because it requires using full stops instead of commas, it becomes inconvenient. Considering the small budget of Estonian universities, these two packages are not affordable as they require a big annual payment. Using the R Commander makes R as convenient as the previous two packages. Furthermore, it is freely available. Therefore, it is recommended to be used in teaching statistics. Although Excel is widely accessible and it has all the statistical procedures, many calculations are needed to use these procedures. Thus, the focus tends to move away from statistics. In conclusion, R is the best choice for students, given the university's budget constraint, when doing statistics.

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THE USE OF ICT IN MATHEMATICS STUDIES - BALTIC STATES' EXPERIENCE

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Abstract: *In this article are collected experience and knowledge about ICT usage in mathematics studies and applied software in three Baltics States Agricultural Universities: Latvia University of Agriculture, Estonian University of Life Science and Aleksandras Stulginskis University (Lithuania). The problem has been approached by analysing and evaluating the scientific literature for the development of the methodological basis of research, which includes three directions: the evaluation of ICT use in the mathematics study process organization (syllabus organization, used e-environment, study materials availability and accessibility to students, ICT use in assessment, ICT for teaching methods and communication); used courseware (mandatory, by teachers initiative) and support for teachers (opportunities to develop professional ICT capabilities, technical support, an access to digital resource materials, exchange of ideas).*

Keywords: information communication technologies, mathematics, Mathcad, Moodle.

Introduction

The new and rapidly growth of ICT has changed the face of the world. ICT has become the main influential determinant in economic, social and human development (Dertouzos, 1997). ICT is being considered as the umbrella for the communication and networking devices and software with applications (Jain, 2006). Rapid technological development is changing society and its attitudes towards education. This process is caused urgent needs to change the education environment. The Mathematics is very much touched by this process. It is necessary to prepare specialists with ability to use ICT, and transfer knowledge and technology into the economy. Mathematics is a discipline which is required as a background for specialists who work in environmental protection, engineering, construction, business, telecommunication, textile, new energy sources, etc. EU directives distinguish 8 key competencies that should be developed for lifelong learning. One of them is for mathematical literacy and competences in science and technology. Mathematics knowledge and competences becomes essential in lifelong learning process. Thus raises the questions: what technological and educational innovative conditions would be necessary in the process of change? What educational environments it is necessary to create in order to motivate the students successfully and effectively act in the professional sphere?

ICT definitely play a crucial role in developing the teaching/learning processes at all stages and no new teaching/learning environments can be created without ICT. The use of new media in higher mathematics education has to help, support and fulfil its most important objectives. One of important areas of their use is in lectures to make them more illustrative and better understandable. The teacher should keep in mind, that technical means are not only to make them the lecturing easier, but that they are for making easier following and understanding the content of the presented material. Applying ICT in the teaching/learning process does not object to the basic didactical principles such as visualization, systemization, links between theory and practice, knowledge consolidation, encouragement of student participation in different activities, individualization and differentiation of teaching etc. There are two connected but distinct issues related to this expansion in the availability of computing power which are of considerable importance in relation to the higher mathematics curriculum. The first is that new approaches to teaching and learning are made possible. The second is that enormously sophisticated mathematical software is now commonly available which routinely allows analysis of problems of such size and complexity that only a few years ago they would have been regarded as research activities (SEFI, 2002).

Given that all students spend only a year to acquire the basic course in mathematics the questions stands as follows: how to organize the mathematical education in the first or second studies' year and to design learning environments that enable students to develop broad spectrum of knowledge and capabilities? The questions had been already answered by the Bologna documents. The aim of the Bologna Process is the improvement of the mobility of students and teaching staff as well as the strengthening of the competition of the European universities in a global education market. As the consequence of the Bologna declaration is the promotion of European co-operation in higher education, particularly with regards to curricular development, inter-institutional co-operation, mobility schemes and integrated programs of study, training and research as well as exchange of experience between institutions and countries. The reform affects not only the structure of university studies, but furthermore leads to European-wide reflection on the suitability of the syllabuses in

mathematics subjects and, of greater importance, on the manner in which mathematics is taught. Therefore in this article are collected experience and knowledge about ICT usage in mathematics studies and applied software in three Baltic States National Agricultural Universities: Latvia University of Agriculture (LUA), Estonian University of Life Science (EMU) and Aleksandras Stulginskis University (ASU).

Materials and methods

The problem has been approached by analysing and evaluating the scientific literature for the development of the methodological basis of research. The article includes theoretical analysis of topical issues like the factors determining good ICT use, technological aids of the learning cycle and potentialities of ICT use in the mathematics education. The literature review unequivocally found that it is not possible to provide clear indicators to describe or measure the use of ICT. However, in several educational researches identifies four main dimensions of ICT assessment (Pelgrum, Law, 2003; Law et al., 2008; Newhouse, 2002): School environment; Teachers ICT capabilities; School ICT capacity and Students. Australian researcher Paul Newhouse gives the outcomes for those dimensions and an explanation of components (Newhouse, 2002).

Table 1.

Factors determining good ICT use			
	Outcomes	Components	Description
SCHOOL ENVIRONMENT	That school environment is supportive of teachers and students use of ICT that prepares students to learn, work and live successfully in a knowledge-based, global society.	Leadership & Planning	The school provides leadership and planning structures based on clear goals that encourage and support teachers and students in their use of ICT.
		Curriculum Organisation	The intended curriculum is organised in a manner that is conducive to the use of ICT to support learning and teaching processes.
		Curriculum Support	Teachers are provided with adequate support to select appropriate applications of ICT to address the requirements of the intended curriculum.
		Community Connections	The school recognises local and global communities as critical partners and stakeholders in the learning and teaching process.
		Accountability	The school has adequate systems to ensure accountability in the use of ICT.
TEACHERS ICT CAPABILITIES	The teacher exploits the characteristics of ICT to support the learning of students and contribute to relevant learning communities.	Vision & Contribution	The extent to which actions in the use of ICT are based on understandings of the purposes and roles of ICT to support all learners with a focus on the two-way relationship between learning and ICT use. The extent to which involvement in learning communities, professional learning and school planning in the use of ICT occurs.
		Integration & Use	The extent to which ICT use is integrated within learning environments to support learning communities. The extent to which the use of ICT is a critical factor in achieving teaching-learning objectives more effectively.
		Capabilities & Feelings	The extent to which a teacher feels capable in supporting the use of ICT and inclined to do so in a manner that considers the roles of the teacher and students.
ICT INFRASTRUCTURE	The school provides ICT capacity to ensure that all teachers and students have immediate access to all software that is required to support the curriculum and adequate support to implement its use.	Software	A wide range of applications is available to students and teachers where the applications are designed to match user characteristics and the requirements of curriculum tasks.
		Hardware	Students and teachers have access to computer processing adequate to use required software applications and digital resource materials. Students and teachers have access to peripheral devices suited to user characteristics and the requirements of curriculum tasks.
		Connectivity	Students and teachers have access to networking, including to the internet that provides high quality access to online services.
		Technical Support	Technical support and maintenance is available to teachers and students when and where required.
		Digital Resource	Teachers and students readily select and access digital resource materials appropriate to their needs.
ST	Students develop an appropriate level of	ICT capability	ICT skills and understandings

	capability, become more engaged with their own learning, and achieve learning outcomes across the curriculum at a higher level.	Engagement	Independence and resilience
		Achievement of learning outcomes	Personal responsibility etc.

In international comparative studies conducted by the Evaluation of Educational Achievement (IEA) were found curriculum and assessment factors: curriculum goals, content, methods, assessment goals and methods (Pelgrum, Law, 2003). Content goals and contents include information, communication, and social skills, as well as meta-cognitive skills, but students' performance should be assessed with great diversity of methods (open test methods, portfolio, diagnostic and summative tests).

Lithuanian researchers Lipeikiene J. and Lipeika A. describe the use of technological tools in the learning cycle of teaching mathematics which includes conceptualization, construction and dialogue phases (Lipeikiene, Lipeika, 2009). The primary courseware intended for the conceptualization phase include visualization tools as well as on-line resources. For the construction phase they recommend the secondary courseware which consists of lower level procedures among them visualization tools, mathematical games and on-line resources and dialogue phase - tertiary courseware – virtual learning environment and teacher's blogs (Lipeikiene, Lipeika, 2009).

ICT support inquiry projects by providing visualizations of scientific processes that are difficult to see and consequently, are quite challenging to understand. Visualizations include interactive models, graphs and simulations. New technologies also support inquiry with analytic tools (e.g. drawing, graphing, data tabling and concept mapping), guidance, support for student collaboration, online interactions with experts and access to information through databases or websites (AAAS, 1993; Linn et al., 2004). Researches prove that approximately 40-50% of traditional classroom material could be eliminated for targeted students; this implies that we should employ a new approach for improving the educational system. In order to duly co-ordinate the study program and teaching with the student's abilities, interests, and learning styles, a variety of instructional strategies and challenging content are used, performing differentiation, which can occur in (Yamin, 2007): content (e.g., teachers must pre-test students, determine which students need direct instruction, plan application of concept through problem solving, and allow students to work ahead independently), process (e.g., vary the learning activities or strategies, use graphic organizers, maps, diagrams or charts to display comprehension, and vary the level of graphic organizer), product (varying the complexity of the product that students create to demonstrate the mastery of concepts) and environment (accommodating the students' individual learning styles). Different strategies for teaching students can be employed to develop alternative activities that go beyond the regular curriculum, to work with students to design an independent project that they would be interested in completing for credit, to involve students in academic competitions in several areas, to create tiered assignments, which have different expectations for different levels of learners, to make efficient use of technology. Virtual Learning Environments can be an essential tool in providing special provisions that meet gifted students' special needs.

ICT could be seen as a facilitator tool for the intensification of study process in the studies of mathematics development. According to Pale in order to intensify the study process we have to get rid of the so called "non-educational" performances such as (Pale, 2005): administration, support, organization etc. by minimizing or automatizing the previously mentioned performances. The support functions are those that are needed in the study process but on their own do not add up to the knowledge or skills of the students. For these processes the students and lecturers use a remarkable amount of time. An essential question is to free the student from a physical presence. Of course it is possible if students have access to all the necessary resources, as well as training and the support for the knowledgeable usage and the professionals who could assist if the student feels doubt or is in need of consultations. These aims could be reached if all the present teaching/learning materials are digitalized and at the same time new e-materials are developed. The materials should be available on-line. A digital library is also a must. It has to be mentioned that the student's marks in previous exams as well as the questions and answers are of great importance for the study processes. Communication with e-mails among students, virtual work-groups, distant synchronized (performed in real time with the lecturer who is connected to the system, a direct communication with the lecturer and with each other) and non-synchronized (communication is possible via e-mails, discussion groups etc.) learning, summaries of lectures, tasks and other processes make the study process more qualitative and easy.

A very important aspect in the development of the future ICT competence is in e-studies. E-studies are the process where the person learns on his own by using technologies. If the classical teaching (face to face) to be aided with teaching using elements of e-learning it is defined as a blended learning. The term itself is quite difficult to define since it is used in diverse ways by different people. On the one hand, there is the traditional face-to-face learning environment that has been around for centuries. On the other hand, there are distributed

learning environments that have begun to grow and expand in exponential ways as new technologies have expanded the possibilities for distributed communication and interaction. The biggest and most common factor behind successful applications to support both learning and knowledge development is the presence of creative people who can drive initiatives forward. This requires a constituency or community who want fast access to ideas and knowledge and have a well-formed model of whatever they want to contribute, preferably do-able within existing technology (Nyhan et al., 2003).

On the findings from different theoretical approaches as well as many years of personal experience in mathematics teaching, is built the methodology for the collection data about ICT usage in mathematics studies at Baltic States national agricultural universities which includes three directions: the evaluation of ICT use in the mathematics study process organization (syllabus organization, used e-environment, study materials availability and accessibility to students, ICT use in assessment, ICT for teaching methods and communication); used courseware (mandatory, by teachers initiative) and support for teachers (opportunities to develop professional ICT capabilities, technical support, an access to digital resource materials, exchange of ideas).

Results and discussion

For the evaluation of ICT use in the mathematics study process organization are created six indicators' groups – syllabus organization, used e-environment, study materials availability and accessibility to students, ICT use in assessment, ICT for teaching methods and communication. Each group consists of several indicators (Table 2).

Table 2.

Evaluation of ICT use in the maathmatics study process organization

<i>Indicators' group</i>	<i>Indicator</i>	<i>LUA –LATVIA</i>	<i>EMU – ESTONIA</i>	<i>ASU – LITHUANIA</i>
Syllabus organization	Mandatory - in the programs is allocated the ECT for ICT	<i>For engineering</i>	<i>For environmental engineering, forestry</i>	<i>No</i>
	Used only by the teachers initiative			<i>Yes</i>
Used e-environment	Moodle	<i>Yes</i>	<i>Yes (for statistics)</i>	<i>Yes</i>
	University information system (IS)		<i>Yes</i>	<i>Yes</i>
Study materials availability and accessibility to students	Only reading on-line resource	<i>Yes</i>	<i>Partly for economics, forestry</i>	<i>Yes</i>
	An interactive materials in internet	<i>No</i>	<i>No</i>	<i>No</i>
	Tests or tasks for self-control	<i>Partly (Moodle)</i>	<i>Partly</i>	<i>Partly (ThatQuiz, Moodle)</i>
	Solving examples	<i>Yes</i>	<i>No</i>	<i>Yes</i>
ICT use in assessment	Final exam /test in e-study system	<i>No</i>	<i>No</i>	<i>No</i>
	Tests during the semester	<i>Partly (for theory)</i>	<i>No</i>	<i>Partly</i>
	Electronic assessment records during semester, available for students	<i>Partly</i>	<i>No</i>	<i>Partly</i>
	Course final mark	<i>Moodle and in university IS</i>	<i>In university IS</i>	<i>In university IS</i>
ICT for teaching methods	An e-lecture	<i>No</i>	<i>No</i>	<i>No</i>
	Independent work tutoring by teacher	<i>No</i>	<i>No</i>	<i>No</i>
	Independent work	<i>Yes</i>	<i>Yes</i>	<i>Yes</i>
	Project work	<i>No</i>	<i>Yes (for statistics)</i>	<i>Yes (for statistics)</i>
	Group work	<i>No</i>	<i>Yes (for statistics)</i>	<i>Yes (for statistics)</i>
Communication	Collaborative learning	<i>No</i>	<i>No</i>	<i>No</i>
	Using Moodle tools	<i>Yes (20%)</i>	<i>Yes (for statistics)</i>	<i>Yes (20%)</i>
	By e-mail	<i>Yes (35%)</i>	<i>Yes (mostly)</i>	<i>Yes (20%)</i>

Despite the fact that the size of Mathematics studies by the means of contents has not been changed for several years, it tends to decrease by the means of time. The question arises - how to intensify the contents of the lectures? One of the possibilities is to use the slide shows during the lectures. In this way the teachers do not have to spend time on writing the material on the blackboard. The slide shows are used in all three universities. However 60-80% teacher prefer to use classical teaching methods.

Nowadays the Course Management System (CMS) Moodle has become one of the most popular e-learning environments in the world. In mathematics studies at LUA are introduced Moodle, at ASU are introduced Moodle and is used the university information system, but in EMU for teaching and learning mathematics widely are used the university information systems. In LUA Moodle is used primarily for reading on-line materials, assessment records, communication and a little - for uploading students' homework.

Between the three universities only EMU has a good experience in using of Moodle in statistics studies. The Estonian author of this article has made four e-courses: *Theory of probability*, *Mathematical statistics for engineers*, *Programming*, and *Logic*. The oldest course is the statistics one and have be used it for three years, already. First, it was created it in the Blackboard environment, but last year, it was transferred it to Moodle. What are the benefits? The teacher does not have to give lectures anymore. The students read all the material on the Internet and after reading it, they take the test, which will reflect how familiar with theoretical material they are. In this course feedback, the students have said that they like answering the tests the most. The course environment allows students to upload their homework, and teacher can write all their grades there as well. The students can even do teamwork in Wiki by writing the analysis for the given task together. Now the students work more than before and teacher can better monitor their work. The same system is introduced in LUA – the teacher can choose to give lectures face-to-face or use e-learning environment, but it is not used by teachers of mathematics yet.

Different courseware is used in LUA and EMU by the teacher initiative. But in the programs of both universities are allocated the ECT for *Mathcad* use. The mathematics syllabus organization at LUA includes the laboratory works - using software *Mathcad* in mathematics study process. In the engineering programs (1st – 3rd semester) is allocated the 0.5 ECT. Currently *Mathcad* is implemented in environment engineering and forestry study programs. For students it allows to get know one of the Math software. They have to solve the homework on the paper, showing the process of solving step by step, but during laboratory works – to solve it using *Mathcad*. For teachers it decreases the time for checking the home works. In LUA master's level mathematics studies are used software *Matlab*.

There are no separation of contact hours for laboratory works in EMU but *Mathcad* is integrated in the practical lessons (3rd and 4th semester). It occupies up to 50-70% of practical works and for *Mathcad* use allocated the 1.0 ECT. *Mathcad* is used to solve complicated tasks with much technical work, to design work, to make graphs as well as to solve very simple, but important calculations. It helps to understand various functions and operations through visualization. The comparison of *Mathcad* use in LUA and EMU are given in the Table 3. The strengths of laboratory works in LUA - computer classrooms have only 15 and 20 work places. There are more than 20 computers in EMU and ASU classes.

Table 3.

Mathcad use in LUA and EMU mathematics studies

Themes (topics)	What is done with Mathcad?	EMU		LUA
		For visuali- zation	Practi- cal works	Labora- tory works
Linear algebra	Operations with matrices, solving determint and systems of linear equations: with <i>Cramer's formulas</i> , <i>Inverse matrix A^{-1}</i> , with <i>functions $rref(augment())$</i> ; <i>geninv()</i> ; <i>lsolve()</i> ; <i>Given ...Find()</i>		yes	yes
Vector geometry	Calculation the vector coordinates, Knowing origin and destination. Vector reference, if known the coordinates. Operations with vectors.			yes
Analytic geometry of plane and space	Create a drawing and drafting of the equations. Check homework, creating drawings.	yes	yes	yes
Limit and continuity	One-side limits, functions limits calculation. Discontinuous function graphs.		yes	yes
Derivative of a function of one variable	Finding the derivative by the function definitions and by the use of <i>Calculus</i> . Investigations of one variable fuctions.	yes	yes	yes
Indefinite integral	Calculation of the indefinite integral using the toolbar <i>Calculus</i> , Integral expressions symbolic transformation. Drawing the integral lines.		yes	yes
Definite integral	Calculation by the Newton-Leibniz formula.	yes	yes	yes

and its applications	Creation the drawings (included functions in parametric and polar forms). Targeting the parameters.			
Differential calculation of functions in several variables	Draw a two-variable function. Finding the partial derivatives and differentials of higher order. Calculation the function extremes.	yes	yes	yes
Multiple and curvilinear integrals	Determine the areas of integration, a mark, The equation system boundary calculations		yes	
Differential equations	Finding integral; Calculations the uncertainty coefficients.	yes	yes	yes
Numerical and functional series	Expansion of functions by series and its applications in integration and for differential equations.	yes	yes	yes

It could be mentioned that the *Mathcad* use needs to acquire a license. Therefore in mathematics studies at ASU is used *Maple* for teaching of students of Faculty of Forestry and Ecology (Magister Level). But concern financial and organizational problems it is not possible to use this program for teaching students of others faculties. It could be mentioned that the *Mathcad* and *Maple* use needs to acquire a license. Therefore in mathematics studies at ASU are widely used *Excel* and open source as *Sage*.

The availability of the ICT infrastructure or software is a condition but it does not automatically result in advanced use of ICT by the teachers in the learning activities. The successful implementation of ICT in learning process depends on the teachers' personal uses of ICT: access to resources, continuing professional development and communities of practice. Using ICT to transform teaching and learning involves understanding teachers' motivation, perceptions and beliefs concerning learning and technology.

Nowadays the pedagogical culture is greatly defined by the teacher's awareness of the basis of the alterations starting from the idea and finishing with real-life implementation in everyday work as well as from the teaching staff's ability of the acquisition of the suitable teaching tools and change his professional activities. The offer of innovations is rather big but the teaching staffs needs time to accept it in accordance with their professional experience and later structure it in their present experience or drastically change it.

There are difficulties in the teacher's academical and professional education. In the process of becoming an innovative person the teacher might encounter with difficulties in letting go from the previously acquired conclusions and even harder is to change the attitude and his individual didactical model which has already been tested and is rather stable (Žogla, 2001). People must be stimulated to acquire new technologies. A very essential is the education process.

What is the situation in these three universities? All three universities have implemented Moodle, as well as organized training for teachers to use Moodle as open source system for integrating new, interactive courses in the study process. Pooling of expertise it is concluded that these courses are about general principles of building e-course, without giving any information about customized virtual environment tools for mathematics teaching in Moodle. Nowhere are offered the courses about tools used directly in mathematical e-learning course design.

A second factor, which characterizes the teachers' dimension, is technical support. In LUA and ASU the technical support for teachers and maintenance is provided by skilled experts: e-studies methodologists. That's why teachers are not stopped from using a Moodle due to technical failure.

In Estonia the situation is more centralized. The Estonian Information Technology Foundation oversees all the e-courses and the problems arising from their creation and use. All Estonian universities and vocational schools are connected to the consortium. There are two projects: one for universities, called "Best", and other for vocational schools, called "Vanker". These projects are mostly financed by the European Union. After the teacher creates an e-learning course or a learning object, she/he could ask for funding from the Foundation.

The third factor is an access to digital resource materials appropriate to teachers' needs. Currently LUA started to create a storage of mathematics methodological e-materials which consists of materials created by department's teaching staff, materials available in on-line, three levels of homework tasks, their solution samples, laboratory work samples, as well as of theoretical tests questions bank. These activities are financing by European Union funds. Thus is formed a team of teachers that share ideas and strategies about incorporating ICT into teaching and learning. It follows that the fourth teachers dimension is to facilitate individuals and groups, enabling the active exchange of ideas between those people.

Conclusion

To create the e-materials for mathematics studies unfortunately is a time-consuming process. To do the material of the course in Moodle is very hard and uncomfortable for teachers. The input of mathematical text is almost impossible. Although Moodle has a mathematical text redactor, it is very bad, as teacher cannot enter every equation what is needed. This is the main reason why the creation of the mathematics e- courses still in the

progress in all three universities. However, the students face difficulties when inputting mathematics text as well. There have to be tools which will help collecting equations from screen very easily with the mouse. In tests or forums could be asked only those questions where the answer is in text format, but for mathematics, it is impossible. At the moment, we can be used only very small part of all the e-learning possibilities. It is able to give the materials on Moodle but could not use any active learning methods.

Thus it could be concluded that ICT are able to use mainly for “non-educational” performances: administration, support and organization functions - course plan, teacher consultations, the summaries of the lectures, self-education materials, examples of task solutions, self-assessment tests, training tasks, the descriptions of practical works, laboratory works examples, methodological pointers, the links to such materials on the internet, communication among students and teacher, to record the marks and the results of tests on the internet as well as to see the changes in the schedule etc.

The other conclusion arises by evaluating the virtual environment tools for mathematics teaching on Moodle. There is necessary for the exchange of ideas between teachers to promote using Moodle for active learning purposes as well as collaboration among the lecturers for the balanced usage of e-studies methods mathematics. Three Baltic States Agricultural Universities should have one place where could be shared teachers experiences. The collaboration and teamwork unites the teacher’s improvement and the study program’s development which is based on the exchange of information among people.

Evaluating the courseware used in the mathematics studies, several conclusions could be outlined. At first, commercially available software packages have become more user-friendly and *Mathcad* is recommended software for mathematics studies. One alternative would be the open source software *Wolfram Alpha*. It is relatively easy to use, gives a solution "step-by-step", provides an opportunity to look for alternative ways of tackling, but, unlike *Mathcad*, it does not allow presentation of results and is not compatible with Microsoft Word.

Secondly, it is clearly, the computer is here to stay and what is needed is a sensible balance between the use of software and the ‘pen and paper’ manipulation which is so essential to an understanding of fundamental concepts. Euler's method would never be used in practice to numerically solve a differential equation. However, in carrying out a few steps of this method on a simple problem a student will learn much about the nature of numerical solutions. Much of this would probably be overlooked if all the students did was learnt the appropriate syntax to invoke a differential equation solver in a commercial software package (SEFI, 2002).

The authors' observations and the experience outline some conclusions about teachers. Namely, new teachers, presumed to be young and recently graduated from university, have a varying level of experience with ICT but they are also gaining teaching experience and skills to manage the classroom environment. Senior teachers, who may even be approaching retirement age, have more classroom experience but are likely to be less skilled in working with technologies. Therefore in order to facilitate the motivation of the teaching staff in the implementation of new technologies we have to use the privileges of both groups and we have to create collaboration between these two groups.

The research shows that the transition into the new teaching with technologies is a rather difficult and time-consuming process. Even while acknowledging the immense opportunities to enhance the education process at all level many disciplines have been slow in adapting to the new technologies and tradition methods continue to hold sway. Evidently the work of teaching staff, their primary education, continuing education, status and the work environment are the key elements in the development. The role of technologies in learning and teaching depends on the lecturer’s access, how much time is invested in self-education and what things he considers to be suitable.

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TREE TAPER MODELLING WITH STOCHASTIC DIFFERENTIAL EQUATION

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Abstract: *This paper introduces the application of stochastic differential equations for the tree taper modelling. We propose to model taper curves using stochastic differential equations that are deduced from the standard deterministic growth function by adding random variations to the growth dynamics. It is assumed that the conditional distribution of the taper diffusion process has an explicit form. We illustrate the efficiency of our method using the Gompertz and Vasicek diffusion processes to model data on Scots pine trees. The results are implemented in the symbolic computational language MAPLE.*

Keywords: stochastic differential equations, taper curves, fixed and mixed models, log-likelihood functions.

Introduction

Predictive forestry is a specific application of the field of mathematical modelling for describing the behavior of an individual tree and stand under a given set of environmental conditions. Height and volume predictive models have been widely accepted as informative tools that provide quick and cost-effective assessments of the growth for product development, risk analysis, and recreation purposes. Taper equations are widely used in forestry to estimate diameter at any given height along a tree bole and therefore to calculate total or merchantable stem volume. One crucial element in these models is the functional response describing the relative diameter of tree stem consumed per relative height for given quantities of diameter at breast height D and total tree height H . The most studied of the taper relations is from simple taper functions to more complex forms (Kozak et al., 1969; Max and Burkhart, 1976; Kozak, 2004; Trincado and Burkhard, 2006; Yang et al., 2009; Westfall and Scott, 2010; Petrauskas et al., 2011b). Taper curve data consist of repeated measurements of a continuous diameter growth process over height of individual trees. These longitudinal data have two characteristics that complicate their statistical analysis: a) within-individual tree correlation that appears with data measured on the same tree and b) independence but extremely high variability between the experimental taper curves of the different trees. Mixed models provide one of powerful tools to analysis of longitudinal data. These models incorporate the variability between individual trees by means of the expression of the model's parameters and in terms of both fixed and random effects. Each parameter in the model may be represented by a fixed effect that stands for the mean value of the parameter as well as a random effect that expresses the difference between the value of the parameter fitted for each specific tree and the mean value of the parameter - the fixed effect. Random effects are conceptually random variables. They are modelled as such in terms of describing their distribution. This helps to avoid the problem of overparameterisation. A large number of mixed-effect taper models have been completed, and the study is still one of the important issues in progress (Trincado and Burkhard, 2006; Yang et al., 2009; Westfall and Scott, 2010; and references therein).

The increasing popularity of mixed-effects models lies in their ability to model total variation, splitting it into its within- and between-individual tree components. We propose to model these variations using stochastic differential equations that are deduced from the standard deterministic growth function by adding random variations to the growth dynamics (Suzuki, 1971; Tanaka, 1986; Rupšys et al., 2007; Rupšys and Petrauskas, 2009, 2010a, 2010b, 2012; Petrauskas et al., 2011a). We thus consider stochastic differential equation models whose drift and diffusion terms can depend linearly or nonlinearly on state variables. Although numerous sophisticated models exist for stem taper, no models have been produced using stochastic differential equations.

The aim of this study is to put forward the advantages of using stochastic differential equations in the analysis of taper models and to show how an adequate model can be made. In this paper attention is restricted to homogeneous stochastic differential equations in the Gompertz and Vasicek type (Rupšys et al., 2007; Rupšys and Petrauskas, 2009, 2010a, 2010b, 2011; Rupšys et al., 2011), whose solution produces the regression term of the fixed effects model.

Materials and methods

Consider a one-dimensional stochastic process $Y(x)$ evolving in M different experimental units (e.g. trees) randomly chosen from a theoretical population (tree species). We suppose that dynamics of relative diameter $Y^i = d/D^i$ via relative height $x^i = h/H^i$ ($x^i \in [0,1]$) is expressed by a SDE, where d is the diameter outside

bark at any given height h , D^i is the diameter at breast height outside bark of i th tree, H^i is the total tree height from ground to tip of i th tree. In this paper is used a class of Ito (1942) SDEs that are reducible to an Ornstein-Uhlenbeck process. The first model of relative diameter dynamic is defined in the following Gompertz form

$$dY^i(x^i) = [\alpha_G Y^i(x^i) - \beta_G Y^i(x^i) \ln(Y^i(x^i))] dx^i + \sigma_G Y^i(x^i) dW^i(x^i), \quad P(Y^i(x_0^i) = y_0^i) = 1, \quad i = 1, \dots, M, \quad (1)$$

where $Y^i(x^i)$ is the value of the diameter growth process at relative height $x^i \geq x_0^i$;
 $\alpha_G, \beta_G, \sigma_G$ are fixed effects parameters (the same for the entire population of trees);
 y_0^i is non-random initial relative diameter.

The $W^i(x^i), i = 1, \dots, M$ are mutually independent standard Brownian motions. Intuitively, we interpret the terms $W^i(x^i), i = 1, \dots, M$ as ecological and environmental noises. The second model of relative diameter dynamic is defined in the following Vasicek form

$$dY^i(x^i) = \beta_V(\alpha_V - Y^i(x^i)) dx^i + \sigma_V dW^i(x^i), \quad P(Y^i(x_0^i) = y_0^i) = 1, \quad i = 1, \dots, M. \quad (2)$$

where $\alpha_V, \beta_V, \sigma_V$ are fixed effects parameters (the same for the entire population of trees).

SDEs approach adds dynamics noise, allows intra-individual variations through fluctuation of transfer rates over relative height, and accounts for not-well understood complex taper process. In this paper is used a segmented stochastic taper process which consists of two different SDEs defined by (1), (2). It conforms to the paradigm of stem taper curve that marks three different stem sections along the bole (two points of inflection): the lower section corresponding to a neiloid shape, the middle section corresponding to a parabolic shape, and the upper section corresponding to a conic shape. Max and Burkhart (1976) proposed a segmented polynomial model that uses two joining points to link three different stem sections. Following this idea the stem taper SDE models (with two joining points) are defined in the following forms (Gompertz-Vasicek-Vasicek),

$$dY^i(x^i) = \begin{cases} [\alpha_G Y^i(x^i) - \beta_G Y^i(x^i) \ln(Y^i(x^i))] dx^i + \sigma_G Y^i(x^i) dW^i(x), & x^i \leq 0.15 \\ \beta_{V1}(\alpha_{V1} - Y^i(x^i)) dx^i + \sigma_{V1} dW^i(x^i), & 0.15 < x^i \leq 0.75 \\ \beta_{V2}(\alpha_{V2} - Y^i(x^i)) dx^i + \sigma_{V2} dW^i(x^i), & x^i > 0.75 \end{cases} \quad (3)$$

where $P(Y^i(x_0^i) = y_0^i) = 1, i = 1, \dots, M$ (stem butt is fixed),

$$dY^i(x^i) = \begin{cases} [\alpha_G Y^i(x^i) - \beta_G Y^i(x^i) \ln(Y^i(x^i))] dx^i + \sigma_G Y^i(x^i) dW^i(x), & x^i \leq 0.15 \\ \beta_{V1}(\alpha_{V1} - Y^i(x^i)) dx^i + \sigma_{V1} dW^i(x^i), & 0.15 < x^i \leq 0.75 \\ \beta_{V2}(\alpha_{V2} - Y^i(x^i)) dx^i + \sigma_{V2} dW^i(x^i), & x^i > 0.75 \end{cases} \quad (4)$$

where $P(Y^i(x_0^i) = y_0^i) = 1, P(Y^i(x_{n_i}^i) = y_{n_i}^i) = 1, i = 1, \dots, M$ (stem butt and top are fixed).

Assume that tree i is observed at $n_i + 1$ discrete relative height points $(x_0, x_1, \dots, x_{n_i})$ $i = 1, \dots, M$. Let \underline{y}^i be the vector of responses (relative diameter) for tree i , $\underline{y}^i = (y_0^i, y_1^i, \dots, y_{n_i}^i)$, where $y^i(x_j^i) = y_j^i$, $\underline{y} = (\underline{y}^1, \underline{y}^2, \dots, \underline{y}^M)$ be the n -dimensional total relative diameter vector, $n = \sum_{i=1}^M (n_i + 1)$. Therefore, we need to estimate fixed-effects using simultaneously all the data in \underline{y} . Both models proposed in this paper use one tree-specific prior relative diameter y_0^i (this known initial condition additional needs upper stem diameter measured at a stem height of 0 m). The transition probability density function of relative diameter stochastic processes $Y^i(x_j^i), x_j^i \in [0, 1], i = 1, \dots, M, j = 0, \dots, n_i$ defined by Eqs. (1), (2), can be deduced in the following form: for the Gompertz stem taper model

$$P_G(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G) = \frac{1}{y_j^i \sqrt{2\pi v_G(x_j^i | \beta_G, \sigma_G)}} \times \exp\left(-\frac{1}{2v_G(x_j^i | \beta_G, \sigma_G)} (\ln y_j^i - \mu_G(x_j^i | \alpha_G, \beta_G, \sigma_G))^2\right) \quad (5)$$

where

$$\mu_G(x_j^i | \alpha_G, \beta_G, \sigma_G) = \ln y_0^i e^{-\beta_G x_j^i} + \frac{1 - e^{-\beta_G x_j^i}}{\beta_G} \left(\alpha_G - \frac{\sigma_G^2}{2} \right), \quad (6)$$

$$v_G(x_j^i | \beta_G, \sigma_G) = \frac{1 - e^{-2\beta_G x_j^i}}{2\beta_G} \sigma_G^2, \quad (7)$$

and for the Vasicek stem taper model

$$p_V(y_j^i, \Delta_j^i | y_0^i, \alpha_V, \beta_V, \sigma_V) = \frac{1}{s\sqrt{\pi}} \exp \left(- \frac{\left(y_j^i - \alpha_V - (y_0^i - \alpha_V) e^{-\beta_V \Delta_j^i} \right)^2}{s^2} \right), \quad (8)$$

$$s^2 = \frac{\sigma_V^2}{\beta_V} \left(1 - e^{-2\beta_V \Delta_j^i} \right). \quad (9)$$

The mean and variance functions $m(x^i | \cdot)$, $v(x^i | \cdot)$ (x^i is the relative height of i th tree) of the stochastic processes (1), (2) are defined by

$$m_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G) = \exp \left(\ln y_0^i e^{-\beta_G x^i} + \frac{1 - e^{-\beta_G x^i}}{\beta_G} \left(\alpha_G - \frac{\sigma_G^2}{2} \right) + \frac{\sigma_G^2}{4\beta_G} \left(1 - e^{-2\beta_G x^i} \right) \right), \quad (10)$$

$$v_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G) = \exp \left(2 \left(\ln y_0^i e^{-\beta_G x^i} + \frac{1 - e^{-\beta_G x^i}}{\beta_G} \left(\alpha_G - \frac{\sigma_G^2}{2} \right) \right) + \frac{\sigma_G^2}{2\beta_G} \left(1 - e^{-2\beta_G x^i} \right) \right) \times \left(\exp \left(\frac{\sigma_G^2}{2\beta_G} \left(1 - e^{-2\beta_G x^i} \right) \right) - 1 \right) \quad (11)$$

for the Gompertz model,

$$m_V(x^i | y_0^i, \alpha_V, \beta_V) = \alpha_V + (y_0^i - \alpha_V) e^{-\beta_V x^i}, \quad (12)$$

$$v_V(x^i | \beta_V, \sigma_V) = \frac{\sigma_V^2}{2\beta_V} \left(1 - e^{-2\beta_V x^i} \right), \quad (13)$$

for the Vasicek model.

Using solutions (5), (8) of SDEs (1), (2), the transition probability density functions of relative diameter stochastic process $Y^i(x_j^i)$, $x_j^i \in [0;1]$, $i=1, \dots, M$, $j=0, \dots, n_i$ defined by Eqs. (3), (4) take the following forms, respectively:

$$p_{GIV}(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \sigma_{V1}, \alpha_{V2}, \beta_{V2}, \sigma_{V2}) = \begin{cases} p_G(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x_j^i \leq 0.15 \\ p_V(y_j^i, x_j^i | m_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G), \alpha_{V1}, \beta_{V1}, \sigma_{V1}), & 0.15 < x_j^i \leq 0.75 \\ p_V(y_j^i, x_j^i | m_V(x^i | 0.75, \alpha_{V1}, \beta_{V1}), \alpha_{V2}, \beta_{V2}, \sigma_{V2}), & x_j^i > 0.75 \end{cases}, \quad (14)$$

$$\begin{aligned}
 & p_{GTV}(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \sigma_{V1}, \alpha_{V2}, \beta_{V2}, \sigma_{V2}) \\
 &= \begin{cases} p_G(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x_j^i \leq 0.15 \\ p_V(y_j^i, x_j^i | m_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G), \alpha_{V1}, \beta_{V1}, \sigma_{V1}), & 0.15 < x_j^i \leq 0.75 \\ p_V(y_j^i, 1 - x_j^i | 0, \alpha_{V2}, \beta_{V2}, \sigma_{V2}), & x_j^i > 0.75 \end{cases} \quad (15)
 \end{aligned}$$

The mean and variance trajectories $m(x^i | \cdot)$, $v(x^i | \cdot)$ (x^i is the relative height of i th tree) of the Gompertz-Vasicek-Vasicek stem taper processes (3), (4) are given, respectively

$$\begin{aligned}
 & m_{GTV}(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \alpha_{V2}, \beta_{V2}) \\
 &= \begin{cases} m_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x^i \leq 0.15 \\ \alpha_{V1} + (m_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G) - \alpha_{V1}) e^{-\beta_{V1}(x^i - 0.15)}, & 0.15 < x^i \leq 0.75 \\ \alpha_{V2} + (m_V(0.75 | y_0^i, \alpha_{V1}, \beta_{V1}) - \alpha_{V2}) e^{-\beta_{V2}(x^i - 0.75)}, & x^i > 0.75 \end{cases} \quad (16)
 \end{aligned}$$

$$\begin{aligned}
 & v_{GTV}(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \beta_{V1}, \sigma_{V1}, \beta_{V2}, \sigma_{V2}) \\
 &= \begin{cases} v_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x^i \leq 0.15 \\ v_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G) + v_V(x^i - 0.15 | \beta_{V1}, \sigma_{V1}), & 0.15 < x^i < 0.75 \\ v_V(0.75 - 0.15 | \beta_{V1}, \sigma_{V1}) + v_V(x^i - 0.75 | \beta_{V2}, \sigma_{V2}), & x^i \geq 0.75 \end{cases} \quad (17)
 \end{aligned}$$

$$\begin{aligned}
 & m_{GTV}(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \alpha_{V2}, \beta_{V2}) \\
 &= \begin{cases} m_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x^i \leq 0.15 \\ \alpha_{V1} + (m_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G) - \alpha_{V1}) e^{-\beta_{V1}(x^i - 0.15)}, & 0.15 < x^i \leq 0.75 \\ \alpha_{V2} + (-\alpha_{V2}) e^{-\beta_{V2}(1 - x^i)}, & x^i > 0.75 \end{cases} \quad (18)
 \end{aligned}$$

$$\begin{aligned}
 & v_{GTV}(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \beta_{V1}, \sigma_{V1}, \beta_{V2}, \sigma_{V2}) \\
 &= \begin{cases} v_G(x^i | y_0^i, \alpha_G, \beta_G, \sigma_G), & x^i \leq 0.15 \\ v_G(0.15 | y_0^i, \alpha_G, \beta_G, \sigma_G) + v_V(x^i - 0.15 | \beta_{V1}, \sigma_{V1}), & 0.15 \leq x^i < 0.75 \\ v_V(1 - x^i | \beta_{V2}, \sigma_{V2}), & x^i \geq 0.75 \end{cases} \quad (19)
 \end{aligned}$$

In this paper, we apply the theory of a one-stage maximum likelihood estimator for the stem taper SDE models (3), (4). Both models have closed form transition probability density functions (14), (15). Thus, the log-likelihood function for stem taper SDE models (3), (4) are given

$$\begin{aligned}
 & LL_{GTV}(\alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \sigma_{V1}, \alpha_{V2}, \beta_{V2}, \sigma_{V2} | y_0^i) \\
 &= \sum_{i=1}^M \sum_{j=1}^{n_i} \ln(p_{GTV}(y_j^i, x_j^i | y_0^i, \alpha_G, \beta_G, \sigma_G, \alpha_{V1}, \beta_{V1}, \sigma_{V1}, \alpha_{V2}, \beta_{V2}, \sigma_{V2})) \quad (20)
 \end{aligned}$$

We focus on the modeling of Scots pine (*Pinus Sylvestris*) tree data sets. Scots pine trees dominate Lithuanian forests, growing on *Arenosols* and *Podzols* forest sites and covering 725500 ha. Stem measurements for 300 Scots pine trees were used for volume and stem profile models analysis. All section measurements include of 3821 data points. Summary statistics for diameter outside bark at breast height (D), total height (H) and age (A) of all trees used for parameters estimate and models comparison are presented in Table 1.

Table 1

Summary statistics of the data set for Scots pine trees across Lithuania

Data	Number of trees	Min	Max	Mean	St. Dev.
D(cm)	300	6.3	53.8	24.6	9.9
H (m)	300	5.6	34.5	20.6	5.4
A (yr)	300	23	161	77.2	25.8

Results and discussion

The parameters of both SDEs stem taper models (3), (4) were estimated by the maximum likelihood procedure. Estimation results are presented in Table 2. All parameters are highly significant ($\alpha < 0.05$). The fit statistics (mean absolute prediction bias, precision, least squares based Akaike's (1974) information criterion, and an adjusted coefficient of determination (\bar{R}^2)) for the SDEs stem taper models (3), (4) are very close to the other commonly used stem taper regression models. The diameters' estimate along the stem for the all SDEs stem taper models proves satisfactory, with mean absolute prediction bias 1.030 cm, 0.899 cm, respectively. The percent of variation explained attains high level 98.6%. To test the compatibility between taper and volume equations of all used stem taper models, the observed volume values from the sampled trees were calculated by Eq. (21)

$$V_i = \frac{\pi}{40000} \left(\sum_{k=1}^{n_i-2} \frac{(d_{ik}^2 + d_{ik+1}^2 + d_{ik} \cdot d_{ik+1}) \cdot L_{ik}}{3} + \frac{d_{in_i-1}^2 \cdot L_{in_i-1}}{3} \right). \tag{21}$$

The predicted volume for the sampled tree is computed using numerical integration. On the whole, for both used taper models the mean absolute prediction bias proves to be 40 dm³. The percent of variation explained attains high levels, equaling 98.7%.

Table 2

Estimated parameters (standard errors in parentheses) of both models									
Eq.	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9
Scots pine									
(3)*	-2.065 (0.017)	10.054 (0.266)	0.287 (0.006)	379.275 (9.479)	-0.002 (4.7*10 ⁻⁶)	0.224 (0.004)	442.481 (18.486)	-0.004 (1.8*10 ⁻⁴)	0.357 (0.010)
(4)*	-2.100 (0.017)	11.926 (0.342)	0.260 (0.010)	277.703 (4.235)	-0.002 (6.1*10 ⁻⁶)	0.227 (0.003)	0.675 (0.009)	4.101 (0.057)	0.236 (0.001)

* $\beta_1 = \alpha_G, \beta_2 = \beta_G, \beta_3 = \sigma_G, \beta_4 = \alpha_{V1}, \beta_5 = \beta_{V1}, \beta_6 = \sigma_{V1}, \beta_7 = \alpha_{V2}, \beta_8 = \beta_{V2}, \beta_9 = \sigma_{V2}$

Taper profiles for three randomly selected Scots pine trees with diameters outside bark at breast height of 6.3 cm, 24.4 cm, 41.7 cm, and total tree heights of 6.8 m, 25.3 m, 33.1 m, respectively, are plotted in Figure 1. Figure 1 consists of stem taper curve (the mean of the random diameter growth process) and standard deviation (the mean \pm standard deviation of the random diameter growth process). Figure 1 illustrates the mean (Eq. (16), (18) – solid line) and standard deviation trajectory (Eq. (17), (19) – dash-dot line) of diameter at any given height. It is clear that these tree forms follow the stem data very closely. Graphical examination leads to the conclusion that SDEs stem taper models (3), (4) describe stem taper quite well.

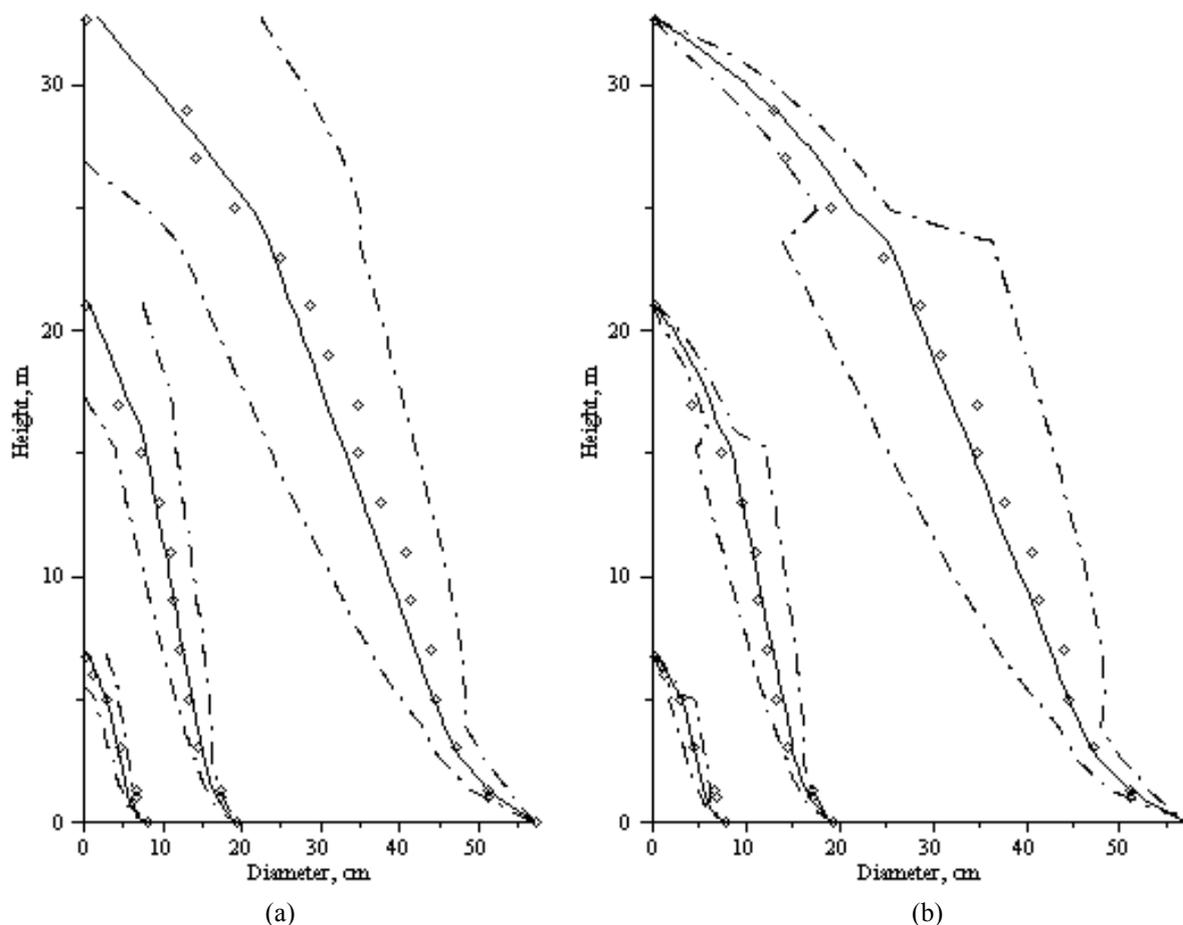


Fig. 1. Tree profiles for three randomly selected pine trees generated using SDEs models (2), (3): (a) Eqs. (16), (17); (b) Eqs. (18), (19).

Conclusion

Two new taper models were developed using stochastic differential equations. The both SDEs stem taper models provided here can be predicted from simple and standard tree measurements: total height, diameter outside bark at breast height, and diameter outside bark at the butt.

The SDEs approach allows us to incorporate new tree variables, mixed-effect parameters, and new forms of stochastic dynamics.

Despite the advantages of the SDEs stem taper models, it should be kept in mind that their main weakness is the sophisticated framework of the mathematical model.

Finally, we may notice that stochastic differential equation methodology may be of interest far beyond the modelling of a tree taper.

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