THE CHALLENGES IN KNOWLEDGE REPRESENTATION FOR ANALYSIS OF INTER-INSTITUTIONAL KNOWLEDGE FLOWS

Ieva Zeltmate, Marite Kirikova and Janis Grundspenkis
Department of Systems Theory and Design, Riga Technical University
1 Kalku, Riga, Latvia, LV-1658

ABSTRACT

It is essential for the teaching staff to be able to represent and to analyze a level of students` acquired knowledge that allows to adapt to the frequently changing learning situations caused by individual differences of students and to the changing teaching standards in different educational institutions. The paper identifies inter-institutional knowledge flows in the context of educational system. Options of prototype development for consistent knowledge flow support have been discussed too. The proposed solution allows to overcome the challenges of teaching domain complexity with respect to dimensions of time and scale.

KEYWORDS

Knowledge flow, knowledge representation, Frame System, complexity challenges.

1. INTRODUCTION

In each educational institution the teaching domain specifics may be structured differently and, in many cases, represented tacitly rather than explicitly. That leads to different knowledge representations that are utilized by different people involved in student education. During the learning process students pass through several educational institutions and obtain knowledge based on each of structured presentations they come across. To establish where student knowledge complies with standards and university requirements, it is necessary to analyze and evaluate prerequisite knowledge levels of freshmen and other features of education process. It is possible to accomplish the given task with a knowledge flow supporting prototype that has an acceptable knowledge acquisition and representation form.

The objective of this paper is to describe the solution according to the domain specifics that allows to analyze students` knowledge and the actual knowledge transfer. As a result, a provided prototype can be used to support inter-institutional knowledge flows. To improve the students` knowledge quality it is necessary to take into consideration his/her domain knowledge. Exploration of knowledge transfer allows to predict students` knowledge in the future, to set adequate entry requirements at the university and to adjust these requirements to changes.

Authors acknowledge that they haven't found similar solutions that are specific for inter-institutional knowledge flow representation in the educational institution context. The conceptual structure that serves as the starting point of knowledge identification was made and saved within the shell called Frame System.

The paper is structured as follows. In Section 2 knowledge flows of educational process are described, the existing knowledge processing approaches overviewed and the details of the developed knowledge schema presented. Section 3 gives an overview of the chosen knowledge representation tool – the Frame System and discusses complexity challenges that affect the solution. The solution taking into account significant aspects: time and scale is discussed.

2. APPLICATION DOMAIN SPECIFICS

The knowledge transfer in the subject of Informatics was chosen as an application domain and explored in terms of the analysis of inter-institutional knowledge flows (Zhuge 2007). To improve and to understand the activities, roles and related information associated with educational process in the scope we need to identify, store and analyze knowledge flows taking into account time dimensions. First, it is necessary to create some structured notes or schema that serves as a guideline, and is common or shared as well acceptable in all knowledge flows. The knowledge schema is mainly needed to embody some kind of standardized solution and to contribute the knowledge predictability that can serve as a structure for knowledge acquisition. The development of prototype based on designed schema can help to manage a knowledge transfer.

2.1 Knowledge Flows

Secondary school students enter the university with different levels of acquired knowledge, depending on the school, teachers, available technologies and personal qualities. The differences between knowledge content and amount which the first year student is offered at the university and is able to acquire are quite big, too. The knowledge coordination in educational process can be useful to fit student contingent needs and efficiently respond to changes in educational process. A knowledge transfer between members involved in the educational process may create the following inter-institutional knowledge flows:

- the flow between Ministry of Education and the school that carries information about educational standards;
- the flow between the school and the university that carries information about entrant’s knowledge in computer science domain;
- the flow between the university and educational institution of a teacher that carries information about student’s knowledge. The flow can serve as a feedback that allows to improve teacher’s education;
- the flow between the teacher’s educational institution and the school that carries information about teacher’s knowledge in computer science domain;
- the abstract flow between science and the university that carries information about scientific theories. Thanks to science the outcome of the intellectual activities carried out by humans is devised. For example, science incorporates scientific papers, methodologies and technologies.
- the flow between the industry and the university that carries information about students` knowledge and skill requirements required by industry.

All knowledge flows in some way include information about the educational standard in Informatics (Standard 1993). The standard is used to understand the specific domain knowledge content and knowledge usage. Applicable solution can help to identify, acquire and coordinate essential knowledge in education process and transforms it into a representation form that can be used in domain analysis.

2.2 Knowledge Schema

The standard of general secondary education in Informatics in Latvia is used to create the course structure or knowledge schema. The standard consists of twelve pages and includes the description of competences and skills that a student must achieve in the subject of Informatics. Basically, the standard serves as the guidelines for the development of the Informatics courses in secondary schools. Unfortunately, the content is hardly readable and information presentation form does not allow to understand the requirements in unambiguous way. The standard was analysed to acquire fundamental concepts of the domain. Using the descriptions of concepts and related subconcepts the logical relationships between the concepts were acquired. As a result of the analysis of the standard, a clearly structured knowledge schema which is easily realizable in terms of the domain was created. The assumption is made that the created structure is the normative standard for the domain and each student is able to reach some knowledge level in the domain.

Concepts of domain were classified and organized in one structure where each concept represents one knowledge element. A knowledge element can be either part of or can include another knowledge element. Each knowledge element can have properties that describe the details of concept and relations that allow to understand the concept's significance and location in the whole schema. It means that the context and logics of knowledge elements are acquired identifying the relationships with other elements. A knowledge element can be connected with elements that are located somewhere in the structure creating the horizontal hierarchy. Concepts can be decomposed in two different types of subordinate concepts (see Figure 1):

- The first describes knowledge or learning outcomes that are associated with remembering and understanding. Concepts are reflected with lightened shading.
- The second describes skills or learning outcomes associated with ability to apply, analyze and evaluate. Concepts are reflected with darkened shading.

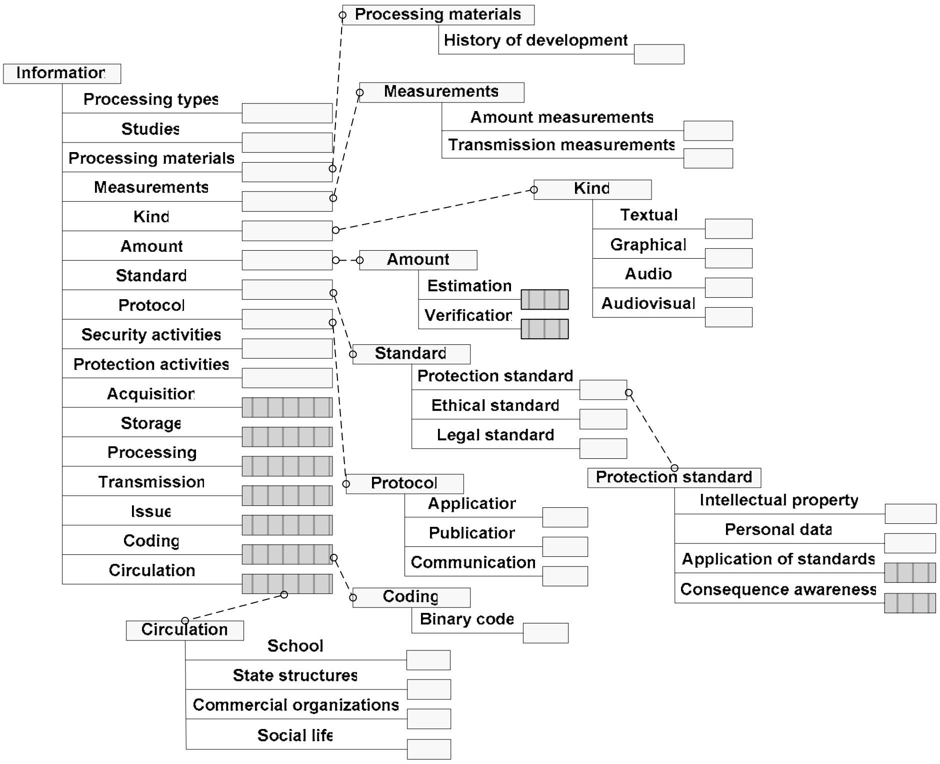

Figure 1. Example of knowledge schema

To show the decomposition example the concept *Information* from the Figure 1 is used. The concept includes ten subconcepts that refer to understanding: Studies, Processing types, Processing materials, Measurements, Kind, Amount, Standard, Protocol, Security Activities and Protection activities. Seven subconcepts that refer to skills are also mentioned: Acquisition, Storage, Processing, Transmission, Issue, Coding and Circulation.

The knowledge schema is structured, combined collection of concepts, relations and additional attributes that can contribute to knowledge gathering, interpretation of context, analysis and generalization. Students are significant members in inter-institutional knowledge flows and the defined structure is provided to create the prototype to obtain and integrate students` knowledge and additional information for the successful knowledge fluctuation analysis. For example, additional information can be obtained about students. With respect to the prototype it is supposed that each student will use the given knowledge schema to represent his/her knowledge in the domain. Students` answers will produce values for attributes related to concepts in the given knowledge schema that will allow to process the stored knowledge. The knowledge schema can help to automate the management of knowledge to some extent. When the knowledge structure is defined the solution must be chosen to provide intuitively clear knowledge representation, acquisition, storage, maintenance and analysis using the knowledge schema.

2.3 Requirements for Tool Suitability

Several aspects that are important in consistent knowledge representation and maintenance were taken into consideration and the following tool suitability requirements stated:

- processing of incomplete information;
- knowledge acquisition and storage based on the created schema;
- two different types of concepts, associative relations and decomposition hierarchy representation;
- all necessary aspects about the chosen concept consistent representation – describing concept related additional information;
- visual knowledge acquisition and representation to guide a considerate knowledge acquisition from students. Structured, but expressible – to display everything that is necessary at a certain moment;
- development of statistics; Knowledge we are interested in is acquired in continuous time (over years) from numerous individuals (first year students);
- knowledge representation of numerous students. One shared structure is used for many instances with similar knowledge in the prescribed domain;
- acquired knowledge analysis, evaluation and potential entrant's knowledge prediction;
- and the last, but not least, important requirement: the tool must be easily accessible, applicable and adaptable for the knowledge schema and information reuse.

The prime requirement is not only to acquire and represent domain concepts, but also to represent and maintain additional information (specific for each case) about concepts in the context of student knowledge. The complexity is increased because of a need to reuse the created schema, which to a certain extent is persistent in time and shared by all students who provide the values (knowledge) for schema. The values also are changing each year with the change of students` contingent. At the same time the existing values must be saved in the context of history (past) to be able to analyze and to create statistics. Implementation of the knowledge schema must be flexible in time. Time and scale inflicts constraints for the choice of knowledge representation techniques. Summarizing all requirements it is obvious that there is a need for some kind of knowledge processing technology that fulfils four consequential roles: capture or acquisition, representation, analysis and sharing.

It is logical that there can't be knowledge processing without representation. The provided domain representation must be successful to allow organization of knowledge and to promote easiness of the context understanding. Obviously the knowledge level provided by the knowledge schema requires to use some integrated tool that contributes foreseeable and expressive knowledge representation. Considering the requirements and the existing resources the tool Frame System (Zeltmate 2007) was chosen as the solution for knowledge schema representation and retention.

3. USAGE OF FRAME SYSTEM

The Frame System is a tool (Valkovska 2005) that is developed in the object–oriented programming language (C++ builder), integrated with a database (MS Access) and can represent domain ontology and concept related values. Within the Frame System it is possible to obtain and store knowledge using the features of the knowledge representation structure called a frame. Frame-based knowledge representation is well known subset of the knowledge representation (Karp 1993). The tool is suitable for the knowledge representation in situations of incomplete information. Certainly it means that the representation of the knowledge schema with the concept's associated properties and relations can be provided.

3.1 Tool Description

The Frame System is the frame-based knowledge representation system that uses Minskys` frame idea (Minsky 1975) and the Structural modelling approach (Grundspenkis 1997). This kind of solution helps to work with knowledge in the situation of incomplete information, providing a rich description of domain.

In the Frame System a tree structure (hierarchy) is used to represent a hierarchy of concepts. Also a horizontal hierarchy that is more complex can be used to demonstrate the relations between concepts.

Visualized representation that allows intuitively represent the students` knowledge is an advantage of the Frame System. The basic element in the shell is a *frame*. A frame encapsulates small information chunks. A frame has a name, slots with labels describing the concept's attributes or features, and possible values for each attribute (Karp 1993). Designing the Frame System a novel structure called a *Frame Set* was created and implemented to provide full (more complete) representation of concepts (Zeltmate 2007). The Frame Set consists of several correlated components: attribute frame, contact frame, behavior frame and procedure frame. Within the Frame Set the names of concepts, properties, procedures, behaviour, and relations between concepts can be defined. In the proposed solution a two level hierarchy of frames are used: a class and a subclass. A class frame specifies information that is typical for a concept that represents a knowledge element; a subclass frame specifies a subordinate concept that is a part of class.

The Frame System is developed in Riga Technical University therefore it is easily accessible for the authors. The functionality of the Frame System helps to implement most of the proposed requirements. If something is changed in the real world, it is possible to make changes also in the representation within the Frame System. As it is listed above, it is possible to work with incomplete information. For example if the value of some property (that characterizes the concept) isn't provided by a person who represents his/her knowledge the tool sets the default value "unknown". When new information is available about the property it is possible to change the value "unknown" to the acquired value.

The Frame System allows representing the knowledge schema concepts (see Figure 2) and provides easy retention for structured representation of concept relations in the data base. Within the Frame System full concept names are visible instead of the incomprehensible identifiers – the knowledge is represented in the tool in the same manner as it is provided. The created and represented knowledge schema can be used to acquire someone's knowledge.

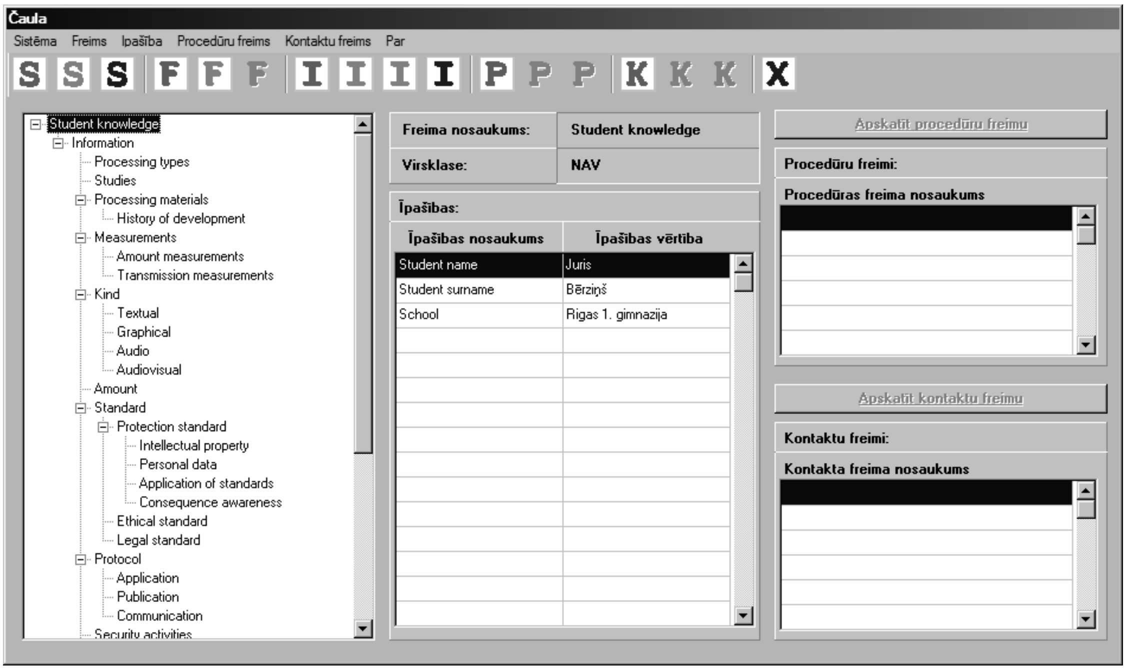

Figure 2. Insight the Frame System

The Frame System allows to capture not only the structure but also detailed problem domain characteristics. It is possible to represent knowledge with different decomposition levels and contexts. The decomposition level depends on the degree of detailed elaboration of the domain concept. The concept decomposition can be represented within the frame class hierarchy. The students` knowledge about the concepts and other additional attributes can be represented within the defined knowledge schema as frame properties. The concept properties and relations improve understanding of the context and logic about the domain. The knowledge acquired from the student (for example, student's name) also can be saved in the database using the Frame System.

The Frame System representation form for the knowledge schema is suitable for knowledge identification and maintenance but unfortunately the tool lacks functionality that guarantees the storage of multiple students` representations simultaneously in one shared database. Besides, the students` knowledge can be represented only at one state of time i.e. at one time moment one knowledge schema and corresponding values can be represented. Of course, the representation can be changed in time within the tool, but there isn't provided the retention for the history of the knowledge changes. The time and multiple instances are complex characteristics of domain that affect the existing solution. The chosen tool serves as a step between the domain schema and the flow supporting prototype. The Frame System must be adapted and integrated with other tools to deal with the technical problems produced by the complexity and to create a knowledge flow supporting prototype. Trying to organize student representation of the domain we are interested in the necessity to overcome the complexity challenges.

3.2 Complexity Challenges and Proposed Solution

Considering the domain characteristics it is evident that each student is an individual with different knowledge, so in each case a knowledge schema is fulfilled differently. The storage of the history (individual's knowledge changes) requires time properties. Without the retention of knowledge that is delivered in continuous time and from multiple individuals it is hard to carry out the knowledge analysis, evaluation and accumulation of statistics. Likewise the prediction of the potential entrant's knowledge without the support of time and instance properties in the tool is a cumbersome procedure.

The knowledge schema is shared for all instances and is not frequently defined. Therefore, if the content of the knowledge schema is changed it is easy to change also the representation of the schema in the tool for all instances. To represent multiple instances the *instance dimension* (see Figure 3) was created. Within the instance dimension the properties that characterize the instance originality is defined.

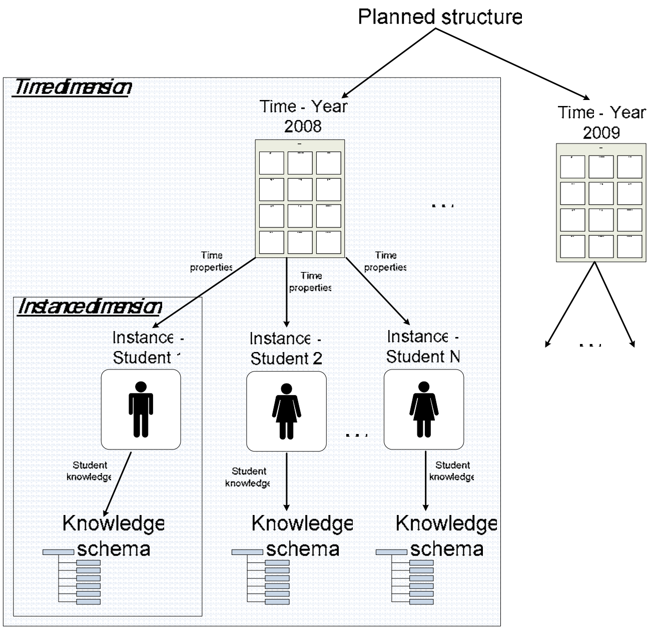

Figure 3. The planned structure

To include and represent time properties of the domain (for example, one year) the *time dimension* (see Figure 3) is proposed. The time dimension can help to represent knowledge models in time. Every time dimension provides the representation of one time moment. Since information about students` knowledge is taken in discrete time each year there is some abstract state in time that is fixed and described. In the planned structure one time dimension allows to represent one year. Additional time properties such as a month, a day can be varied for each instance dimension. For both dimensions only the distinct characteristics are defined within the dimension properties and common shared features are planned to be define only once.

Due to the complexity problems that are introduced by the time and the instance number the decision is made to use the Frame System, changed database, and the Web based prototype (see Figure 4). It is planned to use the Frame System for knowledge schema representation and maintenance. The database will be used for the knowledge, information retention and processing (knowledge analysis and evaluation). The prototype will be used for the knowledge acquisition from students, knowledge representation and, therefore, supporting inter-institutional knowledge flows.

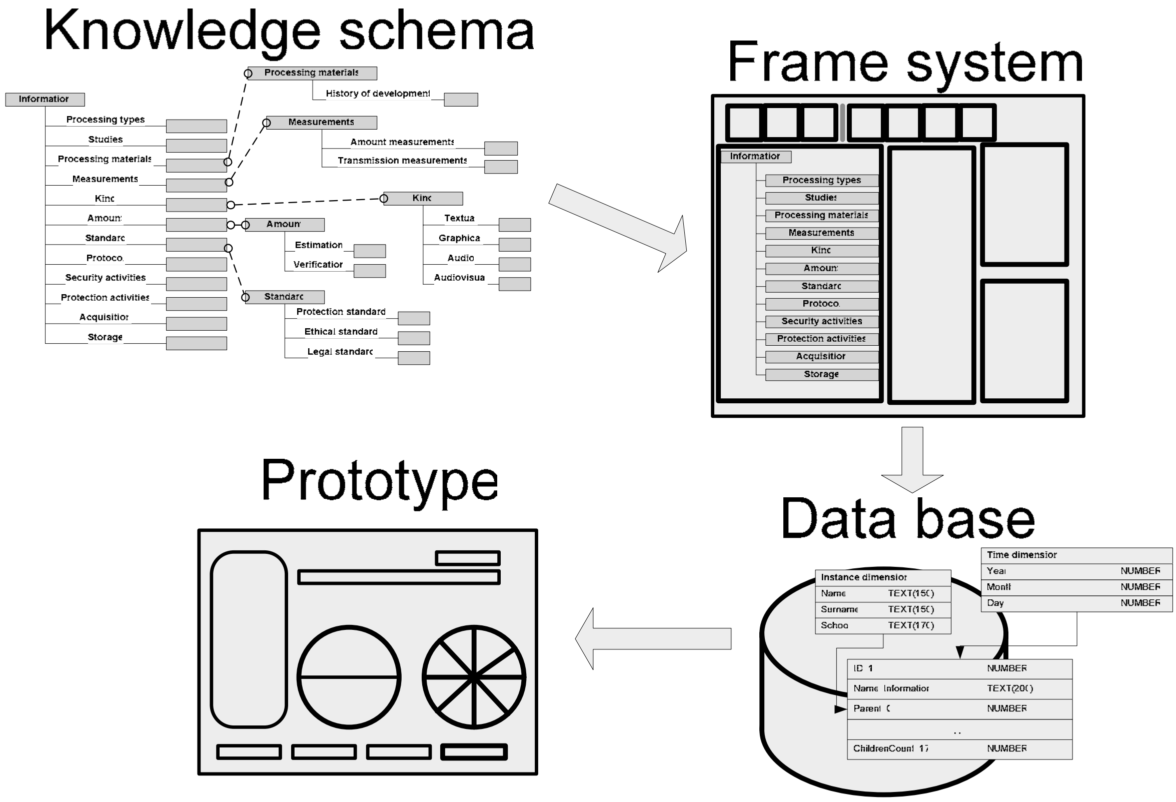

Figure 4. The proposed solution

It is necessary to use some knowledge representation schema in the database to provide corresponding semantics for the gained knowledge. Without the schema the knowledge retention is a time-consuming procedure. For the existing database structure that is designed for the Frame System the time and instance dimensions was added to create a shared database for the domain. A shared database can provide storage, revision, analysis and also the multi-user facility for a large amount of data using integrated tools for data management.

The Web prototype uses the same knowledge schema that is stored in the database to acquire the students` knowledge. Every student can access his/her page where the provided knowledge and the knowledge analysis results are represented. The analysis will be done comparing the prognosis and acquired knowledge (the predicted knowledge versus existing knowledge). All the necessary information will be represented and shared to provide consistent knowledge flow support. The knowledge sharing will allow to organize feedback to other educational institutions. In the proposed solution the amount of information that is requested from the student is minimized. The solution provides the analysis and comparison of different individual knowledge. It allows to access, analyze and compare answers of individual students in different moments of time. It also allows to predict the probable knowledge in the future.

4. CONCLUSION

Research efforts were motivated by two main goals. The first was to understand and to evaluate what students actually know in the concrete domain as well as to obtain descriptive, though structured view about educational process results that are achieved after the secondary school and to provide feedback to educational institutions. The second goal was to anticipate (predict) the approximate students` knowledge in the following years, analyzing the collected information that includes multiple educational aspects. One of main objectives of this work is to adapt to circumstances provided by existing educational process and standards. The course standard was used to build the knowledge schema and to find knowledge that is worth to represent and analyze. The knowledge schema was supposed as standard solution for equivalent knowledge acquisition that allows collecting essential information about students` knowledge.

The Frame System was inspected in connection with provided requirements and implementation of a new solution that provides domain required functionality. Ideally, from the obtained student knowledge, it must be possible to predict potential entrant's knowledge for the next year and to identify the right educational strategy. The analysis will help to find inconsistencies between the knowledge that a student really can have and the knowledge which is required in the first year or must be as prerequired condition.

The obtained results allow to access the students' knowledge, to identify "knowledge gaps" and to adapt to a real level of knowledge. Thus, it is possible to provide prerequisite inter–institutional knowledge flows and to provide a feedback.

ACKNOWLEDGEMENT

This work has been partly supported by the European Social Fund within the National Programme „Support for the carrying out doctoral study program's and post-doctoral researches" project „Support for the development of doctoral studies at Riga Technical University".

This work has been partly supported by the project "Development of the prototype for the support of inter–institutional flow of knowledge" at Riga Technical University (grant number ZP-2007/06).

REFERENCES

Book

Ministry of Education, 1993, The educational standard in Informatics, Injunction Nr. 237, Riga, Latvia, 12 p.

Zeltmate, I., 2007. Frame system development for structural modelling knowledge representation purpose, Master thesis, RTU, Riga, Latvia, 214 p.

Journal

Minsky, M., 1975. A Framework for Representing Knowledge, *The Psychology of Computer Vision*, (ed. Winston P. H.,) McGraw – Hill Book Company, New York, 1975, pp. 211-277.

Zhuge, H. et al, 2007. The potential energy of knowledge flow, *Concurrency and Computation: Practice & Experience*, Volume 19, Issue 15, John Wiley & Sons, pp. 2067-2090.

Conference paper or contributed volume

Grundspenkis, J., 1997. Structural Modelling of Complex Technical Systems in Conditions of Incomplete Information. *Modern aspects of management science*, No.1, Riga, Latvia, pp. 111-135.

Karp P. D., 1993. The Design Space of Frame Knowledge Representation Systems, Technical Report 520, SRI International, Artificial Intelligence Center, 49 p.

Valkovska I., Grundspenkis J., 2005. Development of Frame Systems Shell for Learning of Knowledge Representation Issues. In: Proceedings of the International Conference on Computer Systems and Technologies – CompSysTech'05, Varna, Bulgaria, June 16-17, 2005, (Ed. Rochev B., Smrikarov A.), The Bulgarian Chapter of ACM, pp. IV.11.-1 – IV.11.-6.