CROWDSOURCING SUPPORTED MODELLING AND ANALYSIS INFRASTRUCTURE FOR INTELLIGENT MONITORING OF NATURAL-TECHNOLOGICAL OBJECTS

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ABSTRACT
The effective use of the results of ground-space monitoring and its integration with the processes of national economic management, within the intensification of human activities and recent years natural disasters and major accidents, becomes important strategic factor for accelerating socio-economic development of any region of the world. This article discusses the possibility of combining modern social technologies and the process of ground-space monitoring of natural and technological objects, as well as improving the efficiency and social importance of this process, by involving public representatives to the dissemination and use of the monitoring data.

Keywords: social technologies, crowdsourcing, ground-space monitoring, natural-technological objects, intelligent technological platform

1. INTRODUCTION

In recent years, mankind has increasingly faced with natural and technological disasters, which may be explained by the intensification of economic activities of people in the scientific and technological progress, is causing unwanted and dangerous natural and technological phenomena. At the same time as the development of science and technology society becomes more protected from natural and other disasters, the number of victims is reduced, but the total damage from disasters is rising. To reduce the risk of developing dangerous situations, a global monitoring of risk areas and facilities is needed, as well as the creation of a common information space to provide objective information to all interested parties.

Remote sensing from space provides a unique opportunity to obtain information about the objects and phenomena on a global scale with high space and time resolution. The criteria for the appropriateness of space systems in the solution of a problem are the relevance of its solutions, economic efficiency or the impossibility of solving by the traditional technologies. Most effective for the monitoring of the majority of natural and technological objects is the solution, integrating traditional and space monitoring tool.

The monitoring information regarding incidents and disasters is received typically from different data sources (e.g. biometric systems, aerospace systems, etc.), and, therefore, it is heterogeneous by nature (e.g. electrical signals, graphical, audio, video information, text, etc.). Thus, since modern natural-technological objects are very complex and multifunctional ones, their monitoring should be performed in conditions of large-scale heterogeneous data sets. Currently, the monitoring and control of natural and technological systems are still not fully automated.

Developed within the project INFROM "Integrated Intelligent Platform for Monitoring the Cross-Border Natural-Technological Systems" technology (Merkuryev, Sokolov and Merkuryeva 2012) involves the creation of an intellectual platform for the processing and use of the results of both ground-and space monitoring. Project provides the development of a common information space to monitor natural and technical objects-border states, providing for the government and the public topical environmental information for use in education, science, business, case management, and will also provide additional independent source of operational information on natural and technological hazards processes.

Another important result is to attract people to the development of innovative technologies and the active use of space activities. Developed intellectual platform will also help to reduce the risk and minimize the impact of natural or technological disasters by helping the timely notification of the population in the case of the disaster and its prognosis. To achieve this, it is proposed to use modern social technologies (crowdsourcing) that have been widely spread in many areas of the economy.

2. CROWDSOURCING AS A MODERN SOCIAL TECHNOLOGY

Recently conducted by a well-known Gartner Inc. company studies have shown the need for entrepreneurs, willing to win the competition in the market, choosing the new business models (instruments and processes), which primarily will be based on social networks and media (Bradley and McDonald 2011). One of the such tools is the crowdsourcing, which is a conceptual part of the Human Computing, which can take various forms (Participatory Sensing, Urban Sensing, Citizen Sensing), in accordance with the scale of involvement of the people, tasks, they are addressed to design, and incentives that are designed to facilitate their participation.

The term "Crowdsourcing" is derived from the words crowd and outsourcing; this is a process required people, who are not organized in any other system, to perform a specific job. The creator of the term Jeff Howe considered crowdsourcing as a new social phenomenon that is beginning to emerge in certain areas (Howe 2006), as a phenomenon of bringing people together for the solution of the problem without any reimbursement, and the consequences of such groups/associations for business, solving similar tasks professionally. The method consists in the fact that the task is offered to an unlimited number of people, regardless of their professional status or age. Participants of a crowdsourcing project form the society that chooses by discussing the most successful solution of the given problem. For businesses, this method is an inexhaustible resource for finding solutions to solve their own problems and issues, a powerful tool that allows to adjust the cost-effectively development, including the development of the most customer-oriented products.

Currently a number of social tools are ranked as a crowdsourcing; researchers from Crowdsourcingresults (Dawson 2010) proposed a comprehensive classification of modern methods of crowdsourcing (see Fig. 1), the most popular of which are:

1. Reference Content, when everyone who knows more, improves reference resource. The most popular such resource is Wikipedia;

2. Content Markets, when visitors locating and evaluating some content, and site owners are allowed to produce of its best examples;

3. Crowdfunding is a collaboration of people who pool their resources (money) to support projects initiated by other people or organizations;

4. Competition Platforms, when the customer announces, placing job online platform; actors offer their solutions and evaluate the proposals of colleagues, as the result the best work is chosen, which is usually rewarded; one of the most famous examples of such resource is the site Zooppa.com;

5. Micro-tasks, when the customer announces the use of human intelligence to perform small tasks that cannot be formalized and solve by computers (Human Intelligence Tasks). The most famous site is the platform Amazon Mechanical Turk;

6. Crowdsourcing Aggregators, when the performers take on a client project, divide it down into individual tasks that are offered in the form of micro-projects for crowdsourcing workforce, and then aggregated with ethyl results. This approach allows solving large-scale, automated by hard task. Indicative of this type of platform is the site of CrowdFlower;

7. Cycle Sharing, realizing of the idea of using computers for volunteers distributed computing.

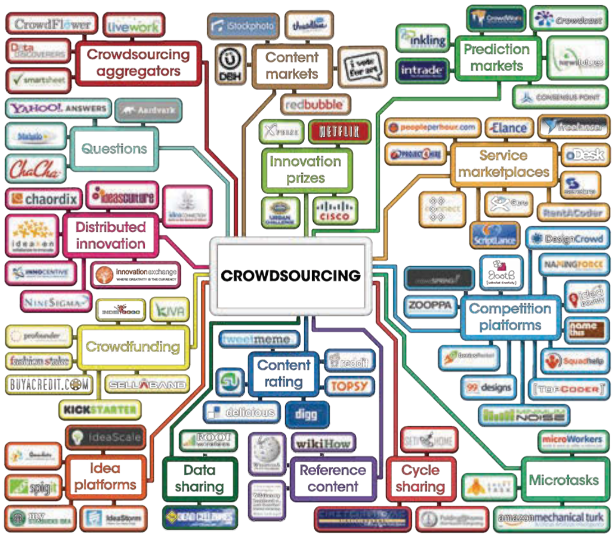

Figure 1: Methods of crowdsourcing (Dawson 2010)

3. CROWDSOURCING IN THE TASKS OF MONITORING

Remote monitoring has a long history of use for collection of environmental measurements. Many sensor networks have been deployed to monitor Earth's environment, and more will follow in the future. Environmental sensors have improved continuously by becoming smaller, cheaper, and more intelligent. Due to the large number of sensor manufacturers and differing accompanying protocols, integrating diverse sensors into observation systems is not straightforward. A coherent and integrated infrastructure is needed to treat sensors as interoperable, platform-independent and uniform way. The concept of the Sensor Web reflects such a kind of infrastructure for sharing, finding, and accessing sensors and their data across different applications. It hides the heterogeneous sensor hardware and communication protocols from the applications built on top of it. The Sensor Web Enablement initiative started by Open Geospatial Consortium defines the term Sensor Web as "Web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application programming interfaces". Thus, the Sensor Web is to sensor resources what the WWW is to general information sources – an infrastructure allowing users to easily share their sensor sources in a well-defined way.

Environmental management and monitoring systems provide an important application for the crowdsourcing-based paradigm, particularly in the area of integrated planning and management.

More specifically, crowdsourcing can be integrated in environmental planning, management and monitoring at three different levels:

1. Setting up a social network, for a better comprehension of the underlying social system:
    - Network identification;
    - Interest characterization;
    - Stakeholder clustering and representative selection;
    - Social disambiguation of interests.
2. Putting humans in the loop, in order to exploit human potential as sensors, task solvers and decision makers:
    - Human sensing;
    - Human judgment for task solving;
    - Co-deciding.
3. Eliciting collective knowledge on the environmental systems by exploiting situated and distributed knowledge and expertise, i.e., the so-called social capital.

Thus, crowdsourcing can be applied not only to monitor the status of the selected object or area, but at the same time, increase the awareness of people about the behaviour of the monitoring object. The motivation for engaging the public in monitoring is two-fold (Stevens and D'Hondt 2010). On the one hand, the system of crowdsourcing can complement modern assessment methods to achieve a high degree of spatial-temporal granularity at lower costs. On the other hand, the active involvement of citizens in the processes of decision-making control and increases their self-awareness and sense of responsibility. Not surprising that numerous international reports (European Parliament and Council (EPC) 2002; United Nations Environment Programme (UNEP) 1992) show in the participation of all concerned citizens, at all levels for sustainable socio-economic development. For example, the introduction of smartphones as a personal instrumentation reduces barriers to achieve the democratization process monitoring.

We are starting to see the impact of emerging these technologies on information security - 14% of large organisations had a security breach relating to social networking sites and 9% had a breach relating to smartphones or tablets (PWC 2013), thus assuring security of industrial and private information assets is becoming extremely sensitive and topical issue. There is huge number of available free-ware and paid methods of information protection from unauthorized access by unwanted individuals (Dorogovs and Romanovs 2012).

4. INTEGRATION OF TRADITIONAL AND SOCIAL DATA

Mobile phones increasingly become multi-sensor devices, accumulating large volumes of data related to our daily lives. These trends obviously raise the potential of collaboratively analysing sensor and social data in mobile cloud computing (Yerva, Jeung and Aberer 2012).

In the same time, there exists a growing fleet of various robotic sensors (e.g., robotic fishes) coupled with the emergence of new and affordable monitoring technology that increases exponentially the amount of data collected from the world's geo-spheres. This puts decision-makers and researchers who work with these data in a completely fresh situation.

The two popular data types, social and sensor data, are in fact mutually compensatory in various data processing and analysis. Participatory / citizen sensing (Boulos, Resch, Crowley, Breslin, Sohn, Burtner, Pike, Jezierski and Chuang 2011; Fraternali, Castelletti, Soncini-Sessa, Ruiz and Rizzoli 2012), for instance, enables to collect people-sensed data via social network services (e.g., Twitter, Waze, Ushahidi) over the areas where physical sensors are unavailable. Simultaneously, sensor data (Figure 2) is capable of offering precise context information, leading to effective analysis of social data. Obviously, the potential of blending social and sensor data is high; nevertheless, they are typically processed separately, and the potential has not been investigated sufficiently. Therefore, there is an urgent need for fusing various types of data available from various data sources.

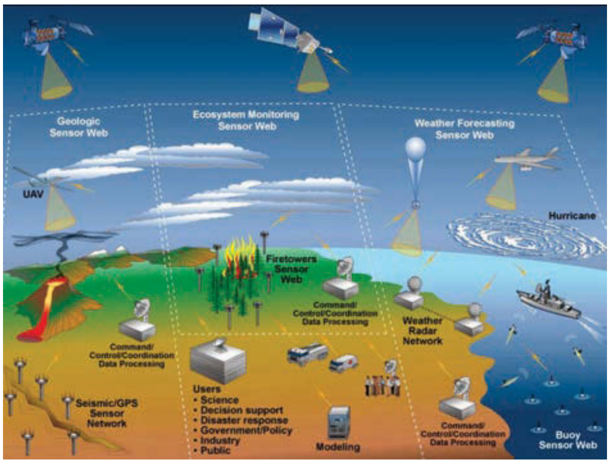

Figure 2: Various sensor data sources (NASA 2008) arranged in a Sensor Web (Fraternali, Castelletti, Soncini-Sessa, Ruiz and Rizzoli 2012)

Data fusion is the process of combing information from a number of different sources to provide a robust and complete description of an environment or process of interest (Durrant-Whyte and Henderson 2008). Automated data fusion processes allow essential measurements and information to be combined to provide knowledge of sufficient richness and integrity that decisions may be formulated and executed autonomously.

The existing projects and platforms for data collection and processing, e.g., GOOS (GOOS 2013), Marinexplore (Marinexplore 2012), Social.Water (Fienen and Lowry 2012), show that the bottleneck of the data market is not in collecting the data, but in the processing the data. Most available data is disconnected, often archived, and sometimes never used again (Marinexplore 2012).

5. CROWDSOURCING MODEL FOR THE INTEGRATED INTELLIGENT PLATFORM OF MONITORING THE CROSS-BORDER NATURAL-TECHNOLOGICAL OBJECTS

Existing space-ground monitoring information processing platform can be without significant cost supplemented with an application that processes the data of social sensors. At a minimum, this social application could consist of two components: a mobile application and server public knowledge base.

Mobile applications are for free downloaded and installed on smartphones, to turn them into mobile monitoring systems social sensors. Smartphones collects information from various sensors (microphone, GPS, descriptive or qualifying user-typed information), and in real time sends to the servers public knowledge base.

Public knowledge base (called also Web-based Community Memory) can be defined as a resource of information and communication technologies that enable the public to record and archive information relating to the management of common property (Steels and Tisseli 2008). Thus, it is part of the software that operates on a central Web server, collects and processes all data received from mobile social sensors, supports a website that allows users to search, analyse and visualize data.

5.1. System Architecture

The objective of the proposed crowdsourcing-supported software platform is to allow blending the heterogeneous social and sensor data for integrated analysis, extracting and modelling environment-dependent information from social and sensor data streams.

The general system architecture consists of four coupled layers (Figure 3):

1. *External data sources*. Environment monitoring is based on data gathered externally by sensors, from structured and unstructured data sources. Data and information providers include researchers, non-researchers, companies, universities, students, communities, primary / secondary schools' pupils.
2. *High-performance computing layer*. High-performance computing layer includes the grid computing cluster, GPU-based computing cluster, environmental modelling subsystem.
3. *Storage layer*. Storage layer is intended for storing and managing high volumes of raw and aggregated data.
4. *Presentation / Service layer*. The presentation / service layer of monitoring system architecture is designed as a set of extendable services. Services are flexible and configurable for various data sources (sensors, structured and unstructured data). Services can be multimodal having a capability to work in automatic, semiautomatic and manual modes.

5.2. Modelling Scenarios

The developed application has a wide range of use, mainly in the form of two scenarios. First scenario: Citizen-led initiatives. Because of the low barrier, in terms of both cost and complexity, concerned individuals can use the platform to study noise pollution in their neighbourhood. The participants can be self-organized citizens with varying levels of organizational involvement: ranging from total strangers that happen to live in the same area; over loosely organized groups of neighbours facing a shared problem; to well-organized previously existing activism groups. The motivation for such initiatives can be diverse: from curiosity about one's daily environment to the gathering of evidence on concrete local issues. These can be long-term issues (such as the problems faced by people living close to airports, highways, factories or nightclubs); short-term ones (such as roadwork's or nearby construction sites); or accidental annoyances (such as manifestations).

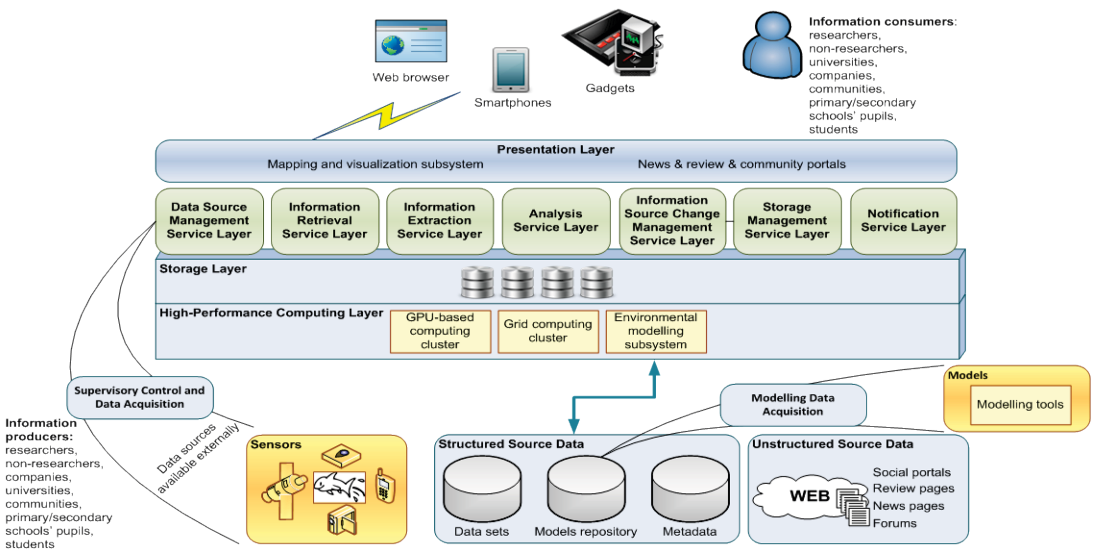

Figure 3: General crowdsourcing-supported system architecture and its components

Second scenario: Authority-led initiatives. Social application can be used by the authorities and public institutions - usually at the municipal or regional level - to collect data on the behaviour of natural and technological objects in their territory. These data can be used to support decision-making and policy-making in areas such as health and urban planning, environmental protection and mobility. When used alongside an existing monitoring system a participatory sensing platform could make up for missing data, help to estimate error margins of simulation models, add semantics (e.g. identification of pollution sources), etc.

In the most effective way social application can be used to control and rapid dissemination of information on natural disasters, major accidents, etc. The prototype of the social application, developed under the supervision of the RTU and SPIIRAS researchers J. Petuhova and S.A. Potryasaev, allow to effectively implementing both of the above described scenarios by the example of the Daugavpils City (Republic of Latvia) (Figure 4).

Figure 4: Crowdsourcing for flood modelling: social application prototype

6. CONCLUSIONS

On the basis of research results presented in this paper it can be marked the importance and effectiveness of integration of remote sensing data, as well as data of other sources with social information in the context of the monitoring of natural-technological systems by focusing on the issues of changing ecosystems, geo systems, climate and providing services for sustainable economy, healthy environment and better human life.

The integration of social and information technologies allows to effectively solving the three biggest issues around managing environment-related data:

- How to access the vast amount of data that is available in different data formats, has different spatial and temporary resolution and quality, as well that reside in isolated silos, segregated and disconnected from each other;
- How to make the time-consuming handling and processing of all this data more efficient;
- How to make the available data, modelling and analysis results publicly available in an efficient and a user-friendly way to facilitate the social interest and responsibility in the environmental monitoring and research processes.

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REFERENCES

Boulos, M.N.K, Resch, B., Crowley, D., Breslin, J., Sohn, G., Burtner, R., Pike, W., Jezierski, E., Chuang, K.-Y.S., 2011. Crowdsourcing, citizen sensing and sensor web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples. *International Journal of Health Geographics*, vol. 10, no. 1, p. 67.

Bradley, A.J., McDonald, M.P., 2011. The social organization: how to use social media to tap the collective genius of your customers and employees // GARTNER,INC. – Boston: Harvard business review press.

Dawson, R., 2010. *Crowdsourcing Landscape – Discussion. Crowdsourcingresults*. Available from: http://crowdsourcingresults.com/competition-platforms/crowdsourcing-landscape-discussion [Accessed 14 May 2013].

Dorogovs, P., Romanovs, A., 2012. Modelling and evaluation of IDS capabilities for prevention of possible information security breaches in a Web-based application. *Proceedings of the 14th International Conference on Harbor Maritime and Multimodal Logistics M&S, HMS 2012*, pp.165–170. September 19-21, 2012, Vienna, Austria.

Durrant-Whyte, H., Henderson. T.C., 2008. Multisensor Data Fusion. In: Sicilliano B., Oussama K., eds. *Springer Hand-book of Robotics*. Springer, 2008, p. 1611.

European Parliament and Council (EPC), 2002. Directive 2002/49/EC relating to the Assessment and Management of Environmental Noise. *Official Journal of the European Communities*, 18.7.2002, pp. 12–26.

Fienen, M.N., Lowry, C.S., 2012. Social.Water—A crowdsourcing tool for environmental data acquisition. *Computers & Geosciences*, vol. 49, pp. 164–169.

Fraternali, P., Castelletti, A., Soncini-Sessa, R., Ruiz, C.V., Rizzoli, A.E., 2012. Putting humans in the loop: Social computing for Water Resources

Management. *Environmental Modelling & Software*, vol. 37, pp. 68–77.
GOOS, 2013. *The Global Ocean Observing System*. Available from: http://www.ioc-goos.org [Accessed 5 July 2013].
Howe, J., 2006. The Rise of Crowdsourcing. *Wired*, Iss. 14.06, June 2006.
Marinexplore, 2012. Marinexplore: Cutting Ocean Data Processing Time Fivefold. *Marine Technology Reporter*, no. 11/12, pp. 30–35.
Merkuryev, Y., Sokolov, B., Merkuryeva, G., 2012. Integrated Intelligent Platform for Monitoring the Cross-Border Natural-Technological Systems. *Proceedings of the 14th International Conference on Harbor Maritime and Multimodal Logistics M&S, HMS 2012*. pp. 7–10. September 19-21, 2012, Vienna, Austria.
NASA, 2008 Report from the Earth Science Technology Office (ESTO) Advanced Information Systems Technology (AIST) Sensor Web Technology Meeting.
PWC, 2013 Information security breaches survey. *PWC, InfoSecurity Europe, UK Department for Business Innovation and Skills.*
Stevens, M., D’Hondt, E., 2010. Crowdsourcing of Pollution Data using Smartphones. *UbiComp ’10*, 2010, Copenhagen, Denmark
Steels, L., Tisseli, E., 2008. Social Tagging in Community Memories. *Social Information Processing – Papers from the 2008 AAAI Spring Symposium* (March 26-28, 2008; Stan-ford University), pp. 98–103, Menlo Park, California, USA, March 2008. AAAI Press.
United Nations Environment Programme (UNEP), 1992. Rio Declaration on Environment and Development. Proclaimed at the United Nations Conference on Environment and Development, June 1992.
Yerva, S.R., Jeung H., Aberer, K., 2012. Cloud based Social and Sensor Data Fusion. *15th International Conference on Information Fusion*, 2012.

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