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Crowdsourcing-based Technique for the Development of Sociotechnical System with Application to the Monitoring of Natural and Technological Objects

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***Abstract* – Recent natural disasters and major technological accidents, as well as intensification of human activities prove the strategic necessity for the effective use of results of natural and technological object monitoring and its integration within the national economic processes. This paper 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* – Crowdsourcing, ground space monitoring, natural and technological objects, social technologies**

I. Introduction

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 solutions, economic efficiency or the impossibility of solving by the traditional technologies. For the majority of natural and technological objects, the most effective solution is the solution that integrates traditional and space monitoring tools.

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.). Since modern natural and technological objects are very complex and multifunctional ones, their monitoring should be performed under conditions of large-scale heterogeneous data sets. At present, the monitoring and control of natural and technological systems are still not fully automated.

The technology developed within the project INFROM (Integrated Intelligent Platform for Monitoring the Cross-border Natural-Technological Systems) involves the creation of an intellectual platform for the processing and use of the results of both ground and space monitoring. The project ensures the development of a common information space to monitor natural and technical objects – border states – providing the government and the society with topical environmental information to be used in education, science, business, case management; moreover, the project will also provide additional independent sources of operational information on natural and technological hazard processes.

Another important result is to attract people to the development of innovative technologies and the active use of space activities. The developed intellectual platform will also help to reduce the risk and to minimize the impact of natural or technological disasters by means of timely notification of the population in the case of disaster and its forecasting. To achieve this aim, it is proposed to use crowdsourcing as a social technology that has been widely spread in many areas of the economy.

The approach of crowdsourcing focuses on the distributed assignment of work to an open community of executors. A typical crowdsourcing application has a Web interface that can be used by two kinds of people: work providers can leave in the system the specification of the work they need; work performers can enrol, declare their skills, take up and perform the work. The crowdsourcing is a conceptual part of the Human Computing that can assume a variety of forms (Participatory Sensing, Urban Sensing, Citizen Sensing), according to the scale at which humans are engaged, the tasks they are called to solve, and the incentive mechanisms that are designed to foster participation.

The crowdsourcing is closely related to the concept of volunteered geographic information, i.e., spatial information created by amateur citizens, that has recently provided an interesting alternative to traditional authoritative information from mapping agencies and corporations, and several recent papers [1], [2] have focused on more fundamental issues raised by this new source. Data quality is a major concern, since volunteered information is asserted and carries none of the assurances that lead to trust in officially created data. During emergencies, time is of the essence, and the risks associated with volunteered information are often outweighed by the benefits of its use.

The objective of the current research is to develop a high-performance cloud-based platform that allows blending the heterogeneous social and sensor data for integrated analysis, extracting and modelling environment-dependent information from social and sensor data streams.

II. Review of Crowdsourcing Technology

The term "crowdsourcing" is derived from the words "crowd" and "outsourcing"; this is a process required by people, who are not organized in any other system, to perform a specific job. Jeff Howe, the creator of the term, considered crowdsourcing to be a new social phenomenon that is beginning to emerge in certain areas [3], a phenomenon of bringing people together to solve 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. According to Daren Brabham, who was the first to define crowdsourcing in the scientific literature as an online, distributed problem-solving and production model, the key ingredients of crowdsourcing are the following [4]:

- an organization that has a task that needs to be performed;
- a community (crowd) that is willing to perform the task voluntarily;
- an online environment that allows the work to take place and the community to interact with the organization;
- mutual benefit for the organization and the community.

Participants of a crowdsourcing project form the society that chooses by discussing the most successful solution to the given problem. For businesses, this method is an inexhaustible resource for finding solutions to their own problems, a powerful tool that allows adjusting the cost-effective development, including the development of customer-oriented products.

At present, a number of social tools are ranked as crowdsourcing; researchers from Crowdsourcingresults [5] proposed a comprehensive classification of modern methods of crowdsourcing covering 22 categories. The most popular methods of crowdsourcing are the following:

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

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

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

4. Competition Platforms, when the customer announces a competition at an online platform, actors offer their solutions and evaluate the proposals of colleagues; as a 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 solved 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 into individual tasks that are offered in the form of micro-projects for crowdsourcing workforce, and then aggregated. This approach allows solving large-scale, automated and hard tasks. The site CrowdFlower is the largest provider of crowdsourcing solutions;

7. Cycle Sharing is the method of crowdsourcing that uses computers for volunteer distributed computing.

There are many ways how crowds can help businesses achieve their objectives; however, this often simply replaces existing approaches to sourcing suppliers or get some organizations supporting functions performed in a different way [5]. It does not fundamentally change the nature of the company, but new crowd business models will emerge to complement the ones we can see today. According to crowdsourcing researchers Ross Dawson and Steve Bynghall [6], there are seven core crowd business models (Fig. 1):

- Marketplaces, matching buyers and sellers of services and financing through mechanisms including bidding and competitions; crowd categories of this model are: service marketplaces, competition markets, crowdfunding, equity crowdfunding, microtasks, innovation prizes, innovation markets; the model implemented, for example, in kickstarter.com, freelancer.com, innocentive.com.
- Platforms, software and processes to run crowdworks and crowdprojects, for use with internal or external crowds; crowd categories of this model are: crowd platforms, idea management, prediction markets; the model implemented, for example, in ideascale.com, spigit.com, consensuspoint.com.
- Crowd processes, services that provide value-added processes or aggregation to existing crowds or marketplaces; alone category – crowdprocess; implemented, for example, in liveops.com, crowdflower.com, smartsheet.com.
- Content and product markets, sale of content or products that are created, developed, or selected by crowds; crowd categories of this model are: content markets and crowd design; implemented, for example, in quirky.com, made.com, redbubble.com.
- Media and data, creation of media, content, and data by crowds; crowd categories of this model are: knowledge sharing, data, content; the model implemented, for example, in inquora.com, imdb.com, hunted.com.
- Crowd services, services that are delivered fully or partially by crowds; crowd categories of this model are: labour pools, managed crowds; the model implemented, for example, in geniusrocket.com, bzzagent.com, thinkspeed.com.
- Crowd ventures, ventures that are predominantly driven by crowds, including idea selection, development, and commercialization; alone category – crowd ventures; the model implemented, for example, in my3p.com, sensorica.co.

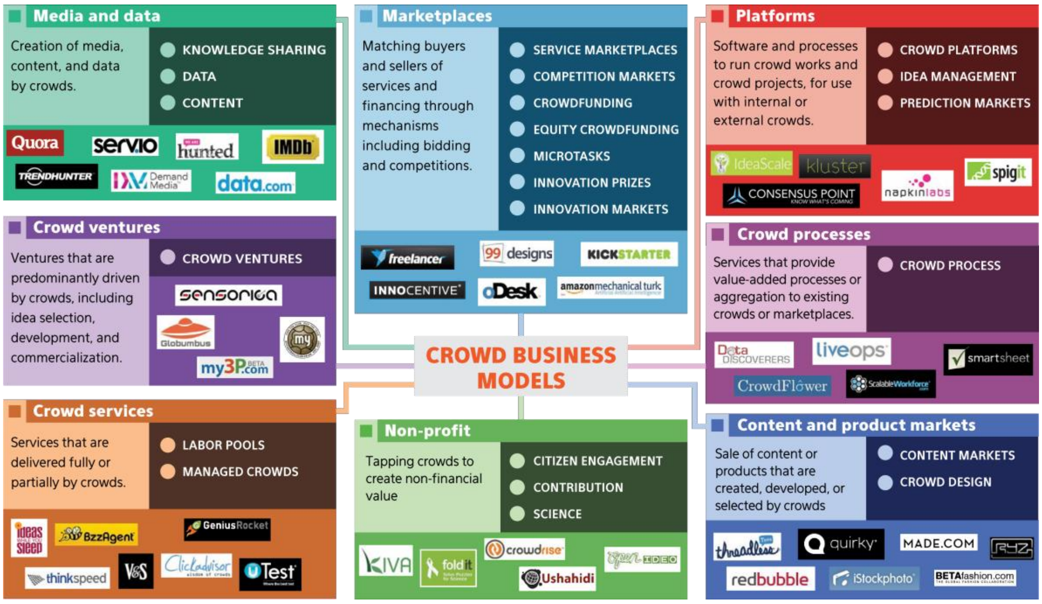

Fig. 1. Crowd business models

Each business model relies on a set of specific monetization models, including across transaction fees, subscriptions, and content and product sales [6]. Business models define how resources are brought together to create a magnetisable value. In crowd business models, the resources are primarily based on crowds. Some of these crowd business models combine a wide variety of the crowdsourcing categories. The underlying business model for each of these categories is fundamentally the same, just applied in a different way.

III. Crowdsourcing in the Tasks of Monitoring

A. Crowdsourcing in Environmental Management

Remote monitoring has a long history of use for collection of environmental measurements. Many sensor networks have been deployed to monitor the Earth's environment, and more sensor networks will follow in the future. Environmental sensors have been 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 an 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" [7]. 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 of 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, to increase the awareness of people about the behaviour of the monitoring object. The motivation for engaging the public in monitoring is two-fold [8]. 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 increases their self-awareness and sense of responsibility. Not surprisingly that numerous international reports (European Parliament and Council [9]; United Nations Environment Programme [10]) show the participation of all concerned citizens at all levels for sustainable socioeconomic development. For example, the introduction of smartphones as a personal instrumentation reduces barriers to achieve the democratization process monitoring.

B. 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 [11].

At the same time, there is a growing fleet of various robotic sensors (e.g., robotic fishes) coupled with the emergence of new and affordable monitoring technology that exponentially increases 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 techniques and analysis. Participatory / citizen sensing [12], [13], for instance, allows collecting people sensed data via social network services (e.g., Twitter, Waze, Ushahidi) over the areas where physical sensors are unavailable. Simultaneously, sensor data (Fig. 2) is capable of offering precise context information, leading to the 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.

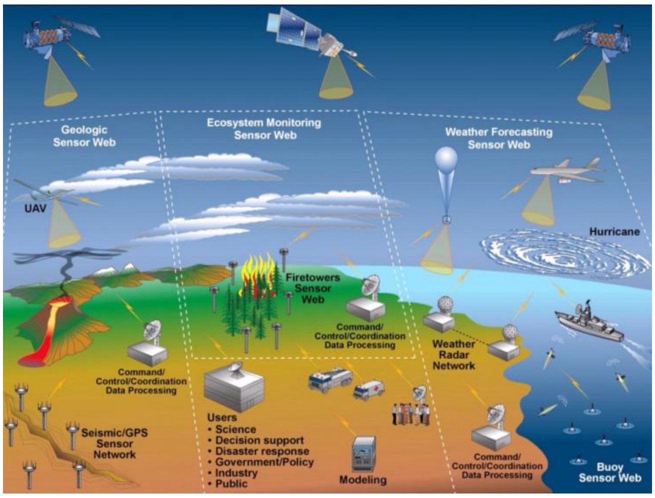

Fig. 2. Various sensor data sources arranged in a Sensor Web [13]

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 [13]. Automated data fusion processes allow essential measurements and information to be combined to provide knowledge of sufficient richness and integrity whose decisions may be formulated and executed autonomously.

The existing projects and platforms for data collection and processing, e.g., GOOS [15], Marinexplore [16], Social.Water [17], show that the bottleneck of the data market is not in collecting the data, but in processing the data. Most available data is disconnected, often archived, and sometimes never used again.

IV. Crowdsourcing-Based Framework for the Sociotechnical Monitoring System

The 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-based public knowledge base.

Mobile applications are downloaded free of charge and installed on smartphones, to turn them into mobile monitoring system social sensors. Smartphones collect information from various sensors (microphone, GPS, descriptive or qualifying user-typed information), and in real time send to the server 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 [18]. 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.

A. System Architecture

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

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

1. External data sources. Environmental 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 school 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.

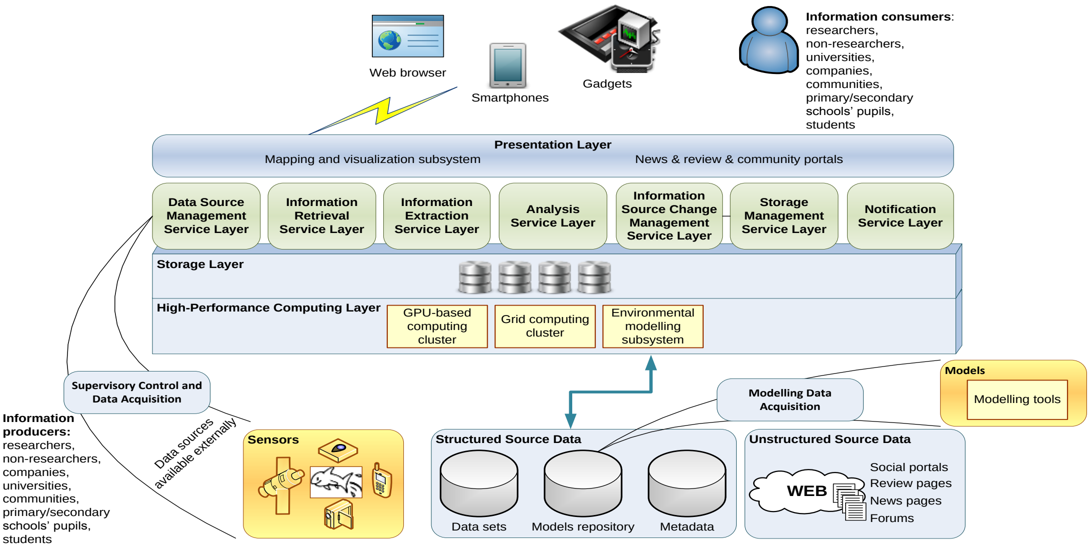

Fig. 3. General crowdsourcing-supported system architecture and its components

B. Modelling Scenarios

The developed application has a wide range of uses, 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 existing activist 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 or nearby construction sites); or accidental annoyances (such as manifestations).

Second scenario: authority-led initiatives. Social application can be used by the authorities and public institutions – usually at the municipal or regional levels – 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 such areas 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. [19].

In the most effective way, a social application can be used to control rapid dissemination of information on natural disasters, major accidents, etc. The prototype of the social application, developed under the supervision of RTU (Riga Technical University) and SPIIRAS (Saint Petersburg Institute of Informatics and Automation of the Russian Academy of Science) researchers J. Petuhova and S. Potryasaev, allows effectively implementing both of the above-mentioned scenarios by the example of Daugavpils City (Fig. 4).

Fig. 4. Crowdsourcing for flood modelling: social application prototype

C. Social Sensor Network: Political and Economic Perspective

The presence of the social sensor network creates a new institutional set-up, which may have an impact on the socially important decisions by the authorities. Let us develop a stylized example and discuss potential economic consequences of the social sensor network deployment.

Features of our model follow the classical political and economic framework, e.g., see [20], [21].

Let us consider a municipality populated by a large number of individuals, e.g., the population is interpreted as an interval [0, 1]. A generic individual is denoted by i. Once the individual joins the network and installs the required application on his smartphone, he observes a measurement of the state of the nature in his location. We denote it by $z^i \in [0,1]$. This piece of private information provides an objective valuation of the air quality in the neighbourhood, for instance. Then the private measurements $z = (z^1, \cdots, z^N)$, are submitted to the centralized Web server and everyone learns the distribution of valuations $f(z)$. This aggregated data is public information. Municipality is governed by an office-holder. On the one hand, the office-holder has decision-making power with respect to urban planning, e.g., he/she can decide whether to provide public goods or not, and how to distribute costs among inhabitants. Let us suppose that the public project is a park. On the other hand, the office-holder is also an inhabitant and observes his/her private measurement z^d , where superscript d stands for a decision-maker. Let us denote the size of the park by Q, and the costs are given by a convex function $K(Q) = \frac{1}{2}Q^2$. Costs are shared equally among inhabitants. Individual i derives a quasi-linear utility from park provision:

$$u(z^i, Q) = z^i Q - \frac{1}{2}Q^2. \tag{1}$$

Taking perspective of the individual who has observed z^i, an optimal size of the park is equal to

$$Q^{*,i} = z^i, \tag{2}$$

i.e., the higher i's observed air quality is, the more he/she enjoys the park built in the area. Applying the utilitarian welfare criteria, the socially optimal size of the park is found by solving the following maximization problem:

$$\max_Q \int_0^1 \left(zQ - \frac{1}{2}Q^2\right) f(z)\,dz. \tag{3}$$

It is straightforward to see that the welfare is maximized $Q^* = \bar{z}$, with $\bar{z}$ being average:

$$\bar{z} = \int_0^1 z f(z)\,dz. \tag{4}$$

Let us consider now the decision by the office-holder. We suppose that his/her observation is $z^d < \bar{z}$. Consequently, if he/she decides to build a park of size $Q^{*,d}$ he/she will maximize his utility, but not the social welfare. Alternatively, if he/she decides to build a park of size Q^*, he/she will be worse off.

The crucial aspect of the authority decision-making depends on the following questions:

1. Is the information collected through the social sensor network binding? If the aggregated data serve only an informative purpose and bear no legal consequences for the decision-maker, then he/she has a lack of incentives to follow the network recommendation.

2. What are the future career concerns of the current office-holder? In democracies, for example, office-holders are often concerned about their re-election chances. Let us discuss the following scenarios separately:

- The office-holder does not have re-election concerns (e.g., he/she is in his/her last office term). Unless the office-holder is a benevolent public official, he/she again lacks incentives to implement a socially optimal solution, as it is in his/her hands to implement the best alternative for him/her.
- The office-holder cares about future elections (e.g., he/she is in his/her first term and intends to maximize re-election probability). If the re-election decision by the electorate solely depends on the distance between the park size provided currently and the socially optimal size, then the expected utility of the office-holder can be written as follows:

$$\begin{aligned}&\pi(|Q_1 - Q^*|)\cdot\left[u(z^d, Q_1) + \delta\cdot 1\right] + \left(1 - \pi(|Q_1 - Q^*|)\right)\cdot u(z^d, Q_1).\\ &= u(z^d, Q_1) + \delta\cdot\pi(|Q_1 - Q^*|)\end{aligned} \tag{5}$$

where $\pi(\cdot)$ stands for the re-election probability, Q_1 – for the public project size and $\delta \in (0,1)$ – for a discount factor. It is assumed that the office-holder derives utility 1 from being re-elected. In this scenario, the office-holder will choose Q_1 such that the expected utility is maximized.

The following remark is in order. In the model above, we have assumed that there is a high population density and a single deviation by submitting a false measurement does not influence the aggregated distribution. In reality, especially in rural areas, the population density is low and the number of inhabitants is rather a discrete number N than an interval. In this case, there is a positive probability that a message sent by the sensor of an individual i has a direct influence on the average valuation and, consequently, on the optimal level of the public project. Thus, there is a potential threat of the measurement manipulation and submission of a false message $m^i(z^i) \neq z^i$, instead of a true message $m^i(z^i) = z^i$. since truthful measurement submission is of highest importance for the efficient collective decision-making, one needs to design an appropriate tax/subsidy scheme. The scholars of the mechanism design have come up with a variety of models supporting truth telling as equilibrium in similar cases (e.g., see surveys on the mechanism design by [22], [23]).

We see that the social sensor network provides easy means to involve people in the decision-making process and information aggregation; however, it does not fully solve the problem of selfish behaviour of decision-makers. There are several routes for future research. One path is to link decision-making with the results of the information aggregation. Let us suppose that a candidate for an office in the municipality can credibly commit that he/she will implement a welfare optimal project, such a credible commitment can take a form of a public contract signed by the candidate and verified by the local court. The contract would specify sanctions against the office-holder if he/she does not implement socially desired public project, e.g., his/her right to stand for re-election may be questioned. In the election race with several candidates, inhabitants of the municipality can then cast their votes based not only on candidates' platforms, but also on whether such promises are supported contractually (for the concept of contractual democracy, see [24]).

Another path of future research is to allow for heterogeneity among citizens with respect to environmental issues. Let us suppose there are just two individuals, who live close to each other and observe almost identical measurements. The only difference is that one individual likes hiking and cares about air pollution, and the other individual is disturbed by the noise created by the railway. The authority is budget-limited and can fix only one issue at the moment. The issue the authority deals with first depends on the measurements of both individuals. Often in such scenarios, the individuals will find optimal to manipulate information, pretending that their problem is the most urgent one. In such situations, implementation of the efficient decisions by the local authority is contingent on transfers between individuals, meaning that utilities of the individuals are transferable.

V. Conclusion

On the basis of research results presented in this paper, it is possible to mark 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 and technological objects. The integration of social and information technologies allows effectively resolving the three major issues concerning managing the environment-related data: a) how to access the vast amount of data that is available in different data formats and has different spatial and temporary resolution and quality, as well as reside in isolated silos, segregated and disconnected from each other; b) how to make the time-consuming handling and processing of all data more efficient; and c) how to make the available data, modelling and analysis results publicly available in an efficient and user-friendly way to facilitate the social interest and responsibility in the environmental monitoring and research processes.

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References

[1] Goodchild, M.F. *Citizens as sensors: the world of volunteered geography*. GeoJournal, 69(4), 2007: 211–221.
[2] Goodchild, M.F., Glennon, J.A.. *Crowdsourcing geographic information for disaster response: a research frontier*. International Journal of Digital Earth, Volume 3, Issue 3, 2010, pages 231-241
[3] Howe, J., *The Rise of Crowdsourcing*. Wired, Iss. 14.06, June 2006.
[4] Daren, C. Brabham. *Crowdsourcing*. MIT Press, 2013 - Business & Economics, 138 pp.
[5] Dawson, R. *Crowdsourcing Landscape*. Crowdsourcingresults, 2010. Available: http://crowdsourcingresults.com/competition-platforms/ crowdsourcing-landscape-discussion [Accessed August 26, 2013].
[6] Dawson, R., Bynghall, S. *Getting Results From Crowds: The definitive guide to using crowdsourcing to grow your business*. Advanced Human Technologies, Inc., 2012, 240 pp.
[7] *OGC Sensor Web Enablement (SWE) Initiative*. Available from: http://www.opengeospatial.org/domain/swe [Accessed August 26, 2013].
[8] Stevens, M., D'Hondt, E. 2010. Crowdsourcing of Pollution Data using Smartphones. UbiComp '10, 2010, Copenhagen, Denmark
[9] 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.
[10] United Nations Environment Programme (UNEP), 1992. Rio Declaration on Environment and Development. Proclaimed at the United Nations Conference on Environment and Development, June 1992.
[11] Yerva, S.R., Jeung H., Aberer, K. Cloud based Social and Sensor Data Fusion. 15th International Conference on Information Fusion, 2012.
[12] Boulos, M.N.K, Resch, B., Crowley, D., Breslin, J., Sohn, G., Burtner, R., Pike, W., Jezierski, E., Chuang, K.-Y.S. 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, 2011, vol. 10, no. 1, p. 67.
[13] Fraternali, P., Castelletti, A., Soncini-Sessa, R., Ruiz, C.V., Rizzoli, A.E. Putting humans in the loop: Social computing for Water Resources Management. Environmental Modelling & Software, 2012, vol. 37, pp. 68–77.
[14] Durrant-Whyte, H., Henderson. T.C. Multisensor Data Fusion. In: Sicilliano B., Oussama K., eds. Springer Hand-book of Robotics. Springer, 2008, p. 1611.
[15] *The Global Ocean Observing System*. Available from: http://www.ioc-goos.org [Accessed 5 July 2013].
[16] Marinexplore: Cutting Ocean Data Processing Time Fivefold. Marine Technology Reporter, 2012, no. 11/12, pp. 30–35.
[17] Fienen, M.N., Lowry, C.S. Social.Water - A crowdsourcing tool for environmental data acquisition. Computers & Geosciences, 2012, vol. 49, pp. 164–169.
[18] Steels, L., Tisseli, E. 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.
[19] Maisonneuve, N., Stevens, M., Ochab, B. Participatory Noise Pollution Monitoring Using Mobile Phones. Information Polity, 2010, vol. 15, no. 1,2, pp. 51–71.
[20] Besley, T. *Principled agents?: The political economy of good government*. Oxford University Press, UK, 2007.
[21] Persson, T., Tabellini, G. *Political Economics: Explaining Economic Policy*. MIT Press, Cambridge, MA, 2000.
[22] Jackson, M.O. *Mechanism theory*. In Derigs U. editor, Encyclopedia of Life Support Systems. EOLSS, Oxford, UK, 2003.
[23] Mas-Colell, A., Whinston, M. D., and Green, J. *Microeconomic Theory*. Oxford University Press, New York, NY, 1995.
[24] Gersbach, H.. Contractual Democracy, Review of Law and Economics 8(3), 2012, pp. 823-851.

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Arnis Lektauers, Andrejs Romānovs, Vitālijs Butenko, Semjons Potrjasaevs, Aleksejs Čumiks. Uz kraudsorsingu bāzētas sociotehniskas sistēmas izstrādes pieeja ar pielietojumu dabas un tehnoloģisko objektu monitoringam
Pēdējā laikā pasaulē vērojamās dabas un tehnogēna rakstura problēmas, kā arī antropogēno darbību intensifikācija globālā mērogā arvien vairāk apliecina stratēģisku nepieciešamību pēc efektīviem dabas un tehnoloģisko objektu monitoringa risinājumiem. Šajā rakstā ir apskatītas moderno sociālo tehnoloģiju un dabas un tehnoloģisko objektu virszemes un kosmiskā monitoringa procesa integrācijas, kā arī šī procesa efektivitātes un sociālās nozīmības palielināšanas iespējas, iesaistot valsts institūcijas un sabiedrību monitoringa datu ieguvē, izmantošanā un izplatīšanā. Dotā pētījuma mērķis ir izveidot augstas veiktspējas mākoņdatošanas platformas prototipu, kas ļauj kombinēt heterogēnus sociālas izcelsmes kraudsorsinga datus ar automatizētu sensoru datiem integrētas apstrādes, analīzes un modelēšanas nolūkiem. Izstrādātā tehnoloģija ir intelektuālas platformas un vienotas informācijas telpas pamats gan virszemes, gan kosmiskajam monitoringam, nodrošinot valsts institūcijas un sabiedrību ar aktuālu informāciju par apkārtējā vidē notiekošajiem procesiem ar plašu pielietojumu izglītībā, zinātnē un uzņēmējdarbībā, vienlaicīgi pastāvot kā jaunam neatkarīgam informācijas avotam sabiedrības informēšanai par pastāvošajiem riskiem un ārkārtas situācijām dabas un tehnogēnajos procesos. Balstoties uz integrētu sociālo un sensoru datu apstrādi, izmantojot kraudsorsinga pieeju, izstrādātā tehnoloģiskā platforma ļauj savlaicīgi informēt sabiedrību par potenciālajiem vai pastāvošajiem ekoloģiska un/vai tehnogēna rakstura draudiem.

Арнис Лектауэрс, Андрей Романов, Виталий Бутенко, Семен Потрясаев, Алексей Чумик. Основанный на краудсорсинге подход разработки социо-технической системы применительно к мониторингу природно-технологических объектов
Природные катастрофы и техногенные проблемы последних лет, а также глобальная интенсификация антропогенной деятельности все более и более подтверждает стратегическую необходимость выбора эффективных решений мониторинга природных и технологических объектов. В настоящей статье рассматривается возможность совмещения современных социальных технологий и процесса наземно-космического мониторинга природно-технологических объектов, а также повышения эффективности и социальной значимости этого процесса путем привлечения представителей общественности к распространению и применению данных этого мониторинга. Целью данного исследования является создание высокопроизводительной платформы облачных вычислений, позволяющей комбинировать гетерогенные социальные данные краудсорсинга с данными автоматизированных сенсоров для последующей интегрированной обработки, анализа и моделирования. Созданная технология представляет собой основу интеллектуальной платформы и обобщенного информационного пространства наземного и космического мониторинга, обеспечивающего государственные и общественные институты актуальной информацией о происходящих в окружающей среде процессах, с широкими возможностями применения в сфере образования, науки и предпринимательской деятельности, одновременно существуя как новый независимый источник информации для информирования общества о существующих рисках и чрезвычайных ситуациях в природных и техногенных процессах. Разработанная на основе интегрированной обработки социальных и сенсорных данных с использованием подхода краудсорсинга технологическая платформа позволяет своевременно информировать общественность о существующих или наличествующих угрозах экологического или техногенного характера.