Procedia Computer Science
Volume 29, 2014, Pages 1646–1655
ICCS 2014. 14th International Conference on Computational Science

Personal decision support mobile service for extreme situations

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Abstract
This article discusses aspects of implementation of a massive personal decision support mobile service for evacuation process in extreme situations, based on cloud computation platform CLAVIRE and a virtual society model. The virtual society model was constructed using an agent-based approach. To increase credibility the individual motivation methods (personal decision support and user training) were used.

Keywords: Agent-based modeling, mobile services, urgent computing, virtual society, personal decision support

1 Introduction

Modern mobile phones and tablets are multi-purpose devices that provide their owner with rich interaction with the real world, including voice, internet, positioning technology and local interaction. In the aggregate with cloud customisation tools for modern mobile devices, it gives the opportunity to organise massive mobile services (MMS), focused on personal decision support in a variety of situations (e.g., different types of navigators, organisers). One of the most promising areas of application of MMS is support of mobile users in extreme (including emergency) situations. It provides information and intellectual support to users in a potentially dangerous area, in order to preserve their lives, health and property. It includes notifications about emergency situations and organisation of evacuation (i.e., removal of persons from a dangerous place to the safe zone). Existing methods of informing and notification the population are extensive and do not take into account the individual characteristics and location of the persons. As a consequence, it raises numerous violations of evacuation rules, such as interrupting the chain of information or failure to follow official

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 Selection and peer-review under responsibility of the Scientific Programme Committee of ICCS 2014

doi:10.1016/j.procs.2014.05.150

regulations. In contrast, the adoption of mobile technologies focused on personal decision support allows not only increased speed of response to potential danger, but also to independently take measures to reduce personal risk.

The main features of the research and development of modern MMS for personal decision support in emergency situations are their dynamics and interactivity. The results of the MMS computations are not static instructions, but a set of scenarios weighted according to the degree of danger, allowing the user to make their decision on the ground. The agent-based modelling technology has been used to construct these scenarios in terms of incompleteness and uncertainty of the input information. The implementation of MMS requires use of cloud technologies for realisation of resource-intensive modelling procedures and data processing because of the complexity of the used models and scenarios. This article discusses aspects of implementation of personal decision support MMS for evacuation process in extreme situations, based on cloud computation platform CLAVIRE (V. Knyazkov, V. Kovalchuk, N. Tchurov, V. Maryin, & V. Boukhanovsky, 2012) and an agent-based model (Torrens, 2012)(Johansson & Kretz, 2012) of virtual society.

2 Related works

In general, mobile services can be classified into the types: emergency, navigation, information, advertising, education, billing and entertainment. Any of these types can be Location Based Service (LBS) (Schiller & Voisard, 2004) i.e., group of applications and services that utilize information related to the geographical position of their users in order to provide value-adding services to them (Giaglis, 2003).

Mobile technology for support the actions of people during extreme and emergency situations implemented in various countries. For example, in the USA the Federal Communications Commission adopted the network structure, operational procedures and technical requirements in response to the Warning, Alert, and Response Network (WARN). The Commercial Mobile Alert System (CMAS) (Daly, Sennett, & others, 2010) was developed as a result. CMAS provides the distribution of emergency alerts to customers with compatible devices via Cell Broadcast (a technology similar to SMS, but for all phones in the range of a cell tower). Similar services are developing in various countries. The richest research was conducted in Australia (Aloudat & Michael, 2010). The key idea is the ability to receive notifications for almost all mobile devices in the emergency area. These solutions allow us to deliver alert notifications to the maximum number of persons, but impose restrictions on the technology used. That leads to a reduction of the functional possibilities of service (e.g., GPS or GLONASS based positioning) and loses the variability and quantity of the information contained in the notification.

Using mobile applications for modern mobile platforms allow us to avoid the lack of variability and quantity of the notifications. This approach was used by many companies. For example Hurricane Pro by Kitty Code allows tracking of storms. UbAlert by Bump Network is the disaster social network where people can share knowledge about danger situations. Mobile Rescuer by EMERCOM of Russia contains the handbook of police, hospitals and fire departments and allows sending of emergency signal to pre-selected contacts.

However, they are primarily focused on the warning of people about the situation itself. None of these solutions provide support (including decision support) of the evacuation process on a personal level.

Objective of widely used decision support is to move the situation from the current state to some desired future state (de Walle & Turoff, 2008). For example the European Commission founded the RODOS (Niculae, 2005) DSS that could provide support for offsite emergency management at all times following a nuclear accident and that would be capable of finding broad application across Europe unperturbed by national boundaries. Some collaboration tools, e.g. Sahana (Sahana, 2006), aim to improve the decision support process. Sahana is a tool for coordination and managing aid and volunteers, tracking relocation sites etc.

The lack of decision support is due not only to the already established action system for emergency situations, but also the user-specific information perception of extreme and emergency situations. In our work we combine the different approaches, such as modern mobile technologies, decision support, personalization technologies, cloud computing and agent-based modeling into a single service.

3 Concepts of personal decision support

First of all, there is the individual perception associated with a tendency that the term "danger" is partially replaced by the term "risk" (Yamori, 2007). Accordingly, people often do not appreciate the potential threat, but the combination of the probability and consequences of adverse events, as well as the impact of this direct threat to them and their family. As a consequence, individual interest relates only to threats in close proximity that require orientation of MMS on local solutions.

Another side of this problem is that the lack of personalisation of emergency warnings reduces their credibility.

At the same time such a warning approach leads to a false reduced fear of natural disasters. People often do not respond to messages in the hope of a complex solution by emergency services. This leads to an idle state awaiting rescue. In contrast, people get individual motivation to act when they have the opportunity of personal risk management and assessment of the situation.

The challenge of increasing people's motivation in emergency situations is being solved in many countries, but there is no one decision because of different social factors (Trainor & Mcneil, 2008). The experts agree that the main parameters of emergency notifications are clarity and presence of specific personal instructions for action in a specific situation, as well as the possible consequences and how to manipulate them. The main problem currently is the development of trust between the user and the MMS, and training users to use MMS in everyday conditions for the subsequent rapid response in emergency situations. As a consequence, it requires the development of MMS functions for personal decision support not only in quite rare emergency situations (e.g., floods, earthquakes, etc.), but also in private extreme situations related to personal users' risk, which are formed on the basis of their own problems.

MMS for personal decision support in extreme situations is a geoplanner (Verpoorten & Coninx, n.d.) containing a task list, formalised by the user. MMS allows the user to store the most important GPS-based locations and apply some actions to them (e.g., sound off, recall, connect WI-FI, etc.). Doing a certain set of actions every day the user gets used to the prompts, responds to the application GUI (graphical user interface), sees it as friendly and is focused on MMS notifications. Designation of buildings and their assignments in the daily mode gives the perception of specific routes and assistance centres in extreme situations mode, which allows users to not only navigate the complex situation, but also to make decisions, i.e., assume risk management. Thus, in the daily routine users can develop trust of MMS recommendations, which helps users to adapt to the service and allows partial reduction of the risk of conflict of decisions in the future.

4 Structure and organisation of MMS

An overview of the organisation of a personal decision support MMS for evacuation process in extreme situations, based on cloud computation platform CLAVIRE and a virtual society model, is shown in Figure 1.

The service requires the use of Early Warning System (EWS) to obtain sufficient time for the response to current situation. As input data service was used the city infrastructure data

(Openstreetmap and Wikimapia), landscape data (ASTER GDEM), demographic data (anonymous data provided by Federal Migration Service of Russia) and social-economic characteristics of population. This data and EWS data using by agent based model of virtual society and its problem processing (Holsapple, 2008) DSS. Since the simulation (including decision support) is computationally intensive process, we were used the infrastructure of the cloud platform CLAVIRE to simplify the access to the computational resources. Also cloud technologies, namely push-technology, were used to organization of warning notifications delivery to users.

The necessity of using push-technology is dictated by the modern approaches in the communication between the server and the mobile applications (e.g. no need all the time to keep the application running).

Figure 1: MMS organisation scheme

1. Getting the forecasting information about the emergency situation. Server core includes a subsystem for interaction with early warning systems including running under CLAVIRE, e.g., (Boukhanovsky & Ivanov, 2012).

2. Collecting the current population density data in the emergency area using mobile operators' cell towers interfaces and assessing the total number of people (not only MMS users) (Horanont, 2010).

3. Sending emergency notifications to users. Performed in parallel with step 2. Push-technologies such as Apple Push Notification Service (APNS), Google Cloud Messaging (GCM) and Microsoft Push Notification Service (MPNS) were used to send notifications.

4. Simulation of the distribution and dynamics of population in the emergency area. This problem is solved by a virtual society model. The model is executed in the environment of cloud computing platform CLAVIRE.

5. Simulation of panic and evacuation. The input data will be the coordinates of MMS users and results of claim 4, i.e., distribution of people (crowd). This problem is also solved using CLAVIRE's composite application. The problem of modelling involves the estimation of population density associated with mass panic and spontaneous evacuation (e.g., escape to hills during floods). In addition, evacuation routes are constructed and optimised for MMS users. Service allows finding of the optimal and alternative evacuation routes (Figure 1).

6. Sending evacuation information to users. Implemented similarly to claim 3.

5 Simulation of population dynamics

In order to (a) able the MMS to function in the real world (when the subscriber is not alone in the area) and (b) to test the effectiveness of MMS the virtual society model has been used. The virtual society model using an agent-based approach to study the dynamics of population density, as well as the interaction between a population and the environment. Agent-based modelling is a simulation method where the behaviour of decentralised autonomous agents determines the behaviour of the whole system, i.e., "Bottom up". The life of virtual society passes in a special environment, which is an abstract grid structure.

Members constituting the virtual society model – the agents – were endowed with approximated characteristics and attributed to a number of socio-economic classes. Initially classes were marked out in a way to ensure the majority of transportation (both commuting and leisure-related) activities performed in the city throughout the day were covered. The primary criterion for allocation was the level of income could be related to consumer, transporting and residential preferences of agents. Some organizations such as CACI ACORN conducted similar researches in the classification of the population (CACI, 2010). Further detailing of the specification involved introduction of gender and employment divisions as well as estimated proportioning of classes. Since there was no substantial research carried out in social sciences previously to report thoroughly on the commuting behaviour of representatives of various social groups, the majority of the features describing the elements of the artificial society were compiled from both qualitative and quantitative sources.

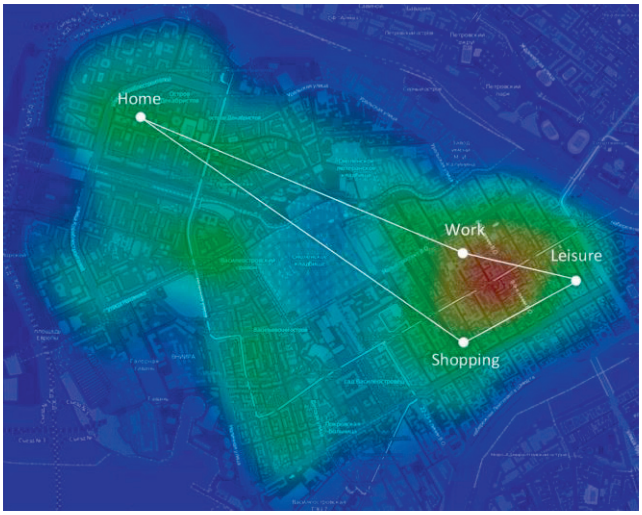

Figure 2: Agent's daily movement on population density map

A set of consistent rules was designed to allow formalisation of the process of modelling the daily mobility of an agent – a maximum trip rate, hierarchy of activities (for instance, commuting has a higher priority than a trip to entertainment or shopping sight) and temporal characteristics of travelling (approximate time for an agent to leave the place of residence was linked to his/her class and qualification/employment characteristics, as well as the return time and probability of being late) were introduced. Subsequently, proportions (diversified by the major classes' sub-groups employment status) of people setting off to travel on a particular day and those who, due to abstract reasons, have to remain at home were established in order to make the model even more realistic. All the regulations listed above were further used to produce daily scenarios (organised into timetables, with cells representing periods of travelling or staying at a particular destination point) for classes that encompassed probabilities of various trips to be performed, their destinations and purposes of travelling.

Whereas socio-economic classes are mainly suitable for simulating routine activities, travelling patterns and interactions, there was a substantial need to introduce a classification that would be effective in describing the differences in behaviour of agents put into abnormal conditions with higher levels of uncertainty and risk (e.g., natural disasters that limit the number of transportation alternatives such as floods). The solution was found in outlining classes of physical capacity built around age as a basic criterion determining the mobility (an abstract ability to perform particular relocations, such as walking (Verwey, 2010) or overcoming obstacles (Ketcham & Stelmach, 2004) and their speed in km/h) of an agent. A total of seven age-related classes were introduced, followed by an extra class, constructed to account for the limited physical ability of a group of agents to move around autonomously. These classes are the following: under 5; 6–16; 17–29; 30–44; 45–55; 56–66; over 67; disabled (being split into subclasses namely: walk, transportable and non-transportable). Each of the agents representing one of the classes listed bears a set of characteristics (agility, stamina, power, passability) that determine his/her mobility and may vary in the range from 0 (min) to 3 (max). The open list of features was extended by adding factors affecting the potential decision-making of agents: control, information, role, transport and marital status. Finally, for the sake of the approximation precision of transportation characteristics, substantial environment-related factors were added to the model, including up/down-hill movement, terrain passability, weight of the load and various characteristics of the incoming threat.

Possible contradictions between characteristics that were to arise when generating agents on a map and micro-level features of the environment lead to a need for the introduction of conflict-eliminating regulations. The rules determining the performance of the physiological classification described above (as well as its integration with the socio-economic classification) are organised into the following groups:

1. Direction-of-the-movement rules – regulations concerning the priority of particular "destination points" and the use of transport, for instance, "the minimal interval between the perception of the emergency warning and actual relocation of individual is approximately 10 minutes" and "in case there are no places of mass congestion of people nearby, agent would go to the nearest upland".
2. Terrain-related transportation speed rules – determine to what extent the type of the terrain and presence of obstacles affects the speed of the agent and the way they correlate with the load he/she is carrying. Every class has a mean speed which can be modified when environmental or agent-related factors come into action. Here is an example: "If an agent is overcoming an obstacle/go up the hill and carries a load, his speed is decreased by 0.5–1 km/h compared to his normal upward speed (mean physiological class speed multiplied by the upward decreasing coefficient) ".
3. Transportable disabled agents (2^{nd} disability category) and children below 5 years old transportation rules – explain how these specific groups of agents relocate and deal with obstacles: "None of the groups of agents have an ability to carry a load", but "if the representative of one of these classes moves up the hill or encounters an obstacle on the way, his/her movement speed is equal to the one that of an advantaged agent when carrying a load and moving upward/overcoming an obstacle".
4. Correlation with socio-economic classification rules are designed as proportions that bind two systems of characteristics of agents together, but also include rules established in a natural language, such as "A disabled agent of the 3^{rd} disability category can be a member of every of the socio-economic classes, but his transportation is limited (does not commute/travel through the city autonomously)".

The model requires detailed configuration of the parameters for the specific city:

1. City infrastructure (Crooks & Castle, 2012): living houses, hospitals, universities, offices, road infrastructure, etc. OpenStreetMap, Wikimapia and Instagram data and anonymous database of Federal Migration Service of the Russian Government have been used.
2. Landscape data. ASTER Global Digital Elevation Map has been used. ASTER GDEM is a product of METI and NASA.
3. Social, economic and physical capabilities characteristics of the population.
4. Calibration (See & others, 2012) of dynamics of population density (Kaiser & Kanevski, 2010) using mobile operators' cell towers data.

6 Evaluation of MMS efficiency: Krymsk's flooding

Simulation of the efficiency of personal notifications based on MMS in the case of a catastrophic flood was performed. A situation similar to the situation in Krymsk in 2012 was chosen as a simulation scenario.

On July 6–7, 2012, the powerful rain, constantly maintained by the high convective instability of the atmosphere clouds, persisted for days in the South-West area of the Krasnodar Region in Russia. This led to very strong and prolonged rains in the area.

The data obtained from automatic weather systems allow us to conclude that the main amount of precipitation that generated catastrophic flooding in the basin of Adagum river (tributary of Kuban river), refers to the period from 22:00, 6 July to 03:00, 7 July. In this period there was continuous rain with the intensity of 35–45 mm per hour. The basin of Adagum river is characterised by a dense hydrographic network, considerable slopes and stream channels. From 23:30, 6 July to 01:00, 7 July, according to the hydrological post, the water level increased by 81 cm. The water level at 01:00 had not reached a dangerous level (6.8 m for this post) which threatens the lives of people and causes significant material damage. During the next hour a 3.5 m jump occurred. The maximum level reached 9.95 m at the flap of the hydrological post and 9.5 m below the bridge. The highest level was achieved between 03:00 and 04:00.

We have modeled a flood similar to the one that took place in Krymsk (Krasnodar Region, Russia). However, it was by no means an attempt to replicate the exact properties of the particular event. For realisation of experimental research, modelling of the process of flooding (Krzhizhanovskaya et al., 2013) with Dynamic, Rapid Flood Spreading Model (DRFSM) was used (Figure 3). The limitation of the model is that it is not suitable for very fast spreading floods (e.g., tsunami) because it does not solve the energy balance equation. The flood model takes topographic data of the area and then the data of water discharges at different sites. The topographical picture of the area is based on ASTER Global Digital Elevation Map, and water consumption on the basis of data reports from the Federal Service for Hydrometeorology and Environmental Monitoring of Russia.

Distribution of the flood is achieved by transfer of water between the zones of influence. The water level, average discharge and average speed are calculated for each zone of influence. The virtual society model is used for simulation of the population.

Figure 3: Maximum level flood (a) – simulated, (b) – by official report.

Yamobi.ru have published the research results (Yamobi, 2013) that have been obtained by the processing of Google Analytics, Liveinternet and Openstat data about operating systems for mobile devices in different cities of Russia. Research results shows that approximately 27% of the residents of Krasnodar Region are users of smartphones. In our research we assumed that the proportion of service users among smartphone owners is 50%. Thus the number of users was amounted approximately 15000 (assuming that the data for the Krasnodar Region are suitable for all region cities).

Time before flood, min	0	5	10	20	30
MMS users (agents) caught by flood, %	34	21	12	7	4

Table 1: Influence of the MMS warning notifications on the evacuation process.

It was assumed in the simulation that all agents began to evacuate immediately after receipt of the notification. The evacuation was spontaneous (in the direction opposite to the water) for agents. However MMS user-agents were evacuated on a calculated shortest path to a safe place (hills). Table 1 shows that early warning of the population reduces the number of victims, as well as that the increase in the time of early warning reduces the proportion of the population affected.

MMS is focused on massive usage, so it requires high reactivity to the applied solutions. Mobile device and PCs with the following specifications were used for the experiments. Mobile device: dual-core CPU, 768 Mb RAM, 3g Internet Access, OS Android 4.0 (HTC Sensation Xe). PCs: quad-core Intel i7 CPU 3.4 GHz, 8 GB Ram, 1 GB/s network. Simulation of the density dynamics of population was calculated for the 24 hours of the model time with 1 second step. Table 2 shows the averaged time characteristics of the overhead costs associated with the work of the MMS.

Time characteristics were defined:

T1 - Time costs of simulation of population density and dynamics and evacuation.

T2 - Time to send push messages on the ways of evacuation service GCM.

T3 - The infrastructure costs associated with CLAVIRE.

Time characteristic	Mean, s	50%-Quantile, s	90%-Quantile, s	95%-Quantile, s
T1	496	489	503	511
T2	1.03	1.02	1.11	1.12
T3	1.91	1.67	2.03	2.14

Table 2: Time measurements

Table 3 shows that the most expensive part is using the cloud-based infrastructure for simulation. Additional infrastructure costs are relatively small (about 2 seconds). Time of sending notifications using push-technology is also small (1 to 2 seconds); the main time is associated with the latent GCM-service. In general, the time required in the considered scenario is acceptable from the point of view of support of decision-making in the characteristic scale development of the situation (tens of minutes to hours).

7 Conclusion and Future Works

Massive mobile services are complex systems containing many components, where each component solves a variety of specialized tasks. During the design and development of personal decision support MMS for evacuation process in extreme situations, based on cloud computation platform CLAVIRE and virtual society model, many factors were taken into account.

The general reactivity of the whole system should be satisfying by the specific tasks of the MMS. It is also important to take into account the general developer recommendations, such as the ability to use the client applications for different mobile platforms while developing server-side API. It requires the use of common standards and protocols.

The virtual society model should be calibrated as accurately as possible to obtain adequate population density results. The real-world data should be used to do this. Such data include city infrastructure, landscape, social, economic and physical capabilities of the population and calibration of dynamics of population density using mobile operators' cell towers data. For future work, we will consider the mapping of real social networks received from social media (e.g., Facebook, Twitter, vk.com) on the agent-based model of virtual society. This will allow us to expand the possibilities of social simulation in the service due to additional interactions between agents. For more accurate results we also planned the integration with additional collision detection model which is not taken into account at the moment.

The individual motivation methods should be used for personal risk management and assessment of the situation. Such methods include: (a) personal decision support; (b) user training – daily mode of mobile application helps to develop user's trust to service's recommendations and reduce the risk of conflict of decisions; (c) adaptation of service to user by use of adaptive interface (future work). It is important because of the conditions of usage. It is difficult to use unfamiliar or supersaturated GUI elements in extreme conditions.

8 Acknowledgements

This work was financially supported by the Government of the Russian Federation, Grants 074-U01 and 11.G34.31.0019. We also thank the HR Wallingford team, for providing a free license for the DRFSM software.

References

Aguirre, B. E. (2004). Homeland Security Warnings: Lessons Learned and Unlearned. *International Journal of Mass Emergencies and Disasters*, *22*(2), 103–115.

Aloudat, A., & Michael, K. (2010). Toward the regulation of ubiquitous mobile government: a case study on location-based emergency services in Australia. *Electronic Commerce Research*, *11*(1), 31–74. doi:10.1007/s10660-010-9070-0

Boukhanovsky, A. V., & Ivanov, S. V. (2012). Urgent Computing for Operational Storm Surge Forecasting in Saint-Petersburg. *Procedia Computer Science*, *9*, 1704–1712. doi:10.1016/j.procs.2012.04.188

CACI. (2010). *The ACORN user guide. Technical report. http://www.fcc.gov/document/fcc-renames-cmas-wireless-emergency-alerts-wea.*

Crooks, A. T., & Castle, C. J. E. (2012). The integration of agent-based modelling and geographical information for geospatial simulation. In *Agent-based models of geographical systems* (pp. 219–251). Springer.

Daly, B., Sennett, D., & others. (2010). Commercial Mobile Alert System.

De Walle, B., & Turoff, M. (2008). Decision support for emergency situations. *Information Systems and E-Business Management*, *6*(3), 295–316.

Giaglis, G. M. (2003). Towards a Classification Framework for Mobile Location Services, 64–81.

Holsapple, C. W. (2008). DSS architecture and types. In *Handbook on Decision Support Systems 1* (pp. 163–189). Springer.

Horanont, T. (2010). A Study on Urban Mobility and Dynamic Population Estimation by Using Aggregate Mobile Phone Sources. *CSIS Discussion Paper № 115.*, (115).

Johansson, A., & Kretz, T. (2012). Applied pedestrian modeling. In *Agent-based models of geographical systems* (pp. 451–462). Springer.

Kaiser, C., & Kanevski, M. (2010). Population Distribution Modelling for Calibration of Multi-Agent Traffic Simulation, 1–10.

Ketcham, C. J., & Stelmach, G. E. (2004). Movement control in the older adult. *Technology for Adaptive Aging*, 64–92.

Krzhizhanovskaya, V. V., Melnikova, N. B., Chirkin, a. M., Ivanov, S. V., Boukhanovsky, a. V., & Sloot, P. M. a. (2013). Distributed Simulation of City Inundation by Coupled Surface and Subsurface Porous Flow for Urban Flood Decision Support System. *Procedia Computer Science*, *18*, 1046–1056. doi:10.1016/j.procs.2013.05.270

Niculae, C. G. (2005). *A socio-technical perspective on the use of RODOS in nuclear emergency management*. The University of Manchester.

Sahana. (2006). Sahana Wiki Community. *http://www.reliefsource.org/foss/index.php/Sahana.*

Schiller, J., & Voisard, A. (2004). *Location-based services*. Elsevier.

See, L., & others. (2012). Calibration and validation of agent-based models of land cover change. In *Agent-based models of geographical systems* (pp. 181–197). Springer.

Torrens, P. (2012). Urban geosimulation. In *Agent-based models of geographical systems* (pp. 435–450). Springer.

Trainor, J. E., & Mcneil, S. (2008). A Brief Summary of Social Science Warning and Response Literature A Report to COT Netherlands.

V. Knyazkov, K., V. Kovalchuk, S., N. Tchurov, T., V. Maryin, S., & V. Boukhanovsky, A. (2012). CLAVIRE: e-Science infrastructure for data-driven computing. *Journal of Computational Science*, *3*(6), 504–510. doi:10.1016/j.jocs.2012.08.006

Verpoorten, K. L. K., & Coninx, K. (n.d.). Portable Personal Displays for Co-Located Collaboration with Limited Screen Space.

Verwey, W. B. (2010). Diminished motor skill development in elderly: indications for limited motor chunk use. *Acta Psychologica*, *134*(2), 206–14. doi:10.1016/j.actpsy.2010.02.001

Yamobi. (2013). Top 10 smartphone cities in Russia. *http://yamobi.ru/posts/opublikovan_top-10_gorodov_rossii_po_urovnyu_proniknoveniya_smar.html.*

Yamori, K. (2007). Disaster Risk Sense in Japan and Gaming Approach to Risk Communication. *International Journal of Mass Emergencies and Disasters*, *25*(2), 101–131.