Multidisciplinary Research on Geographical Information in Europe and Beyond
Proceedings of the AGILE'2012 International Conference on Geographic Information Science, Avignon, April, 24-27, 2012
ISBN: 978-90-816960-0-5
Editors: Jérôme Gensel, Didier Josselin and Danny Vandenbroucke

EMdroid: Integrating Volunteered Geographic Information from the emergency scene for better situation awareness during emergency response

Nikola Davidovic
University of Nis, Faculty of Electronic Engineering
Aleksandra Medvedeva 14
Nis, Serbia
nikola.davidovic@elfak.ni.ac.rs

Leonid Stoimenov
University of Nis, Faculty of Electronic Engineering
Aleksandra Medvedeva 14
Nis, Serbia
leonid.stoimenov@elfak.ni.ac.rs

Abstract

Within our research of the Emergency GIS we have tried to extend the classic approach to the usage of spatial data within the emergency management with novel concepts of user generated geo-content. Our goal is to include citizens into process of emergency awareness that will lead to better results in early warning and prevention of crisis events trough development of partnership between community and official emergency institutions and agencies. Therefore, we have developed prototype of a mobile application for collecting georeferenced content in the field EMdroid. It provides users with the ability to capture videos, images and sounds or type text that will include the location data according to their actual position. Supported by proper emergency GIS infrastructure, users sending such data to EOC can provide critical information for emergency response and improve situation awareness of the emergency crews even before they are dispatched on the location of the emergency.
Keywords: emergency management, crisis, VGI, GIS, smartphones.

1 Introduction

Emergency events are a constant threat to services, companies, institutions and private properties. The most important is that emergency situations often endanger lives of population affected in various ways [1]. Each country has numerous institutions and agencies that are involved in cases of emergencies, among others fire department, police, health care, emergency technical services and in rare cases military. Institutions that are in charged for emergency response are in most cases well equipped with contemporary technologies including GIS customized to support their activities during crisis and each possessing valuable and accurate geo-information for the field of their work [2].

After the emergency event, the response time of emergency teams needs to be reduced as much as possible. In most cases citizens, that can be referred to as *first spotters*, witnessing emergency event the moment after occurring alert emergency authorities. But explaining to emergency officer the hazardous event using the emergency line (112 / 911 / 000). in most cases isn’t enough to make conclusions before the crews are dispatched in the field. Therefore, witnesses should be able to provide additional valuable information from the emergency scene using contemporary technology developed within the field of GIScience

The concept of Volunteered Geographic Information (VGI) [3], based on gathering georeferenced content has been used for past several years extensively. It provides users, having no prior experience in geographic information technologies with the ability to create and publish geo-information that is visualized over some kind of imagery base provided by numerous Web 2.0 services available today. Contemporary mobile devices can also be a powerful tool for collecting such georeferenced content.

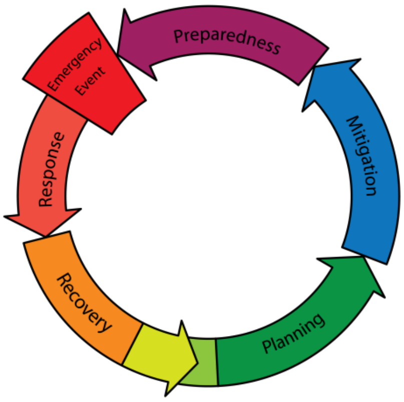
With the emergence of smartphones and tablets with camera and GPS, and with increasing of the mobile networks’ coverage and bandwidth, each person carrying such device becomes a wireless sensor in the field [4]. Integration of these, so-called sensors into a large wireless sensor network with proper support of new Web and GIS technologies become possible. Voluntarily collected georeferenced content using mobile devices, related to the current situation in the area affected by the emergency event can be used. Combining such data with existing emergency infrastructure, people on the scene can become valuable source of information for first responders that can supplement emergency managers with up-to-date information from the emergency scene. By gathering photos, videos, descriptions, sounds, accelerometer readings and other sensed data from the field, they can provide better situation awareness and response planning prior to dispatching crews on the scene. We think that such public sensing applications can contribute to the process of emergency management.

This paper proposes a solution for supporting emergency management activities by enabling citizens to provide valuable data from the scene on voluntary basis using the concept of VGI [4]. It is based on a special mobile application that integrates into the existing emergency infrastructure. First spotters on the scene using their mobile phones with such application become live sensors that provide initial data on emergency event. The rest of the paper is organized in the following way. The second chapter describes the current research in the area of VGI and possibilities of its usage in the domain of emergency management. The third chapter presents the proposed architecture that integrates VGI data from the emergency scene with existing emergency GIS infrastructure It also describes the advantages that such data should provide in order to improve situation awareness of emergency managers. The fourth chapter presents the mobile application EMdroid for collecting VGI data on the emergency scene.

2 Related work and enabling technology

According to numerous researches [5, 6], emergency management can be divided into several phases. Phases form a cycle covering the time from the start of the first actions taken in order to prepare for the emergency event to the mitigation that takes place after disaster as shown on Figure 1. These phases are Planning, Mitigation, Preparedness, Response and Recovery. It is significant to note that data (especially geo-data) created in the Response phase can be used for various analyses. Emergency managers can learn using such data thus improving their effectiveness in the phases that will follow. In addition, such new knowledge can positively influence emergency infrastructure and staff, especially in cases of emergencies that occur relatively frequently in the same places (e.g. forest fires, flooding etc.).

Figure 1: Phases of Emergency management.



Emergency management relies on precise data about people, properties, infrastructure and environment before, during and after emergencies. It is notable that 80% of this data has a spatial component or location [7]. GIS as a tool that can visualize spatial data over digitalized maps, is a key point of integration of diversified information crucial for emergency management. GIS provides critical information for emergency staff needed for decision-making during emergency events. It also enables simulation of emergency events through modelling which allows its users to adjust data and scenarios for prediction, planning and estimation [8]. In emergency management different kinds of GIS clients are used. Desktop GIS is used by decision makers, Web GIS portals are used by other involved parties including wider population while mobile GIS is used by field crews that are dispatched to the emergency scene [9].

Emergency GIS heavily relies on official spatial data. Last decade has been significant for the establishment of policies, best practices and legal frameworks in order to support the development of Spatial Data Infrastructures throughout the world. Different organisations and initiatives have been formed to support such processes, to name few Global Spatial Data Infrastructures Association, UN Geographic Information Working Group (UNIGWG) and Infrastructure for Spatial Information in Europe (INSPIRE) [10]. Today, the development of the SDIs involves participation of different parties in the process of creating, using and sharing geo-data. The standards and specifications created by Open Geospatial Consortium(OGC) and adopted by International Standards Organization (ISO) are the basis of vast majority of SDIs developed on both national and international levels. Although OGC standards are fundamentally influencing better interoperability among different SDIs on different levels and aim to provide access to spatial data for different kinds of users, including citizens, alternative ways of creating, updating and disseminating geo-data have emerged.

In addition to previous, due to the high costs of maintaining official SDIs up to date, National mapping agencies are reducing financing for their regular updating leading to the loss of relevance for many objects. In addition, high costs make consumption of such data expensive for most of the users. Therefore, some authors propose systems that enable users to influence data by suggesting corrections and by uploading GPS locations of new geo-data with predetermined symbology that are later reviewed by administrators who decide if the correction proposals will be accepted [11]. This kind of partnership between official agencies and users can potentially improve not only the quality but also the quantity of available geo-data. Although the accuracy of such data can be argued, sometimes it is better to have data, inaccurate to some extent, than not having it at all.

The body of literature that has been formed during the past several years refers to such volunteered contributions as the concept of VGI describing it as a subset of Crowdsourcing that is related to GIScience [12]. VGI allows people to create or assemble geographic data by collecting geometries, tagging or annotating geographic features, uploading geo-referenced photos, videos or other sensed data related to a specific place on the Earth on voluntary bases. Such data can be later disseminated using different public GIS services [13].

Recent advances in software, hardware and communication infrastructure development that can be associated with the VGI have led to development of new ways of creating geo-content. Notably, the most popular applications that provide such features are Google Earth and Google Maps. By allowing users to create placemarks, routes and overlays, geographic features are transcending from the mere geometrical visualisations of the characteristic of the space to the full descriptions of the place [14]. In [15], such descriptions of the place are termed “cyberscape”, and from the users point of view, can range from strictly local (e.g. user’s house, street) to national and international (country, top of the mountain, beach). Web and mobile platforms that are completely based on the users’ contributions and enable them to actively create geo-data are Open Street Map and Wikimapia [16]. Such platforms are more accessible to different stakeholders in the process of creating geo-data, specifically citizens that contribute such content on voluntary basis, compared to existing GIS infrastructures such as the official geoportals. Foursquare is a Web and mobile application that enables users to “check-in” by posting and sharing their location with other users. Such “check-ins” are rewarded with points and badges for each user. Also, users can provide “Tips” for places that can be shared with other users, thus contributing to the descriptions of venues (places). Lately, social networks such as Twitter and Facebook have introduced the location feature which can be used to share the user’s location when posting content. For example, Twitter users can share only the information about the place they are in (neighbourhood, town, or state), but some third party applications provide the possibility to share the exact address or the coordinates.

Voluntarily collected geo-information can significantly contribute to the each phase of emergency management [17]. In [15] is discussed the usage of Google Maps for mapping flooded areas during the post Hurricane Katrina response and recovery. Some authors refer to such communities that create content used as external assistance to official agencies during crisis as online disaster-response community (ODRC). In most cases, they are comprised of formal and informal networks of people that collect invaluable information especially during response and recovery phases. Help provided by ODRC influences other phases as well especially trough raising community disaster awareness and forming aid organisations or by dissemination of information about the disaster itself and relief efforts. ODRCs also provide necessary assistance by raising funds or helping field crews with work force [18]. The use of data from various social media sources combined with public institutions additional contribution in emergency management is presented in [19]. Analysing such data on specific topic can lead to better decision-making that is based on more facts.

Lately, these volunteer efforts have led to development of specialized GI platforms that can be used in crisis events such as Ushaidi and SparkRelief [20]. Platforms that have been used during major crisis since Haiti Earthquake are in most cases based on the Ushaidi Web software that can be set up in no longer than few hours after the emergency event. Ushaidi has even formed a Standby Task Force consisting of volunteers from all over the world. These volunteers are trained for using their platform and are ready to help with mapping all the important information when an event occurs.

Contemporary development of mobile devices (mobile phones, smart-phones and tablets) provides possibilities for the further enhancement of support for VGI applications. Ever more functionalities that are available on computers can be ported to mobile devices. Additionally, mobile devices have advanced methods for positioning thus enabling users to add exact location data to created content. The ability of combining different methods for positioning (GPS, WiFi location, network base stations triangulation) speeds up the process of acquiring location and improves the accuracy, which is essential for emergency management applications. This opens the possibilities of combining user generated geo-content with existing GIS infrastructure within emergency operating centres (EOC). For instance, people witnessing emergency event (by spotting a wildfire or major traffic accident) often use their mobile phones for reporting such events, but they often do not know the exact location of it [21]. Therefore, in this paper we present VGI mobile application for alerting official agencies in cases of emergency events. Such application will help emergency managers to accurately pinpoint the location of the possible emergency event and to acquire additional data in the form of images, videos, sounds and text that will provide initial insight in the scale of the event.

3 Architecture of VGI supported Emergency GIS

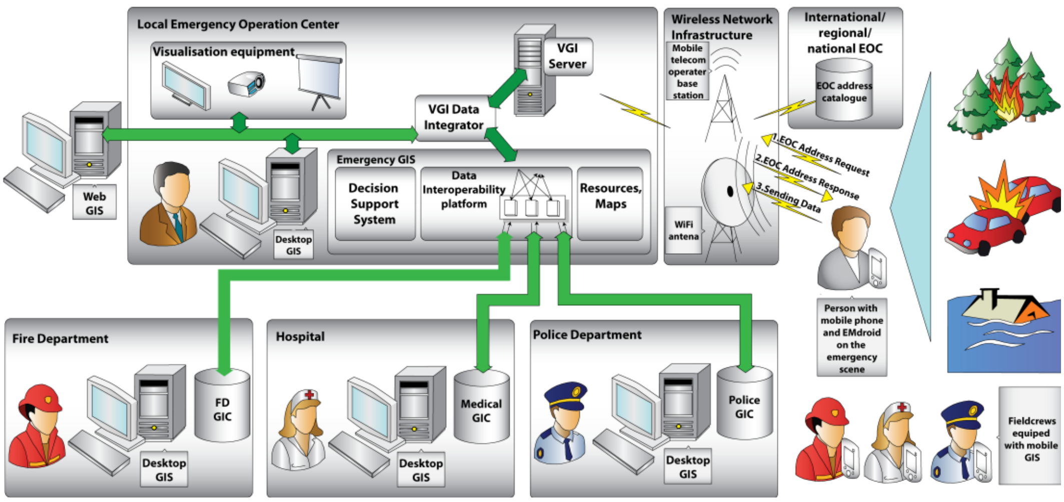
Emergency systems that include GIS are well established in most countries and are used by emergency officers on everyday basis. Such Emergency GISs integrate all available geo-data provided by different institutions (such as utility companies, agencies responsible for traffic, local infrastructure, population, police and fire departments etc.) that maintain their own SDIs for different purposes. Integration of information from all these sources provides the needed knowledge required in the process of visual representation and analysis of hazardous events. VGI that will be integrated with the existing available information will raise situation awareness during crises.

The architecture of the proposed emergency system, based on the GIS that integrates VGI collected at the emergency scene is presented on the Figure 2.The main components of the system are:

- Special mobile application EMdroid installed on mobile device (described later in this paper)
- EOC server catalogue residing in the global/regional/national EOC headquarters.
- Existing Emergency GIS infrastructure used in local EOC to support emergency managers. Such Emergency GIS is based on integration of information from different sources that are well described in the body of literature [22, 23]

The user on the emergency scene uses a mobile device with installed special emergency VGI mobile application EMdroid. The mobile application provides the user with the ability to capture video, image, sound or text that describes the emergency scene and to acquire exact user's location.

Figure 2: Architecture of the VGI supported Emergency GIS



According to user's perception, she can classify the content thus suggesting the emergency officer the nature of hazardous event she is witnessing. The Web address of the target server on which the user will upload the collected data is acquired from the EOC server catalogue. The communication is provided by wireless network infrastructure consisting of mobile telecommunication network and available WiFi access points on the scene. Positioning is provided by all three available methods: GPS, network base station triangulation and WiFi access points.

The EOC server catalogue is a repository that maintains the information about local EOCs and their VGI server addresses. The geographical area of activity of each EOC is stored in the catalog. According to the location provided by the user, the EOC server catalogue responds with the appropriate server address and emergency phone number of the EOC that is responsible for that area. Therefore the user doesn't need to know which institution should be contacted in order to report emergency event. This is very important in cases when user is not familiar with the location especially when she is in other town, region or country and when she is not sure to whom the event should be reported.

Local EOC maintains its own Emergency GIS infrastructure. It uses different data for supporting emergency management. Such data contains information about [24]:

- Emergency phenomena (e.g. landslides, floods, earthquakes, places with higher risk of wildfires), their location, frequency, magnitude and so on.
- Environment in which the emergency events might take place: topography, geology, geomorphology, soils, hydrology, land use, vegetation, and so on.
- Assets that might be affected in the cases of such events: infrastructure, population, settlements, industry and so on.
- Assets that can be used during response to the emergency event (special vehicles, storages containing needed resources, access roads, useful infrastructure and so on).

Emergency GIS consists of following components:

- Data interoperability platform
- Decision Support System
- Resources and Maps manager

Data interoperability platform provides infrastructure for data interchange in the local community environment. Each institution or agency involved in the emergency management process has its own Geographic Information Center (GIC) and maintains its own data (spatial and non-spatial) according to its needs. Data interoperability platform integrates data from each GIC of interest and provides complete SDI with all the available information.

Decision Support System maintains the knowledge data that is constructed during the learning process according to data acquired in previous response and recovery phases. It also includes predefined response plans created during preparedness phases. Combining data about emergency event with response plans provides the possibility of immediate reaction according to predefined procedures.

Resources and Maps manager provides the spatial data relevant for EOC that can't be found in other GICs. These data are maintained by emergency managers and include data about civil organizations, specialized firms, private resources that can be used during the development of the event itself. Such information is invaluable especially during crisis of large extent.

In order to receive users' VGI data from the emergency scene, VGI server is used. The address of this server is provided to the user by EOC server catalogue. The server classifies the received content according to the tag provided by the user that sent it. VGI server also provides VGI data for Emergency GIS. Upon receiving of the report, the server pushes notification to the VGI Data Integrator. VGI Data Integrator handles the integration of the received content with existing spatial data. Effectively it overlays the data over the map in the form of point geometry features using the proper symbology, according to the classification of the event. Such information is presented to the emergency manager using desktop GIS on the workstation. The emergency manager is able to review the received content and decide which steps will be taken afterwards in order to properly react to the emergency. According to the nature of the event emergency manager can decide to which institutions the data will be forwarded along with the proper recommendations about the scale of the crisis. Recommendations include plans, the number of the field personnel, types of vehicles, routes that should be used etc. Sent data are visualized in GICs of the departments that are determined to take action and dispatch emergency crews on the field. Further analysis of received data is done using different visualization equipment in the EOC where more decision makers are included in tracking the development of the crisis. During the course of the event, other users will also provide additional VGI content thus improving the overall situation awareness. Received content can be further disseminated trough dedicated or public Web GIS applications in order to properly inform general public.

4 EMdroid

Users witnessing the emergency event on the scene need to have the ability to easily provide the critical information on the nature of the hazardous event as quickly as possible. The time for creating such data needs to be minimal. Therefore, special application has to be available on the user's mobile device that will lead the user through a series of seamless steps that will result into generated geo-referenced content. Such application has to rely on technologies that are already supported on vast majority of contemporary mobile devices such as positioning, camera, microphone, large touch screen etc.

Nowadays, smart-phones with operating systems such as Android, iOS, BlackBerry OS and Windows Phone 7 are holding around 70% of the worldwide market share [25, 26]. Android OS for mobile phones and tablets is gaining ever more users every day. Android applications can be executed on the large scale of mobile devices from different manufactures. Additionally, such applications can be distributed over the Google Market or be made public for the community elsewhere. Therefore, every citizen that wants to be able to provide such information using Android mobile application can download and install it.

Because of accounted advantages, our prototype application for collecting emergency VGI data EMdroid has been developed for Android OS (Figure 3). Upon starting the

Figure 3: The process of acquiring video using EMdroid mobile application

application the initial screen is presented to the user allowing her to choose which type of data she wants to create. The application uses native Android providers for camera, microphone and keyboard. The process of acquiring video using EMdroid application is shown on Figure 3. User starts video capturing by selecting camera icon. The installed application for capturing video is presented to the user. Upon capturing the content, the user initiates the process of acquiring location using native Android location capabilities. If for any reason the actual location cannot be acquired, the map is presented to the user on which she can select her approximate location by tapping.

The user has the ability to add some additional description to the content. The most important is to annotate the data by selecting the category of hazardous event from the list of predefined values (i.e. fire, wildfire, flood, landslide, crash, chemical accident, crime etc.). This classification is of great importance for emergency managers because it provides better initial understanding of the reported problem, thus speeding up the process of the response. Also, user has the ability to include additional text description of images, videos and sounds. Nevertheless, these descriptions shouldn't be very detailed because they require additional time to be typed even on full QUERTY keyboards that are supported nowadays. Collected content is automatically time-stamped and user cannot change its date or time. This is very important for proper tracking of the development of the crisis within the EOC. In most cases, emergency event can endanger lives of the people nearby. Such critical situations may influence the ability of users to use application due to the fear for their life or property. Therefore, we tried to make application as intuitive as possible, which is reflected through the simple user interface with large buttons and usage of native applications for camera, and microphone to which users are already accustomed. Application also supports store and forward functionality. After collecting data and acquiring location, the user can relocate to the safe distance and then upload the content to appropriate server address automatically acquired from the EOC server catalogue. Store and forward is particularly useful in cases when communication infrastructure is clogged or destroyed by emergency event. In such cases user can upload data from other locations where communication is available.

5 Conclusion

Lately, VGI has been the hot topic of the research community. Numerous authors are researching the possibilities of emergency systems based on VGI that could be used in various phases of the emergency management. Development of smart-phones and tablets and their high adoption among users provides the opportunity to develop specialized mobile applications that can be used for creating first data on the emergency event. By providing such data, users can effectively improve the situation awareness of the emergency managers in early stages of such event.

GIS infrastructure that is used for emergency management is well developed and provides static spatial data and different analysis capabilities. Combined with VGI, such systems can provide faster, adjusted and more accurate emergency response. EMdroid application tends to provide collecting data on emergency event for common user as simple as possible. The user only has to follow simple steps in order to report hazardous event.

In order to provide wider access to such applications, they have to be developed for different types of mobile devices and operating systems. The future research needs to address how stressful conditions influence users. Also, possibility of providing direct streaming of video using mobile phone camera from the scene that can be viewed or projected on the 3D model of the terrain will be investigated in the future. The problems such as scalability, credibility, privacy and potential for inclusion of large number of potential users of different ages, educational and social status should also be investigated.

References

[1] S. Zlatanova, D. Holweg and M. Stratakis. Framework for multi-risk emergency response, in: C. V. Tao and J. Li, editors, *Advances in Mobile Mapping Technology*,pages 159-171. Taylor&Francis, London, ISPRS Book Series, 2007

[2] B. Resch, D. Schmidt, D. and T. Blaschke. Enabling Geographic Situational Awareness in Emergency Management. In: *Proceedings of the 2nd Geospatial Integration for Public Safety Conference*, New Orleans, Louisiana, US, 15-17 April 2007.

[3] M. F. Goodchild. Citizens as voluntary sensors: spatial data infrastructure in the world of Web 2.0, *International Journal of Spatial Data Infrastructures Research 2*, pages. 24–32. 2007

[4] M. F. Goodchild, Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69, pages 211–22, 2007.

[5] L. Stoimenov, B. Predić, V. Mihajlović, M. Stanković. GIS interoperability platform for emergency management in local community environment, *Proceedings printed as book, 8th AGILE Conference on GIScience*, Estoril, Portugal, 26-28.5.2005., Eds. Fred Toppen, Marco Painho, pp. 635-640.

[6] S. Zlatanova, D. Holweg. 3D geo-information in emergency response, In *Proceedings of the Fourt International Symposium on Mobile Mapping Technology (MMT'2004)*, Kunming, China, 2004.

[7] A. Mobaraki, A. Mansourian, M. Malek, H.Mohammadi Application of Mobile GIS and SDI for Emergency Management, *ISPRS Commission Technique I. Symposium*, pages 95-100. 2006.

[8] FEMA Mapping and Analysis Center. What is a Geographic Information System?, available at http://www.gismaps.fema.gov/gis01.shtm,

[9] P. van Oosterom, S. Zlatanova and M. Fendel, editors, *Geo-Information for Disaster Management*, Springer-Verlag, Berlin, 2005.

[10] M. Craglia, M.F. Goodchild,A. Annoni, G. Camara,M. Gould,W. Kuhn, D. Mark, I. Masser,D. Maguire, S. Liang, E. Parsons. Next-Generation Digital Earth. A position paper from the Vespucci initiative for the advancement of geographic information science (editorial). *International Journal of Spatial Data Infrastructures Research 3*, pages 146–167. 2008.

[11] D.Petrovič and B.Kovačič. Web Application for Topographic Maps Changes Acquisition. In *Proceedings of 6th Mountain Cartography Workshop*, Lenk, Switzerland. 2008.

[12] W. Kuhn. Volunteered geographic information and GIScience. *In Workshop on Volunteered Geographic Information*, University of California, Santa Barbara, pages 86–97. 2007.

[13] S. Elwood. VGI: future research directions motivated by critical, participatory, and feminist GIS, *Geojournal 72(3-4)* pages 173–183. 2008.

[14] R. S. Purves, and A. J. Edwardes. Exploiting Volunteered Geographic Information to DescribePlace, *Proceedings of the GIS Research UK 16th Annual Conference*,D. Lambrick, editor, pages 252-255. 2008

[15] M. Crutcher and Z. Matthew. Placemarks and Waterlines: Racialized Cyberscapes in Post-Katrina Google Earth. *Geoforum 40, no. 4*, pages 523–534.2009

[16] D. Coleman. Volunteered geographic information in spatial data infrastructure: an early look at opportunities and constraints. In *GSDI 12 World Conference*. Singapore 2010.

[17] B.Tomaszewski. Situation Awareness and Virtual Globes: Applications for Disaster Management. *Computers and Geosciences*, 37, pages 86-92. 2011.

[18] M. Laituri and K. Kodrich. On line disaster response community: People as sensors of high magnitude disasters using Internet GIS. *Sensors*, 8, pages 3037-3055. 2008.

[19] F. O. Ostermann, and L. Spinsanti. A Conceptual Workflow For Automatically Assessing The Quality Of Volunteered Geographic Information For Crisis Management, In *Proceedings of AGILE 2011*, Utrecht, the Netherlands. 2011.

[20] E. Naone, Internet Activists Mobilize for Japan, http://www.technologyreview.com/communications/35097/page1/ (last access 12.03.2012.)

[21] C. Thomas. Hills fire-spotters go hi-tech available at http://www.adelaidenow.com.au/news/south-australia/hills-fire-spotters-go-hi-tech/story-e6frea83-1226223365325 (last access 09.01.2012.)

[22] A. Buccella, A. Cechich, , and P. Fillottrani. Ontology-driven geographic information integration: A survey of current approaches. *Comp. & geosciences*, 35 (4). 2009.

[23] U. Visser, H. Stuckenschmidt, G. Schuster and T. Voegele, Ontologies for geographic information processing. *Computers in Geosciences* 28, pages 103–117. 2002.

[24] D. Balaji, R. Sankar and S. Karthi., GIS approach for disaster management through awareness - an overview, In*Map India 2002 Proceedings*, New Delhi, India, 2002 http://www.gisdevelopment.net/proceedings/mapindia/2002/index.htm

[25] Gartner Press Release. Gartner Says 428 Million Mobile Communication Devices Sold Worldwide in First Quarter 2011, a 19 Percent Increase Year-on-Year, http://www.gartner.com/it/page.jsp?id=1689814 (last access 10.01.2011.)

[26] IDC - Press Release. Worldwide Smartphone Market Expected to Grow 55% in 2011 and Approach Shipments of One Billion in 2015, According to IDC, available at http://www.idc.com/getdoc.jsp?containerId=prUS22871611 (last access 10.01.2011.)