How volunteered geographic information can be integrated into emergency management practice?

First lessons learned from an urban fire simulation in the city of Coimbra

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ABSTRACT

In the past few years, volunteered geographic information (VGI) has emerged as a new resource for improving the management of emergencies. Despite the growing body of research dedicated to the use of VGI in crisis management, studies are still needed that systematically investigate the incorporation of VGI into practical emergency management. To fill this gap, this paper proposes a research design for investigating and planning the incorporation of VGI into work practices and decision-making of emergency agencies by means of simulation exercises. Furthermore, first lessons are drawn from a field study performed within a simulation exercise of an urban fire in Coimbra, Portugal, implemented together with local civil protection agents. Emergency management practitioners identified a high potential in the pictures taken *in-situ* by volunteers for improving situational awareness and supporting decision-making. They also pointed out to challenges associated to processing VGI and filtering high-value information in real-time.

Keywords

Volunteered Geographic Information; Emergency Management; Simulation; Fire.

INTRODUCTION

The term Volunteered Geographic Information (VGI) was coined by Goodchild (2007) and concerns the information provided voluntarily by citizens to which a geographical location is or may be assigned. A great diversity of information can be considered under this VGI umbrella, such as photographs made available at collaborative projects (e.g. Flickr, Instagram), vector data in the collaborative maps of OpenStreetMap (https://www.openstreetmap.org), or classifications of satellite imagery such as in GeoWiki project (http://www.geo-wiki.org/).

One particular area where VGI may be valuable is to provide updated information (in near real time) about extreme events and disasters, such as floods, fires and earthquakes (Goodchild & Glennon, 2010). In these cases, volunteers *in loco* may make use of smartphones equipped with GNSS (Global Navigation Satellite System) receivers to provide first-hand observations, which contain information about what is occurring on the ground. Thus, VGI can be useful for one of the main problems in emergency response, which consists of acquiring situation awareness (Yin et al., 2012).

In the past few years, there has been a growing body of research works that deals with VGI for disaster management (see Horita et al., 2013 for an overview). Most of these works are dedicated to analysing and understanding information provided by citizens via social media, mainly focused upon the response to emergencies (Landwehr & Carley, 2014). Another source of VGI that has been investigated in the context of disasters is the so-called *mobile crowd sensing* (Ma et al., 2014). Instead of relying upon general social media platforms to generate VGI, this type of VGI is collected with dedicated applications that can be used by citizens to purposefully report more specific and structured information, e.g. as part of citizen observatories (Degrossi et al., 2014). As such, the profile of people in the 'crowd' who generates VGI in this kind of project may vary considerably, ranging from citizens of the affected population, up to trusted volunteers who may have more specific skills and/or expertise - called "bounded crowdsourcing" by Meier (2011).

Despite the growing body of research works in this area, studies are still missing about how to incorporate the information provided by volunteers in the form of VGI to the work practices and decision-making processes in all phases of the emergency management cycle (Turoff et al., 2013). In particular, in order to be able to productively and effectively rely upon VGI for improving situation awareness during an unfolding event, emergency agencies and civil protection agents must become familiar with VGI and ideally practice the collaboration with citizen volunteers during planning and preparedness. To support this need, research studies must investigate how to design processes and systems that enable integrated information flow between citizens and public organisations.

In the pursuit of this goal, this insight paper reports a simulation exercise of an urban fire performed in the city of Coimbra in Portugal, in which participants of a training school played the role of citizen volunteers and worked together with local emergency agents (i.e. fire-fighters, civil police and civil protection agents). The main contribution of this insight paper to the literature of VGI in crisis management is twofold: (i) to propose a practical design for planning the practical incorporation of VGI into work practices and decision-making of emergency agencies by means of simulation exercises; (ii) to present first lessons learned from the exercise as regards to the potential usefulness of the *in-situ* information provided by citizen volunteers and the potential difficulties that need to be solved to allow effective information of such data into emergency management.

RESEARCH DESIGN AND METHODS

The research design of this study consists of a quasi-experiment with the goal of proposing and evaluating a practical incorporation of VGI into work practices and decision-making of emergency agencies by means of simulation exercise. The simulation exercise of an urban fire was carried out in May 2015 in the neighbourhood that includes the historical site of the University of Coimbra (UC), in Portugal - declared in 2013 UNESCO world heritage. The area of the exercise, locally known as “Alta”, is characterised by wooden buildings in narrow streets serpentining the university hill (see Figure 1).

The chosen area is very problematic in case of the occurrence of a fire, for the following reasons: a very dense urban fabric, with contiguous buildings and very narrow streets, some of which are too narrow for emergency vehicles to get through; a large percentage of old buildings built with a large amount of wood; during daytime vehicles are often parked in places that block the passing of larger fire brigade cars; there is a large percentage of elderly population in the area.

The simulation exercise was performed as a joint effort of the civil protection local authority of Coimbra and also of a training school held at UC funded by the COST action TD 1202 (Mapping and the Citizen Sensor). An overview of participants and respective roles played is given in Table 1. The simulation exercise involved the following emergency agencies: the local Civil Protection Authority, two volunteer and one professional Fire

Brigades, two police forces, namely the Police for Public Security (PSP) and the Municipal Police, and the safety office of UC.

Figure 1. Images of the exercise location (the "Alta" neighbourhood in Coimbra)

The response of the official forces was separated into two stages, an initial stage where real means were used (so-called LIVEX phase), involving three vehicles from the Professional Fire Brigade, one for Tactic Command (VCOT), one for Command Communications (VCOC) and one Light Vehicle Fire Fighting (VLCI); two vehicles from the Volunteer Fire Brigades, one VLCI and an Urban Fire Fighting Vehicle (VUCI); and two vehicles from the police forces, all with respective crew (about 4 officers per vehicle). In the second phase, corresponding to the situation when the event would take larger proportions, the response was only simulated corresponding to the Command Post Exercises (CPX) mode, where no real additional means are employed.

Organisation	Number of participants	Role played in the exercise
Training School participants	20 students	Citizen volunteers
Municipal Civil Protection	2 agents	Emergency responders
Professional Fire Brigade	3 emergency vehicles with crew	Emergency responders
Volunteer Fire Brigades	2 emergency vehicles with crew	Emergency responders
National and Municipal Police forces	2 vehicles with crew	Emergency responders
UC safety office	1 officer	Emergency response (associated to university buildings)
UC students	4 MSc students	Assistants
Academic staff	4 Faculty members	Organisers and facilitators

Table 1. Overview of the participants of the simulation exercise

Scenario

Several preliminary meetings took place first with the local civil protection authority and then with representatives of other institutions involved. These meetings enabled the choice of the type of simulation exercise and its location. The chosen scenario was a night fire, starting at 22:00 in one of the buildings of the university (Palácio dos Grilos), since at night these buildings are empty and therefore a night fire would take more time to be detected and would more likely take large proportions. Since the simulation exercise had to take place during the day, a real time (time of the simulation exercise) and a virtual time (time of the simulated event) were considered in the following procedures. This initial choice of the event was followed by a more detailed analysis of a feasible scenario based on the experience of the involved professionals, which resulted in a table where the chronological sequence of events (start time) that were supposed to occur and be reported to the authorities during the simulation exercise was listed, with the location of their occurrence (street name) and the description of the observed event. Table 2 shows some of the considered occurrences and Table 3 the types of events considered and the type of information they may provide to the authorities.

Start real time	Start virtual time	Location	Event
10:02	22:02	Couraça de Lisboa	Smoke visible in the vicinity
10:05	22:05	Rua da Ilha	Intense fire visible in "Palácio dos Grilos"
10:07	22:07	Rua Dr. Guilherme Moreira	Street blocking with parked cars are reported
10:08	22:08	Rua da Ilha	Risk of explosion (cars parked next to intense fire)
10:10	22:10	Palácios Confusos	Fire propagation to neighbouring buildings

Table 2. A sample of the simulation exercise event planning

Events	Usefulness
Smoke visible	Fire location
Fire starting in buildings	Fire location / Evacuation needs
Intense fire	Fire location
Parked cars	Street blockings / Secondary hazards
Road works	Street blockings
People in danger	Evacuation needs
Elder people in danger (and number)	Evacuation needs / Necessary means
Injured people (and number)	Evacuation needs / Necessary means
Injured children (and number)	Evacuation needs / Necessary means
Flooded street	Street blockings / Secondary hazards

Table 3. Types of events considered

Volunteers

Participation of volunteers in the simulation exercise was organised considering two potential types of volunteers. The first type comprises volunteers that were previously prepared to assist authorities and had specific tasks assigned (i.e. "bounded crowdsourcing"). These volunteers were separated into three subgroups (of 3 volunteers each) to collect information about the following focus areas: 1) people in danger; 2) road status; 3) possibility of occurrence of secondary hazards. These volunteers used the KoBo Toolbox (http://www.kobotoolbox.org/), an open-source framework for mobile data collection. On the day before the exercise, they received training covering relevant information for emergency management and the software tool, and prepared the application by designing specific forms to collect the information found relevant for each geographic area.

The second type of volunteers considered (henceforth called "informal volunteers") was aimed at simulating citizens that were incidentally at the location of occurrences and wanted to spontaneously report something they considered of interest to authorities. These volunteers used a prototype of an application developed at UC (so-called "Hydra application"), which is targeted to be used by common citizens to collect information on several types of events of interest to the Civil Protection Authority, such as urban/forest fires or floods, when anything is observed that is considered to be of potential use. This type of volunteers was also subdivided into three subgroups, each one following a different route during the simulation exercise.

To organise the information that was supposed to be observed by each group of volunteers and then to be sent to the Civil Protection Authority, an orientation map (Figure 2) was given to student assistants. One assistant accompanied each group, with the indication of the route that each group should follow. Some spots were highlighted in the orientation map where particular events were supposed to be observed and also the time they should be reported. A numbered poster was supposed to be shown to the volunteers at a particular time and location, in order to simulate a real event. Figure 2 shows one of the maps used and Figure 3 a picture of an event indication that volunteers were supposed to report. Besides the events indicated in the posters, all groups were free to report whatever other events they may have observed and considered of interest.

Figure 2. Example of map used by one group of volunteers

Figure 3. Assistant in the simulation exercise showing a poster that indicates an event supposed to be occurring

DEVELOPMENT OF THE SIMULATION EXERCISE

The alarm call was made at 10am (real time) through the European common emergency telephone number (112). The defined mechanisms to start the means of assistance were followed and the Professional Corporation of fire-fighters was contacted. Due to the seriousness of the occurrence, a site command centre (SCC) was set up for the control of all fire brigade operations (Figure 4). Such SCC consisted of a senior fire officer (who played the role of site commander), two fire-fighters (the site commander's assistants), and three crowdsourced information operators (all three, training school participants) – two of them received and processed information reported by volunteers using the KoBo application and one operator dealt with the data collected with the Hydra application. The process of "information reception, information processing, and actions" was operated at SCC following a "triangular" structure illustrated in Figure 5.

Figure 4. The site command centre

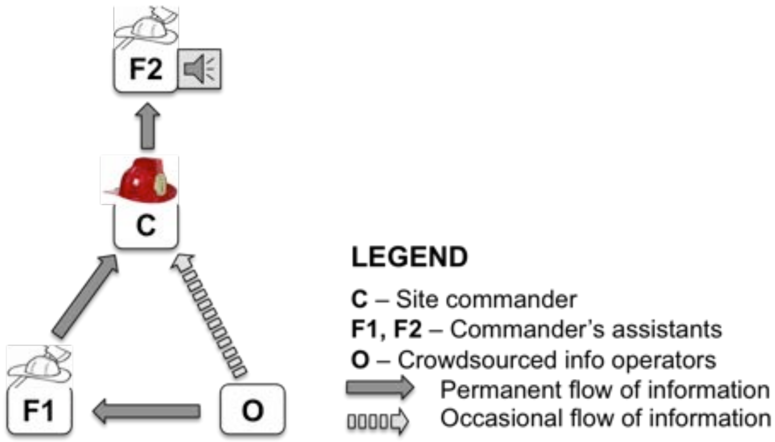

Figure 5. The site command centre (SCC) operational structure

As reports came through operators O (see Figure 5) told orally fire-fighter F1 (see Figure 5) about information uploaded. Fire-fighter F1 wrote down chronologically a timeline of events that would be told to the site commander only when asked by him – in fact, as the site commander took decisions and associate actions were told to fire-fighter F2 (see Figure 5), site commander would then ask F1 about the next event in the timeline, and so on so forth. Quickly it became clear that the flow of posts was rather intense and respective information too much to be processed on the fly – as a matter of fact, site commander explicitly commented that at a certain point.

Further to the comment above, operators O had to adjust their procedure and intuitively started filtering themselves the reports posted. As they skimmed through reports, some of them were simply skipped. Operators also figured out that there was no time to process all data posted. Operators started then focusing on what the site commander considered as most crucial: what is happening; how many people (if possible, specifying as follows: in danger, injured, dead); and where.

Photographs uploaded by volunteers were found of most interest as they may convey information possibly omitted by volunteers. As a matter of fact, firefighter F1 frequently asked to see photographs himself when uploaded – e.g. the door number of a local restaurant was found out this way; many customers in there were trapped in a rather smoky atmosphere.

DISCUSSION AND CONCLUSION

Although there are previous studies based on simulation exercises (e.g. Perry 2014), our study is – to the best of our knowledge – the first to report about the incorporation of VGI in a simulation exercise in order to evaluate its impact on practices and decision-making processes of emergency managers. This resulted into important first lessons learned for all the groups of participants involved. First, the simulation exercise described herein showed to be very useful for the following aspects: 1) the simulation was able to give civil protection authorities and emergency agents a concrete perception about the potential of VGI and the information that may be provided by volunteers in the field; 2) it allowed the identification of difficulties, problems and challenges raised by the use of VGI to assist authorities in real-time.

As regards the potentials of VGI, authorities involved considered photographs taken by volunteers particularly useful. Trained professionals can extract a lot of relevant information from them, such as position in a street (given by the door number or some landmarks visible in the photographs), buildings number of floors, type of road blocking (and possibility of access as well as type of vehicle that may be used), existence of particular types of buildings that require a differentiated response (such as schools or hospitals), level of severity of events (injuries, flames, affected population), etc.

However, the use of VGI in real-time also poses challenges in an unfolding crisis. In the beginning, all information received was communicated to authorities in the site command post, but soon it became clear that there was a need to filter it. This task was then overtaken by volunteer information operators at the command post, who aggregated data received and then communicated it to the operation commander's assistant, who in turn filtered the information again before passing it over to the operation commander. What is relevant depends on the stage of the emergency, and therefore may not be easy to filter automatically. For instance, reporting smoke may be relevant or not, depending on the development of the event (beginning, peak or end) and its location, i.e. reporting smoke may be relevant for detecting a fire but not particularly useful about a place with a known on-going fire.

We thus hope that this study is able to contribute not only by offering important insights about the potentials and open challenges to be addressed, but also by presenting an approach to introduce VGI in simulation exercises. These in turn may be replicated within other communities to allow exchange and mutual learning among emergency managers, researchers and citizens in general.

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