A Review of Information Communication Technology Applied on Common Tasks during Times of Emergency

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ABSTRACT

Research in emergency response systems has produced significant literature in a very short span of time. We review a corpus of published works on how Information Communication Technology (ICT) is being utilized and the type of tasks ICT attempts to support in the event of a crisis due to disasters, whether natural or man-made. In our research, we have been able to distinguish eight types of tasks supported by technology during a disaster. We list some of these technologies used by the public, practitioners and researchers to illustrate the current trends of technology usage. We also identify gaps and technology needs that require our attention. Given the increasing frequency and severity of disasters, this research is timely as it (1) contributes to our understanding of the trends of development and technology use during times of crises and (2) identifies potential areas for future work to improve ICT's role during times of emergency.

INTRODUCTION

We are prone to large-scale emergencies on a daily basis, most of which are unforeseen. These emergencies are either a result of changing climate, accidents, political disruptions or terrorist attacks. The year 2011 has already been declared as the costliest year for natural disasters measured in economic terms[1], while the year 2010 has been labeled as the year of natural disasters due to a high loss of human lives[2]. It has been widely acknowledged that the frequency and severity of large scale crises will likely increase[3]. How people and organizations respond to such crises is changing, given new developments in social media outlets, private communication devices, sensor and broadcasting technologies, which are influencing the way people seek, gather, process, and communicate information. However, we are yet many years away from utilizing the full potential of Information Communication Technology (ICT) in times of crises. To acknowledge and understand ICT's increasing role in crisis management, we need to know what types of ICT is available, how it is being used, and by what groups of users. This knowledge will inform the design and development of future ICT.

In recent years, we have seen an increase in the number of ICT tools and systems available to emergency responders and to those affected by a crisis. This has been matched with a significant amount of research that discusses various aspects of emergency prevention, response and preparedness. However, because research on emergency and crisis management using ICT is interdisciplinary, the literature is spread across research areas making it hard to capture the full breadth of the research landscape and discern patterns from it.

A few studies have provided some review of specific research in emergency response. The 59th issue of Participatory Learning and Action, published by the International Institute for Environment and Development,

[1] http://www.msnbc.msn.com/id/43727793/ns/world_news-world_environment/t/already-costliest-year-natural-disasters/#.TsqX5D3Troo

[2] http://www.rooseveltcampusnetwork.org/blog/2010-year-natural-disasters

[3] As we write this paper, large regions of Thailand, including some areas of its capital Bangkok, are submerged under water. (http://www.bbc.co.uk/news/world-asia-15610536)

discusses how web 2.0 technologies are crucial in development work and presents **a few case studies of Web 2.0 tools** being used for development work (Ashley, 2009). Addams-Moring et al. (2005) survey early warning technologies available and provide a simple taxonomy for mobile emergency announcement systems. Palen and Liu (2007) provide an overview of how the public makes use of technology-mediated communication in the event of a crisis. They mention the different characteristics of citizen-to-citizen communications, deriving their observations from case studies of different types of crisis. Our review takes a wider approach than this previous research, and aims to provide an overview of ICT used in common tasks associated with crisis-related events.

In this paper, we review research literature from multiple sources to:

1) Understand the current trends of technology use in times of emergency,

2) Get a sense of the ICT researchers' contributions in this field and shed light on how ICT research is being applied to real world problems, and

3) Identify problem areas which have received little [or less] attention.

We use the terms crisis, emergency, natural hazards, and disaster inter-changeably despite the subtle differences in their definitions. We refer to terrorism as disaster as well because terrorists, in the last two decades, have increased the scale of the attacks to maximize causalities and economical loss (William L. Waugh, 2007). The damages incurred by recent terrorist attacks are very similar to those incurred by natural hazards.

We first report on our methodology used for this survey and then present our results.

METHODOLOGY

The first step in our approach was to collect papers touching on the breadth of technology in times for emergency. We distilled literature from proceedings of the ACM CHI Conference on Human Factors in Computing Systems (CHI) and the Information Systems for Crisis Response and Management (ISCRAM) over the years. We also retrieved papers from other sources that were available through the ACM and SpringerLink Digital Libraries. We used several keywords, including: "emergency", "information systems", "disaster relief", "floods", "earthquake", "tsunami", "hurricane", "cyclone" and "fire-fighting" and their combinations. We went through the references of the papers retrieved to pull out more relevant works.

We collected over 100 papers which mentioned a certain aspect of technology use. Most of these papers touched upon the subject of communication, as shown in Figure 1. The reason for this is based on the observation that communication exists throughout all the stages of a disaster and the activities undertaken.

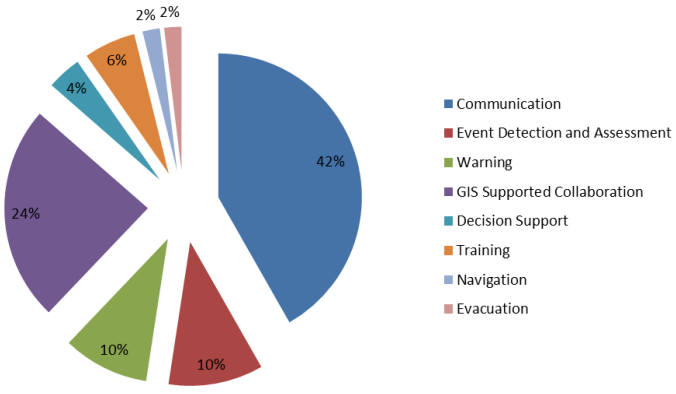

Figure 1. Classification of the corpus based on the eight identified tasks in our review.

We analyzed each paper with an answer to each of the following questions, in particular 4 and 5:

1. What is the main motivation?
2. What methodology does the research employ (e.g., case study, ethnography, etc.)?
3. What types of emergency situations are addressed?
4. *What are the tasks?*
5. *What technological tools and/or methods are used or presented for the tasks?*

6. How are these tools and/or methods evaluated?
7. What are the results and conclusions?
8. What are the different terms used in the paper?

Our review of the papers, particularly the answers to question 4, led to the identification of patterns of *tasks and actions* that would normally take place independently of the type or magnitude of the emergency situations. We categorized the papers according to these tasks and actions. See Figure 1 (above) for the distribution of works in each of these categories.

In a final analysis, we identified eight categories or groups of tasks (Table 1) and a set of requirements (criteria) for a publication to fulfill to belong to a particular category. In cases where a paper met the criteria of more than one category, we considered only the main focus of the paper. The categories are not mutually-exclusive. Geographic Information Systems (GIS) supported collaboration, for example, can qualify as a type of Communication task. However, for simplicity, we treat each category as independent of the others and do not consider the possibilities of one category being a sub-category of another.

Category	**Criteria**
Communication	Technologies aiding in (1) communication among the first-responders, the public and the victims, and (2) information creation, dissemination and validation.
Event Detection and Assessment	Technologies which are used towards disaster prevention, early response and damage mitigation.
Warning	Technologies used to alert and inform the public of potential dangers.
GIS Supported Collaboration	Map-based technologies which help in collaboration.
Decision Support	Technologies which suggest possible actions and aid in decision making.
Training	Technological tools used to train first responders for any emergency response activity.
Navigation	Technologies that assist in navigating to/from affected areas especially when paper maps are less useful (for instance, when an area is flooded because of the need to constant update of information).
Evacuation	Technologies used to assist in emptying affected areas or areas under risk to save human lives.

Table 1. List of categories and their criteria for grouping the papers in our review.

Further to the above categories, we consider field/ethnographic studies as a very important area of work. Technologists need to understand the behavior and the actions of first responders, volunteers or the affected to design effective and sustainable technologies. Despite a dearth of literature in this area, we came across some very valuable studies (e.g., Landgren and Nulden, 2007; Dawes, Cresswell and Cahan, 2004; Yates and Paquette, 2010; Landgren, 2005). However, we have excluded from our review the results from field/ethnographic studies.

RESULTS

Communication

Release of the major micro-blogging platform Twitter in 2006 brought about a key change in online communication by expanding the bounds of social networking. It was followed by an explosion of twitter web, desktop and cell phone clients like Twitterific, Seesmic and Twhirl. The possibility of making twitter updates through cellphones particularly enabled people to broadcast information from crisis hit areas. Case studies of twitter usage during and in the aftermath of Oklahoma Grassfires in April 2009 (Vieweg, Hughes et al., 2010), Red River Floods between March and April 2009 (Vieweg, Hughes et al., 2010), Haiti Earthquake in January 2010 (Yates and Paquette, 2010), Chile Earthquake in February 2010 (Büscher, Mogensen et al., 2008) and Yushu Earthquake (Yan Qu, Zhang et al., 2010) suggest that micro-blogging can serve as an important platform for situational awareness and disseminating information about relief activities.

Following the mass use of twitter for relief activities, Twitter launched Hope140[4], a portal to highlight social movements and provide a starting point to interested volunteers. Hughes and Palen (2009) provide preliminary evidence that users who adopt the micro-blogging technology in irregular emergency situations are more likely to become long-term users of the technology after finding it to be useful. Qu et. al. (2009) in the analysis of Sina-Weibo, a Chinese twitter-like micro-blogging tool, categorize the tweets into categories as shown in Table 2.

Category	**Description**
Informational Messages	
Situation Update	Providing factual information about what was happening in the earthquake area. Such information improves situational awareness in disaster response.
General Yushu Relief Related	Any other Yushu relief related information, including donation, mourning activities, and touching stories.
Other	Other earthquake related information.
Action-Related	
Requesting Help	Requesting help or describing the needs of earthquake victims or rescuers. Such information often leads to others' responses or actions to address the needs or problems.
Looking for Missing People	Seeking or publishing information about missing people, especially family members or friends.
Proposing Relief Actions	Proposing relief actions to the general public.
Relief Coordination	Coordinating relief efforts; organizing actions.
Opinion-Related	
Criticizing	Criticizing government agencies, organizations or individuals.
Suggesting	Providing suggestions to the government, rescue agencies or individuals.
Other opinion	Appraising or making comments without explicit appraisal or criticism.
Emotion-Related Expressing personal feelings—such as anxiety, sadness, anger, pride, confusion, etc.—or providing social and emotional support, including mourning, blessing, comforting, encouraging and expressing concerns for victims.	
Microblogging System Related Suggesting or reflecting on how Sina-Weibo should be used in disaster response.	
Off-topic Messages irrelevant to the earthquake.	

Table 2. Qu et al.'s classification of micro-blogging patterns (Yan Qu, Zhang et al., 2010).

The same categorization, however, can arguably be applied to messages broadcasted on other social media platforms including blogs and social networks. Such open communication raises several ethical issues involving information privacy and manipulation of those affected (Hughes, Palen et al., 2008), which have not received much attention (Heverin, 2011). Rumors, intentional or accidental, are just as easily propagated. However, as Mendoza et al. note, the online community tends to question rumors more compared to verified news, a pattern which can possibly lead to the identification of rumors through an aggregate analysis of the data collected (Mendoza, Poblete et al., 2010).

[4] http://hope140.org

The introduction of micro-blogging and social networking technologies has aided in the prevalence of *citizen journalism.* Meraz (2006) provides an assessment of such technologies that benefited citizen journalism during Indian Ocean Earthquake, the 2005 London Underground and Bus Bombings, and the 2005 US Hurricane Katrina disaster. Leading news avenues are no longer the only popular source of updates on world events. The internet has brought broadcasting to the fingertips of the general public. During times of emergency, individuals present at the location can provide updates. Apart from micro-blogging, photo sharing community websites like Flickr are used for photographic documentaries of disaster events (Liu, Palen et al., 2008). Palen and Liu (2007) provide a good overview of how citizens are using technology to participate in relief activities. Many news agencies, like CNN, encourage the public to send in their stories as text, photographs or videos (Schlieder and Yanenko, 2010). With such open access to mediums of mass communication, the trust factor becomes a concern and something requiring an innovative technological solution. There is always a need to verify and validate the information as the sources, the credibility and the intention of the sources is often unknown.

Event Detection and Assessment

There is an element of unpredictability in most types of disasters. Ideally, an event should be predicted accurately before it happens but, in any case, an early detection can help rapid humanitarian responses which can result in the saving of lives and infrastructure. In his work to estimate loss in earthquakes, Wyss (2005, 2006) notes that it is possible to distinguish disastrous earthquakes from inconsequential ones within less than an hour after the event. This difference is important for rescue operations because the flow of information from the hardest hit areas to the outside can take a considerable period of time.

Systems for prediction and detection of natural disasters need to be modeled in a way that they withstand the severe shocks; however, there is not much literature available that highlights these challenges.

There are several websites which provide alerts and early warning regarding natural disasters.

Floods

One way of monitoring floods is through remote sensing. Powerful data analyzing algorithms are employed to detect floods in real time. Global Disaster Alert and Coordination System (GDACS), a web-based public tool for monitoring floods, utilizes image processing algorithms to monitor floods at a global scale (Groeve and Riva, 2009). Light Detection And Ranging (LIDAR), among others, is used to generate Digital Elevation Models (DEMs), which can be used to simulate flood maps and provide a simulation for flood planning (Buckles, Steinberg et al., 2008).

Earthquakes

There are several organizations that provide information about earthquakes as soon as one is detected. PAGER, Prompt Assessment of Global Earthquakes for Response[5] (Wyss, 2005), World Agency of Planetary Monitoring and Earthquake Risk Reduction (Wyss, 2006) and The Global Disaster Alert and Coordination System (Groeve and Riva, 2009) are some examples of such organizations.

A novel approach in detecting earthquake uses humans as sensors (Sakaki, Okazaki et al., 2010). When an earthquake occurs, people tend to update their status messages on social networks or write micro-blogs about it, which enables detection of an occurrence and propagation of an earthquake.

Terrorism

It can be dangerous for security officials to detect certain types of events (due to the presence of radioactive material). Live testing strategies to intercept such acts of terrorism can impose dangers to the protagonists involved. As a solution, some researchers are exploring publicly-available software like Second Life[6] (a virtual world environment) to test strategies before introducing them in real life (Wu, Liu et al., 2008).

Researchers at UC Berkeley are currently developing small sensor packages that could be integrated into cell phone handsets to turn cell phone networks into sophisticated mobile sensor networks that can detect abnormalities like unusual traffic or bio-weapons[7]. As an interface to such system, WIPER is one example that

[5] http://earthquake.usgs.gov/earthquakes/pager/

[6] http://secondlife.com

[7] http://www.wired.com/gadgets/wireless/news/2005/08/68485

can provide emergency planners and responders with a system that will help to detect possible emergencies as well as to suggest and evaluate possible courses of action to deal with the emergency (Schoenharl, Madey et al. 2006).

Warning

An efficient public warning system is essential to alert and instruct the general public about a crisis, diverting them from danger. Most countries still use a siren as a basic warning system, which automatically rules out a population with hearing problems. Research shows that on average "37% of the population does not hear the siren and that 61% do not know what to do when the siren was sounded" (Smeets and Sillem, 2005). Accessibility is an important aspect of an effective public warning system (Brooks, 2006). CAP-ONES is one example of an alert system which focuses on people with disabilities (Malizia, Acuña et al., 2009).

Mobile phones are largely being used now to alert and instruct the public. These systems are referred to as Mobile Emergency Announcements (MEA). Addams-Moring et al. provide a simple taxonomy of existing EMAs (Addams-Moring, Kekkonen et al., 2005), which distinguishes three types of such systems: pre-planned, ad-hoc, and semi ad-hoc. This categorization is based on the authorities' plan of how well advance in time and in how much detail to use a particular technology.

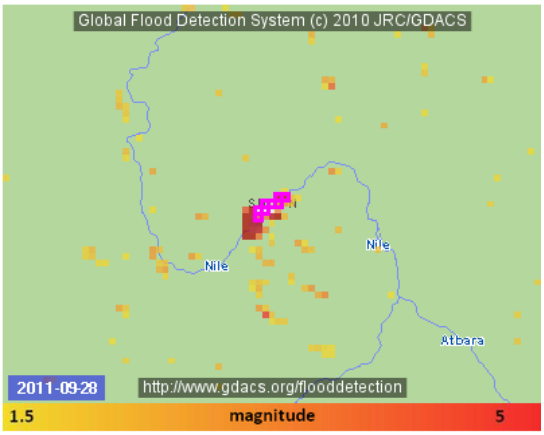

Figure 2. Snapshot of GDACS in action

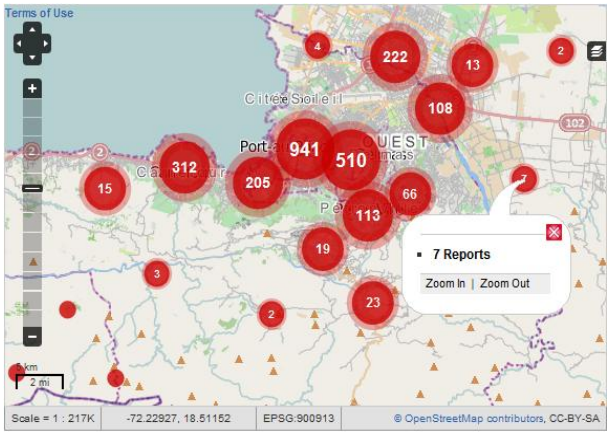

Figure 3 UShahidi Incident Map for Haiti Earthquake

GIS Supported Collaboration and Decision Support Systems

The most popular type of crisis communication today is through web-based Geographic Information System supported Collaboration. The International Network of Crisis Mappers[8], for example, is a very large international online community of individuals with different professional backgrounds who engage in mapping during humanitarian crisis. An international conference for crisis mappers is held annually and brings together professionals from different areas to assess the role of crisis mapping and technology in times of emergency.

Whatever the type of crisis, GIS tools play an important role in the planning of relief activities. The origin of two popular open-source GIS supported collaboration tools, UShahidi[9] and Sahana[10], are evidence to this fact. UShahidi was initially developed to map reports of violence due to poll rigging suspicions in Kenya following their elections in 2008. Sahana, on the other hand, was developed in the aftermath of the 2004 Indian Ocean Tsunami (Careem, Bitner et al., 2007). The system has been deployed to track requests for assistance and information through several natural disasters, the most recent one being that of the tsunami Japan. A case study of active deployments is available on Sahana Foundation website[11].

One of the problems with GIS supported collaboration is the difficulty of keeping track of current situations. Crisis mappers post requests for helps but as Goolsby (2010) notes, these requests are usually not followed up, and therefore one does not know if those requirements have been fulfilled.

[8] http://crisismappers.net

[9] http://ushahidi.com

[10] http://sahanafoundation.org/

[11] http://sahanafoundation.org/products/

While working with maps, symbology becomes important. Because of the complicated nature of the maps and the types of purpose they serve, it is impractical to have common standardized symbols. Different maps use different symbols, which sometimes becomes hard to interpret. From the results of the interviews of Department of Home Security (DHS) mapmakers, Robinson and colleagues (2010) conclude that a better decision for future work is to develop process for formalizing, refining and sharing mission specific map symbol standards.

Training

The most important measure that can be taken to face any kind of emergency is to be prepared for it. A great deal of work is being done to train fire-fighters at the front-line through simulations as replicating a real fire-fighting scenario can be expensive and dangerous (Berlo, Rijk et al., 2005). Apart from front-line action, trainings to facilitate communication and coordination have also received considerable attention. There is valuable literature available where researchers have worked alongside firefighters to better understand their nature of work, which would allow technologists to come up with tools to support front-line work and to design high-fidelity training simulations (Denef, Keyson et al., 2011). However, high fidelity simulations are not the only kind of training technology available. Toups et al. (2011) find their zero fidelity tool, Teaching Team Coordination game (T2eC), to work effectively in teaching fire emergency responders team coordination skills.

One of the areas which have not received sufficient attention is training tools for the interception of terrorist activities considering complications like the risks posed especially if there are bio-chemical weapons.

Navigation

Disasters like fires and floods often damage a great amount of infrastructure. It makes navigating to and from as well as within disaster areas very challenging, and also puts at risk the life of the first responders. In one of the aerial search and rescue missions during the Australian floods, a pilot had to improvise using an iPhone app to navigate when the maps in the chopper were not of much use due to flooded roads (Dunlevy, 2011).

Indoor reconnaissance missions taken by firefighters are very risky activities, which involve navigating through an unknown burning building with a limited supply of oxygen. Firefighters rely on their skills for way finding. Technology for this kind of job has to be very reliable. Ramirez and Dyrks (2010) show how they choose ambiguity as a tool to guide their design process of a simple way finding tool in an environment as rigid as fire-fighting.

Evacuation

Mass evacuation planning requires an understanding of human behavior, which is likely to vary from place to place given different cultural norms. Many research groups are working on developing simulations that exhibit human behavior patterns in order to help practitioners plan effective evacuation techniques (Johnson, 2005). Moreover, evacuating a building is different from evacuating a flooded area. Documenting the different type of evacuations and field studies remain an open research area.

CONCLUSION

While a considerable amount of work has been done in crisis prevention and damage mitigation through the use of ICT, there is still further work ahead. Considering the damages that still incur due to natural or man-made disasters, the objective of using technology to mitigate loss is far from having been achieved. Each year, we hear of floods and earthquakes causing a great deal of damage in terms of human lives and infrastructures. The geographic and economic condition of countries presents a greater challenge to technology. A majority of countries in the world are poor and do not have the resources to invest in advanced technologies to manage disaster risks.

We conclude our research by mentioning some open areas for research:

- There have been several types of terrorist activities noted, which could involve explosives, chemical or biological weapons. Training professionals to intercept terrorists involves a lot of risks that technology can help overcome by providing a virtual environment for training.
- Several tools are available online which help organizations and volunteers raise funds for disaster victims. These tools, however, are only limited to collection of funds. People who contribute have a need (and the right) to know how and where the funds are spent. Providing a platform to support such transparency can engage more contributors.

- Though online communication has accelerated the propagation of information, it has accelerated the propagation of rumors as well. *Information validation and verification* are two areas that deserve more attention especially if tools are being misused and draining tight resources allocated to relief work.
- Maps are an important visualization tool while crisis mapping by professionals and volunteers has become a mass and diverse but very important collaborative activity. User studies in this area can further improve the use of map symbology and provide a consistency vocabulary across different sites. Perhaps an international effort can be raised to ensure some consistent methods for providing user input to indicate specific needs during a crisis.

REFERENCES

1) Addams-Moring, R., M. Kekkonen, et al. (2005). A Simple Taxonomy for Mobile Emergency Announcement Systems. *Proceedings of the 2nd International ISCRAM Conference*. Brussels, Belgium.
2) Ashley, H. e. a. (2009). "Change at hand: Web 2.0 for development." *IIED and CTA*(Participatory Learning and Action 59).
3) Berlo, M. v., R. v. Rijk, et al. (2005). A PC-Based Virtual Environment for Training Team Decision-making in High-Risk Situations. *Proceedings of the 2nd International ISCRAM Conference*. Brussels, Belgium.
4) Brooks, M. (2006). Challenges for Warning Populations with Sensory Disabilities. *Proceedings of the 3rd International ISCRAM Conference*. NJ, USA.
5) Buckles, B. P., L. Steinberg, et al. (2008). *Analysis, Modeling, and Rendering of Urban Flood Events*. The Proceedings of the 9th Annual International Digital Government Research Conference, Montreal, Canada.
6) Büscher, M., P. H. Mogensen, et al. (2008). When and how (not) to trust IT? Supporting virtual emergency teamwork. *Proceedings of the 5th International ISCRAM Conference.* Washington, DC, USA.
7) Careem, M., D. Bitner, et al. (2007). GIS integration in the Sahana Disaster Management System. *Proceedings ISCRAM2007*. Delft, the Netherlands.
8) CDR.A.Thomas Mignone, J. and C. R. Davidson (2004) "Public Health Response Actions and the Use of Emergency Operations Centers." *Prehospital and Disaster Medicine*.
9) Dawes, S. S., A. M. Cresswell, et al. (2004). "Learning From Crisis: Lessons in Human and Information Infrastructure From the World Trade Center Response." *Social Science Computer Review* **22**(1): 52-66.
10) Denef, S., D. V. Keyson, et al. (2011). Rigid Structures, Independent Units, Monitoring: Organizing Patterns in Frontline Firefighting. *ACM CHI Conference on Human Factors in Computing Systems*. Vancouver, BC, Canada.
11) Denef, S., L. Ramirez, et al. (2008). Handy Navigation in Ever-Changing Spaces - an Ethnographic Study of Firefighting Practices. *Designing Interactive Systems*. Cape Town, South Africa.
12) Dunlevy, G. (2011). "Flood rescue helicopter pilot relied on iPhone for navigation." Retrieved September 20, 2011, from http://www.couriermail.com.au/news/flood-rescue-helicopter-pilot-relied-on-iphone-for-navigation/story-e6freon6-1226045049383.
13) Fuhrmann, S., A. MacEachren, et al. Chapter 20: Geoinformation Technologies to Support Collaborative Emergency Management. *Digital Government*.
14) Goolsby, R. (2010). "Social Media as Crisis Platform: The Future of Community Maps/Crisis Maps." *ACM Transactions on Intelligent Systems and Technology*.
15) Groeve, T. D. and P. Riva (2009). Early flood detection and mapping for humanitarian response. *Proceedings of the 6th International ISCRAM Conference*. Gothenburg, Sweden.
16) Heverin, T. (2011). Microblogging for Distributed Surveillance in Response to Violent Crises: Ethical Considerations. *iConference*. Seattle, WA, USA.
17) Hughes, A. L. and L. Palen (2009). Twitter Adoption and Use in Mass Convergence and Emergency Events. *Proceedings of the 6th International ISCRAM Conference*. Gothenburg, Sweden.
18) Hughes, A. L., L. Palen, et al. (2008). "Site-Seeing" in Disaster: An Examination of On-Line Social Convergence. *Proceedings of the 5th International ISCRAM Conference*. Washington, DC, USA

19) Johnson, C. W. (2005). Applying the Lessons of the Attack on the World Trade Center, 11th September 2001, to the Design and Use of Interactive Evacuation Simulations. *ACM CHI Conference on Human Factors in Computing Systems*. Portland, Oregon, USA.

20) Landgren, J. (2005). Shared Use of Information Technology in Emergency Response Work: Results from a Field Experiment. *Proceedings of the 2nd International ISCRAM Conference*. Brussels, Belgium.

21) Landgren, J. and U. Nulden (2007). A Study of Emergency Response Work: Patterns of Mobile Phone Interaction. *ACM CHI Conference on Human Factors in Computing Systems*. San Jose, CA, USA.

22) Liu, S. B., L. Palen, et al. (2008). In Search of the Bigger Picture: The Emergent Role of On-Line Photo Sharing in Times of Disaster. *Proceedings of the 5th International ISCRAM Conference*. Washington, DC, USA.

23) Majchrzak, A. and H. B. P. More (2011). "Emergency! Web 2.0 to the rescue!" *Communications of the ACM* **54**(4): 125.

24) Malizia, A., P. Acuña, et al. (2009). CAP-ONES: An Emergency Notification System for all. *Proceedings of the 6th International ISCRAM Conference*. Gothenburg, Sweden.

25) Mendoza, M., B. Poblete, et al. (2010). Twitter Under Crisis: Can we trust what we RT? *1st Workshop on Social Media Analytics (SOMA '10)*. Washington, DC, USA.

26) Meraz, S. (2006). Citizen Journalism, Citizen Activism, and Technology: Positioning Technology as a 'Second Superpower' in Times of Disasters and Terrorism. *International Symposium on Online Journalism*. University of Texas at Austin.

27) Palen, L., K. M. Anderson, et al. (2010). A Vision for Technology-Mediated Support for Public Participation & Assistance in Mass Emergencies & Disasters. *Proceedings of ACM-BCS Visions of Computer Science*. Edinburgh, United Kingdom.

28) Palen, L. and S. B. Liu (2007). Citizen Communications in Crisis: Anticipating a Future of ICT-Supported Public Participation. *ACM CHI Conference on Human Factors in Computing Systems*. San Jose, CA, USA.

29) Ramirez, L. and T. Dyrks (2010). Designing for high expectations: Balancing ambiguity and thorough specification in the design of a wayfinding tool for firefighters. *The ACM conference on Designing Interactive Systems*. Aarhus, Denmark.

30) Robinson, A. C., R. E. Roth, et al. (2010). Challenges for Map Symbol Standardization in Crisis Management. *Proceedings of the 7th International ISCRAM Conference*. Seattle, USA.

31) Sakaki, T., M. Okazaki, et al. (2010). Earthquake Shakes Twitter Users: Real-time Event Detection by Social Sensors. *19th International World Wide Web Conference*. Raleigh, NC, USA.

32) Schlieder, C. and O. Yanenko (2010). Spatio-temporal Proximity and Social Distance: A Confirmation Framework for Social Reporting. *Proceedings of the 2nd ACM SIGSPATIAL International Workshop on Location Based Social Networks*. San Jose, CA, USA.

33) Schoenharl, T., G. Madey, et al. (2006). WIPER: A Multi-Agent System for Emergency Response. Proc. of the 3rd International ISCRAM Conference. NJ, USA.

34) Science, I. o. B. (2003) "Beyond September 11th: An Account Of Post-Disaster Research." *Program on Environment and Behavior, Special Publication #39*.

35) Security, D. o. H. (January 2008). National Response Framework. D. o. H. Security.

36) Shklovski, I., M. Burke, et al. (2010). "Technology Adoption and Use in the Aftermath of Hurricane Katrina in New Orleans." *American Behavioral Scientist* **53**(8): 1228-1246.

37) Smeets, M. W. B. E. and S. Sillem (2005). Intelligent SMS as an Effective Public Warning System: the Inspiring Results of a Dutch Pilot Project. *Proceedings of the 2nd International ISCRAM Conference*. Brussels, Belgium.

38) Starbird, K. and L. Palen (2011). "Voluntweeters": Self-Organizing by Digital Volunteers in Times of Crisis. *ACM CHI Conference on Human Factors in Computing Systems*. Vancouver, BC, Canada.

39) Toups, Z. O., A. Kerne, et al. (2011). Zero-Fidelity Simulation of Fire Emergency Response: Improving Team Coordination Learning. *ACM CHI Conference on Human Factors in Computing Systems*. Vancouver, BC, Canada.

40) Vieweg, S., A. L. Hughes, et al. (2010). Microblogging During Two Natural Hazards Events: What Twitter May Contribute to Situational Awareness. *ACM CHI Conference on Human Factors in Computing Systems*. Atlanta, GA, USA.

41) Vieweg, S., L. Palen, et al. (2008). Collective Intelligence in Disaster: Examination of the Phenomenon in the Aftermath of the 2007 Virginia Tech Shooting. *Proceedings of the 5th International ISCRAM Conference*. Washington DC, USA.

42) William L. Waugh, J. (2007). Terrorism as Disaster. *Handbook of Disaster Research*. New York, Springer 388-404.

43) Wu, M.-H. M., A. H.-W. Liu, et al. (2008). Virtual Environments for Developing Strategies for Interdicting Terrorists Carrying Dirty Bombs. *Proceedings of the 5th International ISCRAM Conference*. Washington, DC, USA.

44) Wyss, M. (2005). Earthquake Loss Estimates Applied in Real Time and to Megacity Risk Assessment. *Proceedings of the 2nd International ISCRAM Conference*. Brussels, Belgium.

45) Wyss, M. (2006). The Kashmir M7.6 Shock of 8 October 2005 Calibrates Estimates of Losses in Future Himalayan Earthquakes. *Proceedings of the 3rd International ISCRAM Conference*. NJ, USA.

46) Yan Qu, C. H., P. Zhang, et al. (2010). Microblogging after a Major Disaster in China: A Case Study of the 2010 Yushu Earthquake. *ACM Conference on Computer Supported Cooperative Work*. Hangzhou, China.

47) Yates, D. and S. Paquette (2010). Emergency Knowledge Management and Social Media Technologies: A Case Study of the 2010 Haitian Earthquake. *American Society for Information Science and Technology (ASIS&T)*. Pittsburgh, PA, USA.