Multidisciplinary Challenges in an Integrated Emergency Management Approach

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ABSTRACT

The University of Agder, Norway, has recently founded a Centre for Integrated Emergency Management (CIEM). The centre brings together a highly multi-disciplinary group of local and international researchers in technology and the social sciences. This paper presents an interdisciplinary vision for large-scale integrated emergency management that has been inspired by the transition from platform centric to Integrated Operations in the oil and gas fields, which uses remote emergency control centers collaborating virtually with local responders. The paper discusses some of the most salient research challenges for Integrated Emergency Management.

Keywords

EMIS, Virtual Collaboration, Integrated Operations, Human-Centered Sensing, Citizen Participation, Networks.

INTRODUCTION

Large scale emergencies require response and management under circumstances disrupted by the disaster itself (Simpson and Hancock, 2009). When indigenous systems have been disrupted, emergent groups that often do not share common practice and experiences must be coordinated. On site conditions may have been adversely affected and the lack of integration across phases and organizations, together with exhaustive stress impairs the response quality (Turoff, Van de Walle and Hiltz, 2010). Experiences with Integrated Operations (IO), pioneered in the Norwegian offshore oil and gas fields, suggest a different model – an Integrated Emergency Management approach. This is a promising approach for emergency management and is a realistic goal in the next 10 years.

In an IO approach, teams in onshore control rooms, working in 3-4 time zones around the globe, virtually collaborate with a local offshore workforce to handle oil and gas operations. Since different oil and gas companies implement IO in different ways there is no common description of the IO concept. However, all IO solutions share the following generic properties: 1) Use of ICT and a digital infrastructure to enable new work practices; 2) increased capture of offshore performance data; 3) use of real-time data to monitor and manage operations across geographical and organizational borders; 4) use of collaborative technology to link different actors in a closer, more efficient way; 5) access to expert knowledge (Albrechtsen and Besnard, 2010). IO implementations include processes for all stages of emergency management in oil and gas platforms. A serious test of emergency management using IO has not yet occurred since there have been no recent major accidents in offshore Norway. However, Albrechtsen (2010) argues that IO is an enabler for new practical approaches to risk assessment and management; that risk assessment may be improved through use of real time data; and that it provides better risk visualization and facilitates effective safety support.

Ongoing activities in early alerts, collaborative decision making systems, situation room technology, integration of physical data, remote sensing, geographical data and social media information for emergency management can be viewed as emergent components for Integrated Emergency Management (IEM). This paper proposes three major research challenges for creating a future IEM approach.

CHALLENGE 1: ENABLING INFRASTRUCTURE-LESS COMMUNICATIONS

Today, worldwide cellular networks are the fundamental infrastructure for communications among citizens. However, such an infrastructure is vulnerable in large-scale emergencies. Even in small-scale emergencies, e.g. the storm in west Norway in December 2011, thousands of people can lose network connectivity for weeks. Although satellite-based infrastructure will still be operational after natural disasters, handset prices of around USD 500 – 1,700 and high subscription fees restrict citizens' use of satellite phones. Therefore, improving the resilience of infrastructure-based mobile systems by enabling infrastructure-less ad hoc communications is a paramount theme for emergency management. Thus, availability, reliability, robustness, coverage, and energy efficiency are essential topics for building and deploying ad hoc networks in emergency areas. Future research work concerns:

- Enhancing network connectivity by introducing redundancy to infrastructure-based mobile systems using ad hoc networks. Network connectivity can be improved by using easily deployable ad hoc networks to provide redundant links (Egeland and Engelstad, 2009). However, current works fail to propose concrete strategies on how to combine partial static topology with dynamic links. Furthermore, the performance of such strategies needs to be evaluated through mathematical analyses, simulations and test-beds.
- Rapid deployment of mobile base stations to emergency areas. A promising approach is to integrate ad hoc networks with infrastructure-based communication systems using mobile base stations and mobile devices. This could form a standalone network, e.g., as a citizen-to-citizen, or rescue team-to-rescue team network, or a combination of both. This network could also form an easily deployable temporary wireless network, connecting to other infrastructure networks such as satellite or cellular systems. In such context, a light-weight mobile base station or gateway will be an optimal alternative.
- Reliable and robust communications over large-scale areas for rescue teams and affected citizens. Considering link instability and topology of ad hoc networks, a bi-connected topology has been proposed for reliable communications (Ogier and Spagnolo, 2009). However, this imposes strict requirements on high node density, which is unrealistic in emergency scenarios. Another approach is to develop new MAC mechanisms and routing schemes for low density ad hoc networks in order to provide peer-to-peer reliable communications in emergency scenarios.
- Lifetime extension of communication networks. Recent research (Jung and Ingram, 2011) demonstrates that per-hop transmission range can be extended by cooperative transmissions of neighboring nodes towards a common destination. In this way, an energy constraint node can survive over longer periods, resulting in improved network lifetime. Here work could focus on designing energy-efficient mechanisms to extend network lifetime.

CHALLENGE 2: HUMAN-CENTERED SENSING

Mobile wireless devices such as mobile phones and smartphones are widespread and are often equipped with advanced sensor technology, accelerometer, digital compass, gyroscope, GPS, microphone, and camera. Consequently new types of smart phone applications that connect low-level sensor input with high-level events are emerging (Lane, Miluzzo, Lu, Peebles, Choudhury and Campbell, 2010). These applications can involve individuals, groups of users, and even entire communities. An example is the automatic classification of a smart phone's environment by using its microphone (Lu, Pan, Lane, Choudhury and Campbell, 2009). By combining the smart phone's accelerometer with GPS, the owner's movement patterns e.g. walking, running, or cycling, can be determined (Zhang, McCullagh, Nugent and Zheng, 2010). Interaction between multiple smart phones provides further possibilities. For example GPS data collected from large user groups can identify the places frequented by different subpopulations. Consequently users can receive targeted recommendations on restaurants, shops, etc., based on the behavior of the subpopulation that best fits the user's own movement patterns.[1] Another example is using smart phone sensor technology to determine how the actions of large groups of users cause different types of environmental pollution (Mun, Reddy, Shilton, Yau, Burke, Estrin, Hansen, Howard, West and Boda, 2009).

Recently, "Human-Centered Sensing" (HCS) has been introduced for emergency management, using humans as information collectors (Jiang and McGill, 2010). By taking advantage of smartphone based sensor technology, HCS offers the potential for remote sensing and information fusion in an emergency (Schade, Díaz, Ostermann, Spinsanti, Luraschi, Cox, Nuñez and De Longueville, 2012). However, a number of research challenges arise.

[1] Sense Networks http://www.sensenetworks.com/technology.php

Firstly, HCS in emergency situations with ad-hoc networks implies a plenitude of fragmented information, collected and propagated in an opportunistic manner through locally formed “communication hubs” (Hall and Jordan, 2010). Also, different emergency response agencies will have their own interpretation of what is important data, and their own storage formats. Furthermore, crucial data may be provided even by citizens and victims of the emergency, in an ad-hoc manner (Jiang et al., 2010). The resulting data heterogeneity and huge amounts of data, introduces several research challenges (Tomaszewski, Robinson, Weaver, Stryker and Maceachren, 2007). Integrating different formats using a common information model, and the intelligent routing of the data constrained by limited communication resources, are great challenges in HCS.

Distilling pertinent cues from collected information in order to obtain situational awareness at the individual, local, and global level of an emergency, forms a formidable data fusion problem (Hall et al., 2010). Such fusion includes context dependent hazard forecasting, damage and risk estimations, and statistical analysis. The problem must be solved in a decentralized manner, as dictated by the resource constrained computing and communication devices involved. Moreover, spatio-temporal aggregation of information fragments is required since information from geographically related sensing devices may also be used to recognize and track evolving local and global emergency patterns. Additionally, conflicting or even contradictory information, typical in the early emergency phase, requires harmonization, and methods are needed to discriminate between erroneous, misleading, and awareness-bringing information.

Opportunistic mobile phone sensing requires privacy preservation (Kapadia, Tri, Cornelius, Peebles and Kotz, 2008). In some emergency situations, e.g. terrorist attack, shared information could be abused posing significant risks. Information sharing may also lead to the spread of false information. To prevent hostile attacks, HCS should ensure information integrity and guard against information misuse. An ability to interpret sensor readings so that a threat picture may be formed is central to IOs. Furthermore, a comprehensive picture can only be formed when the sensor measurements from several devices are taken in context (Hall et al., 2010), possibly in combination with information from involved authorities.

CHALLENGE 3: CITIZEN PARTICIPATION AND SOCIAL MEDIA

In recent years our society has seen huge advances in information technologies resulting in marked changes in the way that individuals interact and communicate. The emergence of the smart phone and other ICT has given us mobile access to web services, such as social networking sites, which encourage sharing and exchanging information. Through these ICT developments, citizens are now playing a much more active role in providing information to emergency managers. Recent large-scale emergencies, such as the Haiti Earthquake gave rise to an unprecedented surge of citizen involvement where humanitarian workers tried to cope with massive amounts of information provided by citizens through web portals, platforms, and new social networking media, such as SMS feeds, Twitter, etc (Dugdale, Walle and Koeppinghoff, 2012). Such is the increase of citizen participation that current IS for emergency management, e.g. the SAHANA Open Source Disaster Management System and the crowd-sourcing platform Ushaidi, now purposely provide ways to incorporate information sent by citizens through social media and SMS.

Emergency response may be viewed as an integrated socio-technical system where citizens play a key role in shaping the response through information provision and action (Palen and Liu, 2007; Palen, Anderson, Mark, Martin, Sicker, Palmer and Grunwald, 2010). However, this vision has not been realized since our long term approach lacks structure and continuity. IEM should incorporate as an essential element a citizen participation component. Despite the well-documented advantages of citizen participation, e.g. in organizing public action and improvising rescue efforts (Qu, Wu and Wang, 2009), providing practical help with temporary housing and food (Palen, Hiltz and Liu, 2007), providing eye witness accounts and images to help rescue recovery (Cowan, 2005), etc., challenges remain in integrating citizen participation into IO. The first concerns the sheer volume of information that emergency managers receive. Additionally, there are difficulties in processing information in a non-standard format from different sources and in various languages. One solution was to use a globally dispersed, virtual community of humanitarian volunteers to filter and process the information. This solved some problems but it proved difficult at a macro level to manage these communities (Koeppinghoff, 2011). There are also problems with the validity and value of the information, e.g. 80% of reports of people trapped in rubble received via SMS by rescuers from citizens in the Haiti earthquake were incorrect (Koeppinghoff, 2011). However when the information was aggregated it became useful at an area level, highlighting general search locations. In addition archiving and summarizing of information is required if we are to benefit and learn from past mistakes (Starbird and Stamberger, 2010).

TOWARDS AN INTEGRATED OPERATIONS VIEW ON EMERGENCY MANAGEMENT

The fundamental design premises that address the above shortcomings and challenges were discussed in a paper on the design of Dynamic Emergency Response Management Information Systems (DERMIS) (Turoff, Chumer, Van de Walle and Xiang, 2004). The DERMIS design premises, objectives and requirements are applicable to all types of crisis and emergency situations, whether natural, man-made, industrial or humanitarian. It is precisely the lack of situation dependency that makes an emergency response system such a powerful tool. Turoff et al. (2004) furthermore argue that any supporting databases, containing information such as the location and availability of specific resources, hazardous materials, buildings, etc, can be located anywhere. The only prerequisite is that local responders are aware of them and know how to use them if needed.

Confronted with the realities of global emergency response, emergency management stakeholders should rethink the role of IS and seriously consider an IEM approach. The design, development, use and evaluation of such systems must take a prominent place on the agenda of stakeholders worldwide (Van de Walle and Turoff, 2007). Effective IEM will require mobilizing stakeholders and resources from several locations enabled by different forms of ICT support. The challenges of virtual collaboration across geographical and organizational boundaries include developing a shared understanding of the problems, establishing effective mechanisms for communication, coordination and decision-support, and managing information (Powell, Piccoli and Ives, 2004; Dubé and Robey, 2009). The ad hoc nature of emergency management also poses challenges in building trust among participants. Whilst different stakeholders may bring relevant experience, the unique nature of emergency situations requires a different configuration of participants, many of whom have little or no history of working together. This requires 'swift starting virtual teams' (Munkvold and Zigurs, 2007), capable of immediately structuring their interaction through sharing information on the background and competence of the team members, discussing actions and deliverables, defining roles and responsibilities, and agreeing on the preferred communication media. For global IEM operations, cultural diversity (national, organizational and professional) may also represent a challenge for communication, decision-making and role understanding (Munkvold, 2006). Overall, virtual collaboration boundaries should be understood as dynamic, having different consequences in different virtual work contexts (Watson-Manheim, Chudoba and Crowston, 2012); again implying the need for a flexible collaborative IT infrastructure (Evaristo and Munkvold, 2002).

A key challenge in IO is developing functional methods for analyzing the large volume of real-time data from different sensors and process control systems. This involves providing advanced support for data management, visualization and analysis, and defining a functional collaborative work environment. Finding the optimal design of operation centers requires experiential learning. For example, ConocoPhillips, an IO pioneer, is moving away from centers which use large, shared data screens focusing common awareness, to rooms with individual work stations in smaller clusters. Similarly, IEM centers will need to be configured to support awareness and effective data processing of the data received both from rescue operations and from citizens (Palen et al., 2007).

As with research on both virtual collaboration and IO, IEM research should adopt a multi-disciplinary approach, including human computer interaction, information systems, computer science, behavioral psychology and organization science. This also implies a multi-method approach, combining case studies (Zook, Graham, Shelton and Gorman, 2010), experiments (Tyshchuk, Hui, Grabowski and Wallace, 2012), action research (Harnesk, Samuelsson and Lindström, 2009) and design-oriented research (Palen et al., 2010; Turoff et al., 2004).

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