GUEST EDITOR INTRODUCTION:
Technological Challenges in Emergency Management

IEEE Intelligent Systems, Vol. 28, No. 5, July/August 2013,
Special Issue on Emergency Management, IEEE Computer Society.

Sharad Mehrotra <sharad@ics.uci.edu>, Xiaogang Qiu <xgqiu@nudt.edu.cn>,
Zhidong Cao <zhidong.cao@ia.ac.cn>, Austin Tate <a.tate@ed.ac.uk>

Effective management of disastrous events, whether due to natural causes or man-made, is a vital challenge for modern society. Emergency management refers to all phases of disaster relief operations including planning and preparing for disasters, actions taken in the immediate aftermath of a crisis to minimize impact, and recovery actions taken to bring the societal infrastructure back to normalcy.

Each of the emergency management phases consist of a number of activities aimed at mitigating the impact of disasters to human lives and property. For instance, the response phase immediately after the event includes multiple functions such as damage assessment, response needs assessment, response prioritization, coordination and mobilization of rescue operations, resource and logistic planning, evacuation planning, situation monitoring, and timely information dissemination to citizens and organizations.

The complexity of actions taken during emergencies depend upon the severity of the crisis and the entities involved. Depending upon the magnitude and scope of the disaster, response may involve multiple levels of the government (city, county, state, federal agencies), national and international partners, public authorities, commercial entities, hospitals and health organizations, volunteer organizations, media organizations, and the public. For example, if a disaster in the Greater Los Angeles region may require coordination among the 87 cities in the LA County jurisdiction, multiple disaster management area coordinators and several public/private agencies to provide operational views for both crisis and consequence management. In a crisis, such organizations form a loosely coupled and dynamically evolving virtual organization to perform tasks such as medical triaging, evacuation, sheltering, dissemination of food, water, and other supplies to the impacted population, and inspection of damage.

Each of the emergency management tasks are, in general, information driven -- they require governmental leaders, response personnel, and other actors to interpret information and interact with one another to make rapid decisions. The quality of these decisions and the speed at which the process transitions through the phases depends upon the speed with which accurate information enters into the system. As the response proceeds and as more accurate information becomes available, new problems are identified, decisions are reassessed, and response activities may be reprioritized and sometimes even reversed.

The key operative concept in emergency management is that of **situational *awareness***, i.e. enabling awareness of the resources, incidents and needs before during and after an incident. Accurate and timely assessment of the situation can empower decision makers during a crisis to make more informed decisions, take appropriate actions, and to better manage the response process and the associated risks. Situational awareness is traditionally defined at three increasing levels of understanding: a) ***perception***, where elements of the current situation are observed, b) ***comprehension***, where information obtained through observation is combined and interpreted, and c) ***projection***, where sufficient information and understanding exists to make predictions about impending events.

Fuelled by the advances in sensing, networking, and communication, the past decade has witnessed significant advances in emergency management both from the research and practice perspective. A variety of new technologies for rapid capture of evolving situation using sensors (e.g., robotic vision systems for monitoring incident sites), localization and other personal sensing technologies to track the state of responders during rescue operations, satellite imagery for damage assessment), better tools that support seamless information flow amongst organizations for coordination and collaboration between diverse entities, improved GIS tools for evacuation modeling, web-based technologies for resource management including coordinating donations and relief operations as well as portals that support family reunification, use of social media as a major tool to disseminate emergency information and as a collaboration platform, to use of crowd sourcing for rapid interpretation of data for tasks such as damage and need assessment. These new opportunities have also created new challenges the solutions to which have the potential to bring transformational improvements to the response process. Some of these challenges include:

Diversity of information and information sources

Information relevant to decision making might be dispersed across a hierarchy of storage, communication, and processing units. While a few sensor technologies have been incorporated in field level response, the potential such technologies offer remains a futuristic goal. For instance, social media such as blogs, twitter, and information portals have emerged as the dominant communication mechanism of the society. Exploiting such input to gain awareness of the incident, how it is impacting the society, and what the emerging needs are is a critical direction for research in effective emergency management. A related challenge is to build tools and technologies to rapidly identify and find the right information.

Diversity of Information Users

Response personnel might need to share information across diverse, loosely coupled, emergent multi-organizational networks that lack centralized control in which different entities play different roles in response activities, have different needs and urgencies, different and cultures, and potentially vastly different capabilities with respect to technology utilization. Disaster response networks are characterized by heterogeneity in their network relationships (for example, direction and control versus voluntary coordination, or formal or contractual versus informal relationships) and shifting composition as new organizational entities join the network in response to changing conditions and disaster-related demand. These organizations might have policies in place regarding data sharing and collaboration. Furthermore, the networks must rapidly reconfigure (frequent structural and functional changes resulting in expansion or extensions, for example) to adapt to the changing communication and control demands present during crisis events. Finally, different people or organizations have different needs and urgency levels regarding the same information. For instance, although a field worker might require detailed information about the specific location of hazardous materials in a burning building, the monitoring and response team at a nearby command center might only need to know how many hazardous-material locations exist in a catastrophe’s vicinity.

State of the Infrastructure

Driven by factors such as economics, communities usually designs and deploys IT and communication infrastructures for expected usage scenarios and not necessarily for extreme situations. During a crisis, the very infrastructure that we expect to serve as an enabling technology for effective and timely response might itself be prone to failures and vulnerable to malicious attacks. Dependence on IT might thus introduce new additional vulnerabilities to an already fragile process. For example, if emergency organizations start depending solely on technologies such as reverse 911 (a communication solution that combines databases and GIS mapping to deliver outbound notifications to targeted geographical areas via voice and text messages) to communicate alerts and evacuation plans with the public (instead of exploiting citizen networks as is done currently), telephony's failure under extreme loads could have devastating consequences. The challenge is to design IT solutions that are robust and predictable even in extreme situations but that aren't cost-prohibitive at the same time.

About This Issue

Creating the next generation of emergency management technologies requires a variety of innovations in intelligent system technologies ranging from new models for data fusion, semantic understanding of data, modeling emergent events and actions in the environment, HCI, group behavior and dynamics, "big-data" analytics, social media analytics, scenario-based adaptive decision making, to multi-objective resource allocation. Intelligent Systems to support emergency management is a broad topic, and no single special issue can do justice to all aspects of the evolving technologies. In this issue, we focus on opportunities and technologies to leverage new types of data and knowledge representation frameworks for emergency management.

In the paper entitled "Using Shared Procedural Knowledge for Virtual Collaboration Support in Emergency Management" Wickler, Tate, and Hansberger propose a collaborative knowledge creation and representation framework based on artificial intelligence plan representations and built using MediaWiki, the open source and scalable collaborative document editing facility that powers Wikipedia. The framework represents procedural knowledge in a wiki using an informal textual description marked up with formal tags based on a hierarchical task network used for AI planning. The tool can significantly reduce procedural uncertainty by making procedural knowledge explicitly available during disaster events in a familiar form via a Wiki.

In the paper entitled "Heterogeneous and Stochastic Agent-based models for Characteristic Analysis for Super Spreaders in Infectious Diseases" Duan, Cao, Cui, Zheng, and Qiu develop stochastic agent-based models to explore the spread of super spreaders – a small number of individuals who account for a large part of the population to be infected. Identifying super spreaders has clear implications to preventing disease outbreak. The authors built an agent society including models of severe acute respiratory syndrome epidemic progress, human contact patterns, weighted scale-free networks, and infection probabilities and through computational experiments find some key factors that makes individuals super spreaders – these factors include long delayed admission time, active contact patterns, and high pathogen load and shedding rates.

In the paper entitled "Large Scale Auto-GPS Analysis for Discerning Behavior Change During Crisis", Horanont, Witayangkurn1, Sekimoto and Shibasaki analyze human mobility and behavior during large scale crisis using mobility data acquired from over a million users. This research has implications to understanding how humans react to catastrophic situations revealing new avenues of research in crisis management.

In the paper entitled "An Intelligent System for Large-scale Disaster Behavior Analysis and Reasoning", Song, Zhang, Sekimoto, Horanont, Ueyama and Shibasaki introduce an intelligent system, Disaster Behavior Analysis and Probabilistic Reasoning System (DBAPRS), for analyzing and simulating of human evacuation behaviors during large-scale disasters.DBAPRS stores and manages daily GPS records from mobile devices used by over one million individuals. By mining the large dataset of Auto-GPS mobile sensor data, DBAPRS is able to automatically discover and analyze the short-term and long-term evacuation behaviors of people during large-scale disasters. Especially, DBAPRS is able to simulate or predict population mobility in various cities impacted by the disasters. DBAPRS has been successfully applied to the 2011 Great East Japan Earthquake and the Fukushima nuclear plant accident.

Formatted: No widow/orphan control, Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers

The guest editors hope you find the papers in this special issue of Intelligent Systems to be a useful introduction to ongoing work in the important application area of Emergency Management.