AGENT-BASED SYSTEMS FOR DISASTER MANAGEMENT

BY FRANK FIEDRICH AND PAUL BURGHARDT

In recent years agent technology has been successfully applied to many different domains such as e-commerce, control systems, and information gathering and management. Because this technology features the use of artificial intelligence to coordinate collaborative behavior in distributed systems, it supplies a powerful basis for proactive applications in complex organizations. Efficiently responding to large-scale disasters requires many complex tasks to be performed by multiple actors under extreme time and resource constraints. We expect that the application of agent technology can support more timely and enhanced data acquisition, information production, decision support, and action coordination.

Applications of agent technology—agent-based systems—can be used to support many processes throughout the phases of the disaster management cycle from mitigation and preparation to actual response and recovery. Currently, we distinguish two major research areas: agent-based simulation systems, which allow the creation of realistic post-disaster environments, and agent-based decision support systems to support disaster managers on various levels.

Agent-based simulation systems are generally used to model human and systems behavior during or after disaster events. By including up to millions of agents it is possible to analyze complex disaster scenarios and test various response strategies. Agents in this type of system do not provide active decision support, but—although calibration and validation of the behavioral models is difficult—these systems may be used to better understand the dynamics of disasters and may also be included in computer-based training programs. Current research includes, among other areas, post-earthquake rescue simulation, evacuation planning, or spread of infectious diseases.

During disaster response agent-based systems are envisioned to support emergency managers by helping to maintain common situational awareness and by aiding the planning and coordination of response activities. Agent technology may provide benefits to a number of important system requirements for future disaster management applications. Relevant agent characteristics include:

- Capability to act in dynamic environments as well as distributed and decentralized networks;
- Ability to support all relevant levels of information management: information gathering, verification, processing, analysis, interpreta-

tion, and action planning;
- Distributed decision making through multi-agent communication and collaboration mechanisms;
- Possibility to integrate human-like decision making strategies, such as the Belief-Desire-Intention (BDI) or Recognition-Primed-Decision (RPD) model;
- Use of advanced optimization algorithms, such as constraint programming or ant algorithms;
- Use of adjustable autonomy for human-computer-interaction, where the degree of agent autonomy can be adjusted to different task levels; and
- Possibility to integrate trust-based collaboration mechanisms.

Another important advantage is that agents may also be used to create combined systems of systems that integrate legacy information systems, mobile communication devices, sensor networks, human decision makers, or agent-based simulations. Used in this manner, agents are a way to implement a network-centric approach to emergency management. Examples of recent or ongoing research projects include Robocup Rescue [3], Combined Systems [5], Aladdin [2], EQ-Rescue [1], or FireGrid/I-Rescue [4]. The common characteristic of these research projects is their focus on crossing the boundary between generic research on agents and possible applications in the domain of disaster management. For example, within the Combined Systems project at DECIS lab (www.combinedsystems.nl) demonstrators were built for agent-based models for medical response planning and self-evacuation of buildings as well as for distributed perception networks that may be used for environmental and industrial alert systems.

Despite these promising research projects there are hardly any agent systems used in disaster management practice. We believe in the next few years major opportunities lie in planning and training applications that use agent-based simulation systems. Virtual reality systems on top of these simulations will allow improved training through 'serious gaming'. In the short term, intelligent planning agents will mainly be used in those simulated environments. The implementation of more sophisticated agent technology will take longer, but basic applications for specific tasks can be used to incrementally improve current support tools. For advanced systems to succeed, a better understanding of disaster management principles and cognitive processes of disaster managers is essential. Challenges for agent-related research are manifold. They include, for example, the development of comprehensive disaster-related ontologies, which allow the development of agent-based collaboration mechanisms across organizational boundaries, and the development of agent models with improvising capabilities to create or adjust plans on the fly.

The question is often raised whether it is realistic at all to expect agent-based systems to be of use for disaster management. In the past, technological solutions often failed because they did not take into account realities of emergency management decision making and inter-/intra-organizational management practices. While we fully agree that many improvements can be achieved by means of organizational change, we also expect that well-organized disaster response organizations can enhance their performance by making use of agent-based systems in specific areas where information fusion and action coordination can become complex. To identify and develop these areas, we advocate that concurrent work is to be done that fosters both organizational change and technological innovation. Projects combining both perspectives will contribute to establishing credibility for agent-based decision support systems. C

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