Towards a Context-Aware Multi-Party Emergency Coordination System Framework

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ABSTRACT

A framework for an emergency response system is proposed which is an extension of, but significantly different from, traditional group and distributed group support systems. The framework considers the environmental, organizational, and activity-based issues of emergency response for responders and decision makers. These issues are addressed by incorporating context-aware, multi-agency relationship management, and multiparty coordination components into the framework for a context-aware multiparty coordination system.

Keywords

Context-aware, multiparty coordination, emergency response.

INTRODUCTION

The contextual conditions for a major crisis are different from traditional business crises that organizations manage. The differences make emergency management much more difficult to plan for, places different stresses on decision makers, and requires different tools to aid in the response.

Traditionally many of the information system tools used in emergency response can be categorized as group decision support systems (GDSS) or distributed group support systems (DGSS). GDSS was originally defined as a system that combines communication, computer, and decision technologies to support problem formulation and solution in group meetings. GDSS aims to improve the process of group decision making by removing common communication barriers, providing techniques for structuring decision analysis, and systematically directing the pattern, timing, or content of discussion (DeSanctis and Gallupe, 1987). DGSS combines GDSS and computer mediated communication systems (CMCS) to facilitate group decision support from participants in different locations (Turoff et. al. 1993).

This study attempts to enhance the current understanding of emergency response systems by proposing a framework for a context-aware multi-party coordination system (CAMPCS) which is quite different from GDSS and DGSS. Using government reports, quick response reports, NGO reports, and other academic journals addressing major disasters, components contributing to the design and use of a CAMPCS are identified to address issues arising in disaster response. The components are then organized into a framework which consists of three key categories: i) context-awareness components to deal with environmental issues; ii) multi-agency components to deal with organizational issues; and iii) coordination components to deal with operational issues.

HOW GDSS/DGSS AND CAMPCS DIFFER

The proposed CAMPCS is significantly different from traditional GDSS and DGSS in terms of the objectives, users, decision contexts, and working environment (Table 1).

	GDSS/DGSS	**CAMPCS**
Objective	Support group decision making	Support multiparty coordination
Users	Predetermined group	Large scale multiparty participation
Decision Context	Well defined	Uncertain, dynamic, and urgent
Working environment	In an office setting	Mobile environment

Table 1. Summary of the differences between GDSS/DGSS and CAMPCS.

Objective: Group Decision Support vs. Multi-party Coordination

The main objective of GDSS is to improve the process and the outcome of group decision making. GDSS helps group members resolve conflicts and reach mutual agreement. The implementation of the decision is usually not the focus. The main objective of CAMPCS is to support multiparty coordination. Coordination is defined as managing dependencies between activities (Malone and Crowston, 1994). Since activities must, in some sense, be performed by "actors," the definition implies that all instances of coordination include actors performing activities that are interdependent. Although multiparty coordination may also involve group decision making and negotiation, it emphasizes the management of tasks and activities performed by the joint effort of multi-parties, such as communication, resource allocation, scheduling, job dispatching, etc. In other words, GDSS is decision oriented and CAMPCS is action oriented.

Users: Predefined Group vs. Ad-hoc Multiple Party Participation

The users of a GDSS may be a group within an organization or from different organizations. The roles and the relationships of the group members are usually well defined. For emergency response, the participants may be from different authorities, professions, and regions. For instance, earthquake rescue may involve firefighters, police, medical teams, and volunteers locally or internationally. They come together on an ad-hoc basis and identifying their roles and relationships becomes one of the major tasks.

Decision Context: Given vs. Dynamic

The decision context for GDSS is often given and well defined. The focus of the group decision makers is on how to reach a better decision. The decision context for CAMPCS is dynamic with great uncertainty and urgency. In a disaster scenario, things change rapidly and decisions must be made immediately. Collecting context information and taking quick corresponding action is critical for saving human life and reducing property damages. Context-awareness becomes an important component of CAMPCS.

Working environment: Fixed Office Setting vs. Anytime Anywhere on the Move

The working environment for GDSS is mainly in a meeting room equipped by computers connected through fixed-line communication networks. For DGSS there may be several geographically different locations but the individual locations still generally rely on fixed-line communication networks and are not mobile. The working environment for CAMPCS in emergency response can be for anyone at anytime anywhere.

Emergency responders have to work on a disaster frontline. Emergency command centers may be temporally established on the frontline of the disaster scene even without a camp. With the possible and frequently severe damage of communication infrastructure during a disaster, mobile communication is usually the method used to communicate amongst responders and decision makers. Mobile communication is relatively easy to install and mobile devices are most likely used by rescuers.

EMERGENCY COORDINATION SYSTEM FRAMEWORK

The proposed framework addresses three main issues that are frequently discussed in emergency response literature. These issues are identified as environmental issues, activity-based issues, and multi-agency issues influencing emergency response coordination. These issues are all distinct but interdependent and influence the overall emergency response process.

Environmental issues related to the situation of a disaster will influence the agencies that need to respond to a disaster along with what and how tasks will be performed to address the disaster. Similarly, activity-based issues surrounding the tasks to be performed will be dependent on the operating environment of responders as well as the agencies available to provide the tasks as agencies frequently have different roles performing different tasks. Finally, different agencies will need to work together in order to address complex environmental conditions and provide all the resources necessary to complete required response tasks.

Disasters often develop rapidly with great uncertainty making it essential to collect situational information in order to take quick and appropriate action. Context-aware computing is a response component to be used to manage this environment awareness issue by providing better aggregated, filtered, and processed information to decision makers.

In addition to understanding the environment, emergency response often requires the temporary participation of multiple parties with different professions, from different regions, and belonging to different authorities. It is important to make sure they can work together and appropriately handle their work relationships. The multi-party component of the framework is therefore used to deal with multi-agency organizational issues.

Lastly, emergency response needs to organize multiple interrelated tasks in order to respond to a variety of events. Task execution may require resource sharing and activity coordination. The coordination component of the framework addresses the activity-based issues.

Context-Awareness and Environmental Issues

Environmental conditions may be referred to as context. A general definition of context for an information system provided by Dey et al. (2001) is stated as "any information used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, computational and physical objects."

In an emergency response setting, context is much more complex as it can be applied to a much broader range of people, places, and things with greater uncertainty and difficulty to assess. Context information for an emergent event can include the nature of an event (i.e., earthquake, tsunami, explosion, etc.), its location, its magnitude or severity of impact, when it occurred, its immediate impact, the potential affected population, the potential affected area, the speed of onset, the duration of effect, and potential triggered secondary events.

Decision makers, responders, and citizens may also have context information associated with them such as where they are, what their role is, what tasks they are performing, what equipment or resources they require, what resources or equipment they are using, when they started their activity, when their status will change, who they are working with, and more. Higher level contexts may include knowledge of where rescuers are in relation to other rescuers, resources, equipment, or security which could provide support if needed, and how long it will take to receive additional support. Information on proximity to victim locations, or search areas to find victims may also be important to rescuers. For victims, context information may include where they are, their health and physiological status, their mobility status, how long they've needed assistance for, or even where they are relative to a physical threat, a safe place, or a search and rescue responder. For decision makers, context information may include what organizations are available to assist, what roles organizations will perform, how to communicate with organizations, what resources are on hand, what resources are required, where are resources deployed, and how resources will get to where they are needed,

In context-aware computing, context-awareness is defined as the set of environmental states and settings that determines an application's behavior (active context) or characterizes the conditions in which an application event occurs (passive context) (Chen and Kotz, 2000). The general components of context-aware systems include information gathering, information aggregation, information interpretation, and automated response. Information gathering is the collection of contextual data from various monitoring systems and call centers. There is a great effort to add monitoring systems to aid in gathering emergency contextual data such as earthquake monitoring systems, sea-level monitoring systems, satellite observation systems, and weather monitoring and forecasting systems. Public reporting to emergency call-centers is also a major source of environmental data. The next function is the aggregation of the information from different sources and organizing and integrating it into a structured data management system. The information can then be used for modeling and interpretation by experts or expert systems. The interpreted results may be used directly by decision makers to plan a response to an emergency. However, with context-aware computing the interpreted results may trigger services or actions such as notification of key personnel, an automated response such as alarms or engagement of backup systems, or the results may be used to respond to information requests.

Using context-aware technology can aid in the collection and aggregation of sensory environmental data in several dimensions to provide passive context information to emergency responders. Use of this data can also be combined with real experts or expert systems to better identify the nature and scope of a disaster to interpret more appropriate responses. The context information can also be used to trigger an appropriate action for an active-context application such as notification of environmental changes, or availability of resources.

Multiple Agencies and Organizational Issues

Disaster response often requires multiparty participation from different professions, specialties, regions, and authorities. Some parties may have previous working relationships but many of them may not. Emergency response is often a dynamic response that may lead to the formation of ad hoc relationships. Organizations with

established relationships have the familiarity with each others' policies and procedures making interdependency more routine. Organizations drawn together for the first time may need to establish coordination relationships to overcome an obstacle or achieve a common goal.

Furthermore, each group of responders have their own responsibilities to consider based on their training, area of expertise, knowledge, tasks, and organizational contexts. These differences can also include legislated requirements on information sharing policy, processes to follow, and communication hierarchies which influence or mandate how these responders operate. As a result, the same emergency can generate multiple requests for assistance from different agencies using different contextual data.

The nature of coordination also depends on how agencies and individuals are able to connect with one another, overcome conflict, and share information or resources. Interoperability is the term used to describe the interaction between multiple agencies. Interoperability is the process of maximizing opportunities for the exchange and re-use of information, whether internally or externally, through the management of systems, procedures and the culture of an organization (Miller, 2000). Technical or hard interoperability, the most commonly discussed form of interoperability, relies on technological factors such as hardware, communication protocols, storage, etc. for the exchange of information. Soft interoperability relies on factors such as semantic, human/political, inter-community, legal, and international operability. Unfamiliar organizations, in addition to making contact, will need to quickly establish connections with key personnel in order to share information and resources. These new connections are likely to be subject to a lack of trust and other behavioural issues impacting the relationship that established communication channels should have already resolved.

CAMPCS would clarify the roles, responsibilities, authorities, and information exchange privileges amongst agencies. The roles describe what role an agency plays in the emergency response while responsibilities describes the tasks the agency is responsible for executing. The system would also identify established authority relationships such as the command and reporting structure for the emergency. Lastly, the system would establish information exchange channels and privileges dictating what information should be exchanged with whom through which channel or contacts. This system would be dynamically maintained in order to reflect the changes in the emergency situation and responding agencies. This system helps address multi-agency relationship management issues which helps add control and order to potentially chaotic multi-agency environments.

Operation Coordination and Activity-Based Issues

Coordination is the last of the key components to discuss. Coordination (consisting of goals, activities, actors, and interdependencies) can be defined as the management of interdependencies between activities to achieve a goal (Malone and Crowston, 1994). Coordination has also been described as the fundamental task of the firm in order to maximize the efficiency gains from specialization (Grant, 1996). Transferring knowledge is not as efficient as integrating knowledge, therefore coordination becomes the priority. In a multi-agency emergency response setting, coordination is the process of getting multiple parties sharing multiple resources to complete multiple tasks. Coordination can be actor-actor based, actor-activity based, or activity-activity based depending on the type of coordination process, with non-human resources intrinsic to all the forms of coordination (Shen and Shaw, 2004).

Coordination in emergency response is necessary to share important contextual information about environment conditions, command and control structure, resource availability, process workflows, and task arrangements. Coordination is then used to assign tasks, allocate resources, and execute a plan.

Challenges with coordination begin with different responders having their own specialties and their own methods of conducting business. The ability to share information, request information, and coordinate activities relies on the ability of responder agencies to work within their own organizational contexts and interface with other agencies.

In many circumstances collaboration is minimised at an accident scene due to uncertainty, asymmetry of information, and lack of incentives (Berlin and Carlström, 2011). Coordination is also a challenge due to hard or technical interoperability issues. Emergency management and communication systems currently in place in most responder organizations are mainly targeted for individual agencies. While effective for single agencies, there is opportunity to extend these systems to support multiple agencies.

To understand the role of a CAMPCS for coordination in crisis response it is important to understand the crisis response process. First and foremost is an emergency event that occurs. This emergency event provides the awareness trigger to begin collecting and disseminating contextual information to responders regardless of the source. A context-aware coordination system can measure, accumulate, and filter contextual data before

notifying key personnel of an emergency and sharing relevant information with key responder personnel. Responders to the scene can then gather additional context information and begin to identify the tasks that need to be performed in order to respond to the emergency. The determination of the tasks leads to the determination of the required resources and agencies to successfully respond to the scene. Resources may include equipment, personnel, or other miscellaneous requirements from within single or multiple agencies. This is another opportunity for context-aware systems to provide resource availability data to key personnel. This resource availability information does not need to be restricted to a single agency, but can incorporate information from other agencies across organizational boundaries with agencies willing to build connections pre-disaster or during the disaster. An assessment of required resources can also be used to identify key contacts and share contextual information with new agencies that may be sought to assist in the response effort. Once resources have been requested, a plan for response is formulated based on the tasks to be completed, the resources available, and the interdependencies amongst multiple responder agencies. The tasks may be performed through workflow coordination activities. Context-aware computing can aid in the connection of agencies, sharing of resources, and sharing of incident information such as the command and control structure and responder roles such that situational awareness is shared amongst agencies and interdependencies are known. During the task execution unexpected situations may occur. This may trigger requests for modification of existing tasks, or requests for new tasks. Completed tasks need to be reported back to commanders for monitoring purposes and to free up resources. This response process flow is repeated until all identified tasks are completed, the emergency is over, or the response is abandoned. This coordination process involves information gathering, decision making, as well as the execution of processes which is different from previous studies focusing on decision making only.

CONCLUSION

A context-aware multi-party coordination system is the type of tool that can enable more efficient multi-agency coordination and facilitate resource acquisition and assignment to improve an emergency response for the benefit of society. An emergency coordination response system that takes context-aware computing components, multi-agency components, and task-based coordination components into account should be able to address the major issues of environmental, organizational, and activity-based factors affecting an emergency response. By integrating these components into one system it is possible to design a comprehensive supporting information system.

This study is leading to the creation of a framework without architecting a solution. Future research direction will include providing a validation of the proposed framework, architecting a system based on the framework, and developing a prototype system for further evaluating the effectiveness of the proposed CAMPCS.

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