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Coordination of Converging Construction Equipment in Disaster Response

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Abstract

During disaster response, it is imperative to timely provide the rescuers with the adequate equipment to facilitate lifesaving operations. However, in the case of the 9-11 terrorist attacks for example, supply of high demand equipment was insufficient during the initial phase of disaster response, challenging lifesaving operations. Prioritization of limited resources is one of the greatest challenges in decision making. Meanwhile, management of geographically distributed resources has been recognized as one of the most important but difficult tasks in large scale disasters. Additionally, resource outside of the disaster affected zone converges into the disaster affected area to assist the response efforts, which is the effect of resource convergence that often made the already complex task of resource coordination even more challenging. Although there are difficulties on managing the converging volunteers and groups, such as the ability to be deployed immediately to the incidents without their appropriate skills and training, construction equipment and its professional operators are specialized entities. The effectiveness of their collaboration in the disaster response operations could be improved through regular participation in drills. As a result, the convergence of construction equipment could be efficiently utilized to facilitate Urban Search and Rescue (US&R). This paper proposes a mobile application that could potentially guide and coordinate the volunteering construction equipment in collaboration with the emergency command and control structure.

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Introduction

Distribution of resources, such as heavy construction equipment, is critical to efficient and effective urban search and rescue (US&R) operations during disaster response. It is imperative to timely provide the rescuers with the adequate equipment to facilitate lifesaving operations (Sullum et al., 2005; McGuigan, 2002). However, management of geographically distributed resources has been recognized as one of the most important but challenging tasks in disaster response (Holguin-Veras et al., 2007; Halton, 2006). Challenges include identification, assignment, location tracking and delivery of resources (SBC, 2006; 9/11 Commission Report, 2004). For disaster response efforts to become more effective, these challenges must be addressed.

During disaster response, search and rescue task forces would need to gain situational awareness of the disaster, activate required resources and capabilities, and to coordinate the response actions (DHS 2008). These steps form a loop to continually gain and maintain the status of the disaster, activate and deploy resources, and to coordinate response actions for an efficient and effective disaster response.

Coordination of resources during disaster response operations has been characterized by various shortcomings that inhibit efficient and effective decision making, and prioritization of limited resources is one of the greatest challenges (SBC, 2006; 9/11 Commission Report, 2004; Auf der Heide, 1989). Limited resources must be distributed efficiently to the first responders to facilitate lifesaving operations. However, the supply of resources such as construction equipment is usually unable to meet the great demand in large scale incidents. This could result in additional casualties (Gentes, 2006; Bissell et al., 2004). As a result, an efficient prioritization and distribution of resources is critical to disaster response efforts.

Motivation

In response to disasters, the initial efforts including US&R are usually and mostly carried out by civilians, which are within the area at the time when the disaster occur (Drabek and McEntire, 2003; Auf der Heide, 1989). These individuals collect relief supplies, provide shelter, and are engaged in a variety of services (Drabek and McEntire, 2003; Wenger, 1992). At the same time, the establishment of the official command and control by the Emergency Management Agencies (EMAs) from the local, state and federal usually takes time, to coordinate task forces and assets to respond to the disaster (Drabek and McEntire, Auf der Heide, 1989). Meanwhile, volunteers and response organizations outside of the disaster affected zone converges into the area to assist the response efforts. This is the effect of resource convergence that often made the already complex problem of resource coordination even more challenging (Drabek and McEntire, 2003; Fritz and Mathewson, 1957). For incidence, this causes on-site congestion from volunteers, material, and equipment that hinders an efficient logistical coordination (Drabek and McEntire, 2003; Kendra and Wachtendorf, 2001). However, provided with the convergence of resources, such as volunteers, equipment and organizations, the response to the incident could become more efficient and effective (Drabek and McEntire, 2003; Mileti, 1989; Auf der Heide, 1989). In the rapidly changing environments of disasters, the convergence

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could bring certain capabilities and flexibilities that do not exist or is not sufficient in the response system (Kendra and Wachtendorf, 2001). How to properly manage the converging resources is then the challenge to be addressed.

One of the greatest challenges of utilizing the converging resources is their ability to be deployed immediately to the incidents without the appropriate and required skills, training and the familiarity to the command and control structure and EMAs (Kendra and Wachtendorf, 2001). In addition, Kendra and Wachtendorf (2001) pointed out that to have an efficient and effective disaster response, it is vital to develop, maintain and take action based on a "Shared Vision" of emergency goals, critical tasks and their need of critical resources. It is difficult to have civilian volunteers obtain such Shared Vision without any prior training and communication with the EMAs.

As types, magnitude and context of disasters vary, the mitigation actions usually need creativity and require responders to improvise to better respond to the incident (Auf der Heide, 1989). However, the official centralized command and control system makes logistics coordination difficult, as it is static and inflexible (Neal and Philips, 1995). The command and control structure is established to coordinate the response efforts and resources of the local, state and federal government, private sector and NGOs (NRF, 2008). The general outline from bottom up is as follows, although it may vary from jurisdiction to jurisdiction: 1) first response teams on site request for resources; 2) the Incident Command Post (ICP) which manages and coordinates several aggregated incidents, such as several collapsed and partially collapsed buildings in the area, provides the resource for the first responders with the resources in their jurisdiction; 3) the county level Emergency Operations Center (EOC) provides resources to multiple ICPs, and establishes priorities for the distribution of resources among the various incidents; 4) a State level EOC is activated if the incident exceeds the response capacity of the County, with the primary role of supporting the local government in responding to the incidents and coordinating resources within the state; and 5) if the incident exceeds the local and state response capacity, the federal government involves its agencies to organize a federal response and coordinates with the states and response partners to mobilize more resources. To accomplish those efforts, the private sector and NGOs coordinate and support response actions of the governments. However, this approach inherits various challenges that inhibit an efficient utilization of available response resources.

During the initial phase of disaster response, access to heavy equipment is critical to the relief efforts (Gentes, 2006; SBC, 2006; Kevany, 2005; Bissell et al., 2004). Heavy equipment is a necessity during response operations such as 1) rapid debris clearance of the transportation network for first response teams to reach blocked hazard zones, 2) careful lifting of damaged structural elements in conditions when human power is not sufficient, and 3) selected debris removal to clear structural materials to facilitate void searches and tunneling under collapsed buildings (ELANSO, 2009). In destructive events, the best timing of saving victims is within the first 24 hours right after the impact of the disaster (Mizuno, 2001). However, in major disasters, supply of heavy construction equipment for rapid removal of collapsed building sections are often not able to meet the massive demand. In the Loma Prieta Earthquake, there were also challenges faced in the early US&R due to

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the lack of available heavy equipment (McGuigan, 2002). Heavy equipment, which supports critical lifesaving activities, must be efficiently located, assigned and distributed to meet the urgent demands in US&R.

Objective

How response units perceive information to make decisions is critical. When disasters occur, information needed is not always available. Before the Haiti Earthquake for instance, there is little information regarding the road network and the spatial entities on existing digital maps. After the earthquake, this lack of information hindered the response operations. However, volunteers in Port-au-Prince filled in cartographic blanks in the maps which became very detailed and were accessible to the public online (OpenStreetMap, 2010). It is also important to emphasize that initial information collected about the disaster is often inaccurate (Quarantelli, 1983). For this reason, assessment of resource needs has to be a recurring procedure that continues throughout the duration of the incident, to update information for all entities involved within the disaster response operations (Auf der Heide, 1989). In the case of Haiti, the volunteers used text messages, GPS, and hand drawings to dispatch thousands of updates for road names, building collapse, and injury locations (OpenStreetMap, 2010; Ushahidi, 2010). The officials used the information to guide their emergency workers, including the Marine Corps and Red Cross (Ushahidi, 2010). Although there are drawbacks in this approach of information update, the benefits outweighed in the case of Haiti (OpenStreetMap, 2010; Ushahidi, 2010).

The objective of this paper is to implement a mobile application for responding equipment to communicate with a public web service that is capable of receiving and storing information discovered and updated by civilians and first responders. The mobile application could be potentially used by officials in the command and control system and volunteering personal, equipment and materials.

Approach

A decentralized approach that facilitates immediate equipment distribution in response to disasters is proposed by Chen and Peña-Mora (2011). An Equipment Control Structure, which is inspired by the behavior control structure of honeybees' foraging (Biesmeijer and Seeley, 2005), enables a collective decision making process for equipment coordination. With the Equipment Control Structure applied to facilities management such as construction equipment distribution, disaster response operations have the potential to become more efficient. Each volunteering Equipment Unit will make its own decision on where it will carry out the disaster relief effort.

Based on the decentralized approach the authors proposed for the converging resources (Chen and Peña-Mora, 2011), the mobile application –proposed by this paper– could automate information gathering and decision making for an Equipment Unit. An Equipment Unit is assumed to be a complete crew formed by the equipment, the operator and the required labor and material.

Information Technology approaches have great potential to make equipment coordination more efficient. GIS analysis and visualization with GPS tracking could provide to the authorities an overall view of how all the equipment move and

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distribute in the disaster affected areas. The aforementioned decentralized process could be implemented to automate decision making for each Equipment Unit through a software agent (Fiedrich and Burghardt, 2007) that processes the computation in the background and suggests further steps to Equipment Units. The agent could be deployed on a smart phone, PDA or a portable computer with GIS/GPS for visualization and tracking (Figure 1d).

The authors' former work on damage assessment and GIS visualization (Peña-Mora et al., 2010) has great potential to support and be integrated with this research. Damage information in US&R including hazards, structural damage, and trapped victims could be collected by the Building Assessment System (Figure 1a), which is developed based on standard building assessment procedures used by US&R structural specialists (Peña-Mora et al., 2010; USACE, 2008). Assessment information is stored in the digital format. Each ICP could use the collected digital information to cluster all demand in its jurisdiction (Figure 1b). The EOC could host a data server, to serve as the Dance Floor (Chen and Peña-Mora, 2011), to broadcast resource demand (Figure 1c). Equipment Units could use digital devices to access demand information and the software agent installed would suggest which ICP the unit should be deployed and provide route guidance (Figure 1d). In Figure 1b, the red diamond markers overlaid on the map are the ICPs within the disaster affect zone. The blue circles are available Equipment Units and the green triangle is the EOC.

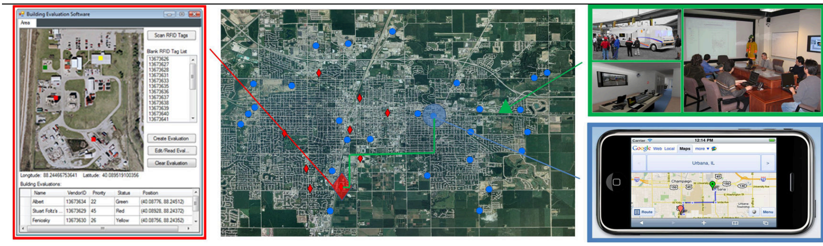

Figure 1 a) User interface of BAS (left); b) Spatial Visualization of the Damaged Zone (center); 3) EOC and data server (top right); and d) Digital device, e.g. an iPhone, for each equipment unit (bottom right).

For volunteering Equipment Units, a public web service could provide the converging resources a source of information as to guide where the resources should converge. The web service takes discovered or updated demand information into its database and provides access to the public.

When a person in the disaster affected area discovers a location where there are victims that need help, for example victims are trapped under collapsed structural elements, the person discovered the situation could send this piece of information to the web server through a handheld device with network capability such as a personal device assistance (PDA), a smart phone, or a touchpad device. The information uploaded by the person and all other information provided by other people could be seen through a webpage. As a result, the webpage could serve as an information hub for unassigned disaster response resources, such as Equipment Units. This way the

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productivity of the unassigned resources could greatly increase, avoiding unnecessary idle due to the overload of the official command and control system.

There are certain assumptions for this to work. We assume that there will be access to computer networks such as a wireless 3G network. In cases if infrastructure-based networks are not presented, an ad hoc network approach could be taken (Peña-Mora et al., 2010). We also assume there will not be malicious injections of information into the web service. In addition, for this web service to be worth using, the situation of the disaster response scenario is assumed to be in the condition when the official command and control system is saturated. In other words, the command and control system is overloaded by the massive tasks to be carried out, such as US&R, resource activation, assignment and coordination.

The implementation of the web service is as follows. MySQL is chosen as the database. The database holds information such as the entry key/id, the timestamp of when the piece of information is received, the latitude and longitude coordinates of the location, a photograph of the situation, potential number of victims, the condition/severity of the victims, and textual comments. The web interface is written in PHP for its easy access to databases and the ability to program logic in HTML web pages. Google Maps V3 API is used to display spatial information. The web service is programmed to automatically annotate the reported victim location with the photograph taken and the textual information.

The result of the civilians reporting of equipment demand could be viewed via the server through an internet browser (Figure 2). People who are interested in helping the disaster relieve efforts could visit the web service and see where help is needed.

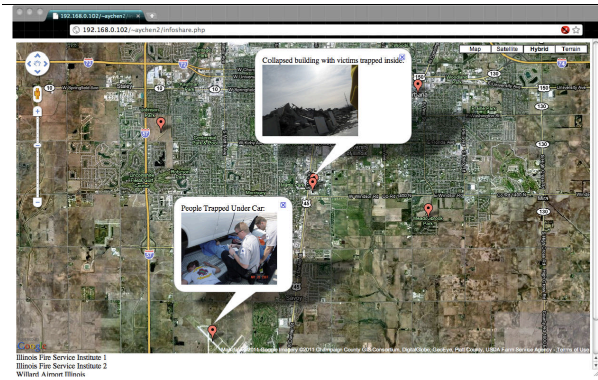

Figure 2

Conclusion and Future Work

In this paper, a mobile device is expected to facilitate coordination of Equipment Units. Through mobile devices, Equipment Units connect to a web service that takes information from users who discover equipment demand on the disaster affected area and publishes the information on a map is presented. The web service provides

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Equipment Units the necessary information for the decentralized decision making proposed by the authors (Chen and Peña-Mora, 2011). Mobile devices take the information and automate decision making for the Equipment Units.

Although this approach of equipment distribution could result in non-optimal assignment and arrangement of equipment utilization, it is under the assumption that the official command and control system is overloaded. As a result, this web service could potentially be used to guide construction equipment to respond to demands in the early phase of disaster.

Future work would be to further implement algorithms into this process. In a large scale setting when the official command and control system is overloaded, demand for equipment could be in a great number. As a result, clustering of discovered demands needs to be performed on the server side, to avoid overloading information to the Equipment Units. In addition, an algorithm to rank demand locations for a Equipment Unit based on the number of demand, spatial attributes, severity of demand and the capacity of the piece of equipment could be highly useful to help decision making of the crew.

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A Management System of Roadside Trees Using RFID and Ontology

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ABSTRACT

As roadside trees are important asset of road infrastructure, standardized inspection and diagnosis guidelines and records have been proposed in Japan. However, the ledgers and records are usually paper-based and the database, if employed, is often weak and poor. Thus, the recorded data has not been used for maintenance, remedy, and renewal of roadside trees effectively by road administrators. Furthermore, each governmental or municipal agency has its own ledger or database, they use different terminologies, units, tree registration systems so that it is very difficult to compare or combine two or more roadside ledgers or databases. Therefore, in this research, a roadside tree diagnosis system is being developed using Radio Frequency Identification (RFID) and Personal Digital Assistants (PDA) in order to facilitate inspection and diagnosis. In addition, the ontology of roadside tree management is being developed in order to compare and analyze various roadside tree databases. The prototype systems will be applied to real roadside trees and the proposed methodology will be validated.

INTRODUCTION

Since planting trees has various effects such as carbon dioxide fixation, mitigation of heat island phenomenon, reduction of air pollution, scenery enhancement, effect of relaxation, ecosystem maintenance, etc, afforestation in urban area is a very important action as an environmental program. Roadside trees are an essential part of urban plants and their effects include not only the ones stated above but also road safety, disaster mitigation, leafy shade forming. The number of high roadside trees in Japan increased from 3.7 million in 1987 to 6.7 million in 2007, which implies the increase of social demand and importance of roadside trees. On the other hand, roadside trees are surrounded by objects causing growth inhibition such

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