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Using Augmented Reality to Support Coordination and Communication in Disaster Response

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Abstract

In disaster response, there involves a large volume of coordination and communication information being transferred among diverse rescuing groups. There is a need for such information to be aggregated, presented, and assessed in an effective manner. Augmented Reality (AR) could visualize invisible disaster-relevant information such as deformed structure and injured humans buried underneath debris within the real disaster area. Furthermore, AR could mediate human-human communications because the proper blending of the real rescue task and virtual information can be tailored to enhance group-oriented communication and critical decision-making processes. This paper presents a framework that incorporates AR technology to facilitate effective coordination and communication of critical information among diverse rescuing groups by improving their situational awareness. Three focus areas — the command hierarchy, communication protocols, and communication interference — are identified and incorporated into the framework after analyzing typical disaster response procedure. Properties that the physical/technological implementation of the AR system would need to possess are also identified, so as to tailor the framework to be suitable for use for the majority of conceivable disasters.

Keywords

Augmented Reality, wearable computers, disater response, coordination and communication

1. Introduction

In the wake of the 911 terrorist attacks, urban and metropolitan area security has become increasingly important. Apart from the toll on individual cost/human life and suffering, the economic and social impacts from a disaster are readily apparent. Whenever a disaster occurs, there are a myriad of different government agencies, private organizations, and individual first responders involved. As such there is a large volume of communications data being transmitted between these groups. Because enormous social and economic issues are present in such situations, there is a need for such information to be aggregated, presented, and assessed in an effective manner. The prime example of poor coordination between groups was the situation in the aftermath of hurricane Katrina which devastated the Southeast region of the United States. In this instance there was a disjointed effort by the federal agencies and local rescue and law enforcement groups. Similar story was reported by the International Federation for the Red Cross (IFRC) on the Asia tsunami of 2004. High-tech industry is endeavoring to create innovative solutions to prevent future threats to homeland security. The potential threat requires a bold new class of solutions that provide a higher level of security and safety. The military has long understood how to leverage technology for effective preparation and real-time analysis, and now the civilian community is striving to understand technology's benefits. Augmented Reality (AR) is a technology that takes the information obtained from the computer and information system and applies them into the real world. The computer takes the information from the real world, analyses them, then enhance and output the original information with additional sounds, graphics, etc., giving the users a better understanding with the reality than it was without the AR. As computer-based collaborative tools become more common, the human-computer interface is giving way to the notion of human-human interfacing mediated by computers. AR offers new potentials for mediating human-human interactions for the entire rescue process because the proper blending of the real and virtual and the attendant interaction metaphors can be tailored to enhance group-oriented communication and decision-making processes.

This paper presented a design framework which introduces the use of an Augmented Reality collaborative virtual environment (CVE) as a tool which facilitates and improves communication between multiple groups of people. The design looks at attempting to harmonize the efforts of each of the many groups involved in the response and recovery from a disaster. The CVE aims to provide an effective means of by which parties in the disaster area will be able to effectively communicate with various command centers concurrently, as well as providing access to auxiliary information transmitted from sources such as satellites and radar. In this concept, the CVE is envisaged to play an intermediary role between onsite personnel and the command centers, as well as between the various onsite workers themselves. This will allow data to be quickly captured, processed and transmitted by each party in the CVE. Consequently the design will allow for a reduction in the time required to assess and respond to the various scenarios in the disaster area. It will also potentially provide a faster and more accurate means by which critical decisions can be made.

2. Related Work

Disaster response and mitigation have attracted significant research efforts in civil engineering area (Suzuki et al. 2006; Arboleda et al. 2006; Zou and Ren 2006). Some of them focused on the investigation of factors that influence the capability of disaster response. For example, Son and Peña-Mora (2006) explored a response framework into which civil engineers and IT components are integrated to help grasp the relation between situation awareness, collaboration, and performance. Security planners for high-profile events such as gatherings of world leaders are turning to advanced visualization technology to improve their preparedness. For example, during the Summit of the Americas held in Quebec City, Canada, in April 2001, Canada's Defense Research Establishment Valcartier (DREV) demonstrated a unique set of tools for three-dimensional situational awareness developed by Florida-based Harris Corporation's Government Communications Systems Division (GCSD) and powered by computer equipment provided by SGI (2002). Bell and Fogler (2000) developed a virtual reality based chemical plant simulation that was developed for the study of safety and hazard analysis in undergraduate chemical engineering. Russo et al. (2006) configured a collaborative virtual workspace involving distributed collaborative technical teams for disaster management of oil and gas offshore structures. Augmented Reality also attracts attention for application in disaster response area. For example, Leebmann (2004) developed an Augmented Reality system for earthquake disaster response which could superpose an image of reality with a virtual image that extends the visible scene of reality. Its use in disaster management is to represent different invisible disaster-relevant information such as humans hidden by debris, simulations of damages and measures and overlay it with the image of reality.

3. Coordination and Communication in Disaster Response

The disaster response processes involves collaboration among a large number of groups and resources from different natures and geographically distributed, in order to make appropriate decisions within a short period of time. These groups are comprised of many technical experts and decision makers such as engineers, structural engineers, risk analysts, operators, firefighters, police, emergency medical service, etc. Nevertheless, the triad of these first responders may bring about an inappropriate response picture: independently assembled command centers and resources and difficulties in processing information, communication, and coordination. Disaster response should move toward a network-centric approach — a network-enabled approach which links rescuing forces to create a rich, shared, common practice of disaster rescue in motion. This linkage should be an interactive, multiple-player, dynamic environment and is possible due to advances in high-performance computing as well as the ability to display critical information in real time (Money and Ignazio 2003). Wearable computer and Augmented Reality technologies can make this reality.

A disaster cycle typically includes disaster impact, relief, rehabilitation, reconstruction, mitigation and preparedness (UNO 2004). In analyzing the response and recovery procedures, it is also revealed that several aspects warranted special attention. These focus areas are the command hierarchy, communications protocols, and communications interference, which had an intimate relationship with the goals of the conceptual design of AR systems for disaster response. To this end the recent major natural disaster of the 2004 Asia Tsunami was examined. It was found that the overwhelming amount of information regarding the importance of proper coordination and how failure to do so lead to wasted resources and the reduce effectiveness of emergency efforts. The IFRC (2005) described coordination as "the cornerstone" of its response to the Asia tsunami, where great numbers of international and local resources had to be mobilized to "launch immediate relief and rescue operations" (Bhattacharjee 2005). However it was noted that there were shortcomings in the coordination and communication structure, where unlike coordination and communication in the field, the protocols were far more bureaucratic and not suited to emergency situations. Outside of the IFRC organization there were many other parties involved, which ranged from local groups through to International Non-Government Organizations (INGO). It was observed that many organizations took it upon themselves to follow their own agenda for various reasons, the primary one being they believed that they had a clearer insight into the needs of the survivors. As such the efforts often did not achieve maximum results. After the experience gained from the Asia tsunami, several recommendations were made regarding the coordination mechanisms used in future disaster scenarios. One of these recommendations was that a "system for reporting and monitoring of coordination results" (Bhattacharjee 2005). By making this a priority, an organization can hope to better adjust their functions and actions so as to maximize their effectiveness in disaster response and recovery phase. Other recommendations included the creation of more effective coordination and collaboration to further promote intra and inter agency actions, along with enhancing the efforts of government authorities and international aid organizations. However the ability to coordinate within an organization and between organizations are not the only important types of communication that are important during an emergency.

4. Framework of Conceptual Design

The magnitude of the effects of the disaster would have significant impacts on the psychological distress and mental health of the affected community. Therefore, the AR system has to be designed to shorten the time to rescue survivors, and hence their exposure to the disaster.

This section presents the conceptual design framework of an AR system for first responders in the disaster of hurricane (see Figure 1). The limitations imposed are mainly concerned with the number and type of groups participating in the system. The selected groups are: (1) on-site personnel: individuals who are sent into the immediate area of the disaster zone. They are responsible for directly acting and intervening on behalf of their immediate command centers. Examples of these individuals include firemen, police, medical staff, and aid workers; (2) base station: This is the immediate command centers for on site personnel. They contain the first level of decision-making that is not interacting directly with the effect of the disaster. For example local agencies such as the fire and police headquarters, all the way up to national agencies such as the FBI etc.; and (3) command centers: These bodies control and run the individual agencies and represent the upper level of decision makers. This might include the national government, head of state, etc.

4.1 Hardware

The general hardware configuration necessary for supporting the features of the CVE can be broken into the following categories and summarized in Table 1.

Wireless Connectivity: Bluetooth is a short range communications protocol which is also known as IEEE 802.15.1. The operating range of Bluetooth device is limited to 1, 10 and 100 meters depending on the amount of power used to boost the signal, and are referred to as class 1, 2, and 3 respectively. Bluetooth uses radio frequency signals operating at a frequency of 2.4 gigahertz to transmit data, and as such provides omni directional communications. The Bluetooth signal is also able to penetrate obstacles to a certain point before becoming unusable. Bluetooth devices suitable for smaller amounts of data traffic such as microphone input and GPS data. For higher volumes of traffic such as multiple streams of video and/or audio the channel quickly becomes saturated and becomes a bottleneck in the system. Since Bluetooth is a radio-frequency technology it is subject to radio-frequency interferences, and as a result signal distortions can be induced in the Bluetooth device when exposed to these forms of interference. "WiFi" as it is more commonly known, is a radio frequency communications channel. WiFi actually comprises several specifications, namely 802.11a, 802.11b, and 802.11g. WiFi is omni directional and has greater signal penetration compared to Bluetooth. There is an aspect of WiFi which cannot be matched by Bluetooth: operating range. The range of WiFi signals are upwards of 100m when the signal is not impeded, and as a result is suitable for applications where mobility is a primary goal.

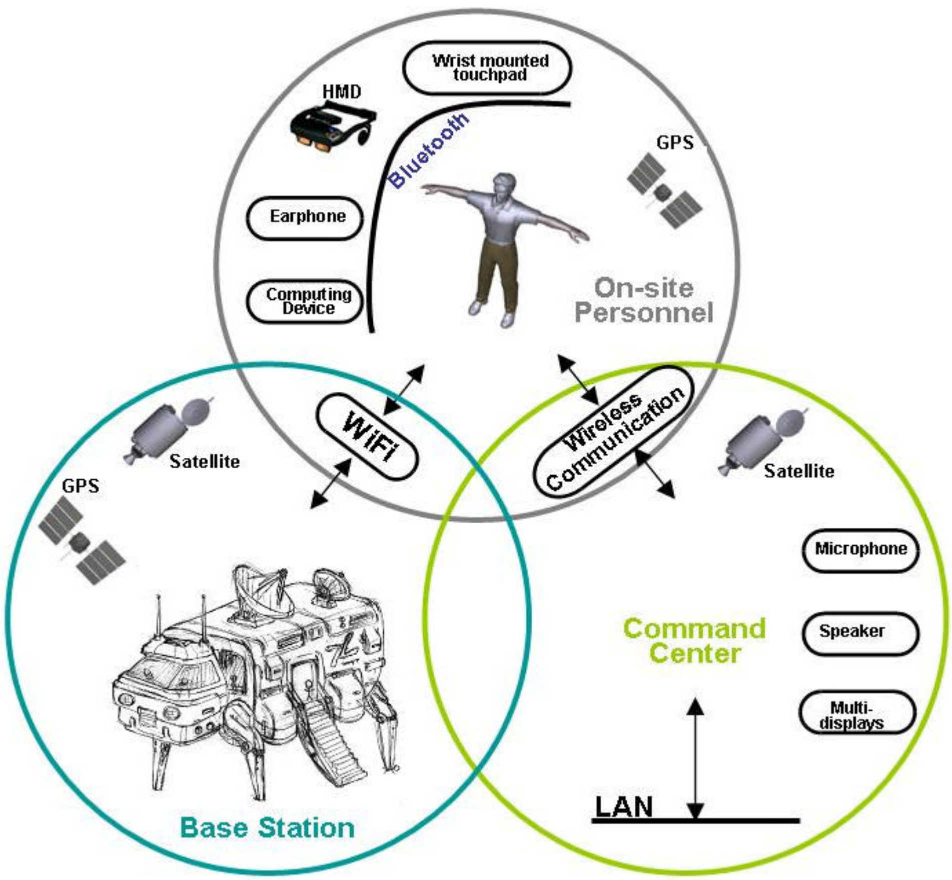

Figure 1: System Architecture of the Augmented Reality Collaborative Virtual Environment

Tracker: The accuracy of the reading can be improved via the use of Wide Area Augmentation System compatible receivers and the use of Differential GPS (DGPS). DGPS is an implementation which provides increased accuracy over that of a standard GPS receiver. Where as normally a single receiver is used, DGPS requires two receivers to operate. In a DGPS implementation one receiver is in a fixed location and is referred to as a base station. The other receiver acts as any other GPS receiver and is completely mobile. DGPS works by comparing the GPS locations of both receivers, hence the term differential, to calculate a greater degree of accuracy for the mobile receiver and as such there needs to be constant communication between the mobile receiver and base station. For DGPS to work effectively the location of the base station needs to be in the vicinity of the mobile receiver, in most cases within tens of kilometers. This is because if the signals received by both GPS receivers pass through the same area of ionosphere, the same interference effects will be equally applied to the signals. Thus when comparing the geographic locations of the 2 receivers, the accuracy of the mobile receiver is increased since the location of the base station is known and fixed. The drawback of DGPS implementation is that of the extra hardware which is required, which impacts negatively on the mobility of the overall system, the maintenance of the base station, and the extra hardware required for inter receiver communication.

Table 1: Technological Configurations for the Three Groups in Disaster Response

	On-site Personnel (mobile)	Base Station	Command Centre
Visualization Display	• See-through head mounted display using Retinal display method to project virtual data directly into the eye • Wrist mounted touchpad	------	Multiple Display capabilities
Audio Output	Earphone/s for audio signals like audio coordination directives and commands	-----	Audio speakers
Input Device	• Microphone for voice recognition (in case of incapacitation of limbs) • Wrist mounted touchpad	------	Microphones
Tracker	• Differential GPS unit • Inertial Movement Unit • Reckon	Differential GPS unit	-------
Communication devices	• WiFi for base station communication. • Bluetooth for HMD, computer, touchpad communication	• WiFi transceiver • Satellite communications dish	• Satellite communications dish • Wired communications medium such as a fiber optics channel • Client/Server LAN
Computing unit	Mobile computing device, similar to ultra portable pc used in the military	Environmental shielding	------
Power supply	Additional battery supply/fuel cell	Hybrid DEG, Fuel Cell power supply	• Mains/utility power connection • DEG as a backup power supply.

Display: The Helmet Subsystem (HSS) is a head-mounted display (HMD) equipped with an organic light-emitting diode (OLED) display which is lighter and cheaper to manufacture than LCD displays. OLED displays however, have shorter lifetimes than LCD displays and are more susceptible to water damage as their organic components are easily damaged. The HSS could be used to provide the first responders with digital maps and hidden data/information from GIS, priority stack and current goal status, internal state, and communication data/information. The HSS is also equipped with a microphone and headset for quick communications.

System Power Supply: Battery/fuel cell are ordinary power supplies for on-site first responders. Diesel powered generators, also known as Diesel Electric Generators (DEG), are small diesel engines which are used when mains power is not available or when the amount of power required is so low that mains power is too great for the load. DEG's run off a tank of diesel fuel which needs to be replenished on a regular basis. This is a benefit and shortcoming at the same time, running off diesel allows the generator a great degree of mobility, however, it also means that its operating lifespan is dependent on the size of the fuel reserve.

4.2 Interface Design

User Interface Design: Now that the types of information dealt with in the design are clearly laid, all these elements, both audio and visual, should be integrated into a well structured and intuitive user interface. The user interface needs to meet strict criteria to ensure maximum comprehension, operational efficiency, and optimal levels of cognition. Without proper design and testing of the user interface, it is possible for an otherwise well designed system to become very inefficient or even unusable. The most difficult user interface to develop would have to be for the mobile unit. Although the composition and display of data such as GIS and GPS information is relatively straightforward, the actions required to actually operate the system's many functions are the most difficult. In contrast, the design of the UI for the command centers is a lot less restricted, especially in terms of physical configuration and power supply. Again however special consideration needs to be spent on this user interface to ensure the operational efficiency design. The user interface that is unobtrusive and allows the user to identify targets, should be capable of overlaying symbols and color data, textual orders and possibly the Rules-of-Engagement autonomously, moreover this data should be able to be manipulated and manually called upon by the user seamlessly.

Database: By showing relevant information users will accomplish tasks much faster. The advantage of the database is that it can show embedded information about an object and help in decision-making. All this adds to raising the situation awareness of the first responders. Having this system will increase group efficiency as all units now have access to a repository of knowledge that is far more comprehensible and aware than a single mind. The critical information need to be non-intrusive and should not distract the users and be blended into the users' real world view.

Navigation system: The Navigation Subsystem (NSS) integrates a global positioning (GPS) receiver and a Dead Reckoning Module (DRM), which takes over when there is no GPS signal, to provide real-time accurate positional information which is used in the map and location projections in the HSS. The NSS could aid navigating the first responders through difficult or unfamiliar or unstructured terrain such as debris. The navigation system could select the shortest and safest route possible to certain destination and visualize it into the first responder's real world view. A system of icons could be used to help create an effective means of navigation. It simply shows the soldier's field of view with steering arrows pointing to the designated location. By using arrows of various lengths a longer arrow meant a larger distance whilst an inversed arrow indicated if a target is directly behind.

5. Discussions

It is envisaged that there is great potential for augmented reality collaborative virtual environments to resoundingly improve the key areas of coordination and communication between the multitude of organizations, groups, and individuals involved. However, there a couple of obstacles the design would have to overcome initially to prove its effectiveness in meeting its design goals. The first and probably most important is whether the design is too broad and needs to be broken into smaller components. As it is the CVE design looks to embrace field personnel all the way to the upper levels of government. This is potentially problematic since some of the data/information which is relevant in some tiers of the command structure may indeed not be relevant for others. As such a lot of information filtering and switching would be required to ensure only essential information is passed to users within the CVE. With so many groups involve within the response and recovery phase it may be wiser to implement several versions of the design that are specifically tailored to individual command tiers. However despite these misgivings we firmly believe that with proper development the use of a CVE incorporating our design elements would provide a far more unified communications mechanism for use in a disaster. As a result, any reduction in the overall effects of the disaster can only have positive contributions to the economic, social, and individual state of well being. Thirdly without thorough testing and evaluation it is difficult to pinpoint specific aspects of the design that could be improved or modified. However we feel that there are certain aspects which are more vulnerable to the need for improvement. Specifically the mobile hardware configuration may well need modifications to improve its performance because of the volatile environment in which it is designed to operate. Not only is the design subject to physical abnormalities, the user is exposed to a far greater level of interference. Specifically the user is subjected to potentially loud transient and background noises which can render the audio capabilities of the system useless without effective shielding. Likewise the changing light conditions could also adversely affect the operation of the see through HMD.

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