Emergency Response Virtual Environment for Safe Schools

by

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Abstract. An intelligent emergency response virtual environment (ERVE) that provides emergency first responders, response planners, and managers with situational awareness as well as training and support for safe schools is presented. ERVE incorporates an intelligent agent facility for guiding and assisting the user in the context of the emergency response operations. Response information folders capture key information about the school. The system enables interactive 3D visualization of schools and academic campuses, including the terrain and the buildings' exteriors and interiors in an easy to use Web-based interface. ERVE incorporates live camera and sensors feeds and can be integrated with other simulations such as chemical plume simulation. The system is integrated with a Geographical Information System (GIS) to enable situational awareness of emergency events and assessment of their effect on schools in a geographic area. ERVE can also be integrated with emergency text messaging notification systems. Using ERVE, it is now possible to address safe schools' emergency management needs with a scaleable, seamlessly integrated and fully interactive intelligent and visually compelling solution.

INTRODUCTION

Emergency responders and planners often have to respond to man-made or natural emergencies in buildings and facilities that they are not familiar with. Examples of such facilities include schools, ports, military facilities, commercial centers, government buildings, utilities installations, bridges, tunnels, etc.

The Columbine High School and Virginia Tech experiences demonstrate the severity and magnitude of emergency incidents involving school populations. First responders and emergency managers have a daunting task when it comes to incidents in school facilities. When an emergency occurs, emergency responders and planners need to quickly locate special areas of concern in the school. Currently, they often have to spend a lot of time getting and studying architectural drawings or browsing through large volumes of information about the layout of the school and the systems and functions of each area in the school. This can be a time consuming task, especially if the information is not easily accessible or is in paper form. It is often the case that such information has to be procured manually and this can take valuable time in emergency situations where every second counts. Moreover, even when this information is procured, it often doesn't reflect the actual layout of the school building as recent upgrades and modifications may be done without updating the architectural plans. Thus, for example, emergency responders may actually find a wall where they expected to find an exit route.

In addition to the above issues, it is often the case that emergency responders need to be able to operate special equipment or emergency systems. For example, they may need to operate an emergency generator or HVAC system that they are not familiar with.

Also, there are typically many schools and school buildings in a geographic area. Therefore, the system must be scaleable and must be able to easily and efficiently capture the knowledge about those facilities. Moreover, because of the dynamic nature of school facilities, the system must enable easy renewal of this knowledge.

In this paper, a web-based Emergency Responders Virtual Environment (ERVE) that addresses the aforementioned issues is presented. The application of ERVE to model a high school facility is presented in order to demonstrate the features of the system.

SURVEY OF VIRTUAL SPACE MODELING AND SIMULATION SYSTEMS

This brief survey will be focused on systems that are particularly suitable for modeling interaction within virtual facilities and that can be used for training as well as for supporting emergency response planning and operations. For example, systems such as those developed specifically for architectural visualization have not been included. Such systems provide very high quality visualization "movies," typically showing a prerecorded flythrough or walkthrough visualization of a facility but provide little or no interactivity with the virtual space.

The significant increase in processing power available for rendering in recent years has led to the development of many virtual space simulators for providing users with operational support and training in a "near-natural" synthetic environment. Applications of the virtual space simulators include training for operation of industrial machines [1,2], power-plants [3], vehicle driving, piloting, traffic-control, maintenance simulators [4], medical procedures training [5,6], emergency response training [7], and military operations training [8].

Misra et al. [7] developed an application called FiRSTE that attempts to address the training needs of first response personnel. The project aim was to determine how effective virtual environments can be for training first responders to meet the difficult challenges of responding to a chemical attack or hazardous material (Hazmat) incident. The use of virtual reality technology in this application can potentially provide training that is safe, flexible, and cost-effective. The system attempts to train first responders in applying proper procedures. It is designed to accommodate personal protection equipment and to be stressful and challenging. The FiRSTE system was built using the commercial Half-Life® game engine. Some of the issues that are still being worked on include addressing issues of hardware and software reliability and detailed functionality.

Forterra Systems and Stanford University Medical Media and Information Technologies Center (SUMMIT) collaborated on research to apply game technology to the training of medical emergency first responders [9]. The research focuses on pre-hospital and in-hospital medical first response to WMD events simulated in a virtual training environment. The system relies on human actors controlling avatars in the virtual environment using a multi-player game paradigm. Hence, the effectiveness of the system will depend on finding suitable human actors and how well they "act" their part.

McGrath et al. [10] used game-based simulation to develop two emergency response applications, the Unreal Triage and the Unreal Tunnel. They developed those simulations using the Unreal Tournament (UT) game engine. In the Unreal Triage simulation, the first responder arrives at the scene of a mass casualty event. A "heads up" display provides information on vital signs and injuries of the various victims [11]. The Unreal Tunnel provides a simulated scenario of the detection and inspection of a suspicious vehicle at a tunnel toll plaza.

Systems that rely on game engines are inherently constrained by the limitations of the game engine. In general, game environment creation software requires extensive effort by a large number of game developers to give the end product professional polish. Setup can be frustrating and technical support lacking. There are still very few industry standards regarding features and user interface. Data exchange between game applications and industry-standard CAD software is spotty at best. Popular game engines can run on Microsoft Windows but not Unix/Linux, Mac, or portable devices and are non-web based so they would not be easily accessible or deployable. Some games tend to be hard to use, especially for novice computer users; thus, tutoring and guidance often must be done by a human instructor prior to using the game system.

There is a need for emergency responders training and support system that realistically represents school facilities and that can be efficiently built and be easy to deploy. By having access to a highly realistic and interactive virtual model, emergency responders can become familiar with the school building and know what to expect in an emergency situation. The system must be easy to use and must enable emergency responders to rapidly gain knowledge about the school, locate key areas and systems, provide instructions on how to operate key systems, and point out locations of potential problems.

The Emergency Response Virtual Environment (ERVE) addresses the aforementioned needs by seamlessly integrating the following features:

(1) An intelligent agent facility.
(2) Response information folders that provide key information about the facility and 3D models and 2D floor plans as well as navigable panoramic digital images.
(3) Live camera and remote sensors feeds.
(4) Geographical Information Systems (GIS).
(5) Chemical plume simulation.
(6) Emergency Text Messaging Notification.

INTELLIGENT AGENT FACILITY

The ERVE intelligent agent [12] provides natural-language instruction with naturally sounding text-to-speech and synchronized multimedia. A near photorealistic animated humanoid provides natural interaction with the user. The intelligent agent can provide debriefing about the school and emergency events as well as instructions on key elements or areas of the school or campus. The agent can provide instructions on how to operate critical systems such as the emergency generator, HVAC system or the Fire Alarm Control Panel. For example, in figure 1 the agent provides information about a chemical HAZMAT incident event.

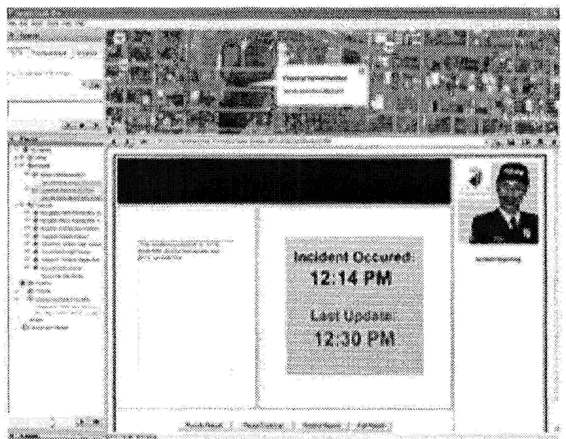

Figure 1: Agent providing event debriefing

As seen in figure 2, in the high school facility application, the agent is providing a short multimedia debriefing that can be given to emergency responders to quickly and effectively familiarize them with the school that is impacted by the emergency event.

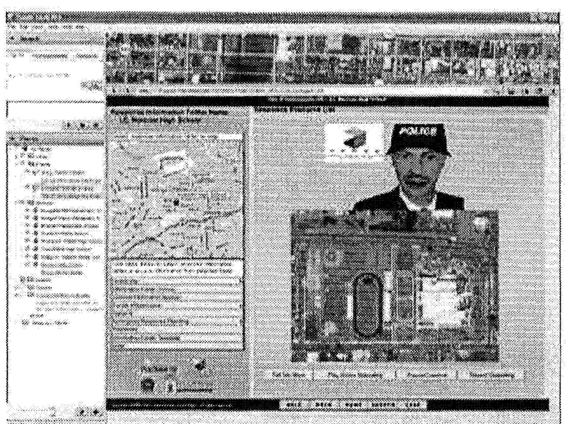

Figure 2: Intelligent agent providing debriefing

Figures 3 and 4 show the intelligent agent pointing out the location of the Fire Alarm Control Panel (FACP) and then, if needed, providing detailed instructions on how to operate it.

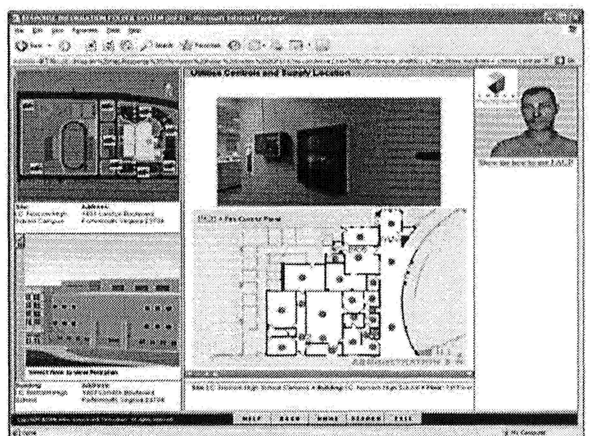

Figure 3: ERVE pointing out the location of FACP

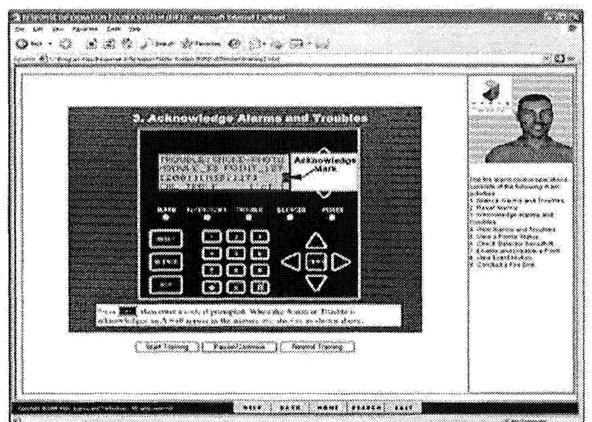

Figure 4: ERVE instructing in FACP operations

The key elements of the intelligent agent are: (1) a modular knowledge-base in which knowledge is stored with embedded synchronization with multimedia content; (2) Natural-language text-to-speech capability; (3) animated human-like virtual humanoids; (4) an integrated web-based framework.

Modular knowledge-base

The knowledge base contains knowledge items. The knowledge items have information about a particular element of the school and the related multimedia as well as intelligent agent gestures and emotions associated with the specific knowledge item. The knowledge is in XML format and thus can be updated using XML-enabled synchronous or asynchronous messaging services. Knowledge is disseminated by passing the text of the knowledge item to the speech synthesis engine to produce the natural-language speech and the multimedia is automatically synchronized with its corresponding knowledge item. In addition, any gestures and/or emotions scripts that are associated with the knowledge item are passed to the virtual humanoid and these scripts animate the humanoid accordingly.

Natural-language text-to-speech

Most web-based training or presentation systems are based on the user reading the material and looking at static or animated illustrations. Some systems present the material using pre-recorded speech with Flash animations and movies. Prerecorded speech makes the content very hard to maintain and update because any small change in wording involves spending a significant amount of time re-recording speech (as well as having to use the same person that recorded it the first time) and reprogramming the multimedia synchronization. In addition, synchronizing the speech with the Flash content using pre-recorded speech is very hard (the speech must be broken down into short phrases) because of the variation in Flash playing speed under different conditions of user interactions.

The ERVE intelligent agent facility uses a speech synthesis engine to provide natural-language text-to-speech. Speech synthesis is done using any SAPI 5.1 compatible text-to-speech voice library to synthesize the agent voice. The use of text-to-speech rather than pre-recorded speech makes updating the content of the speech extremely efficient as it is simply a matter of typing the new information in the knowledge base. Moreover, the multimedia animation is automatically resynchronized with the speech at any speech or animation speed and no additional effort is required to re-synchronize the animations.

Virtual humanoids

The ERVE intelligent agent is visually represented in the virtual environment using photorealistic animated virtual humanoids. The appearance of the humanoids can be customized based on the application. To relate to emergency responders, we created policeman and fireman humanoids to disseminate the knowledge to the users. The humanoids are able to gesture and display emotions. The virtual humanoids obtain the visemes from the speech synthesis engine to provide automatic lip-synching. They also obtain the gestures and emotions script and display them accordingly. The photorealistic animated virtual humanoids present the knowledge about the school with synchronized gestures and emotions and lip-synching and enable the intelligent agent interaction with the user to be extremely natural and compelling.

Integrated web-based framework

ERVE is fully web-enabled so it can be easily added to any web page. The web-based framework seamlessly integrates the ERVE intelligent agent facility with multimedia presentations, natural-language text-to-speech, photo-realistic animated humanoids, 3D models and 2D graphical content.

RESPONSE INFORMATION FOLDERS

Key information about individual critical facilities is collected and organized in a Response Information Folder System (RIFS). The folder allows emergency responders, managers, and planners to quickly get the information they need about the specific school. The folder is organized in 25 standard categories. Figure 5 shows the information folder for the high school application.

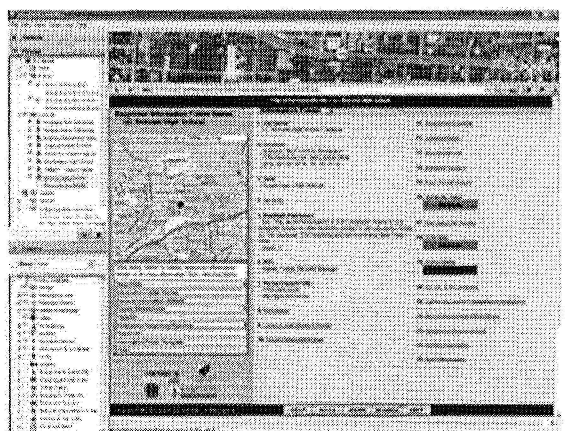

Figure 5: Response information folder

3D Models and 2D Floor Plans of the Facility

RIFS integrates critical information about the school with 2D and 3D visualization of the building interiors as well as the terrain around the school. This allows the user to interactively explore the facility and get a highly realistic and accurate view. For example, the user can navigate to a specific area of the school, such as the location of a critical system. The intelligent agent is integrated with RIFS so that it can point the attention of the user to the system and, if the user requires, offer to provide instructions on how to operate it (Figure 3).

Navigable Panoramic Digital Images

RIFS use of interactive panoramic digital images greatly reduces the effort required to model the school since it makes it unnecessary to build 3D models of rooms' interiors, furniture, etc. Specialized digital photography equipment and software that process and produce the panoramic images allows each room to be captured in one shot that can be quickly set up and processed.

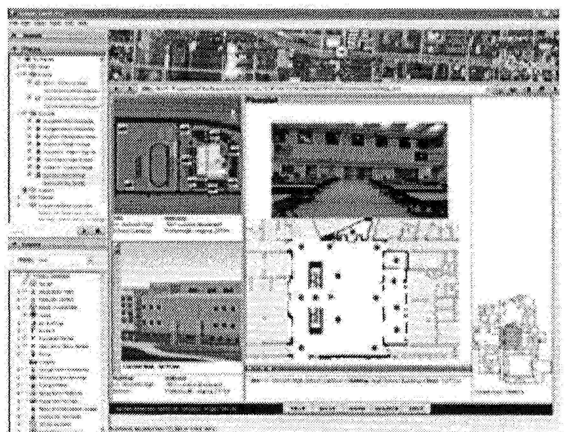

Figure 6: Floor plan visualization with panoramas

The high fidelity of the panoramas enables emergency responders to identify intricate details down to what type of flooring or doors they are going to encounter and to prepare for potential problems or obstacles. For example, the panorama in Figure 6 shows the school cafeteria. The paper plans showed openings where there are steel doors at the end of the cafeteria. So contrary to what the paper plans indicate, this would have been a difficult evacuation route.

LIVE CAMERA AND SENSORS FEEDS

The system provides the capability to display live feeds from IP cameras and remote sensors. This allows the user to get, for example, valuable real-time video of the actual situation developing in the school or around its perimeter.

GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

Geographic Information Systems (GIS) allow capturing, storing, managing, visualizing, and analyzing data and associated attributes which are spatially referenced to the earth. In a more generic sense, GIS is a tool that allows users to perform queries, analyze the spatial information, and edit and visualize geospatial data. ERVE can be seamlessly integrated with GIS. Thus, in the GIS, the user can manage various critical sites in a geographic area and associated geospatial information and visualizations. For example, as shown in Figure 7, the user can use the GIS to display all the schools in a district and overlay the plume produced by a simulated or actual chemical accident or attack based on the output of a simulation model or visualization of real-time sensors data. The user can then locate the critical facilities that would potentially be affected and interface to ERVE to get comprehensive information about those facilities.

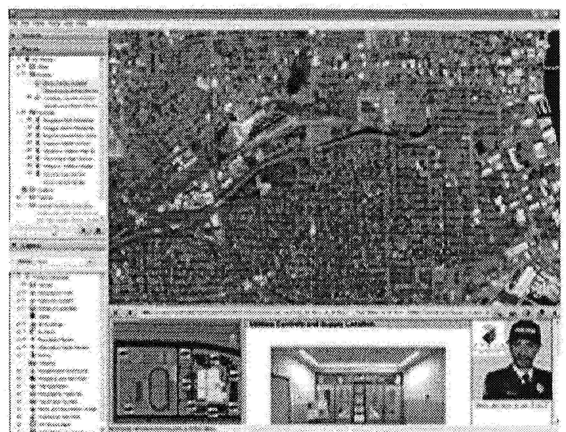

Figure 7: GIS Integration

CHEMICAL PLUME SIMULATION

ERVE is integrated with ALOHA, which is an atmospheric dispersion model. It is the primary software used by emergency responders for simulating releases of hazardous chemical vapors. Figure 8 shows a program developed in Java, which provides the integration with ALOHA.

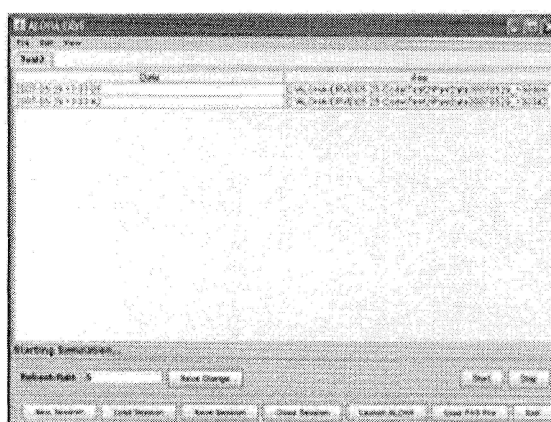

Figure 8: ALOHA Integration

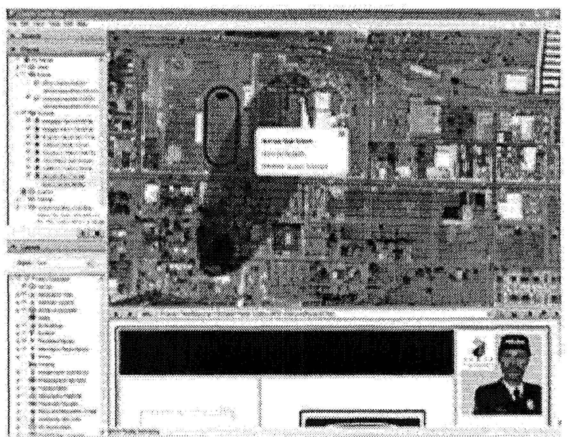

Figure 9: GIS and plume modeling integration

Figure 9 shows the visualization of the ALOHA output image of a chemical plume simulation of a mock chemical Hazmat incident in a semi-transparent overlay in the geographic area of the incident. Seeing that this event affects a particular school, the user can click on the school pushpin and open its associated Response Information Folder as in figure 5 to quickly pull detailed information about the school.

EMERGENCY TEXT MESSAGING NOTIFICATION

In an era where the use of cell phones is ubiquitous, text messaging is one of the effective ways to reach as many members of a target audience as possible in a short period of time. ERVE can be integrated with commercial text messaging broadcast systems to notify the school population of emergencies and appropriate actions. For example, a text message can be sent instantaneously to staff and students that classes are cancelled and that the school is closed due to an emergency.

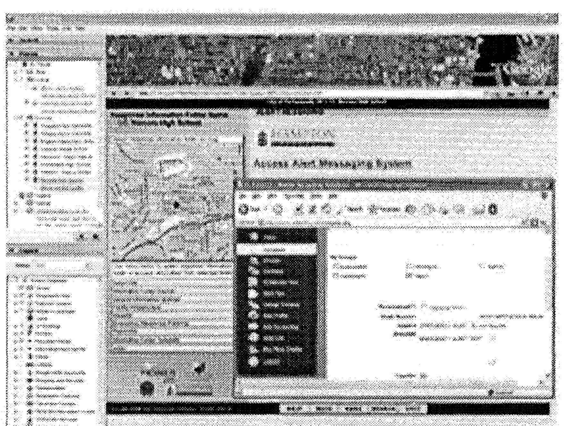

Figure 10: Example of ERVE integration with commercial text messaging systems

CONCLUDING REMARKS

In the present paper, a web-based Emergency Responders Virtual Environment (ERVE) was presented. The system can be used to train and familiarize emergency responders with school facilities as well as for support in actual emergencies. The system is integrated with GIS to allow users to manage all the school facilities in a geographic area as well as monitor emergency events and assess their impact on school facilities. The system guides the emergency responders to critical areas in the facility such as locations of hazardous chemicals, water and gas shut-off valves, fire suppressant equipment, and electrical panels. It provides 3D and 2D visualization of building layout, floor plans, exterior, aerial and surrounding structures. Human-like interactive and emoting intelligent agents provide debriefing and guidance to the user as well as instructions on how to perform complex tasks such as starting up a generator or the use of the fire control panel. ERVE can also be seamlessly integrated with emergency text messaging notification systems. The ERVE solution provides renewable on-demand facility knowledge and can be deployed across PC or portable devices via the Web. The seamless integration of modeling and simulation, virtual reality, GIS, remote sensing technologies, text messaging and intelligent agent technologies have the potential to dramatically improve how emergency responders and planners prepare for and respond to school emergencies. The application of ERVE to an actual high school facility was presented in order to demonstrate the features of the system.

ACKNOWLEDGEMENTS

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VIII. Student Competition Session

An Overview of Student Modeling and Simulation Competitions for Transportation System Design