Simulation and Network-Centric Emergency Response

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ABSTRACT

This paper describes research into the integration of game-based simulations and incident command technologies. The research is at the confluence of two technology revolutions: the influx of new emergency response technologies for emergency responders and the use of computer game technology for serious simulation.

Network-centric emergency response is emerging as a new paradigm, driven in large part by technologies derived from the military sector. Specifically, sensor and information sharing technologies are being introduced to civilian incident command technologies and initiating a revolution in emergency response like the "revolution in military affairs" that has been ongoing for the past decade. The implications of these new technologies for well-established incident command procedures are unclear. Emergency responders will soon be capable of generating vast amounts of data. How will operators-in-the-loop (both incident commanders and first responders) deal with this flood of information?

The integration of game-based simulations with new and prototype emergency response information systems may help answer these questions. Game engines are particularly well suited for multiplayer, real-time representations of reality, and game-based emergency response simulations integrated with information systems can provide a powerful method for evaluating human system integration. Several pilot efforts have demonstrated the value of integrating games and prototype emergency response systems. These include the evaluation and demonstration of mass casualty monitoring system using a mass casualty simulation, and the integration of emergency operation center (EOC) software with a radiation response simulation. We describe these pilot projects and plans to use simulation to rehearse high-consequence events, which will not only lead to better emergency response technologies, but will also allow policy makers to adapt to the new world of network-centric emergency response.

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INTRODUCTION

Emergency response is undergoing a technology-driven transformation. The military has been undergoing such a transformation for nearly a decade, characterized by an increased dependence on sophisticated sensor and information sharing technologies. In the past, sensors and "shooters" (warfighters) were not directly interconnected or networked in military operations. Rather, information from distributed sources was collected centrally at incident command. With the continued introduction of new information technologies, however, sensors and shooters are not separate, and information is available to a much greater number of people throughout the command hierarchy. Platform centric warfighting is being replaced by network centric warfare (NCW). Whether this "revolution of military affairs" will succeed remains to be seen, and reports from the wars in Iraq and Afghanistan indicate that vast amounts of information do not necessarily lead to better performance in combat (Ferris 2004).

The events of September 11, 2001 have provided the impetus for broad changes in emergency response technologies and procedures aimed at improving readiness for high consequence emergency events. Included among the technologies being introduced to emergency response are a myriad of sensors, e.g., physiological and environmental, that are capable of providing a wealth of information to all levels of response. A 2004 National Research Council report found that the similarity in emergency response operations and battlefield conditions implies that situational awareness tools developed for military purposes "could be essential to improving national emergency response capabilities" (National Research Council 2004).

Like NCW, network centric emergency response (NCER) promises to make responders more effective by providing them with more information. But while NCW is an explicit revolution, the revolution in emergency response is happening implicitly, and without clear direction. The uncertain effect of this abundance of information on the structure and role of incident command raises important questions, including:

- Will this network centric approach improve situational awareness, or will large amounts of data overwhelm emergency responders?
- Can the emergency response community adapt quickly to the introduction of new technologies or will there be rejection of technology in favor of "tried and true" techniques?
- What are the effects of network centric emergency response on established hierarchies of command?

Successful introduction of network centric systems in the military has been due, in part, to synthetic battlespace simulations that enable mission rehearsal and virtual prototyping of command and control technologies. Complex information systems must be evaluated in context of realistic conditions with humans-in-the-loop rather than as stand-alone applications. This is the rationale behind the concept of simulation-based acquisition, which recognizes that synthetic environments are valuable tools in developing human-centric systems (Stone 2002).

In the military domain, simulation based acquisition aims for early optimization of system performance, lower risk in acquisition, and better information sharing (Zittel 2001). But simulation based acquisition has not been widely employed in the evaluation of new emergency response technologies, due in large part to the cost of synthetic environment development and the relatively decentralized nature of emergency response organizations. However, recent trends in game-based simulation are making synthetic environments for emergency response affordable for the first time, and this fortunate development occurs at just the right time to deal with the wave NCER technologies.

TRENDS IN DISTRIBUTED SIMULATION

A synthetic environment can be described as a collection of simulations which share information about objects (things with persistent state) and events (things that happen and have no persistence). As such, simulations must have a mechanism for exchanging information about objects and events to interact with each other and external, heterogeneous information systems. The Distributed Interactive

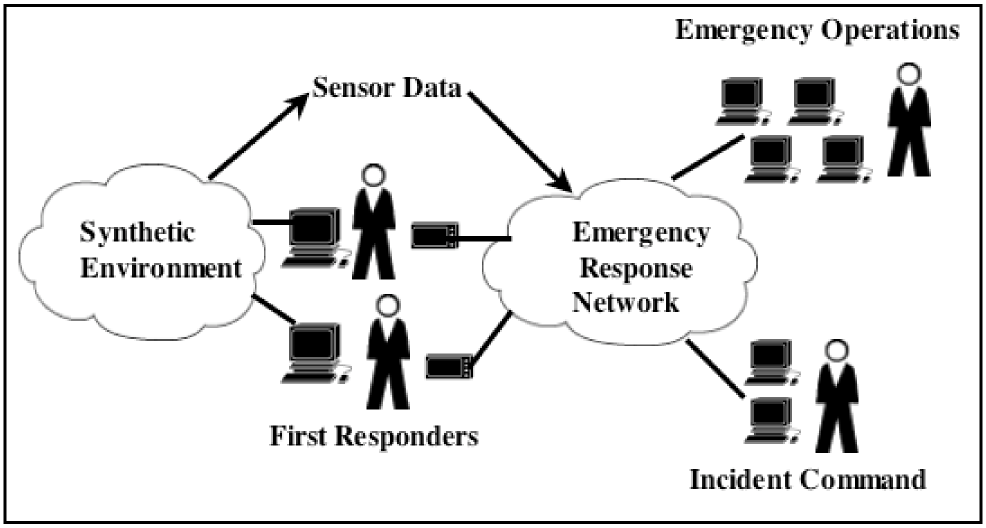

Figure 1 - Synthetic Environments for emergency response with humans-in-the-loop

Simulation protocol (DIS) introduced in the early 1990's made simulation interoperability a reality for a generation of real-time combat simulations. Later, the Defense Modeling and Simulation Office (DMSO) expanded the vision of simulation interoperability by defining and promoting the High Level Architecture (HLA), which allowed heterogeneous distributed simulations to share information.

Broad simulation interoperability promised distributed simulation and reusable models, which would conceivably enable the development of low-cost synthetic environments. Unfortunately, the years since the introduction of HLA have not produced the anticipated results. Instead, the trend has been toward limited interoperability, expensive software licensing schemes, and complex tools for terrain development, intelligent behavior, and proprietary visualization tools. The cost and complexity of distributed simulation have made it prohibitive in many non-military domains.

While the simulation community was struggling with interoperability, the gaming industry made substantial contributions to the synthetic environment concept. By picking up on the basics of distributed, interactive simulation and taking advantage of great improvements in graphics at the desktop machine level, researchers and gaming companies have made advances in terrain building, visualization, and networking that have proven to be more cost effective than military frameworks.

This makes game engines an attractive alternative to expensive and/or complex simulation frameworks. The potential for using game engines for serious simulation has been recognized for years. In 1997, the National Research Council cited some of the common objectives of multi-player games and military simulation: "The underlying technologies that support these objectives address similar requirements: networking, low cost graphics hardware, human modeling, and computer generated characters" (National Research Council 1997). A number of games (Full Spectrum Warrior, America's Army) have bridged the chasm between entertainment and military training simulation. More recently, research efforts have produced game-based simulations for training individual first responders (Misra, Decker, Barker, & Hilgers 2004).

The emergence of game-based simulation and the simultaneous but unrelated trend toward network-centric emergency response represent a fortunate convergence. Game-based simulations as synthetic environment representations of emergency response scenarios make it possible for low-cost immersive simulations to be integrated with emergency response information systems (figure 1).

PILOT PROJECTS

These trends are encouraging, but even a serious game is effectively a stand-alone application. If game engines are to be used as platforms for synthetic environments, they need to be more extendable, reusable, and interoperable. If they are to serve the emergency response community, they must be free of expensive licensing arrangements.

Two projects demonstrate the principle of combining game-based simulations and prototype emergency response information systems. They show that game-based synthetic environments for emergency response can be developed and integrated with prototypes for experiments, exercises, and engineering studies.

Unreal Triage and ARTEMIS

The Automated Remote Triage and Emergency Management Information System (ARTEMIS) project is an example of military technology applied to emergency response (Wendelken, et al, 2003).

Figure 2 - User interaction with ARTEMIS prototype and simulation

The goal of the ARTEMIS project is to integrate advances in communications and analysis technologies into a network-centric casualty care system for crisis events. The prototype system consists of pulse-oximeter medical sensors both embedded in first responder equipment and available as a patch to be placed on casualties. The sensors use ad-hoc wireless routing algorithms to transmit medical and GPS data to Emergency Medical Service (EMS) personnel in the field and to a command vehicle that maintains a communications link with Incident Command. EMS personnel use handheld computers that display the status and location of casualties providing an increased situational awareness while using the automated triage values to prioritize medical support for casualties. The EMS personnel can also use the handheld unit to enter additional observable information about a casualty, which when fused with the sensor data is used to generate a new automated triage calculation. The sensor data is also used to populate a critical incident management system providing commanders with real time geospatial data about the location and health status of both responders and casualties at the scene.

ARTEMIS is designed to enhance the performance of emergency responders, not to replace them. Therefore an appropriate development cycle must include design iterations with human-in-the-loop trials. Rather than expensive mock ups or live trials, the synthetic environment approach was chosen as a virtual proving ground for early ARTEMIS prototypes (figure 2).

Unreal Tournament (UT) was chosen as a Synthetic Environment platform because it encourages the development of game modifications (mods) by its users. UT offers ready support for visualization and network play requirements, and its suite of modification tools makes it flexible and extendible. Developers can distribute game mods without licensing the game engine itself, making it an ideal platform for inexpensive redistribution. Furthermore, a "gamebots" programming interface developed for AI research enables game interaction with external applications (McGrath, Ryan, and Hill 2005). Unreal Editor is the primary tool for creating and editing models, but plug-ins for third party tools such as 3DS Max and Adobe Photoshop allow users to export geometry and textures in useable formats.

In the Unreal Triage simulation (McGrath and Hill 2004), the first responder arrives at the scene of a mass casualty event with multiple victims. A "heads up" display describes the pulse, respiration, and visible injuries of the various victims (figure 3). It also allows the player to "interview" the victims to determine mental alertness.

Figure 3 - Player view in Unreal Triage

Players move using keyboard/mouse controls, but the behavior of non-player characters (NPCs), also known as "bots", must be programmed. Whereas simple behaviors such as path following and reactions are easily defined within the game environment, genuinely intelligent bot behavior is a major challenge in game development. Unrealscript is an object-oriented, java-like language with game-oriented extensions that enable simple NPC behavior, such as having an ambulatory casualty walk to an assembly area based on a user command.

Casualties in Unreal Triage are represented as NPCs. Thirty casualties with injuries ranging from superficial to fatal are simulated in the scenario. The player can "tag" a casualty with a virtual ARTEMIS sensor, which sends biomedical and location data across the simulated ad-hoc network. The real handheld computer and incident command application are used in-the-loop to receive sensor data and send additional observable data to other responders and incident command.

This virtual prototyping process allowed ARTEMIS developers to test assumptions and fix mistakes that could not be identified with conventional prototypes due to constraints of scale, time, and safety. Virtual experiments have resulted in an improved ARTEMIS system. Before the virtual prototype the ARTEMIS team performed a series of small-scale experiments involving less than 5 medical sensors to validate the systems functionality. When the number of casualties scaled to 30 via the virtual prototype the ARTEMIS handhelds suffered performance degradation. The virtual prototype also revealed that the data publication rates of sensors was consuming network bandwidth. Finally, by allowing emergency responders to use the handheld deveice and incident command displays during a simulated mass casualty event a number of human computer interface issues were revealed. These user critiques of user interfaces provided valuable feedback to developers.

The ARTEMIS project will continue to utilize the virtual prototype in their spiral model of software development, by providing the end user with a virtual prototype after each round of development. This human-in-the-loop approach accelerated development time, while incorporating user feedback to produce a human-centered system design.

Unreal Tunnel and the Regional EOCs

An Emergency Operations Center (EOC) is a critical component in disaster response. Many communities, states, and regional organizations have an EOC which acts as the central point of planning and coordination during a disaster (Quarantelli 2001). But when a disaster or catastrophe is of sufficient size to cross jurisdictional boundaries, multiple EOCs may be activated creating yet another coordination challenge. A number of projects are underway to coordinate regional EOCs in regional response networks.

The complex interactions of humans, information, and sensors cannot be well understood without human-in-the-loop exercises and experiments. To gain a better understanding of the interaction of sensors, first responders, and multiple EOCs during a crisis, we developed Unreal Tunnel. The simulated scenario is the detection and inspection of a suspicious vehicle at a metropolitan tunnel toll plaza. Unreal Tunnel simulates the vehicle traffic, law enforcement officers, and data that would be obtained from the toll plaza in such a scenario.

In the EOC, situational awareness is pieced together from sensors, visual information from digital imagery and video, and situation reports (text and voice) from the field. The synthetic environment allows players to generate sensor data, text reports, and video to create an accurate representation of the expected EOC situational awareness during a time of crisis.

Figure 4 - Unreal Tunnel

Unreal Tunnel (figure 4), like Unreal Triage, is a UT mod which communicates sensor information through the gamebots API. In the simulated scenario traffic flows inbound and outbound at the tunnel toll plaza when a fixed radiological sensor triggers an alarm and a suspicious vehicle is detained. An emergency response unit arrives shortly after the vehicle is stopped, and the player inspects the vehicles with more sensors. Since video is a critical sensor in the EOC, game clients can be configured to replicate the perspective of fixed cameras at the simulated tollbooth or cameras within the simulated emergency response vehicles. This digital video is captured from the game client and streamed to the EOC from a digital streaming server.

The Unreal Tunnel/EOC test bed allows engineers to evaluate various protocols for sharing video and sensor data. Perhaps more importantly it creates a means for experimentation, exercise, an evaluation with the "fog of war" induced not only by limited information but excessive information which can lead to contradictory interpretations. As the observe, orient, decide, act (OODA) loop indicates, the effects of a decision based on faulty interpretation can be magnified by the feedback loop inherent in command and control.

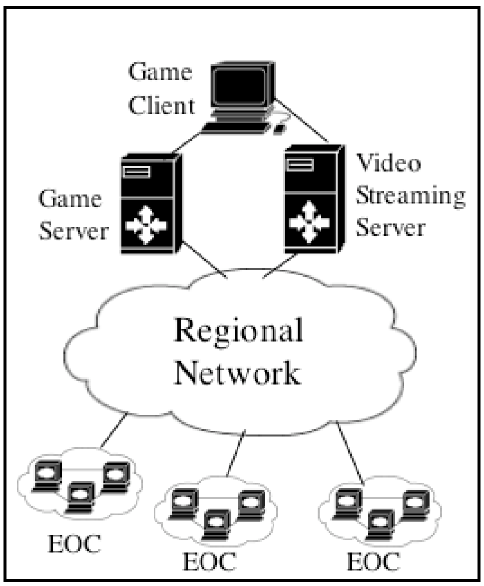

Figure 5 – Unreal Tunnel and a regional EOC network

FUTURE EXPERIMENTS

Better human performance through better systems is the ultimate goal of emergency response technology development. The examples of Unreal Triage and Unreal Tunnel illustrate the potential of game-based simulation for mission rehearsal and virtual prototyping for emergency response. Future studies aimed at quantifying the effectiveness of this approach will help achieve optimum situational awareness.

Successful mission rehearsal is not only determined by successful mission execution, but also in the development of conceptual understanding of the event that can be applied in actual events. Thus, the synthetic environment-based exercise can also provide a rich environment for task oriented concept learning and enrichment. We propose that a series of virtual mission rehearsal exercises, employing emergency response professionals, prototype technologies, and synthetic environments will yield valuable insights into situational awareness and incident command concepts.

In Unreal Triage and Unreal Tunnel, the intended goal is to provide users with realistic stimulus to evaluate the level of emergency responder situational awareness and task load associated with new technology. Therefore the application of methods designed to measure levels of situational awareness is appropriate. There have been numerous studies of concept learning measurement related to situational awareness (Salas, et al. 1995, Stout, et al 1996, and Endsley 1995). There are generally four categories of knowledge elicitation related to situational awareness as described in these and other studies: observations, interviews and surveys, process tracing, and conceptual methods (Cooke 1994).

Observational methods entail recording (through video, audio, scribing, etc.) of participant performance and later analysis of the data as compared to expectations of performance. Interviews and surveys are developed by domain experts and administered after the participant performs the task. Interviews and surveys can be structured or unstructured and provide a means for general understanding of the participants situational awareness. Process tracing is a method of eliciting information about cognitive processes related to tasks being performed by the participant. The "talk aloud" protocol (vanSomeren, Barnard, & Sandberg, 1994) is one example of process tracing where the participant describes their thought process and actions aloud while engaged in a task. Data gathered from the "talk aloud" protocol is typically analyzed based on content coding schemes developed for the task (Ericsson & Simon, 1996). The final category, conceptual methods, involves use of metrics to define relationships between concepts related to situational awareness. A notable method within this category is called concept mapping, where graphical interfaces are used to depict concepts and their relationships to each other (Jonassen, Beissner, & Yacci, 1993).

Two situational awareness assessment techniques, SAGAT (Situation Awareness Global Assessment Technique) and SPAM (Situation Present Assessment Method), have been used with simulations, and are under consideration for this work. The SAGAT works by presents questions related to situational awareness concepts during pauses in a simulation (Endsley, 1990). SPAM, on the other hand presents questions while the task simulation is running (Durso, et al, 1998). In both cases, simulation is the key to measurement of situational awareness.

CONCLUSIONS

Game-based synthetic environments are going to be critical to the successful introduction and acceptance of NCER technologies. Pilot demonstrations show that game-based synthetic environments for emergency response are useful and affordable, and that integration with prototype systems can improve the technology development cycle. Future work with game-based simulation and prototype technologies will incorporate both concept mapping and interview methods to assess changes in situational awareness introduced by new technologies through virtual exercises.

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