Proceedings of the 2006 Winter Simulation Conference
L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, eds.

A CONCEPT PROTOTYPE FOR INTEGRATED GAMING AND SIMULATION FOR INCIDENT MANAGEMENT

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ABSTRACT

This paper describes a prototype that has been developed to demonstrate the concept of integrated gaming and simulation for incident management. An architecture for the purpose was developed and presented at the last conference. A hypothetical emergency incident scenario has been developed for demonstrating the applicability of integrated simulation and gaming. A number of simulation and gaming modules have been utilized to model the major aspects of the hypothetical scenario. The modules demonstrate the value of utilizing simulation for incident management applications. They can be used to highlight the value of simulation and gaming for training applications in particular. Two of the simulation modules have been integrated using a modified implementation of the High Level Architecture to give an idea of the advantages. Technical issues in integration are identified.

1 INTRODUCTION

Simulation modeling has been identified as one of the leading techniques for helping improve the incident management capabilities (National Research Council 2002). A research project at the National Institute of Standards and Technology (NIST) has been focused on developing modeling and simulation for incident management. The effort at NIST brought together a number of researchers and practitioners for a workshop in 2003 to identify the status of the field and the issues that need to be addressed to increase application of modeling and simulation to incident management. The attendees agreed that aggressive actions were needed to encourage use of modeling and simulation for incident management. The action items generated from the workshop were as below (Jain and McLean 2003).

- Develop standards to facilitate integration
- Develop a framework for integration
- Gather input from user community to identify opportunities for application of modeling and simulation
- Develop a roadmap for the realization of envisioned capabilities

A smaller workshop was organized in 2004 for developing the roadmap. NIST researchers have embarked on the activities in the roadmap with constrained resources. The accomplishments include the following developments.

1. A framework for modeling and simulation of incident management (Jain and McLean 2006)
2. An architecture for integrated gaming and simulation for incident management (Jain and McLean 2005)

An overview of the architecture concept is shown in Figure 1. The integrated simulation modules are intended to provide technically correct solutions. The gaming modules are included to provide the interaction required for training. The simulation and gaming modules should be integrated together through a data synchronization and transfer processor. The integrated capability will allow joint training of first responders and the management level personnel in the preparedness phase. The integrated simulation modules by themselves can be used throughout the incident management lifecycle including the phases of prevention, preparedness, response, recovery and mitigation.

The work reported in this paper is the next step in continuation of this effort. A prototype has been developed to demonstrate the concept to potential user community. The prototype would particularly help explain the concept to those who are not familiar with simulation and gaming and their applicability to incident management. A hypothetical scenario involving a dirty bomb explosion in Washington DC has been created. Selected aspects of the incident and the response have been modeled to demonstrate the capabilities of simulation and gaming. The advantages of

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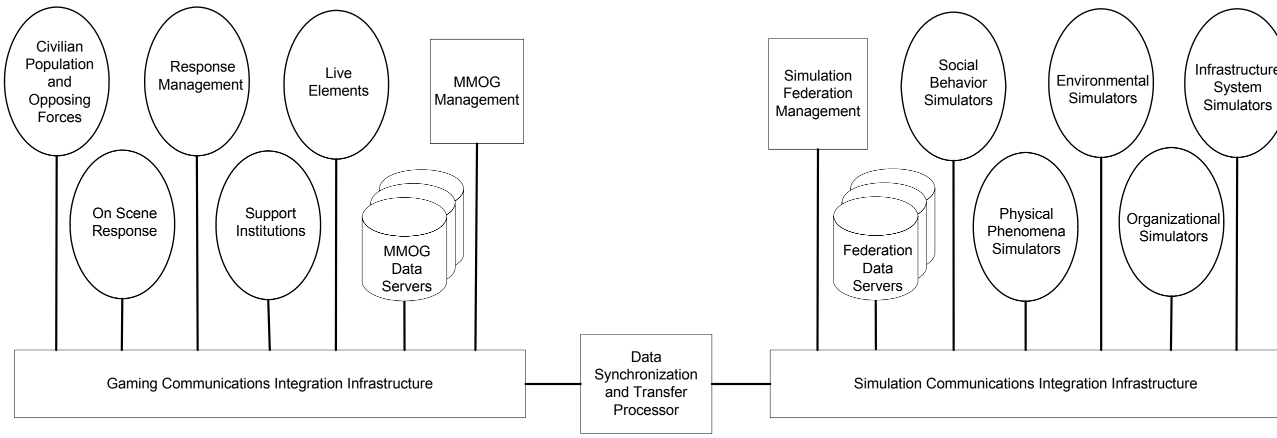

Figure 1: Architecture Concept for Simulation and Gaming for Incident Management

integration are highlighted through integration of two of the modules.

The next section briefly describes the hypothetical scenario. Section 3 discusses the simulation and gaming modules that have been included in the concept demonstration. Section 4 presents the proposed approach for integration including a test implementation for two of the modules. The data needs for building and executing the simulations are briefly discussed in Section 5. Section 6 lists the issues identified from this experience of developing the prototype. The last section concludes the paper.

2 HYPOTHETICAL SCENARIO

The scenario for the concept prototype is based on a dirty bomb attack in Washington DC on the evening of July 4. The fireworks on the National Mall on July 4 attract a large crowd. A large number of people utilize the metro rail system to get to the National Mall. The metro rail authorities actually close the Smithsonian metro station that is nearest to the National Mall to allow better management of the crowd flow on July 4. It does not take much imagination to identify streets nearby metro station entrances as potential targets for terrorists. The selection of public places like a street as the incident location also avoids any concerns that may be raised on selecting privately owned location such as stadiums for such a study.

The scenario uses the area outside Federal Triangle metro station, that is the second closest station to the National Mall, as the target for detonation of a dirty bomb by terrorists. The scenario did not consider the feasibility or means of getting a dirty bomb to the identified location. The probability of such an occurrence is expected to be very low with the typical high security surrounding such an event. The focus of the scenario was on the consequences if such an incident occurs.

The near term consequences of a dirty bomb explosion include the casualties and radiation exposure among the crowd in the immediate vicinity and in the area covered by the plume, and response by police, fire department and emergency medical technicians. The major consequences of the incident and the response need to be modeled for incident management purposes.

3 SIMULATION AND GAMING MODULES INCLUDED

A number of simulation and gaming modules were developed to help understand the issues involved in modeling and integration. Each of the implemented module is discussed below with the full capability desired and the subset implemented for the demonstration.

3.1 Simulation Modules

The simulation modules included in this effort are as below.

3.1.1 Plume Simulation

This module falls in the category of physical phenomena simulators shown in Figure 1. It should model the dispersion of plumes of various kinds including chemical, biological and radiological agents. Inputs may include the characteristics of the agent released, release mechanism used, the location of release point, terrain and structures around the release point, and weather conditions. Inputs may alternately be based on the sensor readings over time in the area of interest indicating the presence of an agent and the direction(s) of the spreading plume. Outputs may include time profile of the plume, and exposure profile for the population in the region affected by the plume over time.

This module was implemented using CT-Analyst software from Naval Research Labs (Boris et al. 2002). This tool provides the desired capabilities for modeling plume dispersion as described above. It models the spread of the plume from the identified location taking into account the weather and the geometry of the buildings in the surrounding areas.

3.1.2 Crowd Simulation

The capability of modeling crowd behavior is a part of the social behavior simulators group in figure 1. It should model crowd status and movement at locations of interest under different event scenarios, crowd behavior and crowd management strategies. The locations of interest may include areas around actual and potential emergency incident sites, major business, commercial and residential areas that may be affected by evacuation directives, and major public transportation points such as bus and train stations, local rail transport stations, and airports. Different event scenarios may include normal, rush hour, terrorist attack, accidental fire, natural disaster, etc. The models may predict crowd movement and crowd density variations along movement directions, predict occurrence of stampede and casualties, perform route planning through the crowd for selected individuals (such as first responders), determine location of individuals as a function of time, predict individual movement times between selected points. Inputs may include street layouts including pedestrian areas, layouts within public buildings such as train stations and public parks, crowd volumes and density data, probabilities for stampede and casualties, weather conditions, location of emergency incidents, behavioral models of individuals, sensor data, and communications. Outputs may include location and status of specific individuals in the crowd, crowd volumes and density by city block and passages within public buildings and parks, crowd movement times between selected points, and crowd management systems data.

The crowd simulation module has been implemented by researchers from University of Arizona using AnyLogic software using the agent based simulation paradigm. Individuals and small groups are defined as agents with each of them having parameters such as age, mobility, knowledge of the area, that determine their reaction to the incident and the behavior (Shendarkar et al. 2006).

3.1.3 Traffic Simulation

Traffic simulation is another module that falls in the group of social behavior simulators. It should provide models of general traffic flow and specific vehicle movements for a given region under different event scenarios (normal, rush hours, off-peak hours, terrorist attack, natural disaster, evacuation, etc.), driver behavioral models, and traffic management strategies. The model may perform automatic route planning for selected vehicles, generate random events that disrupt traffic flow (vehicle breakdowns, accidents, traffic management system failures), determine vehicle locations as a function of time, predict travel times between locations, etc. Inputs may include road network layout and characteristics, traffic management system description and status, individual vehicle locations and status, driver moods, historical traffic volume and vehicle density data, pedestrian data, probabilities for accidents, incidents, weather conditions, location of emergency incidents, behavioral models of vehicle operators, sensor data, and communications. Outputs may include locations and status of specific vehicles, traffic volume and densities by area or road segment, travel times between selected locations, accident data, and traffic management system data.

This capability has been implemented using two modules that simulate traffic at different levels of detail. The Emergency Response Vehicle Simulator models the traffic at a macro level. It has been developed by NIST researchers using Java and Geotools, an open source GIS toolkit (GeoTools 2006). It mimics the movement of the response vehicles from their initial locations to the site of the incident. While individual response vehicles are modeled, the effect of the rest of the traffic is modeled using congestion factors for each road segment that they go through. The travel route is determined using Dijkstra's algorithm.

The micro level traffic simulation capability has been implemented using Traffic Software Integrated System (TSIS) developed at the University of Florida and available through the Center for Microcomputers in Transportation (Mc*Trans*). The model simulates movement of individual vehicles in the immediate area around the National Mall before and after the incident. Following the incident, a number of vehicles come out of parking garages in the area and attempt to leave resulting in traffic jams. The software allows capturing the congestion factors for each road segment defined. The congestion factors determined through micro-level simulation of one area can be used to estimate congestion factors for the wider area modeled in the macro-level traffic simulation.

3.1.4 Health Care Simulation

The health care simulation module is part of the organizational simulator category in Figure 1. It should model the actions of the health care organizations (including emergency medical technicians, hospitals) in response to an emergency incident including the deployment of resources and actions for triage and treatment of injured at the incident site, movement of casualties to hospitals, and treatment at the hospitals. The model logic will include relevant policies and procedures for emergency situations including calling in medical staff, using temporary accommodations for the injured, acquiring needed supplies and equipment. Inputs may include the number, location and type of casualties from an emergency incident, the availability of staff at work and off (on-call), the availability of resources (own and those that can be acquired quickly from surrounding jurisdictions), the time and resources required for attending to each casualty type, and the probabilities of death from different casualty types over time. Outputs may include the operation of the health care system over time including the number of people treated and released, admitted, dead, waiting for treatment, and the state of the staff and facilities (to determine their capability to deal with another incident).

The concept demonstration includes a model for only one part of the health care system, namely, the emergency department. The operation of a hypothetical emergency department for handling the casualties from the incident is simulated. It was developed by NIST researchers using ProModel/MedModel. Casualties arriving at the emergency department include serious cases of trauma and cardiac cases brought in by ambulances and walk-ins with minor injuries and the worried well. The model indicates the build up of queues for the walk ins. The ambulances carrying serious cases are occasionally diverted to other hospitals based on the status at the hospital modeled.

3.1.5 Transportation Simulation

Transportation simulation is a part of the infrastructure systems simulators group in Figure 1. It should mimic the transportation system infrastructure including highways and road network, rail network, waterways, marine and air transport. It should model the impact of man-made or natural disasters on the transportation infrastructure components. Inputs may include the description of the transportation system infrastructure together with its network, characteristics of node points, traffic volumes across arcs and through the nodes, traffic control mechanisms, failure characteristics of major control mechanism and equipment, operation and maintenance resources, multi-modal links and links to other critical infrastructure. Outputs may include the impact of modeled emergency events on the operation of the transportation infrastructure over time.

A metro rail simulation model was developed for the purpose of demonstrating the concept of transportation simulation. The model was developed using AutoMod by NIST researchers with active support from the vendor, Brooks Software. It models the evacuation of people from the incident area using metro rail system. The metro system lines passing through the incident area are modeled. The model helps determine the rate at which the crowd can disperse using the metro system.

3.2 Gaming Modules

The gaming modules would be especially useful for incident management training applications. Two of the modules were implemented, one at responder level and the other at the management level.

3.2.1 Triage Application

Triage is part of the On-Scene Response group of gaming applications in Figure 1. This application allows trainees to play the role of emergency medical technicians conducting triage following a dirty bomb explosion. This module has been developed using collaboration between researchers from NIST and the Institute of Security Technology Studies (ISTS) at Dartmouth College. The ISTS researchers had previously developed the triage application for a airplane crash scenario (ISTS 2006). The NIST researchers created the 3-D geometry of the incident location and worked with ISTS researchers to set up the application.

The gaming application allows a user to move around in the 3-D space representing the incident site. The user can see the fire caused by the explosion, the casualties lying on the ground, the fire trucks, other responders, objects and structures on the street and the surrounding buildings. They can go to each victim and perform triage by looking for the vital signs and asking specific questions if possible. The victims requiring immediate attention can be carried away on stretchers through a gross decontamination station created using hoses from two fire trucks. The application includes audio effects to make the experience closer to reality. A user has to contend with sounds of sirens, victims, limited lighting conditions in performing his/her responsibilities for conducting triage.

3.2.2 Incident Management Strategy Gaming

The strategy gaming application falls under the Response Management category of gaming applications shown in Figure 1 and is targeted at the management level personnel for the responding agencies. This may be used by personnel at the Emergency Operations Center (EOC) to plan out the response resource deployments. The module has been developed by NIST researchers using C#.

The module shows a map of the incident site together with the locations of response resource providers including police stations, fire stations, and hospitals. The map also shows the important buildings around the incident site. The interface provides the capability to place icons representing response resources on the map thus making and visualizing the deployments. The map can be updated based on reports from the incident site. All the icons used are based on standards defined by the Homeland Security Working Group (HSWG 2006).

The application allows decision makers to develop an awareness of the situation and make decisions for resource deployment. These decisions can then be communicated to the responding teams. The strategy board can be updated with locations and damage information as reports are received from the incident. The board can be used with a real incident or with a simulated incident modeled using the concept demonstration prototype.

4 INTEGRATION OF SIMULATION MODULES

The benefit of the individual simulation and gaming modules can be synergistically increased through integration. In the absence of integration, each simulation will have to either make assumptions about the phenomenon modeled by other simulations or utilize summary statistics from the other simulations. For example, the emergency department simulation will have to utilize the arrival rate of ambulances determined by the emergency vehicle response simulation model. Utilizing a distribution based on results from other simulations will result in piecewise simulations of the overall system. Integrating the simulations together such that they can exchange entity information will allow modeling the whole system together. The integrated set will thus allow increased accuracy.

The integration of simulation modules can be accomplished using the High Level Architecture (Kuhl et al. 1999). However, the traditional approach of integrating the simulation using the High Level Architecture (HLA) is quite resource intensive and requires major coordination among the developers of the simulations being integrated. A modified approach involving adapters developed at NIST (McLean et al. 2000) was used for the integration. Two of the simulation modules, the emergency department simulation and the emergency response vehicle simulation, were integrated together using the adapters. Figure 2 shows a screen shot of the integrated execution of the two modules. As the simulated ambulance arrives at the hospital location in the emergency vehicle response simulation window shown in the right half of the screen, it enters the emergency department simulation window shown in the left half of the screen. The ambulance discharges casual-

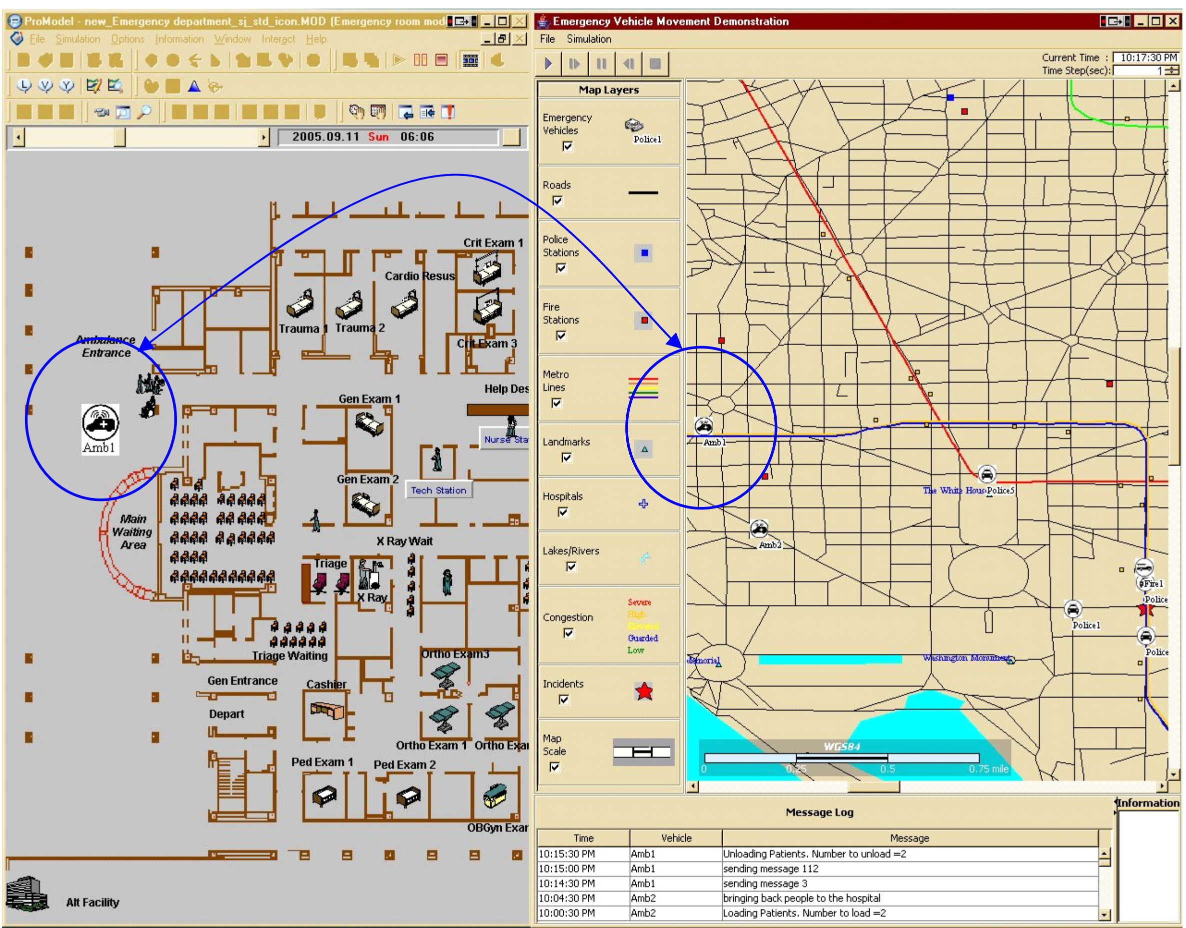

Figure 2. Screenshot of Integrated Execution of Emergency Department Simulation (left half) and the Emergency Vehicle Response Simulation (right half) with Added Annotations Showing the Corresponding Ambulances in the Two Simulations

ties at the hospital and leaves. Again, the movement between the two simulations is coordinated. The two simulations are integrated using a conservative approach with a simulation time step of 30 seconds.

The integration of gaming and simulation modules allows joint training of personnel from multiple levels of organizations. The first responders and management level personnel can be trained together on the same simulated incident. This allows them to share experiences leading to better teamwork and performance. Strategies for addressing the significant technical challenges in the integration of the gaming and simulation modules are currently being investigated. The challenges include:

- Synchronization of time between gaming modules that should execute in real time and simulation modules that have the capability to execute in accelerated time.
- Re-synchronization of gaming and simulation modules after a fast forward or "jump" in simulated time.
- Establishing communications with gaming software since they have generally been developed with proprietary architecture.
- Affecting the event flow in simulation based on actions taken in gaming clients and vice versa.
- Achieving agreement between results of simulations executed at an abstract level and games executed at a detailed level.

5 SIMULATION DATA NEEDS

Development and execution of simulations such as those discussed in this paper will require a large and varied set of data. Two databases have been developed to indicate the kind of data that will be needed to support the simulations. One database includes reference information that may be useful for any incident while the other is specific to the incident. The example databases are developed as two units for illustrative purposes only. It is recognized that the real data may reside in a number of databases spread at different organizations. It may be worthwhile to read some of the data directly from the existing databases while other parts of the data may be read in and stored locally depending on the communication and storage infrastructure available to a community.

The reference database may include information such as natural disaster intensity scales for earthquakes and hurricanes, characteristics of biological and chemical agents, triage categories and tags, capabilities of emergency response equipment such as police cars, fire trucks, and personal protective devices. Such a database will provide the information for modeling the behaviors of the various entities and physical phenomena. It can also serve as the reference for decision makers.

The incident database may include information specific to the incident. Such information would comprise of the map of the area, locations of nearby responding agencies, sites of local, state or national importance in the area, current status, traffic densities on the streets in the area, etc. The information in the incident databases will be utilized to populate and update the simulation models. For example, the incident database may indicate that two fire trucks of type A are close to the scene. The corresponding simulation model will be initialized with that information. The information on capabilities and features of fire trucks of type A will be retrieved from the reference database to correctly model their actions.

6 ISSUES IDENTIFIED

The development of the concept demonstration prototype helped identify the issues involved in building a system with integrated simulation and gaming modules. The issues are summarized below.

- The numerical data inputs for the simulators were generally in proprietary formats. Some of the data had to be entered using input screens of the simulators. The tools developed internally at NIST allowed XML inputs.
- The GIS data inputs could be in a number of several GIS "standard formats." There are multiple file formats defined with different versions, multiple earth models and multiple projections. There is no best combination of these factors and translation errors between the formats are common.
- The imported graphics required varied formats also. For an earlier version of the strategy board, the map had to be downloaded as a bitmap and then converted into Targa (.tga) format. Another tool required the bitmap to be converted to Jpeg (.jpg) format. Yet another required conversion to AutoCAD format.
- The open source software used was not found to be as robust or well documented as commercial software. The lack of documentation such as UML diagrams made it difficult to comprehend the code.
- Communication with some of the proprietary tools was hard to implement as they were not designed to interact with external programs.
- One of the tools was restricted to use by government personnel only.

There were some instances of default standards that helped the process. For example, inputs of 3D models for the two different gaming software used was possible using 3D Studio Max format.

The experience underlined the need for standards for data inputs and outputs for the simulation and gaming modules. Standards are also needed to enable plug and play interfacing of the modules.

7 CONCLUSION

The development of a concept demonstration prototype for integrated gaming and simulation for incident management is expected to help explain the concept to the user community. It has been found useful for the purpose in early demonstrations. The responder community associates simulations with live exercises and table top models. The concept demonstration prototype helps elucidate the concept of computer simulation and gaming and the value it may provide to them. The development also helped verify some of the major issues that were anticipated in realizing the use of simulation and gaming in incident management. Future work is intended to identify and build the infrastructure required for enabling integrated gaming and simulation using independently developed modules. Such infrastructure will include defined standard architecture, interfaces and data formats that allow bringing together desired modules for incident management for different scenarios.

ACKNOWLEDGMENTS

The concept prototype was developed through contribution of several people including the following NIST researchers: Damien Bertot, Tina Lee, Swee Leong, Yan Luo, Guillaume Radde, Benjamin Raverdy, Frank Riddick, and Guodong Shao. External collaborators include Dr. Dennis McGrath, Douglas Hill and Jenny Bodwell of Institute of Security Technology Studies at Dartmouth College, Dr. Gopal Patnaik of Naval Research Labs, Dr. Young Jun Son and his graduate students from University of Arizona, and Louise Rains from Brooks Software.

A number of software products are identified in context in this paper. This does not imply a recommendation or endorsement of the software products by the authors or NIST, nor does it imply that such software products are necessarily the best available for the purpose.

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