Integration of Incident Management Simulation-based Training Applications

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ABSTRACT: *The nation's incident management personnel and emergency responders need to work in a coordinated, well-planned manner to best mitigate the impact of natural and man-made disasters. They need to be trained and be ready to act in view of increased security threats. Training has been traditionally provided using live exercises at a great expense. Simulation and gaming systems could provide a wider range of training experiences at a much lower expense. It would be even more advantageous from a cost and functionality perspective if training simulators could be readily assembled from products created by different developers. This paper presents a framework and a conceptual architecture for integrating gaming and simulation systems for incident management training. Major components in the gaming and simulation systems architecture are defined and interaction mechanisms are proposed. The paper identifies categories of standards required, existing standards, and gaps that need to be filled. Research and standards issues for implementation of the proposed architecture are also discussed.*

1. Introduction

There is a growing need for preparedness for emergency response both for man-made and natural disaster events. The man-made disaster risk has increased due to a rise in possibility of terrorist attacks against the United States. Effective emergency response presents a number of challenges to the responsible agencies. One major challenge is the lack of opportunities to train the emergency responders and the decision makers in dealing with the emergencies. An on the job training approach is not appropriate given the thankfully infrequent occurrences of such events. The responsible agencies have tried to meet the need through organization of live exercises, but such events are limited by the large effort and expense required to organize and execute them.

The limitations of live exercises can be overcome to a large extent through use of integrated gaming and simulation models. The Department of Defense (DoD) has found that use of simulations instead of live exercises for training can reduce the training costs to one-tenth [1]. Use of integrated gaming and simulation over a distributed network can allow people to participate from different locations and thus provide some flexibility in scheduling the resources. Most importantly, use of simulation will allow providing the responders with experience of a wide range of response scenarios and thus significantly improve the emergency preparedness.

Simulation modeling has been identified as one of the leading techniques for helping improve the incident management capabilities [2]. A recent survey [3] indicates that a number of modeling and simulation applications for analyzing aspects of various disaster events exist. These need to be brought together for studying the impact of disaster events as a whole. Not only do we need to understand how a radioactive plume released by terrorists will disperse, we also need to plan what traffic routes people will use to evacuate the affected areas, what demands will be placed on the hospital resources in the area, etc. The individual simulation models such as those for studying the radiological release need to be integrated with those analyzing the traffic movement in the affected area, and with those analyzing the resource constraints of hospital systems, among others.

The need for such integration in the incident management context has been recognized as evident by the urban security project at Los Alamos National Laboratory that integrated plume simulation and traffic simulation to compute exposures to the cars traveling through a toxic plume [4]. The Simulation Object Framework for Infrastructure Analysis (SOFIA) project at Los Alamos National Laboratory developed a software framework for the modeling, simulation, and analysis of interdependent infrastructures [5]. Both of these efforts used ad hoc interfaces and scope of the simulation modules. It would be a fair guess to anticipate a large amount of effort for using the simulations in these projects to model another location or more importantly to integrate them with a simulation representing another aspect, such as, the emergency operations center.

There is a need for standards to facilitate the process of development of integrated gaming and simulation tools for incident management. Standards can enable the integration of independently developed modules to rapidly model a specific scenario.

The development of such standards is a challenging task and needs to be addressed on several fronts. A framework to partition the incident management application space is briefly described in section 2. Section 3 presents an architecture defining the required simulation and gaming components and thus identifying their scope at a high level. Section 4 introduces a conceptual data model for incident management gaming and simulation. Available data exchange standards are mapped against the conceptual data model in section 5 to identify their relevance. An integrated simulation and gaming concept prototype utilizing a few of the modules is described in section 6. The data exchange issues identified while building the prototype are discussed in section 7. Section 8 concludes the paper.

2. Framework for Incident Management

Jain and McLean [6] define an integrated framework to enable an organized approach to the use of simulation for incident management through partitioning of the associated application space. The primary users of such a framework would be developers of simulation tools as they would gain from an organized approach to the incident management area. The framework identifies the scope of the incident management area, provides a scheme to map the current tools and determine the gaps, and helps identify the interfaces that the tools may have to other tools. It would thus help capture the interoperability requirements for the simulation tools. Although the framework has been designed to help guide the simulation efforts, it may be seen that it provides a general scheme for organizing the incident management area. The framework is reproduced here and described briefly to provide the application context for the proposed architecture.

The framework for incident management is designed to be three dimensional for ease of understanding. The three major dimensions are incident, domain and lifecycle phase.

An incident is defined as “an occurrence or event, natural or human-caused, that requires an emergency response to protect life or property” [7]. The kind of incident will have a large influence on the kind of simulation capabilities that need to be brought together for response and its management. For example, a building explosion and fire event requires capabilities for modeling the impact of explosion and fire on the building structure and its occupants, while a hazardous release in the atmosphere requires capabilities to model the dispersion of the release in the atmosphere. Admittedly there are some capabilities that are required for a number of scenarios. These include capabilities such as traffic simulation and information flow simulation. Also, man-made and natural incidents may have similar impact. For example, forest fires can be initiated by intentional or unintentional actions of people or by natural causes.

A domain is defined as a group of entities that have similar characteristics with respect to incident management considerations. The incident may have an impact across different domains including civilian population, critical infrastructure, and environment. The response to and management of the incident may involve multiple domains including government agencies and private sector. Entities within domains may both suffer the impact of incidents and may be involved in response. The domains may be modeled at a level of detail appropriate to the objective of the study.

Incident management includes five major lifecycle phases – prevention, preparedness, response, recovery, and mitigation for emergency and disaster incidents [7]. The capabilities of the needed simulation tools may differ based on the incident management lifecycle phase they are designed for.

Figure 1 shows the concept of Framework for Incident Management (FIM). The three major dimensions described above form the three axes of the cube that is used to represent the incident management area. Each cell in the cube defines the management and/or impact of an incident type or a specific incident on a particular domain and the associated applications required in the phase defined along the lifecycle dimension. The cells will also include the modeling of results of actions by the entities within the domains. The location of the cell along the lifecycle phase dimension classifies the need for the affected domains.

The Framework for Incident Management also defines the framework for simulation as it defines the needs that simulation applications should satisfy. Each cell of the FIM defines needs that simulation tools can fill or support. For example, incident management may need to address the training requirements for government agencies for a fire disaster event in preparedness lifecycle phase. Simulation applications can provide models that train people for various aspects of dealing with a fire emergency, such as determining the escape route, determining the means to put out the fire at individual firefighter level and at the fire company level. The framework thus captures the needs for simulation applications for incident management. The framework also identifies the need for simulation applications for supporting an event at each phase in its totality.

The framework partitions the application space and thus identifies the applications for simulation and gaming modules. An examination of framework indicates that many of the same components will be required to meet the needs of applications represented in different cells. For example, crowd simulation component may be required in all the cells that include the civilian population domain as one of the axes. A separate scheme is hence required to partition the solution space in to standard components. A conceptual architecture is presented in the next section for just such a purpose.

3. Conceptual Architecture for Incident Management Gaming and Simulation

Simulation and gaming-based technologies can together be useful for incident management applications if integrated correctly using an appropriate architecture.

3.1 Requirements for the Architecture

The architecture for simulation and gaming for incident management training should provide the following major capabilities:

- Creation of a federation of simulation and gaming modules appropriate to represent the selected incident management scenario.
- Integration among heterogeneous simulation federates modeling interrelated aspects of the emergency event.
- Integration among heterogeneous gaming modules with trainees role-playing within the same locale in the emergency event simulation.
- Synchronization between the macro and micro-level

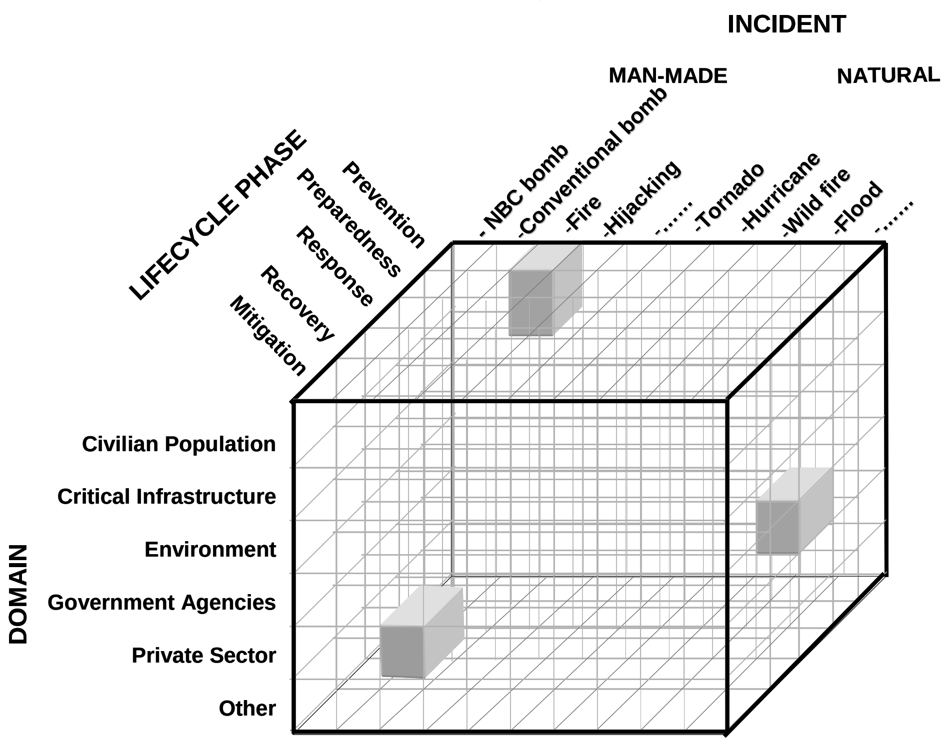

Figure 1. Framework for Incident Management

simulation models and micro-level gaming modules.
- Control over execution of both simulation and gaming modules through a world control console.
- Execution in Massively Multi-player Online Games (MMOG) mode to support a large multi-agency incident management exercise.
- Access to heterogeneous data servers for supporting simulation and gaming modules.
- Management of MMOG execution.
- Management of simulation federation execution.
- Reusability of simulation and gaming components.

3.2 Concept

An architecture to meet the above requirements is conceptually presented in Figure 2. The architecture will have two major subsystems – one for simulation and the other for gaming. Each sub-system partitions the associated solution space. The simulation modules will each represent one of the major aspects of the emergency event or its response. The simulations will be based on defined behaviors of involved entities including the incident management organizations. The gaming modules will provide for role-playing by emergency responders in roles represented in the figure. Simulation and gaming subsystems will have their individual communication integration infrastructure. The two infrastructures will be linked through a data synchronization and transfer processor.

The simulation and gaming subsystem will each contain a number of modules within each of the groups [8]. For example, the social behavior simulators group will include crowd, traffic, epidemic, consumer, and other simulators where the outcome is dependent on social interactions. Similarly, the civilian population and opposing forces group on the gaming side may include role playing clients for victims, general public, terrorists, media, and others.

The proposed architecture will allow the virtual environment to be highly configurable. Simulation and gaming components can be selected and integrated based on a defined scenario. A scenario involving a terrorist attack using a dirty bomb can be modeled using components of the proposed system. The simulation modules employed for such a scenario may include crowd, traffic, explosion, plume, weather, fire, law enforcement, health care, transportation, and communications. The gaming modules for the scenario may include victims, general public, terrorists, fire, police, emergency medical technicians (EMTs), hazardous material teams (HAZMAT), hospitals, shelters, and public transportation. A natural emergency event such as a hurricane would require a different set of modules. The available modules in the proposed architecture can thus be configured for different incident management applications across a range of scenarios.

The architecture concept will also allow flexibility in hardware systems for executing the virtual environment, in particular for training. The system modules can be distributed across a network of machines when training a large team. They may also be set up as multiple processes on a standalone machine using a multi-tasking operating system for individual training.

4. Conceptual Data Model

This section presents a conceptual data model for incident management simulation and gaming from the user's perspective. A more detailed description is available in [9]. The primary objective is to develop a structure for exchanging emergency related information among various emergency response simulations and gaming modules.

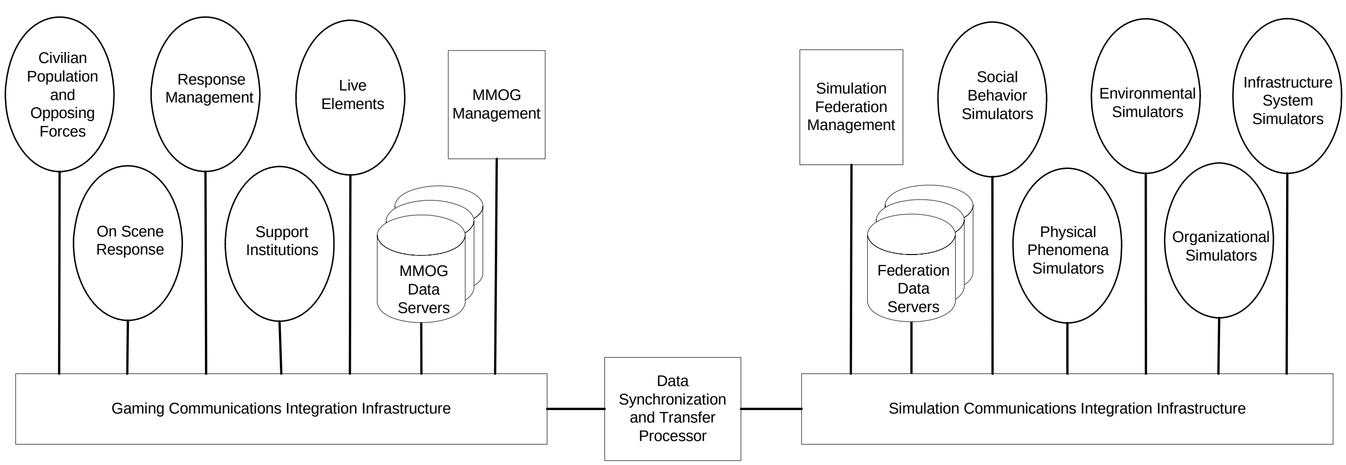

Figure 2. Architecture Concept for Simulation and Gaming Emergency Response Training System

The intent is to define data structures that can be used for both simulating the incident event and for managing actual response operations. The rationale is that if one data structure can serve both purposes, the need for data translation would be minimized.

The conceptual data model describing the top-level data requirements for incident management simulation and gaming is shown in Figure 3. It illustrates the major data elements and their relationships to each other. Thirteen major data elements are defined, namely, *Areas*, *Building-Structures*, *Chronology*, *Demographics*, *Environment*, *Hazard-Effects*, *Incident-Event*, *Infrastructure-Systems*, *Organizations*, *Policies-Procedures-and-Protocols*, *Response-Operations*, *Response-Resources*, and *Social-Behaviors.* The elements are briefly described below.

An incident refers to an event that requires an emergency response to protect life or property. There are two types of incidents: natural disaster and man-made attack. The *Incident-Event* data element is needed to maintain information on the incident, such as event type, event time period, and event status including magnitude and casualty.

When an incident occurs, it helps the response providers to visualize the exact incident location on a map. Depending on the size of the incident area maps at different scales may be needed, such as a street map, local map, regional map, or even national map. An incident site might be a residential house, office building, public facility, park, or metro station. The *Areas* and *Building-Structures* data elements contain map information and the site's characteristics including floor plans.

The *Organizations* data element is used to identify the organizations that provide emergency response support for the incident. These primarily include emergency response providers, for example, Federal Emergency Management Agency (FEMA), fire departments, police departments, hospitals, other federal, state, and local governments, and nongovernmental organizations. The *Organizations* data element contains the personnel contact information and emergency response capabilities.

An emergency organization normally sets its strategic plan for response operations and resource requirements, monitors the activities, and maintains the resources for the incident. The *Policies-Procedures-and-Protocols* data element identifies operational guidance for use by the emergency organizations and other personnel involved in conducting or supporting incident management operations.

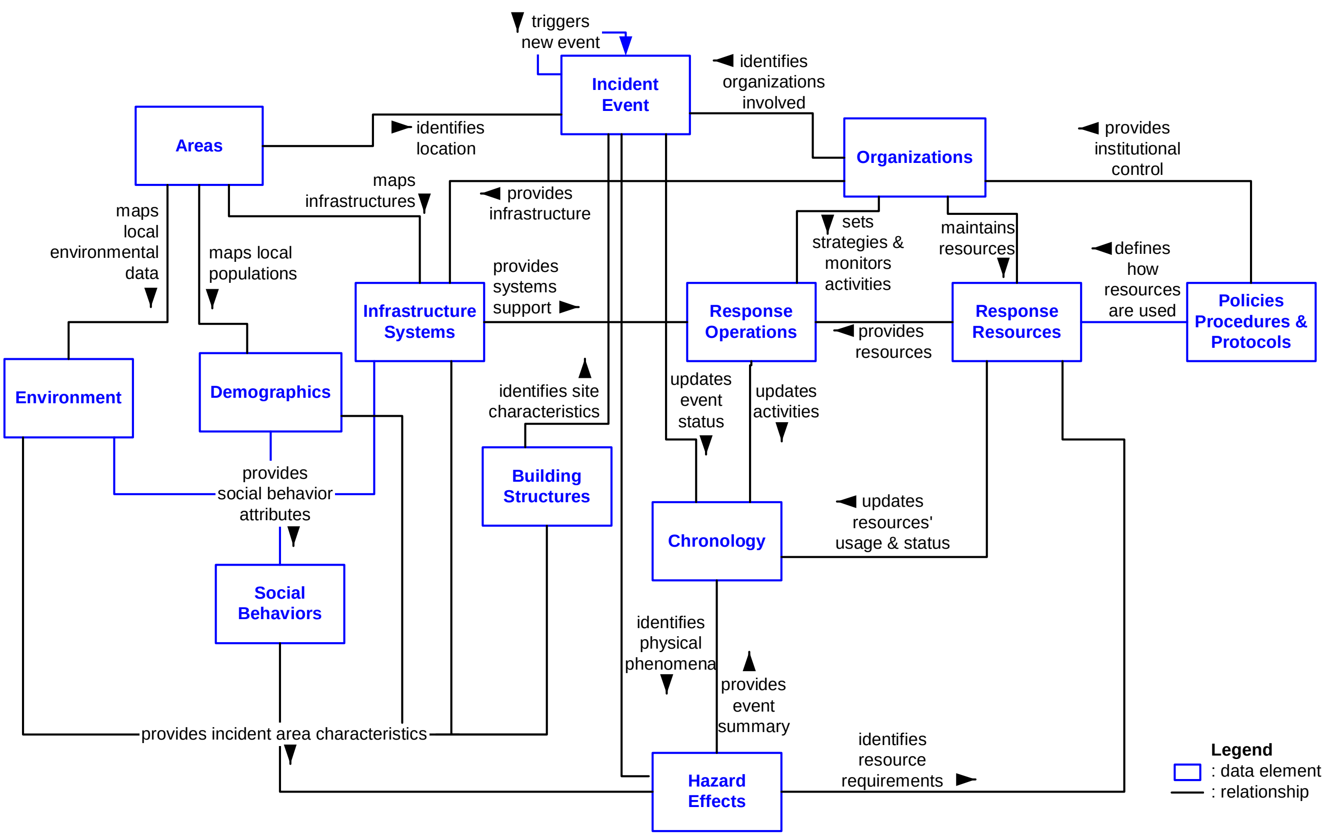

Figure 3. Conceptual Data Model for the Incident Management Simulation and Gaming

The response-operation activities carried out by the emergency response providers may include evacuation, search and rescue, food and water supply, recovery, and cleanup. The *Response-Operations* data element identifies the response-operation activities, organizations involved, resources requirement, resources used, and their status.

Emergency-response resources are personnel, equipment, vehicles, supplies, and facilities available or potentially available for assignment to the incident response. The *Response-Resources* data element defines type and quantity of emergency-response resources, and their availabilities and status.

The *Chronology* data element maintains the event summary information including incident status, response-operation activities, and resource usage and status. The *Hazard-Effects* data element identifies the hazard type, magnitude, and causality of the incident's status or prediction. The types of hazards may include fire, extreme weather, CBRNE (chemical, biological, radiological, or nuclear explosive), and disease.

When the incident area is identified on the map, some population and environmental data of the incident area can also be mapped by using the Census Bureau Maps, National Weather Service databases, and other public/private resources. The *Demographics* data element is used to represent age, sex, and culture of the population. The social-behavioral attributes may include population characteristics, environment complexity, time of day, location, familiarity, mobility, and alertness. The *Social-Behaviors* data element includes data for social-behavioral attributes. Environmental data may include current and forecasted conditions of weather, watershed, atmosphere, and indoor climate. The *Environment* data element maintains different types of environmental data.

Infrastructure systems often play important roles during the incident. Examples of infrastructure systems include transportation, communication, gas, water, electricity, and sewage. The *Infrastructure-Systems* data element maintains the information of those critical infrastructure systems.

5. Available Standards

Table 1 lists the available standards relevant to incident management simulations. These standards are mapped onto the major data elements identified in the data model shown in Figure 3. The standards listed in the table include those that have been approved by standard organizations, those that are undergoing the approval process, and de facto standards that have been adopted widely by users but have not been formally approved. From the table, it may be noted that the standards do not evenly support the thirteen major data elements. It can be seen that only a few of the available standards support the *Chronology*, *Demographics*, and *Hazard-Effects* data elements. There isn't any standard available to describe human behavior and social interactions, and no standard to represent incident events. The research and user communities have to come together to identify priorities for standards and follow through with development.

Table 1. Mapping of relevant available standards to major data elements in the data model

Major Data Element	Relevant Available Standards
Areas	• Content Standard for Digital Geospatial Metadata (CSDGM) [10] • Content Standard for Digital Geospatial Metadata (CSDGM) - Extensions [11] • Governmental Unit Boundary Exchange Standard [12] • Hierarchical Data Format-Earth Observing System (HDF-EOS) [13] • Shapefile for Geospatial Vector Data [14] • Earth-Referenced Spatial Data Transfer Standard (SDTS) [15] • Standard for a U.S. National Grid (USNG) [16] • GeoTIFF [17] • Keyhole Markup Language (KML) [18] • OpenGIS Specifications [19] • Vector Product Format (VPF) [20]
Building Structures	• CityGML - Exchange and Storage of Virtual 3D City Models [21] • National Building Information Model (NBIM) Standards [22] • The CIMSteel Integration Standards Release 2 (CIS/2) [23] • The Collaborative Design Activity (COLLADA)* [24] • The Industry Foundation Classes (IFC) [25]
Chronology	• NFPA Standard Classifications for Incident Reporting and Fire Protection Data [26]
Demo-graphics	• Topologically Integrated Geographic Encoding and Referencing /Geography Markup Language (TIGER/GML) [27]
Environment	• Air Quality - Exchange of Data[28] • Binary Universal Form for Data Representation of Meteorological Data (BUFR) [29] • Digital Weather Markup Language (DWML) [30] • GRIdded Binary (GRIB) [31] • Extensible Markup Language (XML)* [32] • Really Simple Syndication (RSS)* [33] • Flexible Image Transport System (FITS) [34]

Hazard Effects	• Homeland Security Standards Database (HSSD)* [35]
Incident Event	• None located in the search
Infrastructure Systems	• Caltech-USGS Broadcast of Earthquakes (CUBE) Message Format [36] • Common Alerting Protocol (CAP) [37]
Organizations	• Emergency Data Exchange Language (EDXL) [38] • Digital Imaging and Communications in Medicine (DICOM) [39] • Health Level Seven (HL7) Standards [40] • IEEE 1512 Standards for Common Incident Management Message Sets for use by Emergency Management Centers [41] • The International Classification of Diseases [42] • National Response Plan (NRP)* [7]
Policies Procedures & Protocols	• Homeland Security Standards Database (HSSD)* [35] • National Response Plan (NRP)* [7]
Response Operations	• Homeland Security Standards Database (HSSD)* [35]
Response Resources	• Homeland Security Standards Database (HSSD)* [35]
Social Behaviors	• None located in the search
Others (for general purposes)	• The Collaborative Design Activity (COLLADA)* [24] • Comma Separated Value (CSV) [43] • Computer Graphics Metafile (CGM) [44] • Extensible Markup Language (XML)* [32] • Graphics Interchange Format (GIF) [45] • Hierarchical Data Format (HDF) [46] • Humanoid Animation Specification (H-Anim) [47] • Joint Photographic Experts Group (JPEG) [48] • Moving Picture Experts Group (MPEG) Standards [49] • Portable Network Graphics (PNG) [50] • Really Simple Syndication (RSS)* [33] • Tagged Image File Format (TIFF) [51] • Web Feature Service (WFS) [52] • Web Map Service (WMS) [53] • X3D [54]

* The standard is relevant to another major data element category and hence appears elsewhere.

6. Concept Prototype

A concept prototype was developed to demonstrate the applicability of integrated gaming and simulation for incident management and to understand the issues due to lack of data exchange standards. A hypothetical scenario was defined to serve as the basis for simulations. A number of simulation and gaming modules were developed to help understand the issues involved in modeling and integration as shown in figure 4. The hypothetical scenario and each of the implemented modules are discussed below with the full capability desired and the subset implemented for the demonstration.

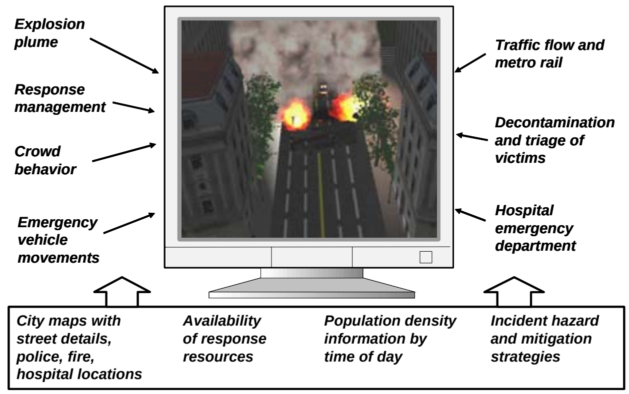

Figure 4. Concept prototype for integrated simulation and gaming for incident management

6.1 Hypothetical Scenario

The scenario for the concept prototype is based on a dirty bomb attack in Washington DC in 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 scenario uses the area outside Federal Triangle metro station, 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 as 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.

6.2 Simulation modules

The simulation modules included in this effort are briefly described below.

6.2.1 Plume Simulation

This module falls in the category of physical phenomena simulators shown in Figure 2. It was implemented using CT-Analyst software from Naval Research Labs [55]. 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.

6.2.2 Crowd Simulation

The capability of modeling crowd behavior is a part of the social behavior simulators group in Figure 2. It 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, and knowledge of the area, that determine their reaction to the incident and the behavior [56].

6.2.3 Traffic Simulation

Traffic simulation is another module in the group of social behavior simulators. 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 researchers at the National Institute of Standards and Technology (NIST) using Java and GeoTools, an open source Geographic Information System (GIS) toolkit [57]. 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 [58].

The micro level traffic simulation capability has been implemented using the 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.

6.2.4 Health Care Simulation

The health care simulation module is part of the organizational simulators group in Figure 2. 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.

6.2.5 Transportation Simulation

Transportation simulation is a part of the infrastructure systems simulators group in Figure 2. 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 working with Brooks Software personnel. It models the evacuation of people from the incident area using the 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.

6.3 Gaming Modules

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

6.3.1 Triage Application

Triage is part of the On-Scene Response group of gaming applications in Figure 2. 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 an airplane crash scenario [59]. 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, and limited lighting conditions in performing his/her responsibilities for conducting triage.

6.3.2 Incident Management Strategy Gaming

The strategy gaming application falls under the Response Management category of gaming applications shown in Figure 2 and is targeted at the management 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 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 [60].

All the modules above were built to represent different aspects of the hypothetical scenario and the ensuing response. Two of the simulation modules, the emergency department simulation and the emergency response vehicle simulation, were integrated together in a distributed set up [61]. Data interfaces were studied for all the modules.

7. Data Exchange Issues Identified

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

- The 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 any of several GIS "standard formats." Multiple GIS file formats have been defined with different versions, earth models, and projections. There is no best combination of these alternatives. Translation errors between the alternatives 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.
- Communication with some of the proprietary tools was hard to implement as they were not designed to interact with external programs.

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 data exchange standards for the simulation and gaming modules. Standards are also needed to enable plug and play interfacing of the modules.

8. Conclusion

A concerted effort is required to enable use of integrated simulation and gaming for incident management applications and thus contribute to improvement of such capabilities. The effort needs to address several fronts including a common understanding of the application and solution spaces and data exchange standards based on common terminology. An architecture was presented to partition the solution space and thus define the scope of the simulation and gaming modules required for incident management applications. A conceptual model was presented to organize the data required for such simulations. Available standards have been mapped to the conceptual data model to establish a baseline. A prototype for integrated gaming and simulation for incident management was built to explain the concept of integrated gaming and simulation and to gain first hand knowledge of the data exchange issues.

Future work is intended to further define 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.

9. Acknowledgement

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10. Disclaimer

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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