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HOMELAND DEFENSE CENTER NETWORK – CAPITALIZING ON SIMULATION, MODELING AND VISUALIZATION FOR EMERGENCY PREPAREDNESS, RESPONSE AND MITIGATION

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ABSTRACT

Emerging simulation, modeling and 3D visualization technologies (3D-SMV) could be used to dramatically improve how we prepare for, respond to and recover from disaster across federal, state, and local lines. It is now possible, at low-cost, to:

- Address 3D-SMV needs with seamlessly integrated, commercial, scalable, networked solutions.
- Provide unique flexibility to reuse 3D-SMV content across PC, laptop, or mobile devices via CD, LAN or Internet.
- Portray fully interactive 3D-SMV on multi-wall display and, without change, on monitors with optional accessories including head-mounted displays, haptic gloves, 3D glasses.

In the Homeland Defense Center Network, ATI is teamed with Eon Reality and University-based Homeland Defense Centers. Each Center has unique expertise in applying 3D-SMV to: urban assessment; surveillance; sensor simulation; critical infrastructure; scalable training; firefighting; and HAZMAT. This paper describes efforts to use these centers to capitalize on 3D-SMV for training and decision support throughout the emergency life-cycle.

1 INTRODUCTION

A wide variety of efforts have been initiated to improve homeland security, including many that capitalize on modeling and simulation tools. The tools include applications for plume simulation for dispersion of radiological, chemical and bio-chemical agents, fire simulations, storm simulations, etc. However, the available simulation tools do not currently integrate Scalable Virtual Reality (VR) & Simulation capabilities. In addition, there is no readily available capability to share information and results across simulation tools.

The 2002 National Research Council report on terrorism (NRC 2002) recommends development and deployment of threat-based simulation models for Emergency Operations Center (EOC) training to identify vulnerabilities in systems and staff and to test and qualify EOC teams throughout the country. Tools in this category use simulations to mimic and present situations created by occurrence of a disaster event. These tools extend from those targeted at decision makers to those targeted at first responders.

Simulation tools for training decision makers present an overall scenario and enable decisions makers to make high level decisions, such as units of first responders to be deployed in different areas impacted by the disaster. Tools at this level typically use one or more computer monitors to graphically display the unfolding of the simulated disaster event and response actions.

A limited number of simulation tools for training of first responders use immersive virtual reality (VR) and allow a first responder to "enter" the disaster zone and react to the simulated unfolding events. Initial analysis indicates that applications should seamlessly use accessories, stereo displays, 3d sound, hand and tracking control, physical feedback to the trainee and/or provide visual cues on the display.

1.1 Homeland Defense Center Network (HDCN)

The Homeland Defense Center Network (HDCN) is a consortium with the mission to help emergency responders enhance public health and safety through 3D simulation, modeling and visualization tools and content. The focus will be on tools and content that dramatically improves coordination, planning, situation awareness, and decision-making of geographically dispersed multi-organization response teams before, during, and after a disaster. The HDCN expects to provide Federal, state and local response teams with ready access to the next generation of training and decision-support. In other industries, these technologies have enhanced retention of training material by over 25 % while increasing viewing by almost 50%.

The HDCN consortium is facilitated by the Advanced Technology Institute and includes Eon Reality and 10 Universities that each act as a regional Homeland Defense

Center (HDCs). The HDCs and HDCN industry members have been working towards low-cost, reusable simulation, modeling and visualization content that every community could use while providing regional access to high-impact, fully-immersive training nationally. To assure reusability, HDCN efforts have been based on emerging industry standards and guidelines. HDCN expects to work with emergency response experts and government agencies to define and realize a roadmap for high priority standards-based research, development and deployment of emergency response simulation, modeling, and visualization.

1.2 HDCN Framework And Basic Requirements

For Homeland Defense Center Network (HDCN) efforts, we identified basic requirements for solutions and underlying development tools. These include:

- **Reduce time and costs to develop models and content for emergency applications** -- using existing 3D simulation component libraries for environments, humans, interactions, incidents (fire, smoke) etc.
- **Be Scaleable**-- applications shall be deployable on various publishing formats, including multi wall immersive systems, stereoscopic or Head mounted displays, PC, Tablet PC and Internet – See Figure 1.

Figure 1: Immersive Environment

- **Provide Flexibility--** permit customization to meet individual scenario needs.
- **Support standardized interfaces** for data import and export between simulation systems, other Software applications and databases.
- **Provide common user interfaces** and enhanced capabilities, e.g., higher level programming languages.

The planned HDCN R&D Framework is defined to enable an organized approach among HDCN members to use when developing applications and products for emergency response. The approach follows the iERF concept suggested by NIST at their March, 2003 Modeling & Simulation for Emergency Response Conference (NIST 2003). The emergency response domain can be classified using various criteria, but the four major dimensions the HDCN has focused on are 1) type of event; 2) emergency life-cycle stage; 3) entities of impact; and 4) Applications and Products.

In "A Primer on Homeland Security" (ANSER 2001), a table (see Figure 2) provides good insight into the Homeland Security mission from the perspective of two of the dimensions - type of event and emergency life-cycle stage. However, the mission is complicated by the third dimension of entities of impact, especially when we realize that the response agencies and the responders are included in that list of entities of impact.

1.2.1 Type of Event

Emergency response agencies have to respond to a number of man-made and natural disaster events. The 2002 National Research Council report on terrorism (NRC 2002) identifies nine focus areas for countering the threat of terrorism using science and technology:

1. Nuclear and radiological threats.
2. Human and agricultural health systems.
3. Toxic chemicals and explosive materials.
4. Information technology, telecommunications.
5. Energy systems.
6. Transportation systems.
7. Cities and fixed infrastructure.
8. Response of people to terrorism.
9. Complex and interdependent systems.

This list is an extension of the list included in the table in the preceding section. While some capabilities are required for many different event types, the type of event will often influence the modeling and simulation capabilities needed. For example, a building explosion and fire 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. Other necessary capabilities include such areas of focus as traffic simulation and information flow simulation.

1.2.2 Entities of Impact

A significant response goal is to minimize the impact of disaster events on "entities of impact". The primary focus is on the population and resources including infrastructure. "Homeland security requires multiple actors, ranging from the federal government through state and local to private entities and individuals, performing interdependently." (Jasak et al. 2002) Models should allow understanding of

	Deterrence	Prevention	Preemption	Crisis Manage-ment	Consequence Management	Attribution	Retaliation
Bio	mission area	mission area	mission area	mission area	mission area	mission area	mission area
Cyber	mission area	mission area	mission area	mission area	mission area	mission area	mission area
Nuc	mission area	mission area	mission area	mission area	mission area	mission area	mission area
Chem	mission area	mission area	mission area	mission area	mission area	mission area	mission area
Radio	mission area	mission area	mission area	mission area	mission area	mission area	mission area
EE	mission area	mission area	mission area	mission area	mission area	mission area	mission area
CS	N/A	mission area	N/A	mission area	mission area	N/A	N/A

Figure 2: Matching Homeland Security Mission for Type of Event and Emergency Life-Cycle Stage

response agency missions, plans, and risk exposures across response disciplines and levels of government. The response disciplines (e.g., emergency management, law enforcement, Emergency Medical Services, and Fire/Rescue) each have very differing missions. Federal, state and local agencies have differing responsibilities and can be expected to arrive at a disaster at different times. The various agency planners and decision-makers need the capabilities to evaluate different strategies to maximize response efficacy in containing and mitigating event impact while allowing them to minimize risk exposure for responders.

1.2.3 Applications and Products

The capability of the Applications and Products will differ, based on their design intent. An application for understanding the impact of the disaster event will have capabilities somewhat different from one used for training emergency response personnel.

Training applications will have more interactive features and will include the ability to unfold alternate simulated event sequences based on trainee response. Similarly, the identification and detection of threat applications will provide a capability for pattern matching against several historical scenarios to determine the likelihood of threat development. Various applications for the emergency response domain are briefly described below.

Training applications include tools that train response agent personnel for the handling of emergency events. These tools may range from interactive simulations, using a monitor, to totally immersive environments. Example training applications include antidote deployment sequence and evacuation management

Planning applications include tools to assess the impact of a disaster event and to aid in development of response action plans. Examples of planning applications include:

- Location of police, fire, and hospital facilities.
- Definition of evacuation procedures.
- Design of a communication infrastructure.

Vulnerability analysis applications focus on evaluation and assessment of emergency response preparedness plans and strategies. Modeling and simulation tools can be used to create a number of disaster event scenarios and evaluate the performance of action plans and strategies. Examples include evaluation of security plans and procedures at a nuclear plant; and evaluation of city emergency response plans

Identification and detection applications include tools that portray given scenarios to help determine the likelihood of a specific type of disaster event. It is anticipated that such tools will use pattern matching logic and past history databases to identify and detect potential threats. Examples of identification and detection applications include:

- Selecting security sweep targets in areas with the majority of inhabitants from a target background.
- Identifying the potential of tornado occurrence, given weather conditions.

Real-time Response Support applications include tools to evaluate disaster impact via real-time situation updates, and use available information to project current and future impact of the disaster. It also includes tools for evaluating alternative response actions and strategies based on the current and projected impact. The evaluations are then used to direct the response actions on the ground.

2 CURRENT HOMELAND DEFENSE CENTER FOCUS AREAS

Each Homeland Defense Center (HDC) has unique expertise in applying 3D-SMV. These unique expertise include: urban assessment; surveillance; sensor simulation; critical infrastructure; scalable training; firefighting; and HAZMAT dispersal prediction. The following organizations currently have HDCs: University of Pennsylvania; Washington State University; University of California Irvine; Texas Tech University; Norfolk State University; George Washington University; University of Central Florida; University of Maine; and University of Missouri-Rolla. Brief descriptions of their current efforts follow.

2.1 University of Pennsylvania Center for Human Modeling and Simulation

The focus is on Human Modeling and Simulation of emergency personnel, security personnel, and cultural immersion, with efforts addressing facial expression tracking, gesture quality recognition and speech analysis. The Center is applying its extensive expertise in human figure modeling and animation, especially with respect to motion specification and control. Example applications include Border surveillance, screening and stronger transportation protection (airport security & checking). The Center is the creator of the "Jack" software (Philips and Badler 1988), used worldwide for human figure animation (see Figure 3) and human factors analysis. Recent research on Virtual Humans includes fast motion generators, natural language interfaces, Parameterized Action Representation (PAR) etc.

Figure 3: Animated "Jack"

The Center's "HDC is designed to train emergency personnel, security personnel, cross-cultural sensitivity, foreign language and cultural immersion," according to Dr. Norm Badler, Director of the HMS Center and Professor of Computer Science at the University of Pennsylvania. "These areas require close-up virtual humans with appropriate behaviors and input channels that can inform them of the emotional or physiological state of the trainee. Some of the methods we use will include facial expression tracking, gesture quality recognition and speech analysis."

2.2 Washington State University

WSU primary efforts are in Hazardous Material (Hazmat) aimed at hands on training in handling and disposing of dangerous devices or chemical/biological materials (see Figure 4). This includes nuclear safeguards (training in facility security) and petro-chemical facilities. WSU VR research includes realistic interactions between human and virtual objects in immersive environments, Bi-directional data integration and Internet-based real-time collaboration between dissimilar systems.

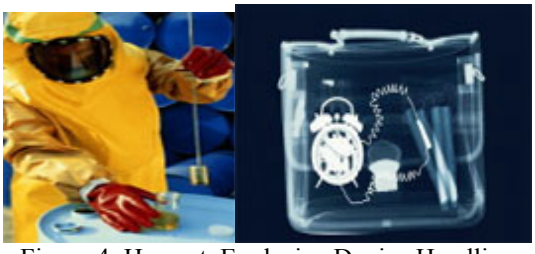

Figure 4: Hazmat, Explosive Device Handling

"The HDC at Washington State University is designed to train emergency personnel, security personnel and first responders, through simulations, in areas such as handling and disposing of dangerous devices or chemical/biological materials, infrastructure anti-terrorist protection and collaboration environments during emergencies. A particular advantage with our joint approach is that all applications are fully scalable, all training can be conducted either on line utilizing normal PC's , immersed using head mounted display or in a theater environment using stereoscopic large screen display systems", said Dr. Sankar Jayaram and Dr. Uma Jayaram, faculty in Mechanical Engineering at WSU.

2.3 University of California Irvine (UCI)

The UCI Homeland Defense Center efforts are aimed at emergency response training and incident response training in urban areas, particularly protection of critical infrastructure (including bridges, critical buildings, rail roads). The Visualization and Interactive Systems Group (VIS) research includes terrain mapping for interactive visualization, vision-based motion tracking for risk assessment (see Figure 5) during catastrophic events, and visualization of large-scale fields with superimposed information. The VIS research efforts are focused on visualization, geometric modeling, computer graphics, and immersive environments.

"The HDC at UCI is designed to train emergency personnel, security personnel and first responders, in areas such as security and rescue training for urban areas. For unplanned events such as terrorist attacks and natural disasters, the quicker one can view the problem, the quicker one can react with a plan. More importantly, emergency procedures can be practiced and reviewed in advance for

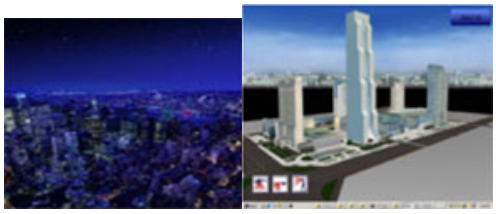

Figure 5: Critical Infrastructure Risk Assessment

many different scenarios enabling various groups working together to understand their roles in the operation. An example would be state and local fire and police working with National Guard troops. Real-time three-dimensional visualization is a fundamental training, communication, and operational tool in the fight against terrorism", said Assistant Professor Falko Kuester.

2.4 Norfolk State University

The Norfolk State University HDC is committed to serving the Hampton Roads area that has become a national center for the military application of modeling and simulation and numerous US Navy operational commands including the Commander Operational Test and Evaluation Force, the Naval Sea Systems Command and the Space and Naval Warfare Center. One key area is maritime security training for border control (training Patrols to secure major US Ports and water ways – see Figure 6). In addition, the NSU HDC will apply extensive web-based expertise in developing scalable web based training applications for first responders that can be seamlessly used either in an Immersive multi-wall system or Head Mounted Displays (HMD) or on a PC.

Figure 6: Maritime Ports, Vessels, and Facilities

2.5 Texas Tech University (TTU)

The Texas Tech Homeland Defense Center efforts are aimed at predictive visualization of dispersions of chemical and biological agents (See Figure 7) in the air, water or within buildings (air- or water-borne local toxic dispersion). This

Figure 7: Gas Dispersal

includes correlation of numerical models for use in chemical/biological areas and adaptation for real time visualization for the purposes of both decision support and communication. In addition, the TTU HDC is working with the TTU task force for Anti-terrorism and Public Security

2.6 George Washington University (GWU)

A key George Washington University (GWU) HDC focus will be protection of US government critical infrastructure (including embassy, consulate, and other government official buildings) from land based vehicle attacks and other terrorist threats (see Figure 8). Other focus areas are transportation safety and security and Executive level responder training for emergency preparation. The HDC will build on experience in modeling and simulation of vehicles, traffic, complex networks, Intelligent Transportation Systems, crashworthiness and occupant protection, and Emergency Management. The HDC will integrate event driven simulations, intelligent agent technologies, and physics based models of vehicles, humans, etc. into an interactive 3-D environment as research, planning, and design tools. These tools and scenarios will be used to dramatically enhance training and to develop "smart" plans that include contingencies.

Figure 8: Protecting Facility Perimeter

2.7 University of Central Florida (UCF)

The UCF HDC approach is to systematically apply simulation, modeling and visualization technology to develop cost effective, scalable and web-based training content (see

Figure 9) to help emergency response individuals, groups and organizations improve their performance and effectiveness. The UCF HDC uses operations research techniques to assess needs and a total systems approach to select the best mix of technology, people and resources to address a performance enhancement need. In addition, the UCF HDC capitalizes on a unique combination of expertise in curriculum management, distance learning and Web-based instruction positions to help provide emergency responders with hands-on modeling and simulation solutions for distributed instruction and training on a local or global scale. UCF develops reusable applications based on SCORM, The Sharable Content Object Reference to create one unified 'content model'.

Figure 9: Reusable Content from Web to Immersive Environment

2.8 University of Maine

The University of Maine has extensive efforts in Crisis Management and is a Co-founder of the Multi-Sector Crisis Management Consortium. Its long-standing activities in Crisis Management/Homeland Security include two major focus areas: 1) Firefighters training for terrorist attacks and disasters (see Figure 10); and 2) Training of first responder volunteers and public. Much of these efforts are within the Extended Homeland Security Laboratory at the University of Maine

Figure 10: Fire-Fighting Training

2.9 University of Missouri Rolla

The new WMD Detection and Decontamination Center is a joint effort between the Center for Intelligent Systems and the Virtual Reality and Rapid Prototyping Laboratory at the University of Missouri-Rolla (UMR). The initial focus is in developing and studying the use of advanced virtual environments for support of homeland security planning and training of first responders. A simulation system incorporating virtual reality technologies is currently being developed to train first responders for terrorist attacks with use of Weapons of Mass Destruction (See Figure 11). The facilities will be used to develop scenarios too dangerous and/or expensive to replicate in a live environment, initially for chemical agent detection and decontamination training. The goal is to provide highly realistic virtual training experiences with integrated physical equipment that can help to evaluate and enhance the effectiveness of first responders. The intent is to capitalize on capabilities developed by the UMR Virtual Reality and Rapid Prototyping Laboratory. These provide collaborative environments that allow interaction between experts at geographically dispersed locations and creation of virtual models by sculpting in virtual reality environments.

Figure 11: Chemical Training Exercise Courtesy of U.S. Army (Released)

3 SUMMARY

The Homeland Defense Center Network (HDCN) is capitalizing on emerging 3D simulation, modeling and visualization (3D-SMV) technologies to develop tools and content to support federal, state, and local emergency response planning, training and decision-making. The HDCN is a collaboration between technology leaders, including Eon Reality and the Advanced Technology Institute, and Homeland Defense Centers across the nation. Homeland Defense Centers, each with unique capabilities in 3D-SMV, are currently located at: University of Pennsylvania; Washington State University; University of California Irvine; Texas Tech University; Norfolk State University; George Washington University; University of Central Florida; University of Maine; and University of Missouri-

Rolla. This breadth of Centers provides support for each region of the nation, while capitalizing on diverse expertise to develop 3D-SMV solutions for various event types (e.g., nuclear, biological, chemical).

To maximize the impact of HDCN efforts, we have identified basic requirements to realize low-cost, flexible, scalable and reusable 3D-SMV tools for planning and decision-making before, during and after a disaster. The HDCN plans to develop reusable 3D-SMV content based on emerging industry standards and guidelines that could be reused at low-cost in every community while establishing regional centers for high-impact, fully-immersive training. This will provide the tools to help response personnel enhance public health and safety by enabling them to more effectively plan and train for effective response while providing responders with instant, highly visual access to mission-critical information when emergency strikes. Federal, state and local response teams will gain ready access to the next generation of training and decision-support based on modeling, simulation, and visualization.

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