TRAINING FIRST RESPONDERS TO NUCLEAR FACILITIES USING 3-D VISUALIZATION TECHNOLOGY

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ABSTRACT

The development of an advanced visualization and simulation tool for first responder exercises and education is presented. This tool exploits cutting edge computer graphics, physics-based effects modeling, virtual reality, and gaming technologies to establish a system that can eventually be used for the administrative planning and training of first responders in homeland security, homeland defense, and combating terrorism communities.

1 INTRODUCTION

To fix ideas, consider that an event has occurred at a college research reactor requiring the response of the local fire and police departments. Unfortunately, when they arrive precious time is lost while first responders are briefed on the layout of the facility as well as those areas that must be protected (areas containing safe shut down equipment). In addition, the personnel must be trained on the use of Geiger counters and other radiation monitoring equipment, the meaning of the various radiation signage and symbols used throughout the facility, and what materials to avoid. Also, the response teams must be taught the difference between contamination and radiation.

In the current political atmosphere, the possibility of such an event occurring is real and local first responders must be trained to handle such events. However, with the current tools, training of the police, fire department personnel, paramedics, etc. would prove too costly for most facilities. Therefore, a low-cost effective training tool must be developed that would allow first responders to tour the facility in a "safe" virtual environment without the risk of radiation exposure or contamination. With the application of the Unreal engine such a tool can be realized.

The application of the Unreal engine (Epic Games) to the representation of a fictitious nuclear research reactor facility located in an urban environment is described. This model could be easily deployed to federal, state, and local first responders to allow them to become familiar with the facility in the event of an emergency situation. The next section will provide background on the use of the Unreal engine, the following section will provide the methodology of developing the model. The last two sections will provide a sample application and the conclusion, respectively.

2 BACKGROUND

With the advent of computers running at greater than 3 GHz and graphic cards containing ½ GBytes of memory, a new realm has been created for the representation of data on desktop computers. Using these contemporary computers, technical writers have gone from creating simple training manuals with artist drawings of complex operations, to complex three-dimensional objects that can be rotated, dissembled, or explored. One of the more obvious applications of 3-D graphics is in the field of computer gaming. Titles like *Doom*, *Quake*, or *Unreal Tournament* may seem like a far stretch from technical training applications; however, these "games" can provide a practical tool in the displaying of and interaction with a simulated environment.

Previously, if an artificial environment was needed for a training exercise, a very specialized application (with an intense learning curve) was required. These applications allowed the user to build the environments, but were limited in the amount of interaction that the end user was allowed to exploit. Also, these "environments" required significant preplanning; they were essentially an animated motion picture production. If the camera angle was not correct, the animation had to be redone. With the leaps that technology has taken, an interactive representation is now possible. With these environments a user can move around both inside and outside and look at the components within the facility from various angles; the user is no longer limited to the creator's pre-conceived "best" view.

The next section will describe how a realistic virtual environment can be designed quickly using inexpensive tools with minimal training, by means of the Unreal runtime package.

3   METHODOLOGY

3.1 Runtime Engine

Creation of a training module requires two elements. The first is the virtual runtime engine. For a virtual environment to be believable, it requires an engine that combines the ability to incorporate both sophisticated shapes and textures as well as algorithms to display (render) them rapidly and in a smooth continuous fashion. It is this ability to quickly render an image that distinguishes the Unreal runtime engine from other software packages that provide fixed rendered images or movies. Because of the ability of the Unreal engine to produce a quality interactive model in a real-time environment, both internally as well as externally, it was chosen as the preferred virtual runtime engine.

The engine allows for modeling the diverse areas within a complex facility along with the vicinities adjacent to the structure. Such vicinities can include populated areas, which can include non-combatant characters that can be programmed to "react" to various situations. The Unreal engine also allows for the inclusion of hazardous environments, such as a radiation environment, into our model. The previously introduced features, packaged with advanced lighting, allows one to create realistic and immersive training environments.

3.1.1 Hazardous Environment

Radiation within a nuclear facility can not be immediately felt or seen. It can only be detected through the use of monitoring devices. One such device is the classic Geiger counter.

The importance of understanding the use of these instruments is vital. For example, if an individual would pick up a Geiger counter and turn it on near a nuclear facility, it would naturally start "chirping", leading an untrained person to thinking he was in a radiation area caused by an event at the facility, when in fact it is only from the natural background radiation field that exists everywhere.

In addition, an untrained operator, can easily misinterpret the display, leading to tragic conclusions. Like a volt meter, a Geiger counter has multiple scales; therefore, if an operator is unaware of the scale setting, he may believe the radiation field is several orders of magnitude higher then the actual value. Or more seriously, he may think the field several orders below the actual value.

Using a library of simulated instruments and virtual environments a player can be taught how to use the various instrument as he or she enters different simulated radiation areas. The radiation field within each of the various virtual environments can be indicated by a simulation of the display of each counter, which will be displayed at the base of the screen as part of the Heads Up Display (HUD).

The implementation of a radiation area is achieved through the use of Unreal's "LavaVolume" (Busby, Parrish, and Eenwyk 2005) designation which allows the designer to model hazardous areas that directly affect the players health. The affect on the health of the player is controlled via the DamagePerSec property. Thus for high radiation fields, a value could be set that would cause the player to be incapacitated after a specified amount of time.

Through the use of runtime scripts, the radiation field can be adjusted. As an example, if the spent fuel pit was cracked (allowing for draining) the radiation field above the pool could be greatly increased as the water level drops.

3.1.2 Other Engine Highlights

Other capabilities in the runtime engine include the modeling of non-players (workers, spectators, or other personnel that could be found in or near the facility). In the current version, these non-combatant characters are static (i.e., they are not animated and remain still) due to the lack of an artificial intelligence (AI). This issue however could be resolved with the inclusion of such programs as SOAR (Magerko et al. 2004). With SOAR, these characters can be programmed to react to radiation poisoning or the fear associated with an unknown event (i.e. a radiation/chemical leakage).

The Unreal Engine also allows for predetermined lighting schemes. What this means for the end user is a more realistic interpretation of shadows in a facility, especially on floors that in real life have poor lighting. This utility could also be extended to include different times of day, either night or day, and allow for varying training conditions.

3.2 Virtual Environment

The second element is the virtual reality environment. The virtual environment provides a training world that allows the "player" to explore a potentially hazardous environment from the safety of his computer. Typically, a model is constructed using the editor that is included with Unreal, Unreal Ed (UED). UED provides a user friendly interface to create realistic facilities. The intuitive interface allows for a smaller learning curve than what was associated with previous techniques (as described in the background section). All of the Unreal engine's capabilities are accessible through UED, making it no longer necessary to have access to the source code of the engine, and eliminating the need to have an extensive programming background.

To enhance the virtual environment, real photographs of plant equipment or interior/exterior walls can be used as textures within the model increasing the realism of the model. UED also allows for the cases where a photograph might not be readily available by allowing for importation of textures from a variety of other programs that could be used for creating realistic textures. The most useful of these programs is Adobe's Photoshop. The use of either photographs or Photoshop allows the designer to create textures that will make the environment more realistic and immersive.

3.3 Facility Vulnerability

Unlike most industrial facility, constant cooling must be provided to a nuclear reactor (for small research reactors this cooling is provided by a surrounding pool) for several days following shut-down. The equipment and associated support systems that provide this reactor cooling capability in the event of an emergency, i.e. emergency core cooling system (ECCS), must be protected. The ORNL developed Visual Interactive Site Analysis Code (VISAC) (Sulfredge, et. al, 2004) software suite was designed to provide the probability of core damage in the event a piece of vital equipment was damaged.

VISAC is a Java-based expert system that provides mission planners with a coordinated capability to predict and analyze the outcomes of different accidents/incidents at various nuclear and industrial facilities. The incidents can range from simple individual equipment sabotage to complex sorties that utilize a range of military weapons, simulated truck or car bombs, or satchel charges. The tar-get facility is generated by either customizing existing 3-D CAD models for near real-time analysis or creating a new model from scratch. Using event/fault tree methodology, VISAC provides the probability of facility kill, the probability of undesirable collateral effects (chemical or radiological releases), and an estimate of facility down time. VISAC is supplied with a library of models that can be customized by the user in both geometry and logic to approximate a number of facilities of interest.

In the future, the VISAC system will be tied to the virtual reality environment to provide immediate feedback to the player on the safety condition of the facility.

4   SAMPLE IMPLEMENTATION

To illustrate the usefulness of the virtual environment, a fictitious facility has been created within an urban environment; the facility represents a gas cooled research reactor with forced cooling. In addition to the reactor building, a separate structure is included that houses the spent fuel storage pool. An overview shot of the facility is provided in Figure 1.

The model is used to illustrate a nuclear facility that could be found at most large Universities. The facility includes several key components that are typical to most research facilities. A charging plate, control room, charging towers, environment shield, spent fuel pool, cranes, and a conference room are represented in our facility. In the simulation, the facility has been located in an urban environment similar to a college area or a downtown type of environment. Though non-player characters are not represented in this version, the vicinities around our facility
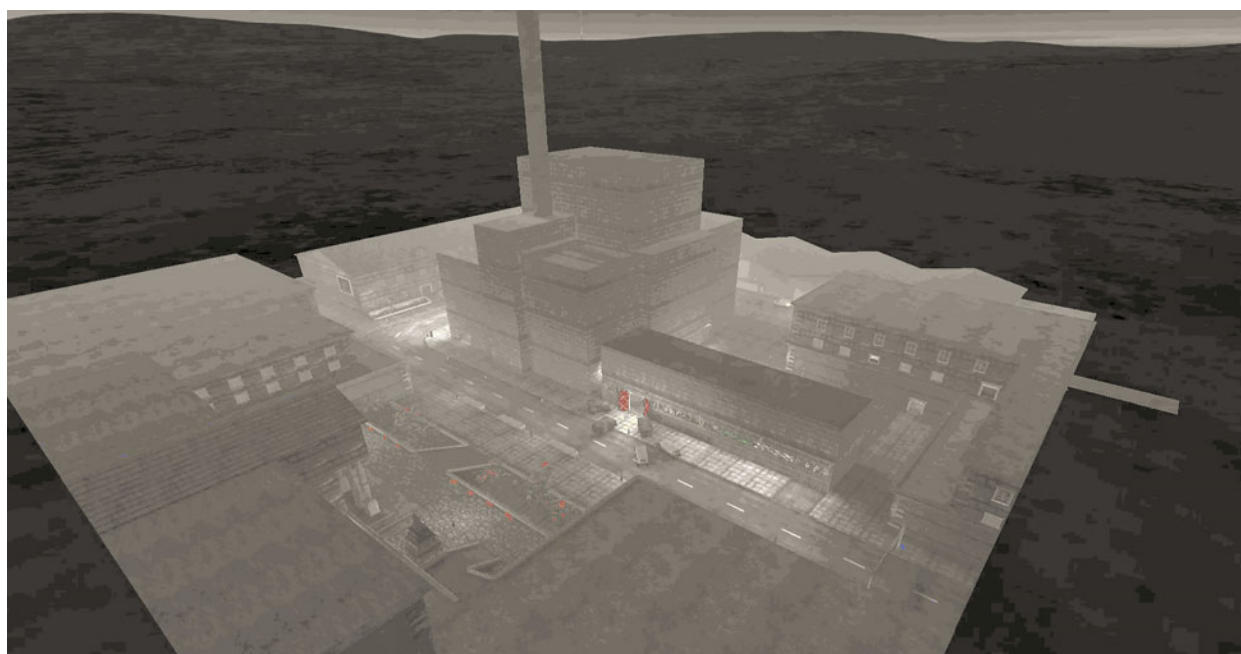

Figure 1: Overhead View of Research Reactor

make it easily conceivable that the area could be populated and that the threat of a catastrophic event at the facility could have great implications for the surrounding populace if a quick and efficient response is not implemented. The following are some of the highlights within the facility.

Figure 2 shows an underwater storage edifice. The structure consists of essentially a water containing storage pool. Within the pool could be any radiation sources from spent fuel to Co-60 radiation sources. Above the pool, is the handling equipment consisting of the fuel handling machine and cask lifting crane, which is located at the rear of the canyon, see insert.

Figure 3 exhibits the reactor refueling floor located on top of the reactor core. At this location, the fuel is inserted and removed from the reactor located beneath the ground level. Also situated on this floor are the heat exchangers that provide cooling to the reactor. Situated several feet above the refueling floor is the main control room where the operators supervise all operations occurring on the refueling floor.

Figure 4 illustrates the vital equipment located beneath the refueling floor. This equipment provides both the normal and the emergency circulation through the reactor core. In the event of an emergency this equipment must be protected from damage. As previously described, this equipment will be integrated with the facility vulnerability code VISAC in the future. Upon establishment of the link between Unreal and VISAC, an immediate feedback to the player will be given on the status of the facility along with the probability of core damage in the event any of the vital equipment is damaged, resulting in possible core damage and subsequent release of contamination to the surrounding area.

5   CONCLUSION

With the current political environment, University research reactors, which are typically located in urban areas, are potential candidates for terrorist attacks. Therefore, local first responders must be ready to respond to any threat at these facilities. Because of the potentially hazardous environments associated with any nuclear facility, training of first responders is an essential part to a successful containment, cleaning, and safety operation. The virtual environments proposed here allow for a low cost option for administrative planning and to help train a variety of first responders so that they will know how, when, and where to act if such an event were to occur.
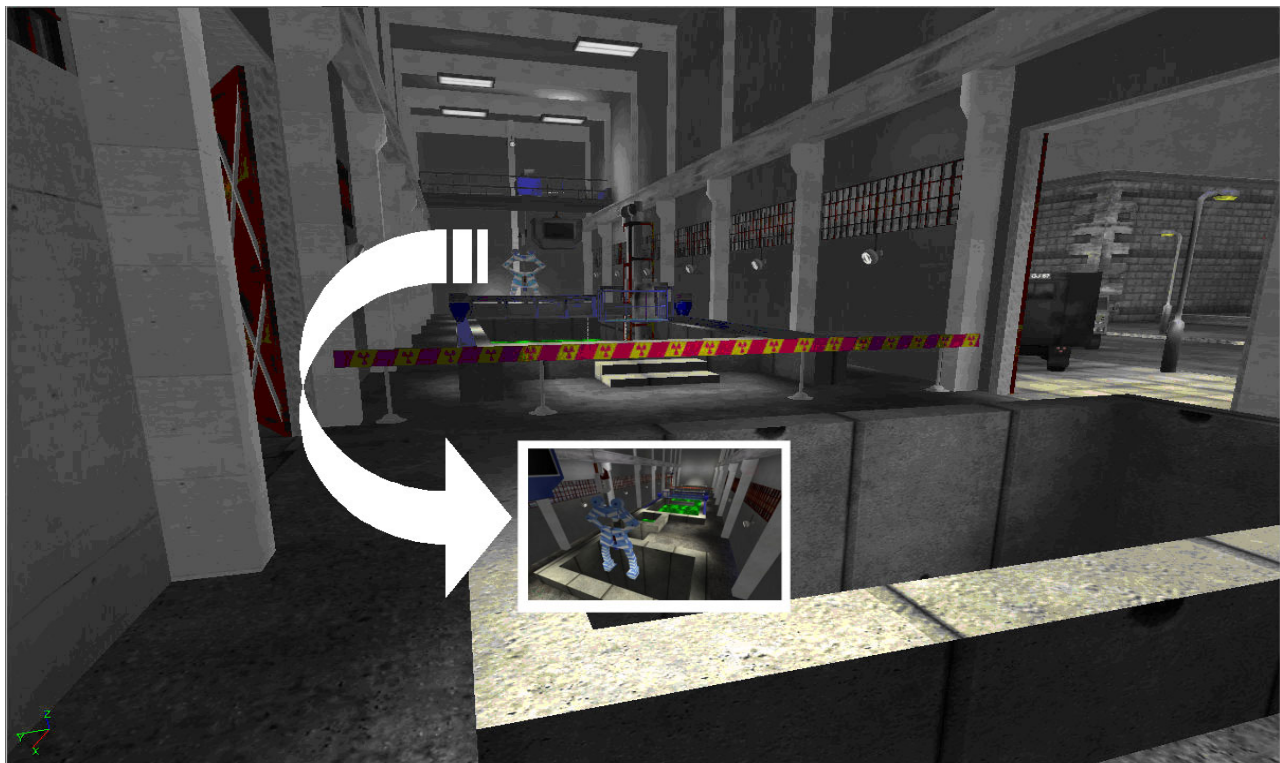

Figure 2: Spent Fuel Pit Area

Figure 3: View of Refueling Floor

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AUTHOR BIOGRAPHIES

ROBERT L. SANDERS is a Senior Design Engineer at Oak Ridge National Laboratory. He is currently involved with studying the vulnerability of various facilities (nuclear as well as chem./bio) to blast damage from military or terrorist weapons as part of a project for the Defense Threat Reduction Agency (DTRA). As part of this work, he founded development of a Graphical User Interface (GUI) to provide fast and easy access to the facility vulnerability database developed through the use of blast calculations. This interface, designated as VISAC (**V**isual **I**nteractive **S**ite **A**nalysis **C**ode), is a tool that allows an analyst access to several thousand plant damage calculations. This provides the user with a convenient, cost effective way to investigate the consequences of explosive blasts within a facility. His e-mail address is `sandersrl@ornl.gov` and his Web address is http://visac.ornl.gov.

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Figure 4. Exterior of Lower Portion of Reactor Vessel Showing Circulators