Virtual Simulation for Training Personnel in Emergency and Security Preparedness and Counteraction

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Abstract **— This paper reports the use of virtual simulation that aims at training personnel for preparedness and counteraction in emergency and security threats. A low-cost platform for virtual simulation has been reused, taking advantage of important features already implemented in this platform. A virtual nuclear site is simulated considering some hypothetical security threats, with invaders trying to steel or escape with nuclear material. Multi-user simulation is performed, with some people belonging to invaders team while others belonging to the responders' one. Virtual cameras installed in the environment help responders monitor suspect behaviors, as well as virtual radiation monitors help detect hidden nuclear sources. Results and further possibilities are commented.**

Keywords **— Emergency preparedness, Security threat counteraction, Virtual simulation.**

I. INTRODUCTION

Emergency preparedness and security threats counteraction are important matters in many different situations, ranging from industrial plants to public environments. Industrial plants such as nuclear, radioactive and chemical plants, among others, involve potential risks for personnel and for the general public. They must be kept in safe and normal operational conditions. Any abnormality must be readily and efficiently solved so as to bring them back to normality. If these requisites are fulfilled, society can benefit from their products and services, with risks minimized.

Besides operational conditions, these types of industrial plants may also involve security matters. They contain materials that may be hazardous if misused, and thus must be highly secured. These may be nuclear sources, chemical products or biological materials to which only authorized personnel can have access. They must manipulate these materials following specific standards so as to keep safety and security while executing their tasks.

Emergencies and security matters may also occur in public environments, where rescue staffs, as policemen and Firefighters, have to aid people from unintended events or even from intentional attacks.

In all cases, it is important to train personnel to be prepared and to counteract these matters. In fact, personnel working in industries or rescue personnel are trained to face emergencies, periodically. Training routines can serve evaluation of many different scenarios, as well as improvements of the corresponding procedures to mitigate risks.

In this context, computer-based simulation has become a good choice for training, since people can face problems first in a safe environment, before being trained in the real ones. Thus, different conditions can be evaluated with simple modifications in the computer simulated environments. These later, in turn, have to represent the corresponding real environments with high fidelity. Computer-based training are not intended to substitute completely training in real environments, but can aid the later. In some cases, computer-based training may be the only possibility, in the cases where risks would be so high that training in the real environments could be very difficult.

In particular, virtual environments have been used by some research groups for these purposes, ranging from training operational activities in nuclear and other industrial plants to response in emergency situations [1]-[21]. Researchers have been reusing computer game engines towards many serious applications [22]-[25] like those mentioned above, besides other as military training [26]-[27]. These game engines constitute the core of computer games, and have already implemented some very important characteristics that enable friendly navigation and interaction among users, and between users and the environments.

This work follows the approach of reusing a game engine. A low-cost game engine serves different simulations, among which security situations. Currently, two cases are described, both involving unauthorized access to nuclear sources, what must be readily counteracted by responders. The game engine features enable friendly adaptation and simulation of these cases, and as will be shown, can be used to simulate many other hypothetical threats. Many users can participate and interact to achieve the desired objectives. Results are shown along with perspectives.

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II. Game Engine Reuse

Researchers who want to perform simulations for the purposes cited in the former section might choose to buy commercial simulation software or to develop their own platforms. First option involves high costs, while developing a computer simulation platform may be a hard work itself. That is the reason for the success in the bridging between computer games and simulation. This has been a very promising field, enabling researchers to concentrate in their own objectives in simulation, taking advantage of all the embedded features. Among the available computer games, two of them have been cited as very suitable for these purposes: Unreal Engine from Epic Games and Quake from ID Software [22]. Our staff has chosen the former, Unreal, but the later should fit our needs as well. In fact, most references found cite the use of Unreal.

Embedded features in game engines comprise: (i) good dynamical graphical rendering; (ii) representation of all the physics involved, to simulate Gravity, collision and movement; (iii) multi-user participation, a common functionality in computer games, either in local networks or through the Internet; (iv) easy environment design; and last, but no least, (v) low cost for research or academic use [22]. Graphical rendering would be a difficult task if it were to be implemented from the beginning. Thus, its implementation in game engines lets researchers free for other tasks. Physics representation turns navigation a very natural experience for users. Multi-user participation enables a number of users to navigate in the virtual environments, seeing each other and interacting among themselves, as well as with the environments, as passing through doors, and colliding with walls or other objects. These game engines come with editors to enable gamers design their own environments, what also enable researchers design their virtual environments.

The following subsections describe the implementation details, specially related to the objects created to fulfill security simulation needs.

1) Virtual Modeling

The virtual environment developed comprises building models that correspond to real ones in the real environment, as well as others that are fictitious. The entire virtual environment, including buildings and open areas, are modeled first by using CAD software, and then these models are imported into Unreal. Fig. 1 shows the modeling stage of two buildings. The one at left is a virtual (hypothetical) deposit for nuclear materials, while the other at right is a building comprised by rooms and laboratories. Textures obtained from photos in the real environment were pasted on walls and other objects for a more realistic appearance. Open space around the simulated environment was also obtained through the use of textures from photographs of the sky and neighboring places, since they are not relevant for simulation, but only for visual appearance purpose.

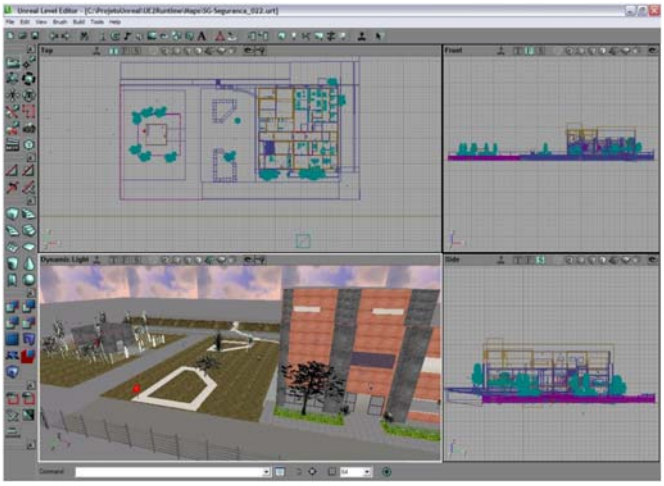

Fig. 1. Virtual CAD model of the simulated environment.

2) Avatar Movement

Avatars are the virtual persons that navigate within the virtual environment, each avatar corresponding to an online participating user. Avatars have been implemented, in a first moment, as controlled by users. This means each avatar moves exclusively under user's control actions, thus following user's cognition. Each one decides how to move his or her own avatar through computer keyboard and mouse commands, or through the use of joysticks. Cognition-based action is very important for user response's evaluation, especially when they face unexpected situations.

Either walking or running movement can be chosen. In emergency situations, as in evacuation from buildings, walking is recommended to avoid any further emergencies because of people falling during escape. But in security situations, running might be chosen in actions to capture invaders. Both velocities have been adjusted to realistic values, so as simulations could represent real situations with fidelity.

More recently, autonomous avatars have also been developed by our staff. They follow specific human-controlled avatars. But security simulations do not make use of them, up to the present, as avatars belong to teams that have to cooperate in coordinated actions.

3) Virtual Cameras

Virtual cameras have been included to simulate real ones that would be installed in the corresponding real environment. Each camera is an object defined in the virtual environment through programming, with its location and direction defined. Thus, the scene obtained from that position at that direction is available for presentation, online, during simulation.

Virtual screens have also been created in the virtual environment, where the cameras' views are presented for users during simulation.

Therefore, it all works as there were cameras installed in the environment, with their respective scenes projected on virtual screens in a surveillance central, to be monitored by a user belonging to the responders' team.

4) Invasion Strategy

To simulate invasion of the deposit building, a fence has been made that begins oscillating and falls in a prescribed time, after an invader touches it. Of course other strategies could be implemented, as the ones already implemented for opening doors, but this was the one chosen to simulate invasion because it gives an impressive view of an unauthorized access.

5) Strategy to Steel Material

The strategy chosen to simulate invaders steeling nuclear material has been implemented by approaching an avatar of this team to the object representing the material to be stolen. Once the avatar approaches it, the later immediately becomes attached to the avatar's body. The avatar can thus walk or run carrying the object.

6) Strategy to Capture Invaders

The strategy adopted to catch invaders has been implemented also by approaching an avatar of the responders' team to the invader's one. The later then becomes unable to move anymore by user's control, but only took by the responder avatar.

7) Nuclear Sources Representation

Nuclear sources have been represented as point sources, through objects created with decaying dose rate levels inversely with square of distance. These objects can me made visible or not, and can also have fixed location in the environment, or can move with avatars.

In this work, the source to be used in the simulation may be visible or not. In the invasion simulation it is visible, but in the escaping simulation it is invisible, so as other avatars could not see it, mainly the ones belonging to the responders' team. It has also been made a moving object, following the position of the invader avatar that aims at sneakily escaping carrying a nuclear source.

8) Nuclear Sources Detection Strategy

An object has been made that detects the radiation dose rate values in its proximity, similarly as a real radiation monitor would do. This object senses the dose rate value that had been defined in the nuclear source object, as described in the former subsection.

III. Results

Both case studies are presented, first one corresponding to an invasion of the simulated site, and the second corresponding to an avatar trying to escape with a nuclear source, detected by a radiation monitor. This later is the most recent development in this R&D. The former is based on [28].

1) Plant Invasion Counteracted by Responders

Fig. 2 shows the virtual deposit building during a simulation, with an avatar positioned near the fence that surrounds it. This fence's entrance becomes oscillating until falling over the ground, once an avatar touches it. This scene shows the avatar in third person view, in which the user sees his or her own avatar from behind. There is another view mode, – the first person view –, where the user does not see his or her avatar, but rather sees the virtual environment exactly from the avatar's position.

Fig. 2. Virtual deposit building and avatar.

Fig. 3 shows the virtual surveillance central with its screens. The leftmost and rightmost screens show different views of the site's limits. The second camera, from left to right, shows an invader trying to enter the deposit building through its fence. The third camera, from left to right, shows the deposit interior, with materials and the nuclear source's case indicated as a blue cylinder.

Different simulations have been performed, with invaders coming from different locations to reach the deposit building. Considering the entire modeled area, two virtual cameras directed towards the outer fence were sufficient to detect the avatars' movements. The camera directed towards the inner fence, in front of the deposit building, is a key one that displays clearly the invasion with the fence falling over the ground. Once the responder standing at the surveillance central detects the malevolent behavior, responders can run to catch the invader.

The main merits of this first simulation are the possibility of using virtual cameras and their corresponding dynamic scenes, in a way that is very similar to real situations. Also, avatars can interact with objects or with other avatars by approaching them, a strategy that showed to be sufficient for the desired purposes.

Fig. 3. The virtual surveillance central with its screens.

2) Tentative of Stealing Nuclear Source

In this case, among many avatars leaving a building, one tries to sneakily escape from it carrying a nuclear source, stolen from a laboratory within this building. In this case, the malevolent behavior cannot be detected by visual means, since the source has been made invisible to simulate a person carrying a hidden object, as would be the case in real situations. A virtual radiation monitor, instead, detects the dose rate level due to the point source, when the invader avatar approaches the one with the monitor. This monitor can be an instrument carried by an avatar belonging to the responders' team, or can be a hidden monitor installed in a door, as well as existing real ones; when somebody tries to pass trough that door, the monitor alarm indicates the dose rate detection.

The next figure sequence shows the monitoring result in the screen's center. Figure 4 shows a null dose rate level (meaning below the background level), a normal situation. Fig. 5 and Fig. 6, though, show abnormal situations due to an avatar trying to escape with hidden nuclear material. When this invader's team avatar approaches the responder's team one that is with the radiation monitor, a rising radiation dose rate level is shown on screen. As he or she approaches more the monitor's position, dose rate level increases. This was shown to demonstrate the monitor's character of detecting dose rate inversely proportionally with the square of distance.

Fig. 4. Normal situation with null dose rate indication.

Fig. 5. Abnormal situation with somebody carrying a hidden nuclear source.

Fig. 6. The effect of nuclear source approaching monitor.

The main merits of this second simulation are the possibility of representing a potential hazardous material that can act at distance, – exemplified by the dose rate level –, that can also be made invisible and that can be detected by an instrument. This open the possibilities of representing any other hazardous conditions.

Both experiments demonstrated the viability of reusing this platform to perform multi-user simulations considering important factors that resemble much the corresponding real environments and situations.

It is not only a matter of demonstrating only the modeling stage of the desired environments, but really the simulation itself, since user-controlled avatars walk within the virtual environments interacting among themselves, and with the environment objects. Users' cognition play the role for the avatars actions, what enables they act as they would do in real environments, taking decisions by reasoning.

IV. Perspectives

This work showed the reuse of an existing computer platform suitable for performing virtual simulation towards more serious applications. The platform reused comprises a number of important features that enables easy adaptation for researchers' purpose, easy creation of virtual environments as well as different objects with specific functionalities. These may be virtual cameras and screens, radiation sources and radiation monitors. Multi-user capability enables performing simulation with a number of users interacting among themselves and with the environment, what can serve to evaluate scenarios with different teams. Users' controlled avatars follow their cognition, what turns simulation more realistic, as people behave similarly as they would do in real situations.

This platform proved to be a very flexible tool that can be used to simulate many different critical scenarios for training personnel for emergency and security preparedness and counteraction. This paper showed two example scenarios, but many others could be planned and tested, depending on end-users' needs.

The fact of game engines have low cost is very attractive for researchers, since they do not need, at least in a first moment, to spend much money. The availability of a platform with so suitable features for virtual simulation prevents researchers from developing a platform from the beginning.

Besides the case studies presented in this work related to nuclear applications, simulations could be readily adapted for other industrial plants and for many other emergency and security threats situations. The simulations performed aim at verifying proof of concept of such an approach for security matters. Two example simulations were performed, but more complex ones can be planned, according to the end-users needs; one can the sky is the limit, since a great number of users can participate simultaneously, and further features may be added, to turn simulations even more realistic.

The invisible radiation point source spreading doses around it could be a source of hazardous material of other types, as the liberation of chemical or biological contaminants. The radiation monitor could be any other measurement instrument.

The reuse of Unreal Engine has showed to be a good choice for performing virtual simulations for training emergencies and security situations.

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