Nuclear Plants and Emergency Virtual Simulations based on a Low-cost Engine Reuse

Carlos Alexandre F. Jorge[1,2], Antônio Carlos A. Mól[1,3],
Pedro Mól Couto[1] and Cláudio Márcio N.A. Pereira[1,3]
[1]Comissão Nacional de Energia Nuclear, Instituto de Engenharia Nuclear
[2]Universidade Federal do Rio de Janeiro
[3]Universidade Gama Filho
Brazil

1. Introduction

Our industrialised society comprises many industrial processes that are very important for everyone, in a wide range of fields. Activities related to these industrial processes, though, involve, in higher or lower degrees, some risk for personnel, – besides risk for the general public in some cases. Therefore, efficient training programs and simulations are highly required, to improve the processes involved, increasing safety for people. To cite an example, nuclear plants pose high safety requirements in operational and maintenance routines, to keep plants in safe operation conditions and reduce personnel exposure to radiation dose.

Besides operational and maintenance in nuclear plants, there are also other situations where efficient training is required, as in evacuation planning from buildings in emergency situations. Also, rescue tasks play similar role. These apply specially for nuclear sites.

Another situation that requires efficient training is security, what has special meaning for plants that involve dangerous materials, such as nuclear plants. Nuclear materials must be kept under high security level, to avoid any misuse.

With these problems in hand, personnel such as supervisors, trainers and planners, traditionally make use of training programs that may involve both theoretical and hands-on stages. However, computer-based training can help training, if performed before the hands-on training stage, for example, so people can face the specific problem they are being trained for, first in a safe environment, before going to the real ones. Computer-based simulations can thus reduce personnel exposure to risky factors, as radiation dose in the nuclear plant example, during the first training experiments. In some cases, training in the real plants or sites can be very dangerous, – if not impracticable –, as in simulations dealing with fire or nuclear contamination avoidance. In these cases, computer-based simulations may be the only means of training and evaluation.

Many publications span through the use of computer-based simulation for training. For the present R&D, two main application-specific problems can be emphasised: (a) computer-based simulation for training of personnel in operational and maintenance tasks, as

exemplified by the following references (Moltenbrey, 1999; Lee et al., 2001, Sebok et al., 2002; Badler et al., 2002; Bluemel et al., 2003; Bluemel et al., 2009; Bloomfield et al., 2003; Ohga et al., 2005; Ródenas et al., 2004; Ródenas et al., 2005; Nystad, 2005; Rindahl et al., 2006, Lebedev et al., 2007; Meyer, 2007); and (b) training for emergency preparedness and response, exemplified by (Louka & Balducelli, 2001; Jain & McLean, 2003; Jain & McLean, 2005; Sanders & Lake, 2005; Shendarkar et al., 2006; Van de Walle & Turoff, 2007).

Virtual reality-based simulations find an important role in computer-based simulations due to their immersive and interactive characteristics (Burdea & Philippe, 1994; Pimentel & Teixeira, 1995; Vince, 1995; Stuart, 1996).

In this work, the interest falls into a more specific use of virtual reality-based simulation, through the reuse of low-cost computer game engines. In particular, one of them was chosen, which is free for academic use, and flexible enough for adaptation to a diversity of application-specific problems.

Game engines reuse for serious applications has become a strong tendency in research (Lewis & Jacobson, 2002; Rosenbloom, 2003; Zyda, 2007; Threnholme & Smith, 2008), being part of the research field known as "serious games". Application-specific problems range from a diversity of areas, as military training (Manijlovich et al., 2003a; Manijlovich et al., 2003b; Prasithsangaree et al., 2003; Prasithsangaree et al., 2004; Zyda et al., 2003; Chatam, 2007), and rescue simulations in emergency situations (Wang et al., 2003a; Wang et al., 2003b; Wang et al., 2003c; Carpin et al., 2009), just to cite some high safety- and security-related ones.

This work deals specifically with the reuse of a game engine for the following simulation problems: (a) dose exposition evaluation for workers in nuclear plants, (b) evacuation from buildings in emergency situations, (c) security threat counteraction in nuclear sites.

2. Related work

This Section gives a brief introduction to R&D work by other research groups, related to the present one, either in the approaches adopted or in the problems to be solved. Some R&D groups adopt more similar or quite different approaches in which virtual reality-based simulations are used, including game engines reuse. This bibliographical research helped making choices among the different approaches found in the literature.

2.1 Emergency and security related simulation

Emergency situations may occur in a broad range of scenarios, as in industrial plants, buildings, or public places. Emergencies may also involve different hazardous factors, as fire and smoke, a diversity of contaminants – as nuclear, chemical or biological ones–, or other related security threats. Here it becomes clear the possible co-occurrence of emergencies and security threats.

To counteract these situations, training is required, what is carried out, in general, in the real places, with people who occupy them. For example, it is common practice to perform building evacuation training with those people who occupy it, so as they can learn how to escape from the building in an appropriate manner, in the case of real emergencies. Also, staffs responsible for planning evacuation and rescue tasks, benefit from these training, as better strategies can be tested and evaluated.

As mentioned in Section 1, though, computer-based training can improve training performance, since people can evaluate different scenarios and conditions first in a safe and flexible environment.

There are different approaches for computer-based evacuation training, that may comprise communication functionalities to improve people's skills, or the use of autonomous avatars (virtual persons) guided through some specific rule, to evaluate crowded situations.

2.2 Radiation dose simulation in nuclear plants

Different research groups have proposed this type of simulation, for personnel training. Operational and maintenance tasks can be tested and evaluated first in such a safe environment, before people enter the real plants. Based on the simulation results, supervisors can perform better planning of working activities. Thus, unnecessary radiation dose is avoided in the first training stages, fulfilling the As Low As Reasonably Achievable (ALARA) principle (ICRP, 1991), which states, in other words, radiation dose for people must be minimised.

Researchers have proposed different approaches for dose simulation (Brissaud & Ridoux, 1992; Knight et al., 1995; Knight et al., 1997; Vermeersch & Van Bosstraeten, 1998; Vermeersch & Van Bosstraeten, 2000; Lee et al., 2001; Nystad et al., 2002; Sebok et al., 2002; Hajek et al., 2004; Ródenas et al., 2004; Ródenas et al., 2005; Ohga et al., 2005; Kim & Park, 2005; Xu & Bushart, 2006). From these R&D, basically two approaches can be summarised: (a) dose rates collected from measurements in the corresponding real plants, (b) dose rates computed by simulation codes.

In all cases, it is common practice to compute and present users the dose received by the avatars according to the time spent in each location within the plant. One important aspect is that, the more accurate is the dose rate representation, the more accurate will be the received dose computation.

2.3 Serious games

Researchers who intend to perform computer-based simulation could make use of commercial simulation software, or develop their own platforms. The former approach may involve high costs, while developing codes may be a hard work itself. But in the last years, researchers noticed that some first-person computer game engines are very suitable for scientific and technological applications. Game engines comprise the core of computer games, which encompass some functionalities that are independent of the specific application for which they were designed, and are very desirable for other non-game simulations (Lewis & Jacobson, 2002). These functionalities are: (a) physics representation – such as Gravity effect and collision handling, (b) efficient graphical rendering capabilities, (c) networking capabilities. The later enable multi-user interactive simulation.

As long as some of these game engines are free or have low-cost for academic use, and are flexible enough to be adapted and reused (Lewis & Jacobson, 2002), researchers can concentrate in their own fields of application and research, taking advantage of all those embedded functionalities.

Among the available game engines suitable for R&D, two of them are recommended as very good choices (Lewis & Jacobson, 2002): Unreal from Epic Games, and Quake from ID Software. Unreal was chosen as platform for this R&D from the beginning, but Quake

should work as well. A broader overview of game engine reuse was covered in a more recent paper (Threnholme & Smith, 2008).

3. Game engine reuse methodology

A free version of Unreal Engine was chosen, which is free for academic or research use, UnrealEngine2 Runtime Demo Version, and is available for download from http://udn.epicgames.com/Two/UnrealEngine2Runtime.html, where the End User License can also be obtained.

As mentioned in Section 2.3, Unreal Engine encompass functionality as physics laws representation, specifically Gravity effect, walking and running velocities and collision detection among avatars, or between an avatar and the virtual environment.

Other functionality is its very efficient graphical rendering capabilities, what would involve hard R&D working, if it were to be implemented. As long as this is already embedded in Unreal Engine, researchers do not need to worry with its technological challenges anymore. Both perspective and stereo views can be chosen.

Another important point is networking, which is also highly desirable in computer games, since they are designed to be played simultaneously by a number of people, in local networks or through the Internet, interacting among themselves. Thus, in serious applications, people can see and experience collision with other people's avatars.

Fig. 1. Unreal Engine classes' structure

Unreal Engine comes with a scenario editor, – named UnrealEd –, originally intended for gamers to design their own playing scenarios. This editor can be used by researchers to design any desired scenarios to be simulated, as plants or buildings. This is done by importing to Unreal Engine scenarios built on CAD software, and generating textures from photos taken in the real places to be simulated.

This R&D work was implemented by personnel of Instituto de Engenharia Nuclear, Comissão Nacional de Energia Nuclear – IEN, CNEN (Nuclear Engineering Institute, a R&D Institution of Brazilian Commission of Nuclear Energy). Therefore, the virtual environments implemented correspond to or are based on some existing buildings within this Institution.

Both male and female avatars are used, from modification of existing ones that had unrealistic dimensions. Users can choose avatars' dressing colours, to differentiate among users.

Unreal Engine source code is not available in this free version used, but the Engine enables code implementation through a scripting language similar to Java, – named UnrealScripting. Original code follows object oriented philosophy, with classes and hierarchical structure. Thus, a class inherit functionality from higher level ones, besides adding their own functionality. Researchers cannot modify existing classes, but can instead replicate them, and perform modification in these new created classes. Therefore, researchers have, in principle, broad possibilities to implement their own desired functionalities.

Fig. 1 shows current classes' structures, with original and created classes. A colour legend enables class identification: (a) in blue: original classes, (b) in orange: general purpose created classes, (c) in green: evacuation simulation-related created classes, (d) in purple: security simulation-related created classes, (e) in red: dose simulation-related created classes, (f) in yellow: other interface-related created classes.

3.1 Modifications for evacuation and security related simulation

The virtual environment for evacuation simulation corresponds to a real building of IEN, with its three floors, rooms and laboratories, designed virtually from its architectural design data. Furniture was also added. Fig. 2 shows the design stage in UnrealEd for this virtual building. In fact, two buildings were designed, the one used for this simulations was the one shown at the right side (in the upper left frame of Fig. 2).

The original avatars' velocities were not realistic, so they had to be changed to more realistic ones. Walking velocity is the important one for emergency and other related serious simulation, since people are supposed to walk in these situations, because running can lead to more serious consequences. Also, within nuclear plants, people execute their tasks walking or standing, but not running. Thus, walking velocity was fixed to a typical value of 1.5 m.s^{-1}.

A time counter was implemented to compute time spent by each avatar, during evacuation simulations. Each user sees his or her own elapsed time on screen.

One user is needed to control each avatar. There is no rule for guide autonomous avatars for now, it is under implementation currently. An advantage of this approach is that users' natural cognition plays an important role, since anyone can make decisions from what he or she sees relatively to other avatar's behaviour. For example, in evacuation simulation, a user can decide to get back when sees other avatars coming from a locked exit. Thus, people behave in a way similar to that they would do in real situations, making their own decisions

through reasoning. Results of this part of the R&D were published earlier, describing implementation details (Mól et al., 2008a).
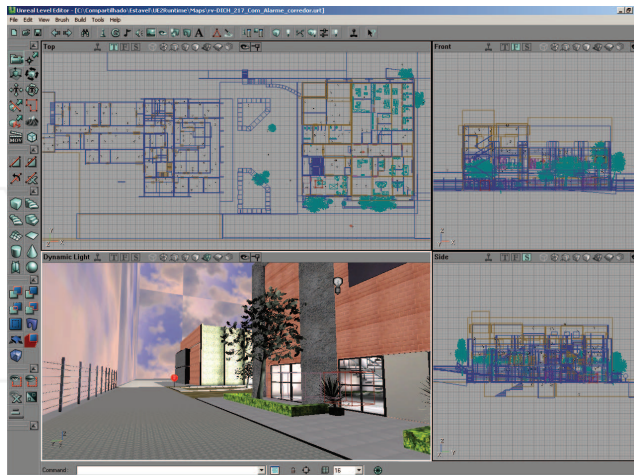

Fig. 2. IEN building's design in UnrealEd

For the security related simulation, a hypothetical scenario was designed, in part considering the real IEN campus, but introducing a virtual nuclear material deposit that would be subject to threat. IEN's campus is supposed to be invaded by intruders to steal nuclear material in that deposit. They must be detected and caught by responders. Fig. 3 shows the developed scenario, where the hypothetical deposit is shown to the left side (in the upper left frame of Fig. 2). Comparing Fig. 3 with Fig. 2, it can be noticed that this hypothetical deposit was designed to the left of the building previously used for the evacuation simulation (in place of the other formerly existing virtual building). Results of this part of the R&D were published, describing implementation details (Augusto et al., 2009).
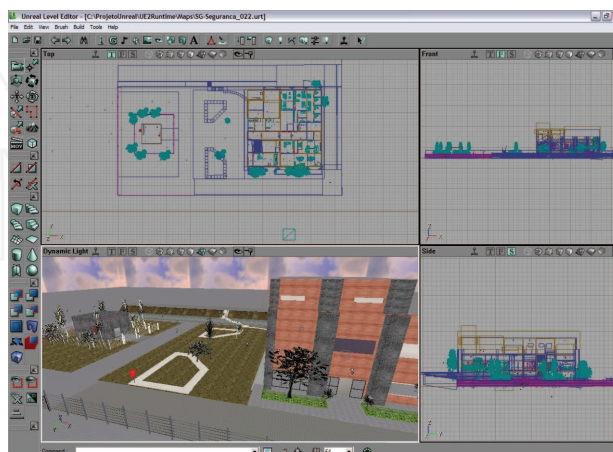
Fig. 3. Hypothetical security-threat scenario

3.2 Modifications for radiation dose simulation in nuclear plants

For this application, an existing nuclear plant at IEN was virtually modelled: Argonauta research reactor. This reactor have been in operation since 1965, used mainly for R&D in nuclear applications. These later span from non-destructive evaluation of materials using radiation, – such as radiography with gammas or neutrons –, to radioisotope production for industrial applications. It is also used as support for the experimental activities of the graduate course of IEN itself, – which as its own graduate program in nuclear engineering and technology –, besides graduate courses of other universities of Rio de Janeiro State, as Universidade Federal do Rio de Janeiro (Federal University of Rio de Janeiro) and Instituto Militar de Engenharia (Brazilian Army's Military Engineering Institute). Some operational tasks, as for example non-destructive evaluation, require that personnel enter and stand or walk through Argonauta's room. Maintenance tasks also require that personnel enter that room. In both cases, they receive dose, what is unavoidable. Simulation can help though optimising tasks planning, to fulfil ALARA requirements.

In this case, the virtual environment was also designed from its architectural design data, thus the virtual environment corresponds to the real one, to evaluate working activities in the safe environment. Fig. 4 shows the design stage in UnrealEd for this nuclear plant.
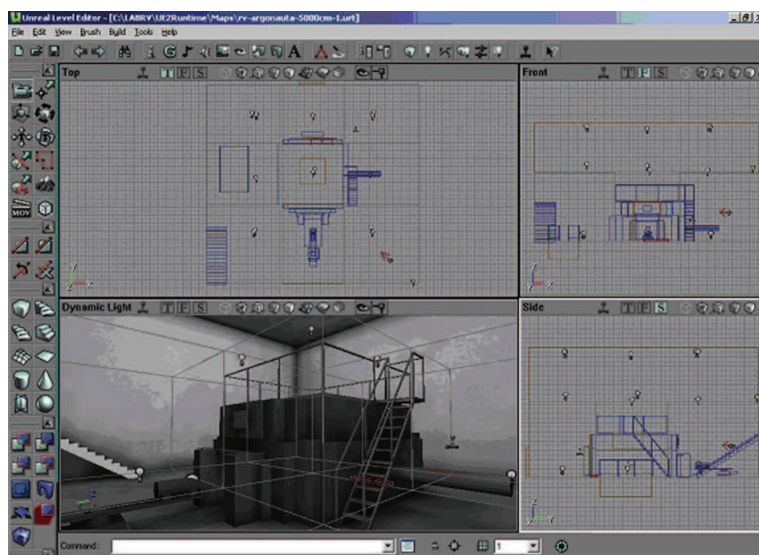

Fig. 4. Argonauta reactor's design in UnrealEd

3.2.1 Offline dose rate

This application specific problem was solved following the approach of using measured dose rates, instead of dose rate computing. There were measurements available, previously collected by the radiological protection service of IEN, during operational routines, which could be readily imported into Unreal Engine. The idea is similar to that used by another research group (Ródenas et al., 2004; Ródenas et al., 2005), which implemented a grid of points corresponding to dose rate measurements. At the time this R&D begun, only scarce

data were available, so a gross grid of points was implemented, but the idea could be demonstrated. A more detailed data distribution would have to be obtained later by other means.

The dose received by the avatars is computed by the dose rate value at its location, considering the time spent there. This was implemented through the use of volumes, in fact prisms with rectangular bases, each one assigned to a constant dose rate value, to represent the hot regions within Argonauta's room. The Engine is able to identify the collision between an avatar and any of these volumes, assigning to the avatar the corresponding dose rate value, for received dose computation. The application informs users on the screen either the dose rate value at his or her position, or the total received dose up to the present time. These prisms can be noticed in Fig. 4 (in the lower left frame). Results of this part of the R&D were published earlier, (Augusto et al., 2007; Mól et al., 2009a).

3.2.2 Online dose rate

The following R&D stage improved simulation through the use of online dose rates, collected by radiation monitors installed in the real plant. Dose rate may vary during operational or maintenance routines, in the former case due to operational power level modification, and in the later one due to opening of any barrier to access the fuel rods in the reactor core or auxiliary radiation sources. This cannot be considered in the former approach, but can be taken into account with this second one. Thus, this is a clear advantage of the online measurement approach.

IEN's staff had for long term developed electronics instrumentation for the nuclear field, what resulted in a diversity of radiation monitors, both portable, to be handled by radiological protection service supervisors during activities, and others to be installed in hot locations (as within nuclear plants' rooms). Those monitors span different types of radiation detection capabilities with the appropriate probes. Some of them were patented and licensed to manufacturing industries.
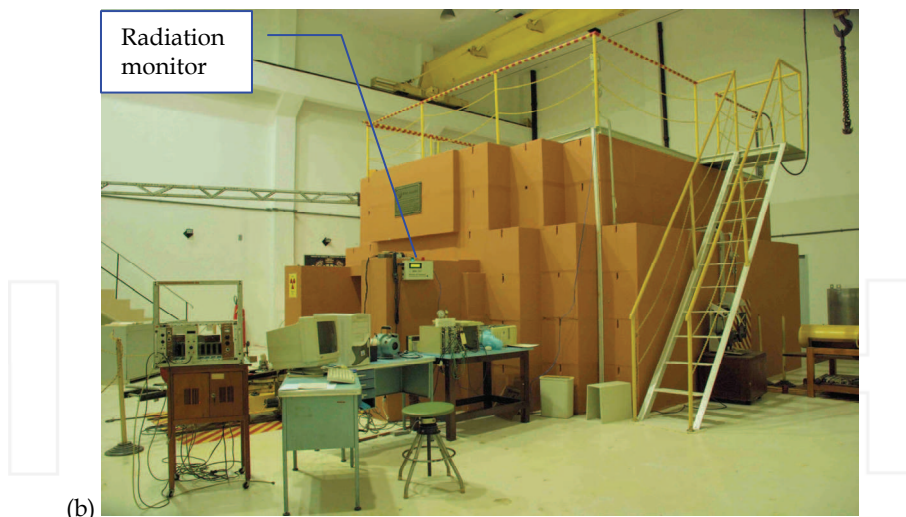

Output radiation channel

(a)
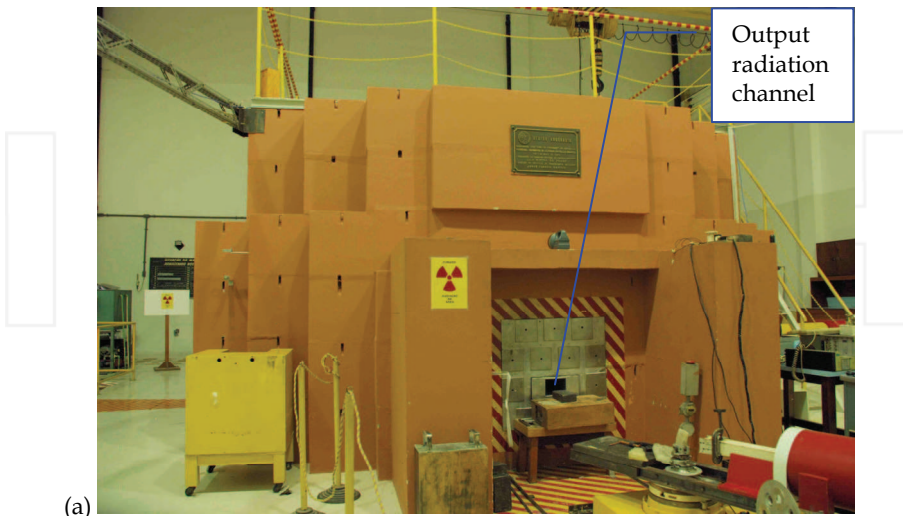
Fig. 5. (a) Argonauta reactor's output channel; (b) One radiation monitor installed near Argonauta's output channel

This R&D made use of one monitor to be installed within nuclear plants rooms, named MRA 7027, for gamma or neutron measurement (Oliveira et al., 1997; Oliveira et al., 2000). Two of them were installed within Argonauta's room, at key locations: (a) one near the entrance, (b) and the other near the output radiation channel, in front of which materials to be tested are put for evaluation, and where dose rates achieve higher levels. Many other monitors could be networked, to collect online data from different locations, depending only on manufacturing and installation of new MRAs, but the main principle could be demonstrated.

Fig. 5a shows Argonauta reactor's output channel, while Fig. 5b shows one of the installed monitors.

This radiation monitor may be networked through RS-485 local network or TCP/IP protocol. The later enables its remote use through Internet. In general, networking is performed with a supervisory computer that presents data for users on screen. In this R&D, measured data was imported into Unreal Engine for avatar's received dose computation.

Three processes were developed for this purpose, in a scheme known as Man in the Middle (MiM): (a) one process collects and publishes data from the monitors, (b) another process feeds these data to Unreal Engine, (c) an intermediate process performs communication (and optionally some processing) between the two former ones.

These three processes can reside in the same computer, or in separate computers. This MiM process was developed with the macro language AutoIt (www.autoitscript.com/autoit3), and communication make use of HTTP protocol version 1.1. Fig. 6 shows the MiM scheme.

Results of this part of the R&D were published earlier, (Mól et al., 2008b; Mól et al., 2009b).
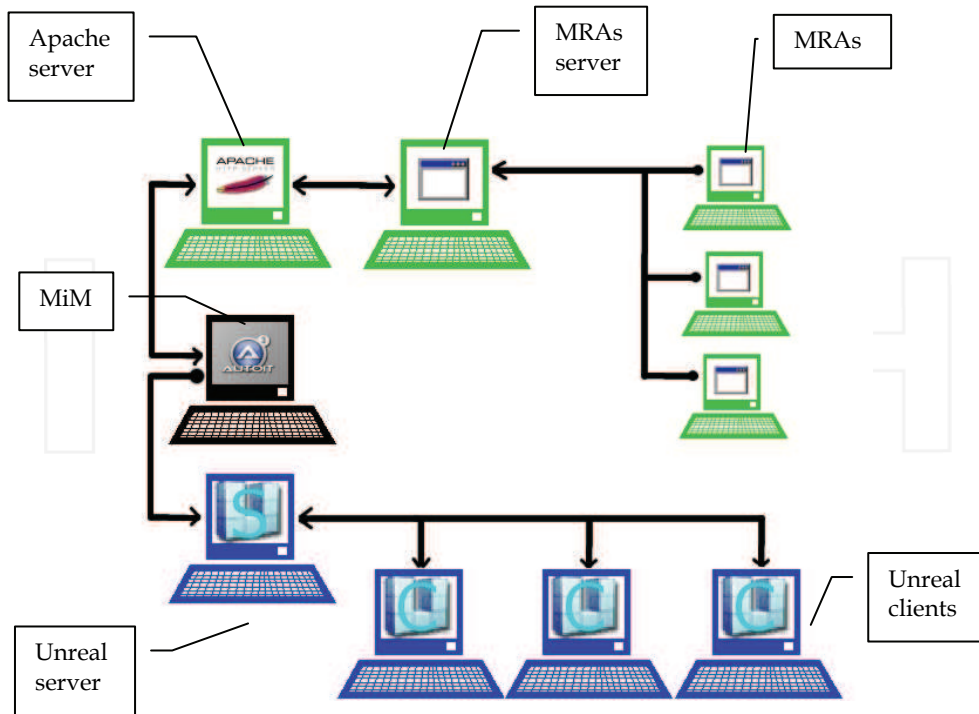
Fig. 6. Networking the monitors with Unreal Engine through MiM scheme

3.2.3 Interpolated dose rate

The later achievement in this R&D, relatively to the dose simulation problem involved two aspects: (a) obtain radiation dose measurements in a finer grid of points within Argouauta's room, for different operating power levels, (b) combine both the offline measurements referred above and online data collected by the radiation monitors to interpolate dose rate for different power levels.

For the former purpose, a measurement campaign was carried out, using portable radiation monitors at a finer grid of points, in a region in the frontal part of Argonauta, meaning to the output radiation channel side. This was so because this region is subject to higher dose rates, and other regions' measurements resulted in dose rate levels around background level, and as such, was not considered in this stage. The region was subdivided into three subareas, comprising the one just in front of the output channel, and two other ones to the sides. Fig. 7a, Fig. 7b and Fig. 7c show the considered areas, named respectively: Area 1, Area 2 and Area 3. Area 2 is the hottest one. Fig. 7d shows the remaining areas not considered, grouped in the so-called Area 0.

Fig. 7. a), b) and c) The areas considered for finer grid of measurements; d) The area not considered

For the later purpose, an intelligent interpolation system was developed using neural networks, to take into account unknown nonlinear effects in dose rate distribution due to power level variation. General regression neural networks (GRNN), (Specht, 1991; Schøler & Hartmann, 1992; Caudill, 1993) were trained, and results showed the system is performing well. Aim is to predict dose rate values for cases not measured, which may occur during tasks execution and can be detected by the radiation monitors installed within Argonauta's room. Results of this part of the R&D were published earlier, describing implementation details (Freitas et al., 2009).

4. Results

4.1 Results for evacuation and security simulation

Relatively to the evacuation simulation, both real and virtual tests were performed for comparative analysis, aiming to evaluate if the later one could really be used as preliminary simulations before the real ones. First tests considered just one person evacuating the building at a time, and later ones considered more people evacuating the building simultaneously. Two runs were performed: (a) one considering only one person, (b) another considering three persons evacuating simultaneously, and results showed the virtual simulations agreed with the real ones.

Fig. 8 shows a simulation screen shot for a third-person view, within the simulated building. In third-person view a user sees his or her own avatar, while for first-person view user does not see the avatar, but rather sees the virtual environment as he or she would do from the avatar's position. The time counter for this avatar is shown in the lower left screen's corner.

Fig. 8. An evacuation simulation screen shot within the building and the time counter

As mentioned in Section 3.1, users' natural cognition plays an important role, and people behave in a way similar to that they would do in real situations, making their own decisions through reasoning. Thus, each user tends to control his or her own avatar for walking through corridors and stairs in a very natural way, searching for the shortest paths. Avatars do not walk, in general, in prescribed paths, as for example in straight lines in the middle of corridors or stairs. Users guide them to freely walk through general curved paths to shorten distances. That is the way people walk in real situations.

Also, as mentioned in Section 3.1, users can make decisions from what they see relatively to other avatars' behaviour. For example, in evacuation simulation, people can decide to get back and search for another exit when see other avatars coming from a locked one, or when see a crowded exit. An example of a crowded exit is shown in Fig. 9. In this situation, an user's avatar may be unable to escape, and have to wait the others get out before going through that exit.

Fig. 9. An example of a crowded exit

Figure 10 shows an avatar escaping through an automatic sliding door. In this case, user has just to get closer to the door to open it. In other cases, for conventional doors that must be pulled, an user's avatar must get close to that door and get back just a bit to give space for the door open. Therefore, preliminary training must be performed so users get familiar with gaming itself, to control the avatars.

Fig. 10 shows another interesting detail. Outdoor environments can be simulated too, but in a rather different way. While indoor environments is designed with CAD software, considering all architectural details, before being imported into Unreal Engine, outdoor environments are designed also with textures obtained from photos taken in the real locations. Fig. 10 shows another campus, external to IEN (in fact the campus of Universidade Federal do Rio de Janeiro), took by photo. But it does not influence simulation, since it only takes part within IEN's campus, it only gives a more visual realism for users. For more details see (Mól et al., 2008a).

Fig. 10. Avatar escaping through a door with outdoor texture-based view

Fig. 11 The hypothetical virtual building of nuclear material deposit, used for the security threat simulation

For the security threat simulation, avatars can run. During simulations, intruders invade the IEN's campus and also the deposit, to steal nuclear material. An avatar of the intruders' team steal material by getting close to it. Then, the intruder can left place running carrying the stolen material. Fig. 11 shows the hypothetical virtual building of nuclear material deposit, used for the security threat simulation.

Four virtual cameras were implemented in Unreal Engine, to simulate surveillance video cameras that would be installed in a real situation. Those virtual cameras' displays are shown in Fig. 12. A supervisor is supposed to monitor any suspect behaviour and inform it to security staff responders, that must immediately catch the intruders. In the virtual simulation, an intruder is caught when an avatar of the responders' team get close to an avatar of the intruders' team, and the later cannot move anymore.

Fig. 12 The four virtual cameras' displays to monitor and detect suspect behaviour

In Fig. 12 it is possible to notice each camera is directed towards strategic views. From left to right: (a) the first camera focuses IEN's campus terrain limit, to detect any invasion; (b) the second one focuses the deposit building, where it is possible to see an avatar of the intruders team trying to invade it; (c) the third camera focuses the deposit building interior, showing the nuclear materials to be monitored; (d) the last one shows also another view ot IEN's campus terrain. Other virtual cameras could be implemented, but simualations were performed with these four, to demonstrate the idea. For more details see (Augusto et al., 2009)

4.2 Results for dose simulation

Results for offline radiation dose rate measurements comprise both gammas and neutrons, because routine measurement involves both types of radiation. Fig. 13 shows a screen shot of such a simulation, viewed in the 2 m × 3 m projection screen available at the Virtual Reality Lab. of IEN, CNEN. This is one option for users, besides the view on PC screen. In both cases, perspective or stereo view can be chosen. It can be noticed both received dose for both radiation types (gammas and neutrons), and also the total received dose, sum of the

two. Received dose is shown in nSv, although its is usually shown in µSv, for the following reason: in µSv, the dose value increasing would take long term, while in nSv users can see clearly the increasing dose value, what gives them a better notion about the ambient dose rate at their position. For more details see (Augusto et al., 2007; Mól et al, 2009a).

Fig. 14 shows results for online measurements. A in this case only gamma data is available, the neutrons column is null. This lacking data could be presented too, if the installed radiation monitors measured dose rate for both types of radiation. Thus, it is only a matter of using different probes, if needed. In Fig. 14a results are shown for radiation dose rate for the two monitors, – for which the virtual ones are indicated –, installed in Argonauta. In Fig. 14b, though, results are shown for received dose for each avatar present in the simulation. Users can switch between both views. For more details see (Mól et al, 2008b; Mól et al., 2009b).
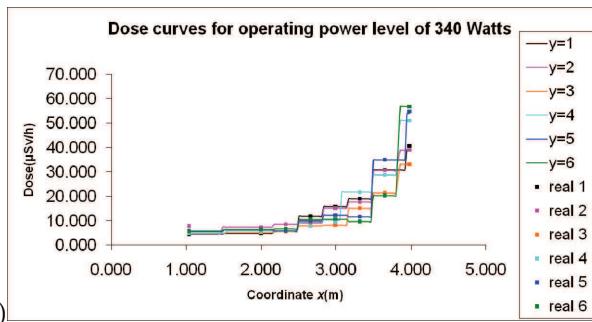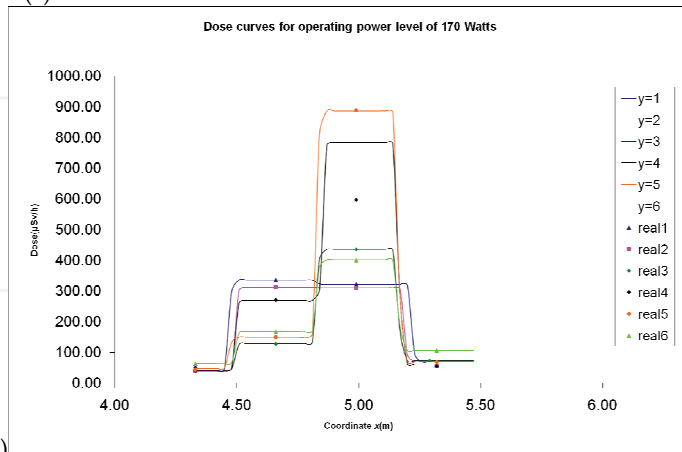

Fig. 13 Offline radiation dose simulation.

(a)

(b)

Fig. 14. Online radiation dose simulation: (a) radiation dose rates collected by the two real monitors; (b) radiation doses received by each avatar.
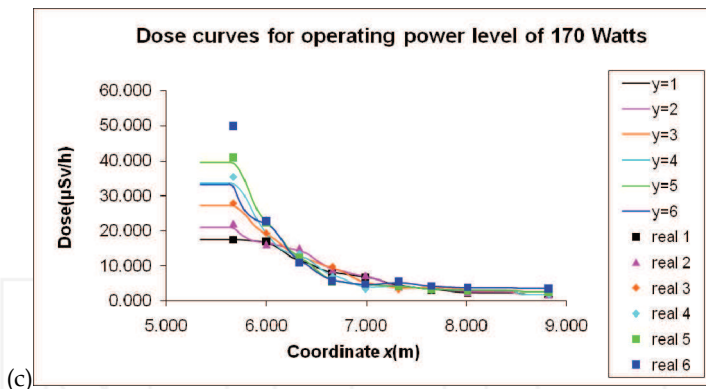

(a)

(b)

Fig. 15. Interpolated radiation dose rates: (a) Area1, operating power level of 340 W; (b) Area2, 170 W; (c) Area3, 170 W.

Results for the interpolated dose rate R&D stage are shown in Fig. 15. Fig. 15a shows interpolation dose rate curves for the operating power level of 340 W, for Area 1, for each x coordinate value; Fig. 15 b shows similar results for 170 W in Area 2 (in front of Argonauta's radiation output channel, see Fig. 7b); while Fig. 15c show results for 170 W in Area3. The points are the values measured during the campaign, while the curves were interpolated by the GRNN. There are many other curves, for the other operating power levels, and also for Area 1 and Area 3, but these three were chosen as example. For more details see (Freitas et al., 2009).

5. Concluding remarks and perspectives

This R&D has been supplying interesting results up to the present, for a diversity of application-specific problems: evacuation simulation in emergency situations, security threat counteraction and received radiation dose simulation, all as support to improve safety for people and security relatively to hazardous materials.

IEN's staff plans to continue and expand this R&D, either improving simulations through more detailed implementations, or directing it towards other application-specific problems. One possibility is to improve interaction between avatars, as with text or voice transmission through computer networking. Another possibility under development is the development and implementation of combined image and video processing and pattern recognition for people tracking within nuclear plants, to assign dose rate values online and dynamically, according to their movement. Other application field of these tracking and recognition techniques is security, for people tracking and identification, as well as suspect behaviour identification.

The reuse of computer game engines have proved to be a very flexible and time-saving platform for serious applications, what encourage us to continue this bridging between consumer graphics and simulation.

8. References

Augusto, S.C.; Mól, A.C.A.; Jorge, C.A.F.; Couto, P.M.; Cunha, G.G. & Landau, L. (2007). Use of virtual reality to estimate radiation dose rates in nuclear plants. *Proceedings of the 2007 International Nuclear Atlantic Conference (INAC 2007)*, DVD-ROM, ISBN 978-85-99141-02-1, Santos, SP, Brazil, September 30 to October 05 2007, ABEN, Rio de Janeiro

Augusto, S.C; Mól, A.C.A.; Couto, P.M. & Sales, D.S. (2009). Using virtual reality in the training of security staff and evaluation of physical protection barriers in nuclear facilities, *Proceedings of the 2009 International Nuclear Atlantic Conference (INAC 2009)*, DVD-ROM, ISBN 978-85-99141-03-8, Rio de Janeiro, RJ, Brazil, September 27th to October 02, ABEN, Rio de Janeiro

Badler, N. I. (2002). LiveActor: a virtual training environment with reactive embodied agents, *Workshop on Intelligent Human Augmentation and Virtual Environments (WIHAVE)*, University of North Carolina at Chapel Hill, Chapel Hill, NC, October 2002,

Bloomfield, A.; Deng, Y.; Rondot, P.; Wampler, J.; Harth, D.; McManus, M. & Badler, N. (2003). A taxonomy and comparison of haptic actions for disassembly tasks, *Proceedings of the IEEE Virtual Reality*, pp. 225–231, ISBN 0-7695-1882-6, LA, CA, March 2003, IEEE

Bluemel, E.; Hintze, A.; Schulz, T.; Shumann, M. & Stuering, S. (2003). Virtual environments for the training of maintenance and service tasks, *Proceedings of the 2003 Winter Simulation Conference (WSC'03)*, pp. II-2001–II-2007, ISBN 0-7803-8131-9, New Orleans, Louisiana, December 2003, IEEE

Bluemel, E.; Termath, W. & Haase, T. (2009). Virtual reality platforms for education and training in industry. *International Journal of Advanced Corporate Learning*, Vol. 2, No. 2, 2009, 4–12, ISSN 1867-5565

Brissaud, A. & Ridoux, P. (1992). PANTHERE RP: a tool for prevision of dose rates, *Proceedings of the 8th International Congress of the International Radiation Protection Association (IRPA 8)*, pp. 2-1677–2-1680, Montreal, Quebec, Canada, May 1992, IRPA

Burdea, G. & Philippe, C. (1994). *Virtual Reality Technology*, John Wiley & Sons, ISBN 0-471-36089-9, New York

Carpin, S.; Lewis, M.; Wang, J.; Balakirsky, S. & Scrapper, C. (2007). USARSim: a robot simulator for research and education, *Proceedings of the 2007 IEEE International Conference on Robotics and Automation (ICRA'07)*, pp. 1400–1405, ISBN 1-4244-0601-3, Rome, Italy, April 2007, IEEE

Carpin, S.; Lewis, M.; Wang, J.; Balakirsky, S. & Scrapper, C. (2009). Bridging the gap between simulation and reality in urban search and rescue. *Lecture Notes in Computer Science (Robocup 2006: Robot Soccer World Cup X)*, Vol. 4434, 1–12, ISBN 978-3-540-74023-0

Caudill, M. (1993). GRNN and bear it. *AI Expert*, Vol. 8, No. 5, May 1993, 28–33, ISSN 0888-3785

Chatam, R.E. (2007). Games for training. *Communications of the Association for Computing Machinery (CACM) – Special Issue on 'Creating a Science of Games'*, Vol. 50, No. 7, July 2007, 36–43, ISSN 0001-0782

Francis, G.A. & Tan, H.S. (1999). Virtual reality as a training instrument. The Temasek Journal 7, 4–15

Freitas, V.G.V; Mól, A.C.A. & Pereira, C.M.N.A. (2009). Real time determination of dose radiation through artificial intelligence and virtual reality, *Proceedings of the 2009 International Nuclear Atlantic Conference (INAC 2009)*, DVD-ROM, ISBN 978-85-99141-03-8, Rio de Janeiro, RJ, Brazil, September 27th to October 02, ABEN, Rio de Janeiro

Hajek, B.; Kang, K.; Lee, Y. & Shin, Y.J. (2004). Internet virtual reality environment for simulating, predicting, and minimizing worker radiation exposure, *Proceedings of the American Nuclear Society's 4th International Topical Meeting on Nuclear Power Plant Instrumentation and Human Machine Interface Technologies (NPIC & HMIT 2004)*, ISBN 0-89448-688-8, Columbus, Ohio, September 2004, ANS

ICRP Publication 60 (1991). Recommendations of the International Commission on Radiological Protection

Jain, S. & McLean, C. (2003). A framework for modeling and simulation for emergency response, *Proceedings of the 2003 Winter Simulation Conference*, pp. 1-1068–1-1076, ISBN 0-7803-8131-9, New Orleans, Louisiana, December 2003, IEEE

Jain, S. & McLean, C. (2005). Integrated simulation and gaming architecture for incident management training, *Proceedings of the 2005 Winter Simulation Conference*, pp. 904–913, ISBN 0-7803-9519-0, Orlando, Florida, December 2005, IEEE

Kim, Y.H. & Park,W.M. (2005). Use of simulation technology for prediction of radiation dose in nuclear power plant. *Lecture Notes in Computer Science*, Vol. 3314, 2005, 413–418, ISBN 978-3-540-24127-0

Knight, T.W.; Dalton, G.R. & Tulenko, J.S. (1995). Virtual radiation fields for ALARA determination. *Transactions of the American Nuclear Society*, Vol. 72, 1995, 105–107, ISSN 978-3-540-24127-0

Knight, T.W.; Dalton, G.R. & Tulenko, J.S. (1997). Virtual radiation fields – a virtual environment tool for radiological analysis and simulation. *Nuclear Technology*, Vol. 117, No. 2, 255–266, ISSN 0029-5450

Lebedev, V.; Mitrofanov, S.; Slonimsky, V.; Aliev, A.; Borsky, Y.; Malkin, S.; Rakitin, I.; Schukin, A.; Gramotkin, I.; Bilik, A.; Medintsov, V.; Kuchunsky, V.; Illichov, A.; Bratteli, J.; Edvardsen, S. T.; Johnsen, T.; Louka, M. N.; Mark, N.-K.; Meyer, G.; Rekvin, S. & Øwre, F. (2007). VR technology used in planning, training, and presentation of operations, maintenance, and decommissioning at ChNPP and LNPP RBMKs, *Proceedings of the Man-Technology-Organisation Sessions at the 2007 Enlarged Halden Programme Group Meeting*, Storefjell, Norway, 2007

Lee, D.J.; Salve, R.; Antonio, A.; Herrero, P.; Perez, J.M.; Vermeersch, F. & Dalton, G. (2001). Virtual reality for inspection, maintenance, operation and repair of nuclear power plants (VRIMOR), *Mid-term Symposium on Shared-Cost and Concerted Actions (FISA 2001) – EU Research in Reactor Safety*, EC, Luxembourg, November 12-15 2001

Lewis, M. & Jacobson, J. (2002). Introduction. *Communications of the Association for Computing Machinery (CACM) – Special Issue on 'Game Engines in Scientific Research'*, Vol. 45, No. 1, January 2002, 27–31, ISSN 0001-0782

Louka, M.N. & Balducelli, C. (2001). Virtual reality tools for emergency operation support and training, *Proceedings of The International Emergency Management Society (TIEMS) 2001*, Oslo, June 2001, TIEMS

Manijlovich, J.; Prasithgaree, P. ; Hughes, S., Chen, J. & Lewis, M. (2003a). UTSAF: a multi-agent-based framework for supporting military-based distributed interactive simulations in 3D environments, *Proceedings of the 2003 Winter Simulation Conference*, pp. 1-960–1-968, ISBN 0-7803-8131-9, New Orleans, Louisiana, December 2003, IEEE

Manijlovich, J.; Prasithgaree, P. ; Hughes, S., Chen, J. & Lewis, M. (2003b). UTSAF: getting the best of consumer graphics into military simulations, *Proceedings of the 47th Annual Meeting of the Human Factors and Ergonomics Society (HFES)*, pp. 2123–2127, ISSN 0-945-289-22-7, Santa Monica, CA, 2003, HFES

Mathieu, R.; Contassot-Vivier, S.; Guillerminet, C.; Gschwind, R.; Makovicka, L. & Bahi, J. (2003). Prospective de la planification des traitements radiothérapeutiques basée sur les réseaux de Neurones, *Journées SFRP-SFPM-FIRAM (Codes de calcul en radioprotection, radiophysique et dosimétrie)*, pp., ISBN, Sochaux, October 2003, Publisher, City

Mathieu, R., Gschwind, R., Martin, E., Makovicka, L., Contassot-Vivier, S., Bahi, J., 2004. Use of the neural networks in external radiotherapy. Current Topics in Monte Carlo Treatment Planning, Advanced Workshop, May 3–5, Montréal

Meyer, G. (2007). Three-dimensional simulation of maintenance activities for planning and evaluation, *Proceedings of the Man-Technology-Organisation Sessions at the 2007 Enlarged Halden Programme Group Meeting*, Storefjell, Norway, 2007

Mól, A.C.A.; Jorge, C.A.F. & Couto, P.M. (2008a). Using a game engine for VR simulations in evacuation planning. *IEEE Computer Graphics and Applications*, Vol. 28, No. 3, May-June 2008, pp. 6–12, ISSN 0272-1716

Mól, A.C.A.; Aghina, M.A.C.; Jorge, C.A.F. & Couto, P.M. (2008b). Virtual simulations of nuclear plants for dose assessment with on-line measurements collected by networked radiation monitors. *Proceedings of the 11th IEEE International Conference on Computational Science and Engineering – Workshops (CSE 2008)*, pp. 367–372, ISBN 987-0-7695-3257-8, São Paulo, SP, Brazil, July 2008, IEEE

Mól, A.C.A.; Jorge, C.A.F.; Couto, P.M.; Augusto, S.C.; Cunha, G.G. & Landau, L. (2009a). Virtual environments simulation for dose assessment in nuclear plants. *Progress in Nuclear Energy*, Vol. 51, No. 2, March 2009, 382-387, ISSN 0149-1970

Mól, A.C.A.; Aghina, M.A.C.; Jorge, C.A.F.; Lapa, C.M.F. & Couto, P.M. (2009b). Nuclear plant's virtual simulation for on-line radioactive environment monitoring and dose assessment for personnel. *Annals of Nuclear Energy*, Vol. 36, No. 11-12, November-December 2009, 1747-1752, ISSN 0306-4549

Moltenbrey, K. (1999). Extreme visualization—a prototype VR system for viewing hazardous environments expands the boundaries of 3D scientific and engineering visualization. *Computer Graphics World*, Vol. 22, No. 1, January 1999, 42–46

Nystad, E.; Drøivoldsmo, A. & Sebok, A. (2002). Use of radiation maps in a virtual training environment for NPP field operators, Halden Work Report HWR-681

Nystad, E. (2005). Improved human performance in maintenance by using virtual reality tools: experimental results and future applications, *CSNI Workshop 'Better Nuclear Plant Maintenance: Improving Human and Organisational Performance'*, pp. 3–5, Ottawa, Canada, October 2005

Ohga, Y.; Fukuda, M.; Shibata, K.; Kawakami, T. & Matsuzaki, T. (2005). A system for the calculation and visualisation of radiation field for maintenance support in nuclear power plants. *Radiation Protection Dosimetry*, Vol. 116, No. 1-4, December 2005, 592-596, Online ISSN 1742-3406 Print ISSN 0144-8420

Oliveira, M.V.; Aghina, M.A.C. & Soares, M. (1997). Sistema de monitoração de radiação 7027, *Proceedings of the 4th Brazilian National Meeting on Nuclear Applications and 11th Brazilian National Meeting on Reactor Physics and Thermal Hydraulics*, pp. 473–476, Poços de Caldas, MG, Brazil, ABEN, Rio de Janeiro

Oliveira, M.V.; Aghina, M.A.C. & Mól, A.C.A. (2000). Sistema de monitoração de radiação 7027 do reator Argonauta, *Proceedings of the 5th Brazilian National Meeting on Nuclear Applications, 8th General Congress on Nuclear Energy and 12th Brazilian National Meeting on Reactor Physics and Thermal Hydraulics*, pp. 473–476, Rio de Janeiro, RJ, Brazil, ABEN, Rio de Janeiro

Pimentel, K. & Teixeira, K. (1995). *Virtual Reality: Through the New Looking Glass*, 2nd edition, McGraw-Hill, ISBN 10: 0070501688 ISBN 13: 978-0070501683, New York

Prasithsangaree, P.; Manojlovich, J.; Chen, J. & Lewis, M. (2003). UTSAF: a simulation bridge between OneSAF and the Unreal Engine, *Proceedings of the 2003 IEEE International Conference on Systems, Man, and Cybernetics*, pp. 1333–1338, ISSN 1062-922X, Washington, DC, October 2003, IEEE

Prasithsangaree, P.; Manojlovich, J.; Hughes, S. & Lewis, M. (2004). UTSAF: a multi-agent-based software bridge for interoperability between distributed military and commercial gaming simulation. *Simulation*. Vol. 80, No. 12, 2004, 647–657, ISSN 0037-5497, SCSI

Rindahl, G.; Johnsen, T.; Øwre, F. & Iguchi., Y. (2002). Virtual reality technology and nuclear decommissioning, *Proceedings of the International Conference on Safe Decommissioning for Nuclear Activities*, pp. 223–238, ISSN 0774-1884, IAEA, Berlin, 2002, IAEA

Ródenas, J.; Zarza, I.; Burgos, M.C.; Felipe, A. & Sánchez-Mayoral, M.L. (2004). Developing a virtual reality application for training nuclear power plant operators: setting up a database containing dose rates in the refuelling plant. *Radiation Protection Dosimetry*, Vol. 111, No. 2, September 2004, 173–180, Online ISSN 1742-3406 Print ISSN 0144-8420

Ródenas, J.; Zarza, I.; Felipe, A. & Sánchez-Mayoral, M.L. (2005). Generation of dose databases for an operator training application in nuclear facilities, *Proceedings of the 3rd International Conference on Education and Training in Radiological Protection (ETRAP 2005)*, Brussels, Belgium, November 2005

Rosenbloom, A. (2003). Introduction. *Communications of the Association for Computing Machinery (CACM) – Special Issue on 'A Game Experience in Every Application'*, Vol. 46, No. 7, July 2003, 28–31, ISSN 0001-0782

Sanders, R.L. & Lake, J.E. (2005). Training first responders to nuclear facilities using 3-D visualization technology, *Proceedings of the 2005 Winter Simulation Conference*, pp. 914–918, ISBN 0-7803-9519-0, Orlando, Florida, December 2005, IEEE

Sebok, A.; Nystad, E. & Drøivoldsmo, A. (2002). Improving safety and human performance in maintenance and outage planning through virtual reality-based training systems, *Proceedings of the IEEE 7th Conference on Human Factors and Power Plants*, pp. 8-14–8-22, ISBN 0-7803-7450-9, Scottsdale, Arizona, 2002, IEEE

Schløler, H. & Hartmann, U. (1992). Mapping neural network derived from the parzen window estimator. *Neural Networks*, Vol. 5, No. 6, 1992, 903–909, ISSN 0893-6080

Shendarkar, A.; Vasudevan, K.; Lee, S. & Son, Y.-J. (2006). Crowd simulation for emergency response using BDI agent based on virtual reality, *Proceedings of the 2006 Winter Simulation Conference*, pp. 545–553, ISBN 1-4244-0500-9, Monterey, California, December 2006, IEEE

Specht, D.F. (1991). A Generalized Regression Neural Network. *IEEE Transactions on Neural Networks*, Vol. 2, No. 6, November 1991, 568–576, ISSN 1045-9227.

Stuart, R. (1996). *The Design of Virtual Environments*, McGraw-Hill, ISBN 10: 0770632995 ISBN 13: 978-0070632998, New York

Threnholme, D. & Smith, S. P. (2008). Computer game engines for developing first-person virtual environments. *Virtual Reality,* Vol. 12, No. 3, September 2008, 181–187, ISSN Print 1359-4338 ISSN Online 1434-9957

Van de Walle, B. & Turoff, M. (2007). Emergency response information systems: emerging trends and technologies. *Communications of the Association for Computing Machinery (CACM) – Special Section 'Emergency response information systems: emergina trends and technologies'*, Vol. 50, No. 3, March 2007, 28–31, ISSN 0001-0782

Vermeersch, F. & Van Bosstraeten, C. (1998). Development of the VISIPLAN ALARA planning tool, *Proceedings of the International Conference on Topical issues in Nuclear Radiation and Radioactive Waste Safety*, Vienna, Austria, August 31 to September 04 1998

Vermeersch, F. & Vanbosstraeten, C. (2000). Software VISIPLAN: a powerful tool for optimisation, *Proceedingns of the 2nd European Workshop on Occupational Exposure Management at NPPs*, Tarragona, Spain, April 2000

Vince, J. (1995). *Virtual Reality Systems*, Addison-Wesley, ISBN 0-201-87687-6, Cambridge

Wang, J.; Lewis, M. & Gennari, J. (2003a). USAR: a game-based simulation for teleoperation, *Proceedings of the 47th Annual Meeting of the Human Factors and Ergonomics Society (HFES)*, pp. 493–497, ISSN 0-945-289-22-7, Santa Monica, CA, 2003, HFES

Wang, J.; Lewis, M. & Gennari, J. (2003b). A game engine based simulation of the NIST urban search and rescue arenas, *Proceedings of the 2003 Winter Simulation Conference*, pp. 1-1039–1-1045, ISBN 0-7803-8131-9, New Orleans, Louisiana, December 2003, IEEE

Wang, J.; Lewis, M. & Gennari, J. (2003c). Interactive simulation of the NIST USAR arenas, *Proceedings of the 2003 IEEE International Conference on Systems, Man, and Cybernetics*, pp. II-1327–II-1332, , ISSN 1062-922X, Washington, DC, October 2003, IEEE

Wu, X. & Zhu, Y. (2000). A neural network regression model for relative dose computation. *Physics in Medicine and Biology*, Vol. 45, No. 4, 2000, 913–922, Online ISSN 1361-6560 Print ISSN 0031-9155

Xu, X.G. & Bushart, S. (2006). Virtual-reality dose simulation for nuclear power plant. *Proceedings of the The American Nuclear Society's 14th Biennial Topical Meeting on Radiation Protection and Shielding (RPS 2006)*, pp. 449–451, Carlbad, New Mexico, April 2006, ANS

Zyda, M.; Hiles, J.; Mayberry, A.; Wardynski, C.; Capps, M.; Osborn, B.; Shilling, R.; Robaszewski, M. & Davis, M. (2003). Entertainment R&D for defense. *IEEE Computer Graphics and Applications*, Vol. 23, No. 1, January-February 2003, 28–36, ISSN 0001-0782

Zyda, M. (2007). Introduction. *Communications of the Association for Computing Machinery (CACM) – Special Issue on 'Creating a Science of Games'*, Vol. 50, No. 7, July 2007, 26–29, ISSN 0001-0782
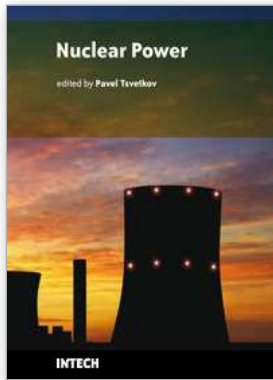
Nuclear Power

Edited by Pavel Tsvetkov

The world of the twenty first century is an energy consuming society. Due to increasing population and living standards, each year the world requires more energy and new efficient systems for delivering it. Furthermore, the new systems must be inherently safe and environmentally benign. These realities of today's world are among the reasons that lead to serious interest in deploying nuclear power as a sustainable energy source. Today's nuclear reactors are safe and highly efficient energy systems that offer electricity and a multitude of co-generation energy products ranging from potable water to heat for industrial applications. The goal of the book is to show the current state-of-the-art in the covered technical areas as well as to demonstrate how general engineering principles and methods can be applied to nuclear power systems.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Carlos Jorge, Antonio Mol, Pedro Couto and Claudio Pereira (2010). Nuclear Plants and Emergency Virtual Simulations Based on a Low-Cost Engine Reuse, Nuclear Power, Pavel Tsvetkov (Ed.), ISBN: 978-953-307-110-7, InTech, Available from: http://www.intechopen.com/books/nuclear-power/nuclear-plants-and-emergency-virtual-simulations-based-on-a-low-cost-engine-reuse

INTECH
open science | open minds