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VIRTUAL DOSIMETRY APPLIED TO THE PHYSICAL SECURITY OF A NUCLEAR INSTALLATION

André Cotelli do E. Santo[1], Antônio C. A. Mól[2], Daniel M. Machado[3], Daniel R. Chelles[4] and Deise G. S. Gonçalves[5]

[1,2,3,4,5] Instituto de Engenharia (IEN / CNEN - RJ)
Rua Hélio de Almeida, 75
Cidade Universitária, Ilha do Fundão, Rio de Janeiro, RJ
cotelli.andre@gmail.com[1], mol@ien.gov.br[2], machado.mol@gmail.com[3], daniel.chelles@gmail.com[4], deise.galvao@gmail.com[5]

ABSTRACT

An important activity to be held in radiation protection is the location of radioactive sources. The present work was devoted to the development of a virtual dosimetry tool for locating and detecting such sources. To this end, was created a three-dimensional virtual model of the Instituto de Engenharia Nuclear – IEN, endowed with virtual characters (avatars), capable of move and interact with the environment, radiation detectors (fixed and mobile) and radioactive sources. Aiming to assist in planning physical security of nuclear installations, the tool developed allows the detection simulation of individuals carrying radioactive sources through detectors installed at strategic points of the site. In addition, it is possible to detect and locate sources by handling portable detectors, operated by characters within the virtual environment.
The results obtained show the behavior of the radiation detectors on continuous profile of radioactive sources, allowing calculate the dose rate at any position of the virtual environment. Thus, this work can assist in the training of security officers, as well as in evaluating the radiological safety of the nuclear site.

1. INTRODUCTION

The physical security of nuclear installations has been a constant concern of the International Atomic Energy Agency (IAEA). Through reports and norms defined in the periodic planning of nuclear security [1] the IAEA guides the nuclear sites more intensely commits to control and security of its radioactive materials.
To promote greater efficiency of the systems of control of these materials training of the teams of security of the nuclear installations is become fulfilled periodically. One way to help these trainings is the inclusion of new tools of computer simulations based on immersive virtual environments [2]. In the nuclear area some works already had demonstrated that such tools can assist in the training in nuclear installations [2, 3, 4]. Virtual environments make possible the qualification for operational procedures without the necessity to display the users to the taxes of ionizing radiation. Other works also show the contribution of the virtual reality in the nuclear area, as the CIPRES [5], developed for the IBERINCO (Iberdrola Ingenieria y Consultoria) and for the Polytechnic Universidad of Valence, that allows the training of operators of nuclear installations simulating operations of fuel recharge; The Vrdose [6] is a tool capable to show the distribution of the dose tax and to supply estimate of occupational doses scenarios of work in nuclear installations. The exposition of human beings the raised

doses of radiation cause damages to the health due to the somatic and genetic effect produced by the ionizing radiations [7, 8]. Therefore the use of computational systems is justified still more as training tools, calculating only a virtual exposition of ionizing radiation instead a real one. A way to produce computational environments virtual is by means of game engines - tools for the production of games, that already had revealed great assistant in the development of simulation systems [9]. The use of core of the game for simulation systems opened a new area called serious games. Different works demonstrate the applicability of the core of the game in this context [10, 11, 12]. Many cases are directed to the training of emergency situations [13, 14]. In the nuclear area, the virtual reality has been used mainly in the simulation of operations in installations with levels of radiation above of the natural standard. In this context, therefore, this work presents a methodology based on nucleus of games for the creation of measurements of virtual radiation, creating the possibility of if implementing, in the virtual tools of simulation, portable and mobile virtual detectors of radiation. As application of this work, detectors were inserted into a virtual nuclear facility physical security procedures are tested**.** The virtual detectors also make possible the measurement and the training of diverse operations in the nuclear area, as for example the training of radioprotection teams.

2. DOSIMETRY

The determination of the tax of exposition (dose-rate) to the radiation in determined point or environment is understood as dosimetry. This rate consists of the relation between the interval of time and the dose of exposition. Rate of exposition is the reason between all the braked electron loads in a volume ΔV of air (in NTP), being these produced by interaction of rays-x or rays-γ with the mass Δm of air of the volume in question. [8].

To express the dose, the unit used currently is Gray (Gy), defined as the dose of radiation absorbed for a portion of material, that corresponds to one joule for kilogram. However, a unit of measure generally used in real measurements is the tax of counting for unit of time, CPS (counts to per second), correspondent the rate of events registered in measurements, being this the unit used in the present work.

The dosimetry norms establish acceptable limits of dose of radiation for the environment and the beings livings creature. In accordance with principle ALARA (As Low As Reasonably Achievable) (ICRP Publication 60, 1990), radiation exposure should only occur when it is really necessary, and must be so low when reasonable practicable, guaranteeing thus the observance of the safe limits of exposition, preventing a harmful dose to the individual.

2.1. Radiation Detectors

Detectors of radiation are devices by means of which it is possible to identify the presence of radiation in the environment, as well as measure its intensity and energy, making possible the detention and localization of radioactive sources. These devices can be found in diverse configurations - as much in fixed or mobile (portable) formats.

For proper use of radiation detectors, it is necessary that the security agents are trained to handle the instrument and also for the correct interpretation of the data supplied for the readings of this. Such training needs careful planning, therefore, beyond involving high costs, they can represent risks to the health of the Individuals Occupationally Exposed - IOE, affecting its limit of annual dose.

3 . VIRTUAL REALITY AND GAME ENGINES

One understands by Virtual Reality (VR) the set of techniques, technologies and interfaces destined to supply to the user the sensation of integration with the computational system and to make possible the immersion of this in the virtual environment (Burdea and Philippe, 1994). With this intention, the VR uses three-dimensional interactions in real time, environments and computational equipment, allowing that the user has the sensation of if relating of actual form with the applications.

Game engines are programs destined the production of electronic games. For this, these programs centralize diverse libraries and necessary functions to the development, simplifying for the programmer fast access to the tools required to the creation of the games and the graphical applications. Some of the functionalities frequently found in game engines are, for example, engine of game properly said, rendering of graphs in two and three dimensions, physics engine, detention of collisions, supported to artificial intelligence and different programming languages, etc.

4. METHODOLOGY

For accomplishment of this work a virtual model of the Instituto de Engenharia Nuclear (IEN) was developed, located in the Ilha do Fundão - Rio De Janeiro - Brazil. Using the tool Autodesk 3ds Max was made the modeling in three dimensions of the pertaining installations to the institute and, through the engine of Unity game 3D created the virtual environment in which the simulations will be carried through.

With more details, they follow described the main tools used in the present work.

4.1. Autodesk 3ds Max

The Autodesk 3ds Max consists of a software destined to the three-dimensional modeling, making possible the creation, animation and rendering of directed models the diverse applications of virtual reality, as virtual games, mockups, cinema, animations, etc [17]. Using this tool was developed the scenario used in this serious game, in accordance with the real installations of the Instituto de Engenharia Nuclear (IEN). The modeling respected the measures and ratio of the institute, aiming at to provide to the user one better immersion in the simulations. The figure to follow presented consists of the image of building of the IEN shaped through 3ds Max. For accomplishment of the present work it was used version 2013.

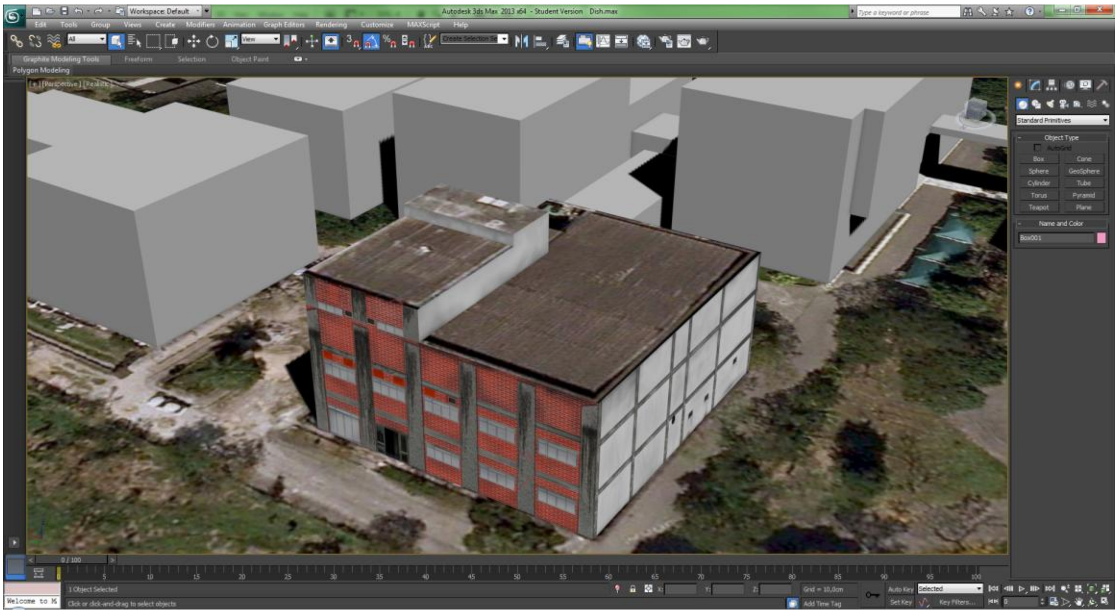

Figure 1: Modeling of building of the IEN in 3ds Max.

4.2. Unity 3D

The Unity 3D consists of a robust engine of three-dimensional game, allied the diverse functions auxiliary for the content development 3D. It is presented as a tool multiplatform and multilanguage programming (it supports C#, JavaScript and Boo) [15, 16]. It possesses vast documentation and active community, facilitating the learning.

The development of the present work was based on this tool, that makes possible the creation of the necessary scenarios of avatars interacting with the environment, the importation of objects shaped in the Autodesk 3ds Max, programming of the radioactive sources and the functioning of the virtual dosemeters (fixed and mobile).

The programming language used for accomplishment of implementations inside of this nucleus of game was C#, pertaining to Framework .NET, chosen for its simplicity and robustness, being object-oriented programming and strong typing.

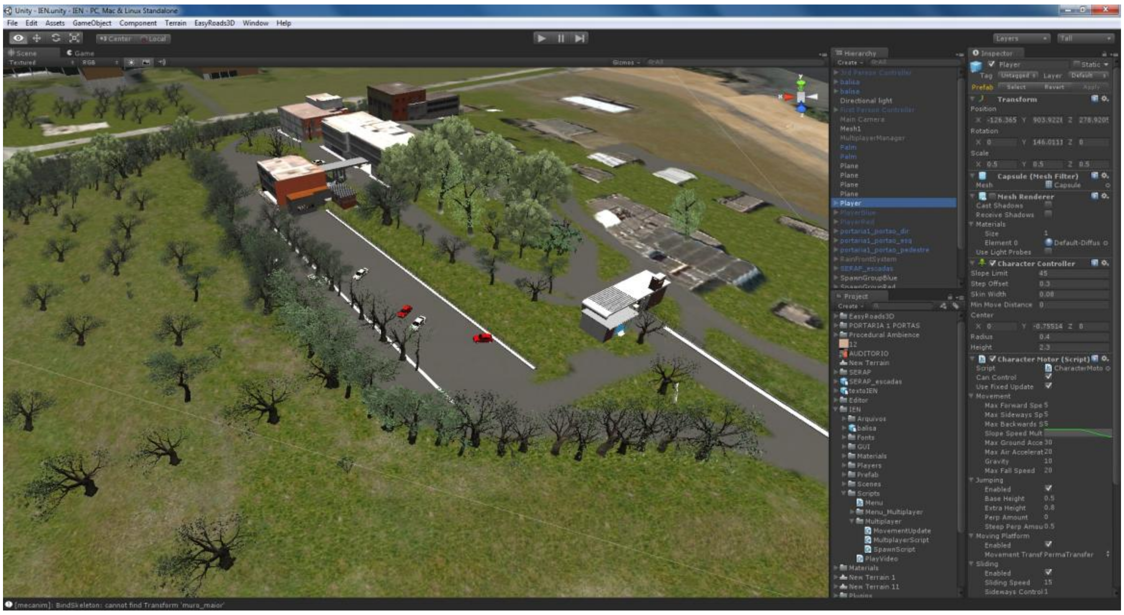

Figure 2: IEN shaped in the Unity 3D.

5. RESULTS

It was carried through the virtual environment, developed in this study, a comparative analysis between real dose-rates, measures in the terrain of the Instituto de Engenharia Nuclear, and dose-rates gotten in the virtual simulations.

The Monitor Rejects Hospital MRH 7029 in set with the scintillation probe SCT 7026 was used. In the first, the average value of referring rates of dose to background (present value in the environment of natural form, without interference of external sources) of the institute was gotten, identified in 140CPS. At as a moment, diverse measurements proceeding from the insertion of a radioactive source in the environment had been collected. The table to follow supplies the values gotten in the experiment.

Source	Distance	Rate of Counts
120µCi	1m	572.90 CPS
		572.80 CPS
		573.20 CPS
		573.10 CPS
		573.10 CPS
	2m	275.50 CPS
		275.50 CPS
		275.30 CPS
		275.20 CPS
		274.90 CPS

a. Dose rates measured in IEN.

The average value of dose rate for a source of 120µCi, to a distance of 1m, was of 573.02CPS, and the average value of this rate with the same sample, at a distance of 2m, is of 275.28CPS. Deducting background, they are had, respectively, rates of doses of 433.02CPS and 138.28CPS.

In the virtual environment, from the gotten experimentally values, it was configured activity of the source in 573.02CPS, considering the inserted radioactive source in the environment in set with the existing activity of background in the Instituto de Engenharia Nuclear. The table that follows provides values gotten from the virtual simulation.

Rate of Counts	Distance	Dose Received
573.02CPS	1.037924m	531.9102CPS
	1.055892m	513.9619CPS
	1.061809m	508.2499CPS
	1.065830m	504.4222CPS
	1.214441m	388.5235CPS
	1.226295m	381.0485CPS
	1.227114m	380.5399CPS
	1.622518m	217.6662CPS
	1.869039m	164.0336CPS
	2.077595m	132.7541CPS

b. Doses received by the avatar in the virtual environment.

The figures that follow show the developed virtual environment, allowing to the visualization of the dose-rate in accordance with the localization of avatar in the environment.

Figure 3: Mobile dosimeter.

Figure 4: Fixed dosimeter.

The tool produced in this study allow the accomplishment simulations to identify the environmental radiation location for both fixed source (located or abandoned in the site), as for identification of sources in movement, that is, perception of the attempt of removal of radioactive sources of a nuclear site.

6. CONCLUSIONS

The present work demonstrated the use of the Virtual Reality in the development of a tool of virtual dosimetry destined to the localization and detention of radioactive sources, with the objective of assisting in the planning of the safety level of nuclear installations. The visualization and the organization of strategies could be facilitated with the use of such tool, as well as the use of this for accomplishment of training and simulation of protection. Future improvements as the internal modeling of the building and the environment around of the IEN will be able to become this more efficient tool.

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