

## Use of Virtual Reality for the development of a Nuclear Waste Repository for Training

**Ricardo Fernandes de Avellar<sup>3</sup>, André Cotelli do E. Santo<sup>2</sup>, Antônio Carlos A. Mól<sup>1,2</sup>, Daniel Mol Machado<sup>4</sup>, Ana Paula Legey<sup>2</sup>,**

<sup>1</sup> Instituto de Engenharia Nuclear (IEN / CNEN - RJ)  
Rua Hélio de Almeida, 75  
21941-906 – Rio de Janeiro, RJ  
mol@ien.gov.br

<sup>2</sup> Centro Universitário Carioca (UniCarioca)  
Avenida Paulo de Frontin, 568  
20261-243 – Rio de Janeiro, RJ  
cotelli.andre@gmail.com

<sup>3</sup> Bolsista PCI - IEN/CNEN  
Cidade Universitária - R. Hélio de Almeida, 75  
Ilha do Fundão, Rio de Janeiro - RJ  
ricardo.arq2017@gmail.com

<sup>4</sup> Bolsista TCT - IEN/CNEN  
Cidade Universitária - R. Hélio de Almeida, 75  
Ilha do Fundão, Rio de Janeiro - RJ  
machado.mol@gmail.com

### ABSTRACT

In Brazil the highest amount of waste generated is low and medium level of radiation. Its management and final destination is important for society and the solution, proposed by the government, involves the construction of a National Repository for Radioactive Waste. Using Virtual Reality (VR), this article aims to develop an interactive virtual model of the repository to assist in the study, evaluation, training of personnel and planning of the installation to be implemented. The method was divided into four steps. The first, called "Requirements Specification and Survey", aimed at acquiring information about the terrain and future buildings of the installation in the real world. The next step, known as "Modeling the Environment" is the construction of the virtual environment itself according to the specifications of the previous method. The third, called "Functionality Implementation" consists of inserting functionalities into the system, such as performing some tasks present in the repository. Finally, the last step is the interactive virtual model of the national repository for radioactive waste, with this tool users can study, evaluate and train conditions/situations of the installation. In conclusion, the results have shown that the tool presented in this work is a possible application of the VR for dissemination and training in nuclear installations. Using this tool, users can visualize and plan strategies to be carried out in a repository, without interrupting the operation of the installation. It can be used for training and operations simulations, aiming to improve the processes without exposing the operators to the radiation.

### 1. INTRODUCTION

A program for the use of nuclear energy to generate electricity called the Programa Nuclear Brasileiro (PNB) is under development and its objective is to build at least four more nuclear power plants in the Northeast and Southeast regions of Brazil by 2030 [8]. With the growth of the energy sector in Brazil for the next years, the issue of radioactive

waste is highlighted, which motivates government actions to solve problems related to its storage [6]. According to CNEN resolution n°. 112 of 2011, the various sectors that generate radioactive waste are responsible for its management. This radioactive waste management covers the operations that begin in their generation and ends with their disposal in a repository, with the main objective to safely managing nuclear waste in order to protect man and the nature of negative impacts [1].

One of CNEN's priority projects is the repository for radioactive waste with low and medium radiation levels, which is directly related to the final deposition of radioactive waste generated in the national territory. This project is part of the solution for the deposition of radioactive waste generated by nuclear energy activities in the country, and has as its objective the implementation of the Brazilian repository, from conception to its construction.

Considering that these facilities store radioactive waste, it is very useful to create methods and techniques that allow the study and evaluation of these repositories, even before their actual construction, in order to assist in its design. In addition, it is also important to disclose to the public the importance of the repository's existence, the mode of operation, and the security criteria involved. Therefore, it would be of great importance to create tools that can assist in the prior planning of activities to be carried out in the areas subject to radiation, so that the limits of radioactive safety are respected. One of the possible ways to accomplish these tasks is through the use of Virtual Reality (VR). Virtual environments have some advantages, among them: (i) attractive to the public, because it allows them to feel immersed in the environments without being exposed to any risk; (ii) allows simulations and evaluations of facilities not yet built in the real world, or that may be difficult to access; (iii) allows the estimation of radiation doses absorbed by workers; (iv) does not expose workers to any radiation level in performing simulations and training, posing no risk to their health; (v) contributes to a better planning of the activities in these areas, measuring the doses received and consequently evaluating the health risks.

Using virtual reality techniques, this article aims to develop an interactive virtual model of the repository for radioactive waste to assist in the study, evaluation, training of personnel and planning of the installation to be implemented.

## **2. THEORETICAL FOUNDATION**

### **2.1. Virtual Reality**

Recently, Virtual Reality, also known as VR, can be considered a technology with enormous potential and applicability in several areas of human knowledge, being possible to use it from training to simulations and virtual experiments. And every day, it is possible to find new applications for this immersive tool.

The VR allows the integration of three basic ideas: involvement, immersion and interactivity. Involvement can be seen as the degree of user motivation with the activity performed, immersion is associated with perception, feeling of being present in the environment and the interaction of the user with the possibility of manipulating virtual objects [7].

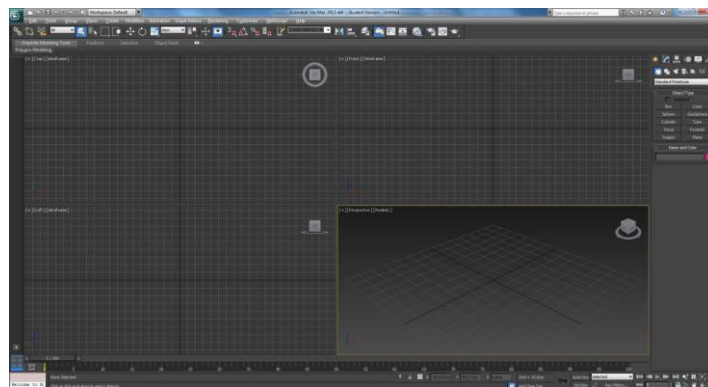
The set of technologies, techniques and interface modes that allow the sensitive integration between a computer system, the user and the immersion in a virtual environment can be called Virtual Reality [7].

### 2.1.1. Virtual Environments

In this environment is where virtual reality simulation occurs, in addition to where the representative scenarios are constructed. Virtual environments can be considered scenarios where it is possible, through an avatar (representation of a person in a virtual environment), to move in the virtual world, interacting with elements, objects and even with other users [5].

### 2.2. Autodesk 3ds Max

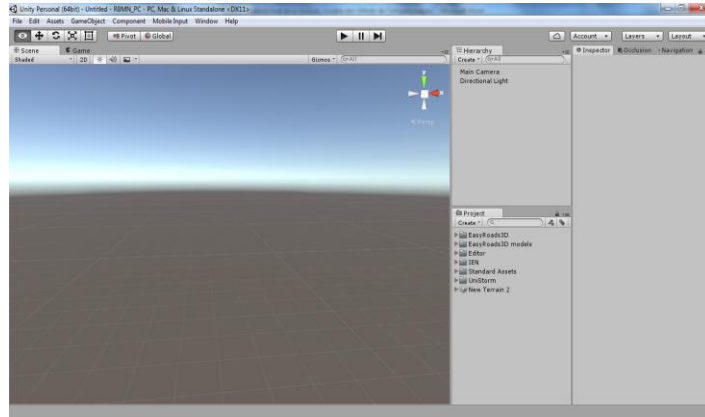
Autodesk 3ds Max consists of a modeling tool that aims to be a complete solution not only in modeling but also in 3D rendering, animation and simulations, thus meeting the needs of various computer graphics professionals in the development of various applications, such as games, virtual mockups, movies, animations, etc. [4]. With great acceptance in today's computer graphics market, 3ds Max (Fig. 1) is one of the leading proprietary tools for 3D modeling.



**Figure 1: Autodesk 3ds Max modeling tool.**

### 2.3. Unity 3D

Unity 3D, Fig. 2, consists of a robust three-dimensional game core, complemented by a variety of functions required to develop virtual games or scenarios, such as libraries for the insertion of physics into environments, lighting and audio. Regarding portability, this software has as strong characteristic its plurality of platforms. Because of this, the developer does not have to worry about the peculiarities of each operating system or hardware, since Unity makes all the necessary adjustments to this compatibility [3].



**Figure 2: Unity 3D interface.**

### **3. METHODOLOGY**

The method proposed in this paper is divided into four steps. The first, called "Requirements Specification and Survey", aimed at acquiring information about the terrain and future buildings of the installation in the real world. In the second stage, known as "Modeling the Environment", consists of the construction of the virtual environment itself according to the specifications of the previous method. For this purpose, Unity is used to create terrain and Autodesk 3ds Max software for creating objects, such as buildings. The third step, called "Functionality Implementation", consists of inserting functionalities into the system using the Unity 3D game core, such as performing some tasks present in the repository, creating virtual characters and a multiuser system.. Finally, the last step was the interactive virtual model of the national repository for radioactive waste, with this tool users can study, evaluate and train conditions/situations of the installation.

#### **3.1 Requirements Specification and Survey**

Initially, a survey was made of the real physical characteristics and topographic images of nuclear facilities, used as repository for radioactive waste, which served as the basis for virtual modeling. For this purpose, research was carried out with the objective of reproducing the basic characteristics present in this type of installation.

The L'Aube Repository [2] was used as an example for the assembly of the virtual scenario, due to the similarity of its physical characteristics with the repository. Figure 3 (a, b) show topographic images of the facility that was chosen for study, while Fig. 4 (a, b) demonstrates the buildings present in this repository, which served as a basis for modeling.



(a)



(b)

**Figure 3 (a, b): Topographic images of the L'Aube Repository [2].**



(a)



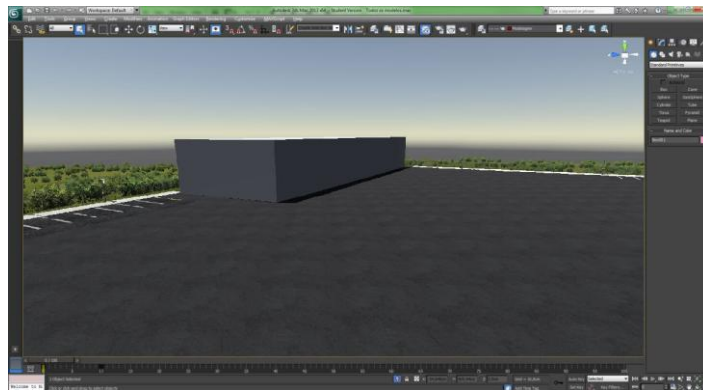
(b)

**Figure 4 (a, b): Existing buildings in the L'Aube Repository [2].**

## 3.2. Modeling the Environment

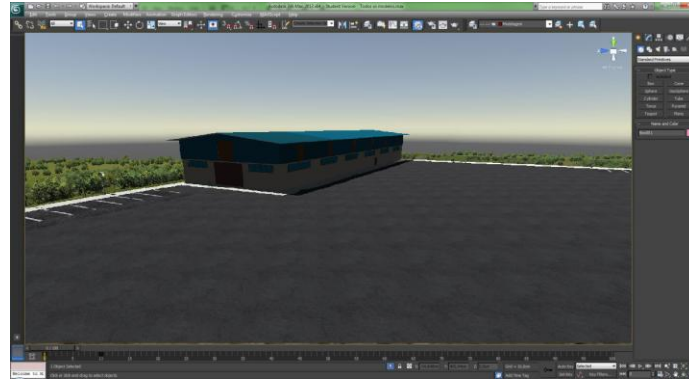
### 3.2.1. Modeling of buildings

The modeling of the buildings was done in Autodesk 3ds Max software, Fig. 5. Only the facades of the buildings were modeled. The technique used was Poly Modeling, which consisted in adding a primitive Box to the virtual space and then, through the tools offered by the software, sculpted the form to the stage where the virtual model conveyed the credibility of being a real representation.



**Figure 5: Modeling of buildings.**

The second stage consisted of the texturing process. Still in 3ds Max, the object had its mesh planned and later transformed into a figure. The texture layers were applied, which were based on photos taken at the site. Fig. 6 shows the planned texture applied to the model, and each of the textured faces coincident with the face of the model that is positioned in the virtual space.

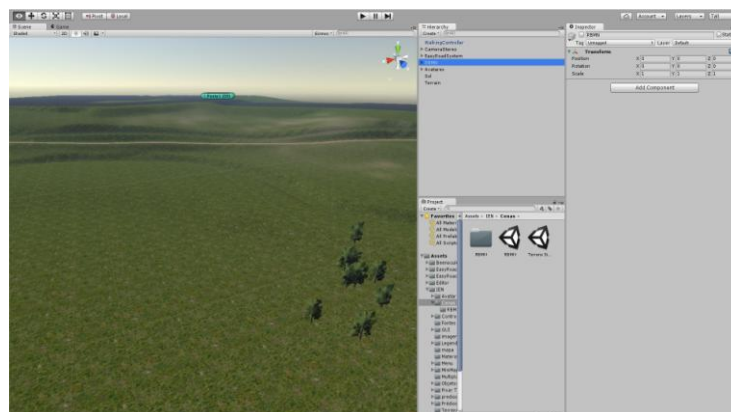


**Figure 6: Textured buildings in 3ds Max.**

### 3.2.2. Terrain Modeling

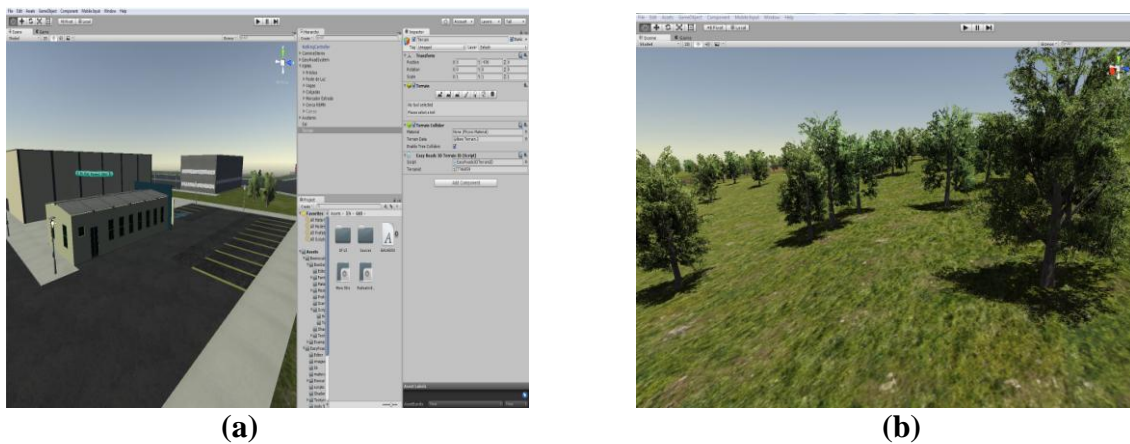
The Unity 3D game core was used to perform the terrain modeling of the repository studied in this work. At first, a standard terrain of the tool was created, without forms, reliefs or textures, to serve as the basis for constructions and alterations. Using the measurements and proportions from the topographic image of the nuclear facility, respecting the extensions and scales of the scenario, the standard terrain of Unity 3D was dimensioned. Thus, the width and length of the developing terrain were adequate to the real ones found at the nuclear site.

From the virtual terrain modeled (in its shapes and dimensions of width and length) and textured, the necessary changes were made pertinent to the relief of this area. Fig. 7 shows the application of the existing characteristics in the terrain, being these natural or coming from existing constructions.



**Figure 7: Geographic characteristics of the terrain.**

With the developed virtual terrain, the insertions of existing objects and buildings in the real environment began. The 3D objects produced in Autodesk 3Ds Max were imported into the Unity 3D terrain. These elements were positioned according to the actual layout of the site buildings, and received scaling within the game core to respect the existing proportions, Fig. 8 (a). Finally, in order to give more realism to the virtual scenario, we also inserted vegetation characteristics, Fig. 8 (b), found in the facility, such as grasses, shrubs and trees.



**Figure 8: Three-dimensional models and terrain with vegetation inserted in Unity.**

### 3.3. Functionalities Implementation

#### 3.3.1. Avatar Features

To provide more realism to the proposed system, changes were made in the characteristics of the avatars present in the virtual environment. Firstly, the visual characteristics of these characters were altered, giving the user a visual identification with characters similar to those commonly found in the nuclear installation, Fig. 9. In addition to clothing and expressions, the height of the avatars was changed to 1,70 m, according to the average height of an adult man, and the characters' velocities of displacement were adjusted to reflect the true speed of movement of a human being within the nuclear facility.



**Figure 9: Avatar walking through the virtual environment.**

### 3.3.2. Multiuser System

The virtual repository can be operated by one or multiple users (each user represented by an avatar). At the beginning of the program, a menu is displayed to define which version the user wants (Fig. 10). In "One User" mode, only one person can use the program, thus controlling an avatar of the simulation. While in "Multiuser" mode, a group of people can interact together in the same scene, with possible collaboration or opposing goals among users. Finally, the "Exit" button allows you to close the application.



Figure 10: Virtual repository introduction menu.

### 3.4 Creation of the Interactive Virtual Model of the National Repository for Radioactive Waste

The Interactive Virtual Model of the National Repository for Radioactive Waste was created (Fig. 11) with the characteristics of a repository to be tested in simulations. It has several avatars and can be used in multiplayer format.

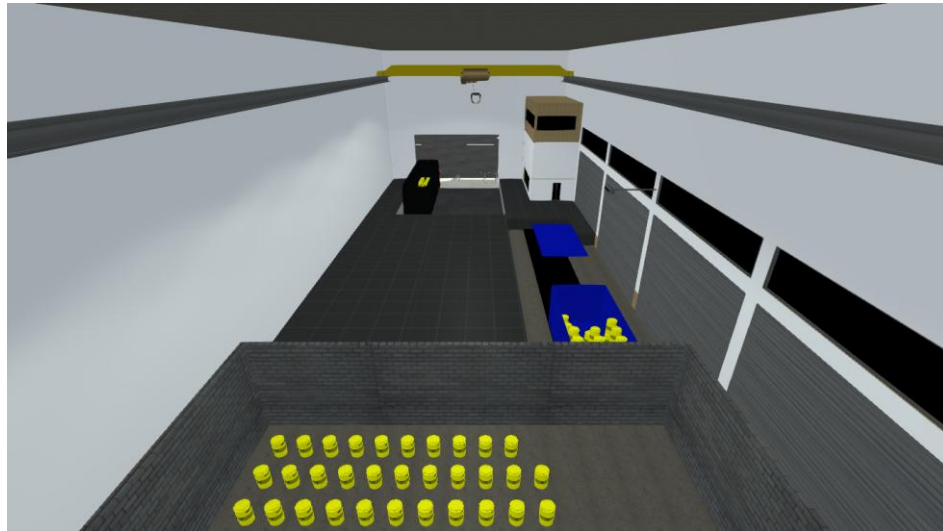


Figure 11: Virtual Model of the National Repository of Radioactive Rejects



## 4. RESULTS

The figures below show the developed virtual environment, allowing the visualization, interaction and simulation of some operational procedures performed in waste repositories. Fig. 12 (a, b) shows the repository for low and medium levels of radioactive waste in operation.



(a)



(b)

**Figura 12 (a, b): Virtual Repository for Radioactive Waste with Low and Medium Radiation Levels**

## 5. CONCLUSIONS

This article showed the possibility of using Virtual Reality in the development of a tool for dissemination and training in nuclear installations, since waste relocation procedures are extremely complex but necessary tasks. With this tool you can visualize and plan strategies to be carried out in a repository of radioactive waste, without interrupting the operation of the installation. It can thus be used for training and operations simulations in order to perfect these processes and without exposing the repository operators to radiation. Future improvements, such as the internal modeling of buildings and a system of communication between users, can make this tool more efficient.

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