2021 International Nuclear Atlantic Conference – INAC 2021
Virtual meeting, Brazil, November 29 – December 2, 2021

ISBN: 978-65-594-1256-3

Methodology to Assist in The Training of Pump Operation Maneuvers of a Nuclear Plant Using Virtual Reality

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1. Introduction

This article proposes a methodology to assist in training nuclear power plant operators in tasks that affect plant availability, such as changing the oil pumps of the main cooling water system (or circulating water). The methodology proposes a tool to assist in training this task, without compromising plant safety and availability. Training effectively and close to reality, through immersive in Virtual Reality [2], using the Unity 2018.3.10f1 program. This program is a virtual object modeling tool for creating and operating interactive 3D content in real time. The concept of virtual reality basically consists of 3 aspects; Immersion: It is linked to the feeling of being inside the environment, promoting the visualization of hearing and spatial location with head movements, reacting to the environment; Interactivity: It is associated with the program's ability to identify user inputs and instantly change the virtual environment, and then promote changes according to the user's actions. It is the ability to produce responses from user intervention in the virtual environment; Involvement: It is associated with how much the environment or task is interesting to the user. It is directly linked to the motivation of a person with a specific activity. The desire to successfully carry out the challenge of the environment or task. This challenge can be active or passive. Active consists in actually participating in a game, with a defined objective, being able to interact with other participants / or with the environment. Passive is watching videos, reading a manual or book. Therefore, a Virtual Reality is able to explore both types of challenges, either separately or together.

2. Methodology

The method for building this environment was to use Unity associated with other modeling tools such as 3D Studio Max 2018, Adobe Illustrator and Microsoft Visual Studio. Thus, the environment was modeled in 3D, trying to represent the real environment and the functionalities implemented. At this stage, priority was given to the physical and functional fidelity of the panel and the environment. In these graphic tools, the description of the algorithms follows the same basic operating logic of the plant's control unit, with the creation of classes for pumps and pressure gauges. The algorithms were created exclusively for the project, using only some pre-existing components in the Unity tool, such as the codes used to move the user around the scene. The language logic used was an object-oriented language, concepts such as class, object, interface and inheritance were used in the implementation. The type of modeling used was polygonal modeling, using basic shapes (cubes, cylinders, planes, etc.) in 3DsMax it is possible to modify them and create different shapes. at least one of the sides to build the shapes. The pressure gauge reproduced in the virtual environment responds according to the situations of pumps and malfunctions. It is a three-dimensional virtual object in the Unity scene, so the float-type values assigned to the pumps are transformed through a specific calculation into a rotation for the virtual pointer, which dynamically positions itself according to the value presented by the system. The pump control logic follows a rule of minimum and maximum pressures highlighted in the real operating model, the sum of the pump pressure values is calculated and evaluated by this logic in order to correctly respond to situations such as virtually simulated failure or low efficiency. The logic was developed for the model, using C# as a way to develop the codes. In this case Visual Studio acts only as an IDE (Integrated Development Environment). In the panel subroutine, in general Unity is responsible for the graphics, 3D rendering and positioning of objects in the scene, and Visual Studio acts as a tool to develop the behavior of these models in the scene. The control logic was developed in Visual Studio code and later integrated into Unity. Adobe's communication to Unity, and Unity's 3D tool is just providing files. Files generated in Adobe Photoshop or 3DSMax are imported into Unity in supported formats such as .PNG for images and .FBX for 3D models. All rendering is done by the Unity Engine, and uses the Pipeline known as URP (Universal Render Pipeline). The assembly for each object was firstly to model the scene (place) where the objects will be added, then each object is modeled separately with the possibility of creating copies of them, if necessary it can be modified without changing the original part.

Figure 1: Main Cooling Water System.

To meet the planned maneuvers, a menu of malfunctions was created [2] shown in Figure 2.

Figure 2: Electrical panel of oil pumps and malfunction menu.

3. Results and Discussion

As a form of evaluation, professionals from a nuclear power plant, with experience ranging between 10 and 41 years, were invited to participate in the use of the created tool and subsequent filling out of the evaluation questionnaire. These professionals were chosen and separated into 3 groups. Group 1 - Nuclear power plant field operators; Group 2 - Nuclear power plant control room operators; Group 3 - Trainer and Conventional Simulator. To assess the opinion of these professionals on the use of a virtual environment in a nuclear power plant as an auxiliary tool, in establishing training and professional qualification strategies, they answered the following evaluation questionnaire:

QUESTIONÁRIO	
Este questionário tem como finalidade avaliar a opinião de profissionais, que atuam na área nuclear, sobre a operação do sistema de óleo da bomba da água de refrigeração principal de uma usina nuclear em um ambiente virtual como ferramenta auxiliar, no estabelecimento de estratégias para treinamento e capacitação profissional.	
RESPONDA AVALIANDO CADA AFIRMAÇÃO SEGUNDO O SEGUINTE CRITÉRIO:	
VALOR	**CRITÉRIO**
5	Concordo integralmente
4	Concordo parcialmente
3	Não concordo nem discordo
2	Discordo parcialmente
1	Discordo integralmente

13. É recomendado o treinamento com as simulações no ambiente virtual antes da prática em ambiente real.				
( ) 5	( ) 4	( ) 3	( ) 2	( ) 1

Comentários (aspectos **positivos** e aspectos **negativos**) ou sugestões:

Figure 3: Research questionnaire

Questions 1, 2 and 3 deal with the physical reproduction of the environment and equipment

Questions 4, 5, 6 and 7 focus on the functionality of pump operation.

Questions 8, 9, 10, 11, 12 and 13 address the feasibility of a virtual model to simulate different training of evaluators.

Viability of the virtual model for simulation and training presented graphically in Figure 4.

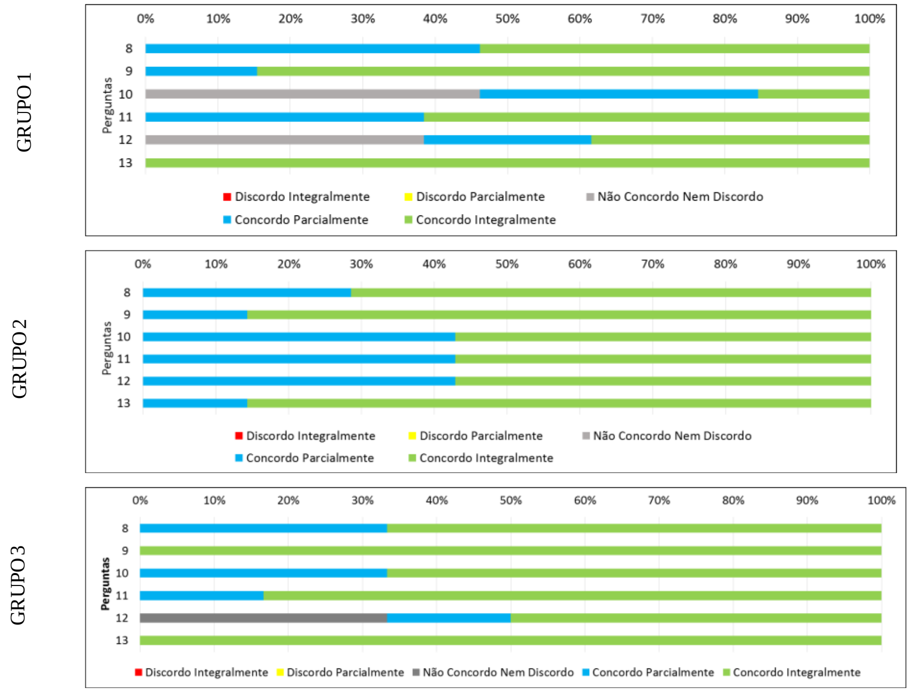

Figure 4: Comparative Analysis of the Result of the Likert Scale

The evaluation questionnaires are still being delivered, but it is possible to see that the results so far indicate that the 1 and 3 groups claim that training with simulations in the virtual environment is recommended before practice in a real environment.

4. Conclusions

With this methodology, it was possible to observe the great interest of the various professionals at the nuclear plant in this type of training. It has also been demonstrated that improvements can be made to existing training and the creation of new training to practice infrequent maneuvers in different plant systems. In this way, human performance, knowledge retention, availability and safety of a nuclear power plant are increased.

Acknowledgements

The authors gratefully acknowledge the support of Instituto de Energia Nuclear (IEN), Brazil.

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