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Review

Review study of virtual reality techniques used at nuclear issues with emphasis on Brazilian research

Márcio Henrique da Silva *, Ana Paula Legey, Antônio Carlos de A. Mól

Comissão Nacional de Energia Nuclear, Instituto de Engenharia Nuclear, Rua Hélio de Almeida, 75, Ilha do Fundão, P.O. Box 68550, 21941-906 Rio de Janeiro, RJ, Brazil

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ABSTRACT

Some of the procedures referred to nuclear issues like evacuation training, waste management and radioactive dose assessment evaluation are related to dangerous situations where the health of the involved personnel can be compromised. For this reason, several researchers have been proposing the use of virtual reality techniques to help on performing this kind of task. Moreover, there are other applications using this type of tool which allow not only the achievement of better results in comparison to the already available procedures but also provide the development of new technologies.

Therefore this work proposes to make a review study concerning to some of the applications of virtual reality techniques and concepts at nuclear issues highlighting some of the works developed in Brazil. To do so, the analyzed researches were organized according to its similarities, objectives and applicability. The goal of this survey is to provide a brief glance concerning to the information about the chronological evolution of this practice describing some of its results besides of showing prospects for further works.

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1. Introduction

Nuclear power is an efficient and reliable source of energy (Whitman, 2007). Despite of the fact it is economically feasible and meets more than 20% of the world's demand for electricity (Abu-Khader, 2009) it is also related to dangerous procedures. Some examples of that can be found in nuclear power plants refueling operations (Ródenas et al., 2004); training emergency first responders to nuclear facilities (Sanders and Lake, 2005); training emergency response personnel (Dixon et al., 2007); evacuation planning (Mól et al., 2007, 2008); evaluation of physical protection barriers (Augusto et al., 2009; Jorge et al., 2011); radiological detection (Sobrinho et al., 2013); methods for minimum dose achievement (Liu et al., 2015); support on planning physical security (Silva et al., 2015) and several others. In all the previous mentioned applications, conducting repeated testing or training

* Corresponding author. Tel.: +55 21 2173 3700; fax: +55 21 2590 2162.
E-mail addresses: marciohenrique@lmp.ufrj.br (M.H. da Silva), ana.legey@pq.cnpq.br (A.P. Legey), mol@ien.gov.br (A.C.A. Mól).

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sessions involves the exposure of personnel to dangerous situations or restricted areas, which is not an option.

For this reason, researchers from different places of the world are using Virtual Reality (VR) techniques and concepts in order to avoid this kind of constraint by means of simulated environments where such procedures can be carried out in a more feasible and safety way. The use of VR technology is not restricted to this type of use. There are other ways to employ it like at ergonomic evaluations as shown in Gatto (2012) and Luquetti dos Santos et al. (2013) and at the development of virtual devices (Jorge et al., 2007; Sobrinho et al., 2013).

Due to the importance of the previous mentioned applications this work proposes to perform a review on some of such. The objective of this study is give chronological information about some of the works related to the use of VR at nuclear research field. To do so, there were identified eight major areas where such applications can be found. They are: nuclear power plant operators training/ergonomic studies; dose assessment; safety training/physical security; development of virtual devices; remote handling; nuclear waste treatment; reactors design and reactors refueling.

The basic characteristics of each are discussed, accompanied by a brief resume of obtained results in each of them besides of showing a perspective of new implementations for future works. The article is organized follows: Section 2 describes an overview of the applications concerning to the use of VR at nuclear issues; Section 3 shows a brief discussion about the works referred on previous chapter; finally, Section 4 presents the conclusion and final considerations.

2. Review of virtual reality techniques used at nuclear issues

In 1983 the simulator-based Halden Man–Machine Laboratory (HAMMLAB) was established by the OECD Halden reactor Project, located at Norway. According to Kvalem et al. (2005), it is the main facility for conducting research at control room design and the role of the operator within such an environment. In addition, it tries to provide knowledge for improving today's control rooms, through the introduction of computer based solutions for effective and safe control of the plant (Kvalem et al., 2005).

The simulations performed at Halden use VR as a tool with purposes of exploring more advanced processes of information allocation and visualization by means of realistic or abstract 3D graphics in real time environments. However, as detached by Boring et al. (2012), HAMMLAB facilities do not map any current plant, i.e., they are strictly focused on research. As the surveys conducted by Halden are not used for training, none of its applications is discussed in the following sections, despite of the importance they have.

A brief glance of a few amount works using VR concepts is described next. To perform the proposed analysis the referred studies were divided according the following areas: nuclear power plant operators training/ergonomic studies; dose assessment; safety training/physical security; development of virtual devices; remote handling; nuclear waste treatment; reactors design and reactors refueling.

2.1. Nuclear power plant operators training/ergonomic studies

Nuclear power plant (NPP) operators training is not a trivial task. It consists on preparing workers to manage normal operational conditions besides of making them aware about what would be the best procedure to correctly deal with an abnormal event. Thus an operator will have conditions to proceed with the right action in order to solve the event at hand. Viewing that nuclear facilities are areas where only authorized personnel is allowed to have access, performing repeated tests for training or other purposes might become a problem.

For this reason the use of VR techniques has become an important ally concerning to that. According to Dixon et al. (2007), virtual environments can be inexpensively and effectively utilized to general training, to communicate the dangers, and to train on procedures to be used when dealing with a radiation emergency. In this work the authors have developed a "fairly realistic" model of the University of Illinois TRIGA reactor for purposes like decommissioning personnel, train first responders and to effectively communicate reactor safety and security issues to students and nuclear personnel. As a suggestion for futures developments are detached a multiplayer mode besides of providing a true 3D immersive experience. Another work referred to the training of operators using VR techniques is shown in Aghina et al. (2007) where a full scope simulator of a NPP control room was proposed.

One of the previously procedure employed to proceed with the operator's training was performed using physical copies of NPP control desks, with the same layout as the real ones. However, these copies were large and expansive which motivated the search for a more suitable procedure. According to this objective, Aghina et al. (2008) have proposed the use of virtual control desks for NPP simulations. Thus they create a cheaper and more practical alternative to the traditional method used until then.

The ergonomic evaluation verifies whether the design stage has adequately considered ergonomic and human-factors requirements. The authors also state that "a system's hardware and software might be well designed, but whether its operators can easily execute their tasks depends on how the system presents information to them" (Aghina et al., 2008).

Giving the importance of the ergonomic aspects, Gatto (2012) and Luquetti dos Santos et al. (2013) have also performed surveys related to this topic. The former presents an ergonomic evaluation of NPP control rooms using VR techniques while the latter proposes to virtually simulate a NPP control room for ergonomic evaluation purposes.

More recently, Jeong et al. (2014) have pointed out that decommissioning workers need to be familiarized with their working environment. This is due to the high radioactivity levels and work difficult during decommissioning of nuclear facilities. According to the authors, on-the-job training approaches could consume much costs and involves poor modifications of scenarios although it could be effective.

Based on it, this work proposed a VR based training system for decommissioning workers. Such system comprehends real-time visualization of worker moving route, real-time detection of worker moving route, and real-time monitoring of worker moving route. It is composed by a head mounted display, which allows the worker to have a first person view of the virtual environment; a monitoring device, which is intended to give the location of the worker viewed in third person mode to the manager and a graphic server. The software used are Unity 3D and a tool for space dose distribution estimation known as MCNP.

2.2. Radioactive dose

One of the most important application of VR at nuclear issues is that referred to estimate radiation dose levels. Due to the fact that it's harmful for all living things, proceed with real tests is not an option particularly in this case. Specifically for NPPs, a better planning of operational and maintenance tasks execution can reduce the dose received by personnel as required by ALARA ("As Low As Reasonable Achievable") principle. Viewing that VR technology can provide immersive and interactive experiences, it has been used as a tool also to deal with this important subject.