A VIRTUAL REALITY SYSTEM FOR HYDROELECTRIC GENERATING UNIT MAINTENANCE TRAINING AND UNDERSTANDING

Alcides P. Junior, Manoel R. Filho, Fábio V. Bezerra, Marcos A. Souza, Pebertli A. Barata, Messias A. Nascimento, Marcelo S. Hounsell

1Federal University of Pará
Department of Electric and Computer Engineering
Rua Augusto Correa No. 1 ZIP 66.000-000
Belém – Pará – Brazil

2State University of Santa Catarina
Department of Computer Science
Campus Universitário Avelino Marcante ZIP 89.223-100
Bom Retiro – Santa Catarina – Brazil

apamplonajr@gmail.com, mrf@ufpa.br, fvvb@ufpa.br, marcosp@ufpa.br, alhobarata@gmail.com, messiasjan@yahoo.com.br, marcelo@joinville.udesc.br

Keywords

Abstract
This paper presents the conception, the design and a prototype of a virtual reality system for learning and maintenance training of Hydroelectric Generating Unit (HGU). The system adopts a modular architecture that makes it expansive and flexible for other areas of assembly training. The system is subdivided in two main functional modules: educative and maintenance. The first one familiarizes the trainee with the structure and with the constituent pieces of a HGU, as well as its general and technical information. The maintenance module offers a program divided in three modes: automatic, guided and exploratory, that increases gradually trainee’s involvement in the system.

1 Introduction
One of the major challenges concerning to industrial plants very large, very complex or cannot be halted, due to financial prejudice, material, or security of persons involved, is the realization of maintenance personnel training. Nuclear power plants, metallurgy or hydroelectric plants have a high level of complexity that conventional training, based on printed material and documents is not adequate to cover, leaving behind a gap between the theory and the practical application of training [1]. On the other hand, training approach using Virtual Reality (VR) allows trainees to virtually manipulate the parts involved on the process [2], furthermore, new employees and recently hired personnel (engineers and technicians), who had not participated the assembly of the industrial installations, are allowed to get familiar and study the parts hidden by the building construction [3], and have other advantages as making the trainee feels being at the real plant, having models which look exactly like the machines on site are used in the training, appropriate advises are given to the trainee by the system when the trainee commits some mistakes, and the assembly and/or disassembly procedure is shown whenever the trainee wants[4].

Guo et al. [5] presented a paper with the use of Virtual Reality as a tool for the visualization of hydroelectric units. It described a study on the advantages of a Hydroelectric Units training method based on RV and it is presented a generic architecture, without implementing it, though.

This paper proposes an educational environment that implements the functionalities suggested on references ([1],[2],[3],[4]), and presents a prototype that uses a Virtual Reality Desktop approach for industry training ([6],[7]) made up of two main modules: the first one to make possible the study of a hydroelectric generating unit, named Educativa Module, and the second one for maintenance procedure training of the hydroelectric unit, called Maintenance Module. The system uses CAD part models of the constituting pieces [8], organized in a hierarchic scene graph [9] and has as database XML files (eXtensible Markup Language) format [10]. The trainee can freely interact with the parts in the virtual world or select actions and execute them. The system has a text area that provides the trainee information on what he is being displayed and about the training procedure in progress. Text information provided along virtual reality is particularly important in educational systems [11].

The second section in this work contextualizes the study of case, a hydroelectric generating unity. The section 3 describes the main components of system’s
architecture and section 4 is about the Educative Module of the system, demonstrating its functioning and the elements that compose the interface. The last section explains about the Maintenance Module, shows its modes and characteristics.

2 Hydroelectric Generating Unit (HGU)

For this study of case, schemas from a Hydroelectric Generating Unit (HGU) from Tucuruí power plant were used ([12], [13], [14]). Located in the North Region of Brazil in the latitude 3º 50' S and longitude 49º 30' W, this plant is sited in Tocantins River in the State of Pará. The altitude is approximately 30m above sea level. The Tucuruí Plant has installed power of 8.370 MW and possesses 23 units; it is the second biggest Brazilian hydroelectric plant and the fifth of the world.

A HGU is a great electricity generator that uses the potential energy of the water unevenness passing by a piping system to move a set of blades (turbine). These ones turn a giant magnet in the interior of an armor of coils (generator) producing electric current through the effect named as Electromagnetic Induction. Thus, a HGU has three main sections: piping, turbine and generator. Figure 1 shows its schematic model.

![Figure 1 – HGU Schematic Model](image)

3 System Architecture

Figure 2 shows a diagram with the system main modules. The dotted border enhances the nucleus of the system which is independent both from the data and exhibition platform.

![Figure 2 - Main system’s modules diagram](image)

The Training Manager is the program central module; its function is coordinating the other modules in order to monitor the performance of the trainee along the training process. Starting from the training manager the trainee selects the module to use, educational or maintenance.

XML documents store the information about the 3D models (name, description, structural data, positioning related to environment, among others). As well as about the training (step sequence, parts that must be manipulated, etc.)

The 3D Loader is responsible for 3D models (mechanical parts) memory loading used in the construction of the virtual world. These models were previously created in the 3D Studio from hydroelectric plant schema and are loaded in the scene graph.

The three following modules operate in group receiving input and producing output to the trainee through the GUI.

The Render is responsible for displaying the virtual environment to the trainee, that is, it involves the driver and the graphical library.

The Text Information Module is the responsible for showing information about object in study to the trainee. The information displayed is dynamic and depends on some factors, such as content of the virtual environment, kind of the training, part level of detail, trainee knowledge, and the executed action.

The trainee Interaction Module holds devices and drivers responsible for receiving the external input from the trainee. These inputs are supplied through mouse and keyboard, that represent the intention and the action the trainee means to take during a part of the training.

4 Educational Module

In this module the trainee can pick a section (piping, turbine or generator), disassemble it and assembly it back again, step by step, and visualize the used mechanical part (being able to interact at will) interpreting textual information on it. Can make HGU parts become transparent to visualize interior sections, navigate through the virtual world and choose five different view angles to be positioned in relevant places for a better understanding of the HGU system. It can execute two types of animation, one of the parts assembly process and another of the system turbine/axle/rotor of generator. The prototype presents basically the same interface for the Educational and Maintenance modules. Figure 3 shows the prototype interface when the Educational module is initiated. The HGU 3D model is in the virtual world field of visualization that was called Virtual Generating Unity (VGU).

4.1 Interface Elements

The system interface is flexible, modifying some of its elements according to what is being on display. This flexibility is obtained by keeping the data about interface elements and the training sequence of each drill in the XML files related to each other.
The interface is divided into: information on the hierarchy of parts and training in the upper part, buttons of action in the left side, virtual world in the center of the screen and the exhibition of text information in the inferior part.

Figure 3 - System Interface with its main characteristics.

In the upper part is located the Menu that makes the training options available, the views, which are visualization positions previously determined in the model and help.

The panel below the menu is the Parts Tree. It displays the hierarchy of objects where the trainee is found, with name and the sequential number.

In the center of the screen is located the Virtual World. The trainee interacts directly with displayed objects picking for getting information, disassemble them, and go down levels in the hierarchy of parts. He can also select other types of interactions in the action buttons as well as execute them over objects or group of objects available in the virtual world.

In the left side there are the Action Buttons whose function is allowing the selection of the type of desired interaction to execute over the objects displayed in the virtual world. The action buttons are divided in three groups: selection buttons, make possible to control the animations, ascend and descend levels in the hierarchy of parts, undo changes performed and redesign the VGU in its initial position, manipulation buttons, to rotate, move or make transparent one or more parts and the navigation buttons that allow changing the position of the observer to points of interest in the training performed, navigation in the virtual environment, etc.

The inferior part of the screen shows synchronized Textual Information along with the actions on the virtual environment. This information varies according to the type of training, its goal and trainee expertise level.

4.2 Functioning

From Figure 3 the trainee can pick with the mouse one of the HGU sections (piping, turbine or generator). Following a sequence, the Figure 4 shows the result of the turbine selection by the trainee.

Figure 4 – Turbine selected by picking over VGU.

The Figure 5 shows the selection of the Turbine Distributor system which is part of turbine. This process can continue until the last constituent part. In each selection, the trainee goes down a level in the hierarchic tree of parts and the information on the new part or set of parts appear in the text area. At any time the trainee can return to the previous level selecting the “back one level” button.

Figure 5 – Turbine Distributor System selected from the turbine and in detail “back one level” button.

Besides being able to examine the constituent levels of each section, the trainee can freely manipulate the parts displayed, receiving information on each one of them. Figure 6 shows the example of the dismounted generator. In order to return to the condition seen in Figure 3 the trainee selects the button “back to start” (detached in figure 6).
To better visualize pieces hidden or blocked by others, the trainee can make parts of the VGU transparent, as shown in Figure 7.

In addition to having free navigation between the parts, the trainee can select through the menu pre-defined views and go straight to standardized positions where the maintenance procedures are carried out. The Figure 8 shows the trainee located in the entrance of the cone. In this point he can set in motion the VGU by “start button” (detached in Figure) and initiate its functioning visualizing the animation of the system rotor of the turbine/axle/rotor of generator.

He can also visualize an animation of the VGU assembly. The Figure 9 shows the beginning of the generator assembly and correspondent “starts animation” button.

With these resources the trainee can explore every part of all sections in VGU, understand its spatial relations and learn general and technical information about parts/sections.

5 Maintenance Module
The objective of this module is allowing that the trainee can virtually execute the maintenance procedures performed in the HGU. The module has three modes of training that depend on the trainee level of expertise on the maintenance procedure he is being trained in. The trainee enters with login and password, allowing the system to register the trainee’s last action so that it can go back to the stop point when returning to the task and his development can be archived. Figure 10, shows the windows for trainee registration and trainee log in.

The trainee can only pass to the next mode of maintenance if completes the tasks of the mode where he is. In each mode the system helps the trainee with messages in text area and in virtual world. At the end of training, the trainee receives an evaluation on his performance in natural language with mistakes and its corrections.

5.1 Automatic Maintenance Mode
It consists in the animation of the steps for the maintenance procedure chosen for training. In this kind of training a minimum interaction between trainee and 3D virtual world occurs. An animation of the chosen maintenance process is exhibited, while information on...
what is occurring is displayed through the text area. This training aims showing the correct positioning of the technician inside the HGU structure and the correct sequence in which the parts must be manipulated. A sequence for maintenance procedure for the junction that is located between the pre-distributor and the superior turbine cover is next presented. First the trainee is situated in the position shown in Figure 11, where he observes the turbine and spiral box where maintenance will be done.

Figure 11 – Above informs trainee’s name and the kind of maintenance, at center shows the observer view in the beginning of the maintenance and below the warning “wait animation until door entrance”.

Next an animation is initiated, which takes the trainee to position in Figure 12.

Figure 12 - Trainee view in front of spiral box door. This is the entrance to this maintenance procedure.

Figure 13 shows the spiral box opening door animation where the trainee will pass through.

Figure 13 - Spiral box door opening.

Figure 14 shows the trainee inside spiral box and heading to maintenance place.

Figure 14 - Trainee view inside spiral going to maintenance point.

Figure 15 shows the animation of the maintenance procedure of junction between pre-distributor and superior cover from the technician point of view. This figure shows the dismounting phase, when the screws of the press-junction had been removed (in white), the press-junction (in green) and finally the junction (in blue). The assembly is performed in the reverse order.

Figure 15 - Maintenance animation of junction between pre-distributor and superior cover

5.2 Guided Maintenance Mode
This maintenance is carried out trainee himself by navigating through the virtual environment to find his positioning in the point where the task will be performed and moving the parts necessary to carry out the maintenance process. On each step in sequence to be followed, the system guides the trainee presenting commands in text area, to show him what to do in sequence, guiding trainee’s learning. If some error is made during the maintenance procedure; the text area shows information indicating the error as well as its correction. In this case the trainee removes the screws, press-junction and the junction and replaces them with the mouse and picking.

5.3 Exploratory Maintenance Mode
In this mode, learning is verified through the accomplishment of the maintenance procedure without any help from the system. In case followed as sample the trainee removes the screws, press-junction and the junction and replaces them using the mouse. No information is displayed in the text area during the
maintenance procedure. If the trainee isn’t able to execute the procedure correctly, the system will return to the guided maintenance showing an analysis of committed mistakes. Otherwise, if the procedure is performed correctly, the system allows the trainee to select a new maintenance procedure.

6 Final Considerations

The first prototype version was finished and implemented in the plant of Tucurui in order to be evaluated by its technical staff. It was demonstrated that this prototype implements the functionalities suggested by references mentioned in the introduction. In this stage the Educational Module and part of the maintenance module have been finished, concerning to the junction between the superior turbine cover and the pre-distributor replacement and the junction between the inferior turbine cover and the pre-distributor replacement.

The research project continues and currently new maintenance procedures are being added, using the same premises seen in the replacement of the superior cover junction.

References


