

Application of Virtual Reality Technology to Nuclear Engineering

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Introduction

What is Virtual Reality?

Virtual Reality (VR) is a computer technology to create or to simulate a virtual scene where users can interact with virtual objects with body language. Generally, three dimensional images of this virtual scene are displayed either on a projection screen or on a HMD (head-mounted display) and interaction is based on head and hand tracking. Features of VR technology include multi-sensory, immersion, interactivity and imagination. At present VR is widely used in the domain of entertainment and education.



Figure 1: Google's Project Tango : image recognition application

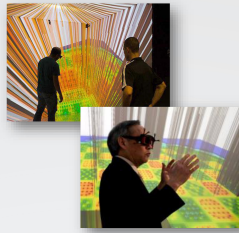


Figure 2: The Virtual Office, Community and Computing lab allows researchers to walk among the fuel rods of the virtual reactor with active stereo and tracking.

Why we apply VR to nuclear engineering?

► To reduce high cost of the consequence of failing the operation in nuclear training

Time and resource spent on education and training at nuclear facilities is significant as the result of high demanding of nuclear security. Traditional training methodologies involving written text and video tapes are useful but lack interactivity and timely feedback. An interactive and virtual training paradigm shows some promise towards achieving the training goals for utility personnel.

► To satisfy the demand of visualization in nuclear scientific simulation and calculation

3D modeling and science simulation play an important part in the field of nuclear engineering. The classical method to present 3D scientific data in 2D images and to manipulate them with mouse, keyboard lead to the loss of a lot of information and can't bring an immersive experience. VR can provide a stereoscopic vision of these scientific data and can make these complex structures more intuitive.

Method

Our Virtual Reality system can be divided into three parts: Virtual Reality Scene, Visualization and Interaction. The system first builds a Virtual Reality Scene and visualizes the scene. Then it captures orders of users and applies these orders to the scene and control objects in the scene. This forms a feedback loop.

Virtual scene

We used SolidWorks to establish 3D models of EPR and established virtual scenes with VTK and Unity3D based on them.

Visualization

We used two methods for 3D visualization: 3D projector and HMD. Principle of 3D vision is to present images with a little difference to two eyes, to simulate images seen by people in the real world.

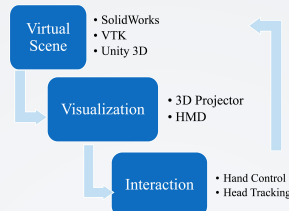


Figure 3: Components of virtual reality system

HMD places these two images on display in front of users' eyes while 3D projector projects them on screen. For 3D projector users can wear a pair of 3D glasses which can filter the non-corresponding image for two eyes, and form the 3D vision for users.

Interaction

We realized two methods of Interaction: Hand Control and Head Tracking. For hand control, the system captures users' gestures, recognizes their commands, applies these commands to objects in the scene, and control their movement, rotation and scaling. For head tracking, the system captures users' head orientation and transmits the information to the scene. So the image will change following the orientation of users' head.

Results & Discussion

3D modeling of EPR primary loop

A series of 3D models of primary loop of EPR have been established including one reactor pressure vessel (RPV) and its inside components, four steam generators (SG), four cooling pumps (RCP), one pressurizer (PZR), connecting pipelines and their supporting structure.

► Scientific simulation

Due to an accurate request in modeling with SolidWorks, our production could be used for preliminary scientific calculation, such as a whole core neutronic calculation conducted by our supervisor Zhang.

► Virtual reality system

Also, an intuitive feeling for nuclear island contribute to science popularization and professional training. Following, figures of whole model of EPR (Figure 5), SG (Figure 6) and the cutaway view of RPV (Figure 7) are shown.



Figure 4: Overview of EPR primary loop

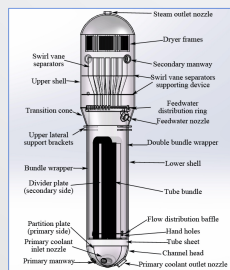


Figure 5: Steam generator

Virtual Reality System compatible with 3D projector

► Virtual scene

A virtual scene has been created in VTK where there are light, camera. We imported these nuclear models and rendered them in this virtual scene.

► 3D visualization

3D project is used to project this virtual scene on a screen so that we can have a stereoscopic vision of nuclear models with a pair of 3D glasses.

► Interaction

We have designed a set of hand gesture which has a high recognition rate and which is easy to learn for interaction with nuclear models. Then we developed Leap Motion in order to capture these designed hand gestures. At last we combined VTK and Leap Motion for applying these gestures to nuclear models in virtual scene.

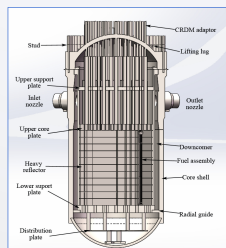


Figure 6: Cutaway view of reactor pressure vessel



Figure 7: Virtual reality system compatible with 3D projector

Virtual Reality System compatible with HMD

► Virtual scene

This system established a virtual reality scene of nuclear power plant based on Unity3D. 3D models of EPR and imported in the scene and rendered with texture. Light and shadow effects and realized in the scene.

► 3D visualization

Images are captured by two cameras in the scene, simulating the binocular vision of human, and presented separately to users' two eyes on HMD. Two lenses are used to focus users' eyes on display.

► Interaction

Sensors are placed on the HMD and captured the orientation of users' head. Single chip machine can analyze the orientation and transmit it to computer through serial port. Receiving the information, the system will rotate the cameras in the scene. So the image will change following the orientation of users' head.



Figure 8: HMD model

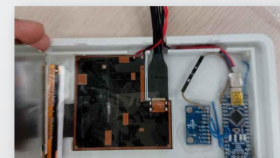


Figure 9: Internal circuit of HMD model

Summary & Future work

Summary

In summary, we had built a model of EPR which can be used in virtual reality and scientific computing. Besides, we had built a system with 3D scientific data stereo-view, displaying the model of EPR, and realized hand control for the system. We had also developed a head motion tracking device which can capture users' head orientation in real time. Moreover, we had built a virtual reality scene of a nuclear power plant compatible with our HMD, and a virtual reality scene of EPR compatible with Oculus Rift DK2.

Future work

Although basic VR functions are realized, our work has some space for improvement. In the part of 3D models, the modeling of some devices in nuclear core has not yet been finished. In gesture control, more functions can be added. Better factory building models can be used to make the scene seem more real. Similarly, textures of building should be clearer or more complete. The algorithm of the head motion tracking can be improved in computation accuracy and efficiency. Our VR system can be used to display scientific computing and to train staff in a nuclear power plant.

Our 3D model can be found by scanning this QR Code and downloading an APP



Reference

- [1] Figure:
<https://maineicwsonline.com/content/16016740-dedicated-team-engineers-apple-working-virtual-reality-project>
- [2] Figure2:
<https://www.cnn.com/news/virtual-office-community-and-computing-lab>