Virtual Reality Application for Simulating and Minimizing Worker Radiation Exposure

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1. Introduction

To plan work and preclude unexpected radiation exposures in a nuclear power plant, a virtual nuclear plant is a good solution. For this, there are prerequisites such as displaying real time radiation exposure data onto an avatar and preventing speed reduction caused by multiple users on the net-based system. The work space is divided into several sections and radiation information is extracted section by section. Based on the simulation algorithm, real time processing is applied to the events and movements of the avatar. Because there are millions of parts in a nuclear power plant, it is almost impossible to model all of them. Several parts of virtual plant have been modeled using 3D internet virtual reality for the model development. Optimum one-click Active-X is applied for the system, which provides easy access to the virtual plant. Connection time on the net is 20-30 sec for initial loading and 3-4 sec for the 2^{nd} and subsequent times.

2. Methods and Results

2.1 Design of Virtual Plant

A 1000-MWe PWR virtual plant model, was designed for system development according to its most common style. It has 2 loops, 2 steam generators and 4 reactor coolant pumps in the reactor primary system, a chemical volume control system, and a spent fuel cooling system. One of the most important technologies used for the virtual plant is rendering normally applied in the game industry. The rendering capacity is 15 frames per second, which enables the creation of thousands of polygon graphics.

Several scenarios were developed which consist of tasks involving external exposure rates for workers in high radiation zones such as work involving maintenance of steam generators, reactor coolant pumps, refueling, and emergency operations.

2.2 Numerical Expression and Algorithm for the Calculation of Radiation Exposure

The whole radiation work space can be represented by N-sections. Radiation exposure in a section can be expressed by integrated by time:

$$tESi_d = \int_0^T Si_p dt \qquad (1)$$

where $tESi_d$ is dose in section i, and Si_p is unit exposure rate in section i, and t is the working time. The whole dose through n sections can be expressed as:

$$ETS_d = \sum_{i=1}^{n} ESi_d \qquad (2)$$

where ETS_d is the whole dose in the work space.

The work space can be denoted by WS = {S0, S1, ..., Sn-1}. Total dose in the WS can be calculated from the sum of the set Si_p = {$S0_p$, $S1_p$, ..., $Sn\text{-}1_p$}. The dose is calculated by checking the time in the section and the time out of the section. Even though there is a possibility to enter a section once again, the whole dose (ESi_d) can be obtained by accumulation of $tESi_d$.

The routines checking whether one goes in or out are accomplished by a module synchronized in virtual space, taking input from count time, section ID, and passing status (i.e., pass=True / False). Figure 1 shows the algorithm to calculate total dose in a work space.

2.3 System Design

The monitoring system consists of a three dimensional virtual model and interlinked simulation program to estimate the dose. This system provides the radiation information with its virtual image. The system includes the server and client as shown in Figure 2.

The client consists of a 3-D browser and EAI (External Authoring Interface) which can maintain document control and applet resources. EAI provides the dynamic interface for the communication between script node and applet client. The server includes applet resources and area information, the radiation exposure rate processing module, and the virtual space synchronous module. Applet resources provide

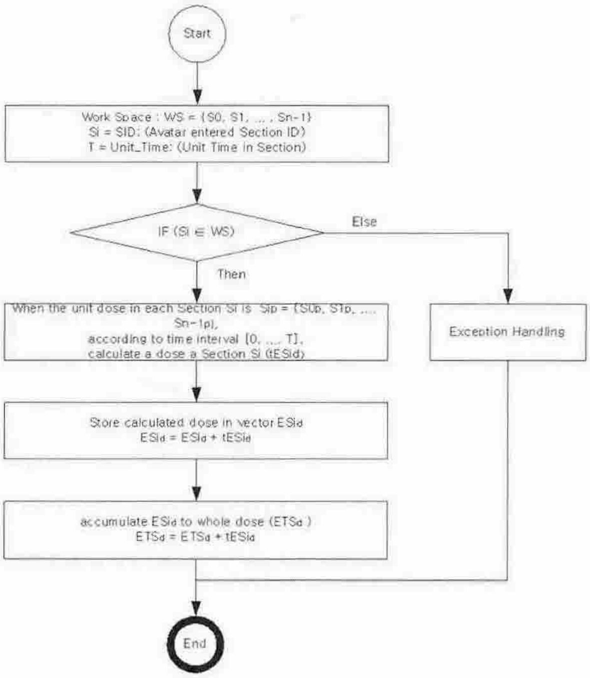

Figure 1. Algorithm to Calculate Dose

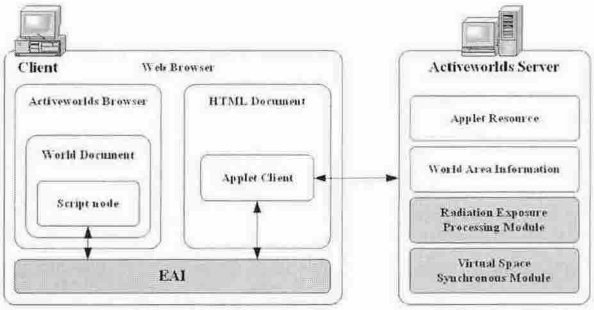

Figure 2. Radiation Monitoring System

information to the avatar if it starts to participate in the world and supports client event synchronization with the server side world.

The communication process consists of the following client-user interactions: (1) If a client (user) requests to participate, the server transmits applet bite code and area information. (2) The client executes HTML including applet bite codes and area information. (3) If the user moves to another area, the client requests new information from the server. (4) Server applet calls the virtual space synchronous module to verify proper information. (5) The Dose treatment module checks the time and section ID, and transfers it to the applet. (6) The applet resource calculates the dose information and displays it.

A Proximity Sensor node is used to detect movement of an avatar. The Proximity Sensor node is in a script node of the browser on the client-side. It is necessary to monitor avatar movement using the node provided by EAI. If the avatar moves in this region, an event occurs. This event sends the message to the server directly. Through the applet client, the EAI offers an interface for communication with the external environment (virtual space synchronization module).

3. Conclusion

Figure 3 shows the virtual plant model using 3D Renderware. Several parts of the Auxiliary Building and Reactor Building have been modeled using 3D internet virtual reality for the process development. Active-X was applied for the system, which provides connection time on the net is 20-30 sec for initial loading and 3-4 sec for the 2nd and subsequent times.

The system design with dose calculation algorithm has been completed and total dose for an avatar has been shown to be accumulated in real time as the avatar moves through the virtual plant. Access is provided through an internet-based server-client relationship. The system is designed to support both routine works in radiation environments independent of exposure rates, as well as work during rapidly changing conditions under emergency operating circumstances.

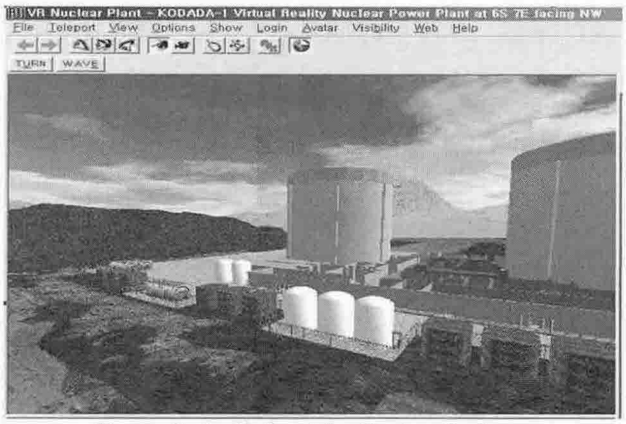

Figure 3. Radiation Monitoring System

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