Visual simulation study of equipment maintenance in dangerous environment

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Abstract: The maintenance characteristics in dangerous environments are analyzed, and the application characteristics of visualized maintenance technology are introduced. The interactive method to implement maintenance simulation is presented using EON simulation platform. Then an interacted Virtual Maintenance Training System (VMTS) is further developed, and the composition and function are described in details. The VMTS can be used in extensive array of application scopes, and it is well compatible to the hardware of virtual reality.

Keywords: dangerous environment; visualization; maintenance simulation; VR; training

1 - Introduction

The equipments that lead to the specification labeling of, under dangerous operating conditions are usually considered as the working environment of equipments or themselves, which could harm the human body. The dangerous environment of the former includes high temperature, strong noise, strong acid, and the latter includes those equipments with strong electricity, strong magnetic field and high radiation, such as nuclear-powered equipments and high pressure apparatus. Due to the harsh environment which has enormous effect on the maintenance personnel, the fault rate of the equipments is high. It has been shown by the past studies that the operators working in such tough environments have higher error rate than that of normal working condition [1]. Two reasons may explain these problems: One is the fact that the equipments of nuclear reactor are so complex that maintenance personnel result in lacking the capacity to locale maintenance experience and to hardly master the characteristics of the equipment and the maintenance technology, while the other point is the fact that maintenance personnel in those dangerous circumstances usually start to panic psychologically, that absent-mindedness effects the ability to fully maintain ones personnel professional knowledge or skill. The effective method to resolve the above problem is maintenance training in dangerous environment once, continued again until those maintenance personnel can overcome the panic psychology and master the maintenance skill. But the equipments in the harsh environment are usually very expensive and it is not appropriate for the maintenance personnel to conduct long-time maintenance training in those work environments. Therefore, it is necessary to introduce modern maintenance training theory and methods. The visualized maintenance simulation that is by using Virtual Reality (VR) has already become an efficient way for such purposes for example.

VR is a way of visualization, interaction and navigation through a dangerous maintenance environment, described by a 3D computer model. A commonly accepted definition of VR is "A computer system to create an artificial world in which the user has an impression of being in the real world and to be able to navigate through the world in order to manipulate objects in the world" [2]. VR technology is useful for planning, training and presentation because it offers a realistic way of simulating the real world in 3D, with the potential for direct user interaction and system feedback. Based on the digital simulation model, the authors of this paper has been developing a Virtual Maintenance Training System (VMTS) of high danger equipments for providing an analysis and

training platform to the maintenance personnel.

2 - Visualized maintenance technology

Modern scientific and technological achievements have been widely applied in various electromechanical equipments, especially those in special environments such as nuclear-powered ships which have more advanced functions, more synthesized technique and more complicated structures. The traditional maintenance training approach is hard to meet the demands of actual maintaining procedures of complicated highly technical systems operating in

hand, many maintenance related data such as maintenance time, work type, maintenance tools, sequence of disassembly, work space and maintenance budget can all be described by the visualized maintenance technology, such as the authors' development of VMTS. In VMTS, the faults can be simulated to check and locate quickly. According to the maintenance theory with the guidance of specialist, the VMTS has been developed to take reach-ability and maintainability into the account of simulating the relevant maintenance work. The structure of VMTS is shown in Fig.1.
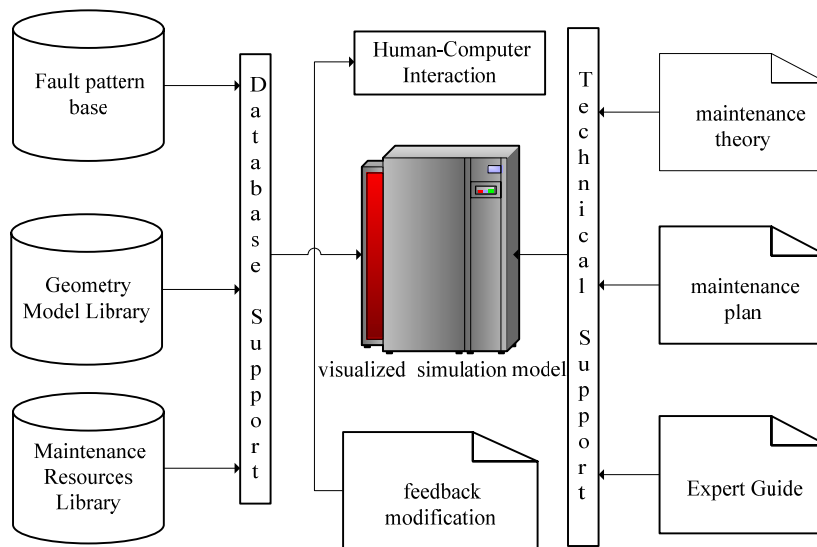

Fig. 1 the structure of VMTS

dangerous environments. A new technology is needed to complement it, and so the study of visible maintenance technology by VR has appeared.

3D digital-models and simulation environments are built in computer by CAD technology, which could make maintenance personnel get acquainted to the equipments and the environment. Through analyzing the simulation model without the physical model or prototype, the manpower and material resource, as well as the training period and the damage to the maintenance personnel can be reduced largely. Virtual disassembly can be realized by virtual maintenance technology based on visualized technology. Through the simulation process, fault analysis and maintenance provide credible data to shorten the development cycle of new equipments to improve the maintainability and to save the cost of maintenance training. On the other

3 - Realization of visualized maintenance simulation

3.1 Modeling

3.1.1 Geometry model

Visualized maintenance is based on entity modeling, which is related to better implementation of interaction and immersion. Special modeling CAD software was chosen to build digital simulation model of equipment and environment, where the triangle faces of model were reduced to balance the simulation speed and the modeling quality. This is important to realize the fluency of simulation process. Then these models are saved as expected file format so as to import into simulation platform. Each part of the

equipment formed a node in the simulation files. These nodes are the minimal units to form maintenance simulation of complex equipments.

3.1.2 Movement model

EON Studio is a basic VR development tool that allows users of all experience levels to build interactive 3D product content quickly and easily. EON Studio is based on the program design language of the process and the node. It can construct simulation route through arranging and connecting function nodes. Especially, the users can use the Script nodes to add new behaviors with the programming language of Visual Basic or Java. All equipments and parts are expected to simulate and have to be build up by movement models, which can in effect enhance interaction, maneuverability and controllability between user and VMTS. As many movement nodes have been integrated in EON Studio such as Place Node, Path Node, Rotate Node, it becomes easier to build the movement models. The user only needs to drag the Mesh node and movement nodes under the same frame, in order to carry out the parts and its movement.

3.1.3 Action model

The action model is the link between the geometry model and movement model. Various movements and real time interactive control can be realized to meet with the operator's purpose. The basic idea of action model considered here is modeling the process of visible maintenance as a discrete event method to advance in time. The concrete implementation method can be seen in the references [3, 4]. The action is realized through different nodes in EON such as Switch node and Script node. Among those nodes, Script node is the important node to implement man-machine interactions. The user can define input and output event and compile EAI(Enterprise Application Integration) communication code through VB Script or Java Script to form a junction function.

3.2 Design and realization of interactive interface

3.2.1 Interaction principle

To transmit data and orders by means of real time interaction, the script is compiled to realize interface

search through the VB Script in EON. The methods include Script interface, EAI interface and so forth. Script node which is the bridge of C++ Builder and EON can describe an event region, intake and exit of the event which are all defined by user. In the development platform of C++ Builder, exterior interface of each object in the system can be created by EAI [5], sequentially actualizing interaction. The relation between model and Script is shown in Fig. 2.
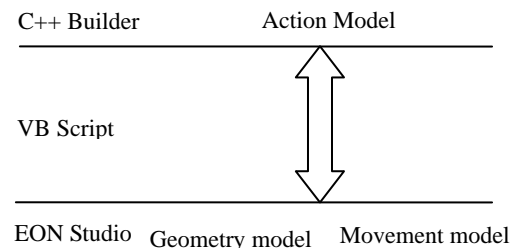
Fig.2 The principle of interaction

3.2.2 Design and implement of the interface

Script nodes are defined as many fields, such as exposedField, eventIn, eventOut, and so forth. The source codes of virtual maintenance are written in every event field corresponding to a function of VB script. Then the in-out function of Script node joins the interactive node in the figure of event and create interior environment interface for preparing the entrance of EAI.

Virtual equipments can be controlled by exterior program or by writing a proper script. The exterior program which is compiled by C++ Builder means the program visiting nodes in the interactive interface. A part of key code of EAI interface is shown here.

```
{ //assume that the eventIn is bool variable;
    //define mysim as the object of class TControl2
        TControl2 mysim;
    //load file, eoz is in the format of EON source file
        mysim->SimulationFile="Filename.eoz";
    //execute file
        mysim->Start();
    //visit eventIn whose index number is zero
        EventName=mysim->GetInEventName(0);
    //transfer true value to the variable,and the value of
```

```
        OleVariant(0) is false
        mysim->SendEvent(EventName,OleVariant(1));
   //end execution
        mysim->Stop(); }
```

The user sends the order to EAI by Buttons or Texts in the interface, and EAI can visit the interface program. After some event about the scripts is fired, the maintenance action can be implemented in virtual environment. While the feedback information is obtained by the method of GetOutEventType( ), real time interaction is realized by GetOutEventName( ) provided by TControl2 Class.

4 - An example

According to the theory and methods mentioned above, the VMTS has been developed for simulating dangerous maintenance work in operating environments. The whole maintenance process of equipments is able to be simulated, and especially the feasibility of disassembly process may also be analyzed. User can define the disassembly sequence which is followed by the VMTS to disassemble training and the analysis of reachability and maintainability. Considering the particularity of the radioactive environment, the maintenance work usually need cooperation by many people to complete the task, and the presence of maintenance personnel should be reduced as short as possible.

The VMTS was designed to achieve the function of distributed VR simulation training in the multi-user mode, to one single apparatus to enhance the training efficiency greatly. The basic principle of the system will be explained in the following: Firstly, the group leader, who will be nominated and he/she will build up the maintenance group, and selects the training task. Secondly, the group members are added to the group. All members of a group have the same operation class except for the group leader. On maintenance training, only task and token are assigned to the members who will execute the maintenance action in virtual environment. All members will see the same virtual scene including the equipments and tools. The principle of assigning task is shown in Fig. 3. The group leader sends a command to a member, and asks the members to complete the command, while other members are waiting until former crew finish the maintenance operation.

The whole VMTS system includes facilities' database, maintenance tool database, maintenance personnel information database, training register and other databases. Users can send the order to the system and get the places, states and parameters of the virtual equipments, resulting from real-time interactive function. For example, some fault types may be trained again and again in order to aim at emphasizing the key step to improve the maintenance efficiency. As users gradually becomes familiar with the equipment to be maintained through the repeated process, the psychological fear of the maintenance workers will be dealt with and over come easily, and the error rates would be reduced.
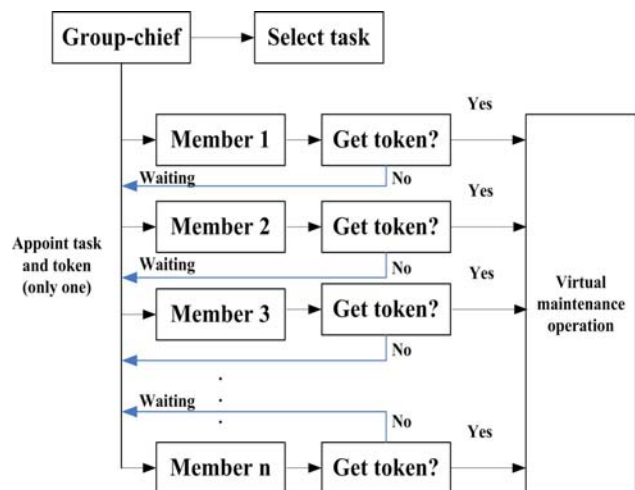

Fig.3. the principle of assigning task

A captured scene of the VMTS usage by the group chief about manipulating a valve in radioactive environment is shown in Fig. 4, while the scene seen by the member named YH1 is shown in Fig.5.The group chief and other group member can share a common virtual environment at the same time, while they observe and control the same scene with different perspectives in a free manner.

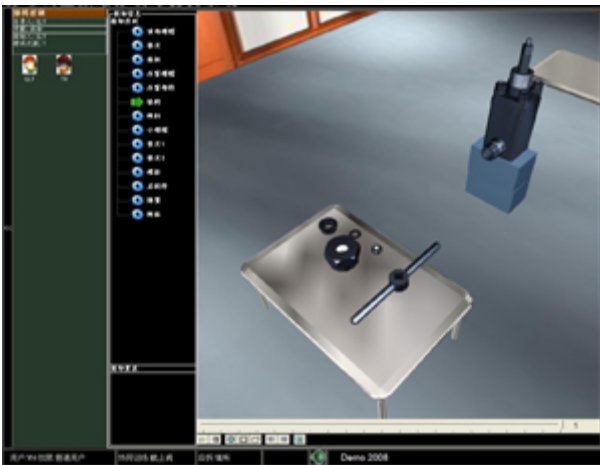Fig.4 The scene observed by the group chief

Fig.5 The scene observed by a group member

5 Conclusions

The dangerous environment has enormous influence on maintenance operation. However, visualized maintenance training technology such as VMTS system as proposed in this paper will be able to reduce the bad influences such as psychological fair of workers for radioactive dose, committing human error, and so forth, by means of prior maintenance training in virtual simulating working environment.

Because of the complexity of the real dangerous environment, the developed VMTS system still has some problems. For example, precise modeling of the complicated scene, simulation of the dose field in radioactive environment and the influence of the high temperature and high pressure for people's behavior leads to, and so forth. Those subjects will be resolved and improved by further research and development by the authors of this paper in the future.

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