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A Basic Study of Virtual Collaborator - The First Prototype System Integration

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Abstract

The goal of this study is to develop a "virtual collaborator" as a new type of human interface environment. The virtual collaborator is an intelligent agent realized in VR space, who can communicate naturally with human like humans do with each other. As the first step of this study, the authors have constructed a prototype virtual collaborator who can behave just like plant operator in the control room of nuclear power plant, although the present prototype has no communication functions with humans. At the present stage, the virtual collaborator can detect an anomaly, diagnose the root cause and operate the control panel in accordance to the operation manual in the virtual space, where the control room of the nuclear power plant is visualized. The prototype system is constructed as a distributed simulation system, which consists of four subsystems: (1) nuclear power plant simulator, (2) man-machine interface simulator, (3) human model simulator, and (4) human body motion simulator. These subsystems have been separately developed and have been combined afterwards.

1 Introduction

Recently due to the increased automation by the introduction of modern computer and information technologies, the machine systems have become so large and complex that the manipulation of the machine system has become a difficult task for users. Especially, in the field of aircraft and power plants, the tendency is conspicuous and an error of an operator may give rise to serious accidents. Therefore, the study on the man-machine interface has been extensively made to improve the relationship between human and the machine system.

In this study, the authors aim at developing a 'virtual collaborator' as an ideal human interface. The virtual collaborator is an intelligent agent robot in VR-space. Human can interact with the virtual collaborator to operate machine systems. It has a human-shaped body and can listen, talk, think and behave like humans.

In this paper, the basic concept of the virtual collaborator, the configuration of the prototype system which has been developed as the first step of this study, and the result of the experimental simulation of the system are described.

2 Configuration of Virtual Collaborator

In order to develop the virtual collaborator who can naturally communicate with human, the authors have contrived the configuration of the system as shown in Figure 1. The virtual collaborator has sensing system, thinking mechanism and effector system like humans. With the sensing system, the virtual collaborator can recognize the actions of human such as motion, speech, gesture and facial expression. With the thinking mechanism he can understand the situation around him and make decisions. And with the effector system, he can behave freely, speak and sometimes express his emotion to the human.

In this study, the authors have studied and developed key technologies to realize such virtual collaborator [1]. They are summarized as follows:

- Bio-Information Sensing Technology

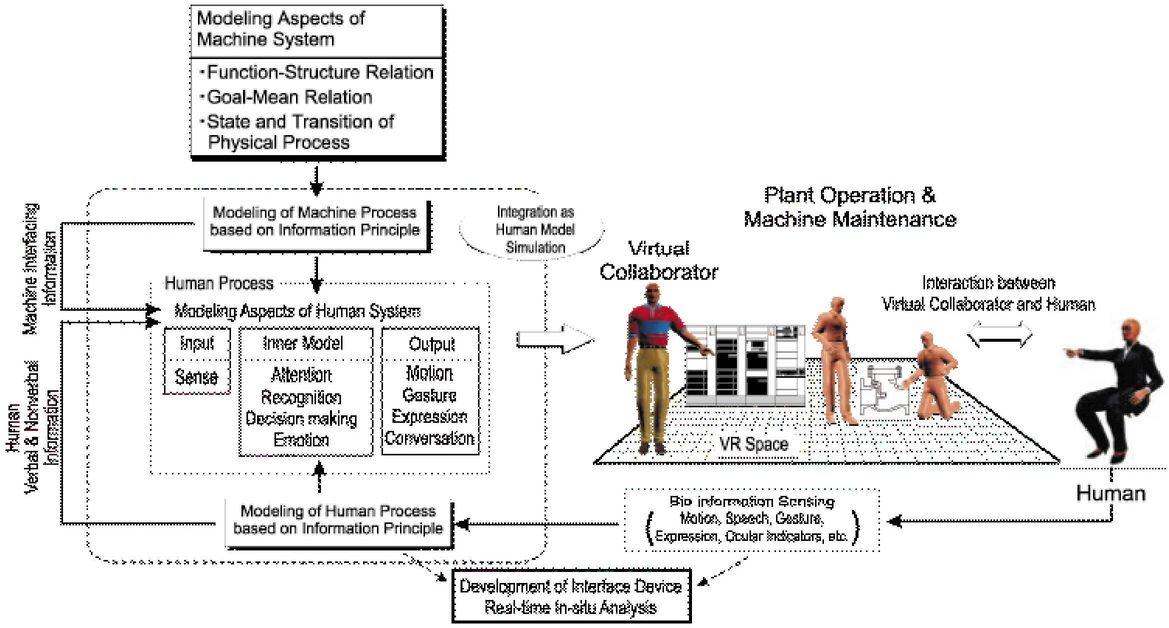

Figure 1: Overall System Configuration of Virtual Collaborator

This is the technology to estimate the human internal states such as thinking process, mental stress and emotion. In order to estimate the internal state, the targets of bio-informatic sensing are not only gesture and facial expression but also various physiological indices such as the distribution of skin temperature, the transition of the heart rate, gaze-point and the transition of the pupil size.

- Human Model Simulation Technology

  This is the technology to realize the intelligence of the virtual collaborator by computer simulation. Concretely, the authors extended Reason's theory as a general human model framework. And the human model was constructed by using a development tool for real-time object-oriented expert system, G2(GenSym Co.Ltd.).

- Synthesis Technology of Human Body Motion

  This is the technology to compose the body motion and facial expression as naturally as possible. In this study, in order to realize natural movement, the body motion is composed from basic motion data. In the motion database, which consists of pieces of motion data obtained by measurement of actual human motion.

In this study, as the first system integration, a prototype virtual collaborator who can behave just like plant operator in the control room of nuclear power plant has been developed by constructing the collaborator's thinking mechanism with the Human Model Simulation Technology and the collaborator's body motion with the Synthesis Technology of Human Body Motion. At present, this prototype system has no communication function with human, but he can detect a plant anomaly, diagnose the root cause and operate the control panel in accordance with an emergency response operation manual.

3 System Architecture of Prototype Virtual Collaborator

In this section, the configuration of the prototype virtual collaborator is described. As shown in Figure 2, the whole prototype system is constructed as a distributed simulation system which consists of the following four subsystems: (1) nuclear power plant simulator, (2) man-machine interface simulator, (3) human model simulator, and (4) human body motion simulator. The details of the four subsystems are explained as follows.

(1) Nuclear Power Plant Simulator

The Nuclear Power Plant Simulator (NPP Simulator) is a real time dynamic simulator of an actual PWR plant, which can simulate various kinds of plant anomalies.

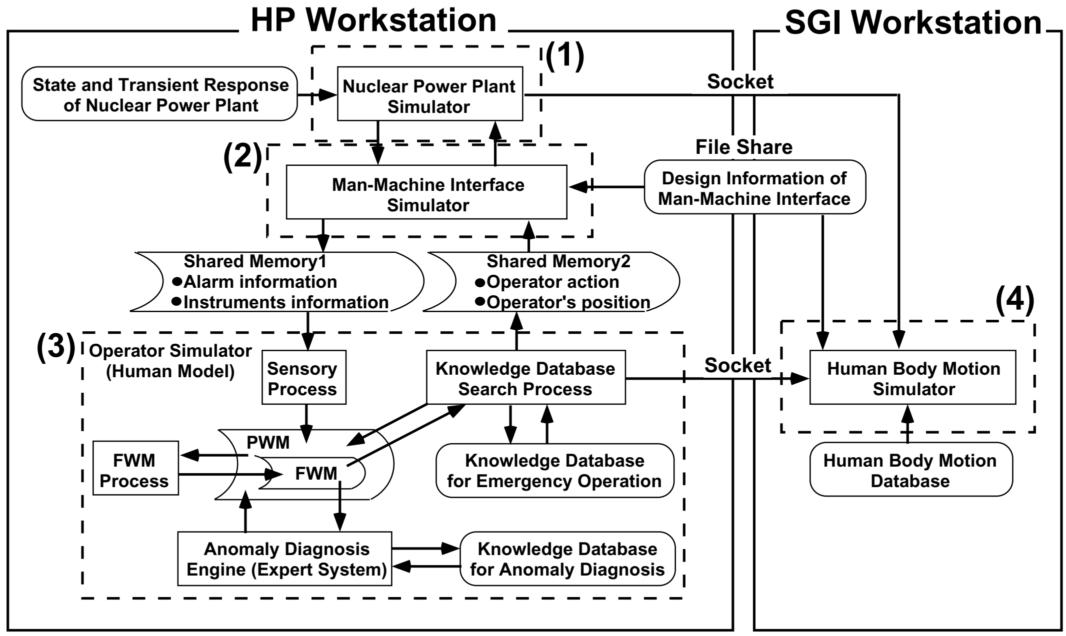

Figure 2: System Architecture of Virtual Collaborator

(2) Man-Machine Interface Simulator

The Man-Machine Interface Simulator (MMI Simulator) is based on-line object-oriented database model to the presented man-machine interface information in the plant control room as 2 dimensional images. And the MMI Design Information database includes the information about layout, shape, location, panel, etc. of various equipments in the control room, and the temporal behavior of instruments.

(3) Human Model Simulator

The Human Model Simulator (HM Simulator) realizes 'intelligent functions' of the virtual collaborator, by employing a general human model framework which consists of sensory process, focal working memory (FWM), peripheral working memory (PWM), knowledge database, database search process, FWM process and anomaly diagnosis engine. Based on the above components, the virtual collaborator checks the control panel, detects an anomaly, diagnoses the root cause by examining hypotheses, and performs appropriate response operations. In each step, the human model simulator drives human body motion simulator in order to visualize the motion of the virtual collaborator in virtual control room. The details of the human model simulator were described in our published paper[2].

(4) Human Body Motion Simulator

The Human Body Motion Simulator (HBM Simulator) generates the virtual space in real time, where not only the body motion of the virtual collaborator but also the various conditions of control room itself is visualized. In order to realize the naturalness of the body motion, first the actual human body motions of "walk" and "operation" were measured by a 3D motion capturing system, and then basic motion database was built by the measured data. When generating the body motion, the appropriate basic motion is selected from the database, and modified to fit the objective motion. By this method, the walk motion of arbitrary direction and distance, and the operation motion of pushing buttons and sliding levers can be generated naturally in real time. The details of how to measure the actual human body motion and how to compose them were described in our paper presented on EDA'98[3].

4 System Integration

NPP Simulator, MMI Simulator and HM Simulator are integrated on a workstation (HP VISUALIZE C200) as separate processes. And each simulator communicates with the other simulator through shared memories shown in Figure 2. The shared memory 1

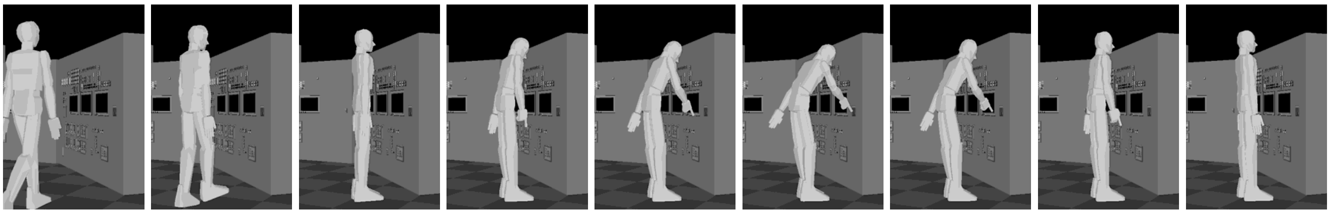

Figure 3: Composition Example of Virtual Collaborator

deals with two types of information; (i) alarm information, and (ii) the focused MMI information. And the shared memory 2 deals with two types of information; (i) information on the operation, and (ii) MMI information, on which the operator is focusing.

On the other hand, HBM Simulator is integrated on the graphics workstation (SGI OCTANE). To visualize the virtual collaborator, it is necessary to compose not only the human body motion but also the control panel of the nuclear power plant. The design information of man-machine interface for HBM Simulator, which includes the information about the control room of nuclear power plant, is reflected to the design of the MMI Simulator.

The control room consists of 10 control panels on which about 500 instruments are located. If all the instruments are drawn with polygons, the load becomes too large, therefore the details of the instruments are drawn with textures.

The necessary information for composing the virtual collaborator in the virtual environment are (1) to which panel the collaborator moves, (2) which indicator he checks, and (3) which instrument and how he operates. In addition, the parameters of NPP Simulator must be sent to HBM Simulator to visualize the control panel. All the above information are sent by socket communication between HP workstation and SGI workstation.

By using the integrated system, some example simulations were conducted to examine the required functions of both each subsystem and the total integrated system. As example simulations, the cases of LOCA (Leak of Coolant Accident) and SGTR (Steam Generator Tube Rupture) were simulated. Figure 3 shows an example scene in which the virtual collaborator operates a control panel in the virtual environment. From the analysis of simulation records, it was confirmed that the developed prototype system could simulate the plant operator who can detect an anomaly, diagnose the root cause and operate the control panel with the natural movement in virtual control room.

5 Conclusions

In this study, the authors have developed the prototype virtual collaborator who can operate the control panels of nuclear power plant with visualizing the control room in virtual environment by applying the technologies, which have been separately developed. The authors are planning to develop the functions to estimate human internal states and communicate with real human as the second step of this study.

Acknowledgements

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