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Feasibility Study on Use of Virtual Collaborator for Remote NPP Control

Jong Hyun Kim, Seung Jun Lee and Poong Hyun Seong

Korea Advanced Institute of Science and Technology
Department of Nuclear Engineering
373-1 Kusong-dong, Yusong-gu
Taejon, Korea 305-701

Abstract

In this paper, we study the feasibility of Virtual Collaborator for Remote NPP Control as long-term research theme. And we present similar and related researches that are fulfilled at I&C laboratory in nuclear department of KAIST. Yoshikawa's laboratory, Kyoto University in Japan, is developing "virtual collaborator", agent robot, which realized in virtual reality. Virtual Collaborator is a new type of human-machine interface which works as "intelligent interface agent" to help machine operators manipulating large scale machine system such as power plant. The Virtual Collaborator is a sort of "virtual robot" which behaves as if an intelligent agent robot in virtual space, who can communicate naturally with human like humans do with each other.

I. Introduction

The developed countries such as United States, Western Europe and Japan, are advancing towards high information societies due to the rapid progress of information and telecommunication technologies [1]. Recently, Korea also intensively expands network facilities of the nation in order to develop Information Technology (IT). Therefore, about a half Korean can browse Internet web page in home, using network like ADSL, etc. Such tendency of digital revolution will inevitably bring about a change of life style of peoples in the society. For example, it is expected that "tele-work" will prevail as a new life style of workers in future. By the prevailing of tele-work at home or tele-work center nearby, people will be liberated from the burdens of traffic hell and stressful office work in city center, and they will enjoy life worthy of self enlightenment, hobby, and social service, as volunteers, as leisure activities for the rest of work.

The tele-work society is a cyber society where people communicated formally and informally, via information highway. There will be a communication places in the cyber society, where people will (i) transmit information, and (ii) share and distribute information, (iii) retrieve information, and (iv) solve problems, via network. The people will recognize those virtual places as "virtual department store, virtual library, virtual university, virtual office, virtual factory, etc." which will compose a virtual society. As an example of virtual university, KAIST begins "Cyber KAIST" program from 1st term in 2001, where students can take a few lectures through KAIST Home page. In fact, this picture will be an image of human-centered automation world in future, in every sector of human society. And the people's new style of mutual communication in the cyber society will be two-fold: participated communication by virtual reality technology, and request communication by agent. In cyber society, people will communicate with other people or machine system, with virtual reality and agent as direct contacting "human interface", via information highway. Therefore, human interface, virtual reality and agent are the keyword of "human-centered" information revolution, so that peoples with old and young, disable or normal, live freely altogether and participate in the society, on the basis of such cyber society.

Manipulation of computers became simpler and easier, when the character interface of the first generation had been replaced by the graphical user interface of the second generation by mouse operation and displays of graphs and windows. But the direct instruction by mouse click is still cumbersome, and everybody does not operate easily.

Therefore, "indirect instruction" interface will be more ideal to people that the direct one. The direct interface is barrier-free to everybody, and it is such that it will respond as flexibly as a secretary, when the person says a few words and then computer will do the details as a kind agent to the user. This will be the third generation human interface, to which user will transmit only his intention via multimedia (character, graph, animation, voice, gesture, brain wave, eye sight, wink, etc.), and the computer will understand the user's intention and adapt him even if user's input is very vague. The human interface of the third generation will be barrier-free and mobile at every place, and one of the key technology towards this direction would be wearable computer and even wearable affective.

Yoshikawa's laboratory, Kyoto University in Japan, is developing "virtual collaborator", agent robot, which realized in virtual reality [2]. The agent itself is a software of artificial intelligence, the concepts of autonomous and spontaneous will give us a worrisome image of a cyborg that it will take the place of human and rule human. The workers will no more work inside the plant site, but they will work at home or tele-work center, or even with wearable computer during moving. That is, they can operate, repair, and administer the plant system, with the collaboration and cooperation with various intelligent agent via information highway which circulates the various facilities in the plant site, worker’s home, and tele-work center.

In this paper, we study the feasibility of Virtual Collaborator for Remote NPP Control as long-term research theme. And we present similar and related researches that are fulfilled at I&C laboratory in nuclear department of KAIST.

II. Network-based Remote Systems

Today, computer network is not only fashionable, but it is easily accessible for many applications. It allows people from great distances to communicate and share information through a simple and easy means. In the Engineering field, network can be utilized for the development of remote monitoring and control system. Network-based systems provide the advantages as follows [3];

- the operator can control the system by the same interface from any places connected to the network without constructing specific infrastructures for communication,
- the system can utilize skills of operator who is in a distant place,
- the operator is able to communicate with other operators through systems physical interaction
- the operator can use many resource which are connected to the network, and
- the system may also utilize the world wide network resources.

Researches on network-based remote system have progressed with application to robotics [4],[5],[6]. As for nuclear application, they have mainly been performed to construct collaboration systems in fusion reactors for many reason, such as the recruitment of new physicist and technicians and an appropriate transfer of knowledge and technology [7],[8],[9]. Remote collaborator is able to provide input and communicate closely with all members of the experimental team as if they were present in the control room of the experiment.

III. Virtual Collaborator

Virtual Collaborator is a new type of human-machine interface which works as “intelligent interface agent” to help machine operators manipulating large scale machine system such as power plant. The Virtual Collaborator is a sort of “virtual robot” which behaves as if an intelligent agent robot in virtual space, who can communicate naturally with human like humans do with each other. The Virtual Collaborator has sensing system, thinking mechanism and effector system like humans have. With sensing system, he can recognize not only the status of machine system but also the actions of human such as motion, speech, gesture and facial expression. With the thinking mechanism, he understands the situation around him and makes decisions. And with effector system, he can not only help operation of machine system but speak, make gesture and sometimes express his emotion to the human. The overall configuration of the Virtual Collaborator is as shown in Figure 1.

The key technology of Virtual Collaborator is summarized as follow : (1)human model simulation, (2)bio-informatic sensing, (3)bi-directional human interface devices, (4)synthesis of human motion, (5)construction of virtual environment. And the authors have been developing such virtual collaborator system by three stages. The first stage is to construct a prototype system as an integration of the above (1).(4).(5). technologies. The second stage is to construct the whole system which includes bi-directional communication function. The third stage is expansion into ‘multi-virtual collaborator system’. The multi-virtual collaborator system is a virtual society realized by Distributed Virtual Environment(DVE), where humans and virtual collaborators communicate with each other in shared virtual environment by using network connected computers.

A prototype system was made up as the first stage of the development, in which the virtual collaborator can behave just like a plant operator in the simulated control room of a nuclear power plant(NPP) in virtual reality space. Concretely, when an anomaly occurs in a NPP, the virtual collaborator can detect it, diagnose the root cause and operate the control panel in accordance with an emergency response operation manual. In each step, he behaves as if he were a real plant operator. It means that the virtual collaborator does not act as a perfect operator but he can simulate individual variations, occasional variations, human uncertainties, human errors. Thus, the prototype system itself can be applied to examine the behavior of human operator by computer simulation with visualization by 3D virtual space.

The whole prototype system is constructed as a distributed simulation system which consists of the following five subsystems: (1)Nuclear Power Plant Simulator, (2)Man-Machine Interface Simulator, (3)Human Model Simulator, (4)Human Body Motion Simulator, and (5)Virtual Space Drawing Process. The subsystem (1),(2) and (3) were integrated as Simulation Based Evaluation Support System for Man-Machine Interface Design (SEAMAID)[10]. The configuration is as shown in Figure2.

The Nuclear Power Plant Simulator is a real-time dynamic simulator of an actual PWR plant, which can simulate various kinds of plant anomalies. The Man-Machine Simulator is based on an online object-oriented database model to the presented man-machine interface design in the plant control room as 2D images. The Human Body Motion Simulator generates the body motion of the virtual collaborator. The Virtual Space Drawing Process generates the virtual space in real time, where various conditions of control panel, the control room and the shape of the virtual collaborator are visualized.

The Human Model Simulator(HM Simulator) was constructed by using a real-time object-oriented expert system, G2 (GenSym Co.Ltd.). According to the two phases of detecting and diagnosing plant anomaly, the HM Simulator also consists of modeling detecting phase and modeling diagnosing phase.

In the detecting phase, the HM Simulator checks the values of plant parameters to find whether some abnormal transients occur. Based on the general human model framework, perception, interpretation and judgment are main cognitive processes in the detecting phase. Therefore, three submodels were constructed to perform these three functions.

The perception submodel was made in two steps to perform the perception function. First, main plant parameters are divided into five groups based on main plant subsystems. Human model selects one of the five parameter groups to be checked stochastically. Then in the selected parameter group, parameters were checked in sequence. The interpretation submodel is to translate the value of parameters into a meaningful message. Here fuzzy logic estimation was applied in order to realize individual variations. Finally, by judgment submodel, whether there are certain abnormal symptoms and which subsystem of plant seemed to be in abnormal state are decided. If there are no any abnormal symptoms then the next parameter will be checked or the next parameter group will be selected. While, when some abnormal symptoms are noticed, the subsystem of plant which needs to be diagnosed will be passed to the model of diagnosing phase.

In diagnosing phase, besides the perception, interpretation and judgment, operators have to formulate hypotheses, to verify the hypotheses and to make a final decision about what kind of abnormal transient had taken place. Therefore, the modeling of diagnosing phase is more complicated. To model such complicated cognitive processing, working memory element (WME) is introduced to model the information elements in short term memory (STM) processing, and the operators' knowledge and experience about diagnosing abnormal transients which are represented as knowledge database in long term memory (LTM) are modeled as a network structure database. Based on such submodels of STM and LTM, the cognitive processing in diagnosing phase is also modeled in accordance with general human model framework.

There are various experiences and various kinds of knowledge stored in LTM. The storage formation in LTM can be considered that it is formulated in a sort of network structure, so that the relationships, processing procedures of such knowledge and experiences are stored systemically. To search such vast network database, there are two ways: similarity matching and frequency gambling. Here the authors focus on the latter one and model such network database and frequency gambling searching way to simulate uncertainties of human operator.

As for the modeling of the vast network database, we only consider operators' experiences and knowledge about diagnosing abnormal transients and divide them in two groups: the knowledge about the control systems of NPP, and the experiences or knowledge about accidents in NPP. If all of the knowledge are represented in one network database, it will become too huge and complex. Therefore the database is divided into module which are units of knowledge about the control systems and plant behaviors in accidents.

Thus, combined with WME and the model of knowledge network database, the cognitive information processing in diagnosing phase is modeled. In PWM processing, four tasks are performed: (1)making WME based on various information coming from external world through sensing organ as well as internally from LTM, (2)setting the processing priority of WME, (3)transferring WME to FWM, and (4)changing the impression index of WME. In the FWM processing, the tasks are performed based on the category of WME. As for the LTM processing, the main task is to search the database according to the keywords. Such task includes searching the parameters to be checked next, searching hypothesis to be verified, searching rules to change confidence score of hypothesis, and so on.

The more details of the Human Model Simulator are described in the papers [11],[12].

IV. Related Works

In nuclear department of KAIST, Instrumentation & Control (I&C) laboratory has studied man-machine interface evaluation and expert systems. Among the results, researches on a model based approach for user interface evaluation [13] and integrated knowledge base tool [14] are closely related to research on the Virtual Collaborator, especially the Human Model Simulator. In a model based approach for user interface evaluation, the human processor communication (HPC) model was proposed. The HPC model is constructed based on the information flow concept. The operator's important task steps in the TTA model (task recognition, user interface manipulation, information processing, and actuation) can be expressed in the form of subparts of total task-performing procedure which is more detailed in the HPC model. The control of nuclear power plant is the complex job which includes communication between an operator and a machine and that between members of an operating team. Figure 3 shows the HPC model of operators in NPP main control room.

The integrated knowledge based tool is a software for knowledge acquisition and knowledge based verification of NPP dynamic alarm processing system using G2 tool and C program. G2 tool is an expert system development tool manufacture by Gensym. The alarm knowledge is acquired from the sensor knowledge in knowledge acquisition parts. In the knowledge acquisition part, the acquired alarm knowledge is transformed to If-then rules in order to verify the knowledge base. In the knowledge verification part, the verification of alarm knowledge base, using Petri net, is performed. The tool is as shown in Figure 4. The knowledge base corresponds to long-term memory of Yoshikawa's the human operator model.

V. Future Works

The Virtual Collaborator can be defined as a sort of computerized automation system to operate power plant. The needs for the automation system are identified as (i) to reduce the number of operating staff, (ii) to save the life-expenditure of the plant equipment, and (iii) to make the start-up or shutdown time constant or as short as possible. The Distributed Virtual Environment corresponds to multi-agent system. To improve the speed and efficiency of dialogue between a plant's humans and the machines they operate, multi-agent technology is seen as a promising methodology. In the area of the power industry that includes electrical networks and nuclear powers plants, a multi-agent architecture has been proposed not only for user interfaces but also for control system design. Therefore, the Virtual Collaborator can be defined as a multi-agent automation system for next generation NPP operation using VR technology.

The main technologies of the Virtual Collaborator are the Human Model Simulator and virtual reality. The Human Model Simulator corresponds to alarm processing system and operator support system which have been developed and researched by many researchers. Since the Human Model Simulator is the brain of the Virtual Collaborator, it can be said that the reliability of the Virtual Collaborator is mostly dependent upon that of the Human Model Simulator. The VR technology is tackled to develop not only man-machine interface, but also many applications such as training, system design support, and etc. However, the feasibility study on the application of the VR technology to main control room design of NPP should be needed.

The research themes related the Virtual Collaborator are summarized as follows;

- research related to Human Operator Simulator,
- research on the real-time communication of remote systems,
- research on the decision mechanism of automation system and distributed system,
- research on the man-machine interface, and
- etc.

References

[1] H. Yoshikawa, “A rumination on human-centered automation world: multiagent system, human interface and people’ s life style,” IEEE SMC Conference Proceedings, vol. 3, 669-674, 1999

[2] H. Shimoda, et. al., “A basic study on Virtual Collaborator as an innovative human-machine interface in distributed virtual environment: the prototype system and its implication for industrial application,” IEEE SMC Conference Proceedings, vol. 5, 697-702, 1999

[3] Tsuyoshi Suzuki, et. al., “Teleoperation of multiple robots through the internet,” IEEE International Workshop on Robot and Human Communication, 84-89, 1996

[4] Robert Itschner, et. al., “GLASS: remote monitoring of embedded systems in power engineering,” IEEE Internet Computing, 46-52, May, 1998

[5] Dirk Schulz, et. al., “Robust visualization of navigation experiments with mobile robots over internet,” Proceeding of the 1999 IEEE/RSJ International Conference on Intelligent Robots and Systems, 942-947, 1999

[6] Ken Goldgerg, et. al., “Collaborative teleoperation via the internet,” Proceeding of the 2000 IEEE International Conference on Robotics and Automation, 2019-2024, 2000

[7] H.M.A. Andree, et. al., “Virtual control room, the REMOT project, Networking Pilot studies,” IEEE tran. on Nuclear Science, vol. 45, no. 4, 1990-2003, 1998

[8] T.A. Casper, et. al., “Support and development for remote collaborations in fusion research,” Fusion Engineering and Design, vol. 48, 231-237, 2000

[9] T.W. Fredian, et. al., “MDSplus remote collaboration support-internet and world wide web,” Fusion Engineering and Design, vol. 43, 327-334, 1999

[10] H. Yoshikawa, “Development of an analysis support system for man-machine system design information,” Control Eng. Practice, vol. 5, no. 3, 417-425, 1997

[11] Wei Wu, et. al., “Study on development a computerized model of human cognitive behaviors in monitoring and diagnosing plant transients, IEEE SMC Conference Proceedings, vol. 2, 1121-1126, 1998

[12] H. Yoshikawa, et. al., “Simulation –based evaluation system for man-machine interfaces,” IEEE SMC Conference Proceedings, vol. 2, 1278-1283, 1998

[13] Hyun G Kang and Poong Hyun Seong, “An information theory based approach for quantitative evaluation of user interface complexity,” IEEE trans. on. Nuclear Science, vol. 45, no.6, 1998

[14] Joo Hyun Park, Poong Hyun Seong, “Integrated knowledge base tool for acquisition and verification of NPP alarm systems,” Proceedings of the Korea Nuclear Society Autumn, October 1998, Seoul, Korea

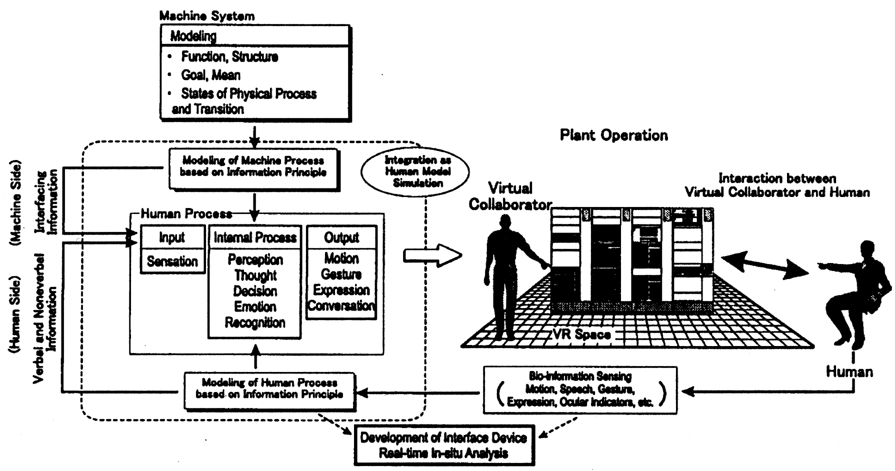

Figure 1. The configuration of Virtual Collaboration System

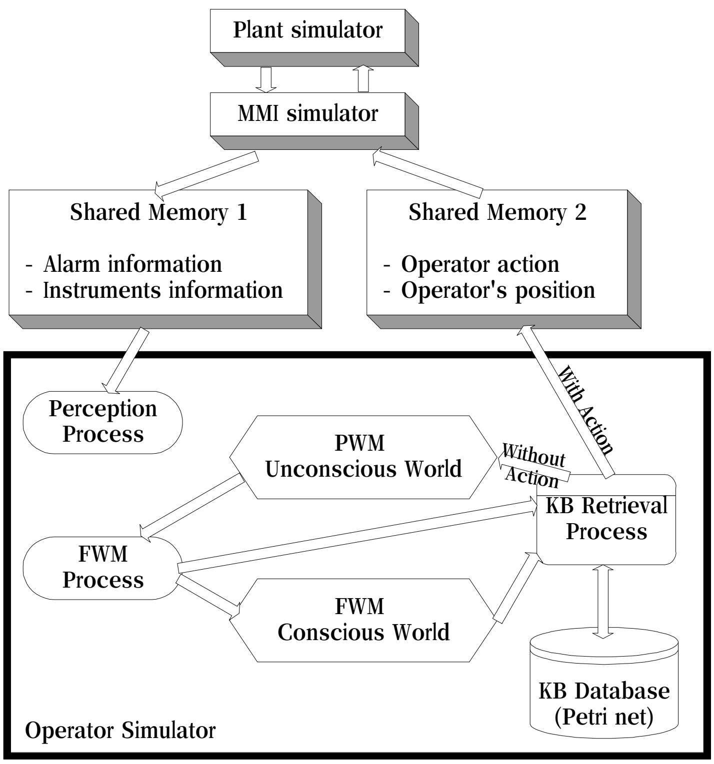

Figure 2. The configuration of the operator simulator, SEAMAID

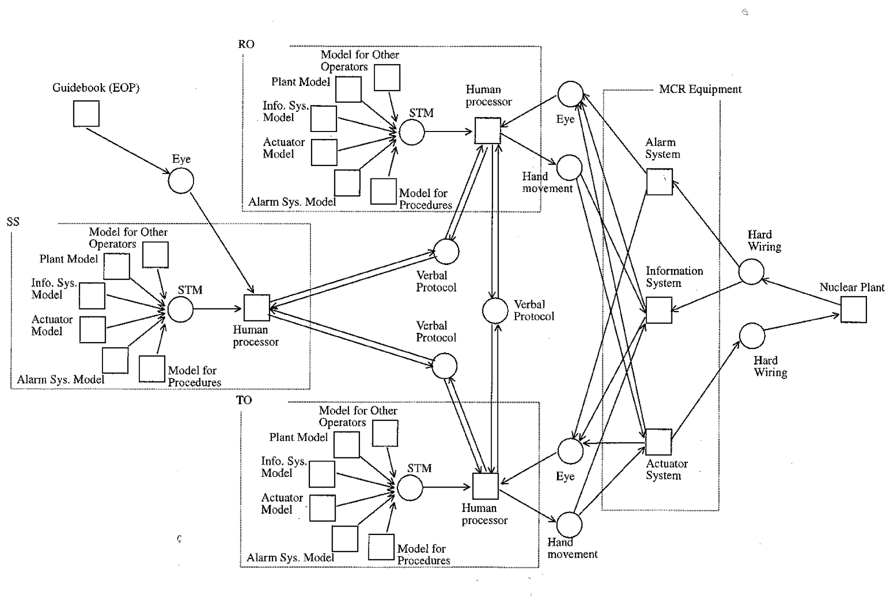

Figure 3. The modeling of an operating team

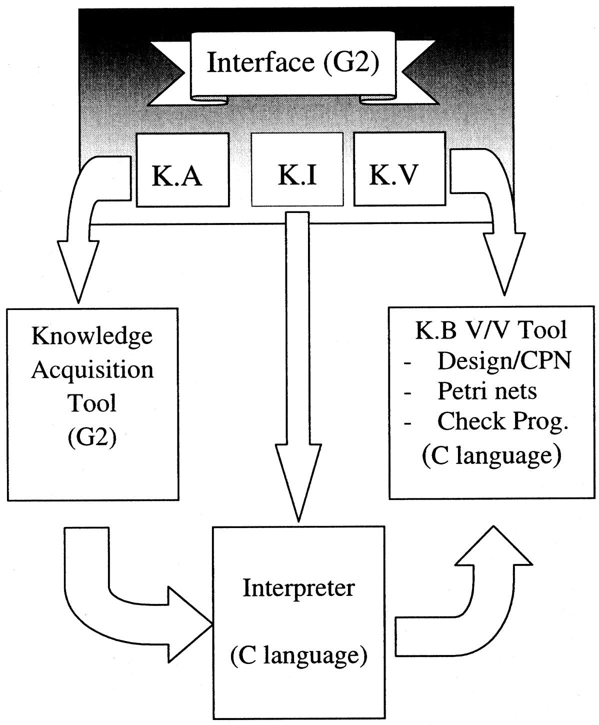

Figure 4. Integrated knowledge base tool