VIRTUAL COLLABORATOR AS INTERFACE AGENT FOR HUMAN-CENTERED AUTOMATION OF PLANT CONTROL

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ABSTRACT

"Virtual Collaborator" is an intelligent interface agent to help machine operators controlling a large scale plant system such as power plant. A prototype system of the virtual collaborator has been developed, and the major functions of the present virtual collaborator are that when an anomaly occurs in a plant, the virtual collaborator can autonomously detect it, diagnose the root cause, and operator the control panel in accordance to the operation procedure. The designed function of the virtual collaborator is validated by demonstrative simulation on a distributed computer network. The implication of this virtual collaborator experiment is discussed with respect to the human-centered automation.

KEYWORDS

Virtual Reality, Interface Agent, Human-Centered Automation

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 operation of the machine systems has become more difficult task for users. Especially, in the fields of aircraft and power plants, the tendency is conspicuous and an operation error may cause serious accidents. Therefore, the study on the man-machine interface has been extensively made to improve the relationship between human and the machine system.

The authors pay attention to communication ability of humans with each other which humans originally have, and try to realize an ideal man-machine interface by an agent robot as an avatar of machine system, which behaves and communicates with humans like humans do. In this study, the agent robot is named "virtual collaborator", which is realized in virtual reality space. It has human-shaped body and can listen, talk, think, behave and collaborate with real humans in operating large and complex machine systems.

A prototype system of the virtual collaborator has been experimented thus far, so that the virtual collaborator can behave just like a plant operator in the simulated control room of a power plant in virtual reality space. The implication of this virtual collaborator experiment is discussed with respect to the human-centered automation, although the authors have not completed the rest functions of the virtual collaborator to communicate with human freely with bi-directional conversation,

2. Basic Framework of Virtual Collaborator

In this chapter, the authors discuss how the basic computation framework of virtual collaborator's "brain model" would be reduced by consolidating the views on human model both in brain science and cognitive paradigm.

2.1 Human Model

According to the views from brain science and cognitive paradigm, the origin of "human consciousness" has been recently paid attention both in brain science and cognitive science. In brain science, human consciousness is interpreted as three levels: arousal (biological consciousness), awareness (consciousness of perception and motion) and self-consciousness (recursive consciousness). Arousal is the basis of human being for behaving with consciousness. The synergistic behavior by awareness and self-consciousness will form salient characteristics of human being as an advanced and active creature. On the other hand of brain science, both self-consciousness and awareness are explained by the following ways by cognitive paradigm. Consciousness is caused by the synergism of three human memory functions. That is, self-consciousness by attentive, sequential process corresponds to FWM (Focal Working Memory), while awareness of smooth automatic coordination of sensing and motor action is supported by the consolidated work of sub-conscious PWM (Peripheral Working Memory) and non-conscious LTM (Long Term Memory).

2.2 Triple Dynamics

The human model as an intelligent function of the virtual collaborator should be modeled by the following four elements:

(1)both the conscious and subconscious process in PWM and FWM,
(2)LTM as enormous knowledge-base storage which supports unconscious processes,
(3)selective input channels of external information via perception system, and
(4)internal input to PWM by recalling information from LTM.

The driver system of virtual collaborator can be described by the three-layered module structure as shown in **Figure 1**. It is configured as a triple dynamics system that consists of the following three dynamic modules:

(1) recursive dynamics described by blackboard model,
(2) rule-based dynamics described by petri-net model, and
(3) model-based dynamics which are given by various motion programs.

Therefore, they will constitute a hybrid computation scheme for the virtual collaborator. Those three dynamics modules are driven being synchronized by the clock timer of rule-based dynamics with generating mutual relationship and interaction with external environment. The detailed configuration of the driver system of virtual collaborator can be depicted as shown in **Figure 2**. This is one solution how the virtual collaborator as a sort of autonomous robot can escape from "Frame Problem" and "Bernstein Problem" which autonomous robot normally encounter in actual implementation.

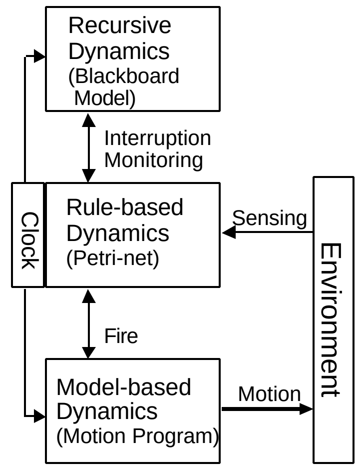

Figure 1. Triple Dynamics System

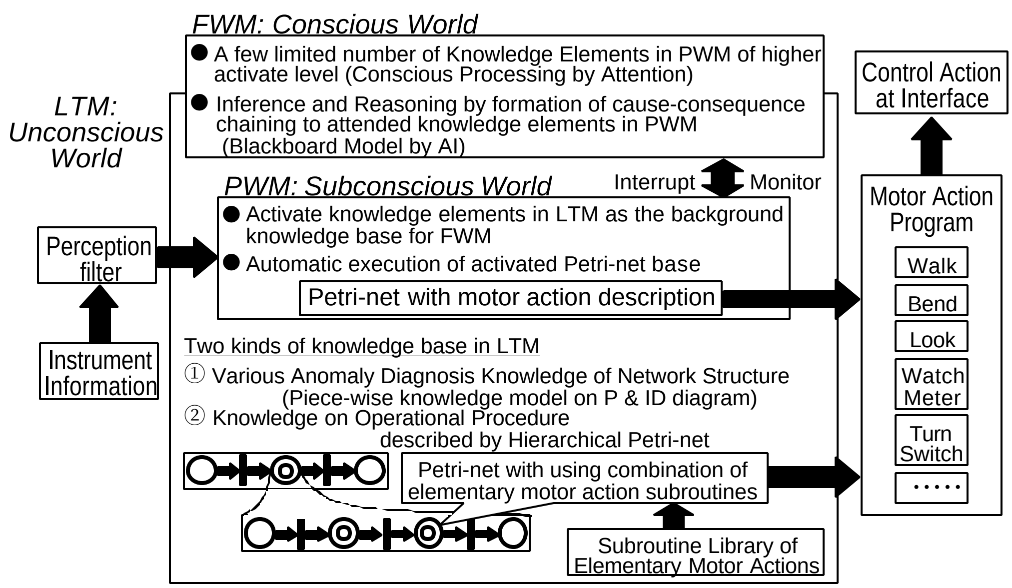

Figure 2. Human Model of Virtual Collaborator

3. Prototype Virtual Collaborator

The virtual collaborator has been developed based on the above stated frame of hybrid computation scheme to visualize the operator's behavior in virtual reality space. By applying the concept of the triple dynamics, the prototype virtual collaborator has been developed who can behave just like a plant operator in the control room of a power plant. Though this prototype system has no bi-directional communication function with human, it can verbalize what it is going to do. The capability of the prototype virtual collaborator at present status is that when anomaly occurs in a power plant, it can detect it, diagnose the root cause of the anomaly by checking the instrument signals on control panels, and then manage the plant condition to the safety shutdown state. This is like an ideal skilled operator, but the prototype system may behave as if he were a real plant operator who has "fallible" nature. 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, based on realization of the triple dynamics. In addition, his behavior is visualized in 3D virtual space and his thinking process is verbalized by synthesized voice.

Figure 3 shows the experimental configuration of the prototype virtual collaborator. As shown in Figure 3, the whole prototype system is constructed as a distributed real-time system which consists of the following seven subsystems:

(1)Nuclear Power Plant Simulator,
(2)Man-Machine Interface Simulator,
(3)Virtual Collaborator Driver System,
(4)Human Body Motion Simulator,
(5)Virtual Space Drawing Process,
(6)CRT Interface Interactive Process, and
(7)Speech Generation Process.

In order to construct the stated virtual collaborator prototype, the authors expanded the capability of a distributed man-machine system simulation system called SEAMAID [1-2] for the part of main simulation in WS in Figure 3. After conducting some simulations by the prototype system and analyzing the simulation results, it was confirmed that the prototype system could simulate behaviors of skilled human operator well in real time, and could visualize the behaviors in the 3D virtual control room. The animated behavior of the virtual collaborator as virtual operator in virtual control room is depicted as shown in **Figure 4**.

At the present stage of the prototype system development, it can be utilized for the following two industrial

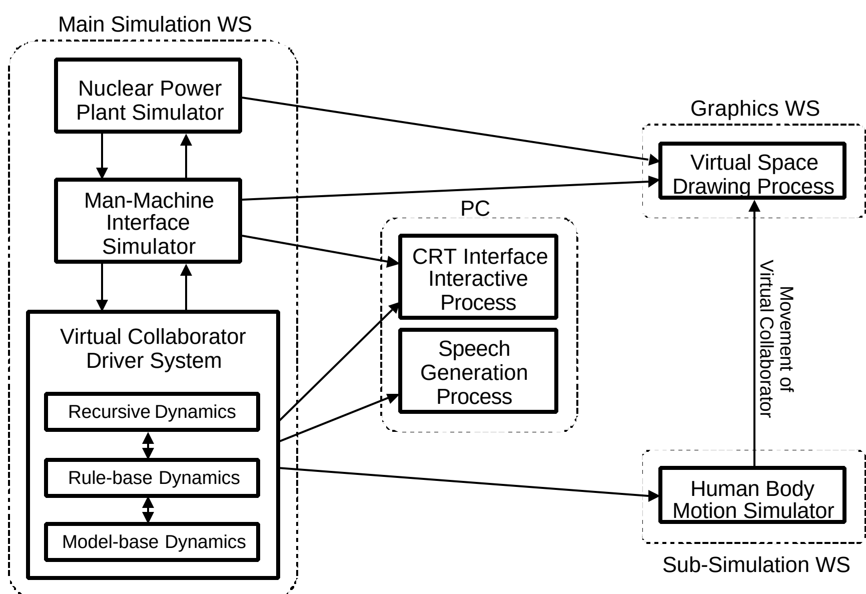

Figure 3. Whole Configuration of Virtual Collaborator Prototype

purposes by its audio-video information visualizing functions in 3D virtual space:

(1) Effectiveness evaluation of the whole man-machine system designing, and
(2) Economical training system for instructing trainees how to operate the man-machine interface correctly. [3-4]

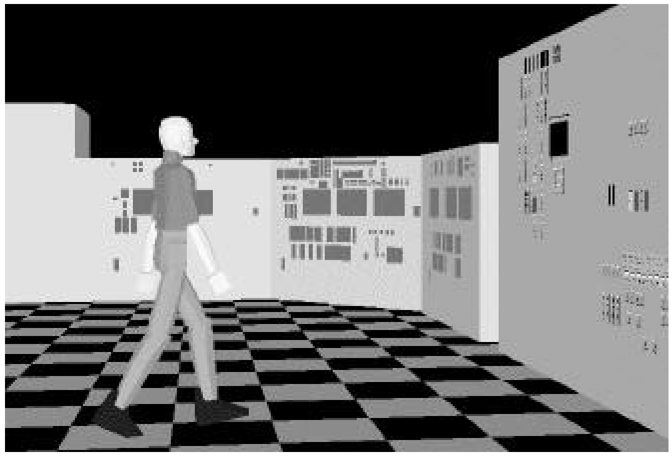

Figure 4. Virtual Operator in Virtual Control Room

4. Towards Bi-directional Communication

As said earlier, the present prototype system has not yet realized the bi-directional communication functions to the humans. At present, the prototype virtual collaborator can verbalize his thinking process; he utters his intention by synthesized voice to present his thinking process explicitly. The utterance corresponds to "think aloud protocol" spoken by subjects in cognitive psychology experiments. The contents of the utterance are the first symptom, hypothesis to the root cause, judgement to the referenced parameters, and so on, which are necessary to diagnose a plant anomaly occurred in nuclear power plant.

In order to realize bi-directional communication, several elemental issues should be studied. They are classified into the two questions:

(1)Will the virtual collaborator understand the contents of human utterance?

(2)Will the virtual collaborator respond and answer back to human timely?

With respect to (1), the utterance of human should be first recognized as a text by voice recognition, and then the text would be analyzed to know the human's intention. Otherwise the virtual collaborator cannot generate proper response plan. With respect to (2), the virtual collaborator should first generate his response plan and then construct the sentence to be uttered by synthesized voice. All of those processes should be performed in real time. **Figure 5** shows a software organization plan needed for realizing such bi-directional communication function to the virtual collaborator. [5] The implementation of such bi-directional voice communication capability to the present virtual collaborator will be authors' further challenge to realize this sort of virtual collaborator, or personified interface agent in future.

5. Implication for Human-Centered Automation

The implication of this virtual collaborator experiment is that the plant control can be fully automated even in the case of emergent situation, and that there would be a possibility that human operator can be excluded from the plant control room, although the above-mentioned experiment was merely a simulation work on computer network.

In future, further introduction of automation will lead step by step to the stage of full automation where the role of human in the control room will be replaced by computer. The authors imagine that the future plant would be full automated plant where supervisors in the headquarters could monitor the plant state via reporting from "virtual collaborators" through internet and make consultations with them to manage the plant system such as change of operation mode, need of plant repairs and maintenance, and so on. This is also a plausible image of human-centered automation in future.

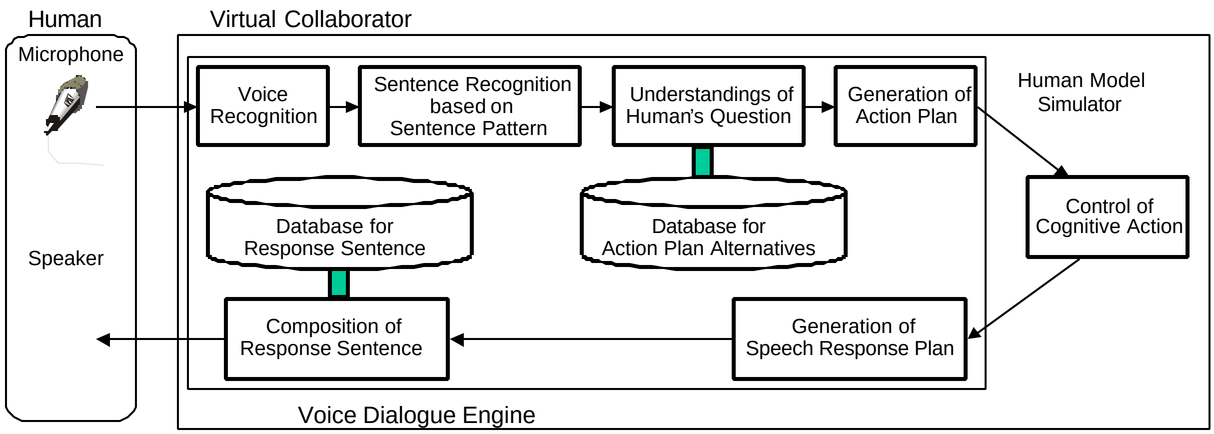

Figure 5. Software System Proposed for Bi-directional Voice Communication

The imaginary figure of working style of humans in human-centered automated plant in cyber society can be depicted as shown in **Figure 6**. Human will no more work at plant site but can stay at his own house or tele-work center with every sorts of work being delegated to "autonomous agents" living on information highway.

6.Conclusion

In this paper, the basic concept of the virtual collaborator was proposed and then the prototype system was configured based on the hybrid computation scheme of triple dynamics of human model. It was demonstrated by an example simulation practice on distributed computer network, that when an anomaly occurs in a virtual

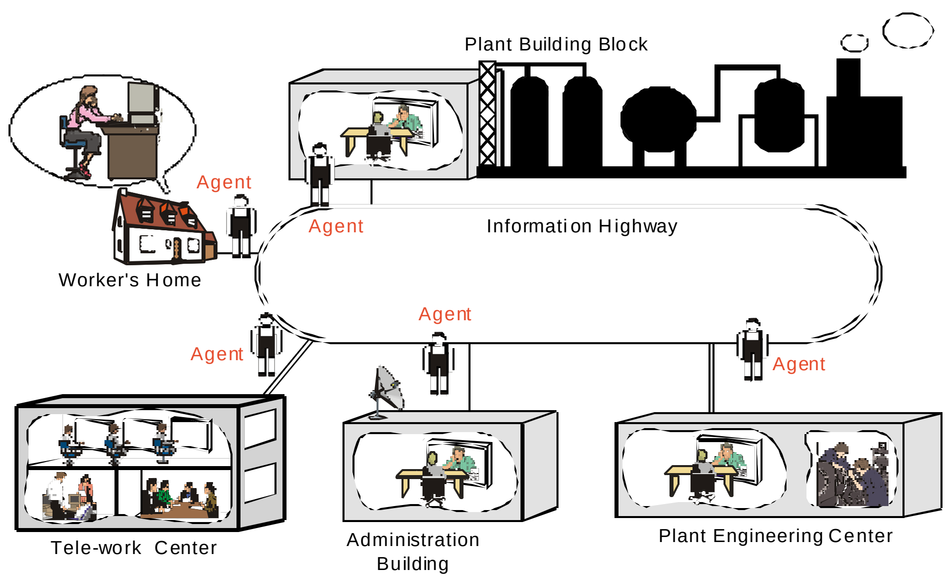

Figure 6. Image of Human-Centered Automated Plant in Cyber Society

power plant, the virtual collaborator could detect it, diagnose the root cause and operate the control panel in accordance with emergency operation procedures. There will be further works needed for implementing bi-directional voice communication, in order to realize the virtual collaborator as an autonomous agent in cyber society.

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