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# Automated Computer-Based Procedure System for Remote Operation System

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Abstract

*In this paper, we study the feasibility of Automated Computer-Based Procedure(ACBP) System for Remote Operation System of Nuclear Power Plant(NPP) as long-term research theme. And we present similar and related researches that are fulfilled at I&C laboratory in nuclear department of KAIST. Remote monitoring system using network of NPP is already designed and built in some NPP.. This research try to add remote operation function to that system, so operator can perform real-time monitoring and control NPP at distance place by using network and web browser without special instruments. But this system has some serious problem. Because it uses network, it cannot guarantee faultless in network accident status. Therefore this research suggests Automated Computer-Based Procedure System to support remote operation which offers solution for network problems. In case network was out of other in emergency situation, so operator cannot connect to NPP, ACBP operate NPP itself. There are 4 persons in Main Control Room(MCR) of NPP : Senior Reactor Operator(SRO), Reactor Operator(RO), Turbine Operator(TO) and Electrical Operator(EO). SRO receives signals of NPP and diagnoses current status of NPP and decides suitable actions for NPP by procedures. ACBP do roles of SRO in such situation.*

# I. Introduction

Nowadays Information Technology(IT) is most popular filed in the world. 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 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 [2].

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 1$^{st}$ 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.

As the network is widely constructed, so we can use network easily at anywhere in the world. And the digital and computer system are popular, many car and electrical product factories already designed and built for remote control. Also various experiments are executed using remote control system at distant place.

In this paper, we study the feasibility of Automated Computer-Based Procedure System for Remote Operation System of NPP 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 Operation 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.

NPP monitoring system using network which real-time monitor plant status is already implemented in some NPP. It can only show plant status and important variables to operator and others who use web browser connected network. In this paper, we would add operation function to that and it could not only monitor but also control plant. The conceptual design of remote monitoring and operation system is as shown in Figure 1. It should have some advantages. The operator can control the system by the same interface from any places connected to the network without constructing specific infrastructures for communication and communicate with other operators, through system's physical interaction. Also, the system can utilize skills of operator who is in a distant place. It however, will have some problems because of network's characters. Security and faultless are very important conditions in NPP but this system cannot guarantee those conditions. By using intranet, the security problem of network could be somewhat improved. Therefore most serious problem is network accident, it makes NPP untouchable state in remote operation system. The components of remote operation support server(control server) is shown in Figure 2. In this paper, ACBP is suggested to solve that problem. ACBP is not

perfect and only show feasibility of reliable remote operation system.

## III. Automated Computer-Based Procedure(ACBP) System

Almost control actions of NPP are executed in Main Control Room(MCR). Operators can monitor all signals and control almost important instrument in MCR. There are 4 persons in MCR : Senior Reactor Operator(SRO), Reactor Operator(RO), Turbine Operator(TO) and Electrical Operator(EO). SRO receives signals of NPP and diagnoses current status of NPP and decides suitable actions by procedures. ACBP is modeled on SRO, so do almost same roles of SRO. If there is fully digitized NPP which can receive all signals of NPP and do all actions for NPP in MCR, ACBP could realize uninhabited and fully automated NPP.

ACBP has some problems because of network's characters, and most serious problem is network accident. It makes NPP untouchable state in remote operation system. Therefore, ACBP has two functions to overcome these problems. First is anomaly detection function and second one is procedure execution function.

The anomaly detection function monitors status of plant and detect what anomaly status is current status if some alarms occur. In anomaly status, human operators show alarm and think what are reasons of that by using own knowledge and experience because it is impossible to search all anomaly status cases. The computer cannot think, but it can search many cases in short time because it is much faster than human. When some alarms occur, this function searches all possible cases. And as other alarm occurs, it cut off cases which don't related the alarm to reduce possible cases. If some case is similar to symptoms of anomaly status in procedure, it decides that this is the anomaly status. "Similar" means that the case same as that over 80%. In addition to the anomaly detection function can confirm the sequence of alarms occurrence, and it is very useful to detect anomaly status.

The procedure execution function is, as it were, automated procedure. If any anomaly status is detected, it starts and operates plant itself according to suitable procedure. Therefore most important role of procedure execution function is to fulfill procedure perfectly and this research use Petri Net for it. Petri Net(PN) can deal with concurrent events, but flowcharts cannot do. PN have ability to represent and analyze in an easy way concurrency and synchronization phenomena, like concurrent evolutions, where various processes that evolve simultaneously are partially independent [10]. Furthermore, PN approach can be easily combined with other techniques and theories such as object-oriented programming, fuzzy theory, neural networks, etc. These modified PN is widely used in computer, manufacturing, robotic, knowledge based systems, process control, as well as other kinds of engineering applications.

This function needs inference engine for judgment of vague information. This research uses

fuzzy algorithm for this problem. In many situations, it may be difficult to capture data in a precise form. In other to properly represent real world knowledge, fuzzy production rules have been used for knowledge representation. A fuzzy production rule is a rule which describes the fuzzy relation between two propositions. Because normal PN cannot deal with vague or fuzzy information such as “very high” and “good”, several Fuzzy Petri Nets have been introduced. As a model of knowledge-based systems, FPN are used for fuzzy knowledge representation and reasoning. In fact, by implementing the FPN model, major features offered by the PN model, such as correctness, circular rules, consistency, and completeness checking, can also be applied. PN have an inherent quality in representing logic in an intuitive and visual way and also can be reduce a simple sprouting tree when applying a FPN-based reasoning algorithm as an inference engine. Besides these applications, FPN theory also provides means to manipulate imprecise and vague information [11]. So, many FPN models are proposed to support fuzzy reasoning and decision making. There are come other applications of FPN in knowledge-based systems, such as inconsistency checking, uncertainty management, and knowledge learning. This research suggest fuzzy inference model which is as shown in Figure 3. It works inference engine by using 3 factors : real factor, rule, and knowledge database. This inference model is similar to human’s thinking process. If we would make better inference model, research on human modeling is necessary.

## 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 [12] and integrated knowledge base tool [13] are closely related to research on the ACBP. 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 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.

Yoshikawa's laboratory, Kyoto University in Japan, is developing "virtual collaborator", agent robot, which realized in virtual reality [14]. 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.

## V. Conclusion

The Remote Operation System for NPP is very long-term research theme. If it were made perfectly, it cannot be adopted to current NPP which cannot do whole actions for plant in MCR. The research of this system can be used to various aims such as computerized automation system. The ACBP is the support system for NPP remote operation system and it 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. Therefore, the Remote Operation System using ACBP can be defined as a automation system for next generation NPP operation using network technology.

This research is on first step yet. Therefore many problems to solve are coming out and much further research for them should be fulfilled.

The research themes related the ACBP are summarized as follows;

- research on anomaly detection function,
- research on Fuzzy Petri Net to ACBP,
- research on more intelligent fuzzy function, and
- etc.

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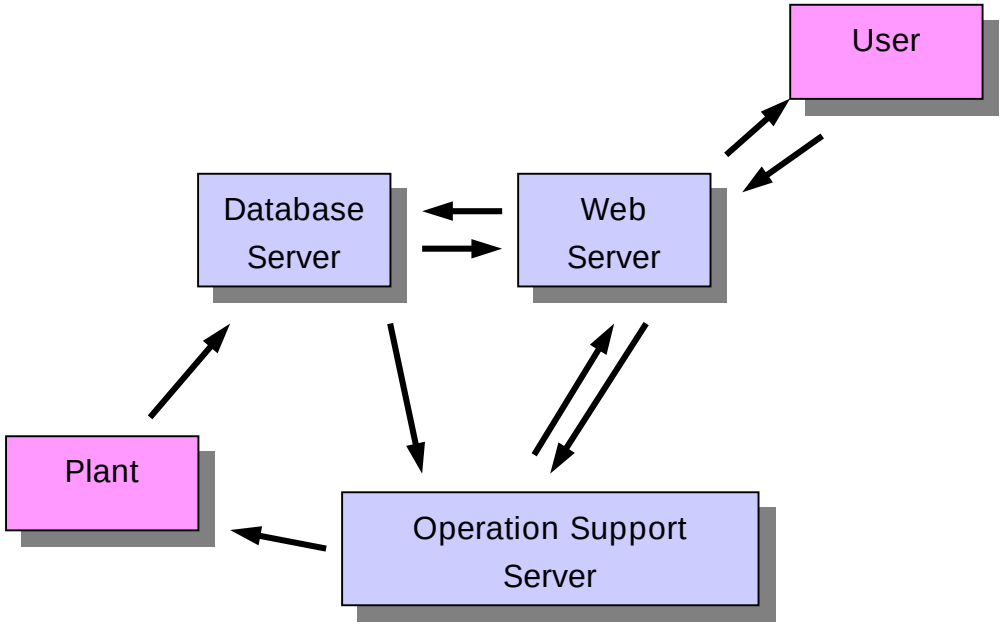


Figure 1.4-Tier system of Remote monitoring and operation system

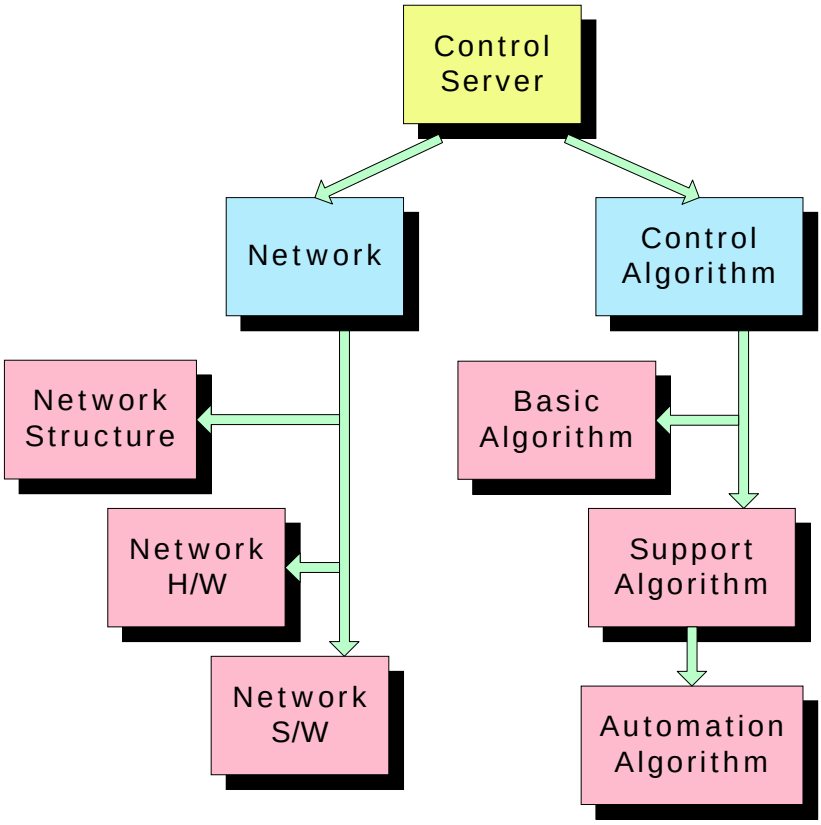


Figure 2. Components of control server

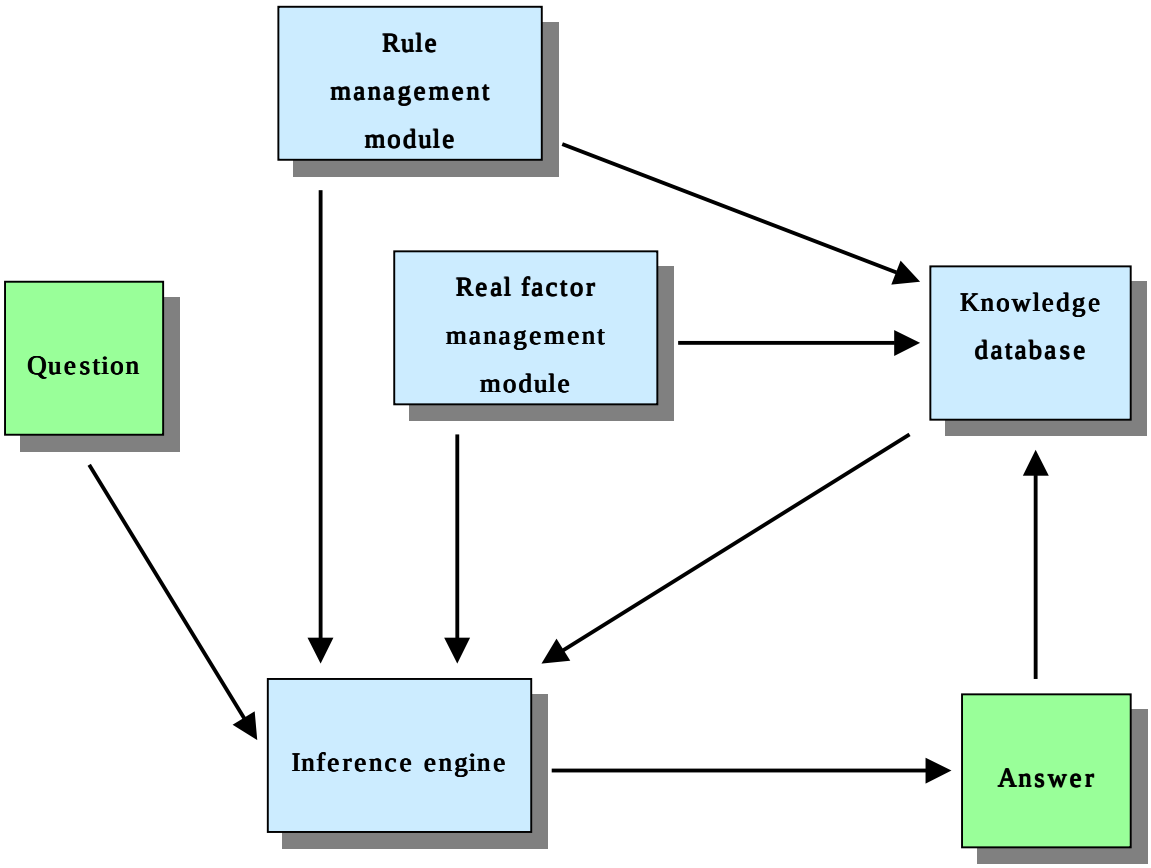


Figure 3. Design of fuzzy inference engine

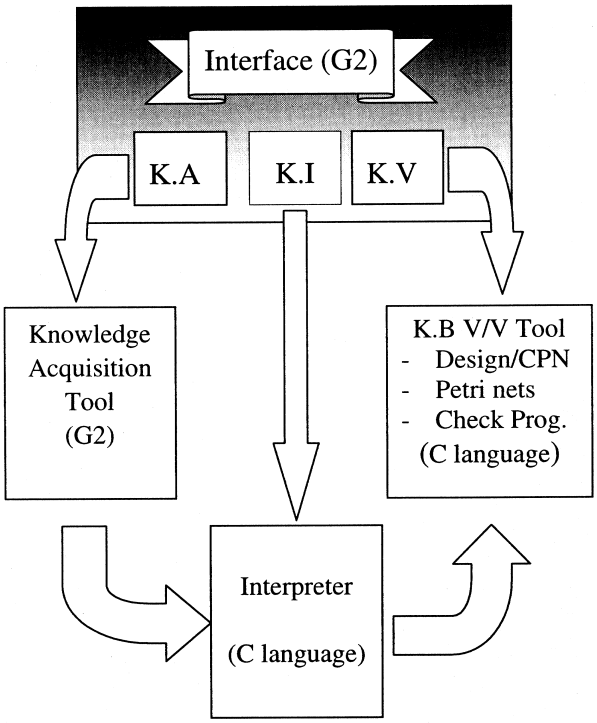


Figure 4. Integrated knowledge base tool