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# Implementation of an Operator Model with Error Mechanisms for Nuclear Power Plant Control Room Operation

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Abstract

SACOM(Simulation Analyser with Cognitive Operator Model) is being developed at Korea Atomic Energy Research Institute to simulate human operator's cognitive characteristics during the emergency situations of nuclear power plans. An operator model with error mechanisms has been developed and combined into SACOM to simulate human operator's cognitive information process based on the Rasmussen's decision ladder model. The operational logic for five different cognitive activities (Agents), operator's attentional control (Controller), short-term memory (Blackboard), and long-term memory ( Knowledge Base) have been developed and implemented on blackboard architecture. A trial simulation with a scenario for emergency operation has been performed to verify the operational logic. It was found that the operator model with error mechanisms is suitable for the simulation of operator's cognitive behavior in emergency situation.

## I. Introduction

In the evaluation of design characteristics of man-machine interface system (MMIS), especially in the emergency situation of nuclear power plants(NPPs), a computer simulation of human-machine interaction has been widely recognized as a promising methodology that can give us some advantages. At first, it can provide us with the detailed information on cognitive process of operators during the emergency situations in NPP. Secondly, through the computer simulation, man-machine interaction analysts can easily investigate many cases by changing conditions, such as knowledge of operator, types of transient, characteristics of MMI, and so on. Also, it will be possible to find out situations causing erroneous behavior of human operator, and to identify essential information to prevent them.

Several cognitive simulation models have been developed using artificial intelligence(AI) techniques by others. CES and COSIMO have been developed using blackboard architecture[1,2]. Furuta's model can simulate the revisable features of human cognitive process using the truth maintenance system theory[3]. In these models, mainly rule-based behavior is simulated. However, in the real world, modeling knowledge-based behavior is sometimes necessary, because a situation can take place by complex equipment and component failures.

An operator model with error mechanisms has been developed to simulate not only rule-based behavior but also knowledge-based one. To represent rule-based behavior, If-Then type rules were used. To represent knowledge-based behavior, Is-Related and Structure rule frame, Symptomatic rule frame, Antecedent rule frame, and Connected rule frame were developed and implemented into the operator model. Fiqure 1 shows the diagnostic structure of the model. The following sections describe how this operator model in SACOM has been implemented.

## II. Sources of Erroneous Behavior

The operator model of SACOM has adopted the simplified framework of information processing based on the Rasmussen's decision ladder model. Figure 2 shows the conceptual framework of information processing in the model. In this operator model, cognitive processing is assumed as navigating among five different cognitive activities (or agents): OBSERVE plant parameters, IDENTIFY the plant status, EVALUATE of plant status, PLAN tasks to be carried out to achieve the target state of the plant, and SCHEDULE procedures in which tasks are broken down to a set of unit operations. Through the optimized activation of those agents, correct intention is formed to solve current problems that operator faces. However, the operator's erroneous behavior is usually caused by inherent limitation of human operator, taking imporper information from MMI, or inappropriate use of his own knowledge. Incomplete knowledge on the situation, attentional resource limitation, and workspace limitation can be considered as examples of the inherent limitation of human operator. These features of the cognitive characteristics are modeled in the present operator model.

### II.1 Inherent limitation of human operator

(a) modeling of working memory limitation

The BB(blackboard) is regarded as working memory which is presumed to hold information produced by activation of five cognitive agents and has a limited capacity for storage, which is six or seven items[4]. The limitation of storage capacity is one of the major causes of the loss of information in the cognitive process. In SACOM, the storage capacity of the BB is defined as an input parameter($7 \pm 2$) of the simulation. If the BB is filled with information during the simulation, the oldest information on BB will be deleted to make space for the newest information.

(b) modeling of attentional resource limitation

Several types of information are written on working memory as a result of cognitive activities. Each type of information controls operator's attention to the other cognitive activities. To model this cognitive process, we adopted the concept of CONTROLLER.

As shown in Figure 1, CONTROLLER controls how operator's attention moves among five different cognitive agents. As discussed by Rasmussen, these five cognitive activities do not always appear sequentially in this order in actual problem solving situations. Some cognitive activities are by-passed or repeated depending upon his own experience, knowledge, and the situation in which problem solving is required. CONTROLLER triggers cognitive agents in accordance with the result of identification or information appeared on BB, using the priority table[See Table 1].

(c) modeling of incomplete knowledge base

One of the major sources of erroneous behavior is his incomplete experience or knowledge on the situation. To model this cognitive characteristic, each If-Then type rule stored in knowledge base has a certainty value representing the degree of operator's confirmation and the number of times retrieved by the cognitive agents.

### II.2 Perception of improper informations

(a) modeling of MMI failure

MMI failures are considered as a major source of improper information perception. Perception of incorrect information on the plant status disturbs operator's correct intention formation, then cause incorrect response. To generate incorrect information caused by MMI failures, Situation Generator of SACOM has some pre-determinded timeline list of the MMI failures.

(b) modeling of information misreading

SACOM has an MMI module to represent the design characteristics. MMI design characteristics are one of important PSFs(Performance Shaping Factors) and can cause improper perception of information. With the poorly designed MMI which failed to accomplish physical and cognitive compatibility to human operators, operators will easily fail to percept correct information.

(c) modeling of attentional narrowing

During emergency situations, operator takes various types of information available from MMI and take them into the cognitive process to repond correctly. Those information draw operator's attention depending complicatedly on their degree of salience under the situation. In the case of hypothesis-driven observation, operator trys to observe specific information strongly related to the current hypothesis, but may ignore the changes in other parameters that are still important on the current situation. So the stronger the hypothesis is, the narrower the attentional field is.

To model this cognitive characteristics, a measure of salience with a threshold is introduced to represent how much operator's attention was drawn by the inforamtion. The value of threshold can be varied according to a cognitive status, such as fixation. Using this simple mechanism, modeling the attentional narrowing caused by fixation is attempted. To simulate this attentional narrowing, the degree of fixation is represented as a certainty value of hypothesis pursued currently. If a hypothesis is strongly believed to be true, the threshold is increased. Then, observation will be made to only information with higher salience value.

### II.3 Modeling of Inappropriate Knowledge Retrieval

In the cognitive information processing, a piece of information recalls other related pieces of knowledge from the long-term memory, and move it to shorterm memory[5]. When there are multiple relations between a piece of information and the related pieces of knowledge, the degree of easiness of knowledge retrieval, or the order of retrieval, varies dependently on his/her experience.

To model the former, similarity matching concept was adopted, and to model the latter, frequency gambling concept was adopted. For an example, in the case of identification of plant status, a piece of knowledge on the abnormal situation related to the observed symptom is recalled as a hypothesis of plant status. If an observed symptom is related to several abnormal situations, knowledge on abnormal situation is recalled on the blackboard in a descending order of strength values.

## III. Verification of Operator Model

A trial simulation of an accident has been performed to verify the modeling of cognitive behavior. In the simulation of IS-LOCA(Interfacing System - Loss Of Coolant Accident), the operator model generate reasonably erroneous behavior[See Figure 3]. During the pre-EOP(Emergency Operating Procedure) situation of the simulation, the operator model generate reasonably incorrect hypothesis due to his incomplete knowledge base.

## IV. Conclusion

Through the trial simulation, it is found that the operator model with error mechanisms is suitable for the simulation of operator's cognitive process being performed by using cognitive agents, operator memory limitations. Also the structural knowledge representation is found to be feasible to simulate knowledge-based behavior in unanticipated simulation.

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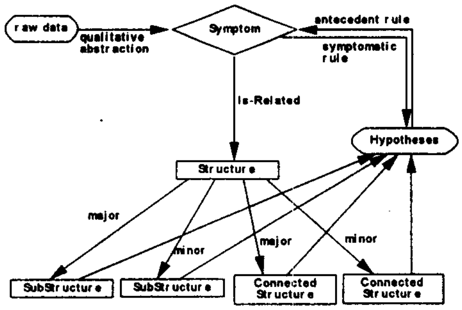


Figure 1. The diagnostic structure of the operator model

| Type of BB Information | Agent to be triggered | Priority |
|---|---|---|
| alarm sound | OBSERVE | Input Parameter |
| parameter status | OBSERVE | |
| observation request | OBSERVE | |
| confiramtion request | OBSERVE | |
| Observation | IDENTIFY | |
| System state | EVALUATE | |
| Target state | PLAN | |
| Task | SCHEDULE | |

Table 1. Priority of triggering agents

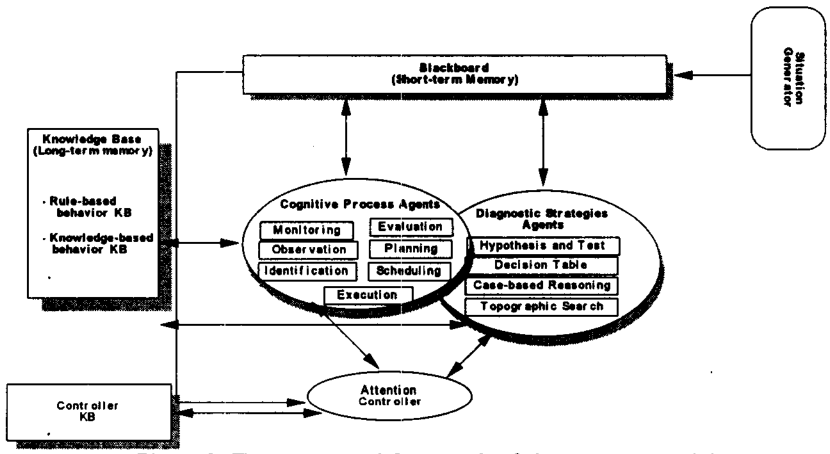


Figure 2. The conceptual framework of the operator model

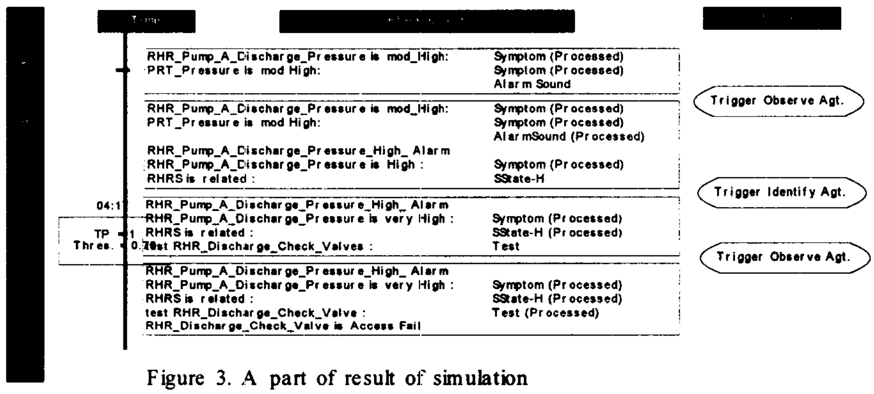


Figure 3. A part of result of simulation