SHORT NOTE

Approach to Knowledge Based Man-Machine Communication for BWR Start-Up Guidance

Yasuo NISHIZAWA, Hiroshi MOTODA, Naoyuki YAMADA and Yutaka WADA

*Energy Research Laboratory, Hitachi Ltd.**

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Computer has so far been used to solve a problem by numerical computation. Many of the engineering problems, however, can be solved more efficiently by the so-called expert knowledge pertinent to the problem. The knowledge used there is sometimes heuristic and not handled by numerical computation. Knowledge engineering (K.E.)[1][2] provides a method to incorporate such knowledge in problem solving.

Core management is a field in which much experience useful for decision making has been accumulated. This note introduces a computer program that receives such experience as pieces of knowledge and makes inference for problem solving with an example applied to a man-machine communication for BWR start-up guidance.

1. Summary of Program

Experts' knowledge comprises not only individual fact and relations among them but also more general or abstract concept. To express such abstract knowledge, the program developed here adopts first order predicate calculus that allows to use variables for indefinite object. In the inference process, variables are compared with individual object and bound to them by unification. Using predicate calculus, individual fact is expressed as a proposition, and a relation among the facts is represented as a production rule that is sometimes called "if-then rule".

Two methods of inference are prepared, that are, forward and backward inferences. Forward inference finds new facts that are concluded by combining rules and previously proved facts. Backward inference proves the solution of a problem by tracing the logics in a backward direction starting from an assumed conclusion. The assumed conclusion can contain variables. These methods can be used in combination.

Experts' knowledge further includes the knowledge about when and how to use knowledge. Such knowledge is called meta-knowledge. Meta-knowledge can also be stored in the knowledge base and is used for inference control such as to proceed numerical computation on the way of inference, or to generate a question to users before looking into the knowledge base. Hierachical structure is employed for context of knowledge. Knowledge in the higher level context can be referred from the lower level context but not for reverse. The program has also the function to explain the process of inference, that is, the way through which it has reached a conclusion. The language used is UTILISP and the computer M-200H.

2. Application to Start-up Guidance

The program has been applied to a man-machine communication for BWR start-up guidance. Start-up scheduling is a problem to find a way to bring reactor power to the rated value without violating any of the operating constraints[3][4]. In the start-up process, the most difficult and troublesome problem is estimation of Xe transient state caused by reactor power change. The Xe behavior brings about a fairly complicated effect on core state. Engineers however can estimate the Xe change by reference to the power history and their experience. Although such estimation is not so accurate as that by numerical simulation, it is useful to decide the reactor operating strategy.

Utilization of such experts' knowledge makes it possible to give a guidance for BWR

* *Moriyama-cho, Hitachi-shi 316.*

start-up through man-machine communication in which the program analyses what is necessary to solve a problem by itself. In the following, described is an attempt of such a knowledge based guidance to the decision making of reactor operation.

The man-machine communication system consists of a knowledge base, an inference engine and a communication equipment. The rules stored in the knowledge base are those of operating constraints, corrective actions for constraint violations, Xe transient state and meta-knowledge for inference control.

Structure of the knowledge base and the flow of information are shown in **Fig. 1**. The amount of rules is 55, out of which, 10 is for constraints, 20 for corrective actions, 20 for Xe transient and 5 for inference controlling meta-knowledge.

The Xe transient state is characterized by the two factors:

(1) Xenon concentration changing pattern
(2) Degree of the change.

The former is determined by reactor power history and the latter by the degree of the power change that brought about the Xe change together with the elapsed time after the power change. The process of the Xe transient state estimation is shown in **Fig. 2** with an example of the rules.

The characteristic of this system is that it adopts backward inference in combination with meta-knowledge to generate questions to the users about what computer needs to

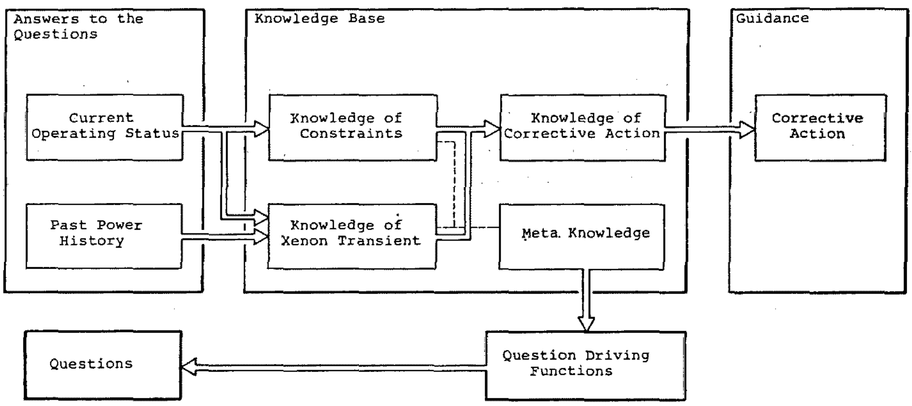
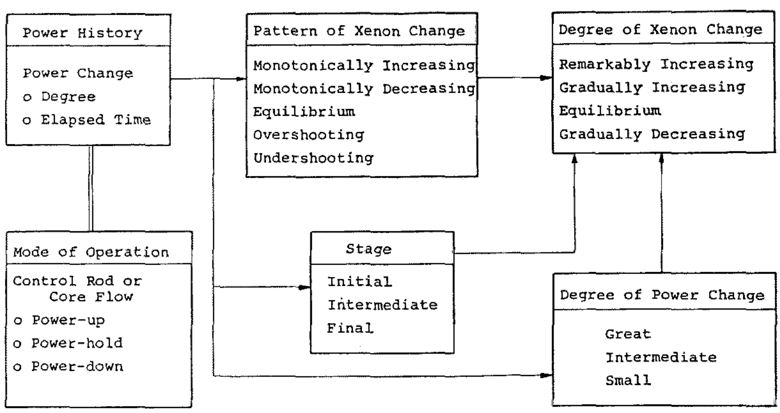


Fig. 1 Structure of knowledge base



Example of Rules

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(If (and (Xenon-transient Overshoot)
         (Power-change Great         )
         (Elapsed-time Short         )) (Then (Xenon Increasing Remarkably))))
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Fig. 2 Knowledge construction about Xe

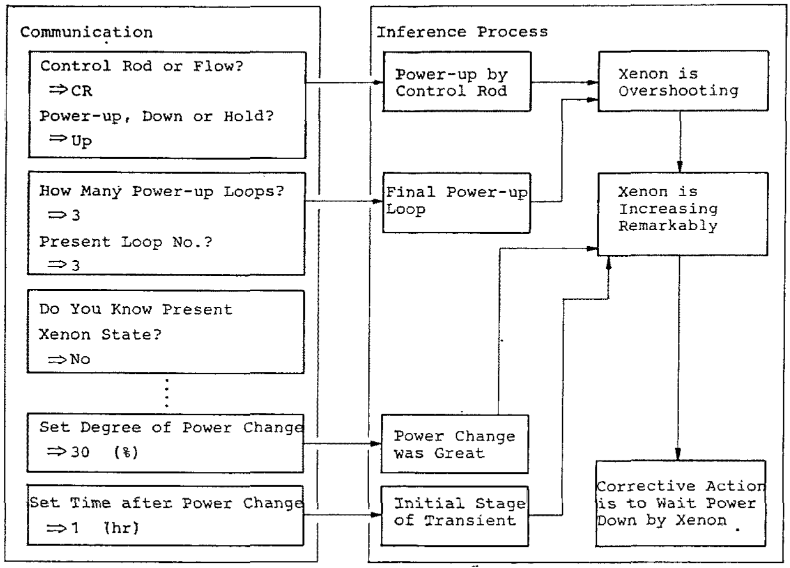

Fig. 3 Example of man-machine communication and inference process (in case of rod block line violation)

know. The inference starts by assuming a conclusion about corrective action if a constraint is violated. It first finds conditions required to prove the assumed conclusion by tracing the logics in the rules and tries to prove each of them. Some of the conditions can be asked to the user for the truth by the meta-knowledge. When the answer is not known, it then looks for a chain to prove the condition as a subgoal.

Figure 3 shows an example of man-machine communication with the inference path to reach the final goal. This is a case to decide the corrective action when the reactor power exceeded its constraint "Rod Block Line". By answering to the questions raised by the program, it has been concluded that (1) the Xe transient state is in the initial stage of overshooting introduced by a great power change and the Xe is increasing remarkably and, thus, (2) the corrective action is simply to wait for the power to decrease.

3. Discussions

The study indicates that some complicated problems as those encountered in a Xe transient state can be solved by using the knowledge about reactor operation, expressed in simplified logical statements.

For practical use, more detail and abundant knowledge should be prepared and the guidance should be more quantitative. Knowledge to meet such a requirement includes numerical simulation. It is, therefore, necessary to couple symbolic manipulation to numeric computation.

The approach introduced here will be a useful technique for intelligent problem solving. Other tasks of core management such as refueling scheduling and long term control rod programming are also handled by this technique.

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