Expert System aided operator's mental activities training

Adam GIECI, Juraj MACKO, Ján MOSNÝ, Augustín GESE
Nuclear Power Plants Research Institute,
918 64 Trnava, Slovakia

ABSTRACT

The operator's mental activity is the most important part of his work. A processing of a large amount of the information by the operator is possible only if he/she possesses appropriate cognitive skills. To facilitate the novice's acquisition of the experienced operator's cognitive skills of the decision-making process a special type of the expert system was developed. The cognitive engineering's models and problem-solving methodology constitutes the basis of this expert system. The article gives an account of the prototype of the mentioned expert system developed to aid the whole mental activity of the nuclear power plant operator during his decision-making process.

INTRODUCTION

Failures and disorders of complicated technological machineries are out of automatic control. They can be mastered only by a quick and exact thinking, good understanding and correct decisions of human operator. To fulfill this task, the operator is obliged to acquire a large amount of cognitive skills which are necessary for the problem solving and decision making respectively. A model of an optimal consequence of the mental activities for a good decision accomplishment is offered by the cognitive engineering. This one should be accepted as a general pattern of the operator s performance during an accident coupling. On the other hand pedagogics knows how to guide the human being to discover solutions for himself rather than to provide a ready-made answer (problem-solving approach). One of the expert system s definitions according to which expert system is capable to help even a novice to achieve result on the level of an experienced expert in the given problem domain, enconraged us to design and develop an expert system (ES), which would be especially aimed to the operator s cognitive activity training. The model of cognitive engineering and problem-solving approach to be mentioned earlier constitute the basis for this expert system. A main idea of this system is to emulate "thinking aloud" of an experienced operator during the accident situation. By means of that type of expert system a stressful accident situation is converted into the situation where the learning by problem solving usually occures. Under those conditions the novice reaches effectively very remarkable approach to the performance of an experienced operator.

Shell of the ES to be used, has a transparent architecture and offers all of the usual functions. It was developed at the Institute of Computer Science of the Comenius University, Bratislava, Slovakia.

At present an application of the expert system for the operator s cognitive activity support is developed and used for the NPP V-1 operator training.

Two years training experience approved a high degree of motivation as well as a real improvement of the analytical abilities and cognitive skills of attendees. It has been appeared too, that using the expert system as a training tool is very important for its next adaption to the control room.

2 UNDER WHAT KIND OF THE CONDITIONS DOES THE OPERATOR START WITH THE PROBLEM-SOLVING ?

Highly coordinated operator's activity, based on the presence of a valid conceptual model changes dramatically in the case the operator appears suddenly in a completely new and at least in its initial development unknown situation. Among such situations we can include serious failures and accidents and when he hardly knows what is matter and what he has to do. The information announcers stimulating the operator's activity before the failure appeared suddenly act as the sources of stress.

Hard paid experience from the most serious accidents of nuclear power plants (TMI, Chernobyl) show that the potential presence of all data was for operators practically unprofitable.

In our opinion, in such situation for an operator it is crucial point a struggle for correct understanding what has happened. This struggle is performed at the "knowledge-based" level i.e. when the operator's activity become to be determined by his own knowledge and judgments only. A repeated contact with the devices is highly dependent on his cognitive activity effectiveness.

3 LEARNING ACTIVITY AS A BRIDGE THROUGH THE STRESS

We have shown that unexpected occurence of a serious failure or accident is a stressing situation for the operator. Therefore the first-rate task of an efficient operator's behavior must be a successive overcoming of the stress load. It seems to us something what is very problematically manageable as a working situation (using data or commands for the operator), turns to be well manageable after the transformation into learning by problem solving. This transformation we consider to be the key moment of our whole solution. Everyone could agree that from the operator's behaviourpoint of view of an accident or a serious failure seems to be a situation of solving new problems. But the stress of an operator could cause chaos in his behaviour and therefore rapidly decrease or even disable the success of a solution. It seems to us that in order to overcome the chaotic behaviour of an operator it can be very useful to make use of operator's ability of learning. That is, to introduce the state of high psychical activity when learning usually occurs. Particularly we mean the learning by problem solving /1/. Above mentioned transformation into the learning by problem solving that is performed by changing (transforming) the stress-causing signals into the conditions of learning Note that the conditions for such learning situation are in the learning theory precisely defined /1/.

For our inventions the first-rate importance of them are the instructions to manage learning activity. They are as follows:

- point out clearly to individual, already known principles and relations, necessary for resulting solution,
- direct cognitive procedure towards the ultimate goal (result) namely when a mistake could be identified precisely, to which a currently chosen alternative leads,
- reduce the collection of possible hypotheses, and they could not tell the result directly.

We do believe that these are obligatory directions also for the advices which should be given by the expert system designed as a replacement for the instructor.

4 INSTRUCTIONS FOR DECISION-MAKING PROCESS SUPPORT SYSTEM

From that what we said about instructions suitable in problem solving it could be obvious that they were equally dependent both on the contents and the time of their presentation. The answer on the question "when and what" information it is necessary to render to an operator we have to look for in cognitive activity models of problem solving and decising. We introduce a figure (Fig. 1) where an operator decising model according Rasmussen /2/ is depicted.

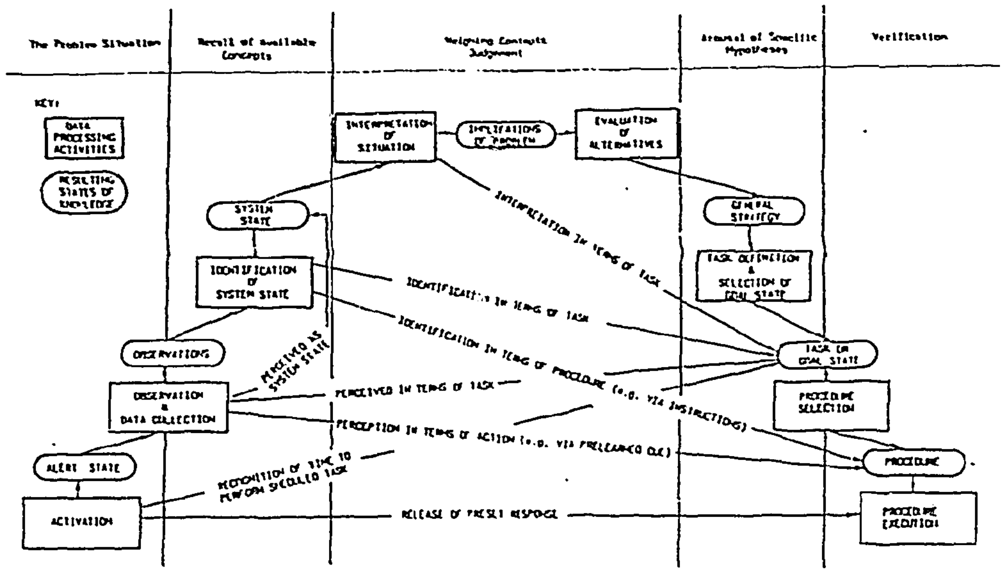

Fig.1. The Interpretation of Problem Solution's Process with Rasmussen's Model of operator's Decision Making

There are the phases of a problem solving process denoted in its background so that cognitive psychology distinguishes them /3/. The model could be considered to be a very condensed expression of the theoretical basis of a solution of the contents and time side of instructions. The Fig.1 tells briefly:

- in the first phase it is necessary to perceive all the important signs of the situation occured. Here a higher attention as well as a fast recognition is inevitable.
- after verification of the occured failure it is necessary to take into account all possible alternatives of the failure's origin and hence also the possible solutions (the second phase).
- after the creation of a sufficiently large collection of the alternatives it is possible to reason which one could be the most likely and to decise for the proper solution (the third phase).
- the inevitable condition of the correct solution finding it is the creation of a verifiable hypothesis for the chosen solution (the fourth phase).
- in the ultimate fifth phase it is necessary to perform

a correct verification of the hypothesis and on its base to judge whether the solution choice was correct.

The successive fulfilment of these activities gives a good chance for success in problem solving. It is quite clear that the solution of a problem requires the assembly of a standardized sequence of information items which, for the given type of an accident or failure, correspond by their contents and rouse an operator's cognitive activities.

We note that such sequence of instructions leads an operator towards the understanding of the global situation in a controlled process, and did not ensure only vanishing of mistakes in manipulation procedures, as it is usual in recent operating procedures.

We have designed the items of such standardized sequence and ordered them (according to their denotation) in the following way: VERIFICATION, CONSEQUENCES, WAY-OUT, DECISION, CLAIMS, PLAN, PROCEDURE, CONFIRMATION, RESULT. The contents of these items is as follows:

VERIFICATION: usually questions aiming to investigate all the necessary data and facts, which confirm or reject the correctness of a signalized failure.

CONSEQUENCES: inform about the most serious damages and threatenings of the accident.

WAY-OUT: point out to all possibilities of the failure recovery and mittigating of the failure consequences.

DECISION: the operator is given important criteria for his decising.

CLAIMS: information about all the conditions as well as requirements which must be kept by the chosen solution.

PLAN: the design of a framed schedule of main tasks in performing the accepted solution.

PROCEDURE: the detailed procedures of individual tasks.

CONFIRMATION: questions concerning the changes which would necessarily appear if the accepted solution was correct.

RESULT: determination of the resulting device status after the parameters stabilization.

5 TINA - TRANSPARENT INFERENCE ARCHITECTURE

The prototype of NPPO-TINA (Nuclear Power Plant Operation - Transparent Inference Architecture) has been developed in the environment for building expert systems TINA /4/.
It is characterized by:

- a free structure of cooperating knowledge bases (KB) integrated by the same inference principle, the knowledge representation is based on mixed frame-rule structure
- a kit architecture, the central part of this system

consists of the inference engine only, all other partial functions and activities of the system are expressed as a knowledge (e.g. knowledge about communication, editing, explanation, etc.) or functions, as shown on Fig.2.

- a hierarchical schedule structure, which enables to solve problems as a dynamically modified hierarchical net of metaproblems, problems and subproblems on a different level of a generalization, importance and interconnections, it allows dynamical changes of strategies during a problem solving.

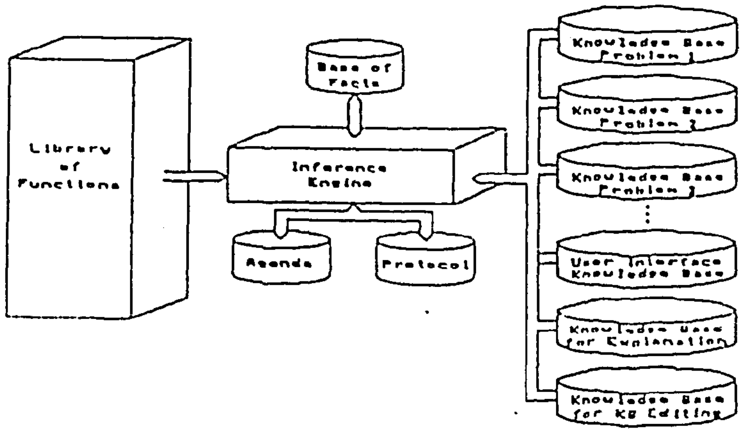

Fig.2. A kit architecture of TINA

6 AN EXAMPLE

For the sake of an experimental debugging and verification of the NPPO-TINA type advisory, the advisory for the failure caused by a fall out of all Primary Circuit Supply Pumps and Boron Regulation Pumps for nuclear power plants of VVER type with the reactor V-213 has been developed as first (/5/, /6/). The prepared advisory is working off-line. In what follows, we shall try to introduce the usage and function of the NPPO-TINA by a brief description of some successively chosen information items for the failure jast mentioned.

The user can choose the required advisory using a menu from a stack of advisories prepared for particular failure types separately. The initially depicted information after choosing an advisory, is an imitation of that failure signalization on pumps fall out, which an operator sees at the control room's alarm window (Fig.3).

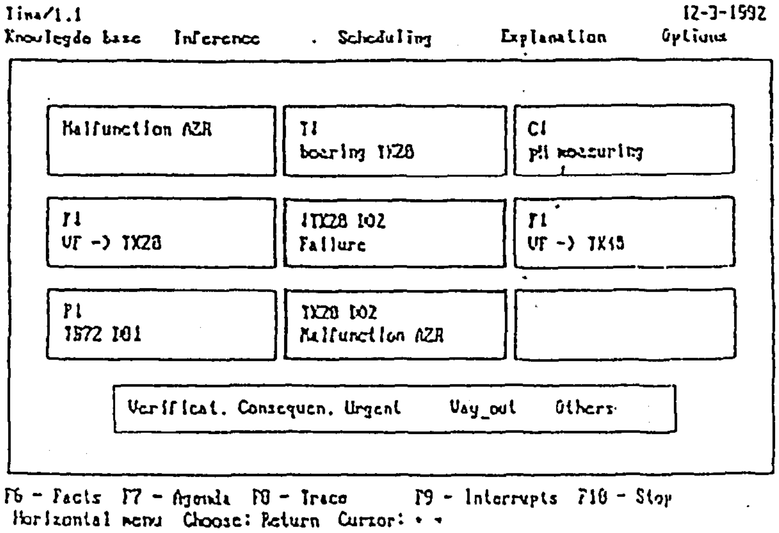

Fig.3. Failure presentation

The denotations of those information items which are of most importance for the operator at this stage, are depicted as labels (from left to right) in a horizontal menu. Generally, the choice of whatever information item could be realized, but it has no practical value.

From the left, the first offered item is VERIFICATION. It is of help in evaluating the validity of the failure signalization, whether the failure appeared really, or the signalization has failed (Fig.4.). The confirmed signalization becomes to be facts for a further processing by the expert system.

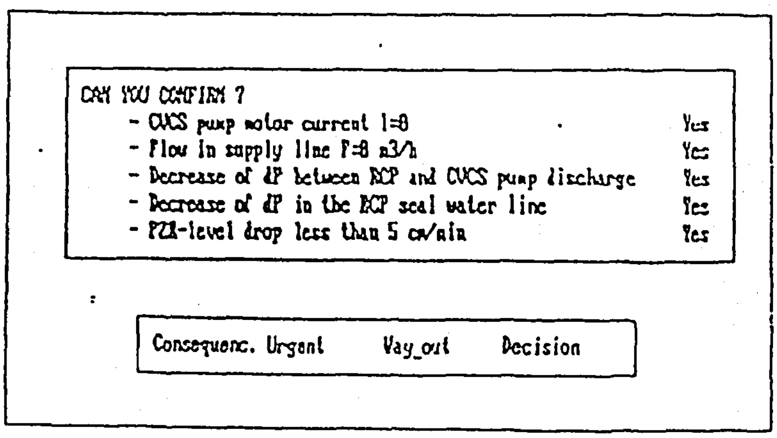

Fig.4. Verification of the failure's symptoms

After confirming the validity of the signalization and after finishing the global identification of the status (using the items CONSEQUENCES + WAY-OUT), the operator is prepared for decising about further operations of the machinery. Choosing the item DECISION, all criteria and circumstances are depicted on the screen, important in considerations on reaching correct solution. After evaluating all of the criteria the proposal of a most suitable solution (Fig.5)

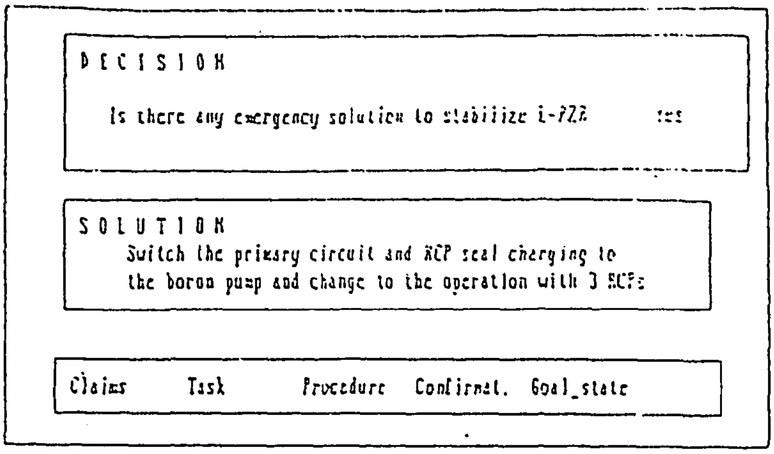

Fig.5. Proposition of the most suitable solution

The further items (PROCEDURE, CONFIRMATION) then following their defined contents only precise the procedure of solution and ensure its correct realization.

The final item RESULT gives the basic definitions of the machinery status, which has to be reached by the correct solution after stabilizing the parameters (Fig.6).

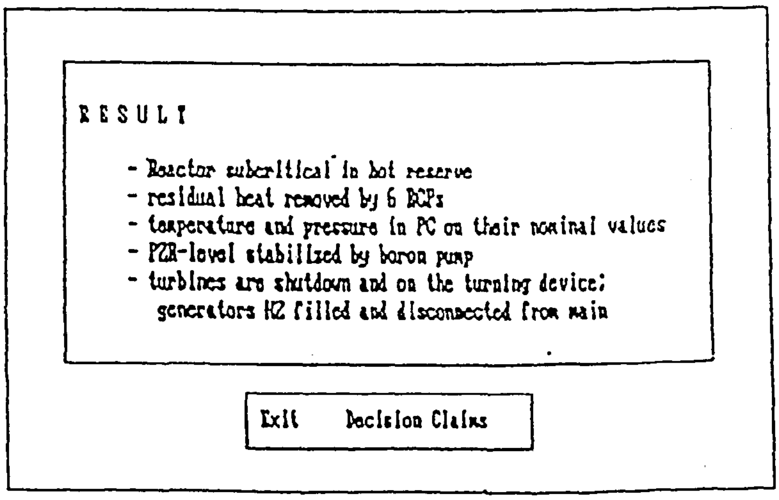

Fig.6. Prediction of the target state

7 CONCLUSIONS

Multiple experimental verifications of the developed advisories of the NPPO-TINA type in operator's training using the full-scope as well as the special function simulator at the Nuclear Power Plants Research Institute in Trnava have confirmed the essential aspects of intended support of cognitive activities training its global functionality. The staff has accepted its +usage in their training. Providing solutions of some stylization and terminology questions there is a very real possibility of its using at control rooms as well.

When using this advisory in training and practicing of the staff, the most valuable experience appeared to be a possibility of very effective transition of cognitive skills of experienced operators into beginners training. Previously used means have enabled that only in a restricted manner. Fixing of the habit of a systematic information processing to which such advisory usage leads operators, could be very useful as well.

The exploitation of expert systems technology as well as its implementation in the PC environment has demonstrated its high value due to very fast processing and transmitting required information. This factor could be very interesting from the aspect of its exploitation at a control room.

ACKNOWLEDGMENTS

The authors are deeply indebted to Jarmila Sersenová and Melánia Sprušanská for their help in preparing this paper.

REFERENCE LIST

/1/ Gagné R.M. 1965. "The Conditions of Learning". Holt, Rinehart and Winston, Inc. N.Y.

/2/ Rasmussen J., Duncan K., Leplant J. 1987. "New Technology and Human Error". John Wiley and sons.

/3/ Gagné R.M., Fleishman E.A. 1959. "Psychology and Human Performance". Holt and Co. N.Y.

/4/ Gyarfáš F. 1988. "Hierarchical management in Expert Systems". Doctoral Dissertation. TU Bratislava. in Slovak

/5/ Berezňák J., Gieci A., Gyarfáš F., Kelemen J., Mikulecký P. 1989. "A Laboratory Realization of an Expert System for Nuclear Power Plants Operator's Decision Support". Technical Report VÚJE 223/89. in Slovak

/6/ Gieci A., Gyarfáš F. 1991. "Knowledge-base Catalyzer for Operator's Decision-making process". Jaderná energie 37, No 10/11, 1991. p.395-404. in Slovak