Coping with Unanticipated Accidents using Emergency Operating Procedures

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1. Introduction

Basically, operators are required to follow emergency operating procedures (EOPs) during emergency situations of nuclear power plants. The EOPs are well prepared and support efficiency and accuracy of operators to cope with anticipated accidents. However, unanticipated emergency accidents such as extreme external hazards may cause dynamic status progresses of the power plant or additional abnormal situations [1]. In this case, simply following EOPs may not be the optimal solution. In [2], unsafe acts associated with a literal following of a procedure were reported. A report of the Fukushima accident also revealed that a tendency to adhere to procedures and prior practices can impede applying effective countermeasures [3]. To overcome the conflicts between benefit and jeopardy of procedures during unanticipated accidents, we reviewed the literature on the perspectives of cognitive engineering and artificial intelligence. From the insights about human planning of the literatures, we also proposed an approach of how to train operators to effectively use EOPs during unanticipated accidents.

2. Multi-level Human Behavior

Human behavior for performing tasks is determined by several types of decisions. Rasmussen developed a Skills, Rules, Knowledge (SRK) taxonomy and defined three types of behavioral or psychological processes present in human information processing [4]. Fig. 1 depicts the mechanisms of cognitive control according to the SRK taxonomy. Knowledge-based behavior (KBB) includes analytical problem solving based on symbolic representation. Since KBB is induced by an unusual situation and requires deliberate attention, KBB is a slow and serial process that requires a considerable amount of effort. Rule-based behavior (RBB) is more experienced behavior and utilizes many "if-then" rules that have been produced from already obtained experience. RBB does not include a reasoning process; instead, it uses familiar perceptual cues to prompt actions. Skill-based behavior (SBB) consists of repertoires of automated behavioral patterns. Humans who are extremely experienced with a task tend to behave at the SBB level without conscious attention.

During unanticipated accidents, the emergency tasks will usually require composite behaviors of all three levels of the SRK taxonomy. However, it is obvious that KBB is effortful and essential to the accomplishment of the tasks. KBB in the tasks is also considered as the most difficult to be reliably performed. In [4], the authors suggested a principle that represents the work domain by an abstraction hierarchy to support KBB. The abstraction hierarchy is a description of means-ends relationships in the system.

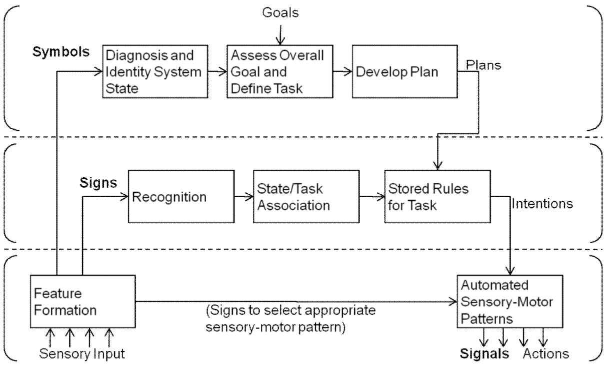

Fig. 1. Rasmussen's SRK levels of human cognitive control [4]. The upper part shows the process of KBB, the middle part shows the process of RBB, and the lower part shows the process of RBB.

3. Automated Planning Techniques

Although artificial intelligence is not human intelligence, the field of artificial intelligence provides significant insight into the human planning process, because the field has been inspired by human intelligence.

The generative planning approaches of artificial intelligence depend on an explicit representation of the states of the world models and the descriptions of goals and actions [5]. These approaches begin with a difference between an initial 'state' and a final 'goal state' and typically search from a number of operations to reach the goal state. Conventional planning approaches are also known to be appropriate for treating complicated and time-consuming tasks.

To cope with dynamic and unpredictable environments, techniques of reactive planning, which decide just the next action based on the current situation, are used [6]. The reactive plan can be represented by if-then rule-based models such as condition-action rules or finite state machines.

Case-based planning (CBP) adapts the cases of plans that have been successful in past situations to new problems [7]. This approach is motivated by a psychological plausibility, which implies that the approach resembles an expert's reasoning. Experts do not plan from scratch but use considerably standard procedures. The second motivation of this approach is efficiency: it avoids the repetition of a plan generation by reusing old plans.

The fundamental case-based planning process consists of plan retrieval, reuse, revision, and retention. The cycle of this process is illustrated in Fig. 2.

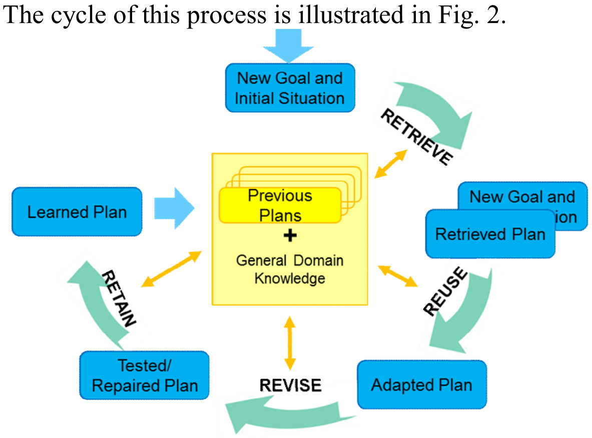

Fig. 2. The case-based planning cycle [7]

The adaptation process in the plan reuse phase is one of the most difficult issues of a CBP. In some cases, a CBP is more difficult than the generative planning approach due to the complexity of the adaptation process. To adapt the old plan to a new situation, heuristic-based adaptation, case-based adaptation, generative planning, or plan merge strategies are usually employed.

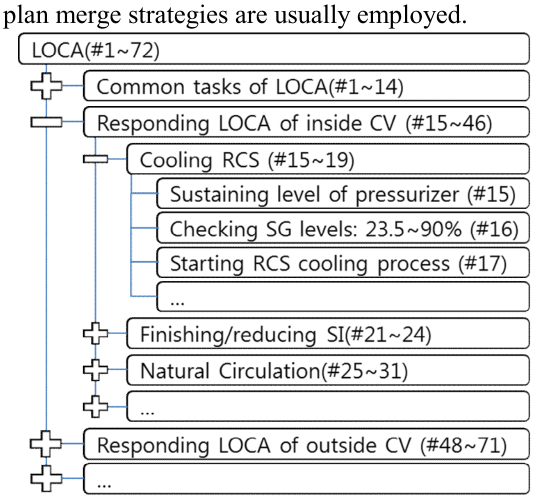

Fig. 3. Hierarchical structure of LOCA scenario

4. Adaptation of EOPs to Unanticipated Accidents

To cope with unanticipated accidents, it is not reasonable to force the operators to use generative or automated planning-like behaviors, since they are under a highly stressed situation and should rapidly respond to the situation. Thus, the strategy using EOPs can be seen as one of the CBPs of artificial intelligence. The problem is how to support operators for effective adaptation of the EOPs. In this study, we propose a plan merge strategy, which uses segments of EOPs.

In the EOPs, there are lots of emergency tasks. By appropriated training, the operators can merge the tasks based on a basis procedure. To do so, the EOPs should be clearly defined as several abstraction levels of emergency tasks and the abstraction hierarchy of EOPs, which was introduced in the KBB principle, would be a proper solution to define the tasks. Fig. 3. shows an example of a LOCA (loss of coolant accident) procedure that is decomposed by means-ends relationships. From the means-ends hierarchical structures of procedures, significant properties or characteristics of the emergency tasks should be defined so that the operators can accurately reuse them during procedure adaptation. Finally, these definitions, relations, and properties of the tasks should be educated to the operators.

5. Conclusions

There are three key processes required to effectively cope with emergency situations: how correctly the operators are aware of the occurring situations, how properly they develop corresponding plans for the situations, and how accurately they execute the plans. This paper presents a way to develop the plans using EOPs from some literature of human planning. Even if professional operators have implicitly shaped good structures of procedures already, it is expected that this approach will provide a more systematic and concrete training strategy. If the operators are trained with this strategy, a higher level of human reliability would be ensured in unanticipated accidents.

Acknowledgements

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