Formal Language and Flowlogic Diagram for Computerized Procedural System

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1. Introduction

Procedures are a set of instructions that operators should follow. There are lots of procedures in nuclear power plants because personnel are requested to use them. The operations with procedures are called rule based operation. The operation without procedures are called skill based or knowledge based operation.

Advanced technology of I&C can automate the procedure operation in industry fields. For example, startup manual operation of equipment can be automated by batched automatic operation like laundry machine. But if system is complex like nuclear power plant, the rule based operation remains in the future.

Most procedures are bound in book. Operator turns pages one by one to perform the instructions. Paper based procedure is good as carryon in the plant. But paper based procedure is not well harmonized with advanced control and monitoring system which is shown in FPD. Thus there has been strong demands that procedures should be computerized.

Computerized procedure system(CPS) shows the instructions in FPD. FPD is capable of stronger interaction than book. Dynamic text and graphics are available in CPS. Information to refer to during procedure execution can be integrated with instructions. APR1400 MCR introduced CPS like Fig.1
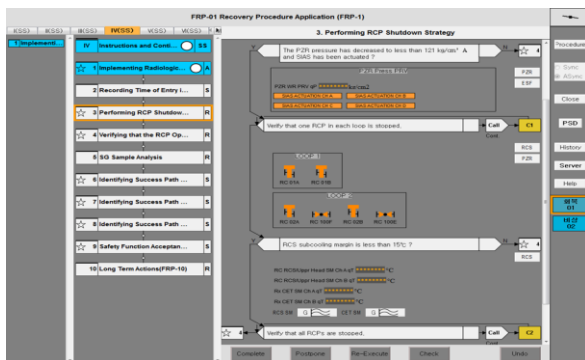

Fig. 1 CPS User Interface.

2. Language for CPS

Language for CPS is different from language for paper based procedures because of dynamic interaction. Syntax and words in instruction are similar to those in paper procedure because they should be comprehensible. But there is additional syntax to indicate workflow among instructions. Paper based procedures indicate the workflow with "goto" word. In structured program language, however, "goto" word has been depreciated. Language without "goto" is considered good language. Instruction in CPS should be created without "Goto". If instructions are arranged sequentially, there is no "goto". The similar principle can be applied to CPS language. But workflow of instructions in CPS is more complicated than in sequence. There are branches or if_then logic among instructions according to plant state or operator decisions.

The instructions are written for operator to do something in plant. After execution of instruction, state of plant or operator changes. There are no meaningless instructions. This interpretation is speech act caught by J.L Austin who was British philosopher. Speech or statements from the speaker carries information to listeners. The information includes facts, commands, and emotions from speaker to listeners. Speech acts in procedures steer the nuclear power plant. Speech acts are called instructions which should not be missed during execution.

3. Procedural Proposition

APR1400 CPS introduced two important concepts; flowlogic diagram and procedural proposition [2].

Procedural proposition can be compared with analytic proposition or synthetic proposition which are propositions to be determined as true or false by its definition or by observation. Both propositions are a framework to accumulate knowledge of human being. These days, propositions have been extended to predicate proposition and modal proposition. Both propositions are valuable tools for artificial intelligence.

Procedural propositions are similar to modal proposition. They become true when read and executed. The proposition has its meaning like speech act. This is because human operators should not miss the actions. Thus procedural proposition has it effectiveness with a specific goal that should be achieved in a procedure.

Since procedure was written before its execution, its effectiveness was evaluated in advance. Operators are required to follow the procedure rigorously. This is why procedural propositions are introduced.

4. Decomposition of task

All types of propositions should be concise to be evaluated true or false. If the proposition is complex, it is difficult to evaluate. The complex propositions are

called molecular proposition. When molecular proposition is decomposed, the decomposed propositions are called atomic proposition. In procedure it is called instruction.
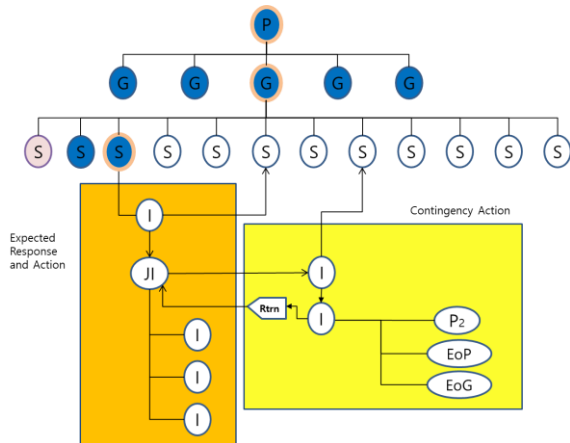

Fig. 2 Decomposition of Procedure

When a procedure is decomposed, decomposition rule should be described. Fig.2 shows decomposed nodes connected by lines. This structure looks similar to book structure. A book is decomposed into chapters, paragraph, sentence, word, and characters. The similar structures are maintained in CPS. Those are gross step, step, instruction, word, and characters.

Recombination rule is inferred from decomposition rules. Procedures are set of gross steps. The gross step is set of step recursively. The set relationship can be presented in a simple tree structure. The step is a graph of instructions. The graph is not simple. APR1400 introduced flowlogic diagram of which skeleton consists of flowchart and logic tree. The flowchart is nodes with arrows. The arrows indicate direction after execution. Flowchart is a usual graph with procedures. If an instruction is a composite sentence, the sentence can be further decomposed into primitive sentences with logic word such as AND, OR, and Sequence. The composite sentence and primitive sentences are called as parent instruction and child instruction. After the child instructions are executed, the parent instructions can be executed.

Thus the flowlogic diagram can be explained primarily as flowchart among parent instructions, secondarily as logic tree between parent and children.

5. Token for execution

While reading a book, a book marker indicates a page of reading. Several book markers can be used occasionally. The similar principles are applied to CPS. The bool markers are called tokens in CPS.

All nodes such as procedure, gross step, step, and instructions can have tokens. After gross step or step are executed, their tokens are generally removed and next nodes are granted with new tokens. But if the step is not at proper condition to execute due to plant state, the step can be postponed with token remaining. All the nodes with token are called UE(Under Execution) nodes.

Node instruction is executed with token too. But granting and depriving tokens from instructions are different from that of step. After execution of the first instruction, its token is not deprived. Another token is created and granted to the second nodes. When the final instructions are reached and executed, all the granted tokens to the instructions are removed.

Once nodes have tokens, those nodes are interactive and can be executed anytime. Even though operator can access to multiple nodes with token, only one node should be selected for execution. The selected node is called a focal node. the UE nodes and a focal node are distinctive in CPS MMI.

6. Multiple Value to propositions

While executing instructions, values of them are evaluated by either human or system. Analytic propositions are rarely used because of their inherent fixed value. Synthetic and procedural propositions are frequently accounted instructions. They are evaluated by observing plant state or by performing instruction. Values of the propositions are defined as null before execution, and true/false after execution. The values of propositions are a little different from traditional proposition logic, predicate logic, and modal logic.

7. Place keeping and others

Whenever instructions are performed, their evaluations are recorded in a file. They are used to analyze operator behaviors or correctness of operation.

There are lots of other functionalities in CPS to support operator. Process variables can be integrated to flowlogic diagram. Focal UE steps can be synchronized among crew members.

8. Conclusions

When CPS was introduced in the past, systematic approach was not enough. But this paper is trying to explain MMIS with logic model. Procedural propositions are introduced and multiple values of proposition are permitted. Logic words to combine child instructions become more powerful with AND, OR, and Sequence.

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