Mathematical Operators for Automatic Evaluation in Computerized Procedure System

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1. Introduction

Language is specific characteristics of human beings. Knowledge has been accumulated by language, and intention of worker is transferred by language. Language is the most valuable invention of human beings.

Language, however, has limitation to describe nature or engineering principles. Note that a picture of camera is better than 100 words and a sheet of P&ID is better than a volume of document written in natural language.

Nuclear power plant is requested to be operated by established procedures rather than by operator's skill. Therefore more than 1000 procedures are written and revised annually. Traditionally most procedures are written in the paper using natural language.

Human operators in the main control room steers nuclear power plant. Advanced main control room consists of monitoring system, control system, alarm system, and CPS(Computerized Procedure System). Are they interfaced in natural language? No, monitoring and control system is designed in the basis of P&ID, and alarm system is presented in either title or list structure. CPS has a little different story. Some CPS are described in natural language, and the other CPS are presented in artificial language such as Flowlogic diagram.

Natural language can be understood by human beings. Whereas artificial language such as P&ID or Flowlogic diagram can have more information and simple grammar if users are educated.

FORTRAN or C++ is another type of artificial language for computer [1]. Both language are written by human beings, but are executed by computer. They are useful to predict scientific phenomena.

On the other hand, CP(Computerized Procedure) for CPS is written by human beings, and executed by both computer and human beings. Computer supports human beings to carry out the procedures. For this purpose, computer evaluates some logic embedded in CP and hints human beings the results. Mathematical operators in this paper are used for these purposes.

2. Types of Operators

APR1400 CPS adopts artificial language called Flowlogic diagram that was developed and named by KHNP. Fig.1 shows APR1400 CPS in Flowlogic diagram.

The window of monitor is decomposed by three panes. The left is monitoring pane to monitor skipped steps, the middle pane show all steps in arrays, and the right pane show the focused step that is usually executed step. Place keeping records are maintained and the present step is presented salient. For example, focal elements are outlined by yellow.

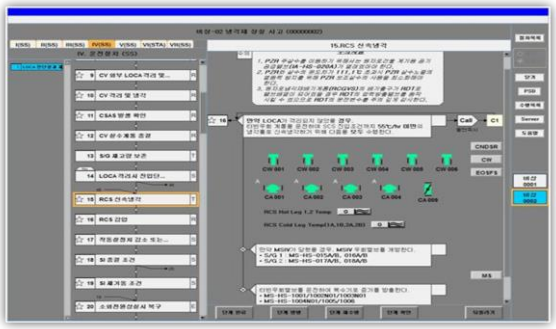


Fig.1 APR1400 CPS

Focused step is rendered in Flowlogic diagram. A typical Flowlogic diagram is shown in Fig.2. Flowlogic diagram looks like combination of flowchart and logic tree. Execution orders among nodes are specified in Flowlogic diagram with arrows or join logic operators. Join logic operator is used to combine parent node and child nodes. Node G in Fig.2 has 3 child nodes; B, E, and F.

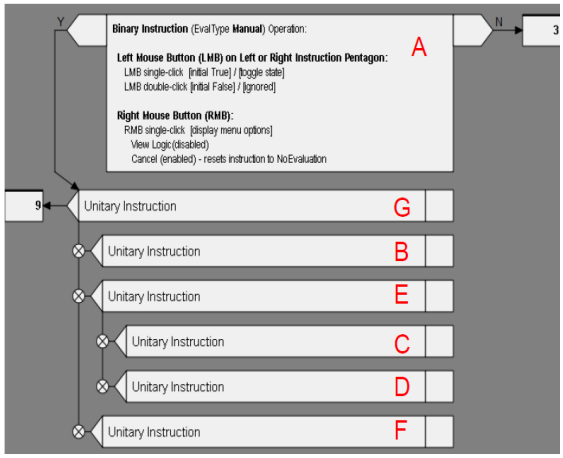


Fig.2 Typical Flowlogic Diagram

Available join operators are AND, OR, and SEQUENCE. When parent node is combined by OR, parent node becomes TRUE when one of child nodes is TRUE.

Nodes in Flowlogic diagram are called instructions that should be executed by crewmembers. Crewmembers toggle instructions in Flowlogic into TRUE/FALSE according to nuclear plant state. Then

CPS shows next instruction to be executed by thickening incoming arrow and activating next instruction.

It is time to introduce mathematical operators with instructions. There are three types of instruction in view of automation; manual instruction, auto instruction, and manual-auto instruction. Manual instructions are evaluated by crewmembers, auto instructions are evaluated by computer, and manual-auto instructions are evaluated by human and checked by computer. Auto instructions in Flowlogic can be distinguished by A mark in Fig.3

Fig.3 Typical Auto and Manual instruction

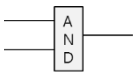
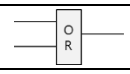
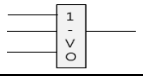
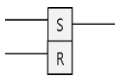
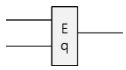
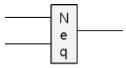
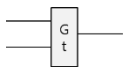
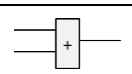
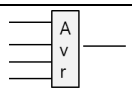
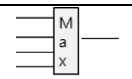
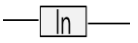
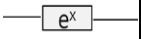
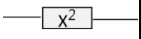
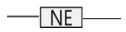
Checking statement such as "Is subcooled margin less than 15 degree?" is written in auto instruction. Because dynamic process variables are available in CPS, CPS can evaluate the instruction automatically using mathematical expression such as 'SubCool < 15'. In this case, less than operator is used.

There are 5 types of mathematical operators according to input or output.

- Arithmetic operator with number input, number output
- Relational operator with number input, Boolean output
- Logical operator with Boolean input, Boolean output
- Timer operator with timer input, and Boolean output
- Execution operator with procedure elements and Boolean output

Table 1 shows typical mathematical operators and its symbols used in CPS. Combination of these mathematical operators make complex statement be TRUE/FALSE. Auto instructions can be embedded by mathematical expression that can be shown if crewmember wants it.

Table 1 Typical mathematical operators

Operator	Symbol,	Description
and		Boolean AND
or		Boolean OR
vote1		True when more one input are true
sr		SR Flipflop
tron		True when input becomes 1. Output remains True until next input comes
eq		True if two input are equal
neq		True if two input are not equal
gt		Great Than Operation between Numbers
plus		
avr		Average among numbers
max		Highest value among X variables
ln		
exp		
sq		
rcnt		True if Now-Absolute Timer(x) is less than set interval(y). The interval is specified as yyyy-mon-day hour:min:sec The interval can be displayed as hour:min:sec
NE		True when instruction is not executed
UE		True when instruction is being executed
ED		True when instruction was executed

Arithmetic, relational, and logical operators are similar comparing other language such as C++, Java. SR operators and tron operators are introduced to provide control logic language used PLC [2]. Task types of procedure execution are diverse so that control activities are needed.

Finally Timer and Execution operators are specific to procedure execution. Timer operator is introduced to record when procedure was started. Execution operator is introduced to check whether specific step was performed.

Comparing spreadsheet program equipped with mathematical expression [3], CPS has similar functions.

In the past, only a few users used these kinds of calculus function. Most users concerned that automatic expression was not transparent to human beings, and that was difficult to edit mathematical expression. These days, there are experiences that procedure execution has been expedited and human error has been reduced due to auto instruction. Besides when auto instruction behaves wrongly, operators can override its evaluation.

APR1400 CPS is reinforcing auto instruction. And procedure writer has freedom to use auto instruction or not. SinKori34 crewmembers have decided to use auto instruction as less as possible. Recent nuclear power plants make use of auto instruction strongly.

3. Variables

Operand of mathematical operator comes from process sensors. But process sensor data are not only source of operand. Generally speaking, data source come from both process sensor and human beings. Mouse click and input by crewmembers are also data sources. Input by crewmembers is defined as CPS variable independently contrasting with DCS (Distributed Control System) variable. Data source from mouse click can be linked with procedure elements. DCS variables are stored in CPSDB (CPS DataBase)

While writing CP using CPSES (CPS Editing System), suitable process variable can be selected.

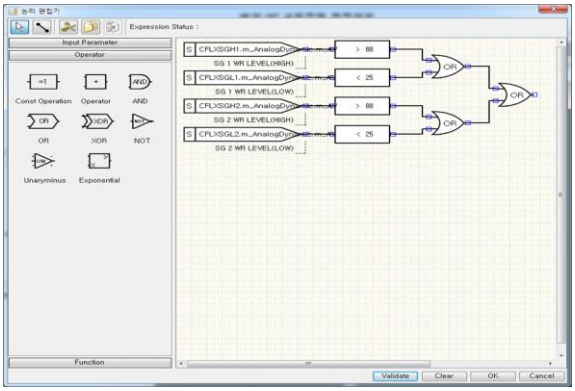


Fig.4 Editor to write mathematical expression

3. Applications and Limitations

Mathematical expression is introduced to be used with auto instructions. 80 % of mathematical operators are utilized for auto instructions. But there are other usages of mathematical expressions.

CAS(Continuously Applied Step) is a step that crewmembers should monitor periodically during procedure execution. It is said that human beings are not appropriate for CAS monitoring. Therefore the entry condition of CAS can be written by mathematical expression. CAS entry condition, however, is much complicated than logic of auto instruction. Therefore there is no CP with CAS entry condition written by mathematical expression. At the present, CAS is handled by human operators.

In addition, procedure entry condition makes well use of mathematical expression. Especially when reactor trip occurs, procedure called standard post trip actions can be opened automatically due to mathematical expression.

Is it enough for current set of mathematical operators to evaluate auto instruction, CAS entry condition, and procedure entry condition. Comparing with programming language that has more powerful functions such as if-then, the mathematical operators might be not enough. If scripting language is provided in addition to mathematical operator, auto evaluation can be more powerful. The scripting capability is provide in most spread sheet language.

4. Conclusions

Mathematical operators are needed for CPS to evaluate auto instruction. The operators cover arithmetic operator, relation operator, logic operator, timer operator, and execution operators. If mathematical operators are supplemented by scripting function, Flowlogic diagram will be powerful.

It is observed that auto instruction embedded with mathematical expression can reduce human errors.

REFERENCES

[1] https://en.Wikipedia,org/wiki/, C++
[2] https://en.Wikipedia,org/wiki/, programmable_logic_controller
[3] https://en.Wikipedia,org/wiki/, Spreadsheet