

# Modeling of a Human Performance by the GO-FLOW Methodology

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**Abstract:** Human performance is quantitatively evaluated by using Rasmussen's Step Ladder model. Take up operator team's response at a PWR reactor incident. Total human error probability is evaluated by THERP method. Then, "Ladder model" is transferred into a GO-FLOW model, and gives quantitative values for elementary factors appeared in the model. Analysis result is compared with the result by the THERP method. Parameter values are also changed and results are examined.

**Keyword:** Human performance; SRK model; Step Ladder model; GO-FLOW; Quantitative evaluation

## 1 Introduction

Evaluation of human performance is an important issue for the safety analysis of engineering systems, because many engineering systems are operated by human and its errors directly produces malfunction or failure of the systems. To evaluate human error probability is a difficult task. Even for a simple action, its failure probability changes in wide ranges depending on persons characteristics, surrounding working conditions, relation to other tasks, and so on.

The authors try quantitatively to evaluate human performance with Rasmussen's Step Ladder model. As an example of human actions, take up operator team's response at the steam generator tube rupture incident in a PWR reactor. Total human error probability as a team is evaluated by THERP method. Then, "Ladder model" is transferred into a GO-FLOW model, and gives quantitative values for elementary factors appeared in the model. Analysis result is compared with the result by the THERP method. Parameter values are also changed and results are examined.

## 2 Human reliability analysis

### 2.1 Rasmussen's SRK model

The Skills, Rules, Knowledge (SRK) framework or SRK model was developed by Rasmussen<sup>[1]</sup>. The

basic idea is that human has three different kinds of behaviors corresponding to required tasks.

In skill-based behavior, an operator requires very little or no conscious control to perform or execute an action once an intention is formed. Performance is smooth, automated, and consists of highly integrated patterns of behavior. For example, bicycle riding is considered a skill-based behavior in which very little attention is required once the riding skill is acquired.

A rule-based behavior is characterized by the use of rules and instructions to select specific actions in a given work situation. The rules can be obtained or prepared by the operator himself through experience or given by some other experts. The operator is not required the knowledge about underlying principles of a system operation, to perform a rule-based control.

A knowledge-based behavior represents a more advanced level of reasoning. This type of control must be employed when the situation is novel and unexpected. Operators are required to know the fundamental principles and laws by which the system is governed. Operators have to make explicit goals based on their understanding about the system states, sometimes with analytical procedures. Operator's workload is typically greater than when using skill- or rule-based behaviors. The SRK model is presented as shown in Fig. 1. with three layer structure.

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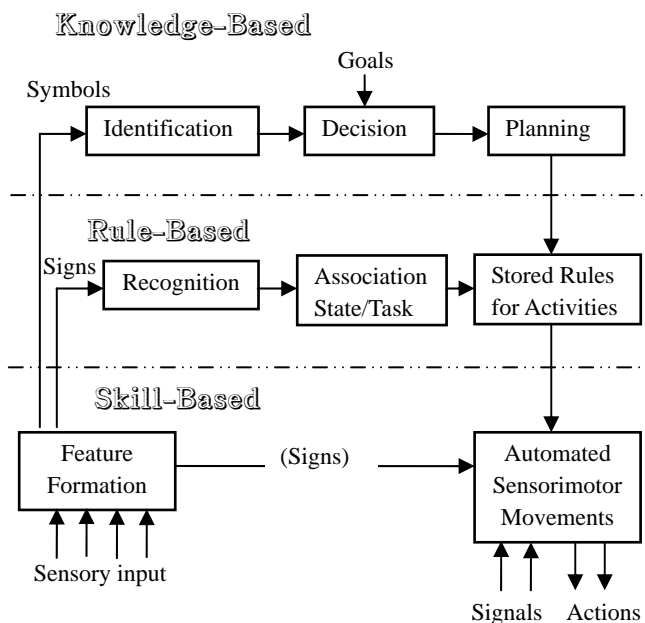


Fig.1 The SRK model.

### 2.2 Step Ladder model

As an extension of the SRK model, the Step Ladder Model is proposed by Rasmussen<sup>[2]</sup>. In this model, there are various stages that an operator could go through when making actions. Possible short cut paths are given in the model. Operator can sometimes execute required action without knowledge based level.

Figure 2 shows a simplified Step Ladder model based on the original Rasmussen's model. This simplified model is used for modeling by the GO-FLOW framework in the present analysis.

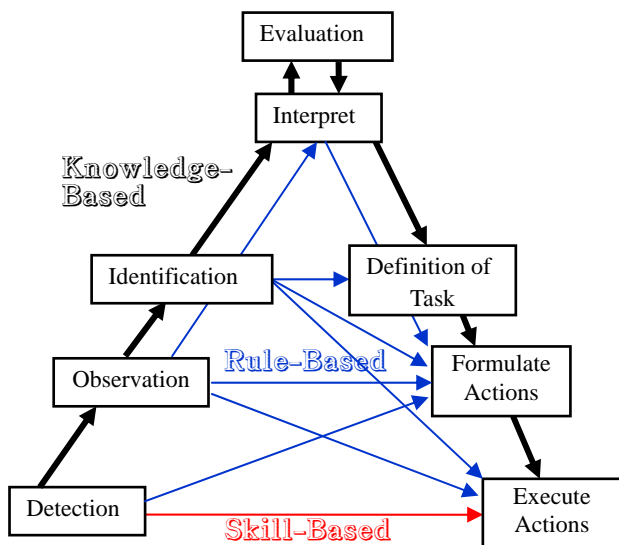


Fig.2 Simplified Step Ladder model.

### 2.3 Human reliability analysis event tree

In HRA event tree, limbs represent a binary decision process, i.e., correct or incorrect performance. At every binary branching, the probability of the event must sum to 1.0. The values assigned to human activities are conditional probabilities. The preceding human actions affect the success or failure probabilities of succeeding actions. THERP<sup>[3]</sup> gives equations for conditional probabilities of success and failure on task "N", given success or failure on previous task "N-1", for different levels of dependence. For example, success probability of N-th task is given as follows in moderate dependent(MD) and high dependent (HD) levels.

$$\Pr(S_N / S_{N-1} / MD) = (1 + 6n)/7 \quad (1)$$

$$\Pr(S_N / S_{N-1} / HD) = (1 + n)/2 \quad (2)$$

Figure 3 is an example of HRA event tree with three actions A, B and C, where action C is a recovery action and brings back a total system to success state.

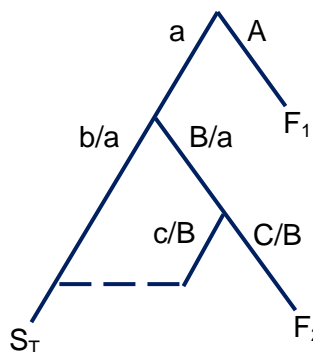


Fig.3 An example of HRA event tree.

### 3 Example of human performance

As an analysis example, the following case is taken up. Three operators are in a control room. They take a series of tasks as an operator group at an incident.

The mission is the isolation of ruptured tube in a steam generator of PWR type reactor. Three operators are a duty operator, sub-team leader and team leader. At each task, the initial action is made by a duty operator and it is supported by team leader and sub-team leader. If some action failure is identified, team leader or sub-team leader recovers the failed action. The dependency between duty operator and sub-team leader action is assumed as high dependent

(HD), and between other relations are assumed as moderate dependent (MD). The procedure is shown in Fig. 4., it is basically rule based behavior.

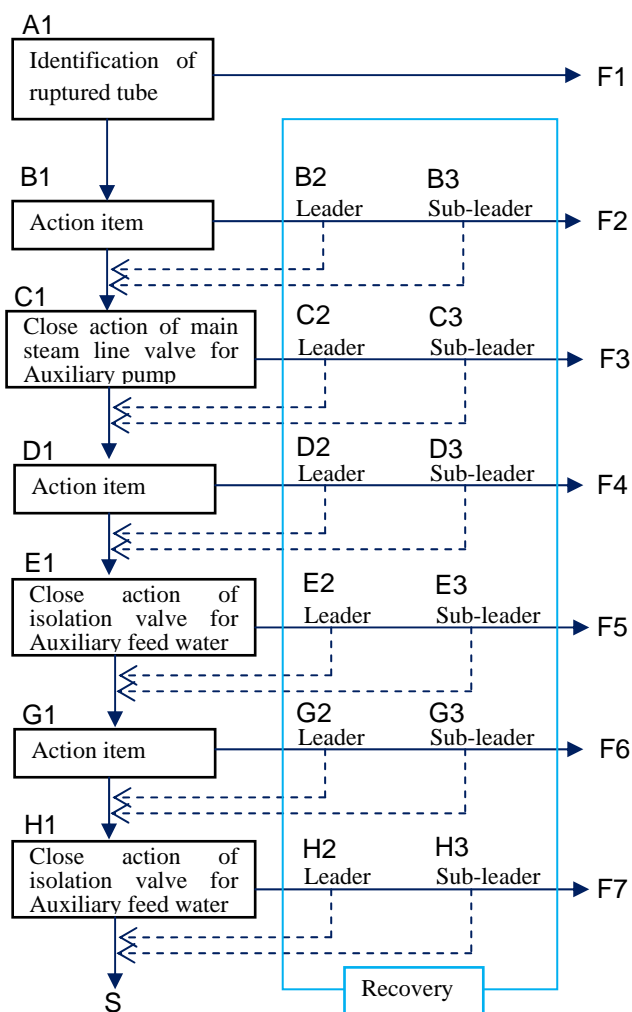


Fig.4 Procedure at steam generator tube rupture.

Above series of task is evaluated by THERP method with the consideration of dependencies between operator actions, under the high stress level (PSF=2). The total failure probability becomes as shown in Table 1. The result is also shown in Fig.6 by the graphical form.

Table 1 Failure probability obtained by THERP method

Median	Mean	95% Upper limit	5% Lower limit
2.2E-03	4.2E-03	1.4E-02	3.5E-04

#### 4 Modeling by the GO-FLOW

The correspondence by a team of three operators at the tube rupture incident is considered as one human

behavior in this analysis. This behavior is decomposed into elementary factors based on the Step Ladder model shown in Fig.2. The structure is easily expressed by a GO-FLOW<sup>[4]</sup> model as shown in Fig. 5. Operator number 1 is a signal generator and operator number 2 gives time duration. These are specific for the GO-FLOW analysis framework. Elementary factors as "Detection" etc. are modeled by operators 3, 10, 20, 31, 36, 38 and 40. Meanings of these operators are written by the side of operators in the GO-FLOW chart. Operator number 4 gives the fraction of skill based behavior in this total human behavior. Operators 7, 11, 14, 17, 21, 24, 27 and 32 give the fraction of rule based behavior for each elementary factors. With small values of these fractions, it becomes that human behavior mainly depend on knowledge behavior. Other operators are logical operators, i.e., "OR", "AND", "NOT" gates. With the aids of these logical operators, GO-FLOW can well express the structure of Ladder model shown in Fig. 2. Output of operator 40 is the final signal which represents the success probability of the procedure taken at steam generator tube rupture.

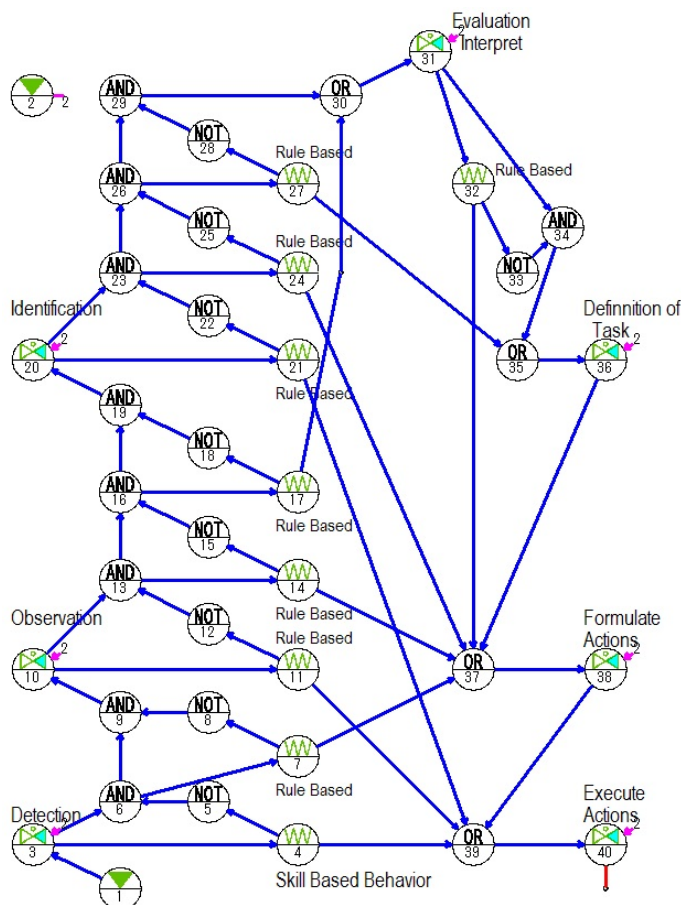


Fig.5 Human behavior modeled by the GO-FLOW.

## 5 Analysis results

Failure data are assigned as shown in Table 2. THERP defines there are at least one expert if more than 2 operators work together. So, the value of 0.3 is given to operator number 4 as the fraction of skill based behavior. The fraction of rule based behavior is given as 0.8, because the operator actions at tube rupture incident are basically rule based behavior.

**Table 2 Failure data used in the analysis**

Elementary factors	Base Values	PSF	Assigned values	EF
Detection	0.01	2	1.632E-3	3
Observation	0.001	2	1.450E-4	3
Identification	0.01	2	1.632E-2	3
Evaluation/Interpret	0.01	2	1.632E-2	3
Definition of Task	0.001	2	1.450E-4	3
Formulate Action	0.003	2	4.470E-4	3
Execute Actions	0.001	2	1.450E-4	3

Distributions of failure probabilities for elementary factors are assumed as log-normal distribution with error factor 3. Monte Carlo simulation with 3000 times trials are performed in the GO-FLOW analysis. Analysis result is shown in Fig. 6, together with the result obtained in chapter 3.

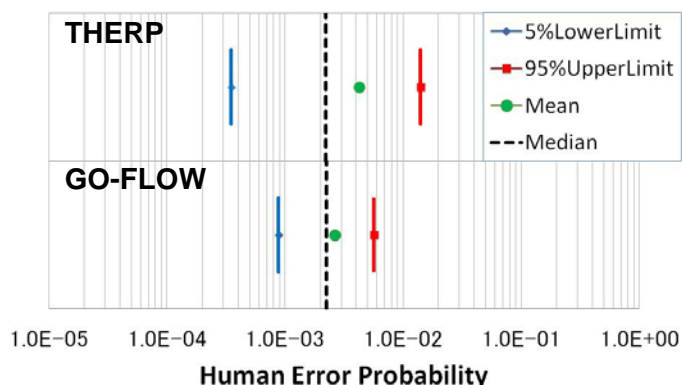


Fig.6 Analysis results by THERP and GO-FLOW.

Human error probability obtained by GO-FLOW well coincide with the result obtained by THERP method. Median values are almost same, but GO-FLOW gives narrow range for the error distribution. So, mean value obtained by THERP is larger than that by the GO-FLOW.

Now, above result is considered as base case, and re-evaluations are made for the case in which parameters have been changed in GO-FLOW model.

If an operator team becomes accustomed with emergency procedures with the extensive training, their response will be more skill based behavior. Let us examine the total behavior by increasing the fraction of skill based behavior in the GO-FLOW model.

If an accident condition is the first experience for operator team, their response will be all the more knowledge based behavior. In this case, fraction of rule based behavior is decreased to 0.1 in the GO-FLOW model, then we can check the tendency of operator response. Following parameter values are used for the evaluation.

**Table 3 Parameter conditions**

Type	No.4 operator	Operators 7, 11, 14, 17, 21, 24, 27, 32
Skill Based Behavior	0.9	0.8
Rule Based Behavior	0.3	0.8
Knowledge Based Behavior	0.3	0.1

Analysis results are shown in Fig.7. As expected, knowledge based behavior gives largest error probability, and skill based behavior gives good performance.

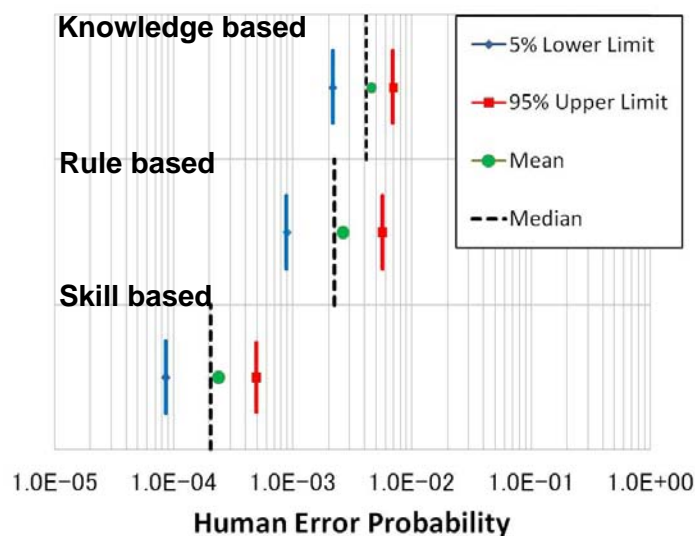


Fig.7 Human error probabilities for Knowledge, Rule, and Skill based behaviors.

## **6 Discussions and Conclusions**

Rasmussen's Step Ladder model can be well expressed in the GO-FLOW model. The quantitative analysis is easily performed, and results shows reasonable tendencies.

In the present study, parameter values are changed in the same for all the elementary factors appeared in the Ladder and GO-FLOW model. But, this GO-FLOW model can give the different values depend on the conditions surrounding operators. So, it provides quantitative tool to evaluate the effects of various conditions to human performance, for example, stress level, personal condition, physical condition, adequacy of equipment, and so on.

The selection of parameter values has still difficulty. But it will be possible to evaluate more easily for elementary factors than evaluate more complex human actions. Also, we can care the consistency between the parameters for elementary factors.

We would like to continue this study and apply this method to more realistic human activities.

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