Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2012

Quantitative Estimation for the Effectiveness of Automation

Seung Min Lee and Poong Hyun Seong*
Department of Nuclear and Quantum Engineering, KAIST, 373-1, Guseong-Dong, Yuseong-Gu, Daejeon, South Korea, 305-701

**Corresponding author: jewellee@kaist.ac.kr*

1. Introduction

In advanced MCR, various automation systems are applied to enhance the human performance and reduce the human errors in industrial fields. It is expected that automation provides greater efficiency, lower workload, and fewer human errors. However, these promises are not always fulfilled. As the new types of events related to application of the imperfect and complex automation are occurred, it is required to analyze the effects of automation system for the performance of human operators. Therefore, we suggest the quantitative estimation method to analyze the effectiveness of the automation systems according to Level of Automation (LOA) classification, which has been developed over 30 years. The estimation of the effectiveness of automation will be achieved by calculating the failure probability of human performance related to the cognitive activities.

2. Methods and Results

2.1 LOA and Information Process Flow

The research of LOA helps understand the function allocation between the automation systems and human operators. LOA hierarchy is developed according to the context of the use of expert systems to supplement human decision making. There are 5-level, 7-level, or 10-level taxonomies of LOA depending on their developer. Among them, we consider a 10-step LOA which provides applicability to a range of the human cognitive function. In 10-step LOAs, level 1 means 'with no assistance from the system' and level 10 means 'with no operator interaction'.

Based on classified level, we try to analyze the function allocation by considering human cognitive function, such as monitoring and detection, situation assessment, plan generation, plan selection, and implementation. And to describe the information flow passed by each cognitive activities of system or human, we need to construct a model that can express the human cognitive process. Modeling the information process flow helps us understanding the requested cognitive function according to the specific automation level.

Examples of information process flow are described in following Fig.1. Information process flow on level-1 automation expresses that human operator are to extract some information from instrumentation system, to conduct situation assessment to identify the current status of plant, to make a list of plan and select, and to implement it by oneself. Information process low model of level-6 automation, which means that 'the system generates a list of decision options, selects it and carries out if the human consent,' expresses that all human cognitive activities except for the implementing activity are supported by operator support systems and implementation is conducted by automation system after selecting an option of plans.

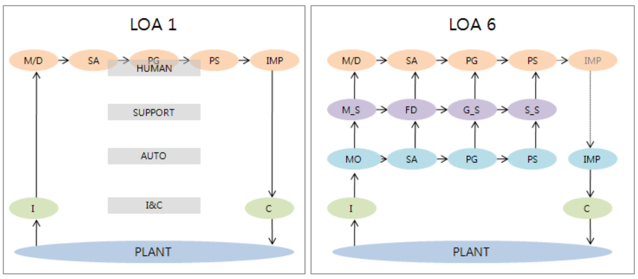

Fig. 1. Modeling the Information Process Flow for Automation level 1 and level 6

2.2 HRA Event Tree and Bayesian Networks

We try to analyze the effectiveness of the automation, thus, we need to calculate the failure probability. Estimations of Human performance for situation assessment are performed using Bayesian belief network (BBN) model. Moreover, to construct the BBN model to add some automation and operator support systems, several nodes should be added in the model. To define the relations among those added nodes in the modified BBN model, human reliability analysis (HRA) event trees are used. Fig.2 shows the event tree that describes the nodes to construct modified BBN model for level-6 automation. In Fig.2, 'Psa' indicates the probability that a human operator fails to conduct the correct situation assessment. P`sa indicates the probability that the fault diagnosis system fails to support safety assessment of human operator. Ppg means the failure probability that human can generate a list of plans, and P`pg means the failure probability of the plan generation function of the computerized procedure system to support the generating plans. Pps also means the failure probability that the human can select the right plan and P`ps means the failure probability of the plan selection function of the Computerized procedure system to support the selection of the right plan. Pimp indicates the probability that a human operator fails to implement a right action, and P`imp indicates the probability that an automatic implementation system fails to control the plant. In here, some values like human error probability can be referred by NUREG/CR-1278.

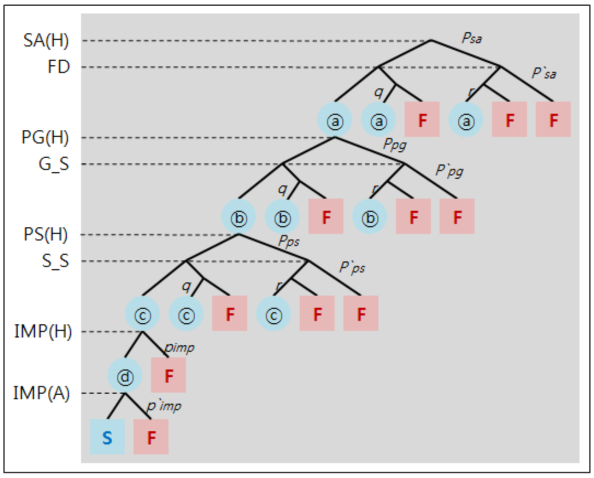

Fig. 2. HRA event trees for automation level-6

2.3Effectiveness of Automation for Human Performance

Performance failure probabilities calculated by Bayesian networks are applied to estimate the effectiveness of automation by using equation (1).

Effectiveness of Automation(x) [%]

$$= \left(1 - \frac{p[\mathrm{LOA}(x)]}{p[\mathrm{LOA}(1)]}\right) \times 100 \quad (x = 1 \cdots n\text{-}1) \qquad (1)$$

Effectiveness of automation(x) means how much the automation of level-x can affect to human performance comparing with no automation adopted. Here, p[LOA(x)] means the performance failure probability when automation level is x. p[LOA(1)] means the performance failure probability when automation level is 1, that is, the performance failure probability without automation system. Here, we cannot consider the level-10 automation(x=10), because human operator does not interact with any automation systems at all. According to eq.(1), we can quantitatively estimate the effects of automation as the increment of the automation level.

3. Conclusions

To measure the effectiveness of automation provides how much the automation could affect the enhancement of human operation performance. Therefore, it is expected that we can quantitatively understand the function allocation with respect to the level of automation. Moreover, we are supposed to estimate how much the human operator would be excluded from whole system when automation is failed.

By comparing the work done here with future work, we can finally analyze the function allocation not from the increment of the automation point of view, but from the increment of the required human cognitive activities point of view.

We try to provide more realistic and effective research about human-automation interaction that may solve the out of the loop unfamiliarity problem. Through the research, it is expected that an appropriate automation and operator support systems can be designed and suggested.

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