Evaluation of Communication Quality using Work Domain Analysis (WDA) Method in Nuclear Power Plant Control Rooms

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1. Introduction

Traditionally, normative and descriptive approaches had been used for simple task not much required cognitive interaction between systems and human. These approaches can cover all expected actions or tasks but if there are any unexpected accidents, human operators have had nothing to do against the accidents [1].

Among several approaches such as normative, descriptive and formative to design or evaluate any human-involved systems, a formative approach is considered to be the most proper approach for complex and complicated systems like Nuclear Power Plants (NPPs).

As the Work Domain Analysis (WDA) is a representative method of the formative approach, it can be applied to complex and complicated domain such as cognitive interaction between systems and human, rather than physical [1]. In other words, actions required cognitive interaction such as communication, problem solving and decision making between human operators working in NPPs can be analyzed by using the Abstraction Decomposition Space (ADS) that is a tool of the WDA.

2. Wok Domain Analysis

The main aim of WDA is to set up the constraints related to the purposive and physical context where human operators work.

2.1. Abstraction Decomposition Space

As shown in figure 1, the ADS is a two dimensional space representing an Abstraction Hierarchy (AH) and a Decomposition Hierarchy (DH) like a matrix [1,2].

Each level of abstraction combined with means-ends relations. These relations can be considered in terms of a how-what-why triad. For instance, Generalized Function A specifies what is under consideration. Physical Function B and C represent the means or how Generalized Function A is achieved. Finally, Abstraction Function D specifies the ends or why Generalized Function A is present in the work system [2].

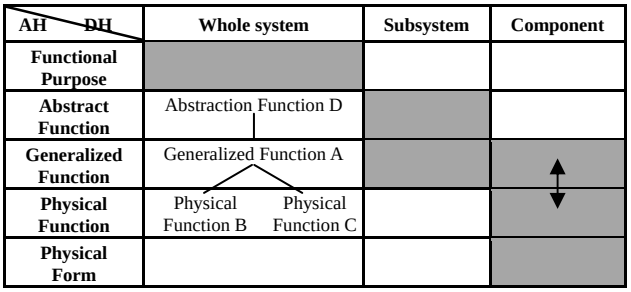

Fig 1. Abstraction Decomposition Space

2.2. Diagonalization of cells in ADS

Cells in ADS are diagonalized from Functional Purpose at Whole system cell to Physical Form at Component cell as shown in figure 1.

Rasmussen collected a set of protocol of human operators engaged in problem solving behavior with various systems. He mapped their verbal reports and actions against ADS models of the diagonal from the Physical Form at Component Cell to the Functional Purpose at Whole System [3].

Using this concept, it is thought that it is possible to know or anticipate the way of communication using the result of the ADS inversely.

3. Interfacing System Loss Of Coolant Accident Scenario

The scenario provided to human operators is the Interfacing System Loss Of Coolant Accident Scenario (ISLOCA) from the high pressure Reactor Coolant System to the low pressure Residual Heat Removal (RHR) System. [4].

4. WDA of NPPs based on the ISLOCA scenario

WDA of NPPs based on the scenario is performed and communication contents are extracted from mapping data between Physical Function and Generalized Function in ADS. The reason why Physical function and Generalized Function are only analyzed is that it is assumed that communication between human operators is distributed in Physical Function and Generalized Function at Component level.

4.1. Mapping Generalized Functions to Physical Functions

Figure 2 shows how Physical Functions, as the role of implemented by physical objects in the system, map into Generalized Functions under the scenario.

4.2. Communication Contents extracted from ADS

Double edged arrow connecting Generalized Function and Physical Function at Component level in fugure.1 is analyzed in previous section and mapping data is derived. Using this data and the characteristic of the ADS, the diagonalization of cell in ADS, explained in section 2.1, it is considered that mapping data has to contain appropriate communication contents. Therefore, human operators working in NPPs under the scenario should make a conversation using appropriate communication contents as many as possible to solve the problem and make a decision.

5. Field simulation in the NPP Control Room under the ISLOCA scenario

In order to apply extracted communication contents, the field simulation with nine crews working in NPPs was implemented. In other words, result should show the correlation between the number of communication contents mentioned by human operators and the ability of the problem solving.

6. Result

Table 1 show the simulation result that only two teams solved the problem with high proportion and more the number of proper communication contents compared to failed teams. However, proportion of communication contents is far more objective method to evaluate communication quality since the total number of communication contents in some failed teams are three times compared to the other teams.

	T1	T2	T3	T4	T5	T6	T7	T8	T9
Problem Solving	Failure	Failure	Failure	Failure	Failure	Failure	Failure	Success	Success
A. the total number of communication contents	110	265	220	281	307	85	192	170	147
B. the number of communication contents identified in mapping data	8	7	10	12	10	7	13	19	17
Proportion (Ratio A to B)	0.0723	0.0264	0.0455	0.0427	0.0326	0.0826	0.0677	0.1112	0.1156

Table Ⅰ: The simulation results of the team communications

7. Conclusion

WDA of a NPP based on ISLOCA scenario was performed. From that analysis, communication contents were extracted. In order to apply extracted communication contents to, the simulation with human operators was implemented. As shown in the results, table 1, the teams that had far more communication contents and high proportion of them got successful results. Therefore, operators need to follow the communication contents identified in mapping data when unanticipated accidents happen. Moreover, the mapping data as shown in figure 2 from WDA could be the criteria in evaluating communication quality in complex systems, in this case NPPs

REFERENCES

[1] Kim J. Vicente. Cognitive work analysis: Towards safe, productive, and healthy computer-based work. Erlbaum: Mahwah, NJ 1999.
[2] Neelam Naikar, Robyn Hopcroft, Anna Moylan. Work Domain Analysis: Theoretical Concepts and Methodology. Technical Report DSTO-TR-1665, Victoria, Australia. Defense Science and Technology Organisation 2005
[3] Rassmussen, J. The role of hierarchical knowledge representation in decision making and system management. IEEE Transactions on Systems, Man and Cybernetics 1985 Mar, SMC-1, 234-243
[4] Nuclear Regulatory Commission. An empirical investigation of operator performance in cognitively demanding simulated emergencies. NUREG/CR-6208, Washington, DC: USNRC; 1994

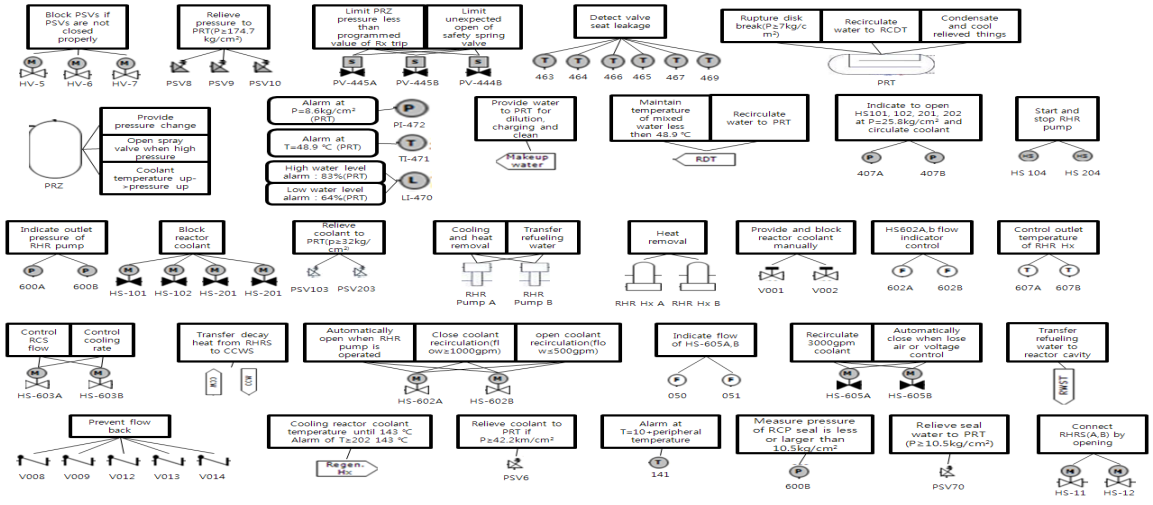

Fig 2. Mapping Generalized Functions into Physical function at Component Level