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Extended Sequence Diagram for Human-System Interaction

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1. Introduction

Unified Modeling Language (UML) is a modeling language in the field of object-oriented software engineering. The sequence diagram is a kind of interaction diagram that shows how processes operate with one another and in what order [1,2]. It is a construct of a message sequence chart. It depicts the objects and classes involved in the scenario and the sequence of messages exchanged between the objects needed to carry out the functionality of the scenario.

This paper proposes the Extended Sequence Diagram (ESD), which is capable of depicting human-system interaction for nuclear power plants, as well as cognitive process of operators analysis. In the conventional sequence diagram, there is a limit to only identify the activities of human and systems interactions. The ESD is extended to describe operators' cognitive process in more detail. The ESD is expected to be used as a task analysis method for describing human-system interaction. The ESD can also present key steps causing abnormal operations or failures and diverse human errors based on cognitive condition.

2. Extended Sequence Diagram (ESD) for Human-System Interaction

The ESD consists of two parts: Human and System.

2.1 HUMAN: Cognitive Process

Human part describes the human cognitive process for decision making. It consists of four stages: perception, diagnosis, choice, and execution. Human part is developed, based on [3] as shown in Fig. 1.

In the perception stage, operators relate raw data to the different physical and logical variables of the plant. This stage assigns a certain cognitive meaning to the signal coming from the environments. In the diagnosis, operators identify the state of the plant and try to find the location and the cause of anomalies or faults. In the choice stage, a procedure to be followed is determined according to the diagnosed result. Finally, in the execution stage, operators commit actions according to the selected procedure.

Through the human part, potential causes of human errors such as the environmental components affected such sensing, perception, diagnosis and choice process can be diversely classified with aspects of human own feature as well as Man-Machine Interface (MMI). For instance, it may indicate wrong alarm setting, difficult perception problem for sense process, the noise, inadequate lighting, poor workplace, unclear message for perception process and insufficient experience, excessive reference/document, ambiguous responsibility for diagnosis process and control hardness or complexity for choice process.

2.2 SYSTEM: Human-System Interaction and System Process

System part is basically same as the conventional sequence diagram. For a digital control room, the system part may consist of MMI, instrumentation and control system, sensors, and actuators. Use case diagram can be used to represent MMI elements. This paper identifies the MMI elements for the operation of safety-related system by using use case diagram as shown in Fig. 2. Operators can use information FPD, ESCM (ESF-CCS Soft Control Module) and Channel Confirm Switch to operate safety related equipment.

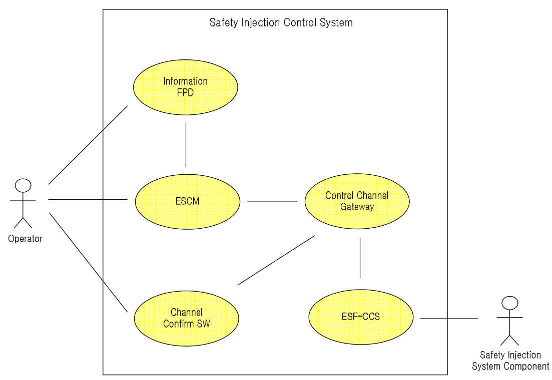

Fig. 2. Use Cases Diagram of Safety Injection Control System

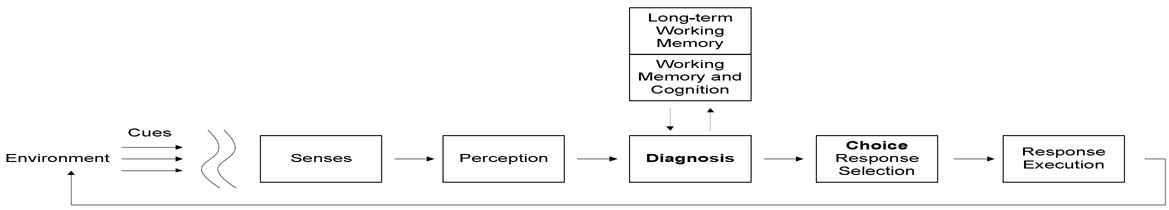

Fig. 1. Information processing model of decision making [3]

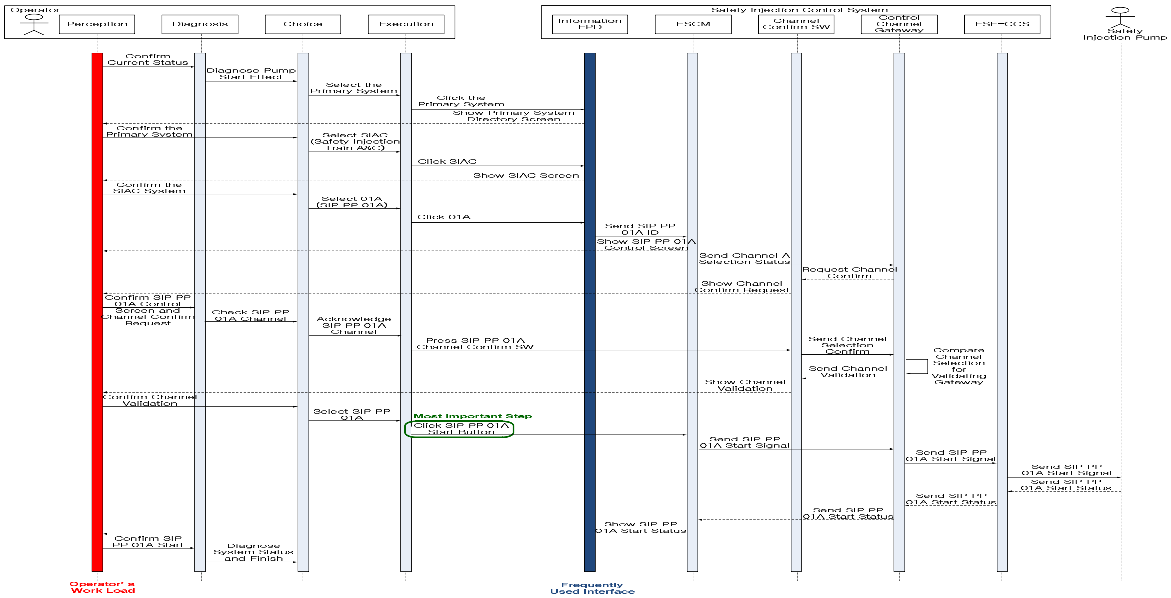

Fig. 3. Extended Sequence Diagram of Safety Injection Pump Start

3. Example: Control of Safety Injection System

This section introduces an example of modeling human system interaction by using the ESD. Fig.3 shows the interactions between operator and systems for starting the safety injection pump. Human part, i.e., perception, diagnosis, choice, and execution, initiates the operation. The ESD illustrates dynamic interaction between operator and control system module in a time sequence. In order to operate safety injection pump, operator should manipulate interface modules many times.

The diagram also shows that perception is the most frequent behavior of operator. It means that the work load of perception is heavier than other steps for this task. Among safety injection control system interface module, information FPD is used the most frequently by operator. The most critical step is starting safety pump. It is the only execution interaction by operator, not roll-backed and crucial step in the system simultaneously. The developed digital interface system may reduce switches (and controllers) by using computer interfaces, but it seems that some re-design for effective manipulation is needed in this point (e.g. message box or confirm from supervisor)

Likewise, the ESD shows many relevant interactions to start safety pump. Furthermore, this method can be used to analyze concretely the potential error and its causes in each step using status diagram.

4. Conclusions

Control systems comprise a large proportion of operating NPPs. Digital control systems contribute to efficient operation and reduce the workforce, but the possibility of abnormal operation and human error is still remained due to its complexity and hardness to define. To guarantee the safe operation, it is critical issue to analyze the human errors.

In this regards, this paper have introduced ESD for analyzing the human-system interactions. The potential advantages of this approach are as the following:

- ESD clearly shows interactions of each work component, and these interactions can be classified by frequency or importance. Based on sequence diagram analysis, interface designer can modify original sequence.
- ESD can be used to identify the cognitive errors based on human own features and enable to create the optimistic environment which prevents errors.
- ESD can be used to identify the impact of system failure on human operators and the critical delivery point requiring operators to carry out direct operation to the control system.
- ESD can be used to identify task-loaded process and enable to assign balanced allocation of workforce.

The ESD is expected to offer more developed way to visualize a system's architectural blueprints including elements such as activities, actors, business processes, logical components and the following diverse potential errors. In addition, this analysis will be applied to other interfaces between human and system for safety.

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