

Study in Cooperative Operation Strategy using Process Mining in NPPS

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1. Introduction

In the overall industry, the Autonomous driving using artificial intelligence (AI), the core of the fourth industrial revolution, is receiving a lot of attention and the level of automation is growing. Since the performance of automation achieve similar with human being, the research of application of automation system to high risk industry such as nuclear power plant (NPP) is performed [1-5]. Automation system can make accurate and faster decision than human. Therefore, it can be useful in situation where a number of signal and alarms are generated at same time, such as abnormal condition of NPP.

However, the complete automation driving without intervention of operator can cause responsibility problem when the accident occurs. For these reason in this study focused on automation system to support operator in abnormal condition. In abnormal condition of NPP, a lot of signals and alarms occurred at same time. It can confuse operators and makes them difficult to rapid and accurate decision. In this case, the cooperative automation system, can support operator's decision and it can contribute to increasing of safety.

Automation system can be divided into 1) Rule-based automation and 2) Knowledge-based automation. Rule-based automation can make judgement based on rule which noted at operating plane and suggest necessary information or actions to operator. On the other hand, knowledge-based automation can suggest highly-related information or actions to operator based on past operation log. The knowledge-based automation system has an advantage that it can suggest necessary information and action, even which not noted in operation plan. In this study, focused on knowledge-based automation and perform the fundamental study to ascertain the possibility to build base of application of knowledge-based automation to NPP.

To simulate application of knowledge-based cooperative automation system in abnormal condition of NPP, generated virtual abnormal condition operation log. Performed process mining using virtual data to found heuristics. Commercial process mining tool, DISCO and ProM, were used.

2. Methods and Results

Knowledge-based cooperative automation system make decision based on, real-time monitoring data and past-operation log learning. Operation log learning can found associated monitoring variables with operator

actions which not stated in operation plane. For these reason, it can suggest necessary information and action which not noted in operation plane. The figure 1 shows schematic diagram of knowledge based automation system.

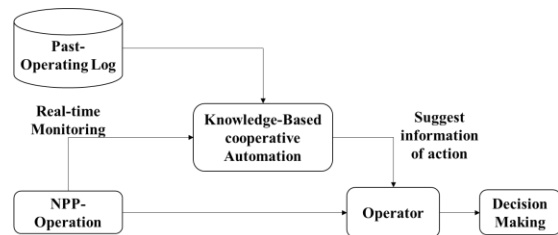


Figure 1. Schematic diagram of knowledge-based automation system

The knowledge-based cooperative automation system, compares real-time data with past-operating logs and suggest information and actions, which appear many times where past similar conditions. As mentioned in above section, due to final decision from automation system can make problem, thus final decision should have make by operator, considering information suggested by automation system.

2.1 Simulated operation log data

Abnormal operation plan (AOP) describes operator action as major contents. To make decision, several monitoring variables, which not noted in operation plan, must be checked. In this study, the actual operator's actions, which not mentioned in AOP, were considered as heuristics. To confirm these heuristics, actual AOP and operation log are required. However, getting actual AOP and operation log was very difficult. To solve these difficulty, generated virtual AOP and operation logs and performed process mining.

The virtual operation logs were generated based on steam-generator tube rupture (SGTR) condition. The procedure for generating virtual data was as follows;

- 1) Creating a criteria scenario.
- 2) Set normal distribution to each operator action and monitoring variable
- 3) To simulate mistakes or immature operator action, make random noise

Following figure shows schematic diagram of virtual operation log. A-1 to A-6 which marked as circle(o) are represent operator action. M-1 to M4 which marked as triangle represent monitoring variable which not noted in AOP. Each operator actions and monitoring variables had distribution based on criteria scenario. The noises,

which simulating mistake of operator or immature operator's actions, were marked as cross(x).

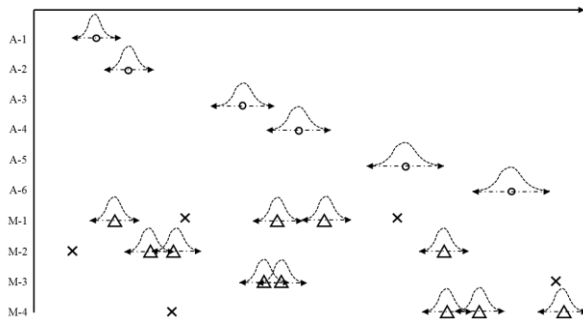


Figure 2. Simulated operation log data generation

2.2 Analysis of heuristics

Performed heuristics analysis, which not mentioned at AOP. Commercial process mining tool, DISCO [6] and ProM [7], were used. The simulated data used for analysis were consist of 15 operator actions and 7 monitoring variables. The total number of data case was 20. The 14 cases were only simulating distribution. The other 6 cases were simulating distribution and noise.

2.3 Analysis result using process mining tools

2.3.1 Analysis result using DISCO

Using DISCO program, analyzed the relationship between each operator actions and monitoring variable and confirm statistical data. figure 3 shows relationship between operator actions and monitoring variables. The dark color in figure 3 means high frequency. The figure 4 shows amount of time taken by each actions.

From figure 3, confirm relationship between operator actions and monitoring variables. The operator actions and monitoring variable, which connected with each other, had context. It means that to make operator actions, the information, which connected with operator actions, is needed. Therefore, provide information, deemed necessary for decision making, to operator can be useful and good for safety aspect.

Through figure 4, checked where needed a lot of information in short time. In this case, operator can be confused and have difficult to make accurate and rapid decision. At these point, it is deemed necessary to apply automation system to support operator.

2.3.2 Analysis result using ProM

ProM program provide several process mining methods, such as Heuristic, Alpha and Fuzzy miner, and dotted chart which can show the start and end time of each actions.

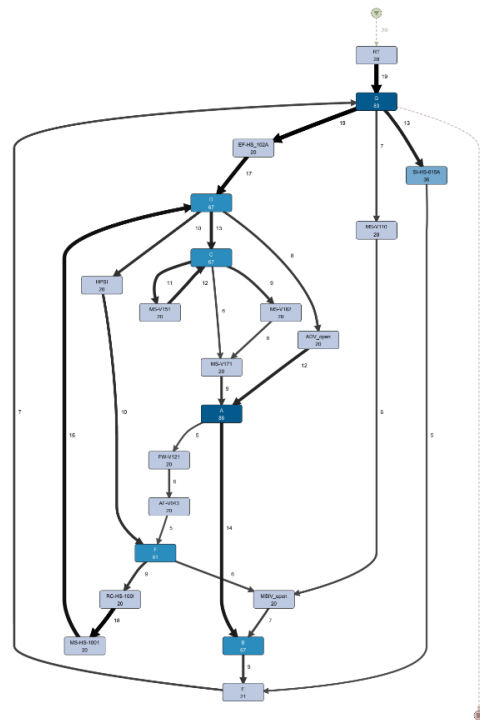


Figure 3. Process mining result (Frequency)

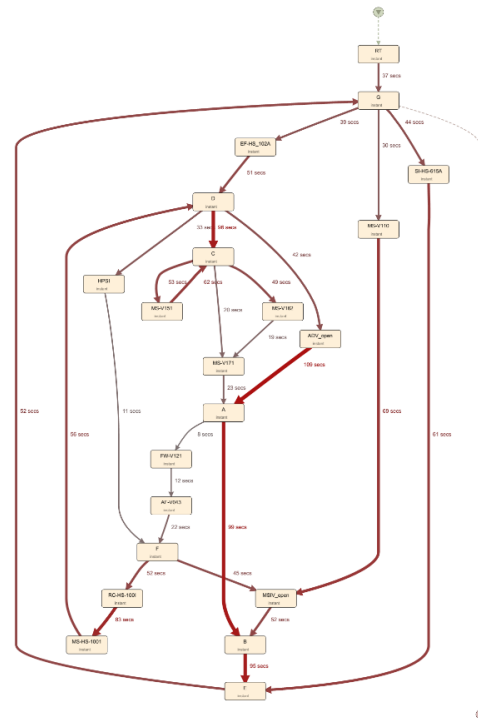


Figure 4. Process mining result (Taken time)

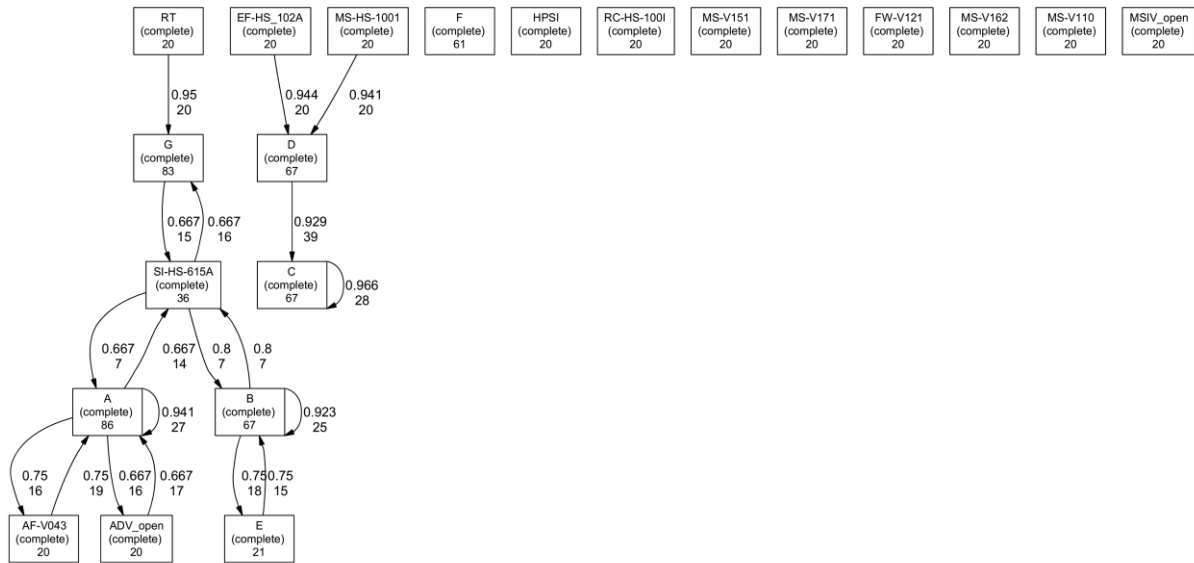


Figure 5. the analysis result of virtual SGTR log data using heuristics mining method. (disconnected)

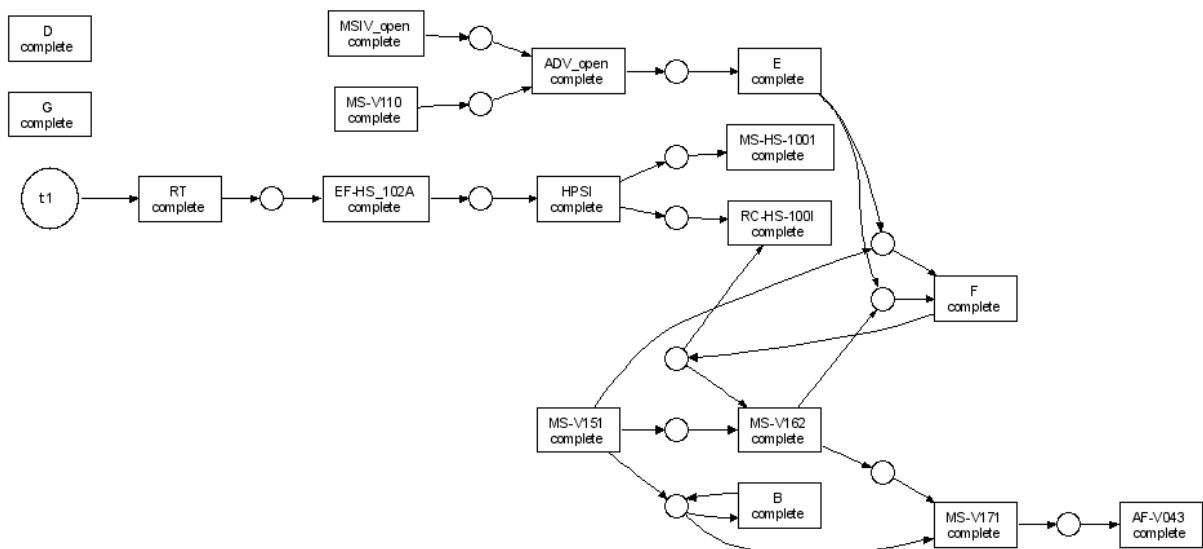


Figure 6. the analysis result of virtual SGTR log data using Alpha mining method.

Figure 5 and 7 show the analysis result of virtual SGTR log data using heuristics, alpha and fuzzy mining respectively. Through these several process mining methods can confirm relationship between operator actions and monitoring variables. For example, the left connection, which shown in figure 5, showed relationship between the events which name RT and G. The event, which name RT, was operator action mentioned in operating plan and the event named G was action which not noted in operation plan. In these case, providing information which shown these relationships can be ensure safety by enabling accurate and rapid judgement of operator.

Figure 7 shows the analysis result of virtual SGTR log data using Fuzzy mining method. Fuzzy mining

method can group events in clusters differently than other analytics methods. The green octagons, which presented in figure 7, were cluster of events. For example, the cluster where on the top in figure 7 consist of three events. Figure 8 shows the configuration of the event cluster.

Fuzzy mining methods also can confirm the context of each event as similar with other process mining methods. Through this appropriate information can be provided at right point.

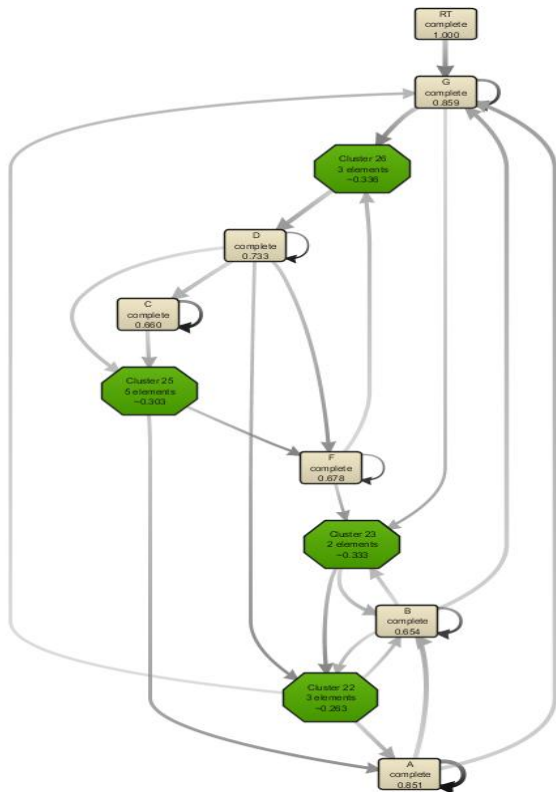


Figure 7. the analysis result of virtual SGTR log data using Fuzzy mining method

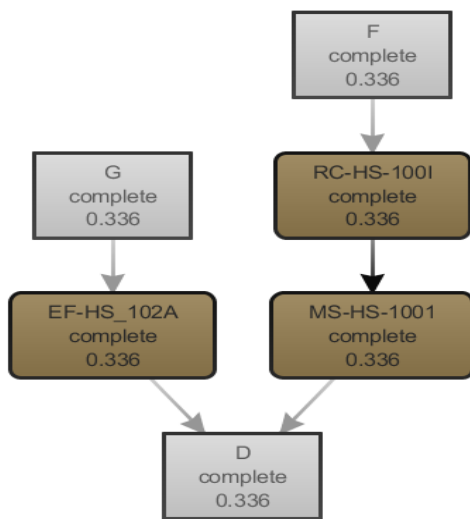


Figure 8. the example of configuration of event cluster

3. Conclusions

In this study, confirm the possibility of application of knowledge-based automation to support operator in NPP using virtual operation log data. confirmed two major following subject;

- 1) Identifying the timing of intervention of automation system by check the time step between each event.
- 2) suggestion of related actions by learning from past-operation log and real-time monitoring.

It can make appropriate intervention of automation when a lot of signals and alarms were occurred at same time. Also automation system can provide operator with information, which expected to be needed, and help operator to make accurate and rapid decision.

It is expected that knowledge-based automation to support operator can contribute to increasing safety aspect of NPP through these advantage.

Acknowledgement

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