Description Method and Failure Ontology for Utilizing Maintenance Logs with FMEA in Failure Cause Inference of Manufacturing Systems

To maintain and enhance the efficiency of manufacturing systems, investigating the causes of failures is crucial. However, this task is challenging for non-experts without knowledge or experience. Therefore, various support methods utilizing past failure analyses conducted by experts have been considered. Until now, failure cause inference using existing Failure Mode and Effect Analysis (FMEA) has been widely conducted. However, the inference results from FMEA have shown low consistency with the candidates of causes enumerated by experts for the same failure. This is because during maintenance, experts focus on more detailed aspects than those covered by FMEA, suggesting the necessity of utilizing maintenance logs, which are actual records of maintenance activities, for failure cause inference. Maintenance logs contain more detailed information than FMEA, but they lack uniformity in terms of description quantity and format. Additionally, while FMEA analyzes the structure of the target system hierarchically, resulting in a clear hierarchy of described failures, maintenance logs lack consistency in terms of which hierarchy to focus on when describing failures. Due to these reasons, current maintenance logs make it difficult to extract the necessary causal relationships for failure cause inference, making reuse challenging.
In this study, we propose a method of describing maintenance logs in a reusable format and an ontology based on the knowledge of experts to organize the described failures. By combining maintenance logs with FMEA, we aim to improve the quality of inferring the causes of failures in manufacturing systems.
To use in conjunction with FMEA, we propose a method to describe maintenance logs by extending FMEA. By describing causal relationships between failures and relationships between failures and functions, each description in FMEA and maintenance logs is represented as an instance of “FMEA+Maintenance logs ontology". Additionally, within the domain ontology representing concepts in manufacturing systems, we construct a “Failure ontology” that represents the knowledge of experts regarding failures. Failures are represented using the “Condition” class to express the conditions to be achieved, the “fail_Condition” to associate failures with the conditions they compromise, and the “happen_in_Action” to associate failures with the processes in which they occur.
To validate the proposed method, we compared inference using FMEA and maintenance logs, employing our approaches, with inference solely based on FMEA, as done in the former study [1]. We evaluated the inference outputs using two metrics: precision and recall, by comparing them with the failure cause candidates enumerated by experts for the same failures. As a result, employing the proposed method, inference augmented with maintenance logs achieved a precision of 0.79 and a recall of 0.47, respectively 7.5 times and 4.5 times higher than inference based solely on FMEA. This suggests that the description method for maintenance logs and the failure ontology are effective in improving the quality of failure cause inference. However, within the outputs, there were instances of word combinations such as "stopper unreadable" that are not feasible in manufacturing systems. This indicates the inadequacy of the domain ontology and suggests the need for further enhancement in the future.

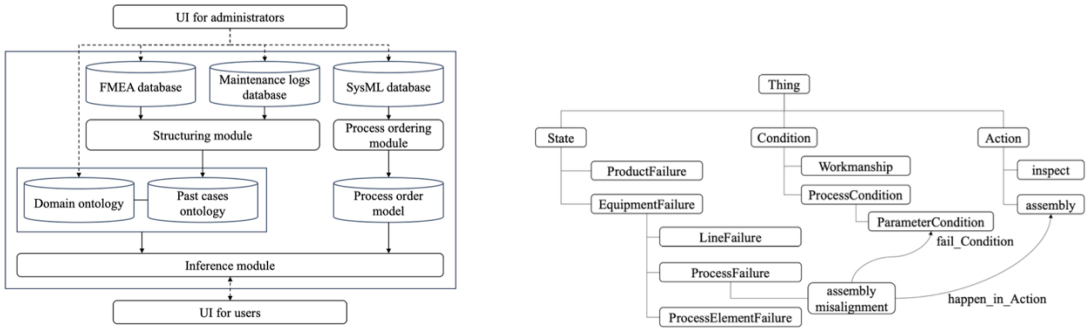

Fig1 Left: Overview of the proposed framework, Right: The failure ontology

Keywords: Manufacturing system, failure cause identification, FMEA, Maintenance log, Ontology

References

[1] Sho Okazaki, Shouhei Shirafuji, Toshinori Yasui, and Jun Ota:“A Framework to Support Failure Cause Identification in Manufacturing Systems through Generalization of Past FMEAs,” *2023 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, pp.858-865, 2023