Development of Virtual Reality System for Identification of Specific Expert Skills in Refinery Inspection Task with Explainable AI

Refinery inspection is the fundamental meintenace task that expert inspectors move around the vast reifinery area and try to find any defects or sign of it. Since even the slight defects will cause serious accidents in later, it owes a critical role for safety management of the refinery. Therefore, to achive the more stable and safety refinery operation, it is important to investigate how expert inspectors can find such a small defects in a vast refinery area, and how different their inspection behavior from novice's one [1], namely, identification of the expert inspection skill is a critical aspects for refinery safety management.

From above background, in a previous work, a Virtual Realiry (VR) system is used to collect data of both experts and novices inspectors, and clarify the differences between them [2]. As a results, they revealed that expert inspectors tend to set their head in more effective position for finding the defects (e.g., lowerer position for leakage inspection). However, the problem of these previous studies in the lack of temporal and spatial specificity of the expert's skill. Namely, since most of existing studies compared the mean value of the entire inspection process by appling statistical analysis methods, i.e., it is unclear "when" and "where" the expert skill was observed in the entire working processes, and this makes difficult to teach the specific skills for novices.

Therefore, to solve the above issue, in this study, we proposed new analytical framework of the refinery inspection skill which based on the Explainable-AI (XAI) technique. XAI is a kind of analytical technique in the mechine learning filed which tries to visualize and explain the reason for generating the specific out such as prediction or classification. Since it can identify the most important part among wntire time series input data, we adopt this framework for solving lack of specificity problem.

In our proposed method, Covolutional Neural Network (CNN) with Class Activation Map (CAM)[3] are used for classification of the data of inspection behavior into two labels (experts vs novices), and visualize the reason for it. Figure 1 shows the example of obtained results from our analysis. The graph shows the head positions of the participants, and the colors indicate their contribution to the prediction results. As shown in this figure, through the visualization of the CAM architecture, we can identify the specific expert skills such as "the expert inspector tend to gaze from lower angle than novices in this equipment". Hence, by comparing one's own actions with those of skilled operators while inspecting similar objects, we believe that the system can encourage novice workers to make specific improvement plans. In the future, we will develop the educational training system based on this results.

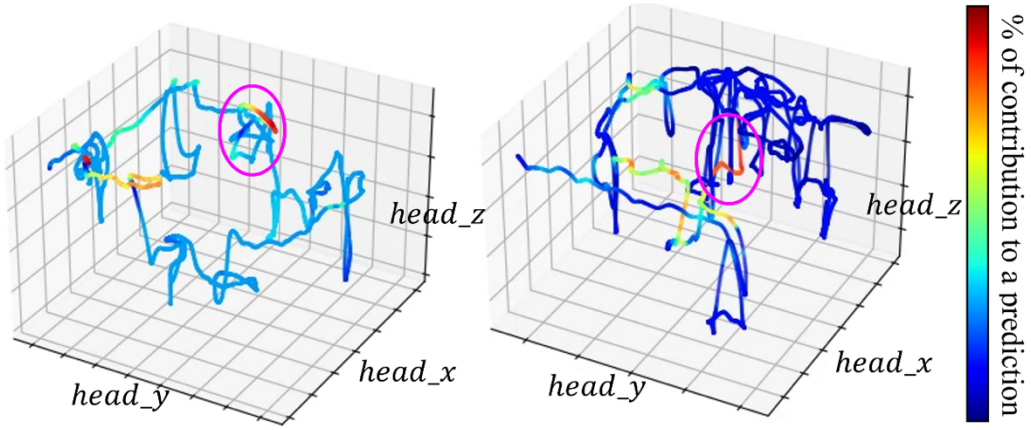

Fig 1. Examples of visualization of the basis for skill discrimination by CAM.

Keywords: Expert Skills, VR, Machine Learning, XAI, CAM

References

[1] Accenture, "FY 2019 Project for Investigation of Security Measures for Oil and Gas Supply, etc. Basic Investigation Report for the Purpose of Maintaining and Improving Security Capabilities.", https://www.meti.go.jp/meti_lib/report/H30FY/000284.pdf, 2019.

[2] R. Takamido et al., "Evaluation of expert skills in refinery patrol inspection: visual attention and head positioning behavior," Heliyon, vol. 8, no. 12, p. e12117, Dec. 2022.

[3] B. Zhou, A. Khosla, A. Lapedriza, A. Oliva, and A. Torralba,"Learning deep features for discriminative localization," in Proceedings of the IEEE conference on computer vision and pattern recognition, 2016, pp. 2921–2929.