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Preliminary Design of a Dataset Construction System for AI-based Analog Gauge Reading in Nuclear Facility

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1. Introduction

Analog gauges remain widely employed in nuclear facilities to measure key operational variables such as pressure, flow rate, and temperature. Regular patrols and monitoring are essential for ensuring both safety and operational efficiency. At present, most monitoring tasks are manually performed by human operators. With the advancement of robotic technologies, however, automation of these tasks is expected to become feasible. Accordingly, the demand for artificial intelligence (AI)-based automatic gauge reading systems deployable on robotic platforms has been increasing.

Recent studies have investigated AI-based gauge reading methods in several countries [1], [2]. In Korea, the Korea Atomic Energy Research Institute (KAERI) has conducted gauge reading studies based on traditional computer vision techniques and has also carried out separate research utilizing multimodal large language models (MLLMs) with Chain-of-Thought (CoT) prompting [3], [4]. An example of analog gauges and a quadruped robot used for automatic reading is shown in Fig. 1.

Fig. 1. Example of analog gauges on pipelines and a quadruped robot for automatic reading in a nuclear facility.

Achieving reliable AI performance requires large-scale datasets with accurate labeling. Nevertheless, collecting extensive real-world gauge data from nuclear facilities is limited by physical constraints and safety considerations. To address these challenges, this study proposes a dataset construction method that enables automatic labeling by integrating real gauge panels with 3D-printed external frames and pointers, coupled with a motor control system. The proposed dataset further allows efficient performance comparison of AI-based gauge reading models.

2. Design of Dataset Construction System for Analog Gauge Images

One of the primary obstacles in developing gauge recognition algorithms is the lack of large-scale training data. In particular, collecting a large number of images with diverse values from the same gauge panel is difficult, manual labeling of the collected images inevitably introduces human error, and environmental variations such as illumination and viewing angles are challenging to replicate in real-world settings.

To overcome these limitations, a dataset construction system was designed to generate analog gauge images with arbitrary values while automatically assigning ground truth (GT) labels. The proposed system consists of four main components: a gauge frame, a panel replacement module, a motor-driven mechanism, and an imaging and environmental control unit. The system architecture is shown in Fig. 2.

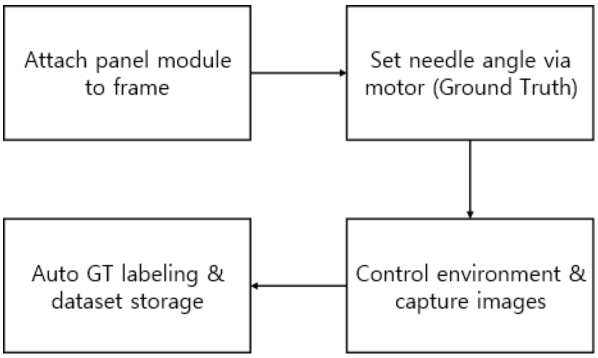

Fig. 2. Overall pipeline of the dataset construction system for analog gauge images.

- Gauge Frame: The external frame, gauge needle, and motor coupling brackets were designed using CAD software and fabricated via 3D printing. This configuration replicates the physical appearance and functionality of real gauges, while allowing easy integration with various interchangeable panels.

- Panel Replacement Module: Gauge panels with printed scales were extracted from commercial gauges and mounted as replaceable components. This enables replication of diverse gauge environments with different units (e.g., psi, bar, °C) and scale configurations.

- Motor-Driven Mechanism: The needle was rotated to arbitrary angles with high precision using a motor control unit. Each motor command was directly mapped to a corresponding gauge value, ensuring that captured images were automatically assigned accurate GT labels. This process eliminates labeling uncertainty and enables the rapid generation of large-scale datasets. An example of the fabricated gauge with motor attachment is presented in Fig. 3.

Fig. 3. Example image of the fabricated gauge with motor attachment.

- Imaging and Environmental Control Unit: Cameras were installed at multiple positions to capture frontal as well as oblique views of the gauge. In addition, the lighting intensity and direction were varied to simulate environmental changes typically encountered in nuclear facilities.

The dataset generated by this system compensates for the difficulty of directly acquiring real-world data in nuclear facilities. Furthermore, it incorporates diverse environmental conditions, including illumination and viewpoint variations. The automated labeling capability also enables rapid construction of training and test datasets, which can be immediately applied to model development and performance evaluation.

3. Conclusions

This study proposed a dataset construction system for analog gauges that enables automatic labeling to support AI-based gauge reading research in nuclear facilities. By combining real gauge panels with 3D-printed external frames and a motor-driven mechanism, the system can reproduce arbitrary gauge values and automatically generate GT labels. Furthermore, by varying camera positions and lighting conditions, the system reflects visual variations similar to those encountered in actual operational environments.

The proposed system addresses the challenges of collecting real-world data directly from nuclear facilities and facilitates the acquisition of large-scale datasets for AI training and evaluation. In particular, the constructed dataset provides a foundation for model performance comparison and algorithm improvement.

Future work will focus on applying the dataset to AI models to validate reading performance and evaluating the feasibility of integration with robotic patrol systems for deployment in real environments.

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REFERENCES

[1] Ben Howells, James Charles, and Roberto Cipolla, Real-time analogue gauge transcription on mobile phone, Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2021.
[2] Leon-Alcazar, Juan, et al., Learning to read analog gauges from synthetic data, Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2024.
[3] Yongho Cho, Wonseo Lee, et al., Preliminary study on image processing methods for automatic analog gauge reading of a mobile robot, Institute of Control, Robotics, and Systems, 2024
[4] Yongho Cho, Wonseo Lee, et al., Preliminary Design of Chain of Thought with Multimodal Large Language Model for Analog Gauge Reading in Robotic Surveillance, Ubiquitous Robots, 2025