Technology Introduction

Development of a Highly Versatile AI Visual Inspection Tool

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1 Introduction

Production lines include processes in which the appearance of the product is visually inspected by humans. These processes are required to achieve inspection worker savings and improve quality assurance by preventing human errors in inspection tasks. In recent years, visual inspection automation has shifted from rule-based methods (a technique that makes judgments based on specific rules and conditions set by humans) to artificial intelligence (AI) technologies. KYB has used AI to develop inspection technologies that can withstand individual product variations and changes in the inspection environment. The company has also developed and used MLOps[Note 1)], a mechanism that efficiently maintains and manages the accuracy of AI models[1)]. However, these development efforts only produced inspection systems for specific targets involving highly skilled personnel. In fact, it was difficult for such systems to respond in a timely manner to the various requirements for automating visual inspections on production lines. To address this challenge, we have developed a highly versatile visual inspection tool that allows factory personnel to create inspection systems tailored to specific targets.

This report presents the system developed for our production lines and its applications.

Note 1) A program facilitating the smooth implementation of AI. This term combines AI and machine learning (ML) with DevOps, a continuous development methodology in the software field.

2 Development Overview

2.1 Flexible System Construction Tailored to Inspection Targets

We designed individual functions of inspection software as independent modules and implemented them using Docker[Note 2) Note 3)] to build an inspection system that can be flexibly tailored to the inspection target. Using Docker allows applications and their execution environments to be packaged as containers, eliminating the need for repeated environment setup from development to operation. This can shorten the development period. Furthermore, each module operates in an independent environment, eliminating mutual dependencies and facilitating maintenance.

The modules we developed can be classified into two groups:

(1) Device modules

These modules provide functions to control devices, such as cameras and PLCs. Once developed, device modules are versatile enough to be repurposed for various applications. The system supports a wide range of cameras to meet factory needs, including from low-cost web cameras to high-performance cameras for factory automation (FA) applications. Additionally, the system is designed to support the communication protocols of multiple manufacturers used in factories.

(2) Inspection modules

Inspection modules provide functions for the preprocessing, AI processing, and postprocessing of images captured from cameras. Unlike hardware modules, inspection modules must be developed individually for a specific target. However, as shown in the inspection flow in Fig. 1, highly common processes have been templatized, enabling implementation through editing the necessary settings during deployment. In the future, we will increase the templates as needed to accommodate inspections that do not fit the standard templates.

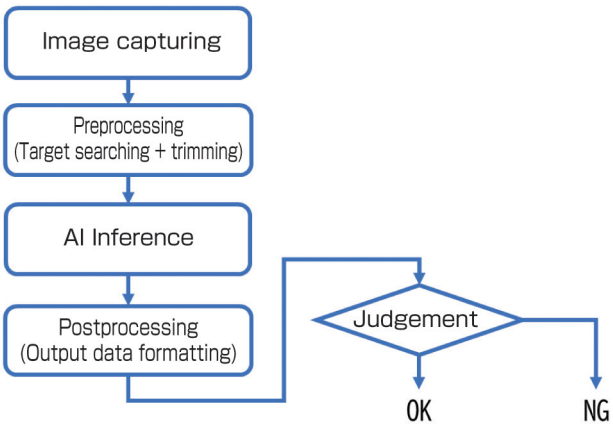

Fig. 1 Inspection flow

In summary, the necessary functions for the inspection target are selected from the developed modules and used to build an inspection system with Docker Compose[Note 4] (Fig. 2). The system reduces building time by more than 80% compared with the conventional approach, in which developers had to build the inspection system from scratch.

Note 2) Docker is a registered trademark of Docker, Inc.
Note 3) A platform for packaging and executing applications as modules.
Note 4) A tool for coordinating and managing multiple modules.

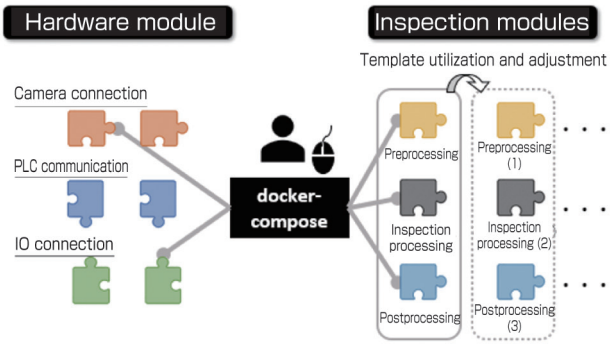

Fig. 2 Building an inspection system

2. 2 No-code Tool

An AI model is created through a process involving collecting image data of the inspection targets, training, and evaluating accuracy. Once the required level of accuracy is achieved, the model is integrated into the inspection machine. These tasks must be performed not only when the inspection machine is deployed, but also during operation when the data distribution shifts due to changes in products or the environment.

Traditionally, developers prepared dedicated training and accuracy evaluation programs for specific targets and resolved issues through trial and error. In this development project, we integrated image data preprocessing, training, accuracy evaluation, and module-compatible model conversion into a single tool. This enables factory personnel to perform tasks of equivalent quality. We have thus developed a no-code tool that can be operated with only mouse clicks. The following explains this tool's functions.

2. 2. 1 Available AI Methods

This tool supports four types of AI models, as shown in Fig. 3, to meet various visual inspection requirements in factories. Additionally, the recent intensified competition in AI performance results in successive releases of new AI models. In light of this situation, we continuously update the tool's functionality to ensure that it also supports models that are expected to improve the performance of our production lines.

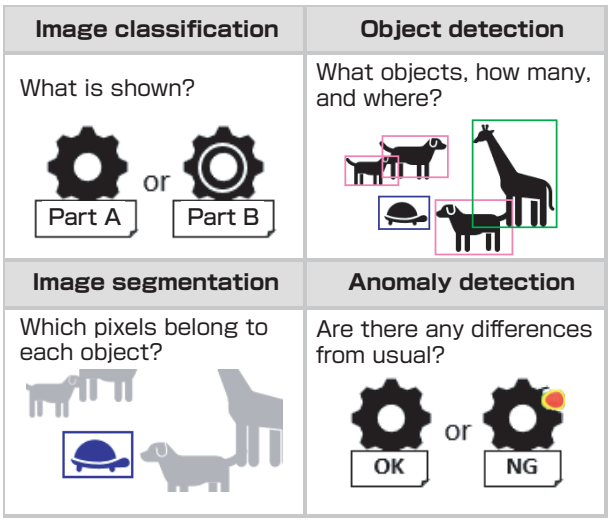

Fig. 3 AI models supported

2. 2. 2 Features to Improve Model Accuracy

We implemented the following three features to create high-accuracy models:

(1) Image augmentation

This feature intentionally adds noise to the original image to generate new images. Having diverse training data makes it possible to build AI models that are highly robust to various fluctuations in production lines.

(2) Fine-tuning

This feature allows pretrained models to be retrained using target image data. High-precision models can be created even with small amounts of training data.

(3) Training parameter optimization

Training hyperparameter settings significantly affect AI model performance. This feature efficiently explores various combinations of hyperparameters to obtain optimal AI models.

Fig. 4 shows the screen of the no-code tool that we developed. Using this tool enables the easy creation of high-precision AI models and facilitates their deployment in factories.

Fig. 4 No-code tool screen

3 Case Studies

The following lists case examples of how the developed tool was applied to KYB's production lines. This report focuses on example 3.

(1) Determining the presence and type of parts to be assembled onto a product
(2) Determining the presence and type of specification labels to be affixed to a product
(3) Determining whether workpieces are properly set in a machining tool or fixture

3. 1 Background

Our flagship product, the shock absorber, includes a piston rod. The piston rod is hard chrome-plated within the range shown in Fig. 5 to ensure resistance to wear and corrosion.

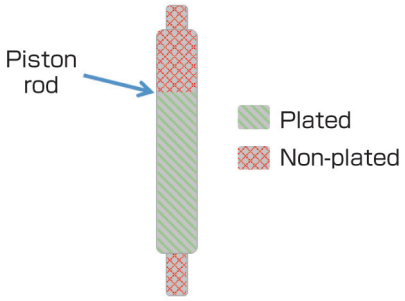

Fig. 5 Plated portion of the piston rod

As shown in Fig. 6, the piston rod is automatically set in a fixture called a "plating hanger," which connects to a conveyor that transfers it to the plating process. During setup, the piston rod is clamped at the top. Then, the masking fixture rises to cover the non-plated area at the bottom of the rod.

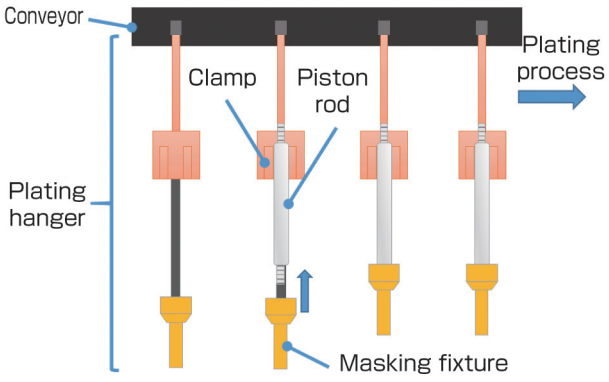

Fig. 6 Installation of the piston rod onto the plating hanger

However, as shown in Fig. 7, when the masking fixture rises, the clamped position of the piston rod may shift due to contact resistance between the bottom of the rod and the fixture. Alternatively, the masking fixture may not rise to the specified height. In this case, the plated area may not meet product specification requirements, resulting in non-conforming products.

Although a setup error detection system with proximity sensors has been introduced, it cannot detect all setup errors. Therefore, plated piston rods undergo 100% visual inspection to ensure product quality. Inspecting a tremendous number of piston rods places a heavy burden on inspectors. This is why there is a strong demand for automation to achieve worker savings and higher quality assurance levels.

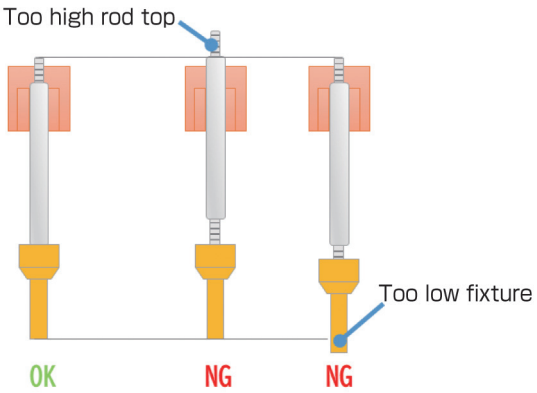

Fig. 7 Piston rod setups

3. 2 System Configuration

Fig. 8 shows the system configuration. The system consists of the hardware compatible with the device modules explained in Section 2.1. Considering the operating environment of the inspection machine, a high-performance camera for FA applications was selected. Additionally, bar lighting minimizes the effects of brightness fluctuations in the target object.

If the inspection machine detects a setup error, it sends a signal to the plating equipment control PLC, which stops the equipment. Thereafter, the line operator takes corrective action.

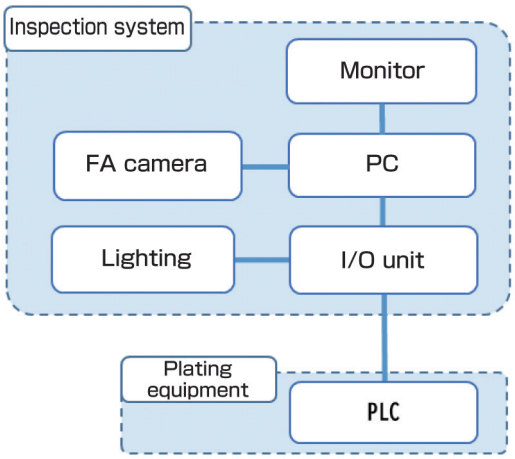

Fig. 8 System device connection

3. 3 Inspection Methods

As shown in Fig. 7, taking an accurate measurement of the top of the piston rod and the bottom of the masking fixture allows one to

determine if the setup is correct. However, the masking fixture gradually becomes discolored and deteriorates when exposed to the plating solution. Its appearance differs depending on its service life, which varies from fixture to fixture. Therefore, it is necessary to accurately detect the endpoint coordinate without being affected by the appearance variations of the individual fixtures.

Traditional rule-based methods struggled to achieve stable endpoint detection. As a preprocessing step for endpoint detection, this development project trains a segmentation AI on images of masking fixtures at different levels of wear to stabilize detection. Additionally, converting the areas detected by the AI into black-and-white images improves endpoint detection using the rule-based method (Fig. 9).

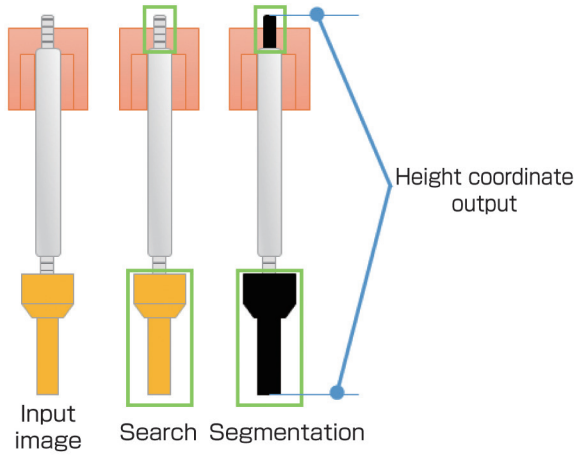

Fig. 9 Illustration of image segmentation by AI

3. 4 Results

We implemented and evaluated the inspection system on KYB's mass production line for continuous operation under normal operating conditions.

The misclassification rate (i.e., the probability of classifying a non-conforming product as conforming) was 0%, and the false positive rate (i.e., the probability of classifying a conforming product as non-conforming) was less than 0.1%. We verified that the system operates stably on the mass production line and effectively improves quality assurance.

4 Conclusions and Prospects

We developed a highly versatile visual inspection tool that allows factory personnel to configure the system flexibly according to the specific inspection targets. Furthermore, by developing the system in-house, we established an environment that allows for low-cost implementation compared with commercially available AI sensors, thereby enhancing its applicability in factory settings.

However, achieving higher inspection accuracy requires not only a high-performance AI model, but also high-quality image data for training. For example, optimizing shooting conditions for specific targets and ensuring the diversity of training data are essential. These tasks require advanced expertise.

Moving forward, we will accumulate expertise and train personnel to utilize the tool by introducing and operating inspection machines. Our goal is to establish an environment where anyone can easily build high-performance inspection machines and further improve quality assurance levels.

5 In Closing

This development project has achieved flexible system construction through modularization and AI model development using the no-code tool. Through these methods, we have successfully established an inspection platform that improves quality assurance levels and allows for quick deployment throughout the entire factory.

Finally, we would like to express our sincere gratitude to everyone in the relevant departments who provided us with tremendous support and cooperation during this project.

References

1) MITSUO, SUZUKI, MIYAUCHI, KIKUCHI: "Development of Stamp Inspection Technology Using AI and Construction of MLOps Platform," KYB Technical Review No.69 (October 2024).

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