AI-Based Image Solution to Realize Labor Saving and Automation at Manufacturing Sites

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Diversification of customer needs and speed of change surrounding the manufacturing industry have been remarkable in recent years. Various products are making their way into the market and the product life cycle is accelerating. In order to meet these customer needs, efforts for high-mix low-volume production, which enables manufacturing of one product with varying specifications, are becoming increasingly important. On the other hand, the manufacturing environment is undergoing unprecedented changes such as a move to provide service as well as other added value instead of strictly focusing on manufacturing. Additionally, the worldwide spread of COVID-19 since January 2020 has imposed major challenges on supply chains and manufacturing sites. To address these issues, it is even more important for companies to strengthen their ability to transform in response to environmental changes (dynamic capability) and to promote digital transformation (DX)[1].

Based on its implementation experience and knowledge, OKI has been supporting customers in the manufacturing market building business systems such as production control systems. Furthermore, in 2018, OKI announced an IoT-based factory solution “Manufacturing DX” that supports the realization of smart factories through the utilization of IoT and AI[2]. The solution aims to solve the issues the manufacturing industry is facing by concentrating and applying OKI’s knowledge with IoT utilization at its own factories, original sensing technologies such as sound, vibration and optical fiber, and AI technology.

As one of the latest effort to support the realization of smart factories, this article introduces an AI-based image solution that will enable quality improvement as well as labor saving and automation of manual work.

Manufacturing Site Issues

Labor saving / automation or robotization of manufacturing is being considered in many factories, and it is being adopted mainly for production line work. For example, many of the manufacturing processes in the automobile industry are automated, and efficient production is possible with a small number of workers. On the contrary, automation has not progressed with many of the “assembly processes” and “inspection processes.” These processes often rely on the skills and senses of experts and are considered difficult to automate.

However, the path to labor saving and automation cannot be closed. The serious problem of labor shortage is being shouted out in every industry, and the problem faced in the manufacturing industry is no different. The decrease in experts and the increase in non-regular employees due to labor shortage cause human errors, such as mistakes in work procedures and variations in work, resulting in products that do not meet quality standards. This may lead to serious accidents caused by malfunctions of the shipped products or trigger a massive recall of defective products (**Figure 1**).

One-step automation may be difficult to achieve, however it is urgent to pass on through digitization the knowledge and skills of workers including those of experts, and DX promotion in the assembly and inspection processes where manual work remains is an effort that the manufacturing sites cannot neglect. For manual work, importance lies in how to digitize the skills possessed by experts. Currently, great expectations are being placed on the utilization of images equivalent to the “eyes” and data/AI equivalent to the “knowledge” of experts.

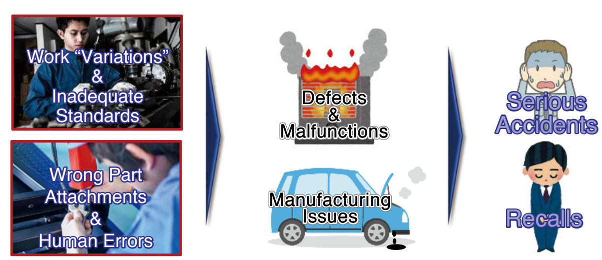

Figure 1. Manufacturing Site Issues

AI-Based Image Solution for Manufacturing

The AI-based image solution is exactly solution for reducing manual labor through digitization of experts’ “eyes” and “knowledge.”

"Imaging," "optical" and "image processing" are fundamental technologies indispensable for this solution (**Figure 2**).

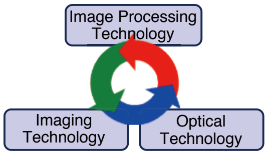

Figure 2. Fundamental Technologies Supporting AI-Based Image Solution

These fundamental technologies are described below.

- Imaging technology is for the image environment and camera selection
- Optical technology is for the image quality required in the analysis and calibration required for that image quality and preprocessing
- Image processing technology is for performing image preprocessing, such as extracting a specific area, and extracting the feature values of the target

Furthermore, in order to apply these technologies to an actual operation at a manufacturing site, a system environment that enables real-time AI evaluation at the edge, that is, AI edge computing is necessary. A system was realized combining knowledge cultivated in OKI's business areas of "manufacturing," "transportation," "construction/infrastructure," "disaster prevention," "finance/retail," and "marine" with the AI Edge Computer "AE2100," which began sales in 2019[3] (**Figure 3**).

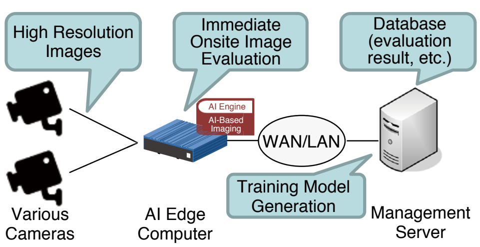

Figure 3. System Environment for AI-Based Imaging

The system environment that should be considered for the AI-based imaging is given below.

- System environment capable of handling high resolution images
- Edge computer environment capable of immediate onsite image evaluation
- Image training (model generation)/management environment
- Management server environment capable of storing evaluation results and product information

As specific examples of OKI's efforts, the "Visible Abnormality Detection System Using AI-Based Imaging" and the "Worker Action Recognition (Behavior Detection) Using AI-Based Imaging" are introduced in the next sections.

Visible Abnormality Detection System Using AI-Based Imaging

The Visible Abnormality Detection System can detect exterior abnormality of a product in real-time through AI-based image analysis at the edge region. The detection result is immediately notified to the worker, and that result together with trace information such as inspected images and product information are stored in a higher level management server for use in quality control and future analysis.

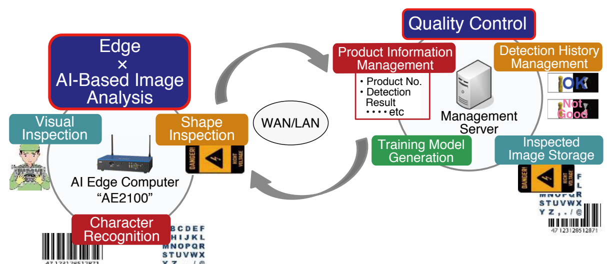

Figure 4. Configuration of Visible Abnormality Detection System

(1) Realization of Visible Abnormality Detection

An image of a product taken with a camera is transmitted to the AI edge computer "AE2100" where it is analyzed using an abnormality detection application to detect the presence of exterior defects. It is assumed that the trained model, which is the basis for normality/abnormality determination, has been generated in advance through AI image analysis of sample data and placed in the AE2100. This enables real-time detection, worker notification, and storage of various trace information into the management server (**Figure 4**).

Two methods of image analysis, "rule-based" and "deep learning," were adopted. The "rule-based" method detects visible abnormalities according to predetermined rules, and it is effective when the characteristics of the inspection are specifically defined. On the other hand, in "deep learning," visible abnormalities are detected according to rules constructed from a set of given images. Normal images and abnormal images are prepared, and a model is constructed and trained to determine normality/abnormality from these images. This method is effective when the characteristics of the inspection are not clearly defined.

(2) Quality Control Using Stored Onsite Data

Detection result of the AI-based image analysis is transmitted together with the inspected image and information for identifying the product, such as product number, to a high level management server and stored as history data. Since the stored information can be searched and referenced at any time, tracing is possible when quality problems occur after product shipment. Furthermore, additional information, such as the cause of defect, on duty worker, product category, and product number, can be combined to enable quality control and quality analysis.

The management server is equipped with a model retraining function that will periodically update the training model on the edge computer (**Figure 5**).

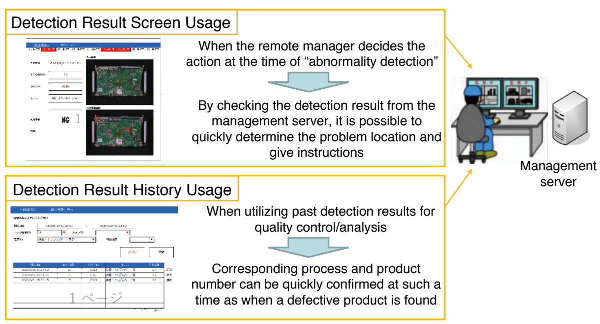

Figure 5. Quality Control Using Detection Results and History Data

Worker Action Recognition (Behavior Detection) Using AI-Based Imaging

Worker Action Recognition (Behavior Detection) is a system that aims to improve product quality by detecting the correctness of work actions and procedures using AI-based image analysis at the edge area. Through the analysis and recognition of the worker's body movement and comparison with the correct movement and procedure, the correctness of the work method and procedure is recognized (behavior detection). In the visual inspection, the quality of the product itself is detected, but detecting the correctness of the assembly and inspection procedures will ensure that quality is not worker dependent.

(1) Realization of Worker Action Recognition

Worker Action Recognition (Behavior Detection) is realized by applying the combined technologies of "skeletal extraction," "action recognition" and "work procedure recognition" to the worker's image taken with a camera. For the analysis, the image data of the worker's body movement (movement of the hands, fingers or tool held in the hand) is used as an input. The "skeletal extraction" extracts the skeletal movement of the worker as a time-series data. In "action recognition," AI compares the extracted data against its pre-learned data to determine what action the movement of the hands or tool depicts. "Work procedure recognition" determines quality by looking for differences between the predetermined action/procedure and the actual action/procedure (**Figure 6**).

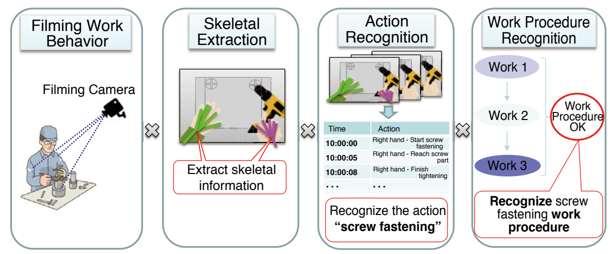

Figure 6. Mechanism of Worker Action Recognition (Behavior Detection)

(2) Quality Improvement Using Detection Results

Detection result of the AI-based image analysis is immediately notified to the worker and stored in the upper level management server as trace information. Experts and managers can remotely check the work status and detection results of onsite workers and give appropriate instructions to improve work efficiency and work quality. Interworking or centrally managing the stored data with the previously introduced Visible Abnormality Detection System will enable quality control of the manual processes from a higher perspective (**Figure 7**).

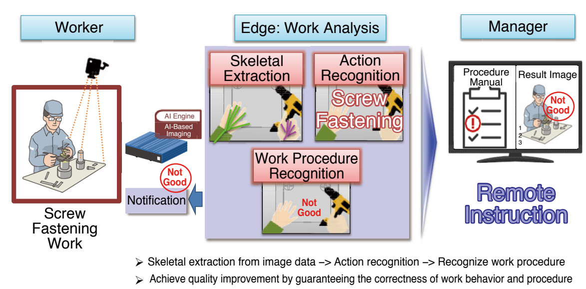

Figure 7. Quality Improvement Using Detection Results

Application Examples

OKI is working on further improving the labor savings and quality at its factories by interworking the Assembly Support System (Projection Assembly System[4]), the Visual Abnormality Detection System and the Worker Action Recognition (Behavior Detection) (**Figure 8**).

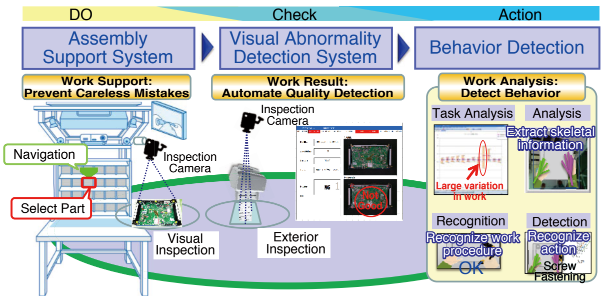

Figure 8. Examples of Initiatives at OKI's Factories

The Assembly Support System supports the digitization of assembly work by providing navigational aid that prevents careless mistakes and collecting work records. The Visual Abnormality Detection System automates visual and exterior inspections by utilizing AI-based imaging and performing AI edge processing with the AE2100. Additionally, Worker Action Recognition (Behavior Detection) determines whether procedure within a work process is as specified or behavior during work related to product quality is correct. Through these initiatives, OKI is constructing and utilizing a mechanism that supports the improvement of manufacturing quality from all directions.

Three specific detection examples using AI-based imaging are introduced below.

(1) Board Mounting Inspection (Example 1)

Confirmation of screw fastening is carried out when the Assembly Support System receives a completion notification of the fastening from the electric screwdriver.

The presence/absence of screws is confirmed by detecting visual abnormality according to predefined rules (**Figure 9**). For the confirmation of the presence/absence of screws, the "rule-based" image analysis was adopted since the characteristics of the inspection are specifically defined. This makes it possible to detect not only the presence/absence of screws, but also whether screws of the correct color, size and shape were used. If an abnormality is detected, the worker is immediately notified and swift measures can be taken.

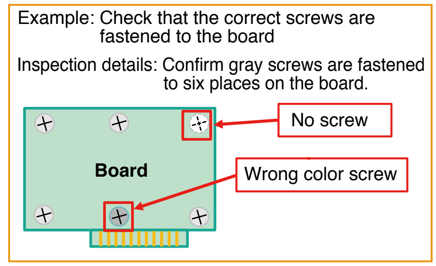

Figure 9. Screw Fastening Inspection

(2) Casing Inspection (Example 2)

During the casing inspection, the top cover is checked for scratches and dirt (**Figure 10**). Since it is necessary to capture vague and various states of defects such as straight scratches, curved scratches and dirt, the "deep learning" method was adopted for image analysis. The model used for the analysis is trained with normal/abnormal images and detection rules are formulated in advance. This enables detection results to be obtained immediately after image acquisition.

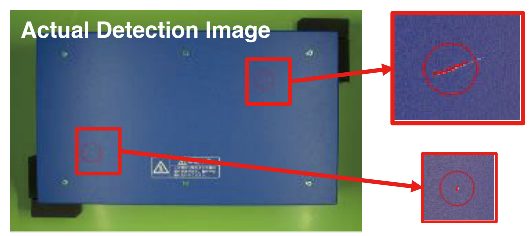

Figure 10. Top Cover Scratch Inspection

(3) Nameplate Character Inspection (Example 3)

In the character inspection of a nameplate, standard characters in a specified section are checked for chipping using "rule-based" image analysis (**Figure 11**). In a given detection, if the brightness value is determined to be black, there is no character chipping. However, if there is a break in the black color, character chipping is determined to exist. An OCR is also used in conjunction to check that the correct characters are printed.

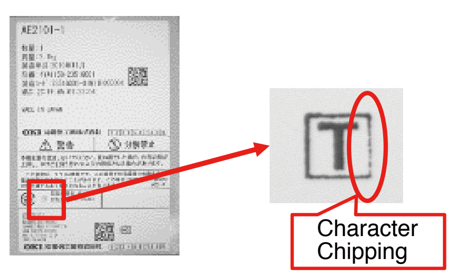

Figure 11. Nameplate Character Inspection

Conclusion

This article introduced the "Visible Abnormality Detection System Using AI-Based Imaging" and the "Worker Action Recognition (Behavior Detection) Using AI-Based Imaging" as promising means for labor saving / automation of manual work in the assembly and inspection processes.

OKI will improve and develop these solutions together with each Manufacturing DX solution to support customers' DX implementation and the realization of smart factories. ◆◆

References

1) OKI Press Release, OKI Formulates "Medium-Term Business Plan 2022," October 29, 2020
https://www.oki.com/en/press/2020/10/z20076e.html
2) OKI Press Release, OKI Launches "Manufacturing DX," An IoT-Based Factory Solution for Realizing Smart Factories, October 22, 2018
https://www.oki.com/jp/press/2018/10/z18044.html (in Japanese)
3) OKI Press Release, "OKI Begins Sales of AI Edge Computer "AE2100" Realizing High-Speed Deep Learning Inference Processing at the Edge and Interworking with the Cloud," October 19, 2019
https://www.oki.com/jp/press/2019/10/z19026.html (in Japanese)
4) Assembly Navigation "Projection Assembly System"
https://www.oki.com/jp/esc/pas/ (in Japanese)

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TIPS 【Glossary】

Dynamic capability
The ability of a company to transform itself in response to the unpredictable and drastic change in the environment and circumstances.