Development of Equipment Manipulation System for Smart Factory Promotion

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Abstract One of the most important items in our efforts to promote DX (Digital Transformation) in order to maintain, acquire, and strengthen corporate competitiveness in the rapidly-changing business environment of recent years has been the shift to smart factories in production factories. In order to realize automatic flow in smart factory promotion, it is essential to collect equipment parameter data, operating data, quality data, etc., automatically post them to a check sheet, and then determine whether the equipment can be operated, based on the results of the check sheet. However, for equipment that does not support IoT data collection and for some data types, these data cannot be collected due to equipment specifications. This report paper describes the construction of a production system infrastructure capable of automatic flow as an original system that can handle these requirements.

1. Introduction

In recent years, various companies have been promoting DX (Digital Transformation) to develop sustainable business by reforming their operations and corporate culture, through the use of vast amounts of data and digital technology. In order to respond to the drastic changes in the business environment, we too are promoting DX to transform our business, operations, and corporate culture through the use of data and digital technology.

As a manufacturer, the most important item in the promotion of DX is the conversion of production plants into smart factories.

We have traditionally implemented quality and productivity improvements through initiatives such as production line automation and process improvements. By utilizing new IoT (Internet of Things) technology and linking information with various systems, we will optimize processes and production in a flexible manner. This will not only further improve quality and productivity, but will also contribute to reducing in-process inventories, shortening delivery times, and improving the efficiency of indirect operations, etc., thereby increasing our market competitiveness.

2. Package Roadmap

Figure 1 shows a roadmap of packages currently being deployed or planned to be deployed until 2029.

High power density power modules are in mass production at DSK (Dalian Sanken) and NSK (Niigata Sanken), and compact high heat dissipation substrate modules are in mass production at ISK's (Ishikawa Sanken) Horimatsu Factory Building B. All of the production plants (manufacturing lines) are in the process of converting to smart factories.

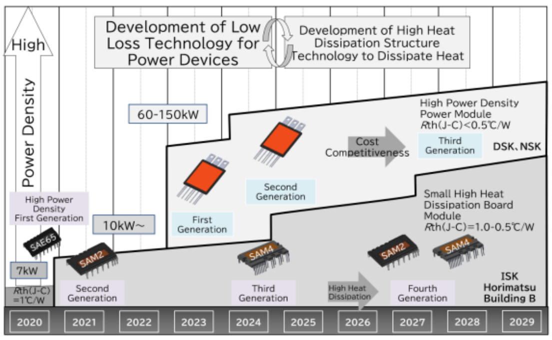

Figure 1: High Power Density Package Development Roadmap

3. Smart Factory Overview

I will give an overview of the smart factories that we are working on.

As shown in Figure 2, our smart factories are intended to reform business processes through the utilization of digital

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technology, including IT infrastructure and various types of data.

Our two main approaches are (1) production line reform and (2) business process reform. The former is aimed at quality improvement, productivity improvement, and cost reduction, through automation, imaging, and IT of production lines, which are mainly direct operations. For the latter, we will use IT data mainly for indirect operations to obtain necessary data immediately, which will lead into a PDCA cycle for indirect operations and speed up decision making.

In direct operations, various data are collected while we implement production line reforms. By utilizing the collected data in indirect operations, we are implementing drastic operational improvements. The goal is to finally achieve unprecedented production reforms through mutual cooperation.

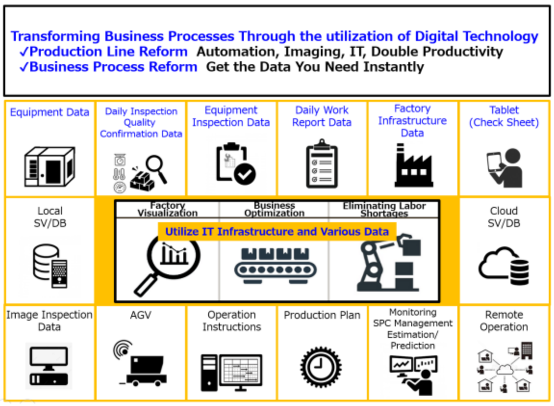

Figure 2: Smart Factory Overview

4. Smart Factory Roadmap

In promoting production plants as smart factories, we are working on the basis of smart factory 9-step activities, as shown in Table 1. The major categories are data collection, storage, and utilization.

The initial step starts with systems that can operate as stand-alone systems, and each successive step combines the systems completed in the previous step to achieve a production line that does not rely on human operators.

Smart factories will enable automatic flow, remote operation, and more efficient design using process data. For this purpose, it is essential to automatically collect various data necessary for automatic control of production lines under stable product quality, and with improved productivity.

Table 1: Smart Factory Roadmap

Deployment	Definition	Initiative Details
Step9	Big Data Deployment	Deploying Process Big Data to Other Systems (IoT) Production Line Reform, Process Reform, DX, Remote Control
Step8	Automatic Flow	LOT Abolished, Individual Piece Management Flow
Step7	Process Control	Line Control and Operation Instructions
Step6	Estimation/Prediction	Preventing Product Defects and Equipment Failures Predictive Scheduling and Feedback
Step5	Production System Collaboration	Mutual Use of Data such as Data Input/Output Processing
Step4	Automation	Automation of Parts and Product Transportation (AGV) Automation of Sensory Testing (Image)
Step3	Data Analysis Utilization	Visualization, Traceability Management, Process Improvement Visualization, New Product/Line Design, Quality Improvement
Step2	Equipment Data Collection	Database of Equipment Data Collection of SG Data Using Cube-Type Database
Step1	Paperless	Abolition of Paper Document, Database Creation, Digitization

5. Background to the Development of This System (Step8 Automatic Flow Issues)

As mentioned in the previous section, an essential item in fulfilling our objective in promoting smart factories is the automatic collection of various data necessary for automatic control of production lines.

Step 8 The desired state of automatic flow is as shown in Figure 3. It shows the flow of data from five perspectives: production facilities, quality checks, data accumulation, BI tools, and people. It is essential to automatically collect equipment parameter data, operating data, quality data, etc., automatically post them to a check sheet, determine whether the equipment can be used based on the results, and automatically control the production line.

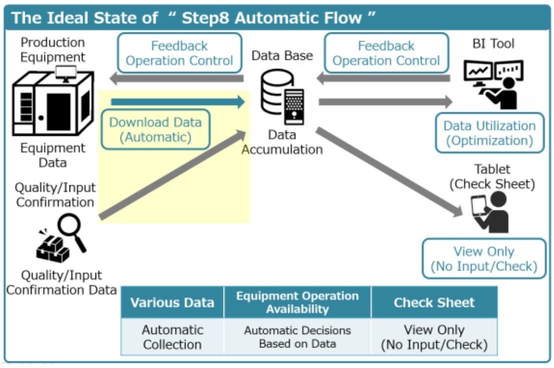

Figure 3: Step 8 Desired State of Automatic Flow

However, in its current state, as shown in Figure 4, there are production facilities and data that are not compatible with data collection (IoT). The data collection process is manual, with human intervention to check the relevant data ⇒ manual input into electronic media ⇒ check the input contents ⇒ transfer the data.

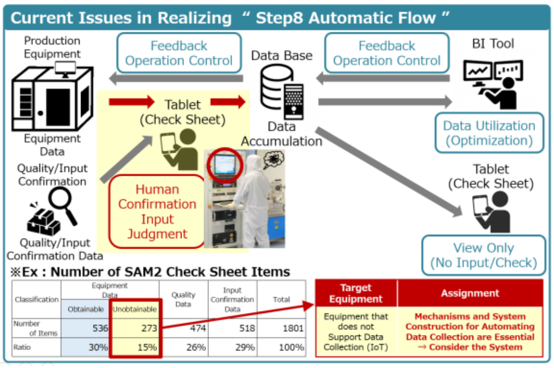

Figure 4: Step 8 Current Issues in Realizing Automatic Flow

Since automatic collection of these data is not possible due to the specifications of the production facilities, it is essential to establish a mechanism or system to enable automatic collection of data. Based on the above background, we developed our own data collection system.

6. Consideration of This System

The following is a description of our consideration of this system.

6.1. Consideration of Changing Equipment Specifications

As shown in Table 2, a study was conducted to see if it would be possible to extract data by changing the specifications of the equipment itself.

In conclusion, we concluded that this method was not feasible due to the limitations on the equipment side, which made it too difficult to modify the equipment. We decided to consider another plan that is feasible without modifying the equipment.

Table 2: Consideration with changing equipment specifications

Consideration Proposal		Equipment Renovation	Overall Judgement
Equipment Specification Changes	Add Data Extraction Functionality to the Equipment itself	× Cannot be Renovated	×
	Scraping the Equipment Monitor Screen *1	× Cannot Add Software	×
	Take a Screenshot of the Equipment Monitor Screen ＋OCR Processing *2	× Cannot Add Software	×

*1 : Screen Scraping ⇒ Extracting on-screen text from a running application.
*2 : OCR ⇒ Abbreviation for Optical Character Reader. Recognizing the text part of image data and extracting it as character data.

6.2. Consideration of a Camera Imaging Method

Next, a study was conducted using the camera imaging method, as shown in Figure 5.

The flow of this method is that the Equipment Monitor screen is captured by an external camera, image correction and OCR processing are applied to the captured image data, and text data is extracted. The installation of an external camera on the front of the equipment monitor may reduce the workability as well as the appearance of the equipment.

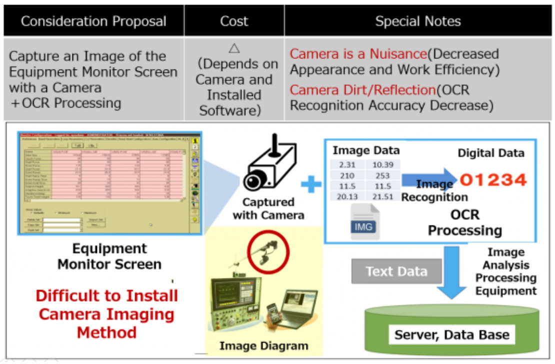

Figure 5: Consideration of a Camera Imaging Method

There is also a concern that dirt on the camera and reflections could degrade the accuracy of OCR recognition. We decided to consider another proposal.

6.3. Consideration of the Monitor Distribution + Screen Capture Method

This proposal was inspired by a hint from casual daily life during the search for another proposal.

Photo 1 shows live game streaming using a popular video content distribution platform.

The same image projected on the game monitor screen is projected to a PC for streaming, and streamed to the streaming platform via streaming software for viewing by the viewer.

Photo 1: Live Game Streaming
(Created with Microsoft Copilot, a Generative AI Engine)

Applying this method, we devised the following system: The system flow is as follows: the Equipment Monitor screen is projected to a PC for streaming, the projected screen is converted to image data, image correction and OCR processing are performed, and text data is extracted. We assumed that this method could solve the problem, so we conducted a more in-depth study.

Figure 6 shows an overview of the video content streaming method, and Figure 7 shows the results of examining the system configuration with reference to the video content streaming method.

First, the Equipment Monitor screen is streamed via a monitor distributor. Next, screen capture is performed on the image analysis processor via the capture board and streaming software. The projected screen is converted to image data, image correction and OCR processing are performed, and text data is extracted.

The advantages of this proposal include a sleek appearance due to the camera-less design, and stable OCR recognition accuracy that is unaffected by dirt and reflections. In addition, by utilizing general-purpose systems and in-house software, we were able to achieve lower costs, and we proceeded to realize the study plan.

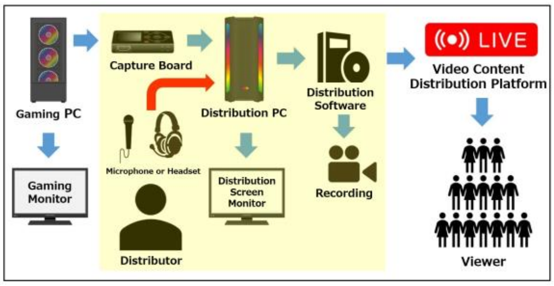

Figure 6: Overview of Video Content Streaming Methods

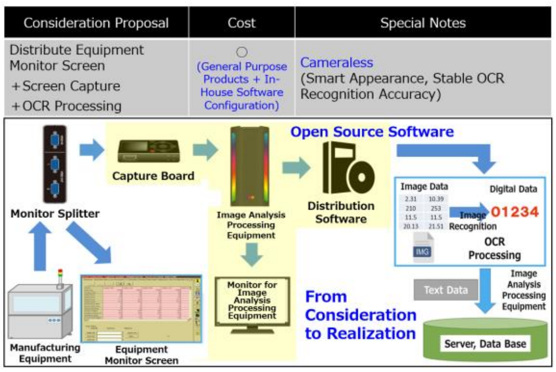

Figure 7: Consideration of Monitor Streaming + Screen Capture Method

7. System Overview

The following is an overview of this system as embodied.

7.1. System Configuration and Operation Flow

The system consists of data extraction and character recognition by an OCR engine, as shown in Figure 8.

The data extraction is for equipment that cannot extract data and cannot be modified by the user due to limitations on the equipment side. Capture equipment monitor screens by applying the video content streaming methods used in popular video content distribution platforms. Using the most suitable general-purpose OCR engine and applying the most suitable image correction to the screen image data obtained improves character recognition accuracy, and data can be extracted as digital data.

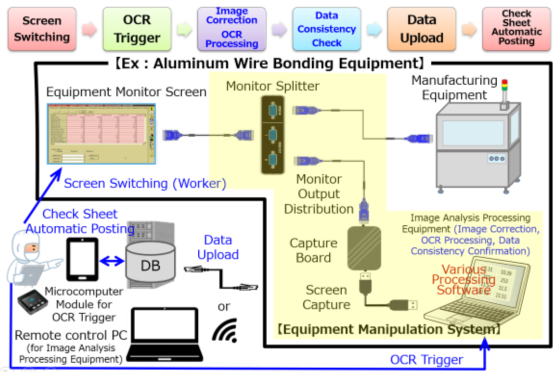

Figure 8: System Configuration and Operation Flow

7.2. Selection of an OCR Engine

There are several important points to consider when selecting an OCR engine, the first and most important being recognition accuracy. It is important to check how accurately the engine can recognize characters in a particular character set and format. Support for the target language is also important, especially when specialized support is needed for Japanese or other non-alphabetic characters.

Processing speed is also important, and the ability to quickly process large amounts of data is an important factor, especially in situations where real-time processing is required. The engine's support for the target document format should also be checked when selecting the engine.

As for the construction environment, whether the engine can be easily integrated with other systems and applications, whether an API (Application Programming Interface) or SDK (Software Development Kit) is provided, whether it is easy to configure and customize, and whether a network environment is required, are also important points.

Regarding the type of license and cost, it is also necessary to comprehensively consider not only the initial cost but also the ongoing support cost, and the operating cost based on the amount of use.

We needed to evaluate these points comprehensively to select the most appropriate OCR engine, and several OCR engines were selected as candidates.

As a result of the selection, we decided to introduce "Company G's OCR engine" into this system, as shown in Table 3.

Table 3: OCR Engine Selection

OCR Engine	Character Recognition Accuracy	Cost	Processing Speed	Built Environment		Overall Judgement
①Company A OCR Engine	○	Paid (WebApp)	△	×	Requires NetWork Environment	×
②Company B OCR Engine	○	Paid (WebApp)	△	×	Requires NetWork Environment	×
③Company C OCR Engine	○	Free (WebApp)	×	×	Requires NetWork Environment	×
④Company D OCR Engine	○	Free (Lib)	×	△	Easy to Set Up	△
⑤Company E OCR Engine	△	Free (OSS)	△	△	Complicated Environment Settings	△
⑥Company F OCR Engine	○	Free (OSS)	△	△	Complicated Environment Settings	△
⑦Company G OCR Engine	○	Free (API)	○	○	Easy to Set Up	○

7.3. Captured Image Optimization

The expected performance cannot be achieved if the quality of images input to the OCR engine is poor. As shown in Figure 9, the recognition accuracy of the general-purpose OCR engine is greatly improved by correcting and optimizing captured images in the preliminary stage of input to the OCR engine.

✓ Image size setting
  Adjusting the size of the image appropriately means text can be displayed more clearly and easily recognized.

✓ Image resolution setting
  Adjusting the resolution of the image appropriately means text can be displayed more clearly and easily recognized.

✓ Binarization
  Converting a color or grayscale image to a binarized (black and white) image clarifies the outlines of characters and makes them easier to recognize.

✓ Mask processing
  Excluding areas that contain noise or unnecessary information makes characters easier to recognize.

✓ Distortion correction
  Since the OCR engine has difficulty recognizing distorted characters, correcting the distortion makes the characters easier to recognize.

✓ Contrast correction
  Emphasizing the contrast between the text and the background makes the text easier to recognize.

✓ Noise removal
  Removing unnecessary noise in the image makes character parts clearer and easier to recognize.

✓ Margin removal
  Excluding areas that contain noise or unnecessary information makes characters easier to recognize.

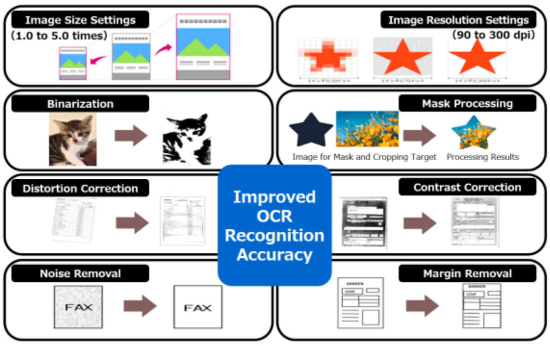

Figure 9: Captured Image Optimization

7.4. Verification on Actual Equipment

Photo 2 shows verification on an actual machine. Verification was conducted using actual production equipment to check the accuracy of the extracted text, and to adjust the position and size of the mask as necessary. We also observed the processing speed for large data sets and evaluated the degree of error for noise and misrecognition. The algorithm and mask settings were fine-tuned based on feedback as needed, and additional adaptive thresholding and other processing techniques were introduced to accommodate variations in image quality.

After the above verification using actual equipment, the versatility, various restrictions, and introduction and operation costs were scrutinized, and the system was officially introduced.

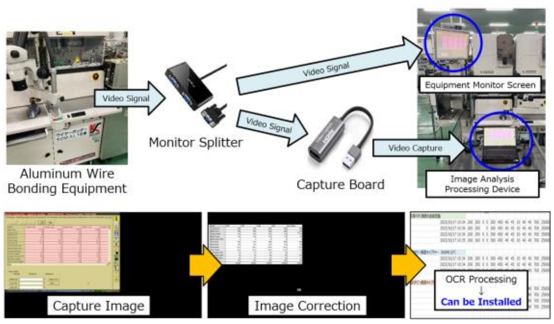

Photo 2: Verification on Actual Equipment

8. Conclusion

In this paper, we outline the equipment manipulation system in our Smart Factory promotion activities at our production factories.

The title "equipment manipulation system" is derived from "automating the operation of equipment by humans" such as extraction of equipment data and input confirmation work.

The development of this system is on track to greatly automate the data entry and data checking tasks that have been performed by workers in the past.

Furthermore, since this system is a data extraction method that can be easily introduced into existing facilities at low cost, it is expected to be deployed in conventional manufacturing equipment. This has established the basic technology for the development of smart factories that can be deployed horizontally.

Now that the path to automatic collection of all equipment data is clear, the only data input remaining is the operator's work verification check.

To address that, we will first review the items in question in cooperation with Ishikawa Sanken, which introduced this system earlier, and work to significantly reduce the number of items.

In addition, a demonstration experiment for "Step 8: Automatic Flow" of the 9-Step Smart Factory Promotion Activity has already started in some of the processes of Ishikawa Sanken's Horimatsu Factory Building B, and we will further accelerate and work toward the realization of this activity in the future.