Featured Articles

Next Generation of Global Production Management Using Sensing and Analysis Technology

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OVERVIEW: Hitachi is working on the development of a next-generation production management system that uses IoT technology and cloud services in accordance with a roadmap of functional enhancements based on maturity metrics. Recognizing that cameras provide a new sensing technique for visualization, Hitachi is utilizing image analysis techniques and integration with production results data to achieve quality and productivity improvements in the short term, and to generate improvement suggestions and perform optimization throughout the supply chain by combining these techniques and results data with big data analytics over the long term. Hitachi undertook an analysis of machining and assembly production sites from a 3M perspective to identify applications where image analysis techniques can be beneficial. Furthermore, Hitachi has developed a technique for detecting deviations from standard operation by extracting feature values representing worker operations from images captured on motion cameras, and demonstrated their effectiveness through a trial conducted using actual images from a manufacturing workplace in a customer co-creation project.

INTRODUCTION

ADVANCES in telecommunications and sensing technologies, and reductions in their costs have fostered interest from different industries in uses for the Internet of things (IoT). Germany proposed its Industrie 4.0 project(1) for integrating the IoT and services into manufacturing processes in 2011, with anticipated benefits that include improved productivity, the ability to deal flexibly with specific requirements, and reduced energy use(2). Similarly, General Electric Company put forward its Industrial Internet concept for connecting industrial equipment to the cloud and using big data analytics to improve speed and efficiency in various industries(3).

In Japan, meanwhile, numerous companies in the manufacturing industry have devised production systems and manufacturing improvement methods that have demonstrated quality and productivity improvements, utilizing improvement activities in which they have been engaged for some time, including the Toyota Production System (TPS), cell production system, and Production Innovations the Daicel Way(4). Furthermore, to improve productivity, the questions of which IoT technologies or cloud services it is best to develop and install, and what form the next generation of production systems should take, are recognized as major topics for study by industry moving forward.

Meanwhile, there have been notable instances of major recalls by the automotive industry in recent years due to defective parts, and these have reinforced the importance of collecting and managing production results data (meaning actual data from the production process, such as component lot numbers, in-process inspection results, and machining conditions) in order to be able to identify the cause of product defects and take remedial steps.

Currently, manufacturing execution systems (MESs) are used to achieve traceability by collecting actual data such as component lot numbers, process data from production equipment, inspection data, and the results of visual inspections by workers, and by linking this production results data to product serial numbers (IDs identifying individual products).

However, when the completeness of this production results data is looked at in terms of the “man, machine, material” (3M) factors of production, there are instances where current data is considered to be inadequate for identifying the causes of problems (see Table 1). For example, even if a deviation from

TABLE 1. Cases in which Adequate Production Results Data is Not Available (at Machining or Assembly Production Sites)
It was found that, in certain cases, the production results data currently collected at manufacturing plants is inadequate for identifying cases of defects.

Category	Type of information	Management method (current)	Completeness evaluation (reasons)
Man	Manual measurements, interventions	Instrument data	△ (unable to identify defective parts, contaminants, etc.)
	Assembly, machining	Inspection by supervisor	× (unable to monitor all work, no quantitative data)
	Visual inspection	Results recorded on a paper form, etc.	△ (variations between workers, potential for data entry errors)
Machine	Gripping of workpiece	Machining center	△ (unable to detect minor abnormalities)
Material	Type of supplied materials, lot numbers	Label check, etc.	△ (potential for reading wrong label or skipping filling ports)

standard operation procedures (SOPs) is identified as the reason for a defective product, it will still be necessary to recall a wide range of products because it is not possible to determine which lots used the same faulty procedure.

There have been many cases in the past where this data has not been managed by a system and there is scope for new improvements in terms of quality and productivity.

The challenge for MESs is to strengthen traceability by widening the scope of production results data that is managed while also seeking to improve productivity.

NEXT-GENERATION GLOBAL PRODUCTION MANAGEMENT SYSTEM

Basic Concepts

To overcome these challenges, Hitachi is developing a next-generation global production management system for machining and assembly production sites. The system uses on-site cameras as a means of sensing to augment the production results data collected by the existing MESs. In addition to integrating this data, which includes video based on 3M considerations, it also uses big data analytics to suggest improvements and incorporate them into "methods" (+M) at each site. Ultimately, the aim is to consolidate and analyze data from manufacturing sites around the world to achieve inter-site coordination and supply chain optimization at a global level. The system is built on a symbiotic autonomous decentralized platform, improving the quality and productivity at each site in the short term, and management efficiency in the long term (see Fig. 1).

Roadmap Based on Maturity Model

To build its production management system for improving management efficiency, Hitachi recognized the need to add additional functions in accordance with the maturity level of its existing systems. To this end, Hitachi analyzed the production management systems at its own factories and devised a maturity model that classifies production systems in terms of six maturity levels, using this as a basis for developing

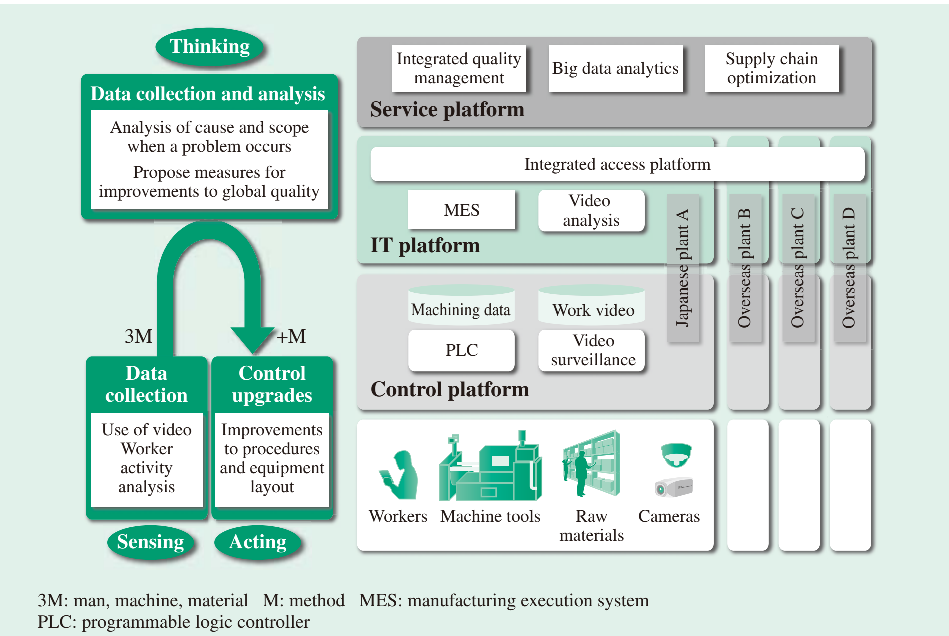

Fig. 1—Basic Architecture of Next-generation Global Production Management System.
In addition to collecting information from manufacturing sites around the world based on 3M considerations, the system also uses big data analytics to suggest quality or other improvements and provide these to the manufacturing sites as feedback.

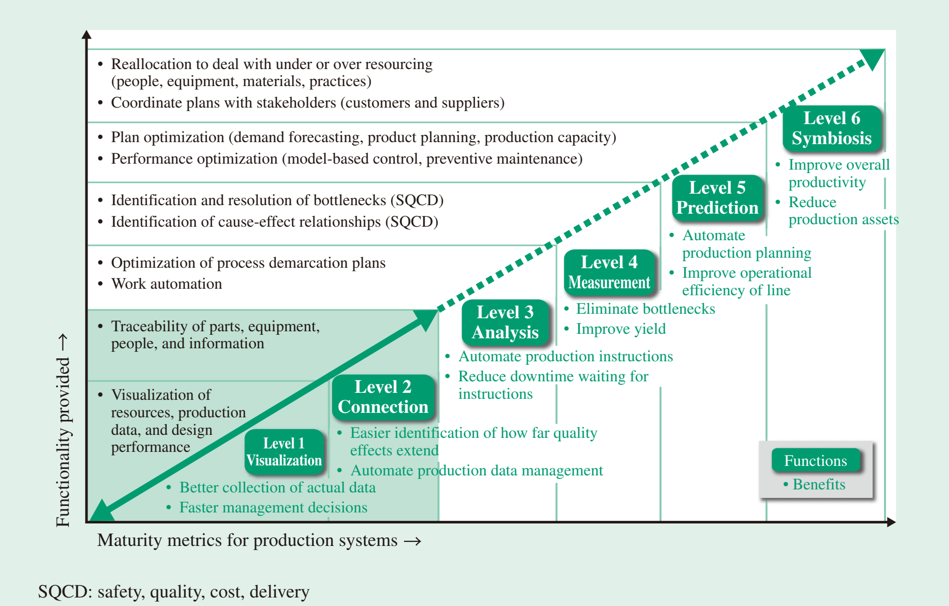

Fig. 2—Maturity Metrics for Production Systems, and the Functions and Value they Provide.
A production management system that can help improve management efficiency can be created by providing additional functions based on the production system's maturity.

a roadmap for system enhancements based on maturity level (see Fig. 2).

Based on site information made available at maturity level 1 (Visualization), actual data is linked together at level 2 (Connection) to achieve traceability. Next, instructions are automated at level 3 (Analysis) and bottlenecks are eliminated at level 4 (Measurement). Plans are optimized at level 5 (Prediction) and system-wide optimization covering multiple sites and stakeholders is the objective at level 6 (Symbiosis).

Primarily, maturity levels up to level 2 contribute to quality improvement, up to level 4 contribute to productivity improvement, and up to level 6 contribute to management efficiency improvement. The next-generation global production management is being achieved by expanding functions based on these production system maturity metrics.

In a co-creation project with Daicel Corporation, Hitachi is currently engaged in functional development and demonstration testing to implement all functions up to level 2 (Connection).

The following section uses the example of a demonstration testing being conducted by Hitachi and Daicel to show how integration of video analysis and MES is being used to improve quality.

VIDEO ANALYSIS

Role of Video Analysis

Video analysis is a technique seen as having great potential for the visualization level of the system maturity model shown in Fig. 2. Hitachi has been building up technology in the field of video analysis for a wide range of applications, including security and factory automation (FA), for nearly 50 years(5). The intention is to use these techniques to extract meaningful information from quantities of video that are too large to be viewed by people in order to identify defects at an early stage and to make improvements to quality and productivity.

The choice of what to analyze in the co-creation project with Daicel was made to enable acquisition of 3M information (see Table 2). To monitor the operations of workers, motion cameras capable of capturing body movements were used. To monitor the movements of supervisory or parts supply staff, panoramic cameras mounted in the ceiling and capable of capturing images over a wide area were used. To capture the progress of parts supply, pan/tilt/zoom (PTZ) cameras capable of homing in on targets with high precision were used. To detect various anomalies in equipment, fixed cameras were used (see Fig. 3).

TABLE 2. Types of Analysis and Sensing Methods
The choice of what to analyze was made based on 3M considerations and sensing methods selected to suit the purpose.

Category	Analysis	Sensing method
Man	Worker activity	Motion camera
	Location of supervisory and parts supply staff	Panoramic camera
Machine	Spills, work-in-progress out of position	Fixed camera
Material	Parts supply	PTZ camera

PTZ: pan, tilt, zoom

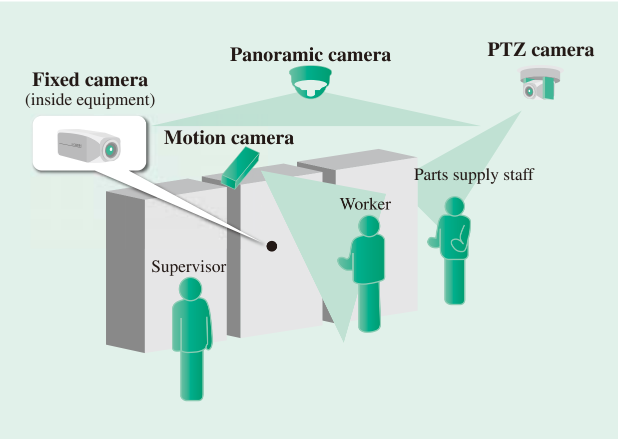

Fig. 3—Camera Locations.
The types of cameras to install at the site were chosen based on the intended analysis.

The following section describes a new initiative in which motion cameras are used to capture worker operations.

Worker Operation Recognition

Motion cameras can capture three-dimensional shapes. In the case of people, it is possible to infer information about the position of joints (such as the wrists, elbows, or shoulders) from these three-dimensional shapes. Hitachi has developed an abnormal operation detection technique that uses this information to detect when worker operations deviate from standard operation.

The basic structure of the algorithms typically used for video analysis can still be used if the input is switched from video to joint position information. This structure is made up of preprocessing to remove noise from the input, feature extraction to identify the information required for interpretation, and a classifier that uses the extracted feature values to make statistical assessments.

Fig. 4 shows a block diagram of the abnormal operation detection algorithm. The preprocessor uses smoothing to remove noise from the joint information and normalization to cancel out information that is not directly relevant to the work, such as arm or leg length. The feature value extractor extracts information (feature values) representing worker movements. These feature values are determined through consultation and on-site observation. That is, the bodily movements to be detected are determined from the results of consultation about which operations represent a deviation and knowledge of what constitutes standard operation acquired through site observation, and this is used as the basis for determining the feature values. The classifier selects the combination of feature values to consider based on the type of work being monitored, and identifies whether there are deviations by performing a statistical comparison with the standard operation model.

Cameras had already been installed at Daicel's Harima plant. To verify the efficacy of the new technique, the abnormal operation detection process was applied to actual data from the plant. This produced examples of visual inspection performed over a long period of time and of the removal of identified products. This demonstrated that the technique can be used to detect deviations from standard operation. In the future, Hitachi intends to devise ways of identifying problematic deviations by combining the technique with production log data.

FUTURE OUTLOOK

The image analysis technique described above is primarily intended as a "connection" function for quality improvement. Along with the comprehensive adoption of connection technologies at manufacturing

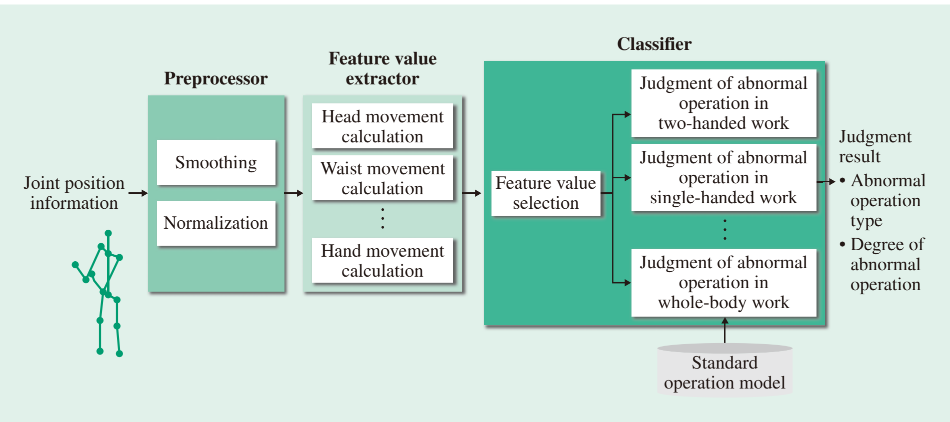

Fig. 4—Block Diagram of Abnormal Operation Detection Algorithm.
The algorithm is modeled on those used for video analysis and has the same overall structure. The individual parts, however, use newly developed techniques.

sites around the world, Hitachi intends to provide capabilities for combining and "analyzing" information collected from different sites to "measure" problems. It anticipates that the following three technologies will be important to achieving this.

The first is edge cognition technology. When using the image analysis technique as a sensing technique at a plant, it is not practical in terms of cost to collect, consolidate, and analyze large amounts of video data in one location. Accordingly, there will be an important role for technology that performs video analysis in realtime at a location close to the manufacturing site, namely within the camera that is the source of the data. The second is ultra-high compression & super-resolution technology. Even when edge cognition is used, there will still be cases, such as when problems occur, where there is a need to forward video data from the site to the company headquarters, a mother factory, or some other remote location. Such cases require the ability to transmit data with high quality and at low cost. The third technology is big data analytics. This is used to generate improvement suggestions by consolidating and analyzing information such as production data collected by the MES or the results of video analysis from manufacturing sites around the world together with actual data on quality or productivity. One example might be to identify differences between quality or productivity at different plants and determine the reasons. These improvement suggestions can then be sent back to the plants as feedback, such as proposals for globally standardized SOPs (methods) or quality standards.

From here, the next level involves automating the optimization of practices at each plant through "prediction." Key technologies include planning optimization based on demand forecasting or production capacity prediction, and performance optimization by preventive maintenance and model-based control.

The ultimate objective is to go beyond the optimization of individual sites to create "symbiotic" production systems that achieve system-wide optimization through measures such as the sharing of resources between different plants or the coordination of planning across the entire supply chain.

CONCLUSIONS

This article has described work on the development of a next-generation global production management system for improving management efficiency at machining and assembly production sites.

A roadmap of the functions required in terms of the 3M factors of production was formulated on the basis of a system maturity model. The article also described work on abnormal operation detection using motion cameras to interpret worker operations and demonstration testing at a customer factory to provide an example of image analysis that uses camera images as a new form of production results data.

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