Video Analysis Solution for Manufacturing Lines

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1. Introduction

In recent years, amid labor shortages and increasing awareness of food safety, there is a growing need for improving the productivity of manufacturing lines and preserving quality. Accordingly, more cameras have been installed to monitor manufacturing sites and analyze the work. Meanwhile, the operators who conduct the monitoring and analysis need to review large amounts of image data sent from cameras in order to respond. Such tasks need to be automated to improve efficiency.

To satisfy such market needs, Mitsubishi Electric Corporation has developed a video analysis solution for manufacturing lines, which is characterized by the use of VCA technology called EIMON. EIMON visualizes the time of each task in manufacturing processes and automates the detection of abnormal work, making it possible to reduce the workload on those who conduct monitoring and analysis. In addition, we have worked to apply this solution to tasks ranging from the introduction of equipment into manufacturing lines to studies on work, by linking with the MELOOK3 series that was released as a surveillance camera system for monitoring and crime prevention.

This paper describes, in consideration of trends in the manufacturing sector, a work analysis technology based on the EIMON VCA technology, and the results of a demonstration experiment of the video analysis solution performed at our factory using the MELOOK3 system and future development.

2. Trend in the Manufacturing Sector and Issues

2.1 Use of IoT technologies in the manufacturing sector

Since the announcement of "Industry 4.0" (Germany) in 2011, reforming the manufacturing industry by actively using IoT technologies has been gaining attention. The governments of various countries have released similar concepts, such as "Connected Industry" (Japan) and "Made in China 2025."

The main element of Industry 4.0 is smart factories where IoT technologies are used to connect manufacturing equipment, sensors, and other types of systems in factories to enable visualization and higher efficiency. Mitsubishi Electric has been promoting "e-F@ctory" since 2003 as a comprehensive solution for smart factories that delivers added value such as higher productivity, quality, and safety.

To further improve efficiency by turning to smart factories, it is important to use information on humans in addition to information on goods. Although information on goods such as equipment can be easily collected by IoT technologies, it is usually difficult to collect information on humans such as workers. One possible method of doing so is to use sensors. However, since contact sensors are stressful for workers for both physically and mentally, image sensors and other types of non-contact sensors are desired.

A main example of the use of image sensors in the manufacturing industry is visual inspections to detect apparent abnormalities in products. In conventional image analysis systems, algorithms need to be selected and combined for each target. However, in recent years, once systems with artificial intelligence (AI) technologies have learned a sufficient number of correct (good) images and incorrect (poor) images, they can make inspections with high accuracy.

Thus, whereas still images are often used for visual inspections, to obtain required information on humans at smart factories, various human movements need to be sensed, and this requires motion video. Since more computer resources are required to analyze motion video than still images, video has not been actively used to date. One possible likely application is to use image sensors to analyze the paths of human movements and to use the data to optimize the layout in factories.

2.2 Issues in the manufacturing sector

While the latest technologies have been introduced in smart factories, it is difficult to secure workers at actual manufacturing sites, the same as in other industries. According to the 2017 White Paper on Manufacturing Industries (*Monozukuri*) issued by the Japanese Ministry of Economy, Trade and Industry, 57.1% of manufacturing companies selected "It is getting more difficult to secure human resources due to the labor shortage" as a problem for maintaining and improving workplace skills at manufacturing sites (Fig. 1). In addition, 21.7% of the companies selected "Making operations more efficient by actively using IT and thorough streamlining" as the most

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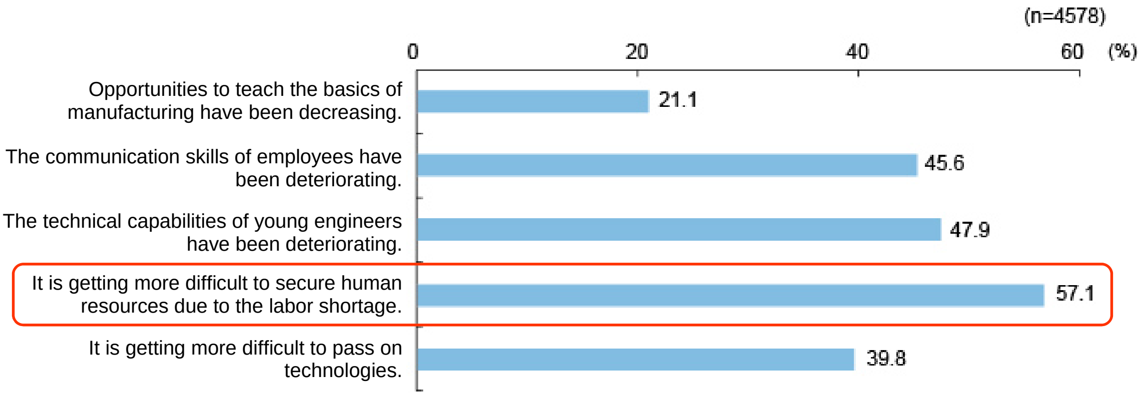

Fig. 1 Challenges in maintaining and strengthening workplace skills

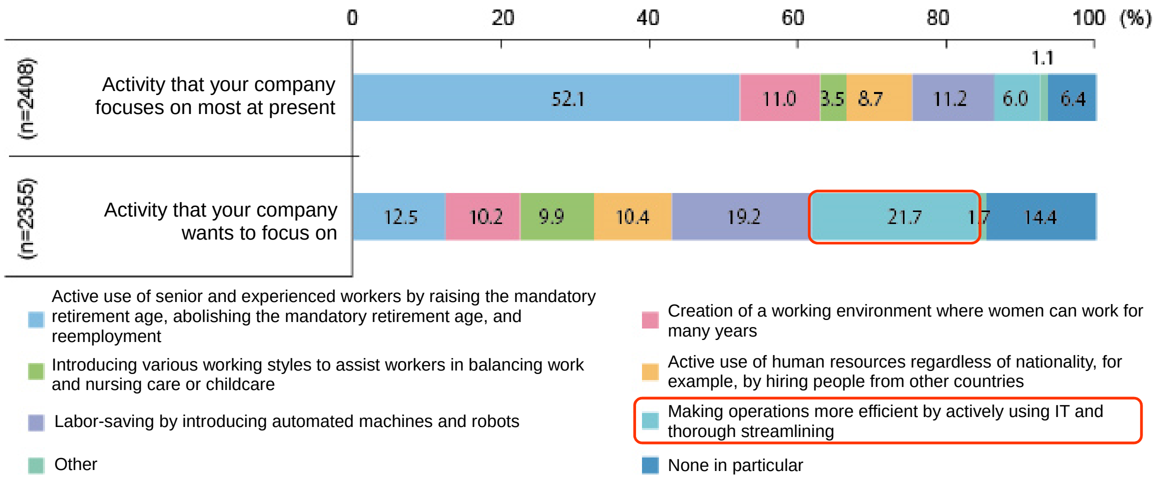

Fig. 2 Most valuable activities amid the shortage of skilled workers (current and future)

important future task to address the labor shortage (Fig. 2).

3. VCA Technology for Production

3.1 Issues to be addressed

To solve such issues, it is necessary to improve productivity by making full use of human resources at manufacturing sites while leveraging the latest technologies such as IoT and AI.

On manufacturing lines, to achieve the planned productivity by improving the production efficiency every day, operators' work is analyzed to reduce wasted movements. In work analysis, the work is analyzed for each process (e.g., assembly and inspection) to identify differences between the normal time and actual work time and thus detect wasted movements that can be improved.

Conventionally, work time was visually measured and at the same time abnormal work and normal work were analyzed. However, the same working process was repeatedly checked and multiple cycles were measured, which imposed a heavy workload on the analysts.

3.2 EIMON

To solve the above issues, Mitsubishi Electric has developed a work analysis technology involving the EIMON VCA technology. In this new technology, the video of actual work (input video) is compared with the analysis target video (reference video) recorded in advance for analysis. This can automate work time measurement and abnormal work detection, which analysts used to do visually. For comparative analysis, a video feature quantity (EIMON) created from each type of video is used. EIMON is a video feature quantity in which the quantity of generation of motion vectors in each direction is calculated for each frame comprising the video and the quantities are arranged in chronological order (Fig. 3). It shows a characteristic pattern unique to each work.

Generally, work on manufacturing lines consists of repeated identical movements. As a result, on EIMON of the input video, the same pattern as that on EIMON of the reference video is repeatedly shown. The execution of work is determined by detecting this repeated pattern and the work time is measured based on the pattern length. In addition, abnormal work is detected by detecting a section that is different from EIMON of the reference video when the factory is operating (Fig. 4).

To obtain information on motion vectors, which is important for creating EIMON, generally it is necessary

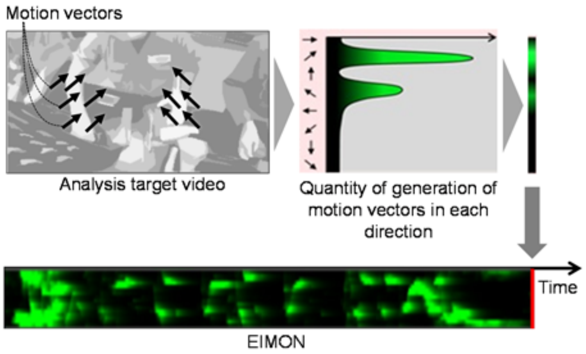

Fig. 3 EIMON generation processing

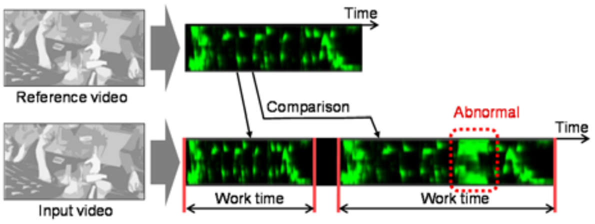

Fig. 4 Same pattern detection and abnormal term detection

to use a decoder to decode compression-encoded video data and then calculate motion vectors using an image processing method (e.g., optical flow). However, decode processing and motion vector calculation take time and the analysis target video cannot be analyzed in real time.

Therefore, we focused on motion vectors in compression-encoded video data since they can be extracted by performing part of the decode processing, thus reducing the burden of decode processing and omitting the motion vector calculation process. This new technology reduces the computational complexity in the process of creating EIMON from video data by approximately 65% (comparison by Mitsubishi Electric) and enables the target video to be analyzed in real time (Fig. 5).

3.3 Commercialization development

We have developed a video analysis solution based on the work analysis technology described in the previous section. In this technology, video is used to analyze workers' movements on manufacturing lines and work time measurement and abnormal work detection are performed in order to support work analysis and quality improvement. Its main advantages are described below.

3.3.1 Screen for distinguishing work details more easily

In addition to numerical data (e.g., work time for each work cycle), normal work and abnormal work are classified by color and the work time is graphed, which allows the analysis results of multiple cycles to be visually checked (Fig. 6).

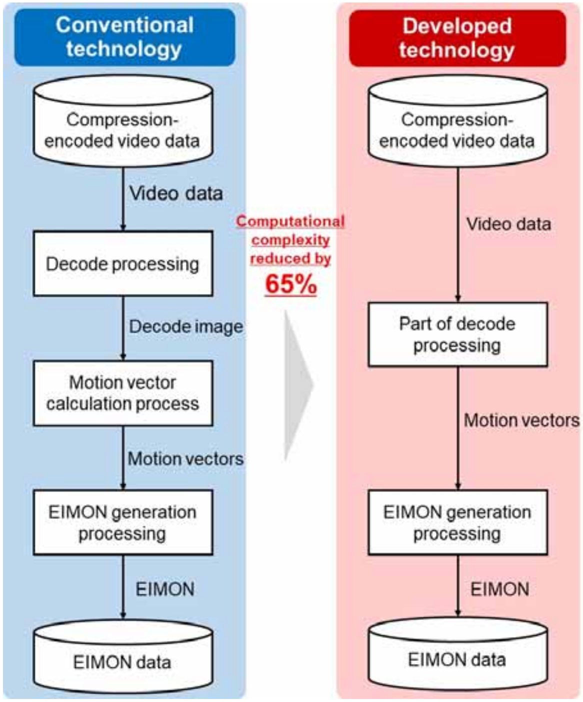

Fig. 5 Comparison between conventional technology and development technology

3.3.2 Analysis based on the application

(1) Offline analysis

When past analysis target video data stored in an external medium (e.g., MELOOK3 recorder and USB memory stick) is imported and the work is analyzed, work time measurement and abnormal work detection can be done by offline analysis (Fig. 7).

(2) Real-time analysis

By connecting the solution to a MELOOK3 system and obtaining a live video stream from the MELOOK3 camera, work time measurement and abnormal work detection can be done in real time (Fig. 7, Table 1). This enables the operator to be notified of abnormal work immediately it occurs.

4. Demonstration Experiment at a Factory of Mitsubishi Electric

To check whether the solution works well in actual use and to understand issues during installation at actual sites, a demonstration experiment was carried out at the Mitsubishi Electric factory that produces the MELOOK3 series.

4.1 Line selection

Mitsubishi Electric has various types of manufacturing lines at factories: lines on which many tasks are done and those on which multiple workers do a number of small operations. As a line for which EIMON is used to analyze the work, the MELOOK3 camera manufacturing line was selected for the following two reasons: (1) Work analysis is frequently performed and

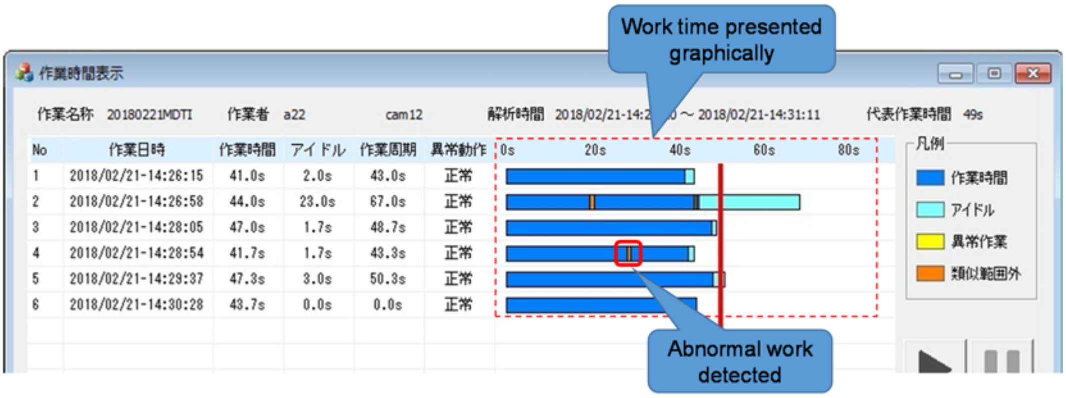

Fig. 6 Analysis result screen

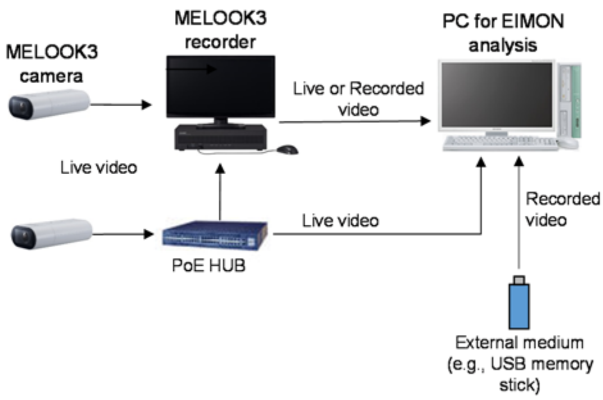

Fig. 7 System configuration

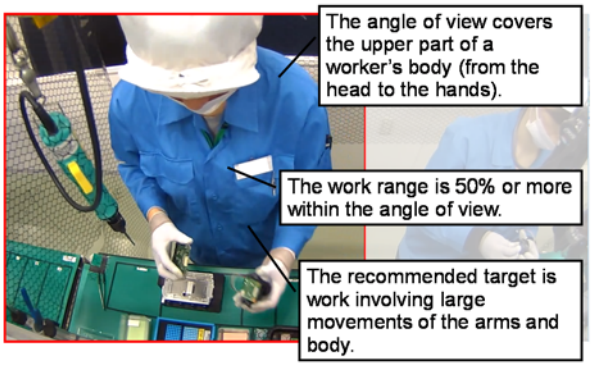

Fig. 8 Angle of view of analysis camera

Table 1 Key points of real-time analysis

Number of streams for analysis	1
Video encoding method	H.264 (High Profile)
Compatible camera	MELOOK3 camera
Compatible recorder	MELOOK3 recorder
Protocol	RTP/UDP
Resolution	1920 × 1080 (FHD)/1280 × 720 (HD)

(2) operations are carried out in a cyclic manner.

4.2 Analysis camera installation

It is important to install analysis cameras so that they can capture movements adequately. We adjusted the angle of view of the camera so that it could capture the upper part of a worker's body including the arms and fingers that are moved particularly frequently, assembly parts, and production tools (Fig. 8).

4.3 Reference video selection

Reference video is essential for work analysis using EIMON. As the reference video, model work in which the tasks were carried out by the predetermined procedure in the normal time was recorded. Then, the start and end of the work cycle were determined and the range of each task was clarified. This was used as the reference video.

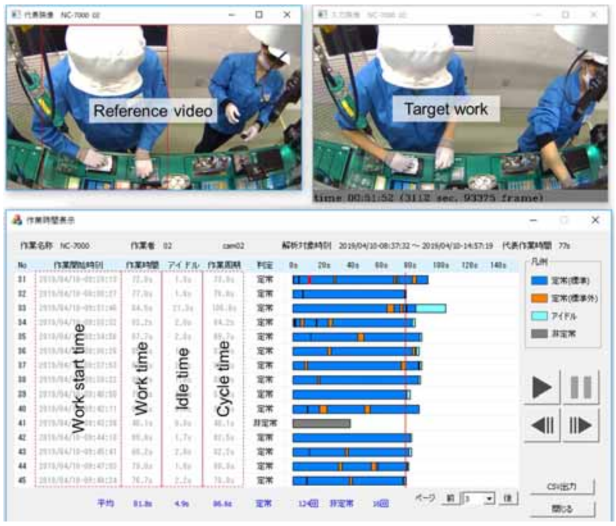

Fig. 9 EIMON analysis

4.4 Work time measurement and abnormal work detection

The MELOOK3 camera production line was shot all day for real-time analysis. The work time measurement function enabled graphing of the work time, which made it easier to see variation in the work cycles. In addition, abnormal work detection results were notified to the worker in real time and thereby abnormal work could be checked on the screen at a glance (Fig. 9).

In conventional visual time measurement, in addition to making the actual measurements themselves, the measured data needed to be organized and plotted on a graph. For example, the manufacturing line used in this study is divided into three processes and the mean work cycle is approximately 90 seconds. Analyzing ten cycles of the work by the human eye would take approximately 45 minutes (90 seconds × 10 cycles × 3 processes), and would take more than an hour including compilation and graphing.

By using EIMON, we could analyze the work in real time and automatically graph the measurement results, reducing the operations by the analyst to a few minutes. EIMON also reduced the workload of the analyst to one tenth or even lower, a remarkable improvement.

4.5 Summary of experimental results

We performed work analysis using EIMON at a manufacturing line at a Mitsubishi Electric factory. As a result, the work time could be measured in real time and automatically graphed, which made the analysis of work time more efficient, and reduced the workload and operation time of the analyst.

In addition, the application has made it possible to detect variations in work time due to irregular work in real time and analyze the work time of all cycles, which used to be impossible, without significant human cost. These improvements help prevent quality problems, solve them quickly, and find new sources of waste and points to be improved, which used to be impossible to find, raising expectations for more efficient manufacturing lines.

Regarding the analysis accuracy, verification at the Mitsubishi Electric factory has confirmed that work cycles can be detected with a high accuracy of approximately 92% and the work time can be measured with a mean error of just 3%. In addition, abnormal work detection allows differences in small movements in work, which used to be difficult to know, to be found promptly.

We found that one factor degrading the analysis accuracy was that movements of workers other than the target worker included in the video affected the generation results of EIMON (Fig. 10). This problem can be solved by optimizing the angle of view and masking the areas of masking the non-target areas.

5. Future Development

The video analysis solution can provide more detailed work analysis by defining elementary operations such as “tightening a screw” and “attaching a label” in advance. Such analysis may make it possible to improve work in a detailed manner by analyzing each elementary operation and extracting bottleneck processes.

We will continue to help raise the productivity of manufacturing lines by improving the analysis accuracy and usability and increasing the product value by performing more demonstration experiments at Mitsubishi Electric factories and actively using the knowledge acquired at manufacturing lines.

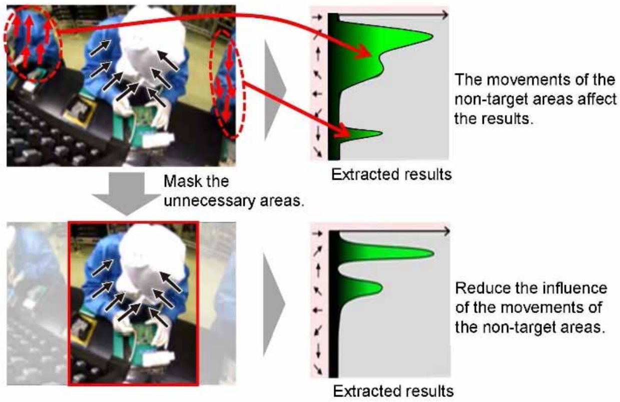

Fig. 10 Effect of movement by non-target workers

6. Conclusion

By combining the EIMON VCA technology with MELOOK3 systems, we have developed a video analysis solution that ranges from taking video to automating abnormal work detection and work time measurement and that can help boost productivity. In addition, the demonstration experiment at a Mitsubishi Electric factory confirmed that the solution can accumulate knowledge through actual operations and also reduce the workload on analysts, showing the usefulness of our solution.

In the future, we will extend the development to create new added values and provide solutions for sectors other than crime prevention by using VCA technologies, while leveraging various VCA technologies involving deep learning and other AI technologies.

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