IoT Solution on Manufacturing Site for Work Support

● Takashi Kanbayashi ● Naomi Momoki ● Takashi Ogami

This paper introduces a solution that Fujitsu proposes as an application of the Internet of Things (IoT) on the manufacturing site. This solution has been put into practice at Shimane Fujitsu, where notebook PCs for corporate use are manufactured to order in small lots. Products manufactured in this plant are custom-made and there are 3,000 types, with each model having 100 to 250 parts. They must be supplied correctly without mix-ups and at the specified timings according to the predefined production sequence. With this situation in the background, we have developed an IoT support tool (hereafter, store picking cart) to facilitate correct and efficient picking work. The development of this solution has its focus on not having human intervention, not requiring a fixed layout (including power supply and LAN wiring) and achieving low-cost operations, and is aimed at continuously improving the manufacturing site. The data gathered using this tool can be linked with the virtual verification tool that we have been offering for some time to carry out cross-simulation. Fujitsu provides this as a solution that can increase the efficiency of manufacturing. This paper presents the *MONOZUKURI* (manufacturing) solution based on IoT utilization practiced by Fujitsu, together with activities for its future expansion and next-generation *MONOZUKURI*.

1. Introduction

In the domain of *MONOZUKURI* (manufacturing), machine-to-machine (M2M) communication, or mutual communication between devices via a network, has been attracting attention since about a decade ago. Up to now, companies in the manufacturing industry have been working on improvement of after-sales services and quality by providing their products with sensors. We have now entered the age of the Internet of Things (IoT), which includes connection between all types of physical objects and people in addition to between devices, and which is drawing interest from outside the manufacturing industry as well.

In this situation, not only Japan but also other major manufacturing powers around the world have started their nationwide activities. Those aimed at rehabilitation of manufacturing such as "Industrie 4.0"[1] of Germany, "Industrial Internet"[2] of the U.S. and "China Manufacturing 2025"[3] of China are gaining momentum. In Japan, the Robot Revolution Realization Council has been founded, and it is attempting a Japanese-led industrial revolution by robots.

Meanwhile, scenes of utilization of IoT assumed on the manufacturing site include improving the manufacturing site and safety, enhancing remote and night-time maintenance services, and monitoring the operational status of machinery and equipment. In addition, creation of new businesses that make the most of plant data can also be expected. Of all activities for utilizing IoT in Fujitsu plants, this paper presents activities for improving the production site and efficiency at Shimane Fujitsu, a group company.

Shimane Fujitsu is engaged in integrated production of notebook PCs in Japan in a multiproduct, high-mix low-volume items from the manufacturing of printed circuit boards to assembly of products. It can manufacture one unit of different products at a time and also has a fully automated integrated line for printed circuit boards. This small-lot mixed-flow production of multiple items is supported by data linking and human-machine collaborative production using radio frequency identification (RFID) tags. This system makes it possible to link between real data from the production site and simulators to realize a cross-verification cycle.

As an example of practice that supports small-lot mixed-flow production of multiple items, this paper presents a solution that links an IoT support tool (hereafter, store picking cart), which uses RFID for supplying parts to the production line, with virtual verification tools (**Figure 1**).

2. Issues with small-lot mixed-flow production of multiple items

At Shimane Fujitsu, notebook PCs for corporate use are manufactured in the order of delivery date. The notebook PCs manufactured here are mainly custom products for different customers containing CPUs and memory chips with a different set of specifications for each customer, amounting to 3,000 types. The number of parts for each model is as large as 100 to 250, which makes it important to supply parts correctly and at the specified timings because half-finished products move in the order of the predefined delivery date.

With this situation in the background, the plant requested a way to resolve the following issues.

1) Focus of attention on product assembly

For workers, providing an environment that helps them to focus their attention on building the products is important and ideally they should be able to work without having to be especially aware of the order of assembly or different types.

2) Ensured supply of parts to assembly process and improvement of picking (selection of parts in units required)

Because the production involves a mixed flow of customized products, part selection errors are not acceptable. Major parts, in particular, must be associated with the correct products. In addition, in order to meet the product takt time, a system that helps workers to efficiently and correctly pick parts from an enormous number of shelves is required.

3) Human-independent system

While ensuring labor has become a major issue recently, work dependent on the capabilities (past experience and individual know-how) of specific workers is not sufficient to accommodate production variations. That is, a system that allows novices to be immediately effective is necessary. With the aim of resolving these issues, we developed a store picking cart according to

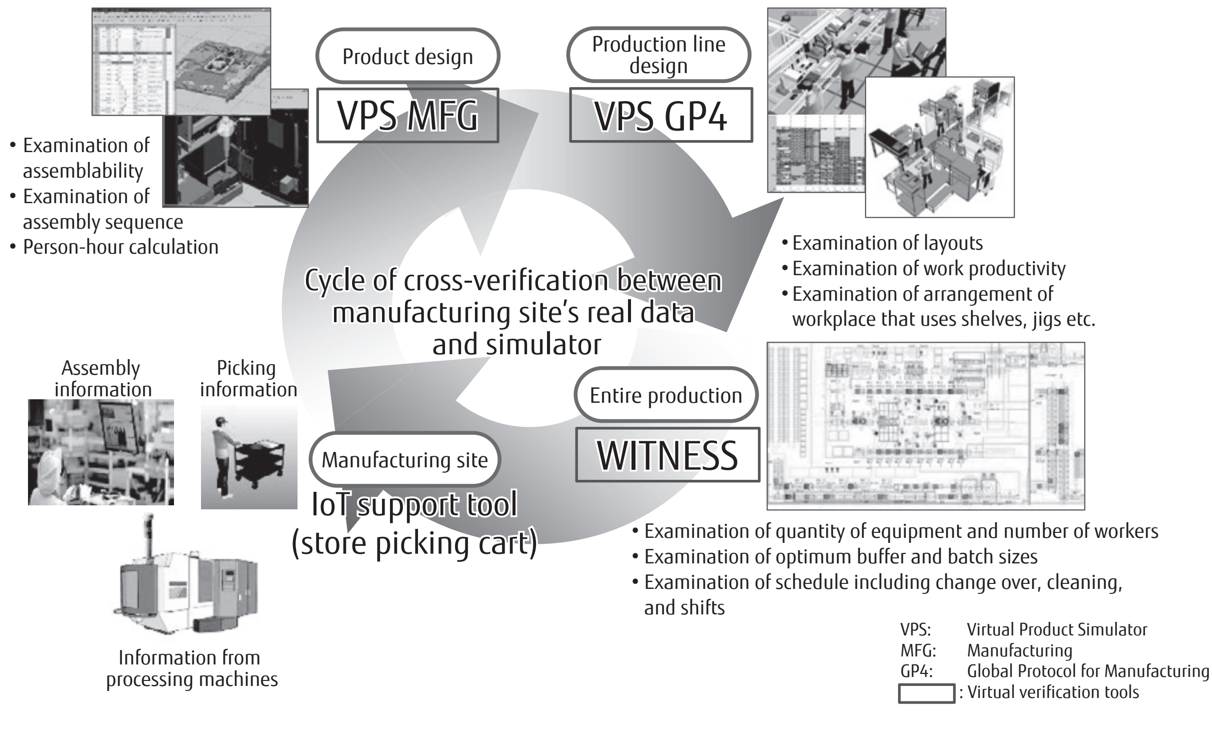

Figure 1
Solution linking IoT support tool (store picking cart) with virtual verification tools.

the development concept as shown in **Figure 2**.

At Shimane Fujitsu, a virtual design verification tool VPS GP4 has been introduced for the purpose of reducing the design time in the upstream process to evaluate the examination of layouts and of flow lines using 3D models before building an actual line. Introducing this tool had the following issues.

1) Visualization of operation

It was necessary to visualize and verify to see if the operation used did not include waste and functioned as initially planned.

2) Acquisition of basic data for improvement

Tools for virtual verification generally require input information prepared in advance such as the product drawings (3D CAD data), production line layout, and order of assembly but preparing all these data newly needed a large amount of labor.

This example shows how these issues can be resolved by developing a store picking cart and linking it with a virtual verification tool.

3. Store picking cart

The store picking cart is positioned as a system independent of the production control system and warehouse management system. It is composed of a combination of devices including:

- management server,
- tablet (on a parts cart),
- wireless access point, and
- RFID reader and RFID tag (using a frequency band of 13.56 MHz).

It can eliminate the need for an expensive mechanism on the picking shelves. The conventional systems that provide picking support are often based on using illumination with lamps mounted on the front of shelves for giving instructions to workers. Specifically, the worker visually checks the location with the lamp illuminated, moves to the shelf and picks a part from the front of the specified shelf. In this case, electrical and LAN wiring must be installed to have the lamps on the shelves come on. Such wiring, once installed, may hinder layout changes required by variations of the production volume, etc.

With the present system, simply pasting RFID tags on the shelves is sufficient, and this significantly reduces the installation cost and does not affect the degree of freedom of layout (**Figure 3**). That is, the picking instruction data sent from the management server are received by tablets mounted on carts and the picking instructions are displayed in order. This mechanism and RFID readers are combined to support the work and maintain the picking quality, which is the feature of the system. The overall flow of operation and data is as described below.

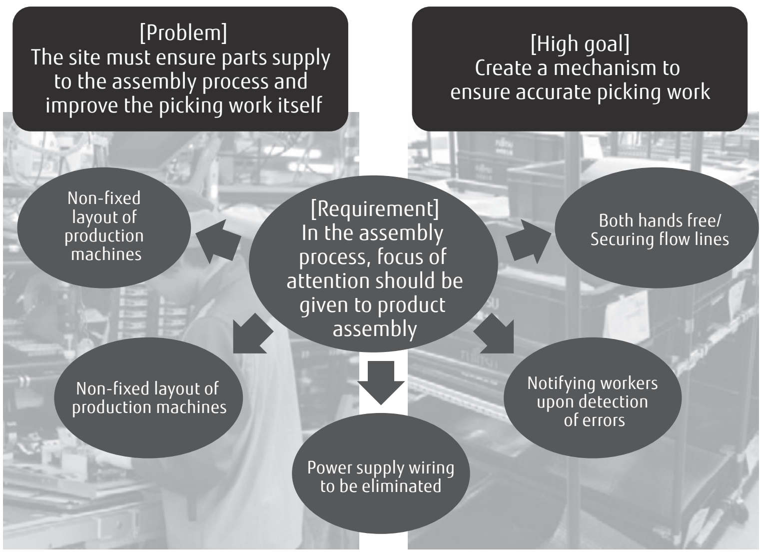

Figure 2
Development concept of IoT support tool (store picking cart).

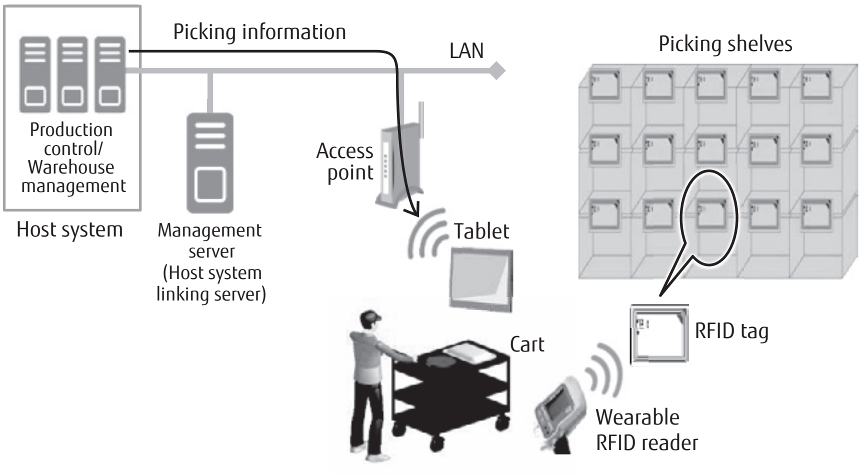

Figure 3
Example of system configuration for store picking cart.

1) Picking information is obtained by the management server.
2) Each worker obtains picking information from the tablet screen via the wireless connection.
3) The worker moves to a shelf according to the picking information displayed and takes a part from the shelf front specified. Any worker who puts his or her hand into a wrong shelf front is notified of the error by vibration.
4) The specified layout location of the part taken out is displayed on the tablet.
5) Information about the next picking is displayed (the subsequent process is repeated).

Data for the picking instructions here are specifically arranged to be shown as information for one part alone. The purpose of this is to show only the information required. This method provides an advantage for skilled workers because it can improve their efficiency of picking by showing information for subsequent work. For unskilled workers or novices, however, the disadvantage of an increased possibility that they will make picking errors due to the greater amount of information to be viewed outweighs the advantage. With this advantage and disadvantage considered, we have narrowed the scope of information displayed.

Standard work time is specified on the manufacturing site and rectifying and synchronizing the flow of goods by meeting the cycle time set in advance is the most important aspect. The point is to establish a system not affected by the skills of workers, or a system without variations of time.

By introducing this system, Shimane Fujitsu has achieved the following items.

1) A 70% reduction in picking and supply errors
    - Errors are pointed out by vibration, which allows novices to work correctly
    - Workers are notified of any wrong shelf chosen by means of vibration, which reduces errors
    - Supply to wrong production lines is prevented because the system gives instructions on which line is to be supplied
2) A 15% reduction in person-hours
    - Processes such as reading the instructions and looking for shelves are eliminated
3) A 40% reduction in the paper operation cost
    - Use of tablets eliminates the need for instructions on paper
    - Instruction information is downloaded in portions to allow prompt response to any unexpected change of plan
    - Use of RFID tags as shelf labels allows parts to be changed only by rewriting data

4. Production-preparation solutions of Fujitsu

As a product lifecycle management (PLM) solution vendor, Fujitsu is the only company in Japan capable of providing strategic integrated solutions for building a next-generation *MONOZUKURI* environment encompassing the entire range of steps from the product planning phase to design and development, processes on the manufacturing site, sales, and support. In addition, most of the products have been commercialized based on the practice within Fujitsu and put to use by large numbers of customers in the manufacturing industry.

Above all, in the domain of production preparation, which is still developing in terms of application of information and communications technology (ICT), operations are conducted by depending on individual skills and they have the following issues.

1) Examination of products

Ease of assembly of products is not considered in the design phase and the burden is shifted to manufacturing.

2) Examination of processes

Examination of layouts is not sufficient and the walking flow lines are not minimized in length.

3) Examination of labor

An excessive number of workers is assigned to supply parts so that the assembly line is not stopped.

To address these three issues respectively, Fujitsu provides product issue solving (VPS MFG), process issue solving [VPS GP4 (GP4 is a global protocol for manufacturing)] and plant issue solving (WITNESS) solutions as digital production-preparation solutions (**Figure 4**). VPS GP4, which is capable of simulating flow lines of workers who supply parts to the line, is described here.

5. Process planning tool VPS GP4

With the conventional process planning, layout planning based on floor plans and planning based on work procedures are common. However, planar drawings and text and numerical information alone are not sufficient as a tool for pre-study. Accordingly, the intentions of the process planner are unlikely to be adequately communicated to the relevant people and achieving those intentions tends to depend on improvements made after the actual line is constructed.

VPS GP4 is a powerful tool for supporting production-preparation operations with a virtual production line that makes use of 3D data. VPS GP4 can construct a production line in a virtual space by using the data owned by a company as existing assets including product drawings (3D CAD data), line layouts (2D drawings and Excel data) and assembly sequence information (Excel data) as input information. It is capable of semi-automatically generating the movements of production line workers and flows of products, which makes it possible to visually evaluate the examination of layouts and of walking flow lines by using 3D models, and in turn to quantitatively measure productivity and workability. Building multiple production lines in reality and picking the optimum one from them is difficult for cost reasons but, by using VPS GP4, multiple production lines can be constructed in a virtual space to decide on the optimum production line.

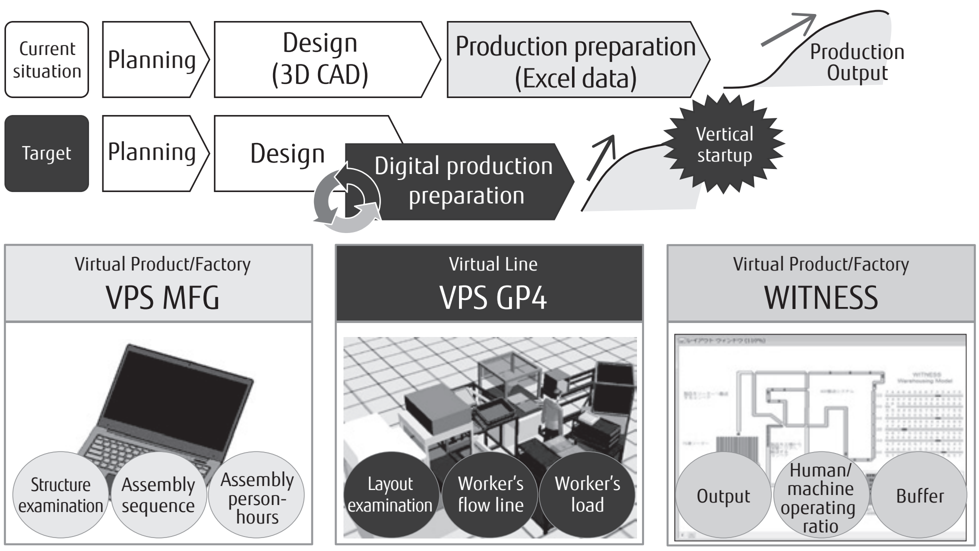

Figure 4
Vertical startup by preparing with digital production.

6. Synergistic effect by solution linking

There are two aims of linking a virtual verification tool with the store picking cart that uses RFID.

1) Visualization of operation

The system is built to record in full who picked what item from which shelf at what time when data are obtained by the store picking cart and these data can be output as the result log data. These result log data can be linked with VPS GP4 to reproduce the actual operation on a virtual screen of VPS GP4. That is, the time taken for each picking process and the picking sequence can be visualized as a walking flow line on the screen for verification. In addition, the dwell times at the respective points can be compared to consider improvement (height and ease of picking) of the shelves themselves.

The most important point here is that this solution linking does not require any special system or operation to achieve visualization. Specifically, it features automatic acquisition of the result log data during the series of processes, which only requires the workers to work as usual for data acquisition, and continuous data acquisition. The point in improvement activities is continuation, and the ability to acquire data without moving the workers around is a major advantage.

2) Acquisition of basic data for improvement

As production life cycles have been becoming shorter or the model mix has been changing, layout changes often take place on the manufacturing site. At such time, if the walking flow lines can be visually evaluated in advance using 3D models to determine the optimum line, the walking flow line sequence can be defined with the store picking cart in advance according to the virtual optimum plan. This allows the user to design and operate a line that mostly meets the purpose from the initial production line launch phase.

7. Future expansion of solution

In addition to improving the efficiency of flow lines and picking work by making use of RFID, Fujitsu is taking an approach of utilizing IoT in the *MONOZUKURI* domain and identifying effective applications to make them into solutions. Specifically, this approach involves visualizing the manufacturing site by using data (such as manufacturing equipment logs and manufacturing performance) related to various events that take place in a plant so as to accelerate the formulation and implementation of improvement measures. The differences between the planned values and performance values are visualized and the log data gathered from sensors are associated with the work plan information on the simulator so that cause-and-effect relationships can be discovered. In this way, information sharing between the management and the manufacturing site, detection of issues for improvement, and simplification of analysis work are realized. In addition, this system allows the workers to directly feel the effect of improvement activities and is used for improving their motivation to work.

Furthermore, verification as described below that make use of IoT is implemented for optimizing production activities. Specifically, Bluetooth Low Energy (BLE) devices are mounted on products to be repaired to visualize their locations and statuses, and the data can be linked with the production control system to instantly grasp the progress of the repair work. This is intended to reduce unnecessary costs by enhancing the quality of manufacturing processes.

In the future, we plan to work on grasping the status of work errors by using image data from the manufacturing site and analyze the cause-and-effect relationship between the status and quality of manufacturing by utilizing data analysis.

In this way, we will gather various types of data from the manufacturing site and combine them with applications already provided or to be newly developed by Fujitsu, and thereby visualize work on the manufacturing site for improving efficiency. We plan to expand the scope of application of this approach to an ecosystem including logistics, suppliers and product users in addition to the manufacturing site.

8. Conclusion

This paper has presented a solution to support small-lot mixed-flow production of multiple items by linking between a store picking cart and a virtual verification tool. Currently, IoT is attracting attention not only from *MONOZUKURI* sites but also other industries. As exemplified by Industrie 4.0 of Germany and Industrial Internet of the U.S. mentioned at the beginning, IoT is at the core of the themes that former major manufacturing powers are working on, and they have their prestige at stake.

For the Japanese manufacturing industry to survive the global competition, Fujitsu intends to develop and offer next-generation *MONOZUKURI* solutions by collaborating with robot manufacturers to improve manufacturing robots and achieve *MONOZUKURI* that utilizes the technology of virtual reality and does not produce physical objects, in addition to the *MONOZUKURI* solutions that have already been provided and the solutions that make use of IoT as introduced by this paper.

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Takashi Kanbayashi
Fujitsu Ltd.
Mr. Kanbayashi is currently engaged in planning and sales promotion of *MONOZUKURI* solutions.

Naomi Momoki
Fujitsu Ltd.
Ms. Momoki is currently engaged in promotion of *MONOZUKURI* solutions.

Takashi Ogami
Fujitsu Ltd.
Mr. Ogami is currently engaged in sales promotion of *MONOZUKURI* solutions.