Reduction of Piping Management Person-Hours through Use of AR Technology at Shipbuilding Sites

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In June 2016, the Ministry of Land, Infrastructure, Transport and Tourism issued the report "Initiatives for the expansion of shipbuilding exports and regional revitalization through productivity revolution in the maritime industry (i-Shipping)." This report sets goals, including achieving a 30% share of the global shipbuilding market by 2025 by utilizing ICT to implement innovation creation and productivity improvements in the maritime industry. In shipbuilding, however, management of things such as piping and related information such as drawings takes an enormous amount of time. To resolve this issue, a system for identifying things and associating them with information through the use of markers is required. Fujitsu made use of augmented reality (AR) technology to develop a piping management system for improving work productivity, including the design, manufacturing, sorting, and installation of piping. In this system, a tablet computer can be held toward an AR marker affixed to an individual pipe to input work records and view installation and other drawings required for work, allowing the reduction of required person-hours. This paper describes the construction of the piping system for Fukuoka Shipbuilding Co., Ltd. as an example of Fujitsu's approach to productivity improvement at a shipbuilding site.

1. Introduction

In June 2016, the Ministry of Land, Infrastructure, Transport and Tourism issued the report "Initiatives for the expansion of shipbuilding exports and regional revitalization through productivity revolution in the maritime industry (i-Shipping)."[1] This report sets goals, including achieving a 30% share of the global shipbuilding market by 2025 through the use of IT to implement innovation creation and productivity improvements in the maritime industry. More specifically, it set targets for "Development/Design," "Shipbuilding," and "Operation," as shown in **Table 1**.[2]

Table 1
Goals for i-Shipping.

Field	Goal
Development & design	• Maintain 20% ship energy efficiency superiority • Halve development period
Shipbuilding	• Increase per capita building volume (on-site productivity) by 50%
Operation	• Eliminate fuel waste • Eliminate ship downtime

In the area of shipbuilding in Japan, productivity has risen thanks to the know-how of engineers. According to the Ministry of Land, Infrastructure, Transport and Tourism, setting annual shipbuilding capacity per capita at 100 gross tons/person for Japan for illustrative purposes, Korea's capacity would be 84 gross tons/person, and China's just 17 gross tons/person.[3] From these figures, shipbuilding efficiency in Japan is high and could be said to be a strength of Japan.

However, while worksite productivity has greatly improved, enormous effort is still required for the management of things such as piping and related information such as drawings and production status. This is due to the fact that, in the case of a medium-sized chemical tanker, for example, the number of parts making up the ship is as high as 10 thousand to 20 thousand hull elements and more than 10 thousand pipes, which all differ in shape and are manufactured as one-off parts. To resolve this issue, a system for identifying things and associating them with information through the use of markers, and a system for inputting and sharing in real time information such as production status, are required.

Therefore, Fujitsu developed a piping management system that manages tens of thousands of pipe items required for shipbuilding and supports on-site workers through the use of augmented reality (AR)[note] technology. Under this system, an AR marker is affixed to each pipe. Workers can read the required information, such as pipe drawings and installation diagrams, by simply scanning the AR marker with their tablet at each work step—design, manufacturing, delivery, sorting, and installation. Further, the pipe production status, installation status, and so on, can be input and shared in real time. This allows improvements in productivity in each manufacturing process.

This paper presents an outline of this piping management system for the improvement of productivity at shipbuilding sites, taking the actual introduction of such a system at Fukuoka Shipbuilding Co., Ltd. (hereafter, Fukuoka Shipbuilding) as an example.

note) Refers to technology that expands and strengthens the human senses by superimposing digital information obtained through the use of ICT to information obtained through the human senses.

2. Impact of poor piping management on worksite productivity

Fukuoka Shipbuilding builds high value-added ships such as chemical tankers and cement carriers at shipyards in Fukuoka and Nagasaki. The company's work consists in carrying out ship design, ordering pipes from external piping fabrication subcontractors (hereafter, subcontractors), having the ordered pipes fabricated and delivered by subcontractors, sorting the pipes, and installing them. In reviewing the productivity of each process, we identified the main points of potential improvement (**Figure 1**).

1) Piping fabrication

Piping ordered by Fukuoka Shipbuilding is produced by a subcontractor, and upon fabrication completion, the control number and other information is filled in in handwriting by the subcontractor. Shipbuilding consists in the fabrication and assembly of parts called blocks that are then assembled on a building berth.[4] However, at present, orders from Fukuoka Shipbuilding to subcontractors are placed in piping system diagram units and not in block units. For that reason, subcontractors fabricate and deliver units in the most convenient order for them from a manufacturing viewpoint. However, since Fukuoka Shipbuilding

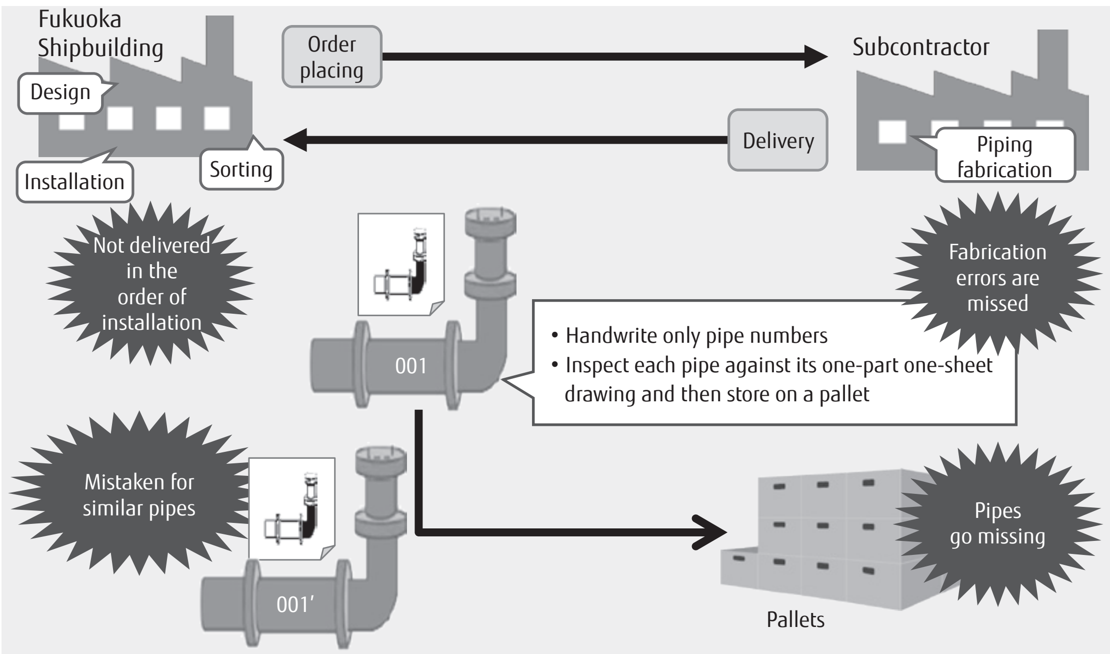


Figure 1
Current operation of Fukuoka Shipbuilding.

requires products in block units in the assembly order, it must request subcontractors to change the order of production.

2) Piping delivery

The subcontractors select pipes and verify that they meet the required specifications as listed in their drawings. Since there are thousands of drawings, many of which are similar, mistakenly selecting the wrong drawing may prevent detection of production mistakes and inspection omissions, and cause rework during installation.

3) Pipe sorting

Fukuoka Shipbuilding checks each pipe and places it on the appropriate pallet (holding the pipes during installation work). For the same reason as that mentioned for delivery, incorrect drawing selection may cause placement of pipes on wrong pallets. Since installation workers take pipes from pallets to carry out the installation work, placing pipes on a wrong pallet causes wasted time spent searching for the correct pipes.

4) Piping installation

The pipes are removed from the pallet and they are installed. Here, pipes that should be on the pallet may be missing to a sorting mistake, or the piping necessary for installation work may not have been made due to the order of production favored by the subcontractor. Also, identifying the installation location of each pipe takes time, and mistakes may be made. Further, Fukuoka Shipbuilding does not know the production status of all pipes, so if there are design changes during production, pipes that have already been made must be discarded and orders for new pipes must be placed. This unnecessarily drives up material costs and shipping costs.

An analysis of the status of each process showed that pipes management and identification were difficult, that pipes and drawings were not linked, making information retrieval difficult, and that information such as production statuses and installation schedules were not shared. As a result, more work was required than necessary, preventing worksite productivity improvements. To remedy this, a system that allows identification of each individual pipe from the time of pipe design, linking of each pipe to its related information, and easy searchability by workers, was required. Along with this, a system that connects Fukuoka Shipbuilding and its subcontractors via a network, and allows input and sharing of piping related information such as production status, was also required.

3. Requirements for pipe identification markers

The identification of individual pipes requires the use of markers of some kind or other, but taking into consideration the work environment peculiar to the shipbuilding industry, such tags are subject to specific performance requirements (**Figure 2**).

1) Excellent water resistance, weather resistance, and heat resistance

Shipyards basically being outdoor environments and the shipbuilding process lasting a long time, physical degradation of markers is a concern as it makes recognition impossible. Moreover, in the case of stickers, peeling is a concern.

2) Resistance to scratches and dust

The stacking of a large number of pipes on each pallet creates an environment conducive to marker damage. Further, in outdoor environments, dust and mud stains decreases the recognition rate.

3) Simultaneous recognition of multiple markers

Since a large number of parts is involved and inspection is time-consuming, functionality capable of recognizing multiple pipes at one time is also a requirement.

Owing to the enormous number of parts, cost must also be considered. In light of the above requirements, the existing technologies of IC tags and QR codes came up as candidates, but IC tags are prone to breaking in the harsh environment of construction sites, and their cost is high. QR codes are also problematic as dirt and scratches make them unreadable.

4. Verification of AR markers for pipe identification

Based on its belief that pipe identification markers satisfying practical use requirements can be achieved through the use of Fujitsu's proprietary AR marker technology (**Table 2**), we developed a prototype and verified its performance.

1) Excellent water resistance, weather resistance, and heat resistance

In collaboration with a sticker manufacturer, we produced an AR markers consisting of a plastic film

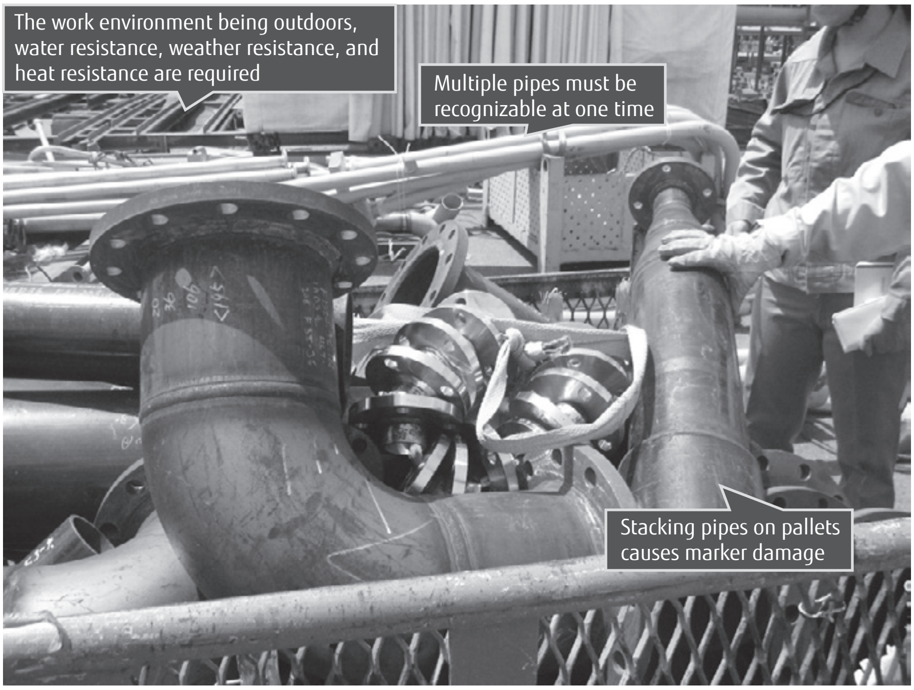
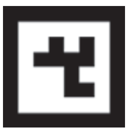
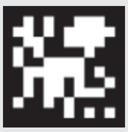


Figure 2
Typical piping storage.

Table 2
Comparison of Fujitsu's AR marker and other markers.

	Fujitsu's AR markers		Conventional markers		
Marker type	8 x 8 modular type	12 x 12 modular type	ARToolKit (free)	Company A (product)	QR code
Number of stored IDs	4,096 max.	999.9 billion max.*2	100 or less	512	90 quadrillion min.
Recognition distance*1	up to 2.0 m	up to 1.4 m	up to 0.75 m	up to 1.4 m	up to 0.4 m
Error correction function (robustness)	Check digit (value check function)	Error correction function (can handle up to approx. 18% missing data)	None	Unknown	Error correction function (selectable correction level: approx. 7% to 30% missing data)
Applications	• For on-site work • For applications that emphasize recognition distance	• AR product standard • For on-site work • For applications that emphasize the number of stored IDs	• Most common AR marker • Popular in research, etc.	Applications, recognition performance, and supported environmental conditions are unknown.	• Only ID storage is considered • It does not have an outer frame, making it difficult to raise the detection position accuracy required for AR.
Marker picture example					

*1: Value measured using Fujitsu F-05D and F-10D smartphones with marker size of 5×5 cm, VGA resolution, brightness of 30 lux or more, and camera angle of 0 degrees to 20 degrees.
*2: Number of IDs equivalent to that on the barcode (JAN-13) on the product, product standard is 10,000 IDs but this number is expandable.

printed with a special ink, and we tested its water resistance and weather resistance. The formulation of the glue used for that marker was adjusted to achieve the desired sticker fastness and removability without leaving glue residue.

2) Resistance to scratches and dust

Verification tests were done using the value check function when reading markers with the FUJITSU Manufacturing Industry Solution PLEMIA MaintenanceViewer. An AR marker was still recognized accurately, even if it had up to 18% of scratching or soiling.

3) Simultaneous recognition of multiple markers

PLEMIA MaintenanceViewer also supports simultaneous recognition. Verification tests showed that up to four AR markers can be recognized simultaneously.

As regards price, existing RFID tags for metal parts cost about 100 yen per tag, whereas AR markers only cost 5 yen each. Considering the huge number of parts involved in building a ship, this is a very significant price difference.

We created AR markers for evaluation purposes and conducted a durability test for three months at Fukuoka Shipbuilding to verify its performance. Based on the results, they decided to use AR markers. The next section describes the piping management system that we built at Fukuoka Shipbuilding.

5. Features of piping management system

The person-hour reduction effect and response to design changes of the piping management system using AR technology (**Figure 3**) are described below (**Figure 4**).

5.1 Person-hour reduction effect

1) Pipes are identified by the affixed AR markers. The operation records of each pipe from its design to its installation can be centrally managed on a server. During piping production, manually sticking an AR marker is less effort than handwriting pipe information as was done heretofore.

2) The worker in charge of a process simply scans the AR marker on each pipe with a tablet's camera

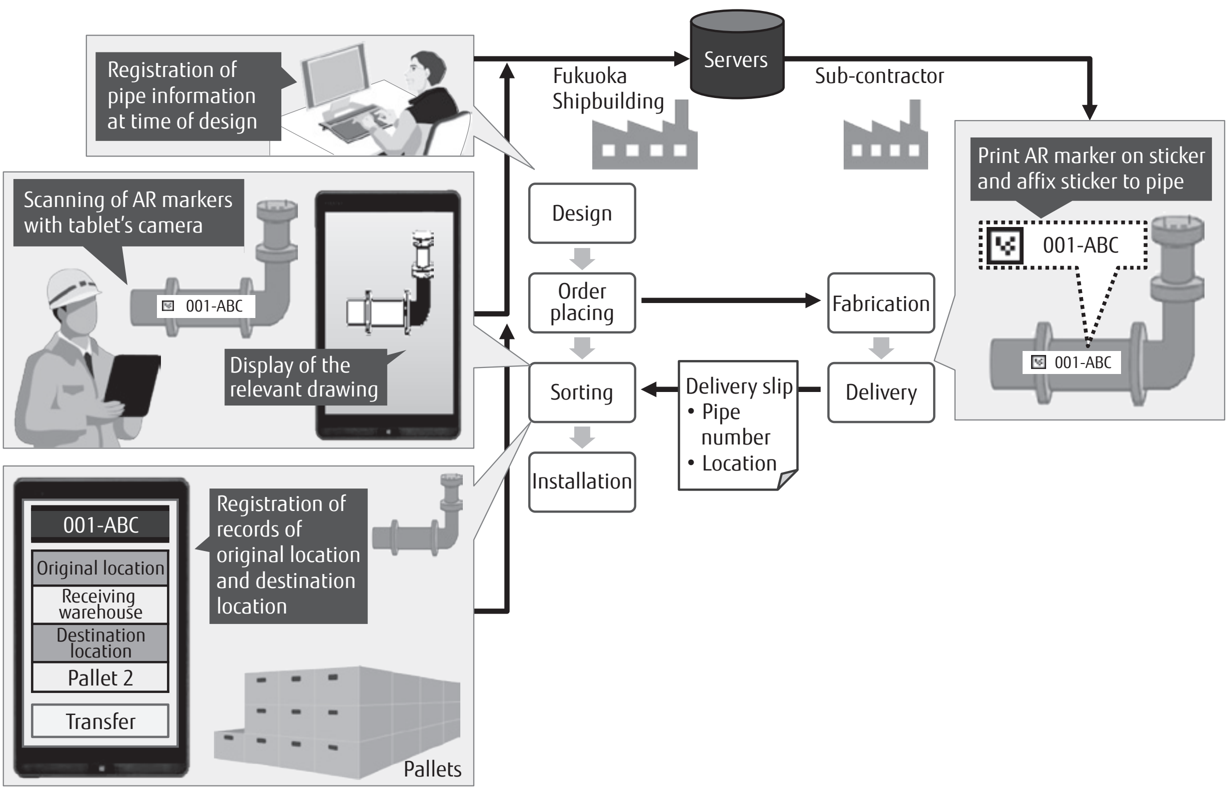


Figure 3
Outline of piping management system.

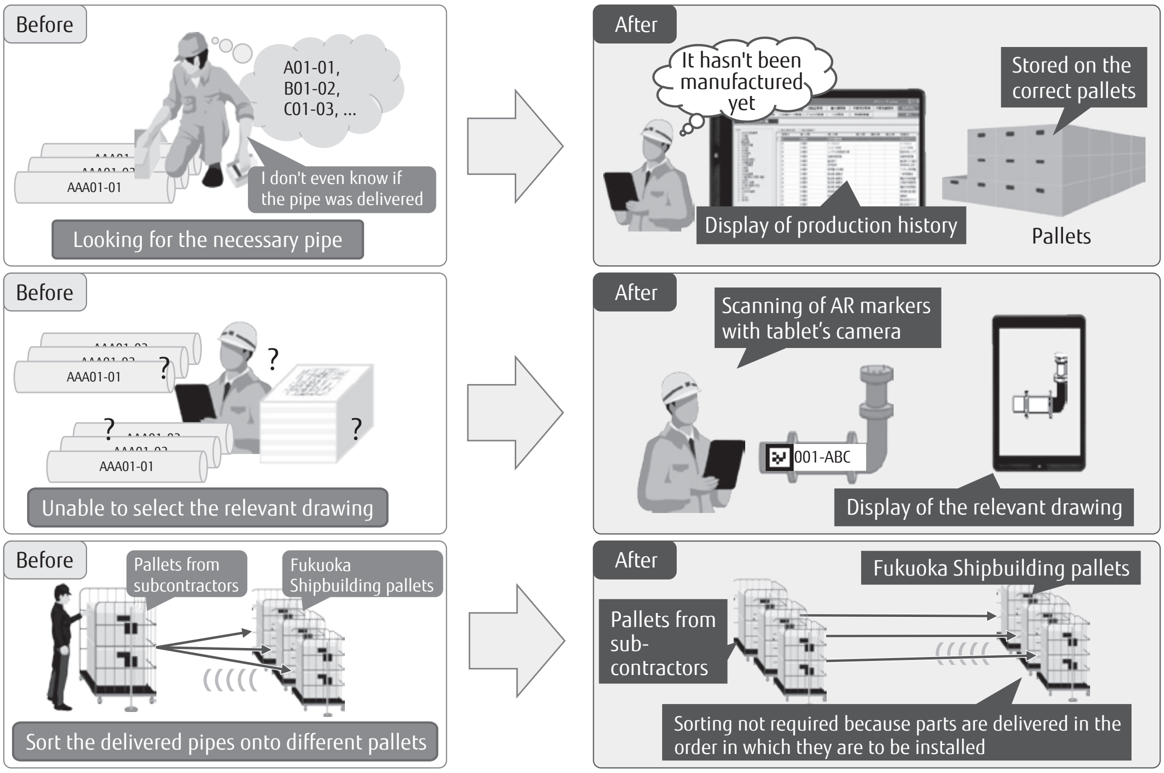


Figure 4
Effect of piping management system.

to record completion of the process. This allows Fukuoka Shipbuilding and subcontractors to share pipe production and installation information in real time. Moreover, this eliminates the need to inspect the actual pipes prior to work, and saves time spent looking for pipes.

3) Information ranging from design to installation is centrally managed on a server. By simply scanning AR markers with their tablet’s camera, workers can easily look up needed information such as pipe drawings and installation diagrams on site. As a result, time spent on the retrieval of drawings at delivery is greatly reduced. Further, since selection of the correct drawing is ensured, production errors are no longer missed and ordered pipes can be reliably manufactured.

4) Connecting Fukuoka Shipbuilding and subcontractors via a network allows them to share information and respond flexibly to schedule and design changes. By sharing installation schedules with subcontractors, deliveries by subcontractors and sorting work at Fukuoka Shipbuilding are unified, eliminating the need to carry out sorting work.

5.2 Response to design changes

When component design changes occur after an order for piping production is placed, it is necessary to investigate the work situation at the departments involved in each process. Until now, this required requesting the remanufacture of piping, but the piping management system makes it possible to know the production status of all pipes in real time.

As a result, it is possible to instruct subcontractors to change their production schedule or to cancel production in the case of an emergency.

6. Future prospects

The piping management system, which focuses solely on piping among ship parts, performs pipe identification and information linking, as well as sharing of information such as piping production status. However, as stated at the beginning, the number of parts that make up a ship is enormous, and management and information sharing for all parts remains to be done. By applying this system to all ship parts, we aim to improve the productivity of the entire shipyard. Furthermore, we believe that this system can be applied not only to the shipbuilding industry, but also to various other industries where parts must be managed, such as the construction industry and the automobile industry.

The main objective of AR technology is to show data superimposed on a real video image captured by the camera of a smart device or the like, using markers as keys. It is advantageous to be able to display information in superimposed fashion on a screen with one marker as compared with existing technologies such as IC tags and QR codes. By placing the information displayed on the screen in a database, any data can be displayed superimposed over actual work images, allowing broad application of AR technology for support of installation work and the like. We plan to conduct to study and implement further improvements in work efficiency through the superimposed display of information.

7. Conclusion

This paper described the features of a piping management system that utilizes AR technology developed by Fujitsu to support productivity at shipyards.

We consider the value of the piping management system to reside not only in the association of things and information and the sharing of piping production and installation status information within a company, but also in the sharing of this information with subcontractors. Going forward, we aim to expand the scope of application of this system to include not only piping but all ship parts, even those made by outside manufacturers, so as to support workers through the superimposed display of information using AR technology for further improvements in productivity and quality.

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