Innovation in On-site Work Using Smart Devices and Augmented Reality Technology

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There is a growing need in the corporate world for improving operations in the field and raising the quality of work through the use of smart devices. To meet this need, Fujitsu provides the FUJITSU Software Interstage AR Processing Server (Interstage AR), which uses augmented reality (AR) technology to overlay digital information obtained via information and communications technology (ICT) on real-world information displayed on a smart device. This product has a variety of features that foster innovation in on-site work. It can improve the accuracy and quality of fieldwork by overlaying information such as operating instructions and manuals needed for on-site operations on screens displaying actual facilities and by providing an intuitive and visually appealing navigation system. In addition, it enables users to input messages while in the field, which improves the accuracy of information passed on to others and facilitates preventive maintenance. Furthermore, it makes work more efficient by incorporating a terminal data cache for offline environments or sites with poor signal reception. These features can produce valuable results for customers, such as shortening work-training periods. This paper introduces Fujitsu's approach to putting this product into actual practice and fostering innovation in customers' on-site work.

1. Introduction

The use of smart devices such as smartphones and tablets has been accelerating in recent years, and, as their functions continue to evolve, the need for using smart devices for business purposes in the corporate world has been growing steadily. For example, there is a growing need for digitizing the paper forms traditionally used for business operations in the field and for linking the digital data collected using them with back-end corporate systems with an eye to improving the quality of work, reducing human error, and improving the quality of customer interaction.

To meet this need, Fujitsu developed and is marketing an augmented reality (AR)[1)] integration platform called FUJITSU Software Interstage AR Processing Server (Interstage AR)[2)–4)] that supports innovation in on-site work through the use of AR technology, which is already widely used in the entertainment industry.

AR is a technology that extends and intensifies the human senses, particularly sight, hearing, and smell, and that supports real-time decision-making and actions in the field. It accomplishes this by overlaying digital information acquired using information and communications technology (ICT) onto real-world information obtained using human senses (**Figure 1**).

This paper describes how Fujitsu is contributing to innovation in its customers' on-site work through the practical application of Interstage AR.

2. Fujitsu's approach

In the entertainment industry, these last few years have seen a dramatic expansion of services using AR technology. For example, there are AR cards for use in "fighting card games" in which holding up a smart device in front of a fighting card will produce a 3D display of a monster or other character. There are also AR concerts in which a virtual performer can be enjoyed by simply pointing a smart device toward the stage in a concert hall and AR commemorative photographs in which the image of a performer can be made to appear by taking a photo that includes a designated object like an information board at an event site.

These developments in the entertainment industry led Fujitsu to consider whether such AR technology could be used to raise the efficiency of operations or improve productivity in the corporate world. Pursuing this possibility, it commenced shipment in August 2013 of Interstage AR, a middleware product that merges the recognition technologies researched and developed over many years at Fujitsu Laboratories Ltd. and the high-reliability and high-availability technologies cultivated at Fujitsu since the host/mainframe era (**Figure 2**). Interstage AR targets operations in the field such as assembly and component mounting on production lines and maintenance and checking in the manufacturing and distribution industries as well as in-store sales. In fact, as shown by case studies involving METAWATER Co., Ltd. and Fujitsu Numazu Plant, Fujitsu was the first in the world to implement AR technology in maintenance and checking tasks.

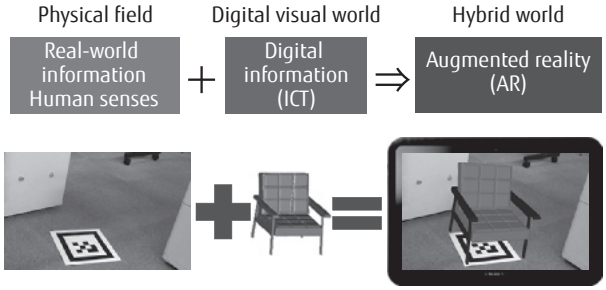

Figure 1
Definition of AR.

3. AR recognition and presentation systems

3.1 AR recognition systems

AR recognition systems can be broadly divided into three types. The features and problem points of each are outlined below.

1) Marker-based image recognition

Systems of this type use a camera mounted on a smart device to recognize a special type of figure or diagram called an "AR marker" that has been attached to a real-world object. The marker is designed to achieve both fast and accurate recognition, and, as a result, its use provides benefits in terms of speed, accuracy, distance, and angle compared with the marker-less image recognition described below. On the other hand, it requires that markers be physically attached to real-world objects, which limits the scope of recognition while also being somewhat inconvenient.

2) Marker-less image recognition

This type of system does not suffer the disadvantage of physically having to attach markers to real-world objects, as is required in marker-based image recognition. It recognizes objects by extracting unique image identifiers (such as feature points) from an image of an object captured beforehand and comparing those identifiers with those of the currently captured image. While such a system eliminates the need to attach markers to real-world objects, the recognition speed drops as the number of objects to be recognized increases.

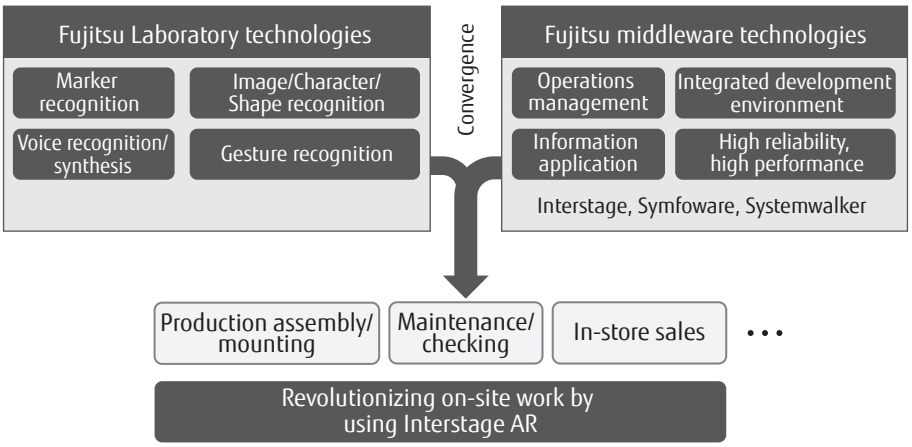

Figure 2
AR targeted by Fujitsu.

3) Location-information recognition

A system of this type uses GPS, acceleration, and geomagnetic sensors mounted on the user's smart device to recognize the user's location, orientation, and direction of movement. This is an effective system when used in outdoor environments in which GPS location information can be accurately obtained, but in urban areas replete with rows of high-rise buildings, the accuracy of such GPS location information is low. Moreover, the system cannot be used where GPS location information cannot be obtained such as some underground and indoor locations. Recently, however, progress has been made in the research and practical application of technologies for determining location in indoor environments by using the intensities of signals from multiple Wi-Fi access points.

3.2 AR presentation systems

Likewise, AR presentation systems can be broadly divided into display systems and projection mapping systems. The following summarizes the features of these two types.

1) Display

Display systems present images on a display monitor or head-mounted display (HMD). They are becoming popular as the use of smart devices expands. Furthermore, for work scenarios in which the user needs to use both hands, the use of wearable terminals such as HMDs that enable hands-free work is being increasingly studied.

2) Projection mapping

As the name implies, projection mapping systems use a projector to project an image onto a real-world object. This enables more than one person to simultaneously view the projected image. However, the projected image may be difficult to see in outdoor sunlit environments in which projector brightness may be deficient.

4. Issues in maintenance and checking tasks at customers' sites

Fujitsu decided to first introduce Interstage AR in maintenance and checking tasks because of the following clear-cut issues in this area.

4.1 High load and low efficiency of maintenance and checking tasks

A large number of facilities and their constituent components targeted for maintenance and checking mean a large workload. In addition, the many round-trips between the field and office that need to be made when a problem occurs such as to pick up manuals tend to increase the costs, worker-hours, and time associated with those tasks.

4.2 Human error

According to a survey[5] conducted by the Japanese Ministry of Economy, Trade and Industry (METI), approximately 80% of industrial accidents can be attributed to human error. This includes bad decisions and reactions, failure to operate facilities as described in manuals, failure to properly reflect new procedures in standard operating procedures (manual defect), and failure to hand down skills and know-how of experienced personnel to young or new workers in the field. This last problem is expected to become even more serious as a large number of skilled personnel are slated to retire by 2020.[6]

4.3 Need for visualizing information beyond human perceptual capability

The on-site installation of a base station for mobile communications, for example, involves the connection of several hundred cables, so erroneous connections and disconnections can occur. Handling such a large number of cables approaches the limit of human abilities, so there is a need for using ICT in some way to visualize and use information that lies beyond the perceptual capability of humans.

5. Problem solutions through Interstage AR

The issues described in the previous section can be resolved by applying the Interstage AR functions described below (**Figure 3**).

5.1 Overlaying of procedures and methods on targets of operations

This function overlays icons on real-world objects in balloon form to display work procedures or present content from operation manuals so that work can be accurately and reliably performed. As a result,

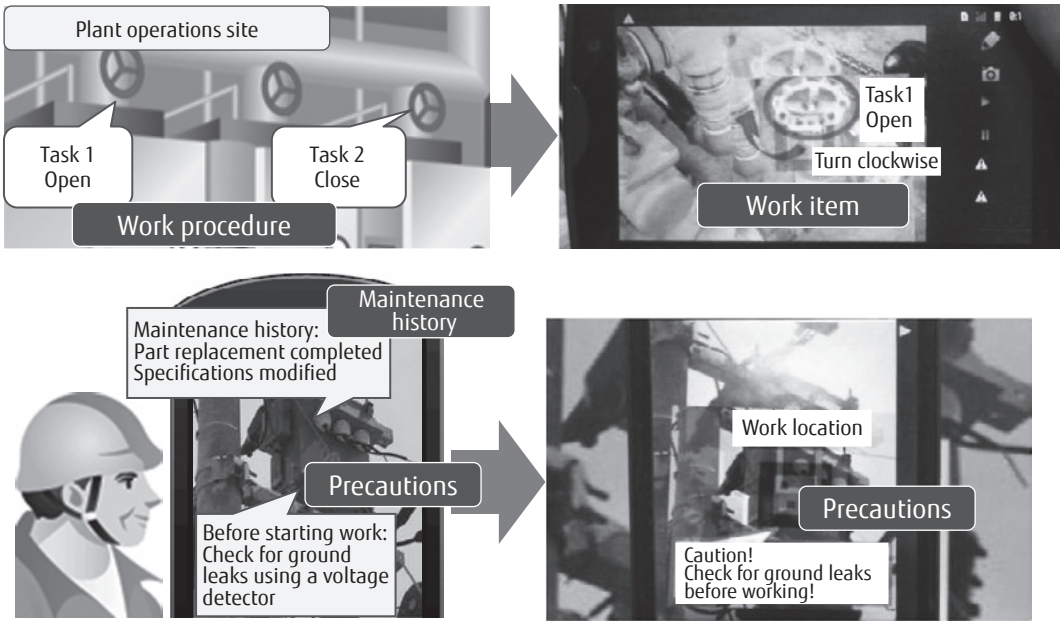

Figure 3
Example of maintenance and checking operations using Interstage AR.

workload in the field can be lightened, and operations can be made more efficient.

5.2 Overlaying of maintenance history

In maintenance work, there are cases in which a worker in the field hands off work to another worker without leaving a status message, resulting in some sort of accident. For this reason, displaying a history of maintenance operations in terms of "who, when, what, and how" before work begins can help prevent human error and eliminate accidents.

5.3 Overlaying of precautions

There are precautions that young or new workers and even skilled personnel can forget, so displaying precautions before work begins such as "Risk of electric shock! Don't touch with wet hands!" and "Don't forget to check for ground leaks using a voltage detector before starting work!" can prevent careless mistakes.

6. Effects of introducing Interstage AR

We here present case studies of introducing Interstage AR in on-site work at METAWATER Co., Ltd. and Fujitsu Numazu Plant.

6.1 Case study: METAWATER Co., Ltd.[7),8)]

METAWATER has been using Interstage AR in the checking of its infrastructure facilities. Previously, when troubleshooting a problem in the field and finding a faulty component, field maintenance personnel were unable to immediately obtain the model number of that component—a critical piece of information, so it took about two months to complete repairs, including checking inventory, submitting an order, and performing other tasks. However, after Interstage AR was introduced, a field worker could immediately see the model number and maintenance history by simply pointing a smart device at the target component, thereby shortening the repair period to as little as two weeks (**Figure 4**).

This approach enables visualization of facilities-management know-how traditionally dependent on the five senses of skilled personnel and the sharing of that know-how with others. Because of these features, Fujitsu received the Good Design Award in fiscal year 2013 from the Japan Institute of Design Promotion, which sponsors this award as a comprehensive design commendation system.[9)]

6.2 Case study: Fujitsu Numazu Plant[10)]

The following effects were obtained after

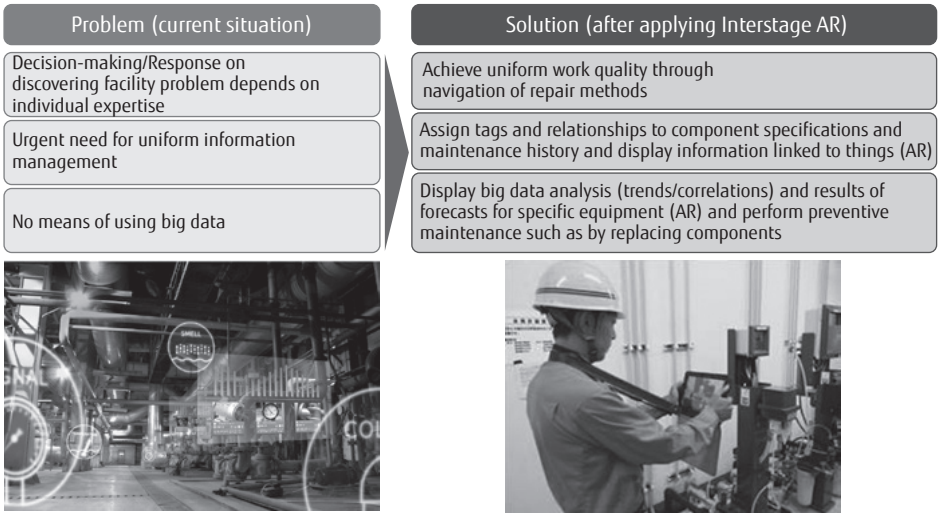

Figure 4
Case study: Maintenance and checking of water and sewage infrastructure at METAWATER.

introducing Interstage AR in on-site work consisting of daily daytime and nighttime checking service of plant facilities such as refrigerating equipment and cooling water pumps.

1) Variation existed in the way that problems were handled between skilled personnel and young or new workers. While a skilled individual could detect the presence of a problem and respond accordingly on the basis of experience and intuition, there were times when young or new workers would either not notice the occurrence of a problem or would not know how to respond to it. On introducing Interstage AR in response to this situation, the occurrence of an event such as "the difference between the condensate outlet temperature and the inlet temperature has become small" could result in the display of information from a skilled individual's maintenance history such as "Remove the scale deposits from the inside of the tubing." In this way, even young or new workers could assess problems in the field and respond accordingly. Interstage AR has therefore succeeded in standardizing work procedures and raising the quality of operations in the field.
2) On discovering a water leak or other problem in the field, a maintenance worker would conventionally return to the office and record the incident on a whiteboard. This information therefore relied on an individual's memory, so there were cases in which accurate reports could not be prepared or smooth handing over of work to others could not be done. This problem was addressed by using the ability of Interstage AR to accurately record and display information at the right place in the field. Specifically, in a manner analogous to pasting a sticky note on 3D space, the field worker could now input "water leak discovered" while still at the location where the leak was discovered. This approach enables accurate and reliable handing over of work and passing of messages, and in this way, Interstage AR has succeeded in improving the accuracy and quality of work.
3) Paper-based forms that record the results of checking or the replacing of components must be filed and archived at the office. This practice makes it difficult for other maintenance workers to find and review those records and increases the number of worker-hours and expenses for corrective maintenance in response to a sudden failure in facilities. The problem was addressed by having maintenance workers input the results of daily checking tasks from their smart devices using Interstage AR. As a result, workers can now check the daily transition of checking results for a one-week period using a dashboard display. Additionally, by simply pointing their smart

device at a facility targeted for equipment check, they can view a display showing temperature trends in that facility for one week on a line graph as well as messages and handover items from the previous workers (**Figure 5**). For example, if this display showed a gradual rise in the temperature of cooling water, a maintenance worker could conclude that the cooling ability of that refrigerating equipment was decreasing even if the upper or lower threshold values had not yet been reached. This feature has made it possible for even young or new workers in the field to judge whether a switch-over to large-capacity refrigerating equipment is needed.

While operations before Interstage AR was introduced depended on paper and individual skills and know-how, the above case studies show that the introduction of Interstage AR has succeeded in standardizing work procedures and raising the quality of maintenance work by digitizing all forms of data and manuals. It has succeeded, in particular, in raising work efficiency through paperless operations by 10%, reducing downtime at the time of a problem occurrence by 1/6, and reducing "near misses" in terms of accidents by 60%.

In addition to the effects described in the above case studies, the benefits listed below can also be expected by introducing Interstage AR.

- Inventory data production results, and maintenance history managed by back-end systems can be accessed in real time from the field.
- Raw data input at the front end such as results of checking in the field can be reflected and fed back to corporate back-end systems in real time, enabling real-time bidirectional use of data between those front- and back-end systems.
- In conventional ICT systems, data in the field and data managed by back-end ICT systems have had an independent relationship, which means that workers in the field have had to search for information on facilities management systems and establish a correspondence between that information and the equipment of concern. Interstage AR, however, enables a worker to obtain needed data by simply pointing a smart device at that equipment, resulting in a significant improvement in data accessibility.

7. Advantages of Interstage AR

In this section, we describe the advantages of Interstage AR provided by Fujitsu and the points of differentiation with those provided by other companies and that achieved using open-source software (OSS).

1) Optimal display of information by context such as business/work task

AR is generally understood as simply a means of overlaying information on real-world scenes. In contrast, Fujitsu's Interstage AR makes it possible to display information optimized for the user or type of business

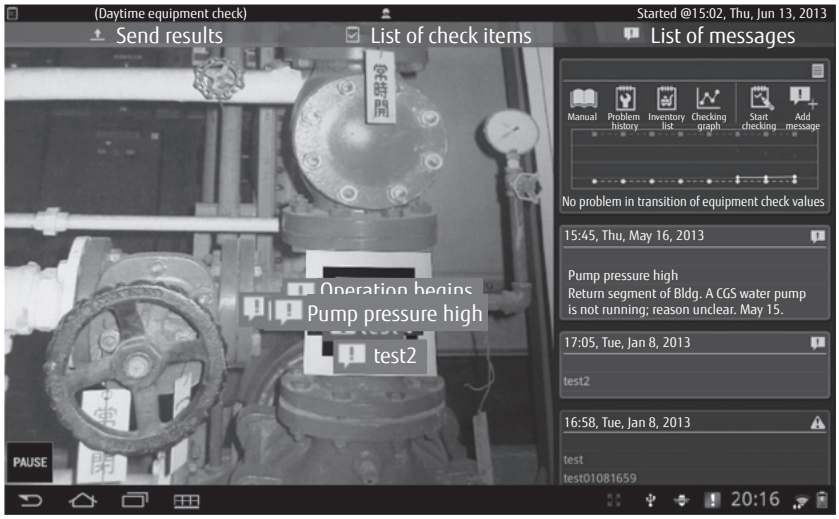

Figure 5
Case study: Daily equipment check service at Fujitsu Numazu Plant.

operation, that is, to switch from one type of display to another as needed. For example, an equipment check worker who points a smart device at a marker attached to the equipment in question would be presented with a check result input form, while a maintenance worker who points a smart device at the same marker would be presented with step-by-step guidance and navigation assistance for the maintenance tasks to be performed.

2) Robust recognition technology for business use (AR markers)

The use of bar codes or quick response (QR) Codes[11] has usually been difficult in outdoor environments exposed to direct sunlight due to "wash out" phenomena in imaging or in dimly-lit underground plant facilities in which camera shaking can occur due to long exposure times. Fujitsu's proprietary AR markers feature robust performance with respect to diverse lighting conditions and recognition distances and can thus be recognized even under difficult environmental conditions. It is also possible to combine object recognition based on AR markers with that based on GPS location information.

3) Content creation through intuitive operations

In the past, developing new content using AR technology took a specialized AR content creator several months at a cost of several tens of millions of yen, and on top of that, users themselves could not add or modify content. Fujitsu's Interstage AR provides a variety of functions supporting the content creation process. For example, it enables a user to select previously prepared tools (character strings, image files, handwriting function, etc.) and arrange text or graphics on the screen using intuitive operations or gestures like pinch/spread and to easily register documents or video clips that users will be able to view through a simple icon-tapping operation. These functions also enable maintenance workers themselves to add, modify, or enhance content in the field without having to depend on content creators for content development.

4) Support of on-site work in an offline environment

On the basis of the results of responding to several hundred customer requests and inquiries, we have learned that there are many sites where public network circuits such as those of 3G/LTE and Wi-Fi cannot be used since those signals could cause erroneous operations in equipment. However, such sites, which include chemical plants, power generation facilities, and underground facilities, usually have a great need for AR functions. In response to this problem, Interstage AR provides a terminal data-cache function that enables server data to be cached in a smart device at locations like the user's office where network circuits can be used and then to be used later in the field as needed.

5) Application development independent of smart devices

In conventional mobile application development, applications have had to run under major OSs, namely Android, iOS, and Windows. This situation, however, has raised concerns about drops in efficiency, productivity, and maintainability in development work. Interstage AR provides a development environment and execution platform that enable applications to be developed using HTML, with which most developers are familiar, which means that developed applications can run under different OSs. The end result has been a dramatic improvement in development efficiency, productivity, and maintainability.

8. New challenges in expanding business

New issues appeared after putting Interstage AR into actual operation in the field.

On-site work using AR in chemical plants, for example, require the provision of smart devices and wearable terminals conforming to explosion-proof, dust-proof, and waterproof standards. Furthermore, on-site work that requires the use of both hands as in an oil refinery calls for a hands-free setup to maintain a safe and secure environment for field workers. There is thus a need for the ability to use AR with wearable terminals.

In addition, there are certain requirements associated with work like the installation of base stations for mobile communications carriers that involves a certain amount of danger and requires a double-check system by a pair of workers. This could be accomplished, for example, by providing a remote back-end support function that enables experienced personnel in a central monitoring room to share images with less experienced workers in the field to confirm work procedures.

There are also some situations in which AR markers cannot be attached to equipment such as food-processing lines in the food manufacturing industry due to the risk of contamination by foreign material

or because of a high-temperature/high-humidity environment. There is thus a need for specifications that would enable the user to select a recognition technique optimal for the target environment such as marker-less image recognition, character recognition, and voice recognition.

Going forward, in addition to revising specifications and adding functions to resolve these issues, we aim to expand business even further from business-to-business to business-to-consumer.

9. Conclusion

This paper described FUJITSU Software Interstage AR Processing Server (Interstage AR) for driving innovation in on-site work using AR technology.

At Fujitsu, we will continue to apply the Interstage AR product to on-site work on the basis of know-how accumulated through actual implementations at customer sites and on the experience gained through in-house practices at Fujitsu. In this way, we seek to enhance capabilities in the field using business as a starting point, provide our customers with effective solutions to raise their competitiveness, and contribute to business innovation.

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