MR-based Equipment Remote Control and 3D Digital Working Guidance for Field-oriented Maintenance

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Abstract –

Recently, as technologies combine, AR (Augmen ted Reality)/VR(Virtual Reality)/MR(Mixed Reality) and advanced sensing equipment are being developed. The possibilities of their application to construction fields is likewise increasing. Research into applying these techniques to facility maintenance, manager training, and safety/evacuation training is being actively conducted. In the case of the existing facility maintenance process, it is difficult to identify the exact management matters and departments that have problems during facility inspection or history management. In the case of complex equipment, it is necessary to respond to equipment maintenance needs through real-time support technology with on-site workers due to the difficulty of promptly dispatching related advanced equipment experts. In addition, digitization of the maintenance manual is required for time, cost and losses to be minimized due to equipment downtime; to improve understanding, thus proper utilization, of non-specialist facilities maintenance and work safety through realistic work guidance based on 3D content. Therefore, in this study, we propose MR-based remotely controlled technology, real-time worker decision-making and work performance support technology for process improvement, preventing quality problems in the field manager-centered equipment inspection maintenance.

Keywords –

Augmented Reality; Mixed Reality; BIM; Working Guidance

1 Introduction

1.1 Research Background and Purpose

Research into application of AR/VR/MR technologies in various ways are also being actively conducted in the construction field. In particular, studies are being conducted to apply such technology in semiconductor and battery factories, where demand continues to increase due to the rapidly accelerating technological development and the fourth industrial revolution.

Plant construction projects are large and involve complex maintenance activities. Therefore, they have a higher project cost than other construction projects and require efficiency in maintenance.

In the construction of battery and semiconductor plants, a huge amount of data is produced at various stages of operation due to complicated internal design, pipe installation, electricity, and other facilities; with many studies being conducted to efficiently maintain them.

As major research for enhancing the work efficiency of plant workers, research on information management systems using QR codes, barcodes, radio frequency identification (RFID), and cloud system technologies is actively being conducted.

However, these technologies make it difficult to provide visually intuitive information to workers, which increases the incidence of human errors. These problems extend the working time at the plant site and cause task revisions.

This study develops a suitable MR-based 3D digital working guidance system through analysis of the maintenance work process at the plant site based on the opinions of practitioners and presents a worker-oriented maintenance work process.

At the existing plant site, workers have performed inefficient operation management tasks due to lack of intuitive work information visualization systems and lack of interoperability due to the dualization of construction sites and offices. In addition, the worker had difficulties in communication with the manager due to the complex plant design. In order to solve this problem, this study draws a plant field maintenance plan for effective equipment location and installation by using a Mixed Reality-based smart device for general equipment maintenance work of the plant.

1.2 The Scope and Methods of Research

This study proposes a 3D digital working guidance system for workers using AR-based smart devices at the plant site. At the plant site, workers have performed maintenance work based on past information and manuals. Currently, due to extensive and complex plant field work, difficulties arise in actual work. The typical maintenance tasks of unskilled worker include difficulties in figuring out the route due to the wide range of plant sites, and human error occurs when replacing equipment. Therefore, in the case of maintenance work, it needs an information exchange system that can intuitively communicate the exact plant site situation between the worker and the manager. Therefore, this study intended to solve such problem through an AR-based smart device.

The method and process of this research is:
(1) Preceding Research Analysis
- Existing review of literature
- Analysis of management characteristic of plant maintenance and process
(2) Requirement Analysis and Function Derivation
- Figuring out smart device applicability in the plant field
- Requirement analysis to solve problems
(3) Establishing MR-based 3D digital working guidance for optimal plant maintenance
- Process Analysis of Plant maintenance
- Analysis of maintenance Work at Plant Site
- MR-Based Equipment Assembly Management Process
(4) MR-based 3D digital Technology at Plant Site.

2 Research Trend

2.1 Literature Review

From the mid-2000s, much research has been carried out in order to derive improvements to general interests in the construction industry such as shortening the construction period, cost reduction, flawless construction, accident-free planning, predictability improvement, waste factor elimination, productivity improvement, and maintenance cost reduction through the use of various IT technologies.

The table below shows some of the existing research pertaining to the subject of smart, IT-based construction. This research focused on the exchange and maintenance of construction information for smooth installation of facility equipment among participants in the project in relation to the plant maintenance process. The process is illustrated in Figure 1.

Table 1. Existing research

Area of management	Research subjects
Construction	Ontology-based BIM modeling; AR-based system framework
Site condition	4D tools for greater efficiency in site management
	Use of smart phone to improve management process; visualization of project information using real-time data sharing and management, wireless communication; and augmented reality
Safety	New 4D safety management and monitoring system ‘C-RTICS2’ for more efficient construction and communication among work partners
	Behavior-based preventive safety system, visualized management with VCS (Virtual Construction Simulation System)
	Note
Construction	Marker-based AR: Research on identification of objects, selection of marker type, marker detection, and marker-less AR technology
Site condition	Wearable device for real-time work coordination
	Wearable device; Cloud system for massive data management
Safety	Set apart in terms of device and visualization method, while similar in technology for communication between office and construction site
	Partly applicable to safety management in terms of carrying out preventive safety management in visualized form

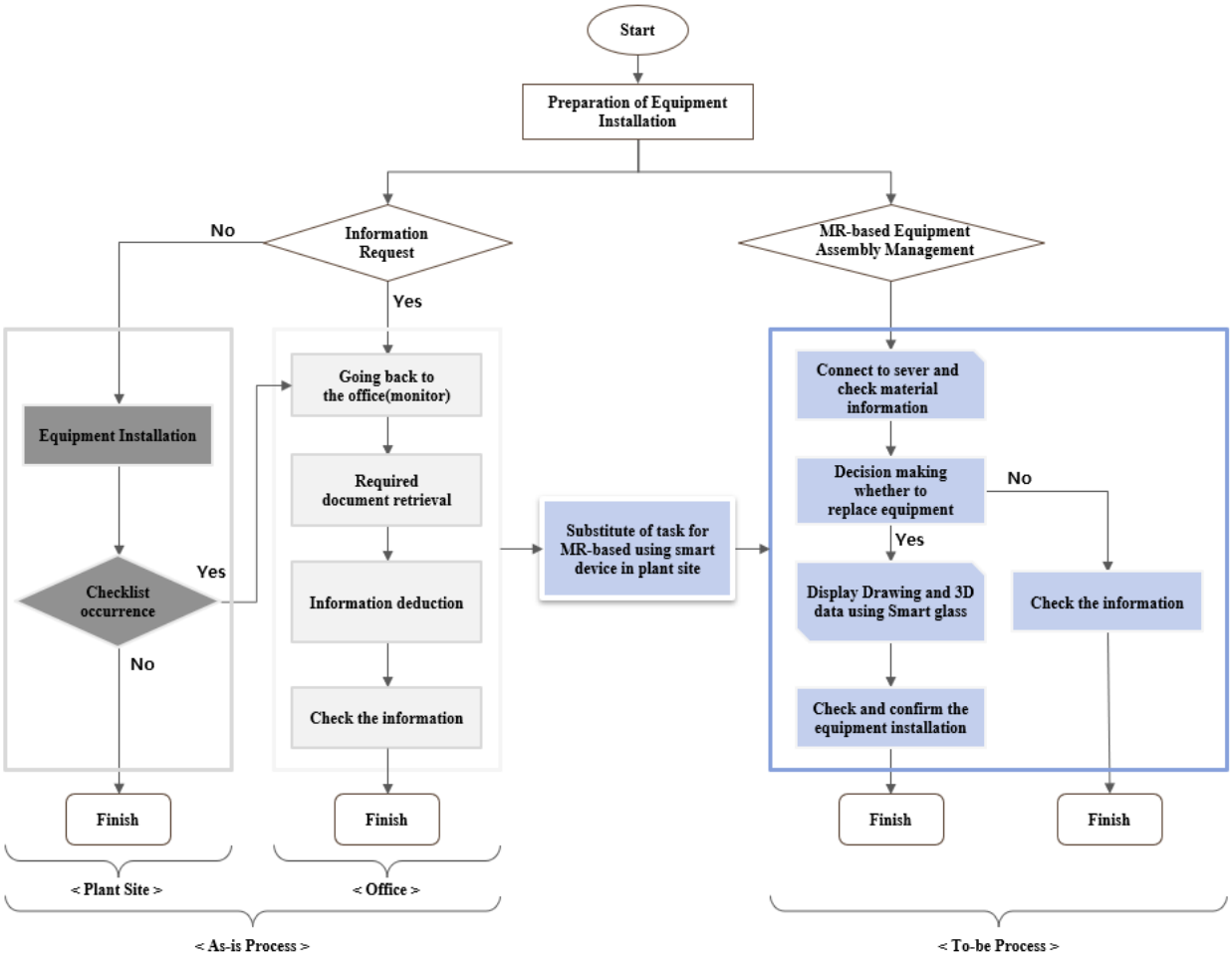


Figure 1. Improved Plant Site Management Process

2.2 Plant Maintenance Management

The equipment replacement procedure at the existing plant site differs depending on the method of obtaining equipment replacement work information. When the worker no longer needs to obtain work information, the worker goes to the site to proceed and finish the work. However, in the event of an unusual occurrence in the middle of the work or when the manager orders the work in the middle, the worker needs a means to receive information. In this case, if the information is complicated, face-to-face communication between workers and managers is needed, or a visualization information sharing system for work orders is required.

In the improved process based on the Mixed Reality, it is possible to intuitively figure out information through 3D digital working guidance during the process of equipment replacement work, and even unskilled worker can more easily understand the work to reduce the occurrence of human error.

3 Analysis of plant workers' needs

According to Moon (2015)[1], as a result of conducting site surveys and interviews with major construction company in Korea, "S", the Construction Assistance App, Data confirmation and check App, Guideline App, and especially Communication support App and Progress Management App at the plant site were found to be required. These territories are tabularized below. This shows that the MR-based smart device system for workers is required to share information at the plant site.

Table 2. Applicable work territories

Direction	Contents
1	Construction Assistance App.
2	Data confirmation and check App.
3	Data input App.
4	Guideline App.
5	Communication support App.

6	Progress management App.

During the materials management and product installation process at the plant site, workers need drawings and related information data. At this time, the information provided exists in various forms and is visualized in various ways and delivered to the worker. When one data is converted, new conversion information is generated by deriving from other data in real time. Various applications of smart devices must be provided to support this.

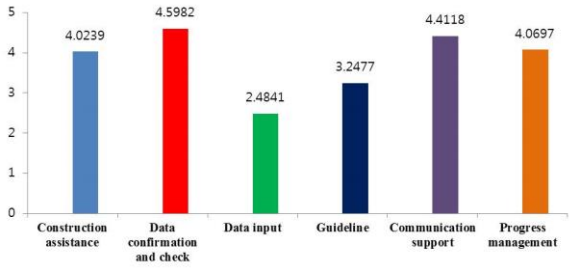


Figure 2. Overall result

4 MR-based 3D Digital Working Guidance

4.1 Worker Equipment Replacement Process Analysis in Plant Site

Through an interview with the Battery Plant Equipment Management Team at the battery plant site in Korea, a detailed work process of the worker was derived from the Mixed Reality-based to-be process.

Workers are assigned to equipment management tasks, identify the location of the target equipment, and move to the site. In addition, the state of the equipment is determined through visual inspection and it is determined whether the equipment is replaced. If it is necessary to replace the equipment, he/she selects a replacement and records the reason. Subsequently, a procedure for applying for replacement equipment is carried out, and another colleague carries the replacement equipment and delivers it to the work site. In the field, the operation of existing equipment will be stopped, and the equipment disassembled. The disassembled equipment is returned according to the return procedure, and new equipment is installed by determining the presence of abnormalities. When the installation of new equipment is completed, the test operation will be performed, and the test operation will be made for diagnosing the normal operation.

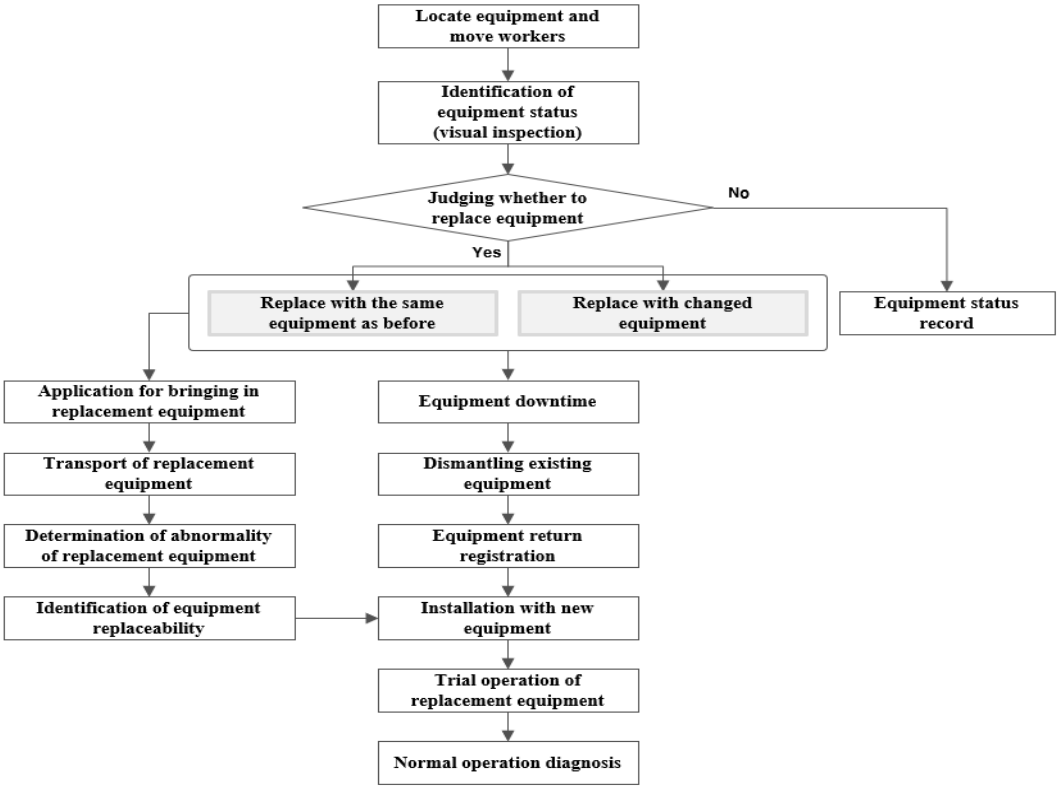


Figure 3. Worker Equipment Replacement Process

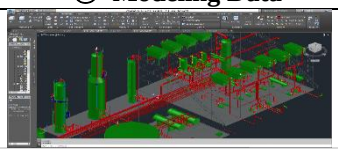
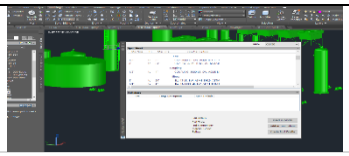
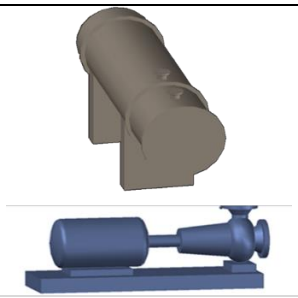
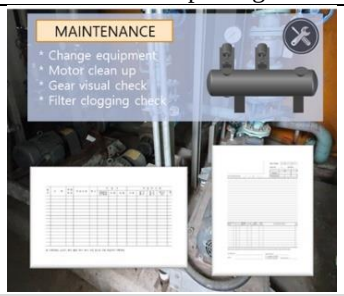
4.2 Usage of AR Data in the plant site

The data types that can be used in the detailed equipment management process based on the mixed reality derived above are classified into four types: 1) modeling data, 2) attribute information data, 3) AR data, and 4) job reporting data.

Modeling data and attribute information data can be extracted from BIM data. BIM data was converted to 3D model-based neutral file format (fbx, ojb) and then mapped to be usable in the AR environment. Also, the modeling data can be used to check the optimal path for operator's navigator and equipment transportation at the plant site, and to check interference between members. The attribute information data can identify the performance of the installed equipment or the cost information, replacement cycle, and the like.

AR data in the form of 3D model can be used to guide the on-the-spot movement route based on a digital map, work sequence guide, and to understand the current state of the equipment. The worker can always record the work contents in the work report data to check the past records of the activities in the field and to understand the operation information of how it is currently operating.

Table 3. Applicable work territories

	① **Modeling Data**
Image	
Type	3D Model
Utilization	1. Use as a digital map on site 2. Equipment type can be checked 3. Check the optimal path for equipment transportation 4. Interference check between members
	② Attribute Information Data
Image	
Type	Object Specification
Utilization	1. Identify the performance of equipment 2. Identify the replacement cycle of equipment 3. Equipment unit price information
	③ AR Data
Image	
Type	3D Model
Utilization	1. Identify the current position of the operator(Based on Device's GPS data) 2. Guidance on the on-site route 3. Guide to the sequence 4. Guidance on current status of equipment
	④ Task Reporting Data
Image	
Type	Work Sheet
Utilization	1. Confirmation of historical information 2. Records of workers' work activities 3. Checking factory operation information

4.3 AR Data-based workspace and equipment replacement procedure

The four types of data classified above can be divided to data available for each step in the worker equipment replacement process analyzed above. Each worker equipment maintenance procedure is divided into three groups as shown in Figure 4. : 'Decision to replace equipment', 'Procedure for returning existing equipment, and 'New equipment replacement procedure', and AR data has high utilization in 'Decision of equipment replacement' and 'New equipment replacement procedure' respectively.

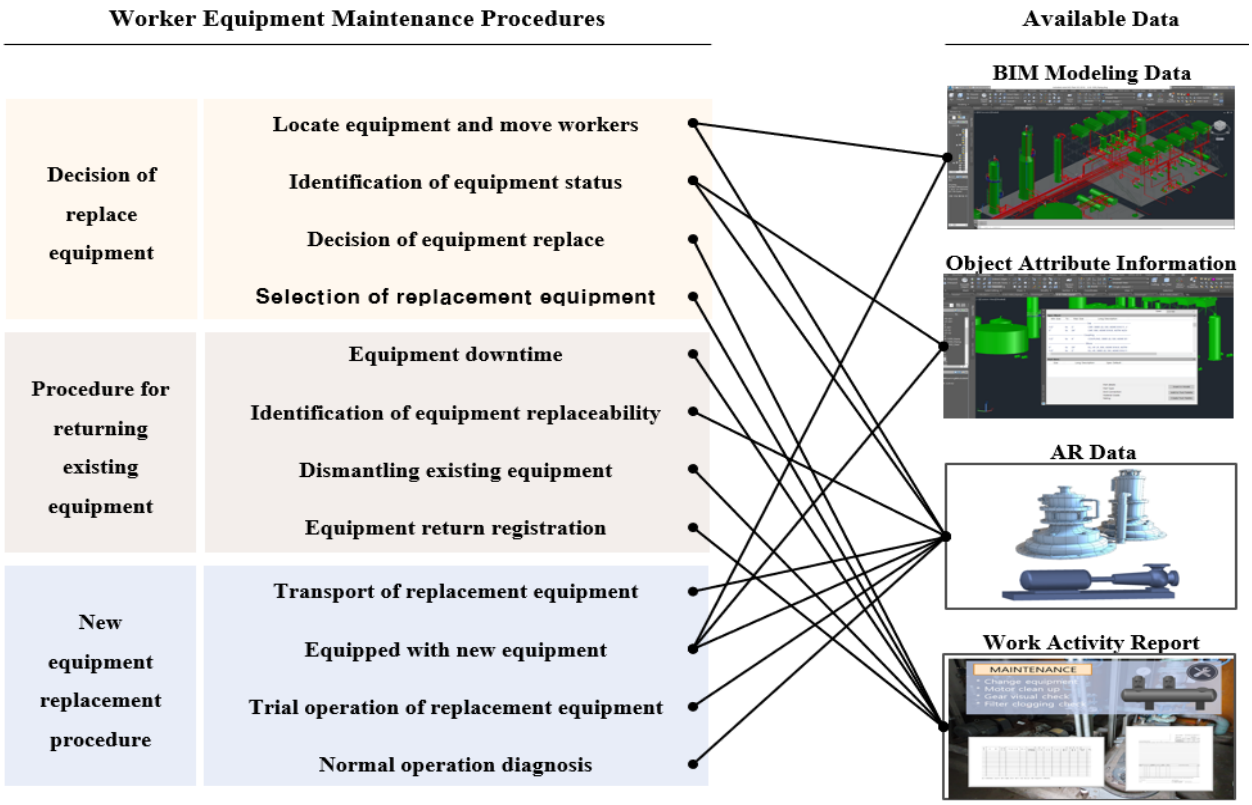


Figure 4. Matching of available data and equipment replacement procedure

When the work activity report is visualized as an AR image, the utilization of AR data is also increased in the 'Procedure for returning existing equipment' stage, and the AR visualization data is used in the overall worker equipment replacement process.

Therefore, BIM Modeling Data and Object Attribute Information can be used as data to implement AR Data. AR Data and Work Activity Report Data implemented based on this can be visualized in AR and used in 3D digital working guidance, as the example in Figure 5. illustrates.

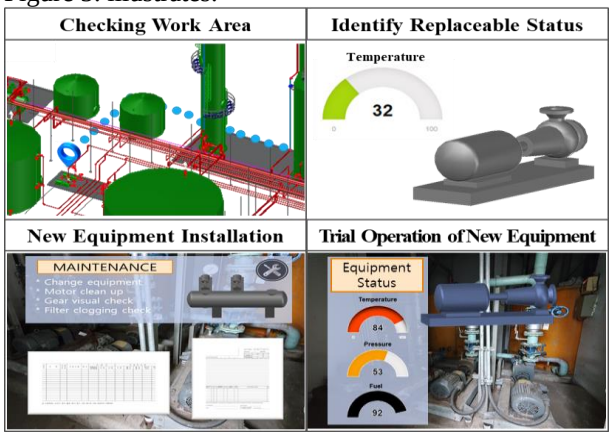


Figure 5. Main application methods of MR-based 3D digital working guidance

5 3D Digital Working Guidance in Plant Site

A 3D digital working guidance test-bed system was implemented in accordance with the Worker Equipment Replacement Process Analysis previously analyzed, and the MR-based work environment was tested based on the equipment replacement work generally performed by workers.

The test-bed environment (Figure 6.) was tested in the following six steps. 1) Work selection, 2) Checking work area and moving workers, 3) Worker Navigator, 4) Check work objects and work contents, 5) Check equipment status, 6) Dismantling existing equipment. The role of each stage is as follows:

1. Work selection: Confirms the work assigned to the worker with AR and selects the work to be performed.
2. Checking work area and moving workers: Figure outs the position of the selected work and the current position of the worker.
3. Worker Navigator: Guides the way for the worker to move from the field to the work location.
4. Checking work objects and work contents: Figures out the contents of the work to be performed by the current worker.

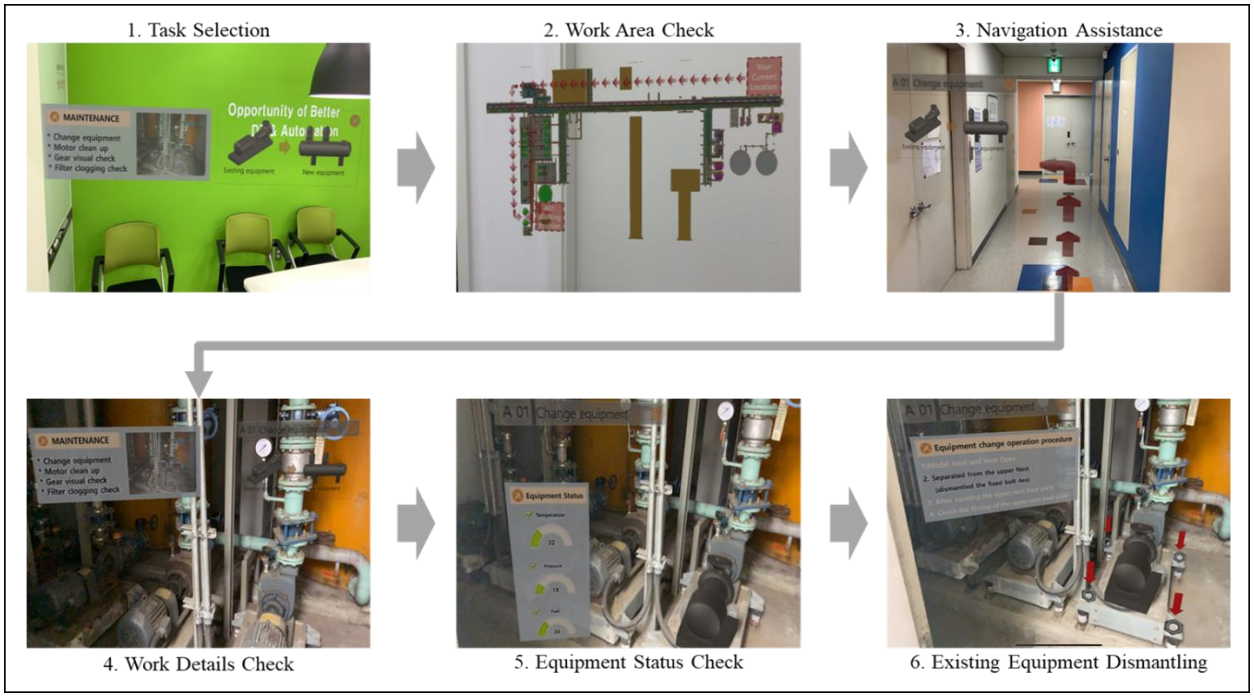


Figure 6. MR-based 3D Digital Working Guidance Test - Worker Perspectives

5. Checking equipment status: Figures out the status of currently installed equipment before the operator performs the equipment replacement work.

6. Dismantling existing equipment: Intuitively guides the operator to the dismantling order of the existing equipment.

In this study, the above 6 steps were experimentally implemented to test the 3D digital working guidance environment for the unskilled or alternative workers to accurately understand the work. If such a system is applied in the field, it is judged that human error can be reduced.

6 Conclusions

This study analyzed the process of the existing plant work, identified problems in the plant site through worker interviews, and analyzed the Worker Equipment Replacement Process. Based on this, detailed work process was derived based on the Mixed Reality-based to-be process, and the applicable data was classified into 4 types (BIM Modeling Data, Object Attribute Information, AR Data, Work Activity Report).

In addition, the purpose of using the data was identified by matching the operator's equipment maintenance procedures with data classified in four types. Among them, four main methods of using MR-based 3D digital working guidance include 'Checking work area and moving workers', 'Identify replaceable status', 'New equipment installation and check', and 'Trial operation of replacement equipment'. Working Guidance environment was built and tested according to Worker Equipment Replacement Process.

This study visualized AR information for workers using MR-based work information data. For visualization information, four types of data were set according to business procedures. Based on this, equipment maintenance workers can increase understanding of their services through AR visualization information. Furthermore, if CPS (Cyber Physical Systems) in which a virtual model and a physical model are connected is introduced, information exchange between managers and workers will be facilitated in real time. In future studies, this study will be used as basic data to conduct digital interface & physical object linkage research on a small number of objects.

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