Augmented Reality- Based On-site Pipe Assembly Process Management Using Smart Glasses

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ABSTRACT

In the pipe installation and management stage which takes the greatest proportion in most construction projects, workers use 2-D CAD plans to inspect 3-D shape construction. Moreover, duplication, error, omission or rework of tasks due to a communication limitation between project participants and inefficient information management can occur, which results in cost increase, delay of delivery time, productivity decline and quality degradation. This study aims to propose a methodology which is to facilitate inspection confirmation in relation to the project error, by providing required on-site information in real-time, using Augmented Reality (AR) technologies by the Smart Glasses. Using AR technologies, the 3-D space information is sent to the smart device, in order to visualize the piping shape in 3-D, thereby understanding the material information and work inspection in construction and management stage.
Keywords -

Augmented Reality; 3-D Visualization; Smart-Glasses; Pipe-assembly

1 Introduction

1.1 The Research Background and Purpose

Due to the size and complicated process, the construction of plant project is difficult compared to other construction project. As lots of data are generated from each stage of plant project (engineering, procurement, construction, commissioning service, operation, and maintenance), the management of huge volume of data emerges as an issue in the plant industry.

Accordingly, various researches have been performed in a bid to come up with plans to improve productivity and effective project management through employment of Information Technology. In this light, information technology such as project management system, personal digital assistant (PDA), bar code, QR code, radio frequency identification (RFID), and web camera is applied in the construction, progress, materials, and workforce management throughout a plant construction project.

However, there is a view that such technologies rather serve to compromise productivity in areas except storing of construction data and other functions, as they cause repetition of one same task due to shortage of technology for real-time data processing and dual system straddling construction site and management office. Therefore, with regard to pipe installation, a process in critical path that takes up 43% of the entire plant construction process, this study aims to present a system for effective data management and construction management that could address the above-mentioned problems while considering the characteristics of a project and site conditions.

This study analyzes the management tasks requiring improvement through questionnaire-based survey and interview and reflects them in an effective management plan to be presented, with a view to coming up system functions that are expected to register excellent on-site applicability. As for management, we witness the presence of various data categories and the inefficient operation of the existing management system, which are interlocked with the existing issues such as the shortage of technology for real-time data processing, the dualization between the site and the office, and insufficient use of existing data (3D data). In a bid to address such problems, this study is going to explore effective pipe assembly and data management through augmented reality (AR) based on-site pipe assembly management system that uses smart devices.

1.2 The Scope and Methods of Research

This study suggests a plan for plant pipe assembly process management that uses smart glass. The failure to perform an efficient data management in plant pipe assembly management is causing much loss, and people are experiencing problems particularly with using 3D data generated in pre-design stages and real-time data on-site. In this light, I aim to overcome those issues by pursuing automated information and efficient management for plan pipe assembly.

The method and process of this research is:

(1) Preceding Research Analysis
- Existing review of literature
- Analysis of management characteristic of plant construction and process

(2) Requirement Analysis and Function Derivation
- Understanding problems of the existing management system based on survey and interview
- Figuring out smart device applicability in the plant field
- Requirement analysis to solve problems

(3) Suggestion of Plant Assembly Management System
- Characteristic and consideration of plant project
- Derivation of function based on requirement analysis
- Pipe assembly management system design based on derived function
- Suggestion of new pipe assembly management process

2 Research Trend

2.1 Literature Review

For the successful implementation of a plant construction project, it is important to follow the trend for complication and up-sizing and shorten the project implementation period by ensuring an accurate and prompt construction management. However, the conventional construction management has generated problems due to issues with communication among project participants, increasing costs and construction period from redundancy, errors, omissions, and repetition in work owing to inefficient data management, and lowered productivity.

Various studies have been carried out to solve the problems. Broadly speaking, a study for enhancing efficiency has been performed through development of a management system, process improvement, and creation of a management plan that taps into IT. The table below shows specifics of each study.

Table 1 Existing research

Direction	Contents
Management system development	Safety management information system[3], supply chain management system[1], automated communication system[2]
Process improvement	Phases of Process Analysis and Improvement[9][10], Construction management Process Improvement with Check & Feedback system as a main[5]
3D models Deduction of management by using IT	Control of Pipe Spool with QR Code[8], Construction site management with mobile augmented reality [7][13][14], Context-Aware[15] [16][17], Inspection based on augmented reality [12][18], Construction equipment, maintenance and safety guideline application[6]

Table 1 shows that research for development of a management system is about developing systems related to safety management, supply chain management, communication etc. for a plant construction management, while research for process improvement is about analyzing different stages of the process and improving worker process. Lastly, studies that have presented a management plan using IT are about managing pipe-spool using QR code, managing construction site using mobile augmented reality, augmented reality based inspection, managing construction equipment, and developing a safety guideline application.

The preceding studies fail to reflect the characteristics of plant construction sites as they heavily focus on improvement of different stages of a process, safety, and materials management. Also, insufficient research has been done on efficient management

through data reuse.

Therefore, this study aims to secure on-site applicability based on survey and interview to come up with requirements. Also, it is going to propose a management system appropriate for plant construction sites by clearly examining the characteristics of smart devices and construction sites. Lastly, the study will present a new process that can effectively apply this on plant construction sites.

2.2 Plant Construction Management

In current pipe construction process in plant fields, process divides into three parts, before pipe installation, pipe installation, and after pipe installation, Figure 1. Tasks, loading materials, plan for installation, installation position and information check, are done before pipe installation. And in after installation step, installation runs by using previously made 2-D drawing and written construction information. After completing installation, information input and review about installation progress, and then complete installation process.

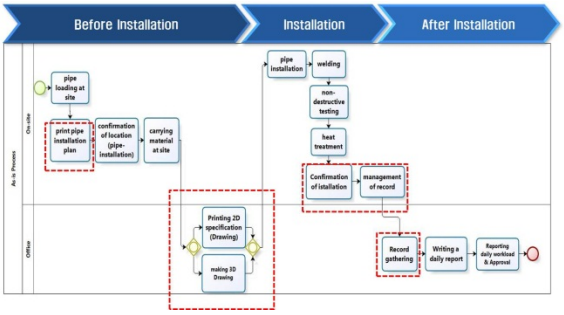

Figure 1. As-Is pipe construction process

To input and output data such as installation plan, construction information and material information, managers go back to management office and confirm again. This is expected to cause some problems of delay of work, loss of data and inefficient data management. Therefore, this study suggests the new process and system for using smart device in plant field to solve problems effectively.

3 Requirements Analysis and Identification of functions

3.1 Survey and Interview

In preliminary preparation for analyzing pipe assembly process and identifying issues and areas of work, I conducted the first field survey and interview with company "S", a major Korean construction company, and to identify more universal demand and requirements, conducted a survey with 4 local and international constructors and 3 partners. The survey was carried out with three different groups of respondents, and the first survey addressed the usability of smart devices while the second one addressed the applicable areas of work for an adopted application. Fig. 2 shows the results of the first survey and includes such items as work efficiency, operational effectiveness, and performance in project management, all created with smart devices.

Contents	Details	Average
Work Efficiency	Work amount	4.2455
	Processing time	4.3086
	Document tractability	4.0811
	Work feedback	3.9764
	Limitation of time and place	4.4566
	Work error	2.8279
Work Effectiveness	Standardization and simplification	3.1364
	Work transparency	4.0179
	Communication	3.6462
	Data management	2.4893
	Sharing information	4.3877
Project Management Outcome	Decision making	3.8728
	Management utility	3.6763
	Construction quality	2.2874
	Required expenses	4.0994
	management ability	4.0845

Figure 2. 1st Survey : Possibility of using smart device for construction management

In terms of work efficiency, participants in plant construction had expectations of reduced work load, reduced processing time, and ease in handling documents from the adoption and development mobile devices and systems. In terms of operational effectiveness, they looked forward to information shared among construction participants. And, in terms of performance in project management, they looked to reduced expenses and advantages from enhanced project management in that documents and data do not have to be printed out.

Table 2 2nd survey: 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.

As shown on Table 2, which provides the results of the second survey, areas of work in which plant construction participants can use applications include

applications related to construction, applications for data check and lookup, applications for data input, applications for work-related guidelines, applications for supporting communication, and applications for assisting construction. This shows that plant construction participants want to apply smart devices in sharing information for design and construction and using them in the field.

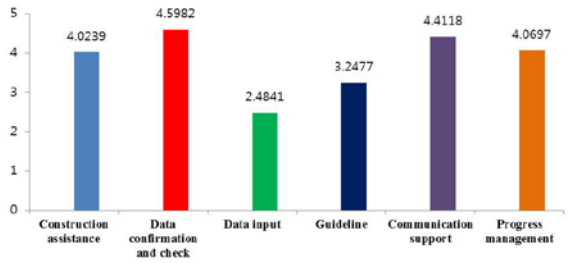

Figure 3. 2nd survey: Overall result

A summary of the second survey shows the needs for applications in different on-site operations, as shown in Fig. 3. It shows that respondents saw the most urgent need in construction-related tasks (planning, materials and equipment, and process), data check and lookup (electronic documents and drawings), and support for communication.

3.2 Analyzing Requirements

Pipe assembly management requires data related to planning, materials, construction, and drawings for installation, which, in combination with the dualization between the site and the office, should generate problems with the renewability of data.

The analysis of requirements for realizing smart device-based pipe assembly process management on plant construction sites points to the need for functions such as real-time data check and assistance to construction operations using 3D data on site.

4 Augmented Reality Based On-site Plant Pipe Assembly Management System

4.1 Realizing Required Functions

4.1.1 Analysis of Plant Construction Site Conditions and Related Considerations

To ensure effective application and utilization of the matters which have been identified through the survey and interview requires realizing functions that consider the characteristics of plant construction sites.

Plant construction sites are characteristically big and laden with great quantities of materials, while the size of materials is large compared to other projects. So, the existing marker-based augmented reality should have difficulty in realizing the functions owing to the problems such as the distance between a marker and a user, the scale of parts, and the on-site conditions. Also, people run into difficulty involved in dealing with adulteration and preservation of markers due to various hazard factors such as high temperature, high pressure, and intense heat, which are characteristic of plant construction sites. Therefore, functions need to be realized while considering these issues.

4.1.2 Drawing Data and Control

As manager working on site can load data on drawings real time and see 3D data instead of the previous 2D data, efficient work and improved understanding become possible.

Breaking from the previous AR mode of recognizing a market and thereby displaying 3D data and adopting the new mode of displaying 3D model on a viewer, it allows a user to put his or her personal control on the environment and thereby flexibly use 3D data in accordance with the size of a part and in a complex on-site environment.

For this purpose, control of camera device and 3D layout viewer are combined on Android OS. In order to render various layout data in 3D, it uses a 3D layout viewer which can control objects and can control individual properties of a layout info, and by creating 3-axis turn and enlargement of a layout on this basis, it can match in 3D a layout and its actual embodiment for any form of structure to compare the physical realization with the layout.

4.1.3 Real Time Checking of Construction Information

To clear the difficulty involved in posting and reading a marker due to a plant construction site conditions, it is realized through wireless networking technology that uses NFC (Near Field Communication) which is a kind of automated data collection (ADC), 3G, 4G, and Wi-Fi network. NFC, which reads data separately, can prevent data mix-up, reads fast and can restore data, while providing excellent security. So, this study applies NFC, considering the site characteristics and its compatibility with smart devices.

Once can receive selected data on a specific part with part ID received through NFC tag, and this is connected to the project management server through real-time networking based on 3G, 4G, and Wi-Fi network. Through connection with the server, managers can look up real time desired information such as pipe

data, spooled data, installation plan, and location data, thus solving the issue of dualization between site and office and increasing operational efficiency.

4.2 Pipe Assembly Management Using Smart Glass

Finally, based on the functions identified as above, pipe assembly management system is proposed using smart glass is proposed.

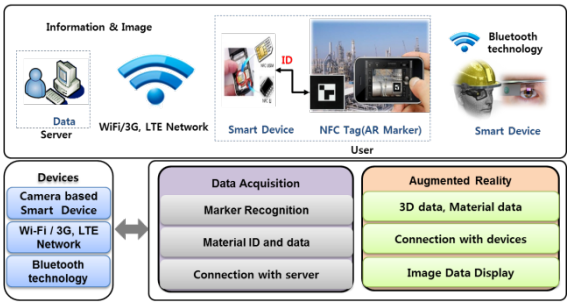

Figure 4. System conceptual diagram

Fig. 4 shows a conceptual diagram and Fig. 5 shows a function diagram proposed in this study for creating the system, which is composed of AR, research, and input.

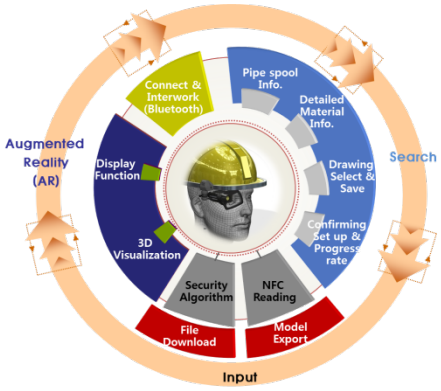

Figure 5. Functional System diagram

Search enables checking part data, selecting and saving a layout through 3D layout preview, checking part data as spooled, checking detailed part data, checking installation, and checking progress, while AR visualizes 3D data through the display of smart glass by syncing smart-Phone and smart glass with Bluetooth based on the searched part. Here, 3D model and various construction data are presented, and additional work can be done on the actual image after the actual image and 3D modeling is saved as snapshots. Lastly, input function is realized through the networking between NFC tag and a smart device, in which security algorithm is automatically applied to read the ID of a desired part.

In separate use of smart glass, communications network and environmental factors (like noises) make it difficult to realize such technologies as voice recognition, touch, and data storage capacity. So, to overcome this, content displayed on smart glass is controlled with smart-phone touch technology, while smart-phone and smart glass is wirelessly connected with Bluetooth technology.

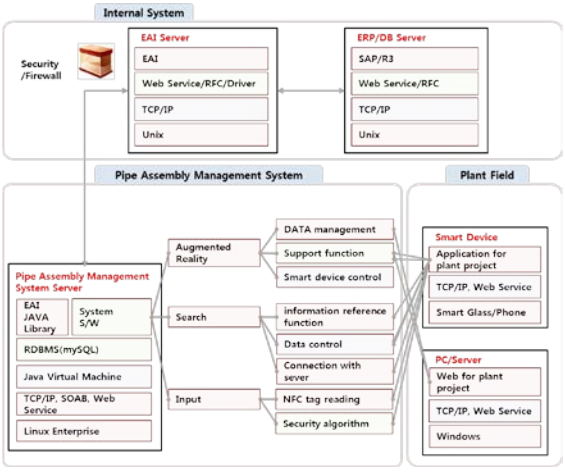

Figure 6. System architecture

When input authority is given with part ID through NFC tag and the NFC chip in the smart-phone, desired part data can be looked up. Then, as data becomes visible in real environment through AR technology using smart glass, it makes it easy for a manager to efficiently process work and understand a complex site.

4.3 Improved Pipe Assembly process

The existing pipe assembly process has created problems in using data due to the dualization between site and office, and if data is requested during on-site work, an operator must return to the office to proceed with the work. Furthermore, as data created in earlier stages is not used but reproduced or partially used, thus causing inefficiency in data management and preventing efficient use of the management system.

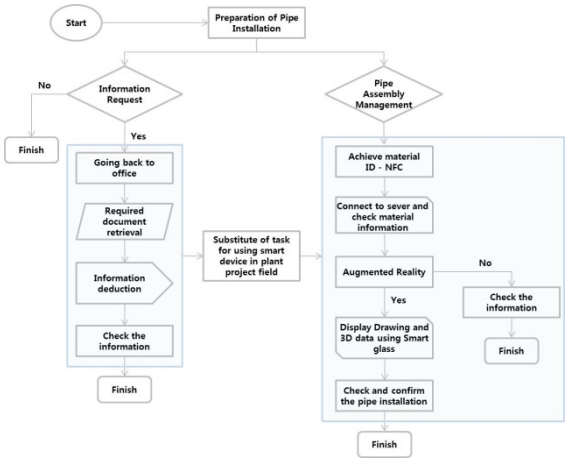

Figure 6. Improved pipe assembly management process

If pipe assembly process management using smart glass is adopted on the site as proposed by this study, it will create a process as shown in Fig. 6.

As for the existing problem with the use of 3D data, one can control visible data according to a specific situation with AR using smart glass and increases the efficiency in construction operations in real environment. And when an operator who tries to check data during on-site operation has to return to the office to proceed with work, he or she can retrieve data on the site from the management system server by using the afore-mentioned networking technology. Like this, the pipe assembly process management system seeks to reduce work time and ensures efficient management task by carrying out real time the pipe assembly management on the site.

5 Conclusions

Based on survey and interview, the study has figure out the on-site applicability of the newly introduced IT devices and identified their issues. Based on this, I have analyzed the requirements and the characteristics of the sites where they are applied, and proposed pipe assembly process management system and a new management process for plant construction sites. The plant pipe assembly process management system suggests realization of functions such as Automated Data Collection (ADC) based on NFC that is provided by smart devices, real-time networking based on 3G, 4G, and Wi-Fi, AR, and Bluetooth.

This is to address the problem caused from the dualization between plant site and the office, the problem caused by the failure to check data during on-site operation, and the inefficiency involved in construction management due to insufficient use of data in earlier stages. And it has been solved with automatic inputting of part ID through NFC technology and real-time check of data related parts and construction work based on real-time networking. Besides, it has successfully addressed visualization using smart glass and layout, a function optimized to a plant environment through 3D object control, storage capacity through syncing smart phone with smart glass by using Bluetooth technology, and the issue of overcoming technological limitations due to plant construction site conditions.

Likewise, the study has proposed a plant pipe assembly process management system based on AR technology using smart glass. Yet, further studies will have to follow to increase its future use and scope of use and secure its applicability. First of all, actual development will have to follow up, and afterwards, needed modifications will have to be grasped through real application on the sites, while various factors such as efficiency, usefulness, convenience, and usability will have to be confirmed.

Acknowledgement

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