Development of a Project Schedule Simulation System by a Synchronization Methodology of Active nD Object and Real Image of Construction Site

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Abstract: The image data of the web camera is used to identify the construction status of the site in a remote office and it can be used for safety management. This study develops a construction schedule simulation system based on the active nD object linked with real image data of web camera from the construction site. The progress control method by 4D object uses a method that the progress of each activity is represented with different colors by progress status. Since this method is still based on a virtual reality object, it is less realistic description for practical engineers. Therefore, in order to take advantage of BIM more realistic, the real image of actual construction status and 4D object of planned schedule in a data date should be compared in a screen simultaneously. Those methodologies and developed system are verified in a case project where a web camera is installed for the verification of the system.

Keywords: Construction Schedule Simulation System, Active nD, BIM, Web Camera

I. Introduction

As construction is becoming larger and more complicated, it is essential to be able to visualize information regarding process progress. Fig. 1 demonstrates the degree of requirement of visualization by construction participant. The contractor has the highest need for visualization of daily progress of structures construction, while the designer needs visualized information of appearance of daily progress and the state of interference in designed parts. Meanwhile, the owner has an interest both in daily progress and in appearance of completion. The visualization technology through BIM can satisfy the visualization needs of each participant, proving its usability in a number of projects.

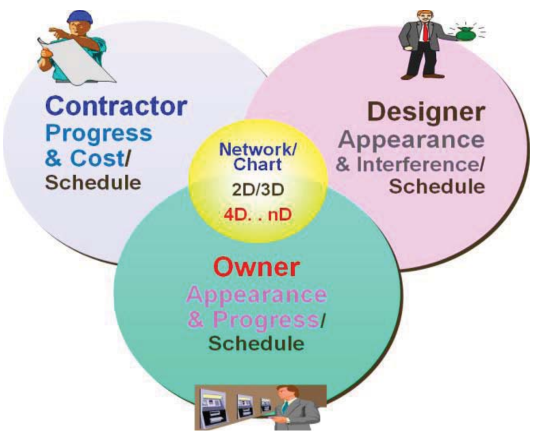

Fig. 1. Needs for visualization of construction information

The visualization of construction information is focused on the construction schedule data in this study. This study develops a BIM system that 4D object can be simultaneously simulated with real image of web camera of construction site. To link real image with 4D object, this study developed a synchronization methodology between real image of web camera and 4D objects of the planned data in BIM system.

With regard to visualizing construction processes by BIM, research has been conducted on the visualization of space interference through 3D objects and on the visualization of process progress and workspace through 4D objects. A group of research has linked existing construction information systems with web-based technology in order to share construction information with a number of participants. For example, Senthikumar [1] established web-based design tools with object-oriented concepts, thereby enabling many project participants to easily share design information. Second, some researches utilized site videos in order to understand the real-time status of construction. Leung [2] suggested a field monitoring system to ensure effective decision-making with project team members based on the state of construction. By providing video conference and whiteboard functions as well as real-time videos of the construction site, this system allows project team members to discuss and share ideas via the Internet. In addition, Chi [3] proposed a methodology to automatically analyze CCTV images of the site and identify objects by dividing them into workforce or manpower or labor and equipment.

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II. CASE STUDY OF TELEPRESENCE

A. *Cases of Application to Video Conference*

Telepresence technology is mostly utilized for video conferencing. Fig. 2 shows a video conference system that enables company members, without physical movement, to participate in business meetings frequently held between the headquarters and branches, thereby ensuring efficient decision-making and minimizing the expenses, time and work gaps required by physical movement. In addition, in terms of eco-friendliness, minimized movement may drastically reduce CO_2 emissions from automobiles and other means of transportation. The two pictures on the right side of the upper line of Fig. 2 are the actual examples of application to Korean companies. Other examples also indicate that the introduction of telepresence has reduced time and money consumed for business trips and enhanced business productivity by making face-to-face communication with executives sitting at the virtual table a daily routine.

B. *Mobile Video Conference*

The recent development of smartphone-related technologies has increased the use of mobile video conferencing. The left picture of the bottom line of Fig. 2 provides examples of the Urban Transit Infrastructure Management System (UTIMS), a mobile office system. UTIMS was adopted by a construction ordering agency that handed out a mobile device to each employee to deal in real time with maintenance management of structures through the WIBRO/3G network. This has reduced the time consumed for maintenance duties from one hour to less than 30 minutes and also improved the work environment by shortening the travel time between offices and construction sites.

Fig. 2. Examples of telepresence application

III. OVERVIEW OF WEB-BASED CAMERA IMAGING SYSTEM IN CONSTRUCTION FIELD

The telepresence system to be developed in this study refers to a process management system used to identify process progress in real time by synchronizing the nD CAD-based process simulation object and an actual image object obtained through web cameras installed at construction sites. Construction works are mostly conducted in outskirts located far away from the city center, and the scale of construction sites is vast. As a result, in simultaneously managing multiple sites, construction managers face difficulties when checking construction progress or any emergency situations such as the delay of construction schedule, complaints, safety accidents or various disasters. In particular, due to the nature of construction work, it is difficult to accurately understand field situations and manage the sites in a multifaceted method if the progress and emergency situations can only be checked through wired communication and documents. That raises the need to visit the site in person and directly check and examine the situations. Therefore, in order to enhance the business efficiency of construction managers, it is necessary to minimize visits to construction sites and introduce a remote management system to monitor field situations and construction progress in real time from a distant location.

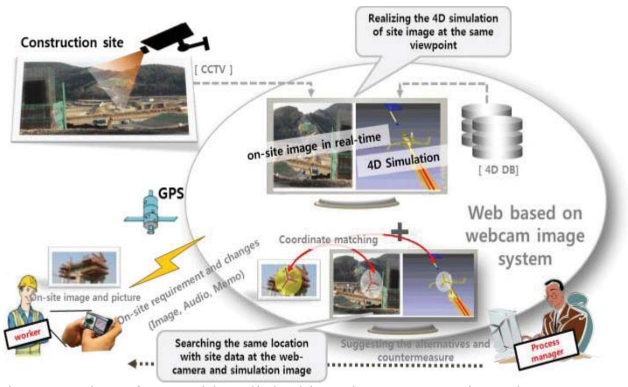

Fig. 3. Design of BIM object-linked imaging system using telepresence technique

Recently, closed circuit television (CCTV) has been widely used in a number of industrial fields for the purposes of security and accident prevention. The same holds true for construction sites, but the use is limited to simply recording field situations in a storage device in an analogue method and, when necessary, monitoring and searching for the fields manually. Some construction sites are equipped with a field monitoring system, but its functions only include monitoring the entire site through web cameras installed in various locations within the site and searching for rough locations and information on construction status. In this vein, this study has developed a BIM object-linked web camera imaging methodology and system, as shown in Fig. 3, in order to improve the ability to monitor construction sites and collect construction information and achieve effective field management and process management.

For establishing a web camera imaging system linked to telepresence with BIM, it is necessary to develop a methodology to synchronize BIM-based 4D simulation information and on-site image information and conduct comparative analysis, and a methodology to effectively reflect the BIM operational system requirements and changes written by site workers after field examination, and then draw alternatives through system analysis.

Ⅳ. METHOD TO LINK WEB CAMERA IMAGES AND MOBILE IMAGE INFORMATION AS nD OBJECT

Since construction managers simultaneously supervise a number of sites, they require a system to collect site information to swiftly identify emergency situations and process status from a distant place, as well as a system to effectively manage such information. To this end, this study suggests method to collect site information from images obtained not only through web cameras, but smartphones that provide high utility in the site, and method to manage image information based on location information.

Fig. 4 demonstrates method to collect on-site information by means of smartphones. Web cameras installed in the construction sites involve high installation costs, do not provide images of marginal areas due to limited range, recognition, and are only able to provide information on construction progress and problems through images. Consequently, on-site workers have to provide relevant construction information about marginal area directly to construction managers. To this end, GPS, compass and various sensors of smartphones have recently been used to rapidly transmit on-site information to remotely located process managers.

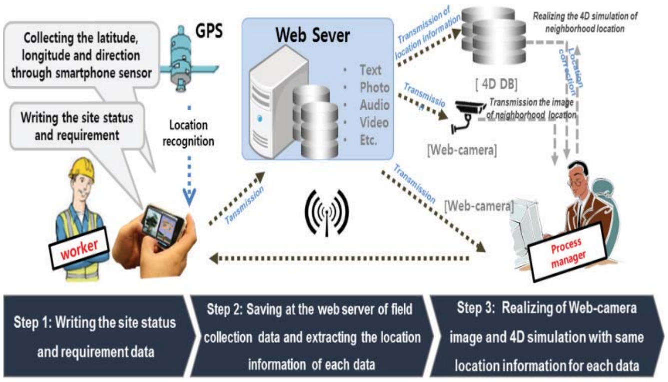

Fig. 4. Method to collect construction site information via smartphones

Under the operational system of Fig. 4, on-site workers prepare photographs or documents with location information for processes that require reporting, or business requests, and transmit such data to the web server to send to remotely located process managers. The on-site information transmitted through the web server is reviewed by process managers, who automatically extract location information from the attached photographs or documents and visually examine relevant processes by applying 4D simulation and web camera imaging coordinates. In other words, managers may transform location information into the coordinate system of the 3D model, which will then show the 4D simulation images of web cameras and smartphones for the same location to enable convenient examination of relevant processes. In particular, location information is drawn from the meta-information generally provided with photographs. Fig. 4 demonstrates how to apply the telepresence technology to managing on-site information received through web cameras and smartphones.

Ⅴ. METHOD OF CREATING 3D COORDINATES OF WEB CAMERA AND MOBILE IMAGES

The telepresence-based web camera imaging system proposed in this study is not a simple monitoring system, but a system that carries out a number of process management tasks by comparing the actual progress in the field with 4D simulation. For the purpose of effective process management, it is necessary to efficiently compare and review of 4D simulation information and on-site images. This study organized method to enable web cameras to provide on-site images after synchronizing on-site images with the 3D-model coordinates to be realized onto the 4D simulation.

In order to watch the on-site images of web cameras in the same method with 3D-model coordinates, 4D simulation and web cameras are set to have the same viewpoint, and the moving distance, direction and angle are transformed into 3D-model coordinates whenever web cameras change their rotation angle horizontally or vertically. In this way, web camera images are synchronized with the 3D model. Particularly, the installation coordinates of web cameras are required in order to set the initial viewpoints of simulation and web cameras. In addition, the coordinates of where the cameras are installed and their heights from the ground are also taken into account in setting the initial viewpoint, in order to enhance the accuracy of the coordinates.

Ⅵ. DEVELOPMENT OF TELEPRESENCE SYSTEM TO LINK BIM OBJECT

The basic function of telepresence system to link BIM object is a generation of synchronized images for 4D object and real mage as in Fig. 5.

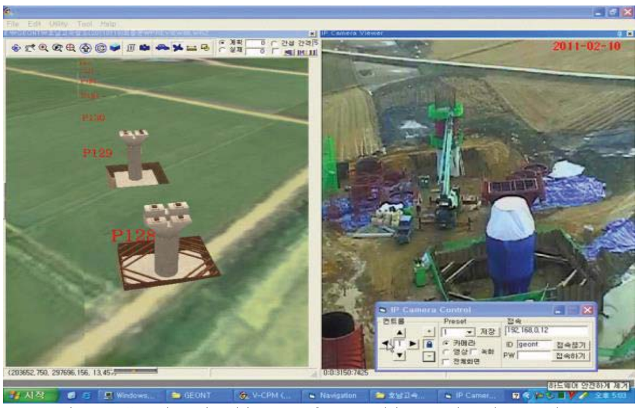

Fig. 5. Synchronized images for 4D object and real mage by telepresence system

Fig. 5 shows an integrated screen between a 4D object by a planned schedule and a real image by a web camera from the construction site. Project manager can directly check the construction schedule comparing with the planned schedule and real image on the same date. This study developed a synchronized method and system between a 4D object by a planned schedule and a real image.

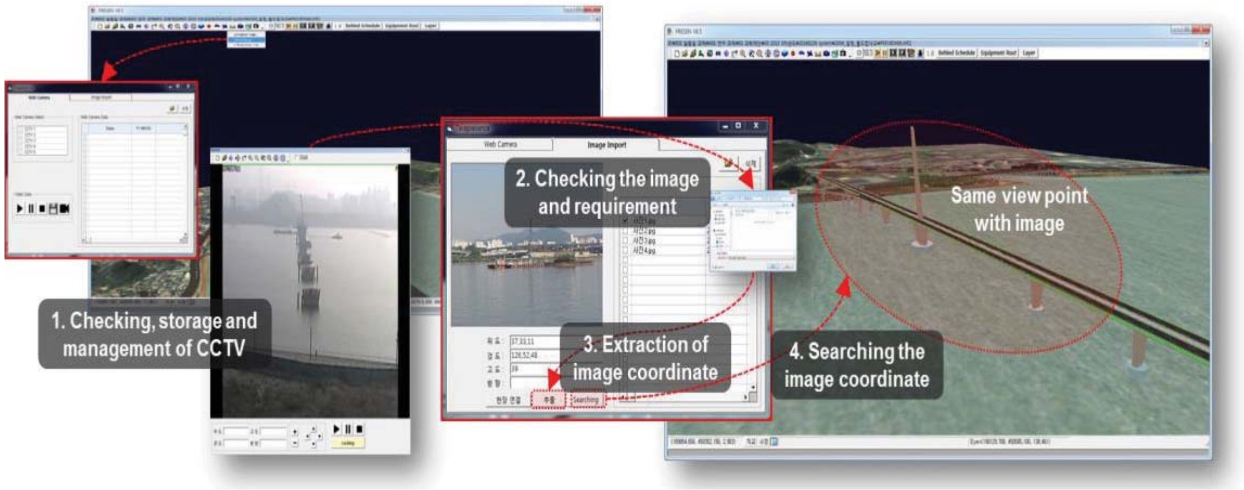

Fig. 6. Examples of applying web-based nD object linkage system for web camera images

Fig. 6 provides an example of applying the web camera imaging system developed in this study. To ensure research cooperation, the system was installed in a construction site. The imaging system used both web cameras already installed in the site and those newly installed in the site by the researchers. As shown in the left of Fig. 6, the web cameras provided real-time images, and such information was stored through the functions of recording, saving, and capturing. The image information obtained was saved according to the date of saving and viewpoint coordinates, enabling the efficient management of history information of the images.

As in the middle picture of Fig. 6, the photographs and document files sent by on-site workers can be viewed in the window of Image Import, and it is also possible to extract coordinates of the attached photographs with the relevant function. The extracted coordinates are automatically synchronized with the viewpoint of the 4D simulator to show the 3D objects located in the same location as in the photographs. For example, the right picture of Fig. 6 indicates the 3D object of the pylon located in the same spot as in the photograph of the pylon construction site. Since this function enables project managers to quickly check requests and problems in the site, they may utilize the system as a real-time monitoring tool to understand the actual situation of the construction site even when they are remotely located from the site.

The imaging system linked to the telepresence system simultaneously provides images of the same location on a divided screen after the synchronization of actual on-site images and BIM objects with coordinates. As a result, it becomes possible to directly check progress by comparing the actual images at this point of time with the simulation object of the 4D planned processes. It is also possible to realize 5D objects in linkage to actual on-site images.

Ⅶ. LINK OF AR OBJECT TO TELEPRESENCE

Traditionally, process management in the construction business has been conducted through two-dimensional progress schedules and drawing, which are expressed mainly with numerical information and therefore do not fully reflect the conditions of the actual construction sites. In addition, due to the two-dimensional perception of spatial information such as structures and workspace in the sites, the on-site reality is not sufficiently taken into account in process management.

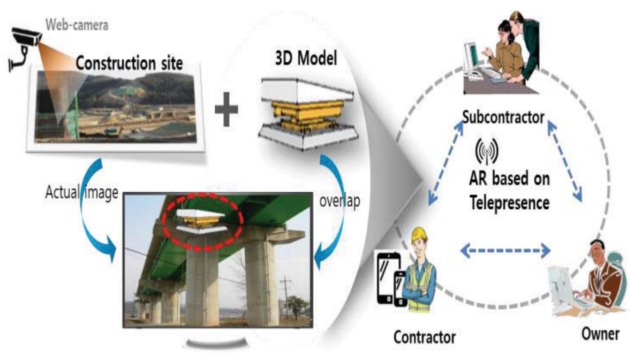

Fig. 7. AR linkage to telepresence

In this regard, this study departs from the traditional two-dimensional expression as shown in Fig. 7, and instead suggests a methodology to link augmented reality (AR) and telepresence techniques to nD simulation as a method to carry out three-dimensional process management with greater realism and multifaceted approaches.

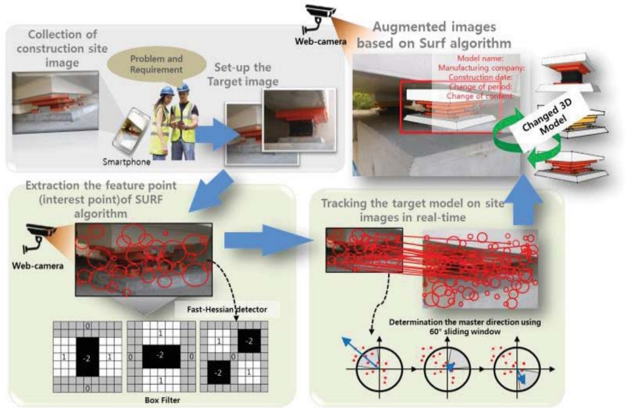

Fig. 8. Method of linking telepresence to augmented reality technology

Augmented reality refers to a form of mixed real images and computer graphics. In its application to process management as shown in Fig. 8, the AR technique simulates a combination of the actual images of progress up to this point and the 3D objects of anticipated progress of completion. By minimizing the gap between virtual objects and real objects in the construction sites, this methodology is expected to provide considerable utility in the future. Furthermore, the comparison of real-time on-site images obtained from web cameras using the AR technique and the images of nD simulation objects will enable 3D-based visual progress management in consideration of real-time conditions of construction sites.

Ⅷ. CONCLUSIONS

Traditionally precedent research cases indicate that the utilization of telepresence technology has increased gradually in construction sites, but such technology is largely limited to video conference functions and acquisition of on-site images for real-time management of construction sites. With the increasing use of BIM object, however, construction information of the sites are increasingly visualized, and functions for field supervision of remote places by means of web cameras are required due to increases in large-scale construction cases. This study developed a prototype system for a telepresence system with BIM objects and suggested an application method to use AR object in a telepresence system.

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