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Method to Use the Augmented Reality for Construction Planning and Management

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Abstract: An architect creates his/her design to meet owner's requirements. Floor plans, perspective drawings, and scale models are used in order for the owner to choose the design. The tools are a little helpful for communication between the architect and the owner in case the owner does not know architecture. The scale models are good, but it is hard to make scale models while design is in progress. 3D CAD is a good tool for communication, but it is time-consuming and requires high-performance computer hardware. Augmented reality is able to show 3D virtual models that are updated by the architect with smart devices such as a smart phone and a tablet PC. The owner frequently reviews the updated design anytime anywhere. This study proposes a method to use augmented reality for architectural design and construction management. The method supports the communication between the owner, the architect and the contractor to review updated designs, and to complete the building project. 3D models expressed in augmented reality are created using SketchUp with 2D drawings for building construction. An Android application implementing augmented reality is developed by Qualcomm Vuforia and Unity on smart devices. Drawings as markers and 3D models are connected in Unity. And functions that temporarily hide unnecessary parts can be implemented in C# programming language. If an owner, an architect, or a contractor looks at a smart phone on a 2D drawing, he/she can identify building elements such as 3D buildings or columns on a screen. This can help communication between them.

Key words: Building Construction, CAD, Augmented Reality, Smart Device

1. INTRODUCTION

A building is created based on drawings and specifications by several stakeholders such as an owner, an architect, a contractor and many subcontractors. The owner's requests are implemented with the drawings, which are realized to the building by the contractor and subcontractors. The drawings and specifications are the documents for contracts, and are basic and essential components to complete the building. The drawings are mostly designed by CAD software.

The contractor uses CAD drawings to communicate with subcontractors, but workers in a construction site usually prefer paper drawings that are convenient for them to understand and do their works. The workers create a real 3D building from 2D printed drawings. When they

misunderstand the drawings, damage or errors in quality, cost, or time may happen in constructing the building. A 3D model (drawing) reduces the mistakes occurring in important or complex works such as rebar placing and beam joints.

A high performance computer system is necessary to use 3D models in a construction site. The computer in the site office reviews the 3D model in various aspects, but it is difficult to use the computer system in the construction site. A portable smart device such as a smartphone, a smart pad, and a tablet PC has good hardware performance to show the 3D model.

Recently, BIM (Building Information Modeling) is used for building design and construction. BIM needs high performance computer system and an operating engineer to show 3D models, then it is not easy for a contractor and subcontractors to use BIM or 3D models in a construction site. AR (Augmented reality) is appropriate to utilize 3D models already made for BIM implementation. AR is a virtual implementation of a 3D model above a 2D image, which can virtually show the building elements on a printed drawing via a smart device.

This study proposes a process to use 2D drawings to make 3D models and a method to use AR for building construction management, and develops an Android application for the smart device. The developed Android app applied to the actual building site. However, only concrete work is reviewed.

2. BUILDNG CONSTRUCTION AND AUGMENTED REALITY

2.1. CAD and BIM

Concerns at the time of introduction that 'CAD will undermine the architectural design spirit and reduce the quality of design products' have been amplified by the increased productivity gained by using CAD and the improved communication between design participants [1]. It is being developed from 2D CAD, which was used to help create drawings, to 3D CAD consisting of objects that embody space and express walls, columns, floors, and windows. 3D CAD refers to computer-aided design that can automatically design 3D objects, supports more accurate design analysis than 2D CAD, and is enhanced in use, especially in architecture, with the advantages of ease of overall formulation and simulation [2].

The advantage of 3D CAD is the object orientation that each part of each building is made up of individual objects, so that the information in the object can be utilized. Object-oriented 3D CAD is not only effective in improving the inefficiency of existing 2D CAD-based design work, but also is an efficient tool for constructing architectural information corresponding to construction informationization database. In other words, it is possible to extend various design information to engineering, construction and even maintenance by using object-oriented 3D CAD at the design phase which is the starting point of construction life cycle as basic data for construction informationization. A method for automatically calculating and estimating the amount of material consumed by the volume or material of an object in object-oriented 3D CAD [3] is also proposed. There is also a 4D CAD model [4] that retrieves the quantity information by schedule in the 3D CAD model and formalizes it. The purpose of this paper is to formulate a series of processes to generate 4D model quickly and easily based on the information that an object has and to retrieve the quantity information by schedule. However, the utilization of 3D CAD in actual construction work is relatively low compared with the utilization of 3D CAD. A typical reason for poor utilization is the increase in design costs. [5]

As object-oriented 3D CAD expands, interest in BIM is increasing, which models facilities in virtual space from planning, design, engineering (structure, facility, electricity, etc.), construction to further maintenance and disposal in multidimensional virtual space. BIM is used in all stages of construction projects, such as using the building model created by 3D CAD to identify the design errors, calculate the quantity, and check the interference of the electrical and mechanical equipments and pipes. A method of selecting a tower crane in the BIM environment in the equipment planning process of the temporary facility planning [6] is also presented. The selected tower crane is displayed in 3D model using CAD in consideration of the contents and volume to lift vertically.

2.2. Virtual Reality and Augmented Reality

4D CAD is a kind of virtual reality that shows construction progress according to time by adding schedule information to 3D CAD model. Virtual reality technology, which expresses designed buildings in 3D virtual space in advance and visualizes the construction process, has been widely applied as 3D CAD is developed. In addition, it provides a lot of help to project and construction management through simulation considering construction environment and resources. In the late 1990s, three-dimensional simulation for apartment house process management [7] shows the process of constructing according to the time as a 3D CAD model, which is a kind of virtual reality technology.

However, since the virtual reality technology excludes the real world image from its implementation process, it cannot directly compare the actual state of the construction and the 3D model stored in the computer [8]. Augmented reality is a technique to overlay a virtual object into actual environments to compensate for the limitations of virtual reality. [9]

Location-based services are provided by using augmented reality for construction projects. This service can be used in smart devices in construction works where location is important, such as road construction. The road management system [10] overlaps data stored at the current road location via cameras to manage and restore roads. This research claims that the system reduced time and cost for road management. MARSIFT (Mobile Augmented Reality System for Infrastructure Field Tasks) [11] also presents a way to present real-time information about actual targets, such as roads, bridges and tunnels, on mobile devices.

Another way to utilize augmented reality is to show and review virtual objects using image markers. A system for manipulating the indoor environment using augmented reality markers and gesture recognition [12] was also developed in Korea. An AR based building management system [13] using markers to indicate the location of cameras and 3D models provides the information of virtual models by displaying building information and facility piping information using small computers and cameras. The system recognizes a tag attached to the main part of the building by a camera and displays 3D models with the information stored in the computer. A study using AR in the housing site layout plan [14] also shows and moves a simple object model in virtual space, providing an environment where users can easily see 3D models.

If VR or AR can show construction progresses, students will be able to improve their understanding of building construction. Park [15] uses AR to train the details and placing of rebars. Using the structural drawing as an image marker, the rebars of columns and beams are displayed in three dimensions on the screen.

2.3. Utilization of Augmented Reality

Efforts to pursue the development of the construction industry by using AR are continuing. In particular, efforts are being made to integrate AR with BIM or virtual reality, and to apply it to safety management as well as construction management.

Chua et al. [16] suggests that BIM and augmented reality should be integrated to improve work productivity in construction work. Experiments by students who have more than one year of practical experience show that existing 2D drawings are being improved in the process of information extraction and productivity with minimum modifications, including QR (Quick Response) codes. This means that the productivity of the construction industry increases with the utilization of BIM. Li et al. [17] reviews ways to utilize VR and AR for construction safety and argues that they will be further used for safety management. Kim et al. [18] present 4D CAD drawings using image markers. Although additional markers are added to the drawings to recognize them, a material model and the like are displayed on a PC basis in AR, but construction information and 4D simulations are difficult to understand in detail. A study [19] was also conducted to introduce augmented reality to Hanok (Korean traditional housing) with complex types and components. It proposed a construction method of new Hanok joints, and researched guidelines and information acquisition method for improvement of workability and process management as mobile AR.

A method of showing a building under construction in a virtual reality space has been proposed, but high-performance hardware is required. However, when augmented reality is used, only necessary parts can be created as a 3D model in virtual space, and the 3D model can be observed from various locations by users manipulating 2D drawings or moving cameras. The 3D shape of the building and each member can be

utilized by using augmented reality in a construction site. It is also possible to check the same model at different angles at the same time by using multiple Smartphones.

Ryu et al. [20] provided an AR model for tower crane selection. Vuforia and Unity were used to develop an Android application representing buildings and two tower crane models in 3D space. This study complements and develops the method and content of this study.

3. DEVELOPMENT

3.1. Development Tools

Tools for implementing AR on Android-based smart devices include Google's AndAR, Qualcomm's Vuforia, and so on. In this study, 3D models expressed in AR are created using SketchUp (shown in Figure 1) with 2D drawings for building construction. In reality, the drawings are realized in most cases that are not easy to convert to three dimensions. As a result, a method of using a sketchup that can easily be converted to a 3D model as a 3D model.

An Android app (application) implementing augmented reality is developed by Qualcomm Vuforia and Unity (shown in Figure 1) on smart devices. Though Eclipse with Vuforia was used to develop the app in the previous study [20]. The 3D models are imported into the Unity without conversion, and are moved and scaled up and down to image markers. 2D Drawings as markers and 3D models are connected inside the Unity. And functions that temporarily hide unnecessary parts can be implemented in C# programming language shown in Figure 2.

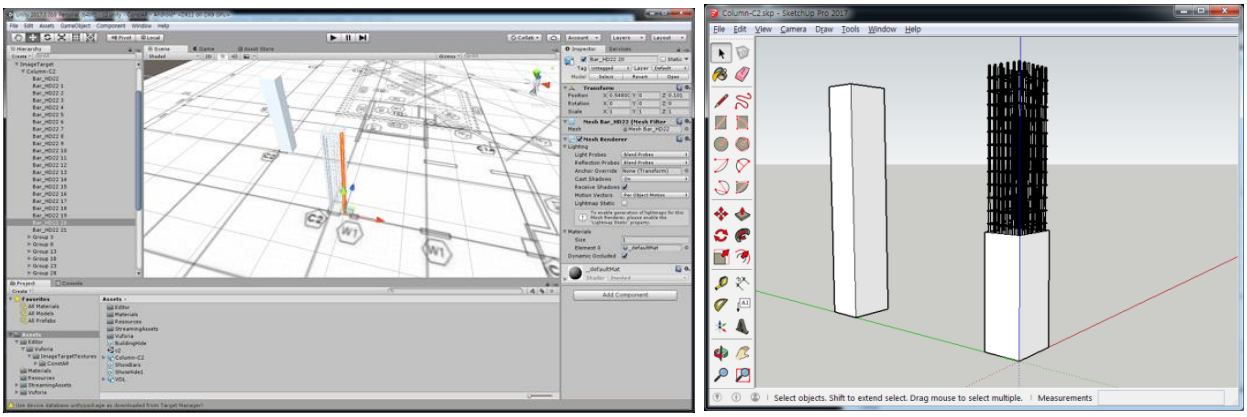

Figure 1. Unity and SketchUp

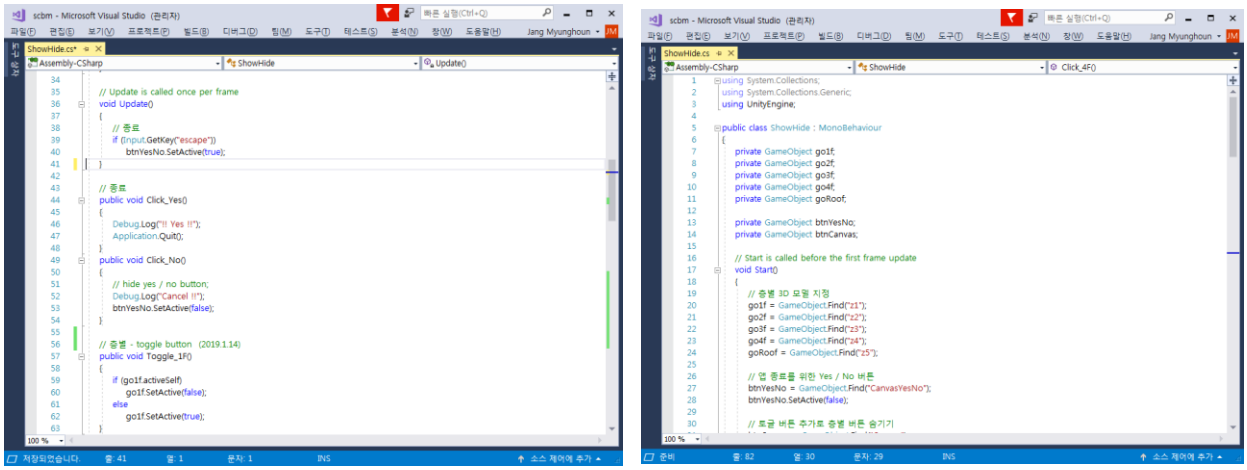

Figure 2. Source code written in C# in Unity

3.2. Utilization in Building Construction Phase

Through an AR app developed based on Android, stakeholders such as a field manager, a worker, and a supervisor can review the whole building, columns, and beams implemented as 3D models on the 2D drawing. They can communicate more conveniently and cooperate in terms of better quality, safety, cost and time.

Figure 3 is a 3D building model on a 2D drawing using AR. A user can see various aspects of a 3D building by moving his/her smartphone running an augmented reality app or rotating a paper drawing. The 3D model of a building made by floor or site is hidden or shown in the AR screen through the C # programming language.

Members of a building represented in the 2D drawing can also be expressed in AR. Figure 4 shows reinforced concrete columns of the building in Unity. They can be placed at the same position to show the reinforcing bars inside the columns shown in Figure 5, and only the column rebars can be shown in AR by making the column's concrete temporarily invisible. This allows you to check the position of the rebars of each column and easily check whether they are installed properly in the field.

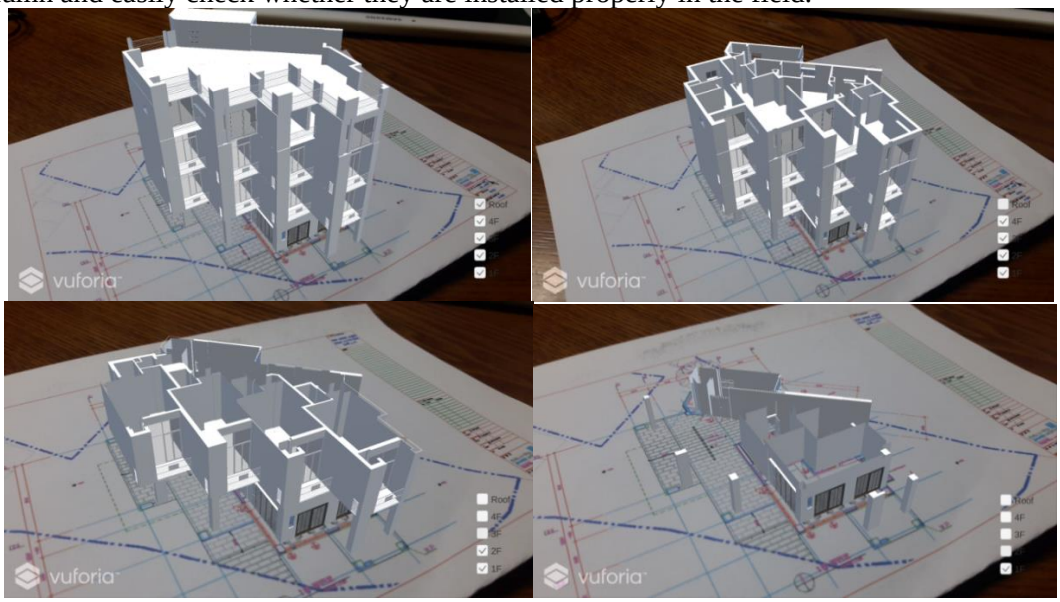

Figure 3. Building model with 4 floors in Augmented Reality

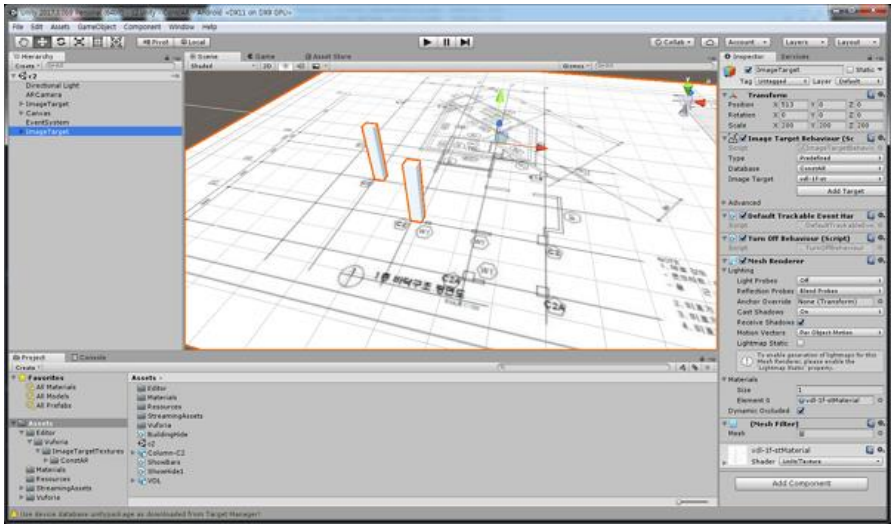

Figure 4. Reinforced concrete columns in Unity

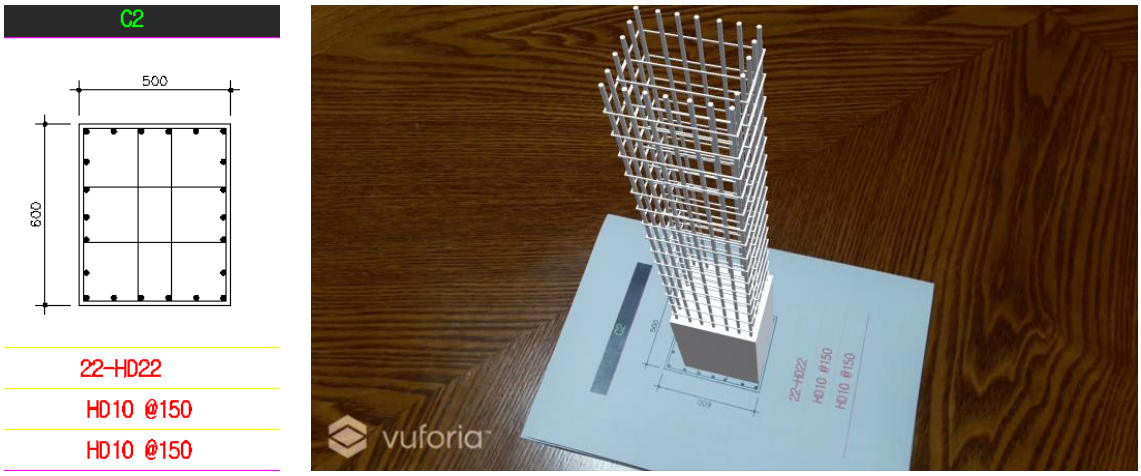

Figure 5. Column section drawing with rebars and AR column model

Figure 6 shows an example to adapt the Android application in a tablet PC. It is possible to compare the AR building model and the real building under construction at the construction by adjusting the scale of the AR model. However, it may happen that the marker is not recognized properly due to sunshine and dust in the construction site. The AR model, which is consistent with the observer's viewpoint, needs to be improved in the future.

Figure 6. Views of the real building under construction and the AR model

4. CONCLUSIONS

AR is used in various fields and applied to the building industry. It is also used to review 3D models for architectural design and to understand rebars in a concrete structure and others drawn in 2D drawings. In this study, an AR app is developed to better manage construction works.

(1) It is difficult to use BIM or VR for construction work. If only the required parts of the drawings are made into 3D models and the drawings are used as image markers, construction errors can be reduced through the use of 3D models, even if they can be easily identified by construction managers or workers at the site. The 3D model of the building was created by SketchUp, and the AR app for Android devices was developed by Vuforia and Unity. The 3D model of the entire building showed the floors to check the construction progress.

(2) AR implemented in a smart device is excellent in mobility, so that a 3D model is viewed in various directions and at various locations, and many users with smart devices can experience AR at the same time. However, when the screen of the smart device is small, the virtual space is expressed in a small size, so that it is difficult to adjust the position of a building or a member and to select a three-dimensional model.

(3) Implementing buildings and components as augmented reality can be used to educate architectural students with little field experience. Because it is difficult to understand the building through the drawings, it is possible to improve students' understanding of the building by observing the AR 3D building in multiple angles and examining the location, size and members of the building. If hidden components of the building such as floor, ceiling, and walls in the future, it will be more helpful for education about building construction management.

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REFERENCES

[1] Kim WY. Introducing 3D CAD to advance construction techniques. The Construction Business Journal. 2007 April; 72:63-65.

[2] Kwon SY, Lee YS, Ahn BJ, Kim WY, Kim JJ. A Basic Study on Extracting Space Information from 3D CAD. Proceedings of Korea Institute of Construction Engineering and Management Annual Conference; 2008 Nov 7-8; Seoul (Korea). Seoul (Korea), Korea Institute of Construction Engineering and Management; c2008. p.645-648.

[3] Oh SW, Sung BJ, Kim YS, Kim JR. The Development of an Automated Cost Estimating System using 3D CAD Building Element Information. Journal of the Architectural Institute of Korea. 2001 June; 17(6):103-112.

[4] Lee JC. Application of the 3D CAD Model Data for 4D Simulation and Quantity Estimation. Journal of Korea Institute of Construction Engineering and Management. 2004 Aug; 5(4):107-114.

[5] Lee SH, Ahn BJ, Kim JH, Kim KH, Lee YS, Kim JJ. An Analysis on affecting factors about lowly using 3D CAD by using the AHP. Journal of Korea Institute of Construction Engineering and Management. 2007 Dec; 8(6):188-196.

[6] Jang SJ, Jeon HJ, Shim TB, Eom SJ, Yun SH, Paek JH. A Study on the Tower-crane Equipment Planning Support System in the BIM Environment. Journal of the Architectural Institute of Korea. 2008 July; 24(7):109-116.

[7] Daelim E&C. A Study On Development Of Cad-Based Simulation System For Construction Process Management In Apartment Project. Final Report. Seoul (Korea): 1997. 189p. Supported by Ministry Of Construction and Transportation.

[8] Jeong SS, Heo J, Woo SK. Development of Building Monitoring Techniques Using Augmented Reality. Journal of Korea Institute of Construction Engineering and Management. 2009 Nov; 10(6):3-12.

[9] Kensek K, Noble D, Schiler M. Tripathi A. Augmented Reality: An Application for Architecture. Proceedings of the Eighth International Conference on Computing in Civil and Building Engineering; 2000 Aug 14-16; Stanford, California (USA). ASCE; c2000. p.294-301.

[10] Chang J.R., Hsu H.M., Chao S.J. Development of a Road Monitoring and Reporting System Based on Location-Based Services and Augmented Reality Technologies. ASCE Journal of Performance of Constructed Facilities. 2012 Dec; 26(6):812-823.

[11] Hammad A., Garrett J., Karimi H. Potential of Mobile Augmented Reality for Infrastructure Field Tasks. Proceedings of the Seventh International Conference on Applications of Advanced Technology in Transportation; 2002 Aug 5-6; Boston (USA). ASCE; c2002. p.425-432.

[12] Kim YJ, Ahn CS, Choi YG, Kim SA, Yoon SW, Chin SY. A Study on Method to Progress Management based Augmented Reality (AR) on Smartphone. Proceedings of Korea Institute of Construction Engineering and Management Annual Conference; 2010 Nov 5-6; Inchon (Korea). Seoul (Korea), Korea Institute of Construction Engineering and Management; c2010. p.309-310.

[13] Park SY, Choi JW. A Study on the Applications of the Augmented Reality Technology for Effective Information Management in Existing Buildings. Journal of the Architectural Institute of Korea. 2005 Aug; 21(8):37-44.

[14] Ryu JR, Choo SY, Jo JS. An Application Method of Augmented Reality Technology for Layout Planning of Housing Complex. Journal of the Korean Housing Association. 2010 Aug; 21(4):89-97.

[15] Park UY. Mobile Augmented Reality for Teaching Bar Placing. Journal of Korea Institute of Building and Construction. 2018 Oct; 18(5):417-477.

[16] Chua M., Matthews J., Love P. Integrating mobile Building Information Modeling and Augmented Reality systems: An experimental study. Automation in Construction. 2018 Jan; 85:305–316.

[17] Li X., Yi W., Chia H., Wang X., Chan A. A critical review of virtual and augmented reality (VR/AR) applications in construction safety. Automation in Construction. 2018 Feb; 86:150–162.

[18] Kim HJ, Kim CY, Jeong HY, Ha SJ, Kim KN, Kim HK. 4D CAD Drawings based on Marker-based Augmented Reality. Journal of Korea Institute of Construction Engineering and Management. 2015 Jul; 16(4):30-40.

[19] Kim SR, Jung YS. Improvement of Workability and Schedule Management using Augmented Reality in Modernized Hanok Construction. Proceedings of CSEIK Annual Conference; 2016 Apr 13-15; Daejeon (Korea). Seoul (Korea), Computer Structural Engineering Institute of Korea; c2016. p.1-2.

[20] Ryu HG, Choi HB, Jang MH. Method to Select Tower Cranes Using Augmented Reality in Smart Devices. Journal of Korea Institute of Building and Construction. 2014 Oct; 14(5):407-413.