Selection of a Tower Crane Using Augmented Reality in Smart Devices

Myunghoun Jang, Yongkyu Yi

Abstract—Appropriate selection of lifting equipments for a high-rise building construction project is one of the important factors to the project's success. Proper position of a tower crane on a construction site is so important to be determined by an expert or an experienced construction manager who draws working range of a tower crane and moves it over a 2D (dimensional) site layout plan. But it is not usual to use 3D CAD, BIM or virtual reality for temporary facility planning or selection of a tower crane. This study proposes a method to use augmented reality to select proper position of tower cranes. An augmented reality prototype is implemented on a smart device to verify the practicability of the proposed method.

Keywords—Augmented Reality, Construction Planning, Site Layout, Temporary Facility Management, Tower Crane.

I. INTRODUCTION

APPROPRIATE selection of lifting equipments for a high-rise building construction project is one of the important factors to the project's success. The selection has no effect on construction planning such as temporary facility planning, stockyards, moving, and especially on erection of framework that is the basis of construction [1]. Material lifting planning and selection of lifting equipments have dynamic co-relation with each other. They are supposed to consider systematically not only construction duration and cost from the viewpoint of construction management, but also working radius, range, efficiency, interference in neighbor buildings, numbers, climbing, maintenance, and dismantlement of lifting equipments [2].

A tower crane delivers materials vertically but has limited distance to lift them. Proper position of a tower crane on a construction site is so important to be determined by an expert or an experienced construction manager. He/she draws working range of a tower crane and moves it over a 2D (2 dimensional) site layout plan. 3D CAD or 3D model is mostly used not to select the proper position in planning phase but to review the intervention of building structure and a tower crane in construction phase. BIM (Building Information Modeling) is used to check errors in design or construction in advance. Furthermore 4D, 5D CAD, and virtual reality are also used. But it is not usual to utilize BIM and others for temporary facility planning or selection of a tower crane. The 3D CAD environment or virtual space is more helpful for planning and reviewing of tower cranes.

Myunghoun Jang is with the Jeju National University, Jeju 690-756 Korea (phone: 82-64-754-3704; fax: 82-64-757-8691; e-mail: jangmh@jejunu.ac.kr).
Yongkyu Yi is with the Jeju National University, Jeju, 690-756 Korea (phone: 82-64-754-3730; fax: 82-64-724-3709; e-mail: ykyi@jejunu.ac.kr).

This study proposes a method to use augmented reality to select proper position of tower cranes. The method shows virtual tower crane models on a real site layout plan via the camera of smart devices such as a smart phone and a smart pad. It reduces the efforts to make 3D CAD models because the augmented reality needs only tower crane models while BIM or virtual reality requires the models of all building components and tower created by 3D CAD. Construction duration and cost are essential to select tower cranes. But this paper focuses on displaying the mixture of 3D tower crane virtual models and a real layout plan in an augmented reality on a smart device.

II. 3D MODEL AND SELECTION OF TOWER CRANES

A. CAD Model

The introduction of CAD (Computer Aided Design) caused a warning that it would spoil design mind and decrease design quality. But, CAD results in productivity improvement and efficient communication of participants in design, and it becomes more popular than expected [3]. 2D CAD as an assistant to draw plans is developing into 3D CAD that display wall, column, floor, window, or door as an object in a 3D space. 3D CAD is a design tool that makes three dimensional objects automatically. It is widely used because it supports more accurate design analysis and simulations than 2D CAD [4]. 3D CAD uses object-oriented elements with the information of building components. Object-oriented 3D CAD is an effective tool to contain architectural information which is transferred through concept design, detail design, engineering, construction, and maintenance of a building and building elements.

A method [5] to use object-oriented 3D CAD has been proposed. It produces a take-off and an estimate from the volumes and properties of 3D objects. A 4D (3D+time) CAD model [6] calculates the amount of materials required to construct a building in every work schedule. But a survey [7] shows that many design companies do not use 3D CAD in spite of its many possibilities because using it increases the design cost.

Object-oriented 3D CAD extends to BIM (Building Information Modeling) [8] that makes models of design, engineering, construction, maintenance, and disposal in multi-dimensional virtual space. All phases of a building construction project make use of BIM. For example, it is used to find design errors and check interferences between pipes and wires.

B. Temporary Works Planning and Tower Cranes

After tower cranes have been used to construct high-rise

buildings, many methods have been developed to select them efficiently. Most of the methods propose the optimum position and the number of tower cranes on a construction site in 2D model using mathematical models, genetic models, fuzzy models, and so on. Positioning tower cranes in a 2D plan has a limit that it is difficult to consider vertical delivery of materials and installation, climbing, and dismantlement of tower cranes at a time.

TFPlanner [9] determines the position of tower cranes using a 2D model. It shows the changing shapes of tower cranes as the construction schedule proceeds. Though it includes various elements such as stockyard, entrance, storage, etc., 3D model is not shown in the system. A method [10] to select a tower crane in planning temporary works considers construction duration, costs and the relation of temporary facilities. The relation is created by the distance of the temporary facilities in a 2D layout plan.

TCSS (Tower Crane Selection System) [11] suggests a method to link selection of a tower crane and construction schedules. It is applied to an extremely high-rise building project and it divides the structure into floors to analyze detail works performed in the floor. This system uses 2D drawings and has a further study to upgrade itself into BIM or 3D model.

3D CAD or 3D model is not usual to select tower cranes because a tower crane has no change except for climbing after the installation. The selection of tower cranes with temporary works planning is so dynamic to need BIM or 3D CAD. A research [12] is proposed to select a tower crane in BIM environment by planning temporary works and equipments management. The tower crane model in 3D CAD is determined in consideration of the contents and quantity of materials to be lifted.

C. Augmented Reality

4D CAD adds schedule to 3D CAD and is a kind of virtual reality that can show the progress of construction with the course of time. The virtual reality displays a designed building model in a virtual space and is also used for construction simulation considering project environment and resources. A 3D simulation system [13] for schedule management was developed in the late 1990's to show the process of building apartments. It is very pacesetting system of virtual reality adapted in the field of construction project management.

Many efforts have been made to use virtual reality in AEC (Architecture, Engineering, and Construction). The virtual reality has its limitations that it is difficult to overlap directly a 3D model with actual image of construction in progress because it overlooks real status of the construction site [14]. A technique to overlaps virtual objects on actual environment to overcome the limitations is augmented reality [15].

LBS (Location-Based Service) is one of augmented reality techniques used in a construction project. A smart device is able to provide the technique in road construct projects where location is very important. Road Monitoring and Reporting System [16] overlaps the current road condition with stored data to manage and repair the road. The system helps to reduce managing time and cost.

Several researches use augmented reality to collect information on site and to compare it with as-planned data. MARSIFT (Mobile Augmented Reality System for Infrastructure Field Tasks) [17] proposes a method to show the real-time information of road, bridges, and tunnels on mobile devices. A research [18] discusses methodology of generating, analyzing and visualizing progress with D4AR (4 Dimensional Augmented Reality) models using daily construction photographs and 4D as-planned model. Distributed augmented reality for visualizing collaborative construction tasks (DARCC) [19] shows virtual models of construction equipment operated and viewed by several operators to interactively simulate construction activities on the construction site.

Another method to use augmented reality shows a virtual model and reviews it on an image marker. The image marker indicates the view of a camera and the position of the virtual model.

A building maintenance system [20] developed on the base of augmented reality provides the information of pipes installed in the building by a laptop computer and a camera. The camera reads a marker on a wall and the computer shows the information and 3D model of the pipe overlapped on the captured image. The building unit layout system [21] enables a user to change the layout by moving the markers for building units in augmented reality environment. The user can show the 3D models of the building units on a computer screen.

III. Tower Crane Selection Model Based on Augmented Reality

A. Developing Tool

This research uses the marker and the method to show 3d models in augmented reality which has been already developed in previous researches [19], [20]. These researches used a laptop computer that is heavier than a smart device. The advancement of IT (information technology) enables the smart device to replace the laptop computer. The model proposed in this paper employs a smart pad with a camera to develop a tower crane selection model in augmented reality.

AndAR[1], NyARtoolkit[2], and QCAR[3] are tools to implement augmented reality in Android based smart devices. Each tool displays 3D models overlapped on a image or icon called a marker via an attached camera. A user can see dynamic views when moving not only a camera but also the marker.

This research uses QCAR that provides augmented reality libraries for Eclipse[4]. Eclipse is Java based programming language. The structure and UI (user interface) of an augmented reality application are implemented by Eclipse and the view and overlapping of 3D models and real images are by C++ programming language. QCAR substitutes a marker with an image target which includes an image, a picture, or a photo as well as a simple icon. For example, a photo of a tower crane

---

[1] Android Augmented Reality. code.google.com/p/andar.
[2] NyARToolkit project. nyatla.jp/nyartoolkit/wp.
[3] Qualcomm Augmented Reality (Vuforia). ar.qualcomm.at.
[4] Eclipse (software). en.wikipedia.org/wiki/Eclipse_(software).

can be an image target. QCAR's Target Management System[5] registers user images. But, QCAR cannot directly show a 3D model made by a CAD software or a 3D modeling software in augmented reality. The 3D model should be converted into an element of the QCAR library through a converting program.

Fig. 1 is a screen image showing a tower crane model on its image target on a smart device. The tower crane model is created by a 3D modeling software and inputted by the converting program. The image for the tower crane model is drawn by a user and registered by the Target Management System. The augmented reality app shows the user image normally to the user, which is encoded within the app.
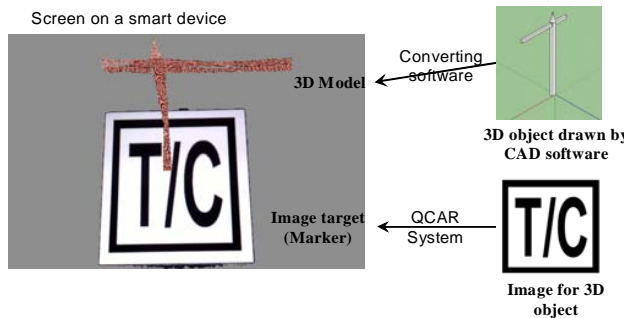

Fig. 1 3D model on the Image target in AR

B. Prototype

A prototype is developed to select tower cranes in augmented reality using QCAR. The prototype app for an Android smart device is coded by Eclipse on Microsoft Windows. 3D tower crane models are made and simplified by SketchUp[6] and image targets for markers are drawn by a typical graphic tool. When a camera of the smart device focuses on the image target, the 3D model appears above the center of the image target. A tower crane on a camera scene of the smart pad is shown in Fig. 2 (a), and Fig. 2 (b) shows two tower cranes on their image targets at a time. A user is able to locate the tower crane by moving the tower crane's image targets on the layout plan and to see diverse view by moving the smart device with the camera. Various locations of the tower crane in augmented reality grant the user the flexibility of temporary works planning.

A simple or complicated image can be an image target. One image target may include several 3D models so that a user could choose one of them to display it on augmented reality. The prototype allocates one image target for one 3D model. It is simple but inconvenient because the user should substitute the image target one the layout plan with another one to show a different 3D tower crane model.

C. Discussions

One advantage in using augmented reality is that the app just as it is could be applied to other layout planning for building

construction projects. A user doesn't have to change an image target or a 3D tower crane model. On the contrary, additional 3D models extend user's choice in case of need.

Another advantage is that a tower crane could be selected like it is in virtual reality though it is actually on 2D layout plan. The traditional method to locate a tower crane on a 2D layout plan uses only working range of the tower crane on the plan or its height and climbing position on the elevation plan. The method makes it difficult to change the type and the location of the tower crane.

The use of tower cranes in high-rise building construction takes an objective to decrease construction duration and cost. But the method proposed in this paper to select tower cranes using augmented reality does not include the optimization of the duration and cost. It focuses on reviewing potential for expansion to building construction planning. Future studies may develop a system for temporary works planning including all of construction duration, cost, materials, and equipments.

(a) A tower crane on its image target
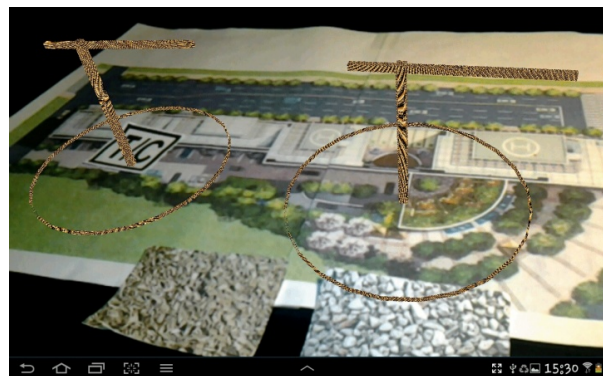
(b) Two tower cranes on different image targets

Fig. 2 Tower cranes on a site layout plan

IV. CONCLUSION

As smart devices become popular with many industry fields, the efforts are made to adapt them the AEC (Architecture, Engineering, and Construction) industry. This research proposes a method to select tower cranes using augmented reality technique on a smart device. The results of the research as follows:

---

[5] Qualcomm's Target Management System offers a convenient web-based tool for Vuforia SDK developers to create this known dataset from input images. ar.qualcomm.at/developer_guide.
[6] Trimble SketchUp. www.sketchup.com.

(1) Virtual reality or BIM shows easily 3D models in virtual space. But it takes effort to make all objects into 3D models. Augmented reality mixes real world and virtual objects and makes 3D models of parts of objects to be shown. This is more economic and requires less time.

(2) The high-rise building construction project uses tower cranes to save construction time and cost. The selection of the type and location of a tower crane needs the consideration of materials, lifting time, lease cost and so on. But, the scope of this paper is to select the type and the location on a layout plan in augmented reality. A prototype is implemented for smart devices.

(3) Augmented reality on the smart device provides dynamic views of a 3D model to a user. All who have their smart devices can experience the mixed reality at a same time from their different angles. But when a smart device has a small screen that shows small virtual space, a user has difficulties to select and move the 3D model.

REFERENCES

[1] Y. S. Kim, J. K. Cho, M. J. Kim, K. M. Cho, and C. T. Hyun, "A Productivity Analysis of Tower Crane Installation Progress Based on Simulation Technique," Journal of the Korea Institute of Building Construction, vol. 10, no. 2, pp. 33-40, Apr. 2010.

[2] J. K. Ho, D. H. Kook, and S. K. Kim, "A System for the Selection of the Optimum Tower Cranes (Opt-TC)," Journal of Korea Institute of Construction Engineering and Management, vol. 8, no. 6, pp. 216-226, Dec. 2007.

[3] W. Y. Kim, "Introducing 3D CAD to advance construction techniques," The Construction Business Journal, vol. 72, pp. 63-65, Apr. 2007.

[4] S. Y. Kwon, Y. S. Lee, B. J. Ahn, W. Y. Kim, and J. J. Kim, "A Basic Study on Extracting Space Information from 3D CAD," in Proceedings of Korea Institute of Construction Engineering and Management Annual Conference, Seoul (Korea), 2008, pp. 645-648.

[5] S. W. Oh, B. J. Sung, Y. S. Kim, and J. R. Kim, "The Development of an Automated Cost Estimating System Using 3D CAD Building Element Information," Journal of the Architectural Institute of Korea, vol. 17, no. 6, pp. 103-112, Jun. 2001.

[6] J. C. Lee, "Application of the 3D CAD Model Data for 4D Simulation and Quantity Estimation," Journal of Korea Institute of Construction Engineering and Management, vol. 5, no. 4, pp. 107-114, Aug. 2004.

[7] S. H. Lee, B. J. Ahn, J. H. Kim, K. H. Kim, Y. S. Lee, and J. J. Kim, "An Analysis on affecting factors about lowly using 3D CAD by using the AHP," Journal of Korea Institute of Construction Engineering and Management, vol. 8, no. 6, pp. 188-196, Dec. 2007.

[8] I. H. Kim, "The History and Concept of BIM Building Information Modeling," Review of Architecture and Building Science, vol. 54, no. 1, pp. 15-16, Jan. 2010.

[9] AIK (Architectural Institute of Korea), Development of Knowledge-Based Temporary Facility Planning System for High-rise Buildings, Final Report Sep 2000-Sep 2002 supported by Ministry Of Construction and Transportation, Seoul (Korea), 2002.

[10] M. H. Jang, and H. S. Lee, "A Method of Evaluating and Selecting Alternatives of Temporary Facility Planning in High-rise Building Projects" Journal of the Architectural Institute of Korea, vol. 18, no. 12, pp. 143-150, Dec. 2002.

[11] J. H. Cho, and H. G. Cho, "An Analysis of Optimized Super Tall Building Tower Crane Selection Which Related With Project Construction Period," Journal of the Korea Institute of Building Construction, vol. 9, no. 6, pp. 131-139, Dec. 2009.

[12] S. J. Jang, H. J. Jeon, T. B. Shim, S. J. Eom, S. H. Yun, and J. H. Paek, "A Study on the Tower-crane Equipment Planning Support System in the BIM Environment," Journal of the Architectural Institute of Korea, vol. 24, no. 7, pp. 109-116, Jul. 2008.

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

[14] S. S. Jeong, J. Heo, and S. K. Woo, "Development of Building Monitoring Techniques Using Augmented Reality," Journal of Korea Institute of Construction Engineering and Management, vol. 10, no. 6, pp. 3-12, Nov. 2009.

[15] K. Kensek, D. Noble, M. Schiler, and A. Tripathi, "Augmented Reality: An Application for Architecture," in Proceedings of the Eighth International Conference on Computing in Civil and Building Engineering, Stanford, California (USA), 2000, pp. 294-301.

[16] J. R. Chang, H. M. Hsu, and S. J. Chao, "Development of a Road Monitoring and Reporting System Based on Location-Based Services and Augmented Reality Technologies," ASCE Journal of Performance of Constructed Facilities, Not printed (Accepted on Aug 1, 2011).

[17] A. Hammad, J. Garrett, and H. Karimi, "Potential of Mobile Augmented Reality for Infrastructure Field Tasks," in Proceedings of the Seventh International Conference on Applications of Advanced Technology in Transportation, Boston (USA), 2002, pp. 425-432.

[18] M. Golparvar-Fard, S. Savarese, and F. Pena-Mora, "Interactive Visual Construction Progress Monitoring with D4 AR - 4D Augmented Reality – Models," in Proceedings of Construction Research Congress, Seattle (USA), 2009, pp. 41-50.

[19] A. Hammad, H. Wang, and S. Mudur, "Distributed Augmented Reality for Visualizing Collaborative Construction Tasks," Journal of Computing in Civil Engineering, vol. 23, no. 6, pp. 418-427, Nov. 2009.

[20] S. Y. Park, and J. W. Choi, "A Study on the Applications of the Augmented Reality Technology for Effective Information Management in Existing Buildings," Journal of the Architectural Institute of Korea, vol. 21, no. 8, pp. 37-44, Aug. 2005.

[21] J. R. Ryu, S. Y. Choo, and J. S. Jo, "An Application Method of Augmented Reality Technology for Layout Planning of Housing Complex,", Journal of the Korean Housing Association, vol. 21, no. 4, pp. 89-97, Aug. 2010.