Efficient 3D Design Drawing Visualization Based on Mobile Augmented Reality

Yeon-Jae Oh*, Kyoung-Wook Park**, Eung-Kon Kim*

**Department of Computer Science, Sunchon National University, 255 Jungang-ro, Suncheon, Jellanam-do, Republic of Korea*

***Division of Culture Content, Chonnam National University, 50 Daehak-ro, Yeosu, Jellanam-do, Republic of Korea*

oksug10@sunchon.ac.kr, zergadiss73@chonnam.ac.kr, kek@sunchon.ac.kr
Corresponding Author: Eung-Kon Kim

***Abstract*—Recently, in manufacturing, machinery, construction and shipbuilding industry, diversified researches of visualizing design drawings without difficulty utilizing augmented reality technology have been performed. In this paper, we propose efficient 3D design drawing visualization technique based on mobile augmented reality. Proposed technique first recognizes design drawing region, and only performs image tracking in its region. Through performance analysis, it could be seen that in technique being suggested in this paper, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.**

***Keyword*—Augmented Reality, 3D Structures, Drawing recognized**

I. Introduction

As augmented reality provides users with enhanced immersion and a sense of reality, it has been applied in diversified fields including broadcasting, shopping, medical service, education, military, game, architecture, shipbuilding and manufacturing business[1-6].

As design drawing is 2D plane and it expresses relevant data numerically, it is hard for construction manager, engineer and users to understand solid form of structures. In order to solve this problem, diversified researches visualizing design drawing without difficulty by utilizing augmented reality technology have been performed.

In this paper, 3D model visualizing technique of augmenting virtual 3D structures on 2D drawing utilizing augmented reality technology is suggested.

Suggested visualized technique recognizes design drawing through smart phone camera without marker and displays it out on camera image by augmenting 3D model.

First, in order to recognize design drawing, edge point is extracted from camera image and it is set as design drawing region by calculating rectangular region. And as feature point for total image is extracted by performing matching for design drawing region only, its calculation volume is less than existing matching method.

Through performance analysis, it could be seen that in technique being suggested in this study, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.

II. Augmented Reality 3D Model Visualization Technology in Industrial field

A research on introduction of augmented reality for site support of 3D design data utilized augmented reality technology for a system in which 3D design data could be supported to site workers in terms of operation and maintenance after ship hand-over in order to ensure sustainable performance of ship[7].

Augmented Reality Technology based plant piping construction management plan aimed at efficiency of piping construction management through real time confirmation of piping information in plant piping construction site and confirmation of 3D piping model based piping installation error being overlapped in actual environment by utilizing augmented reality[8].

In a research on application of augmented reality for inspecting rebar arrangement of civil works, its application could increase understanding of rebar workers by visualizing 3D modeled rebar in actual site in an overlapped form and by utilizing it even to construction inspection stage, suppress cost increase by defect and rework that may be taken place in rebar fabrication work effectively[9].

In a research on application of augmented reality technology for operation and maintenance education for ship building/marine equipment, in order to ensure sustainability of ship building/marine equipment, material and support product sustainability by introducing augmented reality technology at the site, a system that enables education and maintenance support for the system that may support workers more effectively at the time of operation and education for marine equipment/material was provided[10].

Manuscript received November 9, 2014. This research was financially supported by the Ministry of Education (MOE) and National Research Foundation of Korea(NRF) through the Human Resource Training Project for Regional Innovation (No. 2013H1B8A2032217).

Yeon-Jae Oh, was with Sunchon National University, 255 Jungang-ro, Suncheon, Jellanam-do, Republic of Korea (e-mail: oksug10@naver.com)

Kyoung-Wook Park, was with Chonnam National University, Jellanam-do, Republic of Korea(e-mail : zergadiss73@chonnam.ac.kr)

Prof. Eung-Kon Kim, was with Sunchon National University, 255 Jungang-ro, Suncheon, Jellanam-do, Republic of Korea(corresponding author : +82-61-750-3627; fax: +82-61-750-7999; e-mail: kek@sunchon.ac.kr).

III. Efficient 3D Design Drawing Visualization

Augmented reality has been used in diversified fields including construction, machinery, ship building industry as communication tool between managers and engineers because structure of 3D model is visualized on 2D design drawing so that design process of structures to be manufactured could be explained to the users without difficulty and exact user′s requirements could be identified. "Fig. 1" show structural diagram of visualizing 3D model of design drawing.

Fig. 1. structural diagram of visualizing 3D model of design drawing

A. Design drawing management server system

Design drawing management server includes configuration of design drawing management server, design drawing information management module and feature point matching and search module.

Configuration of design drawing management server: Design drawing management server system play a role of saving image, feature points and 3D model of design drawing, searching relevant design drawing by receiving feature point data transmitted from smart phone and transmitting design drawing information and 3D model.

Design drawing information management module: Design drawing management module is to manage design drawing information in design drawing image registered in server. System manager is able to manage overall side information and authorized user is able to manage permitted information only after approaching module through user authentication. In total natural image being used in augmented reality system, each main information and additional information are managed.

Feature point matching and search module: Feature point matching and search module receive information request if image entered from smart phone is available and search information in DB management system. Searched result is printed out in a form of XML.

B. Recognizing Design Drawings

The mobile augmented reality system for design drawing proposed by this paper is implemented using non-marker based AR technology which enables to recognize existing design drawings without inserting specific marker into the drawing. The processes in which design drawings are recognized is shown in "fig. 2".

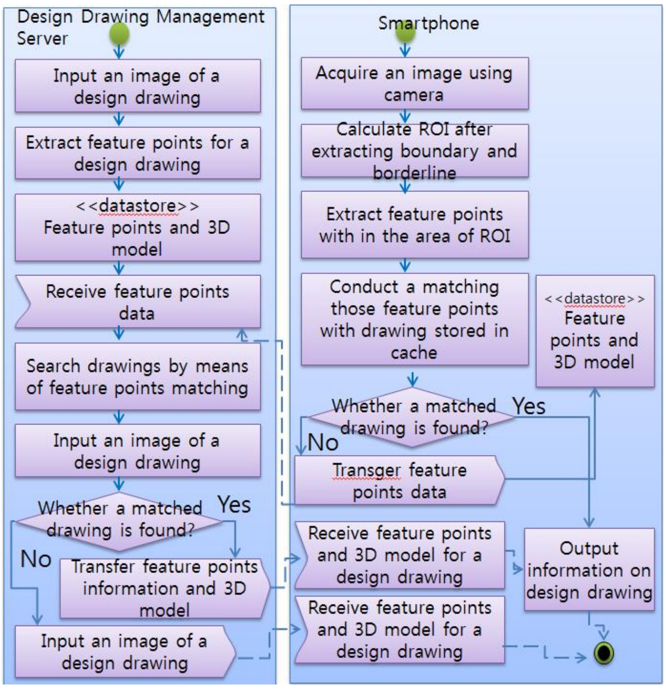
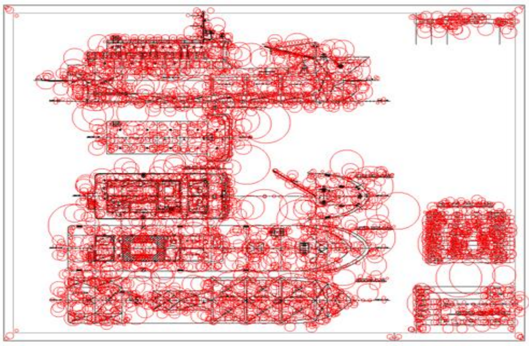
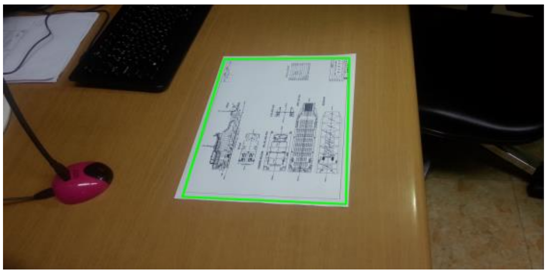


Fig. 2. Design drawing recognition process of design drawing recognition

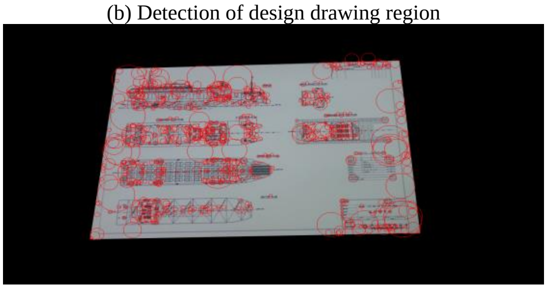
Firstly, design drawings are entered to the server by using scanner. Feature points are extracted from the drawings using feature points extraction algorithm. The extracted feature points are stored in database together with 3D model. Subsequently, drawing image is acquired by taking photo using a camera embedded in a smartphone. From the obtained image, boundary and borderline are extracted. Then regions of interest (ROI) for a rectangle area of the drawing are calculated. After extracting feature points within the ROI, a matching operation is carried out by comparing between extracted feature points and the feature points of drawings stored in a cache. If there exists the drawing with matched feature points, fetch the information about the drawing from cache memory. Otherwise, send the feature points to the server in order to search data stored in server. Once the server receives the feature point data, it retrieves the design drawings stored in its data-base using the method of feature point matching. In this case, the drawings with highest similarity are searched using SURF(Speeded Up Robust Features) algorithm. When the search is completed, the found feature points and 3D model would be transmitted back to cache memory in a smartphone. The smartphone shows the message to the user, so that the user recognizes that the drawing data with matched feature point now exists in cache memory. However, if the server couldn't find the matched drawing in its database, it returns failure message back to the smartphone. Then smartphone displays failure message to the user. "Fig. 3" shows matching process after setting design drawing region based on suggested region setting.



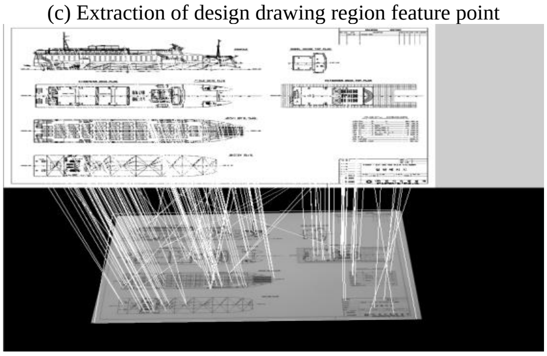
(a) DB of design drawing feature point



(b) Detection of design drawing region



(c) Extraction of design drawing region feature point



(d) Result of design drawing matching

Fig. 3.Matching process after setting design drawing region

DB of design drawing feature point: First, design drawing management server saves design drawing image, feature point data, 3D model as DB and extracts feature points by using SURF algorithm after converting to image size similar to resolution of smart phone.

Detection of design drawing region: Generally, design drawing is rectangular shape and by utilizing this feature, design drawing region is detected. First, unnecessary noise is removed by performing Up-Scale immediately followed by Down-Scale in camera image of smart phone. And then, contour line is detected utilizing inter-regional contour algorithm by changing threshold. After approximating these pointers, whether it is rectangular shape is determined. Coordinate of rectangular vertex is calculated by determining whether line is 4 and it is rectangular shape utilizing edge angle, region.

Extraction of feature point of design drawing: After extracting rectangular drawing region, feature points in region only are extracted. In order to recognize design drawing as marker, after detecting rectangular shaped drawing region in previous stage, features points are extracted for only relevant regions.

Feature point matching of design drawing: Data that extracted typical feature points by its compression and feature points of DB are matched. In system resources such as smart phone or tablet PC and mobile devices having frequent processing speed limit, feature point is matched by applying SURF algorithm.

C. Design Drawing 3D Model Visualization

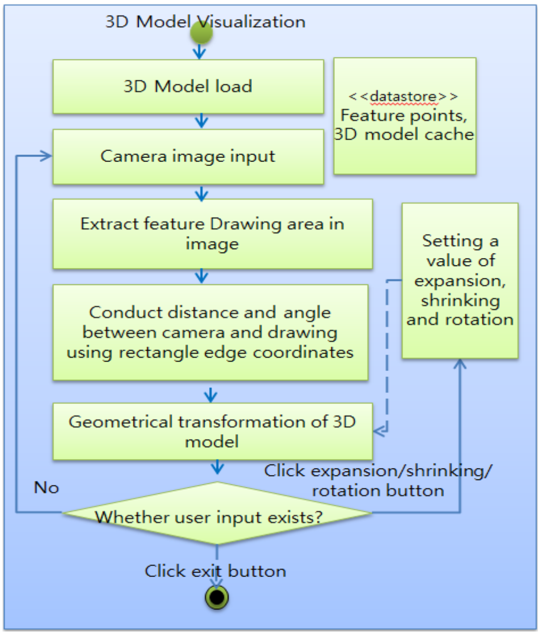
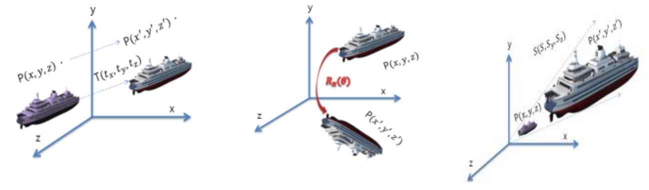


Fig. 4. Process of 3D Model Visualization

Once a drawing is completely recognized, the process to augment 3D model on top of the 2D drawing is being conducted as illustrated in "fig. 4". 3D model and the feature points for the design drawing stored in cache memory are loaded into a smartphone visualization module. Then camera takes a photo of a target drawing. Based on the photo image, ROI coordinates are detected for the rectangle area of the drawing. The edge coordinates of the rectangle are tracked and then a distance and an angle between a camera and a drawing are estimated. Corresponding to an estimated distance and angle, 3D model would be adjusted like moving, expanding, shrinking or rotating. Finally shading effect is added to 3D model. The resulting 3D model is visualized on a screen of the smartphone. In the meanwhile, if there is no user input, all of the above processes are executed under an iterative loop starting from getting input of a camera image. When a user input occurs, correspondent events are handled such as expanding, shrinking, rotating and terminating.

Geometric conversion of 3D Model: If four vortex coordinates of design drawing is known, rotated position and posture of design drawing could be calculated based on camera coordinates system. In this study, camera coordinates system is obtained from vortex of design drawing ROI using a method suggested in geometric conversions. "Fig. 5" shows movement, rotation, enlargement of 3D model



(a) Movement (b) Rotation (c) Enlargement

Fig. 5. Movement, Rotation, Enlargement of 3D Model

Conformity of design drawing 3D model: Image conformity is a process of making two images to be exactly coincided when actual drawing and virtual 3D model are shown in overlapped form. By receiving video image data in Frame buffer of graphic system, 3D model is expressed in overlapped form in setting position. After matching 3D model including its depth value on 3D design drawing, it is displayed.

IV. IMPLEMENTATION AND PERFORMANCE ANALYSIS

A. System Implementation

Developing environment: To analyze feasibility of the proposed mobile AR system for design drawing visualization, android-platform smartphone application and a drawing management server were developed. For a design drawing management server, hardware specification is as follows: INTEL i7 3.40GHz, 16GB Memory and SSD 256GB. As for smartphone, hardware specification is Qualcomm Snapdragon S3 Dual Core 1.5GHz and 1GB memory. Android 4.1.2 Jelly-bean is used as platform. Screen resolution is 1280×800.

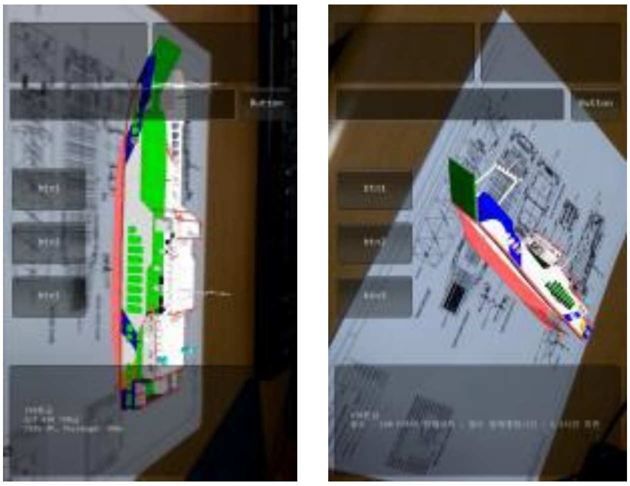
Design drawing and 3D model database: For implementing the proposed system, management server for dealing with design drawings were developed. In conjunction with the server, database was also developed. The database was de-signed to be used for storing 20 types of design drawing images, feature points and correspondent 3D model. The 20 types of models were generated using Catia modeling tool.

Implementation result: The implementation result is explained here. Total 20 models were entered to the system as an input. The system supports to expand, shrink and rotate the image as user wants. Each part comprising the whole image can be displayed. "Fig. 6" shows a demonstration of running mobile AR-based 3D model display system. "Fig. 7" shows screens where an augmented 3D model is presented as rotated image and as partial display.

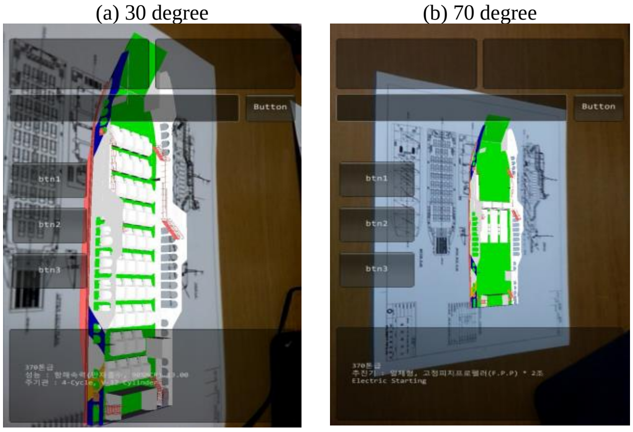
B. Performance Analysis

Performance regarding recognition of design drawing: To estimate system performance, a comparison between the proposed technique and an existing technique was conducted by measuring a recognition rate and recognition time duration for the design drawings. In the proposed technique, ROI is firstly detected within the drawing image and then matching is done by using only feature points extracted from ROI. In contrast, the existing technique extracts feature points from an entire region of the drawing image. For carrying out the sys-tem performance analysis, 20 different types of design drawings were taken pictures using a rear camera of the smartphone which was used in this study. When taking pictures, camera angle and distance to the drawings were varied. Those pictures were entered to the system as inputs. "Fig. 8" shows a scene how a design drawing is taken a picture using the smartphone which is a component of mobile AR 3D model display system.

Fig. 6. AR execution demonstration



(a) 30 degree (b) 70 degree



(c) Car loading (d) Truck loading

Fig. 7. Rotation and Partial display screen of an augmented 3D model

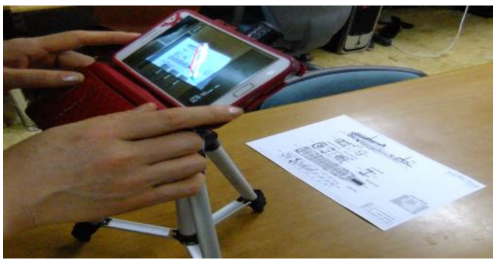
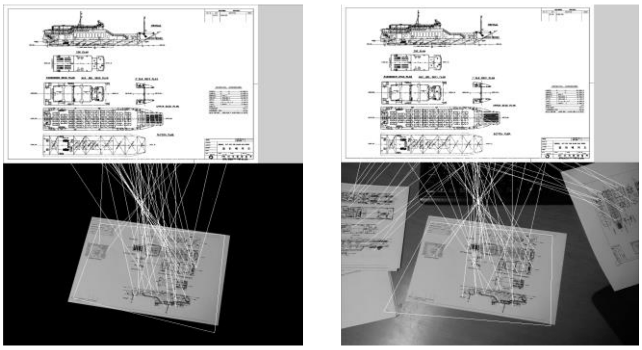


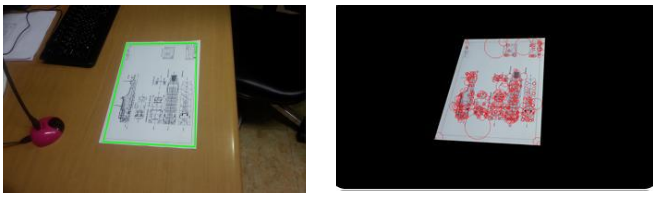
Fig. 8. Drawing test process

Total 20 tests were carried out. In each test, the design drawing was taken from a different direction, for example, front, side and diagonal direction. For each angle and direction, tests were conducted for the pro-posed method and an existing method. Therefore, total number of tests conducted is 180. In this test, measurement items are two: recognition rate and recognition time duration. To get rid of any effect of a lagging time which might occur in communicating between the server and the smartphone, feature points and 3D models were stored in a cache memory of the smartphone prior to conducting tests. The process to detect feature points by extracting ROI from the design drawing is shown in "fig. 9". The technique pro-posed in this study detects and extracts ROI first as illustrated in (a). Secondly, remaining area except for the ROI is marked to be black as presented in (b). Finally, feature points are extracted using SURF algorithm.

"Fig. 10" (a) and (b) shows a matching result for the proposed method and an existing method respectively. In case of Fig.10(a), matching process is carried out only for ROI region. It implies that time to be taken for matching can be lower and matching accuracy can be better than that of an existing technique. In case of Fig.10(b), however, matching needs to be conducted for an entire region of a drawing. It indicates that time to be taken for matching would be increasing. Furthermore, other objects surrounding the core part affects and distracts the matching task.



(a) only within ROI region (Proposed method) (b) an entire region of image (traditional method)
Fig. 9. Feature Points Extraction from Design Drawing



(a) Drawing Region ROI detection (b) Feature points extraction
Fig. 10. Feature points matching for design drawings

Recognition results for the drawings are listed as table 1. According to the figures in table 1, the proposed technique shows higher recognition rate than a traditional method by 5~15%. In terms of recognition time duration, the proposed method shows 23~32% lower than a traditional method. These results come from the fact that the proposed method excludes remaining region by detecting ROI of rectangle area for the drawing prior to carrying out feature point matching. The total number of feature points to match becomes less than that of a traditional method. Therefore, calculation amount would be decreasing.

Table 2 shows a test result of design drawing recognition rate. In case of suggested technique, its recognition rate is app. 95-85% in side and diagonal and it shows difference depending on each angle but in most cases, it recognized almost accurately. However, existing technique showed relatively low recognition rate in side and diagonal and it is understood that in side and diagonal direction, as design do cements backdrop or surrounding objects occupy more regions in camera image, it lowers exact recognition. In 70^o angle, suggested technique showed recognition time shorter than existing technique by app. 4-7% and in 50^o and 30^o, recognition time was represented to be shorter by app. 24-33%. The reason of this result is that in existing technique, as more backdrop or surrounding objects occupy most part of image in low angle, number of extracted feature point is plenty. Table 3 is 3D Model visualization test Results

TABLE Ⅰ.
DESIGN DRAWING RECOGNITION RATE TEST RESULTS

Test Item	Angle	Proposed technique			Traditional technique		
		Front	Side	Diagonal	Front	Side	Diagonal
Recognition Rate(%)	30	95	90	85	80	75	70
	50	100	95	90	90	90	75
	70	100	100	100	100	95	95

TABLE Ⅱ.
Test result of recognition time of design drawing

Test Item	Angle	Proposed technique			Traditional technique		
		Front	Side	Diagonal	Front	Side	Diagonal
Recognition Time(%)	10	410.2	424.6	426.7	548.4	562.3	569.8
	45	427.3	432.5	420.9	530.0	541.1	547.3
	80	410.5	423.1	426.3	478.7	492.6	491.2

TABLE Ⅲ.
3D Model Visualization Test Results

	The number of frames per second
Traditional Method(Tracking an entire region And then performing image registration)	14~20 Frames
Proposed Method (Tracking ROI Rectangle. And then performing image registration)	21~28 Frames

C. *Performance Analysis for Design Drawing Visualization*

To estimate the performance especially for image registration technique used in the proposed visualization method, time to be taken for augmenting process was measured by the number of frames per second. In case of a traditional method, feature points are extracted first. Secondly, a distance and an angle between camera and the design drawing are calculated by matching the feature points. And then, 3D model is geometrically transformed for performing image registration. In the process of feature point matching, a significant amount of calculation is required, so that the image registration cannot be performed in smooth way. In contrast, the proposed method firstly detects ROI of rectangle from a camera image. A distance and an angle between the smartphone and design drawing are to be calculated only within the ROI. Then image registration is performed after geometrically transforming 3D model. An amount of calculation necessary for each frame would be lower. Hence image registration can be performed smoothly. Model visualization test results are presented in table

V. CONCLUSION

In case of visualizing 2D design drawing as 3D model using mobile augmented reality technology, understanding for each design drawing could be enhanced and exact and efficient design and manufacturing process control are enabled.

A system suggested in this study recognizes design drawing based on non-marker by limiting entered image. In particular, as matching is made by recognizing design drawing region and extracting feature point in this region only, its recognition rate is high and calculation volume is marginal. And by tracking once recognized rectangular shape only, 3D model could be visualized on drawing based on limited calculation volume only.

Through performance analysis, it could be seen that in technique being suggested in this study, drawing recognition time was reduced by 4-33%, drawing matching recognition rate was increased by 5-15% and number of output frame per second was increased by 7-8 frames per second.

For future work, it is necessary to generate 3D model for an internal structure of specific part of a design drawing as panoramic images and to display them efficiently.

REFERENCES

[1] Fonseca, David, et al., "Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models." *Computers in Human Behavior*, vol. 31, 2014, pp. 434-445.

[2] Yeh, Kai-Chen, Meng-Han Tsai, and Shih-Chung Kang, "On-site building information retrieval by using projection-based augmented reality." *Journal of Computing in Civil Engineering*, vol.26, no.3, 2012, pp.342-355.

[3] Irizarry, Javier, et al. "InfoSPOT: A mobile Augmented Reality method for accessing building information through a situation awareness approach." *Automation in Construction*, vol. 33, 2013, pp.11-23.

[4] Pachoulakis, Ioannis, and Kostas Kapetanakis. "Augmented reality platforms for virtual fitting rooms." *International Journal of Multimedia & Its Applications*, vol. 4, no.4, 2012, pp. 35-46.

[5] G.D. Michelis, M. Loregian, P. Martini, "Directional Interaction with Large Displays Using Mobile Phones", 4th Annual IEEE International Conference on Pervasive Computing and Communications Workshops, 2006. pp.196-200,

[6] Nee, A. Y. C., and S. K. Ong, "Virtual and Augmented Reality Appli-cations in Manufacturing", *Manufacturing Modelling, Management, and Control*, Vol. 7, No. 1, pp.15-26, 2013.

[7] Lee, Jung-Min, et al. "Active insp ection supporting system based on mixed reality after design and manufacture in an offshore structure." *Journal of mechanical science and technology* vol.24, no.1, 2010, pp.197-202.

[8] Kim, Chang Hwan, "A Development of Automated Pipe Spool Installation Management Process Based on Mobile Augmented Reality for Plant Construction; Civil." *Architectural and Engineering*, vol.56 2010,

[9] Kim, Young-Tae, et al. "Construction and inspection management system using mobile augmented reality." *Frontiers of Computer Vision,(FCV), 2013 19th Korea-Japan Joint Workshop on*. IEEE, 2013, pp. 93-96.

[10] Park, Chan-Sik, and Hyeon-Jin Kim. "A framework for construction safety management and visualization system." Automation in Construction, vol.33, 2013, pp.95-103.

Yeon-Jae Oh
She received the B.S. degree from Korea National Open University, Korea, in 2007, her M.S. degree from department of computer science, Sunchon National University, Korea, in 2009. She is currently a Ph.D. student in computer science at the Sunchon National University, Korea, Her current research interests include augmented reality, image processing, computer graphics.

Kyoung-Wook Park
He received the B.S. degree from Sunchon National University, Suncheon, Korea, in 1997, his M.S degree from department of computer sci-ence and statistics, Chonnam National University, Gwangju, Korea, in 1999, his Ph.D. degree from department of computer science, Chonnam National University, Gwangju, Korea, in 2004. His current research interests are parallel and distribution processing, graph theory, theory of computation, bioinformatics and augmented reality.

First A. Author (M'76–SM'81–F'87) and the other authors may include biographies at the end of regular papers. Biographies are often not included in conference-related papers. This author became a Member (M) of IEEE in 1976, a Senior Member (SM) in 1981, and a Fellow (F) in 1987. The first paragraph may contain a place and/or date of birth (list place, then date). Next, the author's educational background is listed. The degrees should be listed with type of degree in what field, which institution, city, state, and country, and year degree was earned. The author's major field of study should be lower-cased.