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Development and Implementation of AR Application for the Advancement of the Tasks in the Construction Sites

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ABSTRACT

We developed an AR (Augmented Reality) application for productivity improvement in the construction sites. Our application projects the AR model generated from the BIM model on 1 : 1 scale in a real space. The main concept of this system is to use the AR technology for visualizing the completed form of the buildings, reforming the "construction management" and improving the productivity on the construction sites. This system can be used for the "presentation of the completed models" for early decision of the construction related works to be performed, "safety work confirmation" for eliminating and reducing the dangerous activities onsite, "visualization of completed model before the completion of the buildings" for eradication of serious mistakes on quality of the buildings to be build. In this paper, we developed an application that aim to facilitate the usage of AR in the construction site are introduced and the precision obtained in the real construction site is illustrated.

Contents

Ⅰ. Introduction

In the coming future, the Japanese constructions will lack a lot of manpower to work in the sites because of the decreasing population in Japan.

The common problems like, delay and misrecognition of the decision made, critical quality accident of the frame (pile, rebar etc.), mistakes in finishing materials, misplacing equipment, inadequate provisional equipment's, lack of building maintenance information and others still occur in the construction sites. These problems are time consuming as well expensive for the correction. To overcome with these problems, we think of using the AR in the field of constructions to bring the advancement in the tasks performed on the construction sites.

Augmented Reality (AR) is a Computer vision system that gives a view of the real world where the elements are superimposed by computer generated files as graphics, sounds, videos or digital information. AR was first developed in 1968 by Ivan Sutherland at Harvard, where the users were able to experience the computer graphics that made them feel being in the alternate reality. Been around for numerous decades, various developments have been made in the field of AR. The implementation of AR in the medical and various other fields are spreading as a part of business innovation but AR technologies were not applied on construction sites due to the tracking and alignment problems in the construction sites, instead they were used at the office for simulation or collaboration during the design phase of a project.

In the recent years, a huge development in the field of AR technology has been made, which shows the possibilities of applying the AR in the field of construction sites.

We developed a concept of mobile AR application, aimed to visualize the completed form of the models in the construction sites. We have developed an AR

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application that can be used on the iPad® on the construction sites. In this paper, we will introduce about this application and its real implementation in the construction fields by on-site employees. This application was experimented and tested in various construction sites in Japan for validating the effectiveness of our AR application.

Ⅱ. Related works

Shin and Dunston (2) states that the AR technology provides various advantages through visualization and simulation of the construction industry. As an example, allowing the observer to interact with both the actual and the virtual objects and monitor the construction progress by comparing the as planned and as built status of the project (2).

In the past research, Wang and Dunston mentioned that it is very impracticable to train a heavy construction equipment operator in a real condition, so they developed an AR based heavy equipment operator training system called ARTS (3). They used their system on Head Mount Displays (HMD), which was not realistic for using in the construction sites. So, we are using iPad in our system.

AR tracking these days are available for mobile phones and tablets being based on the GPS and compass sensors or IMU device. An accurate 3D tracking technology in the construction sites was introduced by utilizing the 3D points clouds generated from the site photos (4). The tracking system developed by using the 3D point clouds were then made able to work on live videos (5).

Due to the limitations of the GPS, the usage of the mobile AR application is limited to the outdoor environment only. In case of the indoor environment, the localization of the AR points or the device is a challenging job. A mobile AR application presented few years ago combines various computer vision tools, 3D reconstructions and sensors to provide reliable tracking (6). This system integrates the BIM data in their system. Our application is somewhat similar with these system in the current perspective.

A 4-dimensional AR model was developed for automating the construction progress monitoring and data collection, processing and communication in the construction phase of the project (7). Various web based augmented panoramic environment are developed for the documentation of the construction progress (8). The Info SPOT system was an approach for mobile AR maintenance that utilized BIM for facility management based on predefined natural markers (9).

Various related works have been done, but the difference to our system is, we are using the extended AR tracking system and a location-based AR model visualization process. We are using the iPad attached with a structure sensor for calculating the movement and the position of the device, the fiducial markers are used to localize the point for displaying the AR model.

Ⅲ. Our AR application overview

The main concept of our current application is to visualize the completed form of the BIM models in the construction sites in a real time using the AR technology. The onsite implementation image of our AR application is shown in Fig.1. The application can be used for the detailed view of 2D plane, facility installation, exterior image, interior image, skeleton framework visualization etc. The problems in the construction sites along with the merits of using our AR application is shown in Fig.2. The arrows shown in the Fig.2 reflects the relation of the construction problems and the merits of AR.

Ⅳ. Proposed Algorithm

The structure of our proposed algorithm is shown in Fig.3. We have divided the structure of our algorithms in two parts, first part is the preprocessing and second part is the main process of the algorithm as shown in Fig.3 (a) and (b) respectively. In the pre-processing of our proposed algorithm, we develop the AR models from the BIM model and fix the positional relationship of the two AR marker points. The positional relationship of the two AR marker points (point to place the markers onsite) is fixed and save them in the device. The positional relationship of the two AR marker points is effective for localizing the position of the smart device. The extended tracking is used for continuous display of the AR model with high accuracy in the real construction sites.

In our previous works (10), we used the structure sensor along with the iPad, but this time, we are using the inbuilt devices of the iPad using the AR Kit. As the application is turned on, AR space is constructed by using the IMU device, camera image and depth camera image from the device. The two markers are then placed in the local reference point and are detected by using the camera of the iPad. Once the marker is detected, the position of the device is localized by

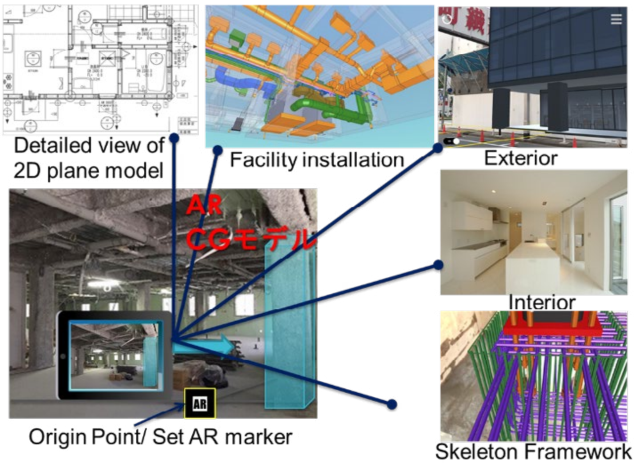


Fig.1 Onsite Implementation Image of AR Application

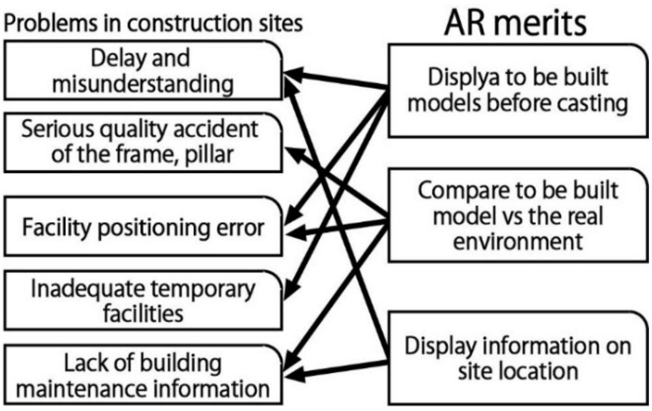
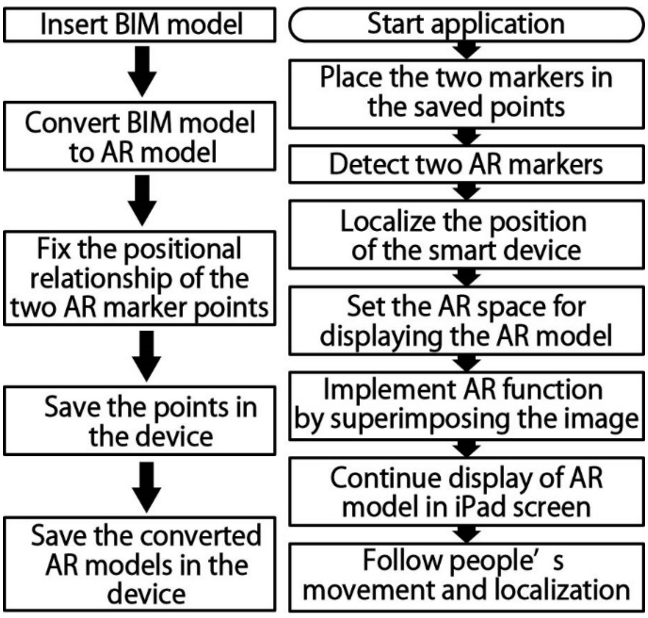


Fig.2 Relation of the Problems in the Construction Sites and the Merits of Using AR



(a) Preprocessing　　(b) Main Process

Fig.3　Proposed Algorithm

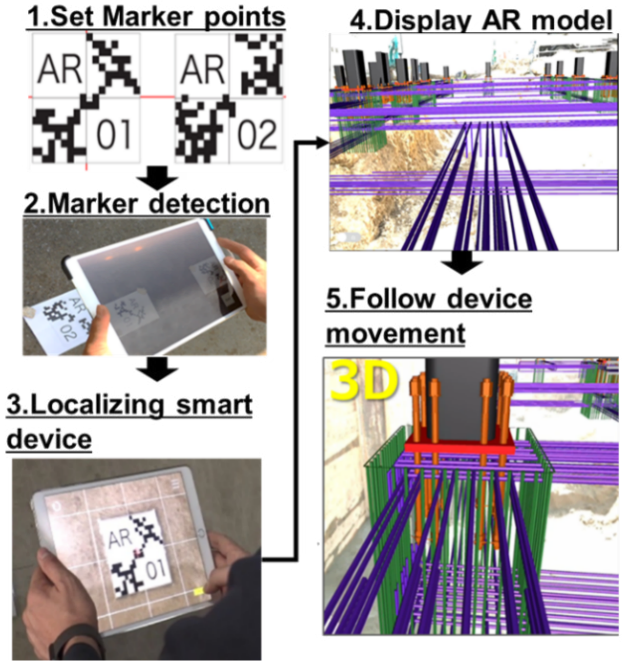


Fig.4 Experimental Representation of Our Algorithm

setting the AR space for displaying the AR model based on the co-ordinates of stored AR marker (two points). AR function is then implemented by superimposing the real space and the AR space image, which in results displays the AR model in the iPad screen with the scale of 1:1. The inbuilt IMU device are used in this process.

The extended tracking is used for continuous display of the AR model even after the loss of the marker. The tracking algorithm is used for tracking the position of the device and reflect it in the AR space even the device moves or changes its position. The workers can inspect their works in the construction sites in a real time by moving from one place to another. Once the fiducial marker is detected, the position of the device is tracked continuously following the people movement using the gyro sensor attached in the iPad, but some position errors related to the precision occurs due to the handshakes and movement of the device. The quality of the IMU device being attached in the iPad also plays a vital role in the precision. The experimental representation of our proposed algorithm is shown in Fig. 4.

V. Testing and Evaluation

1. Testing

We tested our application in a 13-story steel building construction site in Japan. The application was applied for the task related to basic reinforcement of the Rebar construction and grid inking task. These tasks are one of the complicated and complex tasks, where the mistakes and errors occurs very easily.

In case of the rebar construction, the mistakes related to the foundation beam and foundation pillar occurs very easily. To avoid such mistakes, we developed several AR models from the BIM models for getting the prior confirmation of the completed model in the real sites before starting the tasks or in the middle of the tasks or whenever the workers gets confused. This process is very much effective for reducing the mistakes and errors in the construction sites.

In this test, we focused on the rebar construction, which is combined of various stages. We developed and implemented the BIM models related to the rebar construction. The 3D model of the bottom reinforcement, top reinforcement, Pillar and intersected model of the top and bottom beam reinforcement models were developed for testing in the construction sites.

The models used for the testing along with the original site image is shown in Fig.5(a). The 2D AR model and the 3D AR model of the skeleton framework for rebar construction is shown in Fig.5 (b) and 5(c) respectively. The test was performed for checking the intersection of real environment pile rebar and virtual environment foundation beam.

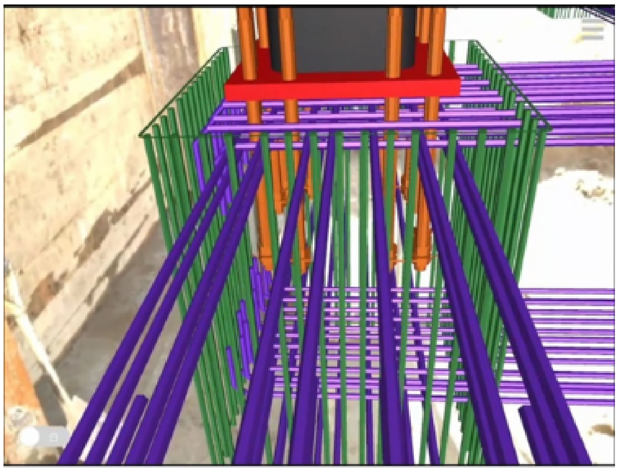
In case of the grid inking tasks, we applied our AR application for overlaying the 2D baseline on the site floor. The 2D Design drawing for the whole floor was overlaid on the floor for omitting the complicated task related to grid inking tasks in the construction sites. The image is shown in Fig.6.

The precision error of about 5cm for 10m distance was obtained, which is not applicable for the grid inking tasks but is applicable for the visualization of the skeleton framework of the rebar construction. The graph showing the precision value of our application based on distance covered is shown in Fig.7. The horizontal axis represents the distance (m) covered by holding the device and vertical axis with the orange line reflects the error in cm. According to the graph, the error value increase as the distance is travelled.

The error calculation was performed by drawing the baseline on the floor by using the grid as shown in figure 8, and the markers were placed fixing the origin point as shown in Fig.8. The blue circle represents the X-axis, red represents the Z-axis and green represents

(a) Original image

(b) 2D image



(c) 3D image

Fig.5 Tested AR Models for Rebar Construction on Site

Fig.6 Overlay of 2D Image on Floor for Grid Inking Ttask

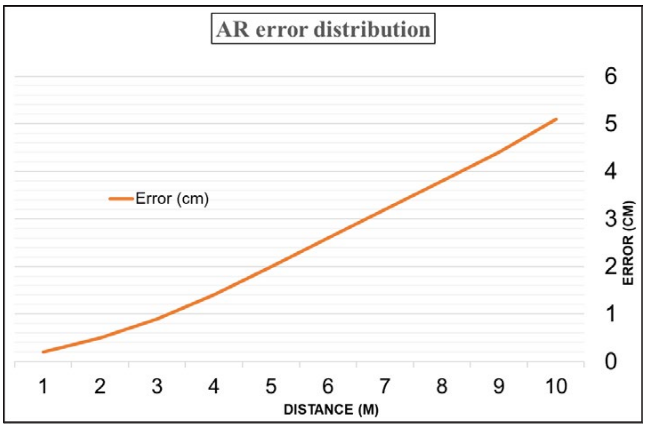


Fig.7 Graphical Representation of AR Error Distribution

the Y-axis. The position error was calculated by measuring the deviation of the grid intersection displayed on the floor and the intersection indicated by AR. The position error was calculated by displaying a red mark (AR point) on the mesh area displayed on the screen as shown in Fig.9. When the person moves holding the iPad, the red mark also follows the movement, but the red mark steadily goes off the mesh area with the increase in the distance. The difference in the distance between the point marked on the floor and the point displayed on the AR environment (iPad) reflects the error distance of the AR application.

2. Evaluation

We evaluated our AR application after implementing it on the construction sites. The test was performed by the workers from the general contractor company and the workers from the rebar company. After testing the application on site, we received the following comments.

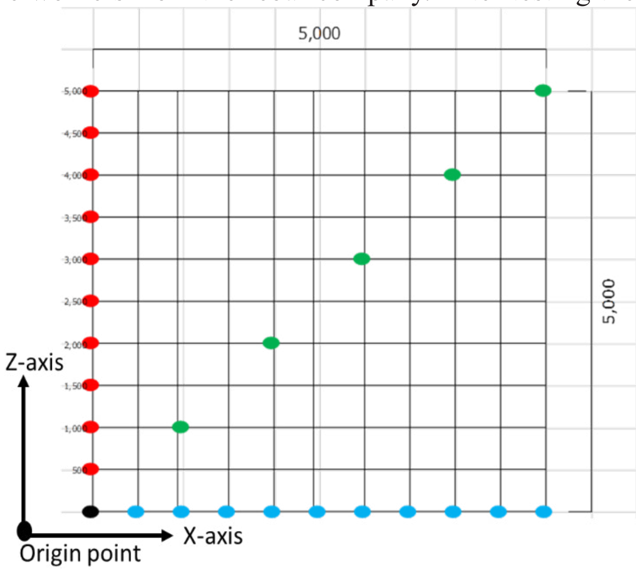


Fig. 8　Grid for Writing the Baseline on the Floor

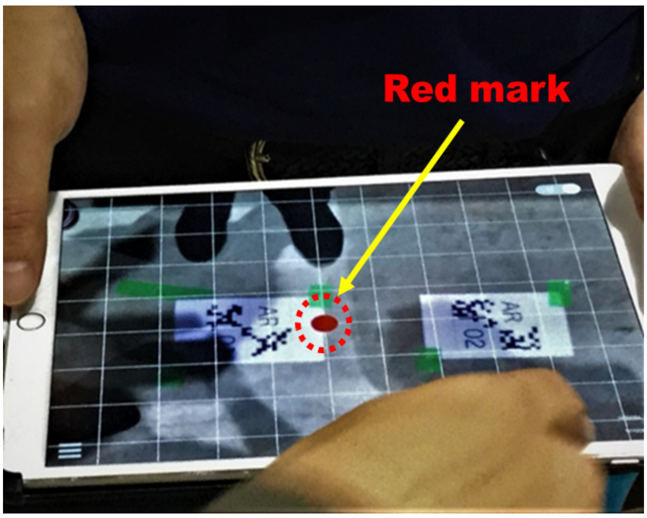


Fig. 9　Display of Red Mark for Device Positioning

Comments from the general contractor company:

- You can show the customer the completed building with AR on the land.
- Can be used as an educational tool for the new employee to understand the flow and method of the works to be performed.
- Easy to generate and understand the image as the model can be visualized on site.
- It can be used for interference check at the time of provisional design

Comments from the rebar company:

- It is good to understand complex layout image on site. It will prevent re-arrangement.
- Can be used for checking intersection bars
- Prevention of reverse strike for intersection joint bars

After receiving comments from the user on site, we evaluated our application as useful tool in the construction sites. The application is very easy to use with iPad, realistic compared to the head worn device. Our application can be used for showing the completed models to the customers before starting the construction. The workers will be able to know the final image of the model, so will be able to minimize the time loss and the mistakes will be evoked, which results in the productivity increment of the construction sites. The application can be used as an educational and safety instruction tools in the construction sites.

To make this application more productive, we plan to trace the construction management process and apply them in our application with the required technological needs. The accuracy of the application must be increased to implement it in the grid tasks as well as the tasks which require a high precision. We plan to apply the image processing tools and the SLAM technology for increasing the accuracy of our system.

VI. Conclusions

Our AR application seems to be effective for the construction workers to confirm the complete image of the building models and the materials to be used. The application was helpful for localizing the device and displaying the completed model on site in a real time. The application was useful for prior confirmation and visualization of the construction sites locally.

The use of two markers seems to be time consuming and need to be reduced to one marker or marker less. The localization of the device suffered an error in cm precision, which needs to be improved for using in the various construction tasks that requires high precision localization.

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