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Research Article

Using Augmented Reality in Construction Project Activities

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Abstract: Augmented reality is one of the innovative technologies that will provide significant benefits to construction project applications in the future. In this study, an augmented reality system is developed for improving construction project activities. By using this system, construction workers, equipment operators, engineers and managers can follow each step of the construction activities that they are responsible for. Users can access necessary information about training materials and construction methods related to the construction works. Thus, construction engineers and workers can learn the correct methods of project activities and prevent themselves to make wrong productions. The system is tested in ceramic tile installation. It has been proposed that the system can improve the quality and productivity of construction activities and therefore provide significant contributions to the construction industry.

***Keywords**:* augmented reality, construction industry, information technology, smart glass.

1. INTRODUCTION

Augmented reality (AR) has a significant potential to improve construction project activities (Meza et al. 2015). AR is the enrichment of the real world with information from the virtual world (Wang and Dunston 2007). According to a common definition, AR is to increase the real world reality phenomenon boarded the virtual world objects on the display of real-world objects (Shin et al. 2008, Milgram et al. 1995). AR is one of the innovative technologies that has a great potential in applications in almost every area. AR is a variation of virtual reality (VR). VR is a computer-generated simulation of the real world. In AR, the real world is much closer to VR (Kuo et al. 2013). The real environment in AR is more dominant than VR. Unlike VR, AR allows the user to perceive the real world combined with virtual objects (Malkawi and Srinivasan 2005). AR is foreseen to use in almost all sectors in the near future. For example; car maintenance in automotive industry, operations in medicine, visualization of books in education, advertising, home furniture placement, visualization of architectural designs, display of inter-vehicular distances in traffic are potential future applications of the AR technology. However, the construction industry is one of the sectors that do not use this promising technology's applications effectively. Within this context, in this study, an AR system, by which workers, equipment operators, engineers and managers can easily access to relevant information about the project activities they are responsible for, was developed. It was aimed to contribute to the literature and sector in this area. The system has the potential to improve construction project activities.

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2. Augmented Reality in Construction

Researches on AR applications in construction have been increased in the recent years (Kwon et al. 2014). Constantly increasing hardware development and monitoring techniques motivate AR applications in the construction industry (Jiao et al. 2013). The use of AR provides significant advantages to this sector. Agarwal (2016) mentioned the advantages of AR use in civil engineering as error reduction, better marketing, review of the project, saving of man-hours, and cost reduction. Computer interface design and new advances in hardware power have developed AR research prototypes and test platforms for architecture, engineering and construction applications. However, most of these laboratory-based prototypes and concepts are explored by computer science or engineering researchers, who choose architecture, engineering and construction applications randomly to develop test scenarios and to prove the availability and efficiency of AR concept as the subject. As a result, the prototype tests cannot reach the level to be ready for the field tests (Wang and Dunston 2007). Behzadan and Kamat (2013) presented a pedagogical tool that uses remote videotaping, AR, and ultra-wide band locationing to bring live videos of remote construction jobsites to the classroom. Another study on the use of advanced technologies in education was carried out by Gul et al. (2008). The researchers have studied the design students on using 3D VR technology. Chen and Huang (2013) proposed a visualized 3D modeling method for discrete-event simulation of transport operations in the field of construction. They applied AR technology in the development of a prototype system that superimposes a 3D model onto images of a construction site. Hammad et al. (2009) proposed new methodology called distributed AR for visualizing collaborative construction tasks. Using this methodology, virtual models of construction equipment can be operated and viewed by several operators to interactively simulate construction activities on the construction site in AR mode. Kim et al. (2012) presented a system for identifying the optimum scenario for equipment operation by intuitively operating the equipment in an AR environment. Park and Kim (2013) have developed a safety management and visualization system that integrates AR, location tracking, building information modeling and gaming technologies. They used AR technology on real-time and location-based safety management in their study on smartphones and tablet computers. Employees can see augmented safety information on their devices, when they walk around in the construction site. Kim et al (2013) developed an on-site management system that focused on site monitoring, task management, and real-time information sharing. For system development, wireless communication, AR, and client–server database were utilized to manage, transfer, and visualize project information on a mobile computing platform. Park et al. (2013) presented a conceptual system framework integrating ontology and AR with a BIM for construction defect management. They proposed three technical solutions for proactive reduction of defects: a data collection template, a domain ontology, and an AR inspection tool. Chi et al. (2013) investigated the potential future applications of AR technology in the construction industry. According to the results of the investigation, they specified that the use of mobile devices in the future will be more effective and cheaper foreseeing the AR technology will increase the application of these devices. Rankohi and Waugh (2013) presented an in-depth statistical literature review of AR technologies in construction. They stated that the future trend is toward using web-based mobile augmented systems for field construction monitoring. Wang et al. (2013) examined articles published between the years 2005-2011 related to AR in construction. The researchers stated that the majority of AR technologies are based on laboratory studies and it is still insufficient to apply to the real construction projects. As a result, researchers have noted that AR technology needs for research that can be applied in real projects rather than laboratory-based researches.

The researches described above and many others (Zhou et al. 2017, Ayer et al. 2016, Guo et al. 2017, Huang et al. 2016) are important studies especially in the last five years in terms of the development of AR technology in construction. However, although there are numerous publications on the use of AR technology in other sectors, the use of this technology in the construction sector is still relatively limited. As mentioned in the literature review, the construction industry needs AR applications especially for construction sites, instead of laboratory-based studies (Wang et al. 2013). Thus, the proposed system in this study can provide significant contributions to the construction industry when considering its application potential.

3. Method

The main aim of this study is to develop a system using AR to facilitate construction project activities. The system enables construction workers, equipment operators, engineers and managers to follow each step of the construction site activities that they are responsible for. Thus, all phases of construction project activities can be made in a more efficient manner. Within this scope, ceramic tile installation, which is a commonly used activity in construction projects, was selected. In order to comply with the standards in the construction methods of this activity, training materials developed by the Turkish Ministry of Education and INTES (Employers' Union of Construction Industry Employers) within the scope of the 'Project for Strengthening the Vocational Education and Training System' have been utilized (Turkish Ministry of Education, 2012). In the first stage of the study, the production methods and training materials of the selected activity are prepared. Animation models of the activity were created in accordance with the construction methods. Animation models have been designed using 3ds Max and Maya programs to show all phases from the beginning to the end of the activity, in accordance with the standards selected. The system was developed after completing the models. In the third phase of the study, the AR software was adapted to the smart glass. In the fourth phase, the AR system was tested. At this phase, system errors have been identified and the system has been revised.

4. System Development

In the development phase; AR platform software, the Maya program, the Unity program, the Xcode and Android SDK programs to develop softwares, the AR camera Vuforia SDK, and Android Studio and C ++ software languages to make smart glasses compatible with Android 4.04 operating system were used. Smart glasses have been used as mobile devices. Each phase of the construction project activity is determined and integrated into the AR system. Applications for each phase are created and buttons are prepared for transitions between the steps. The AR system was designed using the following methods:

- Image Tracking

In the image tracking method, the area, previously scanned digitally, is used. The scanned area is saved in the AR platform software. The models are placed and the image is saved in the scan area database and prepared in apk format compatible with the Android system in the Android Studio software language. Then the setup is performed by transferring to the smart glass.

- Extended Tracking

In extended tracking, instead of a specific area, a wide area scanning is performed and transferred to the AR software platform. It is the process of placing 3D models in the specified locations of the modules depending on the movement of the person. The AR model is prepared in apk format compatible with the Android system in the Android Studio software language and is installed by transferring it to the smart glass.

- Object Tracking

In object tracking, a captured object is recorded in the database and the QR (Quick Response) code is transferred to the AR platform software. This method is valid for standing objects. 3D modeling is placed on the transferred object and it is prepared in apk format compatible with Android system in Android Studio software language and transferred and integrated to the glasses. By looking at the object modeled with smart glasses, one can follow the steps of the construction activity.

- Face Tracking

In face tracking, 3 dimensional models are placed on the face model in the AR platform and adjusted to the face of the person. Relevant codes are prepared using C++ software. The AR model is prepared in apk format compatible with the Android system in the Android Studio software language and transferred to the glasses for installation.

- Marker Tracking

In marker tracking, a marker is prepared specifically for each AR model. The marker recorded in the database is transferred to the AR platform and added to the desired 3D model when the marker is received. Using relevant codes, Android Studio is prepared in apk format compatible with the Android system in the software language and is installed to the smart glass.

For construction project activity applications, first, the real images which will be integrated into the AR system are photographed with object tracking method. 3 dimensional models of construction project activity productions are prepared and AR mobile platform was developed. The 3D models of the photographs were prepared in Maya program in *.obj and *.flx formats. Each phase of construction site activity is prepared in the AR development program. Application area for each stage was designed and forward-backward buttons were created for transitions between the phases. Then, 3 dimensional models are transferred into the AR development program. The imported models and object tracking images are saved in the development program database. The models are designed using 3ds Max and Maya programs to show all phases of the activity from the beginning to the end in accordance with the required building standards. In Figure 1, a ceramic tile model is illustrated.

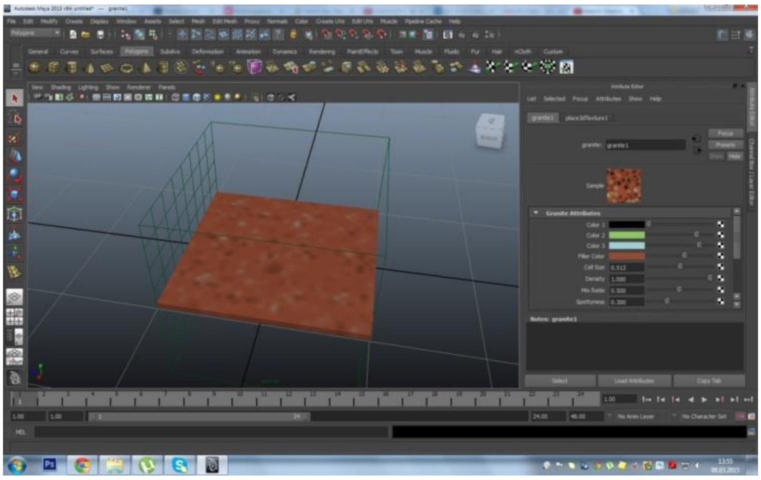

Figure 1: Ceramic tile 3D model.

In the AR development program, 3D images prepared in the Maya program were transferred onto the image that was transferred as object tracking. Then x, y, z coordinate settings and the model matching were completed (Fig. 2). In order to achieve effective results in model matching, distance and height arrangements of the model are performed.

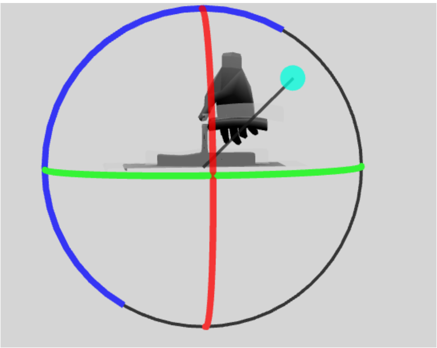

Figure 2: Transferring brick model into the AR development program.

After the model matching process, applications, prepared with Android SDK mobile software, need to be coded according to the platform where they will be integrated. Once the codes for the Android platform have been prepared, transfers will be made in the AR development program according to the selected platform. When the created application file is executed after being transferred to the mobile device, the 3D model appears on the screen. The match occurs when the actual model comes at the front of the image display.

Using smart glasses, the system is tested for ceramic tile installation on a real construction site. In Figures 3 and 4, views taken from smart glasses during the testings are shown.

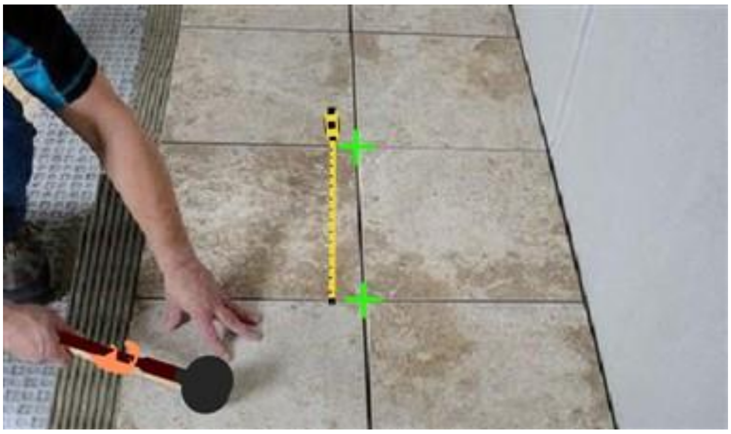

Figure 3: Testing the system using smart glass-I.

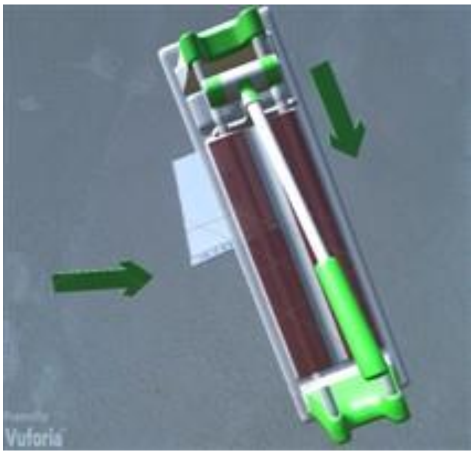

Figure 4: Testing the system using smart glass-II.

5. Conclusion

AR technology applications will provide significant contributions to companies operating in the construction sector. Since AR is a relatively new technology, the application areas in the construction industry are rather limited. However, this promising technology has the potential to be implemented in many different areas of the industry. Parallel to the development of AR technology, it is envisaged that applications will be grow up in the construction sector besides automotive, advertising, food, media, film and many other sectors in the near future. Therefore, it is very important for the construction companies to adapt this technology as fast as possible in order not to lose the competitive advantage in the future. Utilizing AR technology in construction will be a beginning of a new era in this sector. In this study an AR system was developed. By using this system, managers and construction workers can get relevant information, from the beginning to the end, about construction site activities they are responsible for. With this system, the risk of construction activity mistakes will be minimized and the required quality of the production will be ensured. Inexperienced workers can be trained in a faster and cheaper way and their integration with the project will be done easily. On the other hand, experienced workers will have the opportunity to correct their mistakes and incorrect applications or enhance their performance by improving the critical phases in site activities through details reflected in the smart glasses.

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