A Study on the Effect of the Use of Augmented Reality on Students' Quantity Take-off Performance

Sung Joon Suk[a], George Ford[a], Youngcheol Kang[b], and Yong Han Ahn[c]

[a]Kimmel School of Construction Management, Western Carolina University, U.S.A.
[b]Department of Architecture & Architectural Engineering, Yonsei University, South Korea.
[c]Erica School of Architecture & Architecture Engineering, Hanyang University, South Korea.
E-mail: sungjoon@wcu.edu, gford@wcu.edu, yckang@yonsei.ac.kr, and yhahn@hanyang.ac.kr

Abstract

This study examined whether the augmented reality (AR) technology affects the quantity take-off performance of construction management (CM) undergraduate students. The sample for the study consisted of 22 sophomore CM students taking an estimating course at Western Carolina University in the U.S.A. To determine whether AR images help students' quantity take-off performance, the students were asked to take off the concrete volume of a structure twice. At the first attempt, the students were provided only with a 2D drawing that includes a plan and section of the structure. At the second attempt, they had an opportunity to explore a 3D model overlaid on the 2D drawing on their smartphone. Five students calculated correct quantities at their first and second attempts. Ten students did not take off quantities accurately at the first attempt, but with the 3D model in AR, they could reach the correct quantities at the second attempt. Seven students failed to calculate the quantities at both attempts. Forty-five percent of the students showed better quantity take-off performance at their second attempt. There was also a difference in the average scores between the two attempts. The results suggest that CM students can take off quantities more accurately with the help of 3D model images created by the AR technology.

Keywords

Augmented Reality; Quantity take-off; Estimating; Students' performance

1 Introduction

Construction drawings are the main communication tool used in the construction industry. Specifically, 2D drawings have long been used in delivering construction projects and managing facilities. However, representing 3D objects into 2D drawings involves many limitations. Understanding vertical and horizontal elements together with 2D drawings, where their multiple faces and complex connections are not fully illustrated or visualized, is challenging. Creating section views helps synthesize the information from 2D drawings, but they are still represented in the 2D plane; generating thousands of section views for a project is uneconomical.

To overcome these limitations, the construction industry has made efforts to utilize 3D modeling approaches. Many construction companies now use building information modeling (BIM) tools to generate 3D models and drawings. Seeing 3D models and images help project participants have an improved understanding of geometrical shapes and connections. However, using BIM tools and other 3D modeling software is challenging at large construction projects or complex properties with a number of buildings. Most 3D modeling programs need a license for use and require expensive computers with high-level computational and graphical capabilities. Setting up a large number of expensive computers at a project site is impractical and challenging. This issue results in the lack of mobility in utilizing 3D models effectively. Moreover, looking at the details and generating 3D views are the challenges for those who have not been trained in using such sophisticated programs. In addition, numerous 3D modeling programs with different user interfaces are available. For these reasons, 2D drawings are still widely used in construction sites and facility management fields to communicate among professionals.

Virtual reality (VR) and augmented reality (AR) technologies are expected to foster the use of 3D modeling. VR&AR is one of the most promising businesses in the foreseeable future. The Goldman Sachs Group, Inc. [1] estimates that the VR&AR market can generate at least US$80 billion by 2025 and may become a US$182 billion market if AR adoption is accelerated. This value represents a tremendous increase from US$5 billion at the end of 2015. Large IT companies are quickly moving to the VR&AR market. In March 2014, Facebook invested US$2 billion in acquiring Oculus VR, a manufacturer of VR head-mounted display. Mark Zuckerberg said, “One day, we believe this kind of immersive, augmented reality will become a part of daily life for billions of people.” Google developed Google Cardboard, which is a VR platform with VR development tools, and brought low-cost VR headsets to the market. Google also launched an AR technology platform called Project Tango, which can provide mobile devices with a spatial perception ability to track motions and process images with their built-in camera. In addition, Google led US$542 million of investment in Magic Leap, an AR startup company. Microsoft started in 2016, shipping HoloLens, an AR device through which you can mix 3D holographic content into your physical world and interact with both of them. The industry has set the stage for VR&AR to become a prosperous business.

The rapid advancement and wide use of mobile devices such as smartphones and tablets have made VR&AR attractive. Smartphones and tablets are the best devices to implement VR&AR technologies because they have a camera, geographic position system (GPS), Internet access, and display. Furthermore, tracking methods have improved to identify the relationship between the camera and the real-world [2]. Now virtual contexts can be extracted without regular markers that may be difficult to set up all necessary places and complex environments. Various technologies, including development platforms, applications, devices, and marker-less detection, have been, are being, and will be developed for the use of VR&AR.

A number of researchers have investigated the application of AR in the construction field. Wang [3] identified three challenges involved in AR in architecture: extraction of industrial domain knowledge, preparation of reality model, and technological limitations. Dunston and Wang [4, 5] provided a taxonomy used for AR application development. They also classified architecture, engineering, and construction (AEC) operations into five levels: Application Domain, Application-Specific Operation, Operation-Specific Activity, Composite Task, and Primitive Task to map AR technology to AEC tasks.

Chi et al. [6] developed an AR-enhanced user interface (UI) used for a teleoperated crane system. They reported that the integration of AR in the user interface of crane has a positive impact on crane operators. Schall et al. [7] presented an AR system to show visual information of underground utilities, and also addressed problems including 3D modeling, tracking, and interaction that they identified while developing and testing their prototype AR system. Talmaki et al. [8] evaluated a geo-referenced AR system providing the excavation operator with 3D models on the location and type of buried utilities. Shirazi and Behzadan [9] assessed the pedagogical value of an AR-based tool on students’ performance on building design and assembly. Shanbari et al. [10] used ART enabled videos to helped students identify and remember certain masonry and roof components.

However, little research has been conducted on whether AR contents can improve the quantity take-off performance. This study examines the effect of AR contents on CM undergraduate students.

2 Research Methods

Twenty-two CM undergraduate sophomore students enrolled in the Estimating I course at Western Carolina University in North Carolina, U.S.A. participated in this study. The Estimating I is the first course that exposes the students to the quantity take-off process. The course learning objectives are: 1. Take off quantities used to create construction project cost estimates; 2. Read construction documents for planning; 3. Identify methods, materials, and equipment used to construct projects; 4. Use Excel or other software to takeoff quantities; 5. Understand different surveying techniques for construction layout and control; and 6. Understand the concept of construction accounting and cost control. Before taking the Estimating I course, students have typically completed an introduction to construction course, a construction graphics and plan reading course, and a construction methods & materials course as prerequisites of this estimating course. The students who participated had no construction industry experience. Before this study, there were ten class sessions, where the students learned the general rules of quantity takeoff used in the construction industry and how to take-off quantities associated with the earthwork.

A single group, pre- and post-test research design was employed to determine whether AR images help students' quantity take-off performance. The students were asked to take off concrete and formwork quantities of a structure twice. At the first attempt, the students were provided only with 2D drawings that include a plan and section of the structure. The structure consisted of simple retaining walls and continuous footings underneath the walls, as shown in Figure 1. The students were given 15 minutes to take off the volume of concrete and asked to turn in their solutions.

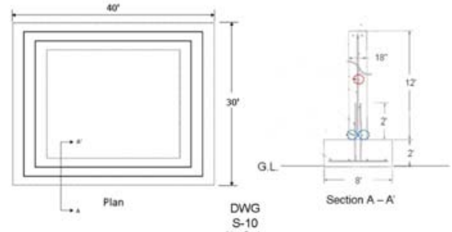

Figure 1. Plan and Section

At the second attempt, they had an opportunity to explore a visualized 3D model overlaid on the 2D drawing on their smartphone, as shown in Figure 2. This AR image was created by using REVIT 2017 and an AR application provided by Augment.com. After a REVIT model of the structure was generated, it was exported as an OBJ file format that is a geometry definition file format. Then, the OBJ file was imported into the AR application of Augment.com. While exploring the AR image on their smartphone, the students took off the volume of concrete in the same 15-minute time period and submitted their solution. The students were not permitted to see what they did at their first attempt.

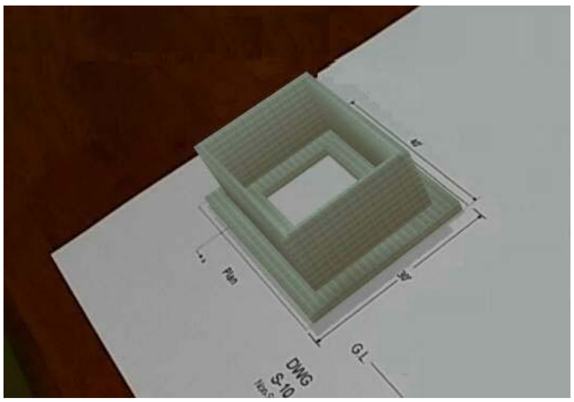

Figure 2. 3D Model Overlaid on Smart Phone

After the two attempts had been graded, a paired t-test was used to compare the mean scores before and after having the students exploring the AR images with their smartphone.

3 Results

Five students calculated correct quantities at their first and second attempts. Ten students did not take off quantities accurately at the first attempt, but with the 3D model in AR, they could reach the correct quantities at the second attempt. Seven students failed to calculate the quantities at both attempts successfully. Forty-five percent of the students showed better quantity take-off performance at their second attempt. The mean of the 2nd attempt was 89.09% greater than that of the 1st attempt, 80.91%. To examine the true effects of the AR images, a paired t-test was conducted. The results of a paired t-test on the two attempts (H_0: 2nd attempt – 1st attempt = 0; H_a: 2nd attempt – 1st attempt > 0) were summarized in Table 1. The results show that there was significant evidence that students' quantity take-off performance was improved at their 2nd attempt (paired t (21) = 3.645, $p <= .05$)

Table 1. t-Test: Paired Two Sample for Means

	2nd Attempt	1st Attempt
Mean	89.091	80.910
Variance	313.420	237.229
Observation	22	
Pearson Correlation	0.806	
Hypothesized Mean Difference	0	
df	21	
t Stat	3.645	
P(T<=t) one-tail	7E-04	
T Critical one-tail	1.721	
P(T<=t) two-tail	0.002	
T Critical two-tail	2.080	

4 Conclusions

The analysis results showed that students took off quantities more accurately with the help of 3D model images created by the AR technology. This means that the AR images increased the students' understanding of the retaining walls and continuous footings. The results suggest that AR technology can enhance understanding of construction drawings for construction management undergraduate students.

The difficulty in the quantification is that construction elements are fully illustrated on the 2D drawings. Furthermore, students usually do not have an extensive field experience that would help them understand the entire shape of construction elements. Field trips to construction sites can foster students' understanding of construction elements. However, it is difficult to have many field trips for a course in a semester. Drawings provided in class may not always be the same ones used for projects to which students take a field trip.

With a rapid development of AR applications, students can easily see AR images on their mobile device. AR images aligned with 2D drawings can provide them with a better understanding of construction elements necessary to prepare an accurate cost estimate. However, there is much work to be done in AR to enhance CM students' experiences. Different types of AR contents for each trade need to be produced to develop students' ability to understand construction drawings effectively. More research efforts are necessary to simplify the procedures used to create AR contents from 2D drawings or building information models.

Reading and understanding construction drawings is a fundamental part of preparing CM students to enter the construction industry. Adopting AR technology in teaching CM students is expected to be a way of enhancing such ability that may need extensive construction experience.

This study used a single group, pre- and post-test research design and had a limitation. The students took off the volume of concrete twice for the same retaining walls and footings. To reduce an effect of repeated practice at the second attempt, the study did not allow the students to refer to what they did at the first attempt. However, the students might realize errors and address them, which may improve the students' quantity take-off performance at the second attempt.

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