Project #140: **Smartphone augmented reality interface to improve the effectiveness of design meetings in projects**

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Aim

To facilitate a design meeting using smartphone AR to improve visualisation and communication processes between stakeholders. Additionally, evaluate its overall effectiveness with Mobile AR and compare results with HoloLens AR.

Project Scope

Stakeholders involved in design meetings in Architecture, Engineering and Construction (AEC) industries have difficulties collaborating efficiently with current methods and technologies. Communication and understanding between stakeholders are not without misinterpretations due to some people having difficulty visualising 3D designs from only 2D drawings. Mixed Reality technologies may be able to aid in this aspect by enabling stakeholder to view and interact with 3D designs that are projected onto real spaces.

Research Objectives

To further develop the AR program from the previous research project to allow it to operate on a smartphone or mobile device.

To develop and test an augmented reality program that allows stakeholders such as engineers, architects, contractors to see a projection of their proposed structure to which can be interacted with and modified intuitively on smartphones and mobile devices.

To compare the implementation of design meetings using mobile AR with HoloLens from previous years research project.

To allow industry professionals to participate in prototype trials in order to obtain valuable feedback that's backed by professional engineering experience.

To allow stakeholders to intuitively alter their projections on smartphones during a design meeting.

Literature Review

Abstract

Collaboration is an integral process of involved in the Architectural, Engineering and Construction (AEC) Industries, as the various parties have different specialisations. There are multiple different interfaces through which information must be conveyed, which is where there are most likely to be misunderstandings leading to costly errors. The common method of conveying design information between parties is through design meetings where drawings are shared, annotated and discussed. How these drawings are interpreted can vary depending on the individual's special ability and how they visualise the design. Especially with complicated 3D models, visualisation can be difficult from just 2 dimensional drawings. Therefore, the use of mixed reality, specifically augmented reality, may aid with the visualisation of construction designs as they would be visible to the user in 3 dimensions.

Introduction

The construction industry makes a significant contribution to New Zealand's economy, making up 4% of New Zealand's GDP in 2003, and that a 10% increase in the efficiency of the construction processes would result in a $1 billion increase in real GDP (Toh, 2003). The value of construction is huge because it is the foundation of modern society. Construction is what makes it possible to have houses, offices, hospitals and many more facilities. The overall process of construction is split into different phases, with the two main phases being the design phase and the construct phase, with the design phase being completed before construction begins. The design phase is where collaboration between the Architecture, Engineering and Construction Industries is necessary, usually occurring through means of a design meeting. The different parties will bring different sets of expertise and will discuss the needs of the clients and the possible designs (Alarcón & Mardones, 1998).

Collaboration is a key part of the design process in construction. It is important for each party involved with the design to have a clear understanding of the models and drawings in order to have productive discussions (Tory & S. Staub-French, 2008). However, it is not always possible for there to be a perfect understanding between the different parties regarding the design, especially as they become increasingly complex (Jensen & Heckling, 1995). This is one of the main issues with collaboration. Therefore, there is room for improvement in this area of design meetings.

Another issue is the human's ability to visualise designs and create a mental model. The time taken to visualise a design can vary depending on the individual. However, it has been shown that it takes longer to visualise a design from a 2D sketch of a 3D model than it would take from a 3D model (M. Tory, 2006). These time delays can translate to costs when considering the overall efficiency of the project.

Augmented reality is a technology that may prove to be useful when attempting to visualise and collaborate in design meetings for projects in the AEC industries. This is where virtual objects are combined and mixed in with reality using projections and screens (Calderon-Hernandez & Brioso, 2018). There have already been studies which have looked into using AR in these industries (Behzadan & Kamat, 2007).

Background

Architecture, Engineering and Construction (AEC)

Architecture, engineering and Construction (AEC) are all very significant industries in many countries globally, not just in New Zealand. The value that is provided by construction is a necessity to the modern world, with larger developed cities relying on construction to house other industries and residents (Becerik, 2004). The construction process is not simple and requires collaborations between many different parties and specialisations (Akintoye & Skitmore, 1991). In simplified terms, architects will mainly consult with the client to identify the physical set up that is desired and will be visible once the construction is completed. The Consulting Engineers then will investigate the geotechnical environment and potential structural designs that will accommodate the needs of the client and the required national standards for strength and serviceability. The contractors are then hired to make the designs in reality to the specifications provided by the consulting engineers. It is also often common for there to be multiple engineering consultants and architects for larger more complex projects (Alarcón & Mardones, 1998). In reality, there would be many people involved each needing and giving specific information to and from others. The number of information exchanges is generally very high and each of these interfaces are prone to errors and miscommunications (Alarcón & Mardones, 1998).

The design phase consists of technical drawings, models and specifications that are used to identify the client needs. Each aspect of the design is handled by different parties. For example, the columns and beams of a building will be handled by the structural engineers while the power and lighting will be handled by the electrical engineers (Alarcón & Mardones, 1998). Once again, these parties will also need to communicate with each other which leaves room for miscommunications resulting in reduced efficiency and increased costs.

Business Information Modelling (BIM) has increased in popularity and is a 3D modelling software that allows all the information of a building design to be accessed simultaneously in one place (Calderon-Hernandez & Brioso, 2018).

Virtual Reality

Virtual reality is where the user is transported to a completely different environment that is entirely conjured by the software and shows no signs of their actual environment (Bricken & Byrne, 1993). A set of goggles are used which have a screen and a gyroscope so that as the user moves their head, the screen in the goggles also moves accordingly, to give the effect that the user is looking around with their own eyes (Bowman & McMahan, 2007). Using Virtual reality gives the user the ability to experience a new construction site before it even begins. The experience is fundamentally different from a 3D model or a computer screen (Whyte, 2003). Immersion is measured by interactivity and vividness. Vividness is how realistic the environment is and how much it is perceived by the user's senses. Interactivity is the ability of the user to change and modify things in the new environment and act as if they were actually in this environment (Burdea & Coiffet, Virtual Reality Technology, 2003).

Virtual reality has a range of benefits especially for education. It provides a way of training someone for something which may not be safe or comfortable to actually do without some experience such as riding a bicycle on busy streets (Bowman & McMahan, 2007). The use of virtual reality would allow someone to 'learn by doing' but without the danger of actually being hit by a car. Depending on how immersive the experience, the VR can provide adequate training to significantly improve performance.

Virtual reality has also been used in the AEC industries to aid with identifying construction errors and helping architects to visualise concept designs (Shang, Whyte, & Ganah, 2005).

The possible downside of Virtual reality is the potential motion sickness that can affect the user, due to a sensory disagreement between actual movement and how much movement the eyes see (Regan, 1995).

Augmented Reality

Augmented reality is where virtual objects are combined with the real environment through either goggles or a camera screen (C. Furmanski, 2002). Essentially, AR is supplementing the real world with virtual objects instead of completely replacing reality (Liuska, 2012). Augmented reality is often called mixed reality for this reason as it is a mix of virtual objects and reality. The three main components that make up AR are: combining real and virtual aspects, interactive and real time and is registered in 3D. (Liuska, 2012)

AR has many benefits such as being easier to create. In VR the entire 360-degree environment must be created, but with AR only the relevant objects that needs to be projected are necessary to create. This means that less time would be consumed in the creation of AR making it a more efficient process. This also means that it is easier to switch on and off the virtual objects without disorientation (Wang & Dunston, 2006).

AR has seen many benefits with many study's showing its usefulness. A study showed that students found it easier to see an object in 3D rather than on a computer screen when working on a construction project (J. L. Perdomo, 2005). AR can also be used on construction site visits to lay the proposed 3-dimensional designs onto the existing buildings.

There are different types of Augmented Reality, some having goggles such as HoloLens, google glasses and many more (Slant, n.d.). Others can be used on certain smartphones and devices with the virtual objects are projected onto the screen which shows the real environment through a camera. Many of the goggle devices are very expensive and difficult to carry around unless there is a specific purpose for using it.

Mobile Augmented Reality uses the hardware already available in tablets and smartphones that are widely accessible (Craig, 2013). The advantage of Mobile AR is that it can be used almost anywhere that a capable device can be used. The devices that support Mobile AR are becoming more powerful while technology continues to improve, but also less expensive.

Design Meeting Issues

The two main issues that arise with design meetings in the AEC industries are visualisation and collaboration. Visualisation is the understanding of the 3D objects or structures in a person's head. Collaboration is the ability for multiple people to interact with drawings and models and communicate this information to each other.

Visualisation

Visualisation is how humans try to picture objects or scenarios in their heads without seeing them. It has been defined as "the mechanisms by which humans perceive, interpret, use and communicate visual information" in the AEC industries (M. Tory, 2006).

Another similar term, "Spatial ability," is explored in a University of Auckland Study (Wong, Yu, & Giacaman, 2019) and is defined as, "the ability to picture and manage 3D shapes within the mind."

It is a huge part of AEC industries because it is required when creating and understanding models and designs. The different parties involved must be on the same page to have productive meetings and discussions. Especially when the drawings are all in 2 dimensions, but the actual design is for a 3-dimensional structure (Tory & S. Staub-French, 2008). As the complexity of the projects increases, the difficulty of visualisation also increases. Rohrer found that visualization (2D and 3D displays) improves people's understanding of simulation, but the 3D visualization have a greater realism aspect than the 2D (Rohrer, 2000). The common method of training spatial ability is through desktop applications or other 2D interfaces, but the communication barrier created by the discrepancy between the 2D interfaces and the 3D concepts of spatial ability diminishes the learning process (Wong, Yu, & Giacaman, 2019).

Traditionally, architectural design is focussed on 3D scale models which can have issues such as having expensive design evolution and limited reusability. The 3D models are also still viewed on a 2D computer screen which do not give a true sense of being in the room (Wang, Wang, Xu, & Shou, 2014). It has been argued that architecture is more that just the layout of the objects in a building (Champion, 2011). The objects have a "thingness" to them that appeals to more than just the senses. There is a kinetic aspect to architecture that is only occurs when moving through the building or house. The use of computer modelling on a 2D screen does not accommodate this, giving a cold mechanical feeling. Augmented reality can increase this feeling of being a real object, as it will be mixed in with the real environment (Champion, 2011).

Efficient collaboration

The AEC industries require large amounts of collaboration to be successful. While technical skills are required, effective communication and a complete understanding between involved parties is extremely important for a successful project (Emmitt, 2010). Therefore, any misunderstandings can have adverse impacts on the project timeline and output quality. Design problems commonly occur due to a lack of coordination or communication between these various involved parties (Alarcón & Mardones, 1998).

In previous years, individual drawings would be made first, which then are brought together for the final drawing. The different components would be done separately, which meant that the designs did not accommodate for all the other aspects that needed to come together for the final design (Wang & Dunston, 2006). However, in recent times 3D modelling and BIM have improved and become the main designing tool while 2D drawings have less importance (Azhar, 2011). Advancements in technology have also allowed multiple people to view and work on the same model simultaneously, giving more visibility between the different parties and specialisations of the project (Azhar, 2011).
Drawings are still used very often in design meetings as it is difficult to share and collaborate a 3D model in a meeting environment. 2D sketches are easier to interact with in a meeting environment but make it more difficult to mentally visualise more complex projects. (Tory & S. Staub-French, 2008).

3D visualisation has become the main problem-solving tool for engineering education and practice. The use of 3D CAD models helps to reduce the misinterpretation of special and logical aspects of construction planning information. However, there is a lack of collaborative problem-solving abilities which need to be addressed before 3D visualisation becomes widely accepted. Interaction in a shared workspace in natural and smooth fashion allows for a collaborative learning process (Dong, Feng, Behzadan, & Kamat, 2013).

How Augmented reality can solve design meeting issues

Virtual and Augmented Reality may be able to provide solutions and improvements to the both the collaboration and visualisation aspects of design meetings. Currently, 3D CAD and BIM are very common and are gaining popularity, the use of paper 2D sketches in design meetings is still very common also (Tory & S. Staub-French, 2008). AR and VR are both advantageous over 2D sketches and 3D computer models because the provide more interaction capabilities. The reason paper is still commonly in design meetings is because of the ability to draw and interact on the paper to discuss and explain certain ideas and layouts (Foley & Macmillan, 2005). With the use of AR especially, this would become possible as AR is more intuitive with interaction when compared to VR (H. Regenbrecht, 2002). The interaction would enable a more collaborative design meeting, allowing parties to get more involved with the design process (Dong, Feng, Behzadan, & Kamat, 2013). It is evident that AR technology may be able to help solve both the issues of collaboration and visualisation efficiency (Wang & Dunston, 2006).

Relevant Work

Transvision system developed aims to create a more collaborative design environment using AR technology. The research states that the issue with CAD based design is that it lacks intuitiveness (Rekimoto, 1996). The Transvision system would also allow two or more people to share the same computer model which is made to virtually exist in real space.

Magic meeting is an augmented reality system that is supposed to support the collaboration of experts when designing a product (H. Regenbrecht, 2002). This system has been used in the automotive industry, where a 3D model could be created on the meeting table and people can interact with the model as if it was a 3D object. The system also gives the ability to interact with the model using 2D applications on desktop. The motivation for magic meeting came as a result of the necessary variety of expertise for creating designs. Meetings were necessary to discuss parts objects in the automotive industry, where a physical mock-up of the part would be taken to the meeting. Participants were either able to get up close to larger parts or pick up smaller parts to get a closer inspection. With 3D AutoCad projections on desktops, these mock-up parts would no longer be necessary and would remove the mock-up part cost. However, the object would no longer tangible or available for closer inspection by all members of the meeting. Using AR would combine the benefit of both, by not having to produce the mock parts, but also being able to inspect the part through virtual reality. Augmented reality is preferred as the virtual object can be seen in the real world and compared with drawings and designs on paper.

Tangible Bits is a user interface that focuses on the tangible nature rather than the graphical nature. It is called Tangible user interface (TUI) and is an alternative to Graphical user interface (GUI) (Ishii, 2008). The study focuses on using the hands to manipulate the object in the way the hand would, instead of using generic inputs such as a mouse and keyboard to move and object. The study highlights how TUI would allow for more interaction and learning, likened to how children learn to count more effectively when using an abacus as apposed to just seeing or writing numbers.

Studierstube is a project which is trying to create an interface for manipulating complex 3D information in a powerful way that would be similar to how the desktop is for 2D information (Schmalstieg, et al., 2002). This is to be achieved using augmented reality and would allow multiple 3D tasks to be opened modified simultaneous, like how a computer can have multiple applications open at once.

Statement of research intent

Past Literature has shown that there is potential is for Augmented Reality to aid in both collaboration and visualisation in design meetings for the AEC industries. There is not a significant amount of research into AR specifically for the AEC Industries, but there are studies in different industries such as the automotive. A previous research paper was conducted looking into the how AR can aid with the efficiency of design meetings, using Microsoft HoloLens as their choice of Augmented Reality. The research goal of this paper will be to continue with this research project, but now comparing the use of smartphone AR with the HoloLens AR that was previously tested. A similar application will be developed, be tested by participants and the feedback from the testing will be compared to research conducted with HoloLens. Smartphones are commonly held among most people so the introduction of Smartphone AR would not require large initial capital investments for businesses in the AEC Industries.

Conclusion

The potential for using Augmented reality in improving the efficiency of design meetings in the AEC industries has been looked into. It is clear that AEC Industries make a up a large portion of New Zealand's and the global economy. A project must be designed before they are construction can commence. The design process requires the collaboration of many different parties through design meetings among other mediums. Currently, 2D drawings and Desktop 3D Models are popular methods of communicating details of the design. However, the ability to visualise and collaborate is lacking with these methods. Studies have shown the potential of using the Augmented Reality to improve both of these aspects of design meetings. Further research is required to determine whether the use of smartphone AR would have the same if not more benefit to design meetings when compared to the use of HoloLens.

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