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# Engineering Education with Mixed Reality

## ABSTRACT

Virtual reality (VR) is popularly applied in different user cases. VR provides experimental learning experience to students by simulating virtual environment and enhances student's levels of engagement in class, as well as giving an opportunity to strengthen connection between teachers and learners. Mixed Reality (MR) is a new technology encompassing both virtual reality (VR) and augmented reality (AR). In this project, an MR application is proposed and developed for the teaching and learning of engineering subject in tertiary education. The application is developed on the HoloLens system. A practicable application has been designed that allows students to visualize the geometry of 3D objects. It was found that the MR application can help students in understanding the learning outcome of the engineering subject in university.

Keywords: Virtual Reality, Mixed reality, HoloLens, education, engineering, design

## Introduction

Virtual reality (VR) can be applied in different areas related to commercial business, entertainment, healthcare, sports and education business, etc.in recent years. And it plays a leading role in education and training field with estimated growth revenue to US $2.2 billion by 2023. Mixed Reality (MR) is a technology encompassing both virtual reality (VR) and augmented reality (AR). It enables users experience and interact with digital content in a real-world environment and gives stronger effects of VR technology in teaching and education. It allows interaction and feedback from the students which are particularly important for enhancing experience in teaching and learning.

Despite various approaches have been developed to help students in understanding engineering subjects with the aids of VR, not much research has been conducted to investigate the effects of MR in teaching engineering subjects in tertiary education. Therefore in this project, an MR application is proposed and developed for the teaching and learning of engineering subject in tertiary education. The application is developed on the HoloLens system. A practicable application has been designed that allows students to visualize the geometry of 3D objects, as well as the exploded diagrams of selected components. The students can command the system through the command manual, or signal the system through gazing, gesturing and voice to implement instructions.

We have collected feedbacks and comments from the teachers and students in the university. It was found that the MR application can help students in understanding the learning outcome of the engineering subject in university, and enhance the skills of teachers in teaching university subjects with the support of MR. The outcomes and recommendations for future work of the proposed MR application are discussed and explained.

This article is organized as follows. The current VR market and MR technology is described in the literature review section. In the methodology section, an MR application is developed on a HoloLens system to help students in comprehending design in tertiary education. A case scenario is created and implemented to teach students the complicated concepts of product design. Tests are conducted to analyze the effectiveness of this MR application and described in the results section. Finally, conclusion is given in the last section.

## Literature Review

Nowadays, the global VR market is expected to grow from estimated amount of US$2.02 billion in 2016 to US$ 26.89 billion by the end of 2022. [Zion2018]. As participants can interact with virtual objects in the immersive stereoscopic visualization of virtual environment provided by VR technology, therefore VR applications are popularly used in different industries including commercial business, sports, entertainment, healthcare, education and training, etc. [Knierim, 2017].

Although VR is widely adopted in many various industries at the moment, VR is found fast and deep adoption in the fields of education and training. In the areas of education and training, VR can be applied in aviation and flight simulation, healthcare education, military training, teaching and training tomorrow's engineers. The industry professionals and experts estimate a Compound Annual Growth Rate (CAGR) of over 59% can be achieved in VR education market from 2018 to 2022. The growth in this market would be the outstanding one among different industries [Yariv2018].

Passing [Passig2009] conducted a meta-analysis on the future application of VR in education. It was suggested that VR can be applied in future rehabilitation and therapy, manipulating bodily self-consciousness, enhancing cognitive skills of students in the future. It seems that VR could suggest a wild paradigm in learning in the future. Besides, VR strengthens connection between learners and teachers in class. VR provides an experiential learning experience by simulating virtual environments to learners. It was suggested to use VR to enhance levels of engagement and study results for students from some educators' previous teaching experience [Kris2017]. Hands-on VR learning approaches can also contribute to increase cognitive and memory abilities. It is suggested that games, simulations, and virtual worlds in VR were effective in improving learning outcome gains of the students in higher education.

With the fast growth of VR technology in recent years, MR further enhances the user experience in experiencing VR techniques. MR is known as hybrid reality, which encompasses both VR and augmented reality (AR). It combines physical and digital content in the same environment, provides real-time users experience interacting with the digital content dynamically. MR technology gives a higher engagement in learning experience and helps students digest and remember the knowledge in class [Ke2016]. The benefits of incorporating MR technology into educational experiences include better engagement and the opportunity for students to experience and better remember what they have learned.

MR can be applied in different aspects in teaching and training. Quint et al. [Quint2015] suggested a system architecture using mixed-reality, which combines physical objects and visualization of digital content through AR. However, most of the recent MR applications are focusing in commercial training and users experience. The effectiveness in comprehending product design is seldom investigated. The application of MR technology in school education is still in its infancy. Engineering Education with MR technology is particularly important to train the future engineers and students in comprehending design and enhancing their creativity.

## Methodology

In this project, an MR application was developed for teaching engineering students in the University. We aim to train the engineering students in

comprehending design structure and inspire their creativity. To facilitate the teaching and training, we have developed an MR application on the latest HoloLens system. HoloLens uses MR head-mounted display smart glasses. It is a self-contained, holographic computer that can engage with digital content and interact with holograms [Microsoft2018a]. The HoloLens system is a comprehensive AR system, functioning the Windows 10 operating system (OS), developed by Microsoft. It includes a central processing unit (CPU), a custom-designed holographic processing unit (HPU), various optical lenses with a holographic projector and different types of sensors. More details on the HoloLens system can be found in [Liu2018]. Figure 1 shows an overview of the designed system configurations.

Figure 2 demonstrates an example of visualizing and exploring a product design with the HoloLens system. The MR application provides an opportunity to students to visualize the product dimension and compare with a real object. An application was designed in this project to allow students to visualize the geometry of 3D objects and its exploded diagrams.

**Figure 1.** *The overview of the HoloLens system configuration* [Microsoft2018b]

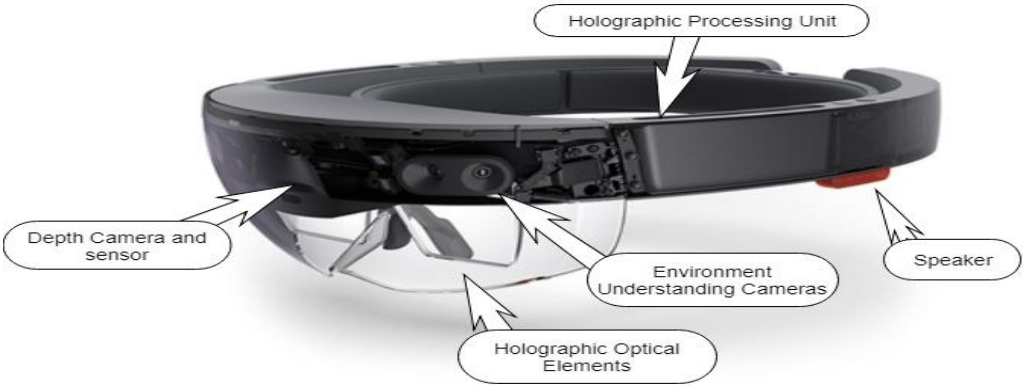


**Figure 2.** *An example of visualizing and exploring a design with the HoloLens system [Microsoft2017]*

A few functional features such as object transformation explode and invisible view of selected components, program reset, etc. has designed in the application. The students can give gaze signal, gesture signal and voice signal to implement the system or command it through the command manual. In the meantime, they can hear the voice navigation giving explanation of functions and features of selectee components from the system.

**Figure 3.** *The air-tap gestures used in the HoloLens Application*

A case scenario in [Tang2018] was employed in the developed application to teach students the complicated concepts of product design. Game engine is used as Unity for application development in this project [Unity2018]. C# is used as the programming languages to design key features in the application. Users can explore different major components of the design structure by using the exploded view or hidden parts in the application. Students need to select the application context through gazing, which acts as the hologram cursor, to signal the system. Figure 3 shows the common air-tap gestures used in the HoloLens Application. Two air-tap gestures are used to select the virtual model in the application context, and transform the model.

In order to investigate the outcomes of the MR application, a group of students will be recruited and invited to participate in the investigation voluntarily. At the beginning, students will be instructed to familiarize with the HoloLens System. 5-10 minutes will be given to the students to familiarize with system operation. Another 10 minutes will be given to students to study the case scenario and understand its design structures. When students have finished the MR experience session, a test with questions related to case scenario model used in the HoloLens will be given to assess their abilities. Open-ended and multiple-choice (MC) questions are included in the test. The finished time of test paper taking by students was recorded as well.

## Results

The test is conducted in a local university in Hong Kong. The HoloLens MR Experience session was opened to all students and 23 engineering students were participated in the test. Students' opinions and feedback in the experience

session was collected. Table 1 summarized the opinions and feedback. Most of the students participated in the workshop as they would like to explore the potential applications and get deeper insight of the VR and MR technologies in different aspects. They would also like to make their own product on the HoloLens system in the future.

Students were required to participate in the test to measure the quantitative result of students' abilities after the experience session. Students' abilities is measured based on their skills in comprehending design, understanding the product functions, visualizing 3D geometry, understanding geometric relationship, and students' creativity. The average marks of each area were calculated and evaluated. Table 2 shows the average marks obtained by the students in the test in five different aspects.

**Table 1.** *Opinions and feedback from the participants*

| **Participant** | **Opinions and feedbacks** |
|---|---|
| *Student 1* | *Allow us to make our own product* |
| *Student 2* | *Can build a product by myself* |
| *Student 3* | *More workshop to teach VR development* |
| *Student 4* | *Trying the HoloLens is very interesting* |

**Table 2.** *Average marks of test in five different aspects*

| **Students' Abilities** | **Average Marks** |
|---|---|
| comprehending design | 3.13 |
| understand product functions | 3.85 |
| visualizing 3D geometry | 3.52 |
| understand geometric relationship | 4.69 |
| Creativity | 3.21 |

It indicated that highest score of test result in understanding the geometric relationships. And similar test results were recorded in visualizing 3D geometry and understanding product function. The results demonstrated the students' ability in understanding geometric relationship through the transformation functions (i.e. translation, rotation) in the designed HoloLens application. It is also believed that a positive and pronounced effects in understand product functions an visualizing 3D geometry come from a better understand in geometric relationship. However, test result in comprehending design and creativity are the lowest, as a more-complex case scenario, which involved complicated structures and large number of parts are included in the test. The average time of students to finish the test was measured as 4'8" respectively.

## Conclusions

In this project, the MR application was developed to teach product design to university students and enhance students' learning experience on

complicated design structure from the traditional methodology. The MR application was developed based on the HoloLens system, which allows students to visualize the geometry of 3D objects. A test was designed to analyse the effectiveness of the MR application and it also assessed the students' abilities in five main areas. The average time of students to complete the test was also measured for future research. The MR HoloLens application demonstrated the successful result as a supplementary tool for engineering education in university and it should be widely used and explored in future teaching subjects.

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