Mixed Reality Improves Education and Training in Assembly Processes

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Highlights:

- The developed AR application for globe valve assembly and maintenance improved the understanding while completing a task by navigating the app in real time.
- AR applications can help in education and training since they are an easy and interesting alternative for current education methods to improve students' understanding.
- AR applications can be applied as a strategy to gain better output and interest in terms of the pedagogical implications.

Abstract. Mixed reality is the outcome of blending the physical world with the digital world, made possible by technological advancement. Mixed reality is the next evolution in human, computer, and environment interaction. Augmented reality (AR) uses a virtual model of the real world, augmented by using a computer to see the real environment through a special display device. Current education and training systems in the engineering maintenance field are still insufficiently directed at the psychomotor skills in learning about machine parts, which makes them less effective for trainees. The oil and gas industry always face problems related to inefficiency due to downtime of critical equipment. This study was conducted at designing and developing a virtual reality (VR) and augmented reality (AR) system as a learning and training platform. This work also reviewed AR applications for machine part maintenance and assembly. An AR system was modelled and developed using the following software: CATIA, Blender, Unity and Vuforia. The effectiveness of using the AR technique in an education and training process was evaluated with 20 respondents among university students. The results showed that using this AR app enhanced the participant's understanding according to certain criteria and can be adopted as a learning method.

Keywords: *augmented reality (AR); mixed reality; unity; virtual reality (VR); Vuforia.*

1 Introduction

Modern computer graphics have been improved over many years and have introduced a new dimension of communication media and accessibility of

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interactive 3D graphics. The user interacting with a computer system has changed along with the development of virtual reality (VR) and augmented reality (AR) devices and technologies. This interaction is provided by a human computer interface for a wide variety of applications, such as training and education, computer aided design, laparoscopic surgery, computer animation and gaming applications [1]. Augmented reality involves computer graphics that are mixed with the real world, the result of which is called mixed reality. Mixed reality is a subset of VR and is a technology for the merging of real and virtual worlds [2].

AR lets the user see the real world superimposed with virtual objects from the computer. AR is a medium that can use 3D visuals for learning and encourages experimentation. AR is used in education for Design Space, Virtual Reality Aided Modeller (VRAM) and Seamless Design with similar goals as studying 3D modeling, design and architecture [3]. VR and AR have also been applied in medicine. The study conducted by Pantelidis, *et al*. [4] presented and summarized the effect of the implementation of VR and AR in different fields of medical training. In the medical field, the development of these applications should be emphasized because new inventions are required to facilitate the work process [5]. The objective of this study was to improve training and education using a VR and AR application. The case study focused on maintenance work in the oil and gas industry, dealing with valves as essential components used in this field. The importance of having immersion and real time navigation motivated the authors to conduct an experiment with AR and VR to improve education and training for maintenance work.

2 Background Study

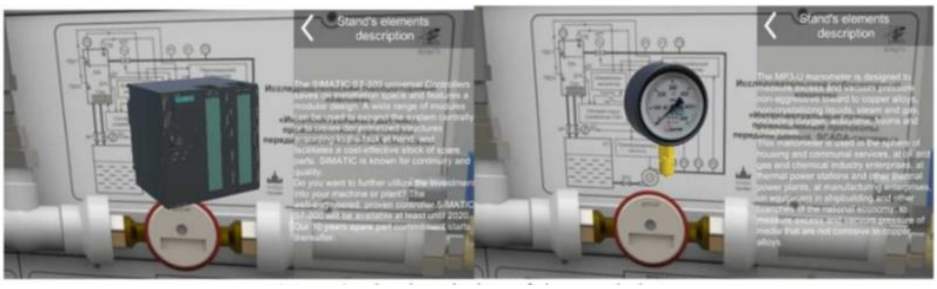
In education and training related to engineering maintenance it is crucial to provide very detailed guidance for any maintenance task to be performed. VR and AR enable a person to learn and train complex tasks in high-risk environments instead of using real equipment in a real training location. The existing VR training systems are usually used in areas such as medical, industrial and commercial training, serious games, rehabilitation and remote training [6]. In education, many methods have been applied and suggested for learning systems with difference techniques and solutions to achieve a better learning process and environment. VR and AR can be media using 3D visual instructions that are easy to learn and encourage experimentation.

2.1 Application of AR and VR in Engineering

One of the purposes of using AR and VR system and devices in engineering studies is to increase the motivation of students or trainees. The AR and VR system or platform can be developed for application in a practical or a class

learning environment. According to Bazarov, *et al*. [7], AR technology will be used widely in the future because many scientific publications appear related to this field of study. New techniques of training are important in educational processes and the use of AR technology is very promising but needs to achieve better results [7].

AR allows the user to experience a task using a 3D model and also get information on the object created in the same AR platform [8], as shown in Figure 1. In AR, information is added to a view of the real world; in VR the user is completely immersed in the virtual world using a special display device. Researchers have found that VR systems can improve the training experience (to improve human skills) in assembling, maintaining and repairing complex machinery and production facilities. VR systems represent a powerful tool for training humans to perform tasks that are expensive or dangerous to duplicate in the real world. Thus, additional information such as integration with haptic technologies to simulate the interaction between humans and products can be used effectively for learning, training, and planning assembly sequences and also for validation of the manual handling of products (including ergonomics and usability tests).



The description of standard elements used in an engineering training system.

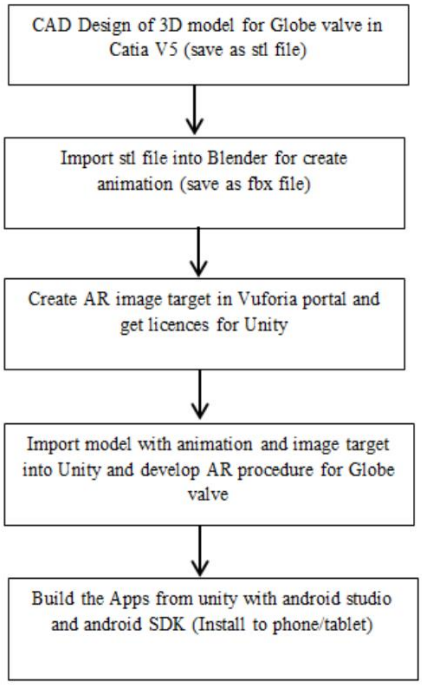
Rohidatun, *et al.* [9] developed a VR system with a haptic controller and an AR system to enhance the learning and training experience. They selected the mechanical assembly process of a valve system as the subject of the task. The evaluation of this system was done by participants from two groups: an ARVR group and a VR group. Both groups carried out the same thirteen steps in the experiment. All participants were evaluated based on the assembly performance results in terms of real task completion time (TCT) and total assembly errors in completing the valve assembly task. The VR interface for training in a virtual environment was presented on a PC integrated with a PHANTOM Omni used as interaction device for the manipulation of virtual parts. The results showed that learning and training with the AR and VR system influenced and enhanced the participants in mastering the valve assembly procedure. They could complete the valve assembly with high performance skill.

2.2 Potential Contribution of Augmented and Virtual Reality to the Oil and Gas Industry

In the oil and gas industry, a lot of machinery and heavy equipment are needed, which are operated by new workers or trainees for training and learning on site. Blackley, *et al*. [10] state that the oil and gas industry is likely to face high injury and fatality rates. Because the training and learning process is experienced by the participants in a real situation, they also experience risks while being trained on site. Thus, it is better to transfer the real-world experience to a VR and AR platform for training.

3 Materials and Methods

This work started with the development of an AR app. The overall process of the app development and app evaluation are explained in the flow chart in Figure 2.



AR app development process.

This project applied several different learning and training methods to improve the skills and performance of the participants through the developed app. The participants needed to complete a given task, designed as a learning and training process for the disassembly, assembly and maintenance of the parts of a globe valve. In a globe valve, the sealing property to prevent leaking of the part between

the body and the bonnet is the most important basic feature [11]. It was chosen as it is an essential component in the oil and gas industry.

3.1 Development of AR Application

There were several steps in modeling the globe valve parts and creating the components of the AR program. These included the process of generating animations for the model, text panels and the user interface. The following steps detail the procedure for the development of the application.

1. Modeling of all parts of the globe valve for the AR application was done with CATIA V5, which helped the designer to get a high quality design [12].
2. The 3D models from CATIA in STL file format were imported to the Blender software to develop animations for the model.
3. The animations were exported to FBX file format to support the Unity software. Some elements from the Unity asset store were used, such as the UI, text, and buttons.
4. An important part of AR application development is the image target asset. An image target is a normal image that is usually placed in front of a camera. This image will then be captured by the camera, after which the 3D model is placed on top of the image target.
5. To get the image target database of AR, a Vuforia license key is required. The image will be selected to set as the marker for the application. After this process, the target image file can be downloaded as a Unity editor asset from the Vuforia developer website.
6. Before proceeding to the next step, all the settings of the AR application in Unity were projected and imported into an Android tablet and phone. To perform this procedure, the APK file was installed on an Android device required by the software, for example: Android Studios, Java JDK and Java JRE.
7. Once all the assets were imported into Unity, the process of 'game scene building' was followed by programming script. After programming, each component was completed (including animations, textured materials, UI buttons and instruction dialogue).
8. After completing all the game scenes, the APK was built and run on an Android tablet.

3.2 Experimental Design and Data Analysis

The design experiment followed some of the methods of the experiment done in Montoya, *et al*. [13]. After gathering data from the experiment, data analysis methods were carried out by the participants. Due to limitations in involving personnel from the oil and gas industry to participate in this work, the experiment

was conducted with mechanical engineering and chemical engineering students from the Engineering Faculty, Universiti Putra Malaysia (UPM).

Two groups were given a questionnaire survey for the perception of the AR learning method. Errors made, user feedback, and responses to the AR application were evaluated. The answers from the questionnaire were analyzed and a statistical t-test was carried out. When a participant brought the Android tablet or phone close to a marker, a 3D image of the pop-up model appeared (as shown in Figure 3). It clearly shows the title of the screen as well as the model of the valve, with details labeling each part's name.

The augmented Globe valve model and labels as seen in the app.

4 Result and Discussion

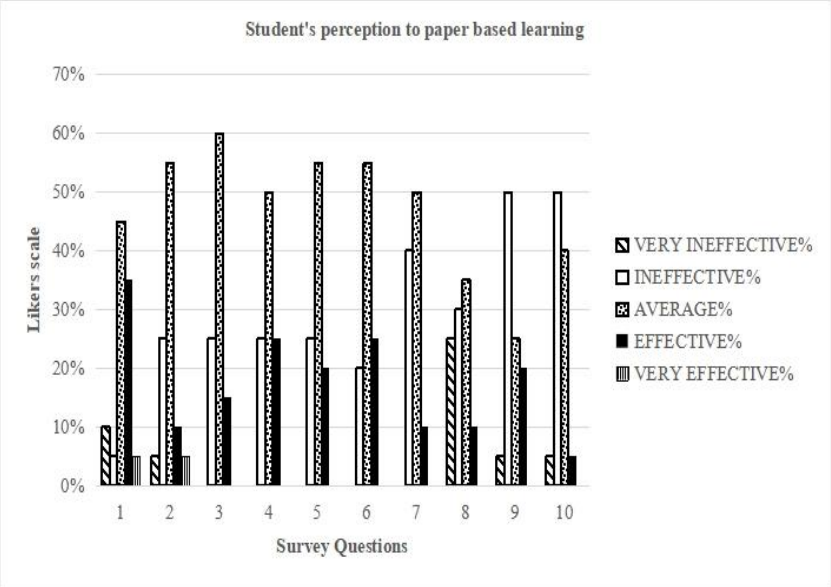
An app was created as the platform for students to better understand the process of globe valve assembly and maintenance. The main assets, i.e. the 3D models, the image target, the UI, and animations, were imported into the Unity software. Vuforia portal was used to generate the AR image target to Unity so that the AR app could use the selected image as a marker. The app was built by using an Android SDK and JDK in order to create an Android APK file. Every scene inside the app was incorporated to present the flow of the learning guide to the user.

The AR application could directly be installed on an Android phone or tablet as soon as the APK file of the AR project in Unity was finished. After installation, the AR app was ready for use. With the Unity software, a user interface (UI) was created for every scene inside the app to present the flow of the learning method. The most important part in each scene is the UI to direct the user to the options of the application.

4.1 Evaluation of the AR Application

Figures 4 and 5 which was tabulated based on graph model by Smith [14] show the feedback of the participants that was collected by using the AR application compared to a paper-based method. There was a high percentage of agreement toward the AR app providing a positive educational experience. It also showed high values of attraction among the participants and high values for the quality of the learning content in the application.

Figure 4 shows the result for the paper-based learning method with the average preference range of the participants. Based on the post-interview conducted upon completion of the experiment, the students found it was not easy to understand the paper-based instructions. The paper-based method did not meet certain criteria of the participants, who require a different presentation to develop their understanding.

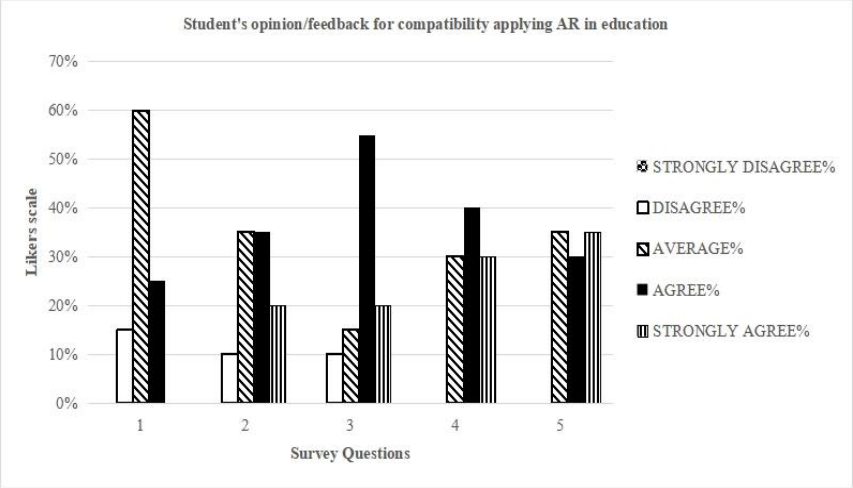


The participants' perception of usual paper based learning method.

Figure 5 shows that 'agree' had the highest score on the agreement scale. In the post-interview, the participants said it was easy and interesting to work with the AR app since it provided an interactive interface and they could navigate it in real time, hence improving their understanding to complete the given task.

The high value for 'average' on the agreement scale means that the AR application learning method also provided better understanding in terms of user

output. This result is in line with the study conducted by Cai *et al.* [15], who stated that AR is better because the user can pay closer attention to the given task.



The participants' perception of the AR application learning method.

5 Conclusion

This study showed that the developed AR application could help in education and training as an alternative method to improve of student understanding compared to existing education methods. In summary, it can improve education or strategies to yield better learning output and create more interest from students in terms of the pedagogical implications. This is an on-going project, where the project for the design and development of a virtual reality maintenance training system is divided into different phases. The first phase includes documentation of the conceptual design, the training function and the process of designing and development of the VR app. The second phase has yet to be carried out. It will focus on the effectiveness of VR in the developed training app for the oil and gas industry specifically for maintenance work.

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