A Novel use for Wearable Augmented Reality in Engineering Education

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Abstract—**The rapid advances in virtual technology has led to great improvement in educational tools. The benefits of using augmented and virtual reality to assist teaching are increased student motivation, better learning experience, interaction with peers through internet and interaction with real world objects. Increased investments in virtual technologies, enhanced user experience and benefits of using virtual technology for teaching makes augmented reality one of the leading technologies for future of education. This project aims at developing a wearable headset based augmented reality application to assist teaching HVAC systems to students. The application has a guided walkthrough of the HVAC system as well as a manipulatable 3D hologram. Unity3D Game Engine has been used to develop the application while Microsoft HoloLens has been used as the platform for implementing the augmented reality application. The application has been implemented and tested to receive feedback.**

Index Terms—**Augmented Reality, Educational Technologies, Head Mounted Display, Interactive Technology, Microsoft HoloLens, Teaching Aids**

I. INTRODUCTION

AUGMENTED reality is 'a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view' [1]. It allows mixing of the real world with the virtual world. The user can see the interactive virtual objects appearing in the real-life environment. This creates an immersive environment which responds to user inputs. This serves as a suitable platform to be used in the field of education.

The number of virtual and augmented reality applications with potential in the education sector extends as much as imagination or ability to adapt materials in traditional format allows [2]. In the recent years, there has been a major spike in investments in Virtual Technologies (VT) by major companies. The research and development is focused on developing an entire ecosystem to support virtual technologies [3]. The VT industry has greatly improved on the initial constraints like high cost, difficulty to create applications, and poor ergonomics.

The use of VT would be greatly beneficial to educational institutions, providing the ability to visualize and learn various concepts like working of machinery, the solar system, medical scenarios, etc. The use of virtual, augmented and mixed reality applications in the field of healthcare has been explored and found to increase efficiency and effectiveness of nursing and healthcare services [4]. In case of engineering education, the positive impact on learning has been demonstrated by developing and testing an application that helps students better understand and imagine the inner workings of a car [5].

Augmented reality allows users to interact with the virtual objects superimposed on real world object through gaze, gesture and voice (GGV) commands. Using portable Head Mounted Display (HMD) devices, students can extend the learning experience beyond the classroom. The control is with the students, enabling them to learn at their own pace.

Virtual technologies can also be leveraged as a motivation for the students to learn. AR is effective in capturing the user's attention due to its ability to provide a different view to the real world. Unlike computer-based applications, AR has the ability to merge teaching aids with reality, leading to an immersive experience.

The major benefits of using virtual technologies in education are [3]:

1. Greater engagement of students and motivation to learn
2. Ability to interact with 3D models, enhancing learning experience
3. Affordability and accessibility of supporting technology
4. Greater interaction as compared to conventional learning materials

This project aims at making use of wearable AR technology to develop an interactive application focused on teaching Heating, Ventilation and Air Conditioning (HVAC) systems to under-graduate students.

II. BACKGROUND

The project has been developed to assist teaching HVAC systems using a novel method. The use of AR helps students visualize the system, and have a deeper understanding of individual components. Apart from this, it helps overcome certain drawbacks of the conventional teaching methods.

Learning the HVAC system is currently done using a working model where the instructor explains the system. In case of the real-world system, it is sometimes difficult to see individual components that are housed within the system enclosure. The enclosure must be removed to look at the components. This might need the presence of authorized personnel to guide the dis-assembling, and assist in re-assembling. There is a chance of injury as well. Moreover, it would be a time-consuming process.

There is a possibility that the teaching method of the instructor may not be suitable for each of the students. There

might be a gap in understanding due to factors like teaching speed, method of teaching, speaking accent etc. There is a possibility that the instructor misses out on an important point while teaching. This might result in an unsatisfactory learning experience for the students.

To overcome these shortcomings, use of an AR based application to aid teaching is needed. The use of virtual technology will allow users to view and learn about individual components almost instantly, without the need for physical disassembly and re-assembly. The learning experience is controlled by the user, at their own pace.

III. DESIGN OVERVIEW

The purpose of the project is to assist in teaching HVAC systems to students using AR enabled Head Mounted Display devices. An application to be run on the HMD is developed that specifically serves this purpose. The 3D application is developed and compiled on the Unity engine and run on Microsoft HoloLens.

The development of the application was based on the ADDIE model guidelines for development of educational AR content [6].

A. Microsoft HoloLens

Microsoft HoloLens are a pair of mixed reality headsets, running on the Windows Mixed Reality Platform under Windows 10 operating system. It is developed and manufactured by Microsoft. HoloLens can perceptively map the surroundings and mix holograms with the environment. The user can interact with the holograms using Gaze, Gesture and Voice (GGV) commands. The HoloLens [7] is seen in Fig. 1.

Fig. 1. Microsoft Hololens

The technical specifications of HoloLens are seen in Table 1.

TABLE 1.
TECHNICAL SPECIFICATIONS OF HOLOLENS

Developer	Microsoft
Manufacturer	Microsoft
Operating System	Windows Mixed Reality
Memory	2GB RAM, 1GB HPU RAM
Storage	64GB
Display	2.3-megapixel widescreen, stereoscopic head-mounted display
Sound	Spatial sound technology
Input	Inertial measurement unit (Accelerometer, gyroscope, and magnetometer), 4 sensors, 120°×120° depth camera
Controller input	Gestural commands via sensors and HPU
Camera	2.4 MP
Connectivity	IEEE 802.11ac, Bluetooth 4.1 LE
Platform	Windows 10
Weight	579 grams

The Microsoft HoloLens was selected for this project due to some prominent features [8]. The HoloLens does not cut off the user from the surroundings. This means that while using the device, the user is still able to see and hear all that is happening around them. This prevents potential accidents.

The HoloLens is an independent wireless device, which gives complete freedom to the user. There is no need to attach the device to the computer or smartphone. This means that the device can be easily deployed in the classroom, or even outside.

Interaction with the device is intuitive and can be learnt easily by the user. The device senses Gaze, Gesture and Voice commands, which are simple and naturally occur to the user. There is no need for extensive training to familiarize the user with the device and application controls.

B. Unity Engine

Unity is a multi-platform game engine used to develop 2D and 3D games and simulations that run on computers, consoles, mobile devices as well as virtual technology gear. It is developed by Unity Technologies. The runtime codes for Unity are written in C/C++ [9].

Unity Engine supports application development for HoloLens and is the preferred tool for most VR/AR creators [10].

IV. APPLICATION DESIGN

The overall application is designed to help the user learn about HVAC systems, visualize and understand the major components, and take temperature readings from an actual HVAC system. The application is divided into 3 major modes: Data Mode, Walkthrough Mode and Hologram Mode as illustrated in Fig. 2.
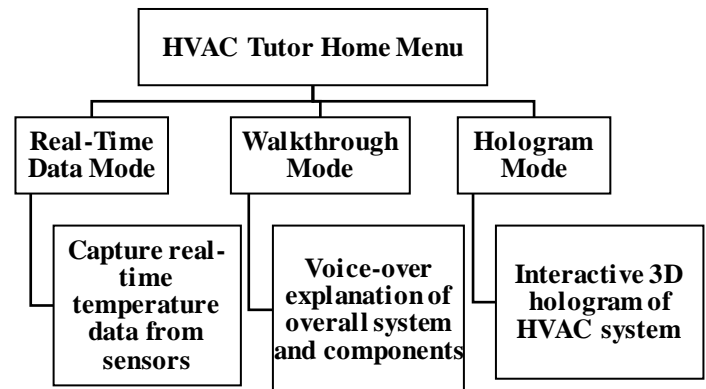

Fig. 2. Application Design Overview Chart

A. Home Menu

As soon as the application is opened, the user sees the home menu, as illustrated in Fig. 3. The user can select the desired mode to continue.
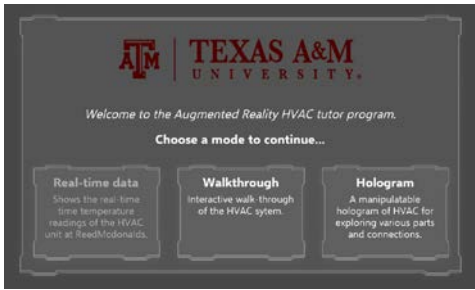
Fig. 3. Application Home Menu

B. Real-time Data Mode

The objective of this mode is to have real time data display on the application. The physical HVAC unit at the laboratory in Texas A&M University has been fitted with multiple wireless temperature sensors at various points, that would be recording and transmitting temperature readings in real time to the HoloLens. Currently, this feature is under development and testing.

C. Walkthrough Mode

The walkthrough mode is a voice-guided tutorial that teaches the basics of an HVAC system. There are 3 distinct windows in this mode. The first window on the left displays the description of the current component, the middle window has a 3D hologram of the component being discussed, and the window on the right displays relevant images that give additional information about the component, as seen in Fig. 4.

Fig. 4. Walkthrough Mode

Each of the component and its working is described in detail by the voice over, along with text displayed on the left window. The appropriate component is displayed as a 3D hologram in the middle window. The user can play, pause, move forward or reverse during the walkthrough. There is also a home button that takes the user to the home menu.

D. Hologram Mode

The hologram mode provides a 3D model of the HVAC system along with various tools that the user can use to manipulate the model, which is seen in Fig. 5. The 3D model displayed is as seen in the Unity 3D window on the computer. When the user sees the model on HoloLens, the model would be superimposed on his surroundings.

Fig. 5. 3D model of HVAC System

The tools are displayed as intuitive icons as seen in Fig. 6, with a description to tell the user how to use the tool. The description is provided for the tool whose icon is in the center of the gaze, as denoted by the pointer. The tools that can be used on the model are Search, Move, Scale, Rotate, Explode and Annotate. The functions of these options are as follows:

1. Search: If the user looks away from the model or moves the model to some place and cannot locate it, then he can use the search option that will display an arrow at the center of gaze, which points towards the model, directing the user to look in that direction.
2. Move: Using this the user can move the model in 3D space.
3. Scale: The user can alter the size of the model to make it bigger or smaller.
4. Rotate: This option allows the user to rotate the model about the vertical axis.
5. Explode: Using this option the user can see the exploded view of an assembly.
6. Annotate: The annotate option provides a description about the component on which it is used. Using this, the user can read and view images related to any component in the system.
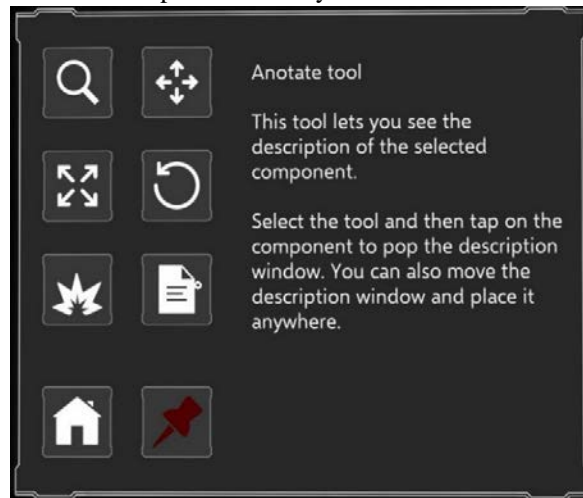

Fig. 6. Tools

E. Using the Application

The application controls are modelled on the primary means of interaction with the HMD – Gaze and Gesture. Voice commands are not incorporated in the current version of the application. Gaze is related to the cursor movement controlled by user head movement. Gaze tells the application where the user is looking, and is ready to interact. Gestures are specific hand actions that tell the application that the user is interacting. In this case the 'tap' gesture is used by the user to select or activate an option.

F. Application Development and Compilation

The application is built on Unity interface where the different scenes are modelled. Unity provides a complete 3D environment in which the user can create menus, animate, write scripts, and organize projects.

The resources used in the application are called assets. An asset may be 3D models, animations, audio, materials, etc. In this project, the various assets include the HVAC 3D model, audio recordings, the materials and textures for the models, and the animations.

Scenes contain the assets of the application. Each scene can be considered as a unique level. The application is designed in 5 scenes. The first scene is the camera scene, where the camera location is defined. The camera represents the user point-of-view. The camera position is copied on to the further scenes. The second scene is the home menu, where the user sees a welcome message and the options to select modes. The remaining 3 scenes are for each of the modes of use, namely Data mode, Walkthrough Mode and Hologram Mode.

Once the application has been designed and built on Unity, Visual Studio is used to compile and deploy it to HoloLens. The deployment to HoloLens can be done wirelessly using its IP address or by connecting it using a USB cable.

V. Development Stages

The design of the application and interface has undergone multiple iterations. In the initial stage, the application included just a 3D hologram, which the users can view and manipulate. But this was inadequate for the user to learn.

In the next stage, descriptive text was added to the components that the user can read. In further stages, the walkthrough mode was developed, which included the voice-over explanation, with the components and their details being displayed in a sequential manner. The hologram mode was also refined, by making the controls more intuitive for the user. The Real-time data mode is under development, and will be incorporated into the application as the next stage.

VI. Testing

The effectiveness of the application can be determined only by testing it on users.

A. Methodology

The application was tested on undergraduate engineering students, with a mix of individuals who do and do not have prior knowledge of HVAC systems. The test was conducted on a group of 10 students. The participants were anonymously identified with serial numbers, starting from Participant 1 till Participant 10.

Initially, the participants were familiarized with the Gaze and Gesture inputs that the HoloLens recognizes. This was done by asking them to use the 'Learn Gestures' application that is pre-installed by the manufacturer. Once the user was familiar with the HoloLens inputs, they were asked to use the HVAC Tutor application.

The users were asked to explore the application on their own, without any guidance from the test supervisor. This was done to check the level of intuitiveness and navigation ease for the application. Once the users finished using the application, they were asked to fill out a short survey questionnaire with yes/no responses. The response details are mentioned in the following section.

B. User Response

The application was tested by users, and their feedback was recorded on a survey questionnaire. The response details are seen in Table 2.

TABLE 2
USER FEEDBACK

Category	Question	Response
Ease of Use	The application was easy to use	Yes (100%)
	I could navigate through the application easily	Yes (90%) No (10%)
	Learning to use the system is easy	Yes (100%)
Usefulness	The use of this application improves learning	Yes (100%)
	Using this helped me understand better	Yes (90%) No (10%)
	I believe such systems should be used during lab sessions	Yes (90%) No (10%)
User Experience	Using the application to learn was a good experience	Yes (100%)
	The use of this system makes learning more interesting	Yes (90%) No (10%)
Future Use	I would like to learn using such systems	Yes (100%)
	Such systems would help me learn better than conventional teaching methods (presentations, online learning modules, etc.)	Yes (90%) No (10%)

It was observed that most of the responses are positive in nature, and the participants were keen on using similar systems for future learning. There is a complete agreement in terms of participant responses when asked if they would like to use such systems in future.

On being asked about Ease of Use of the system, Participant 5 said "It was very intuitive and straight forward. I found the gestures appropriate. The movements are natural, fluid and accurate."

Regarding the Usefulness of the application, Participant 8 said "I did not know much about the system and it was very informative. There was a lot of information given at once. But I got to learn something new in a fun way. I will be able to easily remember the things I have learned since it was interactive and I got to see the insides and know what each part does."

As per Participant 6, the user experience was described, as "This was an entertaining chance for me to test out the systems here in order to learn and understand how the HVAC system worked. It held a functional slideshow similar to a PowerPoint

and held slight changes to the viewing of the system, from its use to the internal components. It held my attention easily."

Participant 8 said "It would be nice to have this implemented in future labs to learn about the topic. It brings a new way to learn and you can be interactive with the system and know that it won't break if you mess up. It could be more interactive, where we could see the individual parts of the while system and not just the exploded system." when asked about future use of the application.

Although there is a positive outlook regarding the use of Augmented Reality systems, this could be due to the novelty of the technology, which might wear out with prolonged use.

C. Areas for Improvement

As per the user feedback, there are some areas where a scope of improvement is seen. These can be broadly classified as:

1. Improvements in the Hardware
2. Improvements in the software
3. Medical issues

Participant 8 mentioned that "The device was a bit heavy in the front, maybe have something that could balance it out." Some of the users might not be comfortable with the equipment resting on their foreheads. Further improvements in technology will lead to reduction in weight of the HoloLens.

Some participants expressed the need for more interactive features in the application. Participant 7 mentioned, "I would like to see the system have more areas for interaction."

Some people are prone to feel nausea or motion sickness while using Virtual reality or augmented reality devices. Further research and development might be able to alleviate this issue.

VII. COST

The HoloLens Development Edition is currently priced at $3000 while the Commercial Suite costs $5000 per device [4]. The cost will tend to reduce with further advancements in technology in the near future. Also, a discount may be given as the use is for educational purposes.

VIII. CONCLUSION

Working with HVAC is both time consuming, complex, and expensive in higher education but the use of HoloLens has made it easier and more intuitive based on our research findings. HVAC Tutor application on HoloLens has been tested to positive feedback from participants. The use of Augmented Reality is truly as an aid to conventional teaching. Such systems may be used in conjunction to other methods of teaching to improve the learning experience. The system is capable of transforming education across the world where equipment or knowledge is not readily available.

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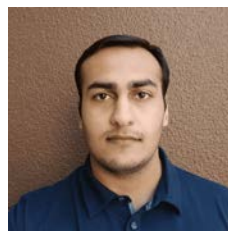
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