Interactive Objects for Augmented Reality by Using Oculus Rift and Motion Sensor

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***Abstract*—Augmented Reality (AR) is a technology to blend the digital computer such as audio, text, animation, 3D models seamlessly to the real-world environment. This technology is going to change the way how people imagine, see and learn in the future. This paper discussed the implementation and development of interactive objects for AR by integrating Oculus Rift, Leap Motion Controller (LMC) and camera. In this project, a video-displayed AR device is created to work together with a special designed AR book. A LMC is essential as a peripheral input device for the user to interact with the system. The application of LMC further enhances the interactivity with different well-designed hand gestures such as thumb up, down and pinching. The proposed design will enhance the user experience for interacting, engaging and responding to the information.**

***Index Terms*—Augmented Reality; Motion Sensor, Interactive Objects; Hand Gestures.**

I. INTRODUCTION

Imagine there are a lot of things that we have in the world that are physical which does not actually necessary to be physical. With the introduction of AR, a technology which allows the real-world environments seamlessly merged together with computer-generated elements, all these things could exist in a digital virtual form such as text, audio, video and 3D objects [1]. By bridging the gap between the virtual and real world, this technology can go beyond the entertainment industry and applicable in the education field. The knowledge which supposedly does not necessary to be in physical form can be passed on to the younger generation in AR environment which is more effective, engaging and interactive compared to conventional education tool.

According to Schwab [2], in the fourth industrial revolution, digital connectivity enabled by software technologies is fundamentally changing society. It also includes the vision as the new interface, where direct access to internet applications and data through vision, an individual's experiences can be enhanced, mediated or completely augmented to provide different and immersive reality. By enabling vision as a direct interface by providing instruction, visualization and interaction, it can change the way that learning, navigation, instruction and feedback for many applications. Today, various AR applications are emerging in an educational environment which may differ regarding their advantages [3] [4] toward the educational outcomes. The visual augmentation is the prime focus of the most AR education applications which existed in the market today. However, the learning experience can be further enriched with added more interactivity between the real world and the virtual contents via the application of the high-tech AR glasses such as Microsoft HoloLens, Google Glass and Magic Leap.

Unfortunately, these current AR devices are too expensive and unaffordable for the community [5]. Thus, this project focuses on developing a more economic AR wearable which comes alive with 3D animated objects by integrating an Oculus Rift, LMC and Logitech C310 webcam. Initially, Oculus Rift is just limited to immersive learning in Virtual Reality (VR) environment. Learning in the virtual environment is engaging, but users are restricted to interact with their teachers and friends who might be in the real world or another virtual environment. With the attached C310 Logitech webcam, the Oculus Rift is well-equipped with a new AR function. The performance of Oculus Rift is greatly improved with added LMC as the peripheral input device similar to mouse and keyboard. Different features are supplemented by the LMC to allow the user to interact with a virtual object in the real world by using both of their hands. The 3D [6] animated models, texture animations and enhanced marker design which suitable to education environment will also be included in the project framework. Therefore, immersive learning process [7] can also be carried out in the real-world environment.

This paper is organized into five sections. Section II provides an overview of the AR system and comparison between different specifications of Oculus Rift Development Kit. Section III covers the methodology of the proposed work to indicate integration between Oculus Rift, LMC and Camera. The results and performance are discussed in Section IV, which showcase the complete video display AR headset, dual mode of AR and hand gesture recognition using LMC. And finally, in Section V concluding remarks are provided.

II. AUGMENTED REALITY SYSTEM

In this section, the history and the definition of the development AR are reviewed accordingly. The characteristics of an AR system are clearly matched to whatever has been well-defined by the expertise.

A. Milgram Reality-Virtuality Continuum/ Mixed Reality Continuum

Reality-Virtuality Continuum [8], known as the Mixed Reality continuum is first introduced by Paul Milgram to describe the concept of AR. Referring to Figure 1, Milgram's Virtuality Continuum illustrates all possible variations and compositions of the real and virtual environment. According to Milgram, the virtual environment is represented at one end of the continuum, and the real-world environment is represented at the other end. The environment in between both extreme ends is known as mixed reality (MR). However, Milgram did not make a very clear definition of the term “Augmented Reality”, which the definition of AR could be reasonable different from people to people. The characteristic of an “AR System” can be imprecisely defined and it is hard to be differentiated between the two terms: AR and VR.

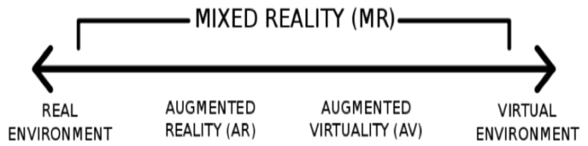


Figure 1: Milgram Reality Continuum

Later, a survey on AR is published by Ronald Azuma to define the taxonomy for virtuality and reality. Azuma’s definition [9] stated that AR is a variation of Virtual Environment or VR. It is noted that the definition of Ronald Azuma on VR is matching the Milgram Reality Continuum. According to Azuma, the main difference between the VR and AR stated that user is completely immersed inside a synthetic world by using VR technologies. In contrast, AR allows the user to see the real world, with virtual objects overlay or superimposed upon the real world. AR System can be identified by the three following characteristics:

- It combines the Reality and Virtual
- It is registered in 3D
- It is interactive in real time

The overall requirements of AR are different to the requirements for VR for the three basic subsystems. Referring to Table 1 as tabulated, the rendering and display requirements in the AR design is less stringent compared to VR. In AR, the virtual object only supplements the real world, hence, fewer virtual objects are required to be rendered in AR system. Besides, the display device for AR is less requirements because AR does not need to replace the whole real world. Surprisingly, in tracking and sensing, AR demands greater input bandwidth, higher accuracy and longer range compared to VR device. It is due to AR requires much more accurate registration than VR [9]. Registration errors will result in visual conflicts. Such visual conflicts can be easily detected by the resolution of the human eye and the sensitivity of the human visual system to differences.

Table 1
The Requirement Differences of AR and VR

	Augmented Reality (AR)	Virtual Reality (VR)
Scene Generator	Less	High
Display Device	Less	High
Tracking & Sensing	High	Less

B. Video Display Augmented Reality Device Operation

According to Figure 2, the marker-based AR system is made up of three main components proposed by [10] which are a camera, a computing unit and a display. The image is captured by the capturing module from the camera. The relative pose of the camera in real time is calculated by the tracking module to enables the system to add virtual components as part of the real scene. The term pose is defined as the six degrees of freedom (DOF) position: 3D orientation and 3D location of an object. The correct pose for virtual objects to overlay is calculated by the tracking module. Lastly, the original image is combined with the virtual objects using the calculated pose and the augmented image will be rendered on the display screen. The capturing module of the design can be replaced by any webcam. In addition, the tracking module can be replaced by sensors in a virtual device such as accelerometer and gyroscope. To improve the performance of the system, the design could be upgraded by attaching a new motion sensor to improve the functionality of the design.

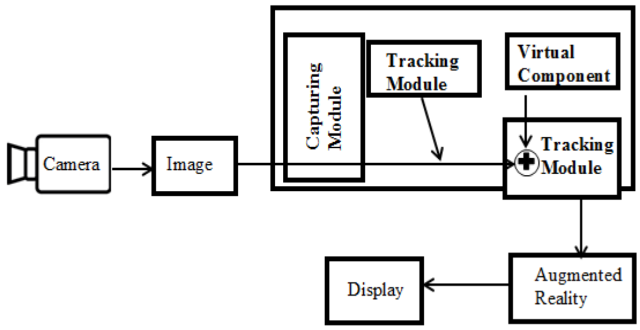


Figure 2: Simple Video Display Augmented Reality Device Design

C. Oculus Rift Specification

Oculus Rift is a virtual device headset [11] designed to allow the user to immerse into the game and look in any direction. Currently, it is not developed to support the AR features. Two development kit version has been released namely Development Kits version 1 (DK1) and Development Kit version 2 (DK2). Besides, there is one consumer version has been released in 2016 namely Consumer Version 1 (CV1).

In comparison to the three version of the Oculus Rift as tabulated in Table 2, both versions of Oculus Rift DK2 and Oculus Rift CV1 are well-equipped with several tracking device and sensors such as gyroscope, accelerometer, magnetometer and infrared sensors which are essential to replace the tracking module as shown in the Figure 2 in previous sub-sections. In addition, these two versions of Oculus Rift are equipped with an organic light emitting diode (OLED) display technology which requires less power consumption and offering a higher picture quality compared to the previous version of Oculus Rift DK1. Hence, both versions of Oculus Rift DK2 and Oculus Rift CV1 are ideal display device in the proposed AR system design. In fact, Oculus Rift CV has a better overall performance over the Oculus Rift DK2 in display resolution, wider field of view and well-equipped with a build in audio. However, Oculus Rift DK2 has been selected in this proposed project due to its lower price and lighter weight. The light weight (refer to table 2) of the Oculus Rift DK2 is more comfort to wear on and it could give a better user experience.

Table 2
The Specification of Oculus Rift Development Kit

	Oculus Rift DK1	Oculus Rift DK2	Oculus Rift CV
Price	$300	$350	$350
Display Resolution	640x800 (1.25:1)	960x1080 (1.13:1)	1080x1200 (1.11:1)
Display Technology	LED	OLED	OLED
Field of View	H: 90º	H: 90º	H: 110º
Weight	380g	440g	470g
Stereoscopic 3D capable	Yes	Yes	Yes
Audio	-	-	Built in Audio
Inputs	DVI, USB	HDMI1.4b, USB, IR Camera Sync Jack	HDMI, USB 2.0, USB 3.0
Head Tracking	Yes	Yes	Yes
Positional Tracking	Yes	Yes	Yes
Sensor	-	Gyroscope, Accelerometer, Magnetometer, Infrared CMOS Sensor	Gyroscope, Accelerometer, Magnetometer, Constellation Tracking camera
Camera	-	Yes	Yes
USB	-	USB 3.0	USB 3.0

III. Project Methodology

A. System Overview

Figure 3 shows the overview of video-displayed AR device which is developed by using Oculus Rift, LMC and Logitech C310 webcam. The real-world image is continuously captured by the webcam and displayed to the user views of perceptions by the Rendering Module. This is basically how the simple video-displayed AR system works in this project. In this project, all the system software development is carried out in the Unity3D environment and Microsoft Visual Studio 2015. The major programming language used for the development of this project is c#. It is a programming language designed by Microsoft for Common Language Infrastructure. C# is a general purpose and object-oriented programming language which is supported in Unity environment development. In this project, C# is used to design the scripting and algorithm for the whole project. The scripting such as the event triggering, spinning of planet and button on click listener written in C# will be in a folder named "Script". The Qualcomm Vuforia software development kit (SDK) is also used to recognize for specific marker such as an image to trigger the corresponding action. The SDK will be imported into the Unity3D development environment. However, it is noted that Vuforia package is mainly developed for mobiles devices such as iPhone, Android and Windows Phone. To use this mobile SDK to support AR experiences in wearable devices such as Oculus Rift, several approaches are required to take place.

Figure 3: System Overview

B. Application Development

According to the flowchart in Figure 4, it is illustrated that the how the Oculus Rift (a VR headset) is added with two new functions to support the augmented reality feature. The first function is image recognition/image tracking are provided by the AR SDK such as Vuforia, ARtoolKit and Metaio [12]. The image target will be preset and stored in the database of the application. The second added function is the hand gesture tracking or hand recognition which is supported by the LMC. The hand image data will be collected by the embedded two cameras and infrared LEDs in the LMC [13]. These data will be analyzed to extract important messages such as an extended finger, finger pointing direction and hand movement direction. These important messages will be used to determine and recognize any predefined hand gesture stored in the application. If any target object/ predefined hand gesture is detected, the corresponding 3D interactive object/action will be displayed to the user. Otherwise, the real-world image is continuously captured by the webcam and displayed to the user. In the project, an interactive AR Book – The Astronomy is designed to work together with proposed AR headset. The book is developed in Adobe InDesign CC, which is a publishing software application used to create a project such as poster, magazines, and books.

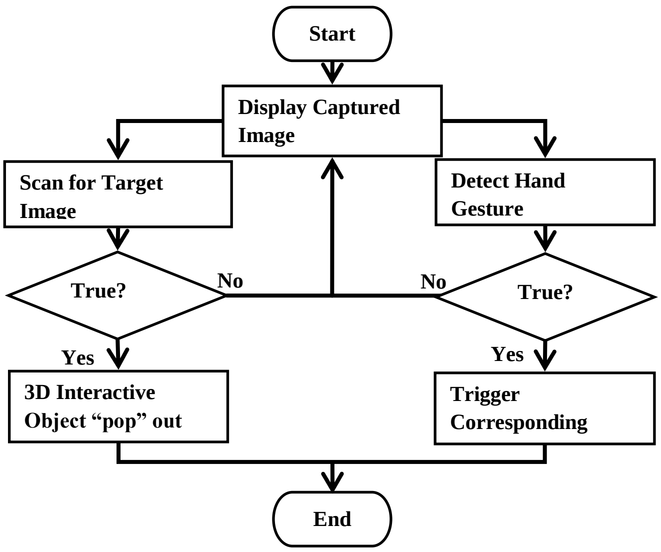


Figure 4: System Flowchart

C. Hardware Connection

Figure 5 shows the connection of Oculus Rift DK2, LMC, Logitech C310 webcam and computer. In this project, the Oculus Rift Development Kit 2 serves as an "inter-connected" device to connect both webcam and LMC. To launch the oculus rift, the firmware of oculus rift is required to be installed first in the personal computer. The software can be downloaded from the official webpage of Oculus Company. According to the DK2 specification, for the full Rift experience, the following system is recommended [11]:

- NVIDIA GTX 970/AMD 290 equivalent or greater
- Intel i5-4590 equivalent or greater
- 8GB+ RAM
- Compatible HDMI 1.3 video output
- 2x USB 3.0 ports and 1x USB 2.0 port

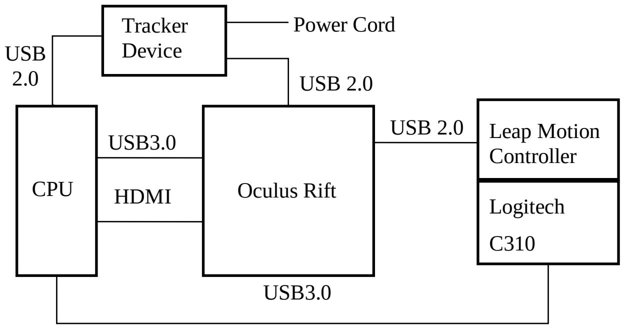


Figure 5: Hardware Connection

IV. Result and Discussion

A. *Video-Display Augmented Reality Headset*

Figure 6 illustrates the front view of the final prototype of the video-display AR headset. By referring to the diagram, LMC and webcam are attached together to the Oculus Rift. The application is developed using a combination of different software and programming language. In Figure 7, the left-sided picture shows the user's view when the user is wearing on the prototype. On the other hand, the right-sided picture is the real-world view.

Figure 6: Prototype Front View

Figure 7: Augmented View of Prototype

B. *The Astronomy*

The Astronomy (refer to Figure 8) is specially designed to work together with the proposed AR headset as one complete system. The book brings the headset user to an adventure to the Moon, Sun and Earth. There are total 6 pages in the book which including the front cover, content table, The Sun, The Earth and The Moon. Each of the pages is designed with different 3D models to enrich the learning experience. One special button key is also included in all pages to test user on their understanding after reading the book. In the content page (figure 8), there are three hidden information pages developed using AR technique. These pages include the About Us Page, User Guide Page and Health Safety Page. The About Us Page is the page that introduces the user on what's our research team is doing, what are the book features and what do we believe in AR technology. Besides, the User Guidance Page is the page that gives the user simple instructions on how to use the book. Lastly, the Health and Safety Warning page is the page to give necessary information to the user to reduce the risk of injury and discomfort when using the video-display AR headset. Users are ensured to read this carefully. It is noted that all these pages are invincible and can only be read if the virtual button is triggered by the reader.

Figure 8: The Design for AR Interactive Book

C. *Dual Mode of Augmented Reality*

The prototype is well-equipped with two modes of functionality. Mode 1 is the AR vision generated by the image captured by the Logitech C310 webcam whereas Mode 2 is the AR vision generated by the image captured by embedded cameras of LMC. The two embedded cameras inside the LMC are utilized to perform Dual Mode (refer to Figure 9 and Figure 10 respectively) of AR experience. The interchange of the two modes of AR features is triggered whenever the hand gesture of thumb up is detected by the system. It allows users can choose their preference learning environment.

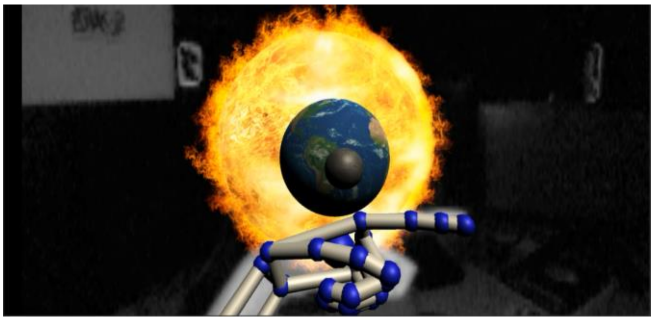
The Figure 9 and Figure 10 illustrate respectively the dual mode of AR experience which is supported by the proposed AR headset. In Figure 9, image source displayed in the headset is captured using the Logitech C310 webcam. In this environment, users could have an unobstructed vision on the real-world. The user can experience an awesome 3D sun model with the sun burning sound effect which helps to set the emotion of reader. At the same time, users can compare the size of the Sun, Earth and Moon in the real-world scale. The Sun, Earth and Moon models are animated with spinning and rotation script which can perform how the Earth and Moon rotate around the Sun. In Figure 10, the image source displayed is captured using the two embedded cameras in the LMC. It provides a cinematic AR experience compared to mode 1 as the real-world vision is a bit dark and blurry. In this environment, the user can have a close look on the sun and interact with it while retaining the vision to a real-world environment. Users can move back and forth the sun by pinching on it. Besides, the Sun model can be rescaled to larger or smaller by pinching it with two hands.

Figure 9: Augmented Reality Mode 1

Figure 10: Augmented Reality Mode 2

D. Hand Gestures Recognition using Leap Motion

In Figure 11(a), users are asked to point the direction of Earth rotation. A series of instructions are given to ensure they fully understand what to do. The Earth and Moon will only start rotating when users point to a correct direction. In this case, users need to point to the left hand-side to rotate Earth model. The pointing left gestures are developed in C# script and it is attached in the 'script' folder. Figure 11(b) shows the real-world view of the user pointing to left.



(a)

(b)

Figure 11(a) (b): Testing on Earth Rotation Direction

V. Conclusion

Based on this project, a video-displayed AR wearable device has been successfully implemented and developed. An interactive AR book named The Astronomy is designed in software Adobe InDesign purposely to work together with headset device. High quality graphic and stunning 3D models are included in the book which can bring a better learning environment compared to the conventional learning process. A few hand gestures such as Thumb Up, Pointing Left and Pinching have been developed to enhance the interaction between the user and the virtual object. The developed prototype supports dual-mode of AR views as well. The application integrated between Oculus and LMC further enhances the interactivity with different well-designed hand gestures to enhance the user experience for interacting, engaging and responding to the information.

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