Mixed Reality Based 3D Simulation Tool

DESIGN PROJECT REPORT

submitted by

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to

the APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

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in

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Department of Computer Science and Engineering

College of Engineering Trivandrum

Kerala

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DECLARATION

I undersigned hereby declare that the design project report **Mixed Reality Based 3D Simulation Tool**, submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of **Prof. Vipin Vasu, Prof. Bincy N Rashad**. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Place: Trivandrum

Date: January 26, 2021

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CERTIFICATE

This is to certify that the design report entitled **Mixed Reality Based 3D Simulation Tool** submitted by **Alan P Aby** , **Anees Babu**, **Muzammil T**, **Najim Rahman Valappil** to the **APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering is a bonafide record of the design project presented by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

Over the years, technologies like AR/VR already invaded spaces in e-commerce, gaming and tourism offering highly immersive and interactive user experiences, with Microsoft's HoloLens and Facebook's Oculus VR pushing the frontiers of this emerging technology. But, in recent times, there has been an increasing interest in applying and stimulating virtual environments to create unique architectural design settings using Mixed Reality. Mixed reality (MR) is the merging of real and virtual worlds to produce new environments and visualizations, where physical and digital objects co-exist and interact in real time. Thus, Mixed Reality allows us to manipulate our perception of our environment, through which virtual settings, equipment and objects are made in the background of our existing space. Traditionally, product development that combines industrial and mechanical design are done in softwares like Fusion360 and SolidWorks, which offers a 3-D view of the structure in a 2-D screen, which constrains the designer to properly visualise the machine and its working. The project aims to create a virtual development tool for designers and machine architects, to build what they visualise in their minds into a virtual reality space. People often find it difficult to analyse depth features of solid 3D objects while in a physical environment. It is difficult for repairing or updating related works to physically break down the structure and analyse the loopholes. In this platform, people can visualize the hidden concepts and structural features of objects or laboratory instruments. Not just the in-depth analysis, visualizing the 3D objects in 3D planes exposes many features that were once not possible using 2D planes. Virtual tools and equipment are used to simulate the functions in 3d planes. Also, Physical measures are not satisfactory in certain situations. Jumping into conclusions with just physical values and without simulating the concept often are not suitable for application purposes of any equipment. In this technology using MR, people can simulate their equipment inputting their physical values so that the people can evaluate the application capability of the design. We can feel the real life measurements and objects in front of the user. Also, it is difficult to interact with the interior of closed or restricted physical objects. Hence this technology makes it easier to visualize the problems, designs of interior parts of an object and detect the measurements of the objects, thereby reducing the risk and difficulty to view the in-depth

features of a physical solid body. Modern advancements in technology ignited the visual concepts and thereby emerged mixed reality based productive technology creating a virtual world in front of our eyes. The virtual world thus created, will operate according to the laws of physics, allowing the designers to see through the end of the product development cycle.

Contents

NOTATIONS

(List in the alphabetical order)

Chapter 1

Introduction

The development of new technologies has enabled the design of applications to create decision-making tools to solve the problems of daily life. Many computing ideas have emerged to achieve these aims, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). VR provides a computer-generated environment wherein the user can enter a virtual environment with a VR headset and interact with it. Although a lack of relation with real space was a problem in VR, AR technology solved this problem and presented a new method of visualization to enable the addition of computer-generated content to the real world. This technology creates an augmented world that the user can interact with. Despite the importance of AR, the separation of the real and virtual world is a serious challenge. This problem decreases the user immersion level during AR scenarios. MR emerged to tackle this challenge with the creation of the MR environment. This environment merges the real and virtual worlds in such a manner that a window is created between them. As a result, a real-world object interacts with a virtual object to execute practical scenarios for the user. There are three important features of any MR system: combining the real-world object and the virtual object; interacting in real-time; and mapping between the virtual object and the real object to create interactions between them. In fact, this application enhances the real environment by making invisible information visible to the user.

Mixed Reality based 3D development simulation tool is a new virtual-real-world interactive simulation project in recent years. Our project provides a platform for engineers and machine designers to make 3D models using MR and to feel like making a real world object.

Traditionally, machine design is done using 2-D technologies like SolidWorks or using OST HMD's like Microsoft HoloLens. However a mature Mixed reality based simulation tool is still not fully discovered. In the era of mixed reality it is possible to bring the virtual world and real world together to the game. Optical see-through and video-see-through are the two types of technologies used for developing the Mixed Reality space. In optical see-through technology, the real-world can be seen directly in tools such as transparent glass. In video-see-through technology, both virtual and real objects are present in an LCD (Liquid Crystal Display). The difficulties and high cost of implementation of OST-HMD leads us to stick with VST-HMD. To apply user's actions in to the screen, we use a Pointer Pen. Pointer Pen have the access to the virtual world and it helps with the simulation and building of 3D Objects.

Chapter 2

Existing Methods

2.1 2D DESIGNING TOOLS

Examples of 2D designing tools are Solidworks, where the engineer takes measurements and simulate the machine in a 2-D plane.

2.1.1 Limitations

Limitations of such a designing tools involves inablity to perceive, and visualise the machine being designed.

2.2 OST HMD BASED SOLUTIONS

The existing solutions for MR based designing tools are fully based on OST-HMD technology like MIcrosoft HoloLens. Following are the limitations of OST - HMD technlogies. Microsoft have successfully built softwares for designing and simulation, but far from perfection.

2.2.1 Limitations

Optical Calibration

Calibration accuracy is one of the most important factors to affect the user experience in mixed reality applications. For a typical mixed reality system built with the optical see-through head-mounted dis- play (OST-HMD), a key problem is how to guarantee the accuracy of hand-eye coordination by decreasing the instability of the eye and the HMD in long-term use.

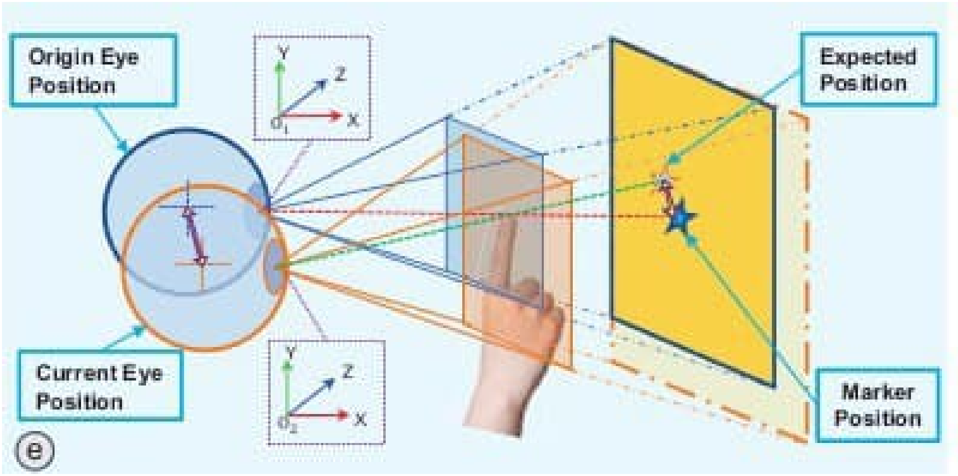

Figure 2.1: Optical Calibration error

Incomplete Rendering of virtual objects in OST - HMD's

As shown in Fig. 2.2 virtual object placement in OST HMD's are not efficient and reliable. Partial rendering of virtual objects fail to give a real-life simulation of the designing tool.

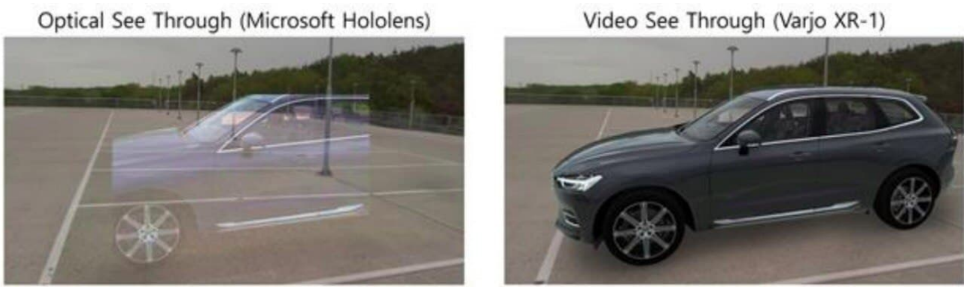

Figure 2.2: Incomplete Rendering of Virtual Objects

Chapter 3

Problem Statement/ Problem Description

Following are the problems statements we are trying to address through this project

3.1 Visualisation difficulty of 3D model in a 2-D plane.

Engineers fail to visualise how a machine would look in real life. Suppose a small equipment, or a part of a machine needs to be developed. Typically, the engineer has to take measurements and then simulate it using a 2-D tools like SolidWorks or AutoCAD.

3.2 Depth analysing difficulty of the machine being designed.

Traditionally, when designing a 3D system in a 2D plane, engineers fail to grasp the depth of the system being designed. A 2D tool can give the length and breadth, not necessarily the perception of depth.

3.3 Physics is not easily simulated and are not satisfactory relatable in a 2D design environments.

Physics and its laws cannot be simulated in 2D design tool. Hence there is a high chance that the design might fail in real life.

Chapter 4

Objective

4.1 Design of VST HMD system including hardware and software

Using the VST HMD system, the engineer would easily be able to design the system into a given space having fixed dimensions without the hassle of taking measurements.

4.2 Solving Depth Analysing problem using LIDAR and VGA cameras

A typical LIDAR sensor emits pulsed light waves into the surrounding environment. These pulses bounce off surrounding objects and return to the sensor. The sensor uses the time it took for each pulse to return to the sensor to calculate the distance it traveled. Repeating this process millions of times per second creates a precise, real-time 3D map of the environment. Discrete VGA cameras ,attached to both sides of VST HMD, are used to map the external environment. Two such cameras along with LIDAR gives the total external mapping of the environment

4.3 Physics Simulation using Unity PhysX engine

Using Vuforia and PhysX engine, physics can be simulated in a designed model.

Chapter 5

Design

Using a suitable architecture in MR applications, while integrating components, facilitates the relationship between them and leads to faster execution of MR algorithms in MR applications. This architecture comprises three parts: the Pen technology, Video-see through Head mount displays, and Processing Unit. The stylus pen contains left and right click buttons to interact

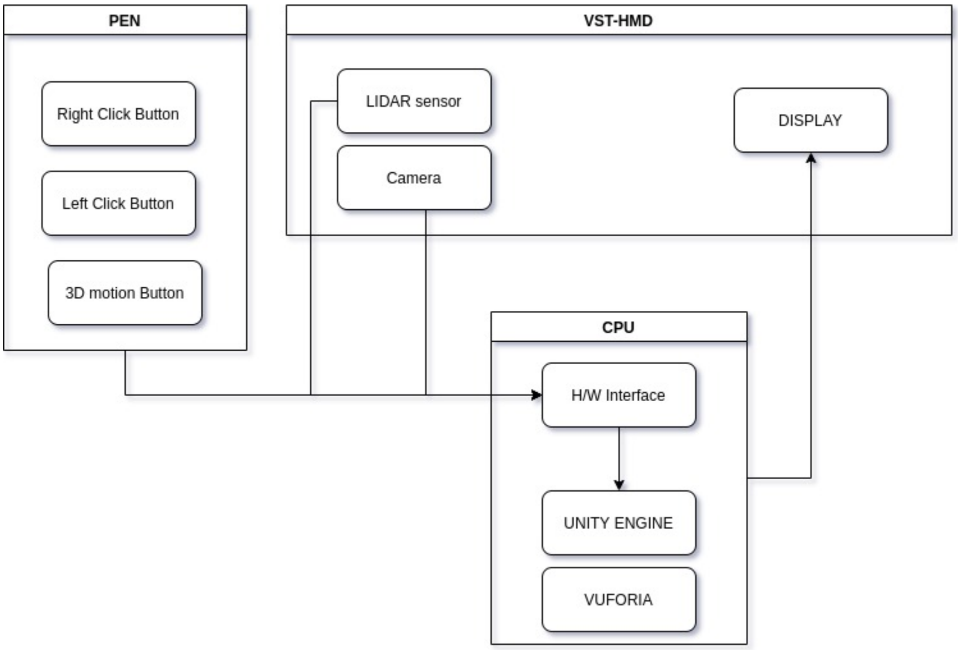

Figure 5.1: Architecture

and also a 3d motion button to rotate the viewpoint. The basic Processor architecture contains inputs of LIDAR Sensor data and Camera data from Video-see through Head Mount Displays and Pen stimulus data from the stylus pen. These signals are given to the processor and the processing unit analyses and Displays or updates the viewpoint of the user in the head mount display.

5.1 Design of the Project

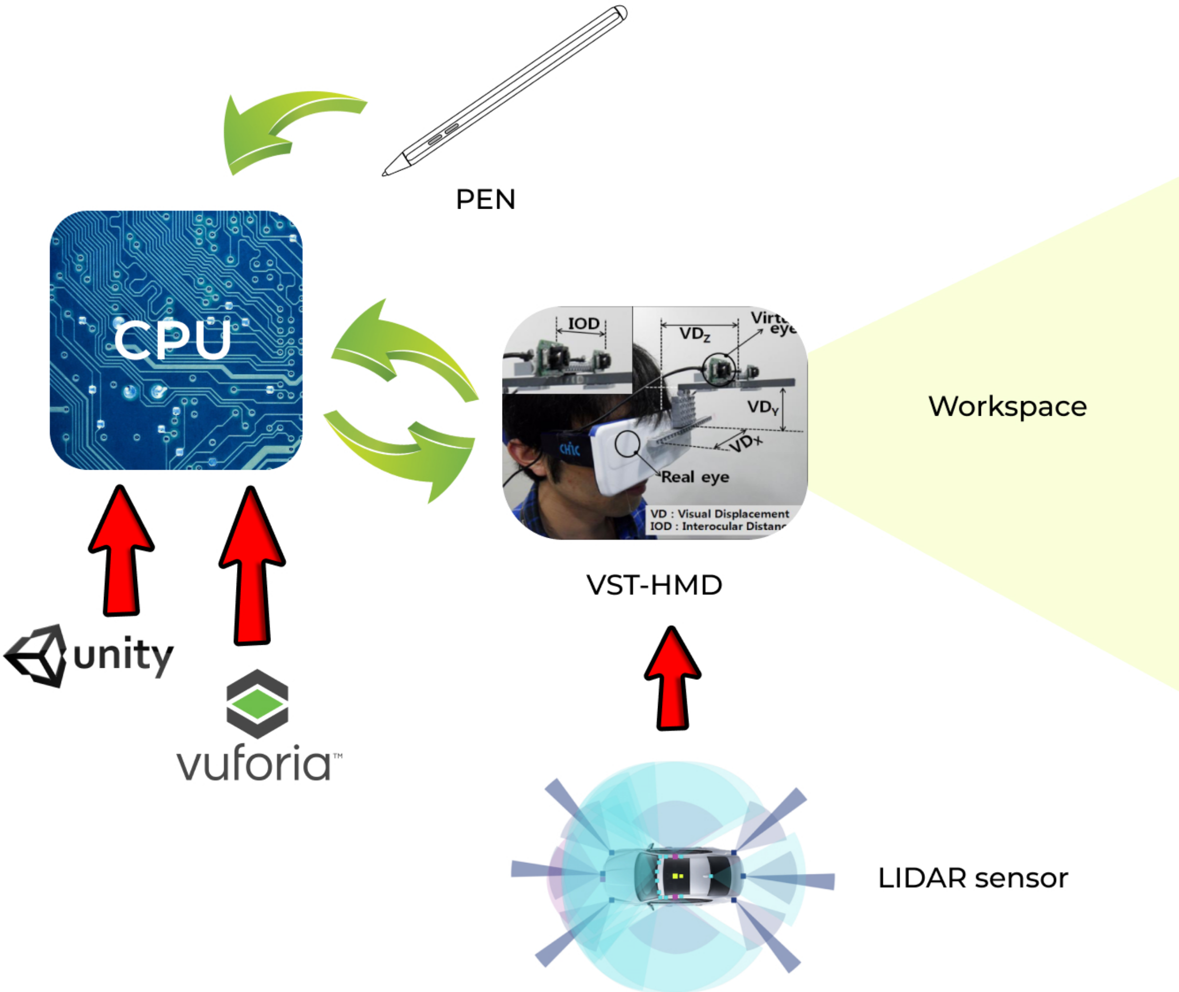

Figure 5.2: Design

This project comprises two parts, Software and Hardware part. The symbiotic existence of both parts are necessary to implement this project efficiently. The detailed designs of each part are given below:

5.1.1 Software

The application of Augmented Reality (AR) based on mobile terminals is a hot topic of interests for mobile applications and human-machine interaction. Mobile AR technique combines the intelligent display, registration tracking, virtual and reality convergence, and human-computer interactions through portable devices or intelligent terminals. This allows the 3D virtual object to be fully docked with the customer's actual scene, thus increasing the perceived range. This study uses Unity 3D modeling to create a three-dimensional model of the scene and to detect and track the totem functions of the Vuforia engine. It can set animation and play video. Interactions between virtual buttons and virtual reality can also be created as virtual buttons. The AR application in the Vuforia SDK is a hub that connects the virtual world with reality. The monitor of the mobile terminal merges the actual video and the virtual object, enabling three-dimensional tracking and registration. This article shows you how to design your game and apply AR technology in a Unity 3D environment

5.1.1.1 Unity 3D

Unity 3D is a cross-platform integrated 3D game engine developed by Unity Technologies Co.Ltd. It can superpose the virtual onto reality and realizes human-computer interaction with some AR development tools.It allows Vuforia SDK extension plug-ins to detect and track under the corresponding ports and creates AR applications and games. It provides ample development box functions to create games and other interactive 3D content.Unity 3D can append sunlight, fog, wind, sky box, water and other physical materials, ambient sound and animated video to the virtual scene. Meanwhile, you can browse, test and edit 3D application scenarios.Also it is available to release to the required platforms, such as Windows, iOS, Android and so on.

5.1.1.2 Vuforia SDK

Vuforia SDK is an AR software development kit for mobile devices launched by Qualcomm. It utilizes computer vision technology to recognize and capture planar images or 3D objects in real time and permits developers placing virtual objects through the viewfinder of the camera and adjusting the position of objects on the background of the camera. Vuforia SDK supports types of 2D and 3D objects including multiple target configurations, images with fewer symbol and frame tags. There is an added function in the SDK. It takes advantage of virtual buttons to detect localized occlusion. Moreover it can select and reconfigure the target image in real time and create a target set according to the scheme. The data flow diagram of the Vuforia SDK is shown in this fig 2.3 The data stream of Vuforia SDK is divided into four modules: inputting, database, tracking and matching and render output. Mobile phones can seize images of each frame in the present real scene through the camera and then match identification objects in the database timely according to the pixel format conversion. After that, it adds preset virtual objects such as 3D models, animation or video to real scenes. It can also interact with these virtual objects, render and output information at mobile terminals

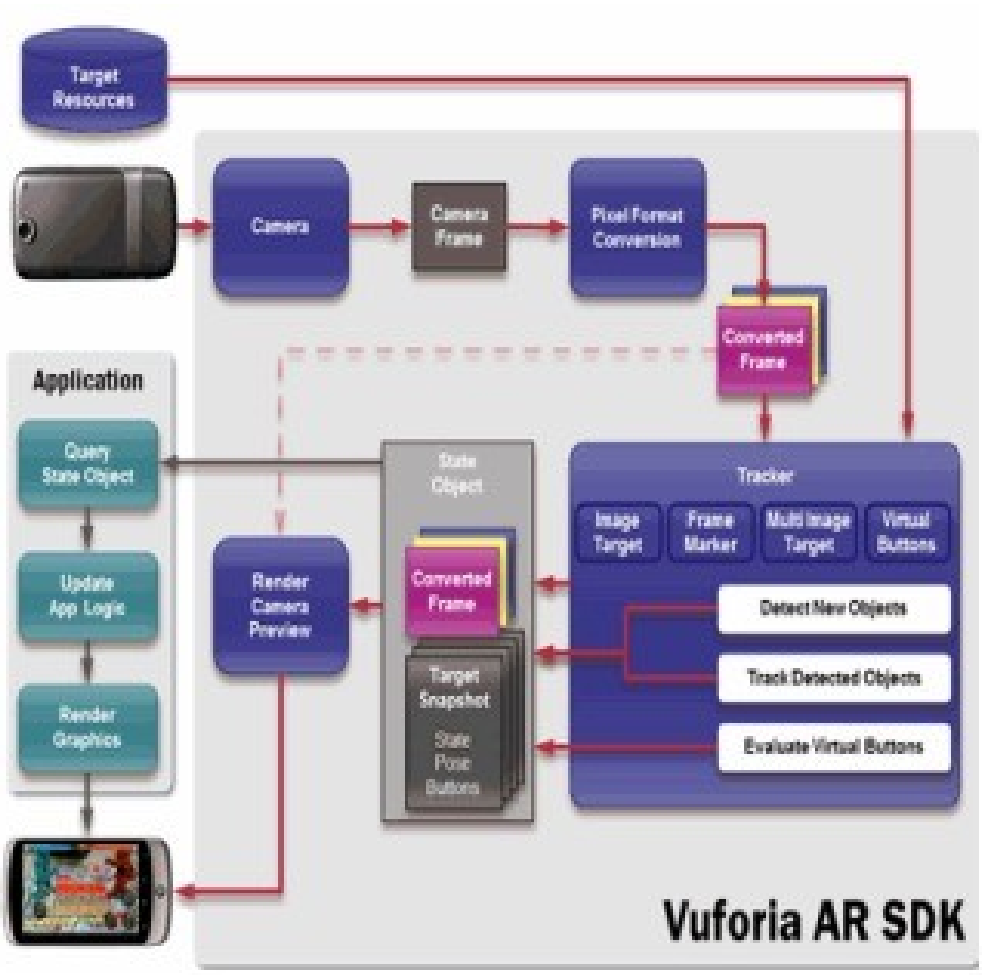

Figure 5.3: Data flow Diagram of Vuforia SDK

5.1.2 Hardware

5.1.2.1 Pointer Pen

Instead of using hand gesture mapping technique, we are using a hardware for user to make 3D objects. This Pointer Pen Can Manage and control the object we created in the virtual world. Its functionality is divided by 3 buttons, they are Left Button,Right Button and 3D Motion Button.

From the fig 2.4 Left button used to select and drag the 3D object Horizontally and also vertically. Right button can show the properties of the 3D objects we choose or make. 3D motion button is used to View and Rotate the object in 360 degree.

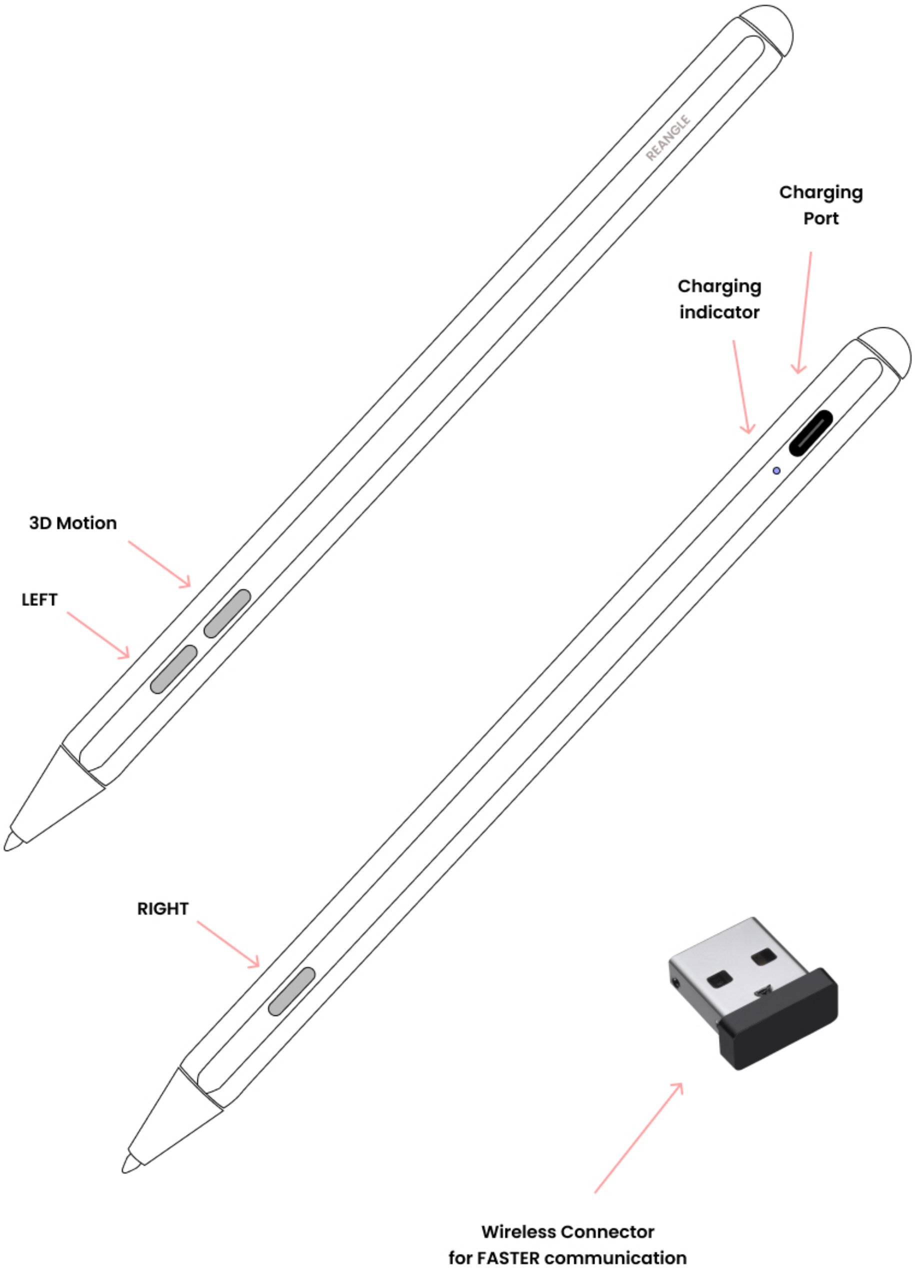

Figure 5.4: Pointer Pen

5.1.2.2 VST-HMD

A video see-through head mounted display (HMD) has a different viewing point than does the real eye, resulting in visual displacement (VD). VD deteriorates visuo-motor performance due to sensory conflict. Previous work has investigated this deterioration and human adaptation by comparing fixed VD and real eye conditions. VST HMD contains 2 or more depth sensors, 2 cameras, and a display

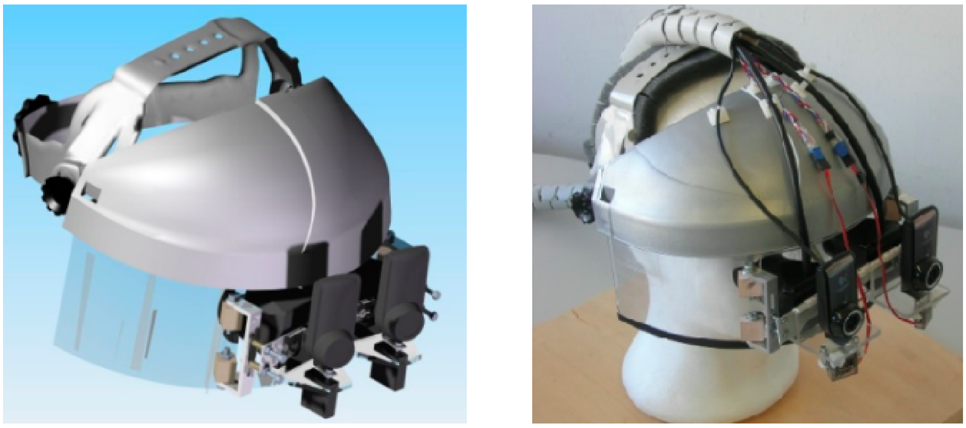

Figure 5.5: Digital and Real model of assembled VST-HMD

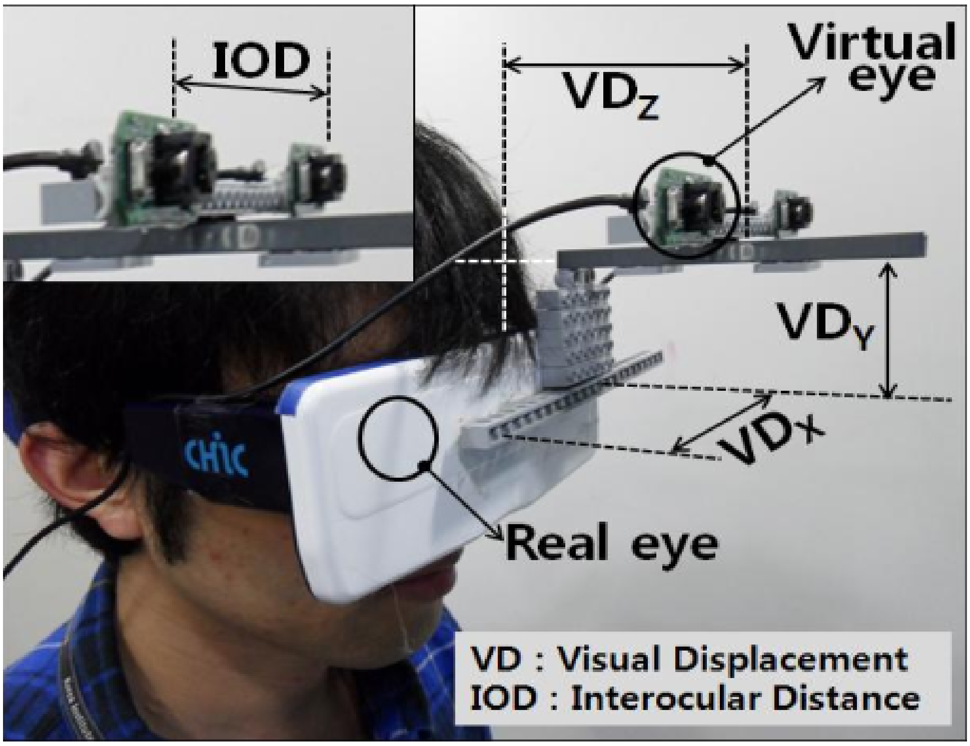

Figure 5.6: VST-HMD

5.1.3 Working

Basically there will be 2 hardware products, stylus pen and VST HMD. Pen will have 3 buttons for right click, left click and 3D plane navigation. VST HMD contains 2 or more depth sensors, 2 cameras, and a display. VST HMD and Unity software helps in finding a better plane for working. With the help of depth sensors in the HMD, we can feel the real life measurement.

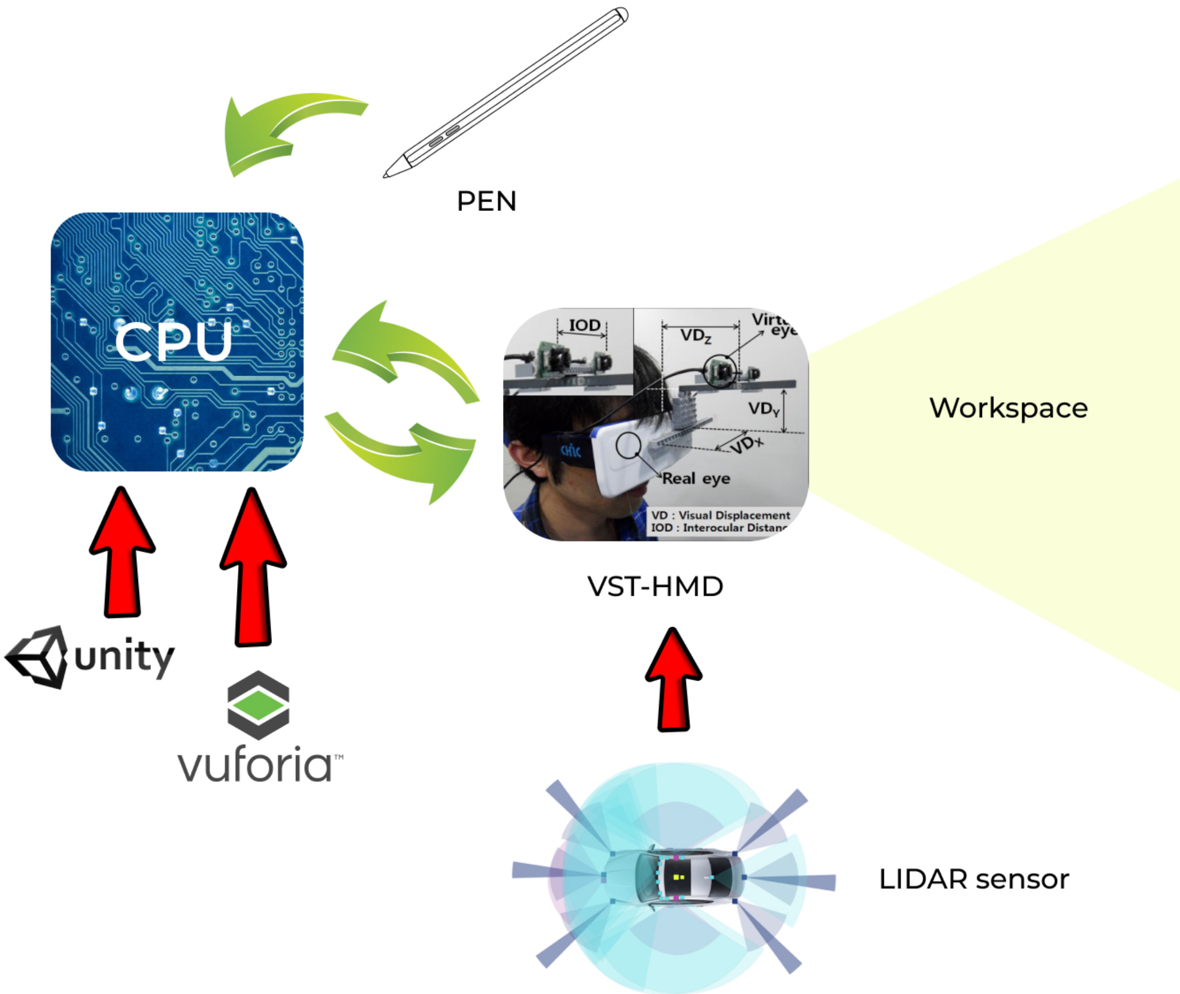

Figure 5.7: Design

By using the pen's right click button, we can place tools and other development objects in different areas of the wall or phases of the selected floor by dragging and dropping. Right click and Left click have the same function of a mouse in 2D plane, i.e, Drag Drop, Rotate, Modelling, and other navigation selectors. Third button helps in 3D navigation of the cursor (similar to 2D navigation of mouse and scroll). Pen helps in creation and manipulation of objects, while VST-HMD helps in visualization, thus the developer can feel the model existing in that particular area. The Light Detection Ranging (LIDAR) sensor signals and camera signals from the VST-HMD and the pen signal from the stylus pen are inputted into the processing unit.

By using Unity VR and Vuforia AR kit, the planes of the surface/wall/floor are detected and a virtual planar surface is created for placing of solid objects or tools. Vuforia has an inbuilt plane detection algorithm. Using the cameras on VST HMD, the whole real world is copied and shown through the displays along with AR and VR manipulations. In this way, the 3D simulation tools using Mixed reality can be implemented.

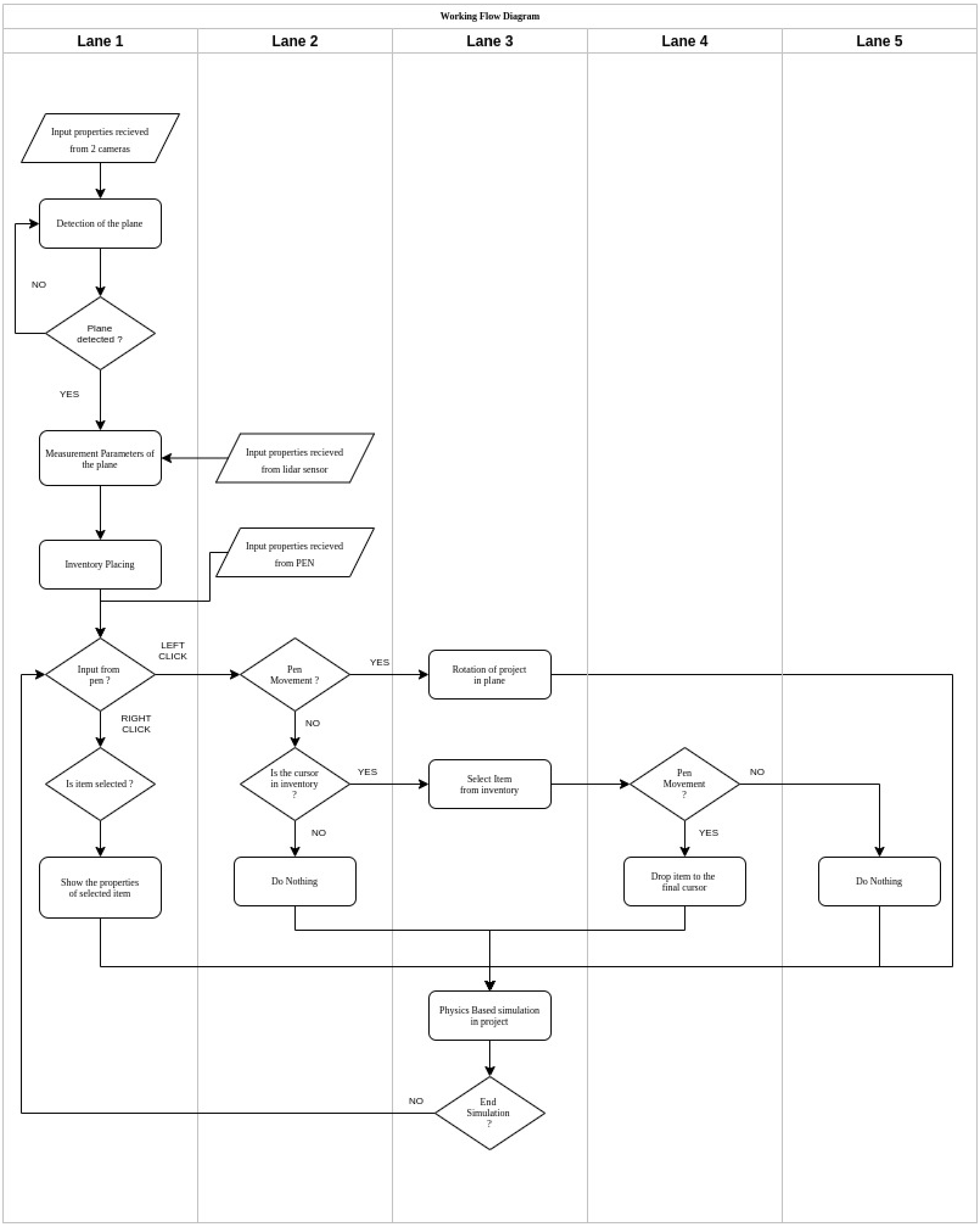

Figure 5.8: Working flow Diagram of MR based 3D Simulation tool

Chapter 6

Future Scope and Conclusion

6.0.1 Future Scope

AR technology can improve the students' laboratory skills. It helped them to build positive attitudes towards physics laboratories. With the advent of effective AI algorithms that use less computational power and memory, the project can be effectively scaled to include life-like experience. The shift from conventional means to experiential methods of transacting learning has seen new-age technologies like augmented reality (AR), virtual reality (VR) and mixed reality — a combination of AR/VR — have been playing a key role in driving learning and edtech engagement. AR/VR has great potential in democratising the educational process and making it a personalised learning experience for learners of all stripes.

AR/VR is not a gimmick when deployed correctly. They allow learners to explore abstract concepts in a distraction-free environment and allow them to connect with the concept. For more advanced ages, we are already seeing a lot of hardware development being done in terms of AR glasses. These will enable grasping and practicing concepts more profoundly with the help of life-size 3D animated content that students can manipulate and observe in their learning space.

6.0.2 Conclusion

Development of 3D simulation tools using Mixed Reality is helpful and effective for the modern era of education and technology. This project when implemented opens up a lot of possibilities and opportunities for the exposure and advancement of the business world.

This was performed with a focus on current trends, challenges, and future prospects. The proposed framework considers important and practical points. This framework is a very useful guide to the MR space such as the various development phases, analytical models, the simulation toolkit, Head mount displays and Stylus-pen technology. MR applications need an appropriate strategy to handle dynamic effects, such as sudden environmental changes and the movement of objects.

We have selected Video-see through head mount display over Optical-see through head mounted display. Video systems give up the unhindered view in return for improved ability to render occlusion cues; the issue of how to really perform occlusion is far from solved, however, and remains an active area of research. Video see-through systems can also guarantee registration of the real and virtual scenes at the expense of a mismatch between vision and prepossession, which may or may not be perceived as a penalty if the human observer is able to adapt to such a mismatch

We have also designed a mouse-like interaction system in a modern-day PC to an MR system, where a stylus-shaped pen with left-button and right-button can interact with the MR application for I/O.

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