# ESE Project Report: Haptic Response Glove for XR


**Group no.: 19**

**Members:**

**Siddhant Narode(51)**
**Suheb Khan(42)**
**Keul Patil(56)**
**Abhinu Paika(53)**
**Ahmed Al Masaabi(01)**

*Done under the guidance of*

**Prof.(Dr.) Manisha Mhetre**
*PhD (Instrumentation and Control)*

**Mr. Niraj Mangalvedhekar**
*XR Developer at Ethosh Digital*

# 1. Table of Content

# 2. List of figures

List Of Images



# 3. List of Tables

List Of Tables

# 4. Abstract

In AR/VR/MR the development of technology with respect to headset is growing exponentially but no matter now good headsets are built, complete immersivity can not be achieved only on the basis of visual presentation of AR/VR/XR. Our project helps the world of XR to get one step closer to complete immersivity in a compatible and affordable manner. The agenda is to create a wearable haptic response device which works on even mobile phones since the launch of ARFoundation and Vuforia has boomed the use of AR/VR in mobile phones. With more and more phones supporting these technologies the use of wearable haptic devices for phones will eventually increase.

# 5. Introduction

This report put forward the motive of developing wearable haptic devices for XR devices, the highlight being compatible with mobile devices which support XR. The Glove has been tested and run on mobile phones for the purpose of this project. To meet one of our main agenda, which is affordability, we have pushed some key functionalities onto the software that we developed in Unity. Hence, the project is broadly divided into Software and Hardware sections. The project was done under the guidance of industry experts in XR development from Ethosh Digital.

# 6. Literature Survey

## 6.1 TacTiles: Dual-Mode Low-Power Electromagnetic Actuators for Rendering Continuous Contact and Spatial Haptic Patterns in VR

TacTiles, light (1.8g), low-power (130mW), and small form-factor (1cm3 ) electromagnetic actuators that can form an exible haptic array to provide localized tactile feedback. Our novel hardware design uses a custom 8-layer PCB, dampening materials, and asymmetric latching, enabling two distinct modes of actuation: contact and pulse mode. We leverage these modes in Virtual Reality (VR) to render continuous contact with objects and the exploration of object surfaces and volumes with spatial haptic patterns. Results from a series of experiments show that users are able to localize feedback, discriminate between modes with high accuracy, and differentiate objects from haptic surfaces and volumes even without looking at them.

## 6.2 A Pneumatic-Driven Haptic Glove with Force and Tactile Feedback

Haptic devices allow us to touch and manipulate virtual objects in an intuitive way. In this paper, we introduce a portable and low-cost haptic glove that provides both force and tactile feedback using a direct-control pneumatic concept. To produce force feedback, two inlet ports of a double acting pneumatic cylinder are opened and closed via solenoid DC valves through Pulse-width modulation (PWM) technique. For tactile feedback, an air bladder is actuated using a diaphragm pump via PWM operated solenoid valve. Experiments on a single finger prototype validated that the glove can provide force and tactile feedback with sufficient moving range of the finger joints. The maximum continuous force is 9 Newton and the response time is less than 400ms. The glove is light weighted and easy to be mounted on the index finger. The proposed glove could be potentially used for virtual reality grasping scenarios and for teleoperation of a robotic hand for handling hazardous objects.

## 6.3 Haptic Glove Using Tendon-Driven Soft Robotic Mechanism

a haptic interface that renders kinesthetic feedback and cutaneous feedback using a tendon-driven compliant mechanism that can render the normal contact force between the fingertip and a virtual/remote object. The interface was designed based on the human hand skeletal model, where the index finger consists of three phalangeal joints (DIP, MCP, PIP), and thumb consists of two phalangeal joints (DIP, MCP). In our system kinesthetic feedback is rendered on PIP and MCP joints of an index finger, and DIP of a thumb. Also, cutaneous feedback is imparted on distal phalanx of both index finger and thumb. Both kinesthetic and cutaneous feedback are imparted, and extend the finger by applying the force on finger joints and a fingertip. Here, the “force” refers to resistive force which acts in the direction of constipating the user's finger movement when grasping the virtual/remote object. Furthermore, we aim to impart kinesthetic feedback on multiple joints with optimized torque control by their weight gained from JND.

## 6.4 Exo-tendon motion capture glove device with haptic grip response (Patent. US10137362B2)

Motion capture and haptic glove systems/methods and devices are provided in this invention. In one embodiment of the invention a motion capture and haptic glove system is described, comprising: A glove portion to be worn on top of a user's hand, the glove having finger portions for the fingers and thumb of the user; a plurality of anchoring finger caps circumscribed around the extremities of the finger portions; a plurality of anchor points configured to generate sensor data identifying a flexion/extension and an abduction/adduction of the finger portions; a plurality of tendon-like cables configured to transmit the flexion/extension and the abduction/adduction data to a plurality of measuring devices for processing; a plurality of return force providers to ensure flexion and tension in the tendon-like cable elements; and a housing structure residing on the forearm and connected to the glove portion via the plurality of tendon-like cables.

### 6.5 Haptic Technology - A Sense of Touch (ISSN: 2319-7064)

Haptics is the science of applying touch (tactile) sensation and control to interact with computer applications. Haptic device gives people a sense of touch with computer generated environments, so that when virtual objects are touched, they seem real and tangible. Haptic technology refers to technology that interfaces the user with a virtual environment via the sense of touch by applying forces, vibrations, and/or motions to the user. This mechanical stimulation may be used to assist in the creation of virtual objects (objects existing only in a computer simulation), for control of such virtual objects, and to enhance the remote control of machines and devices. This paper includes how haptic technology works, about its devices, its technologies, its applications, future developments and disadvantages.

# 7. System Description

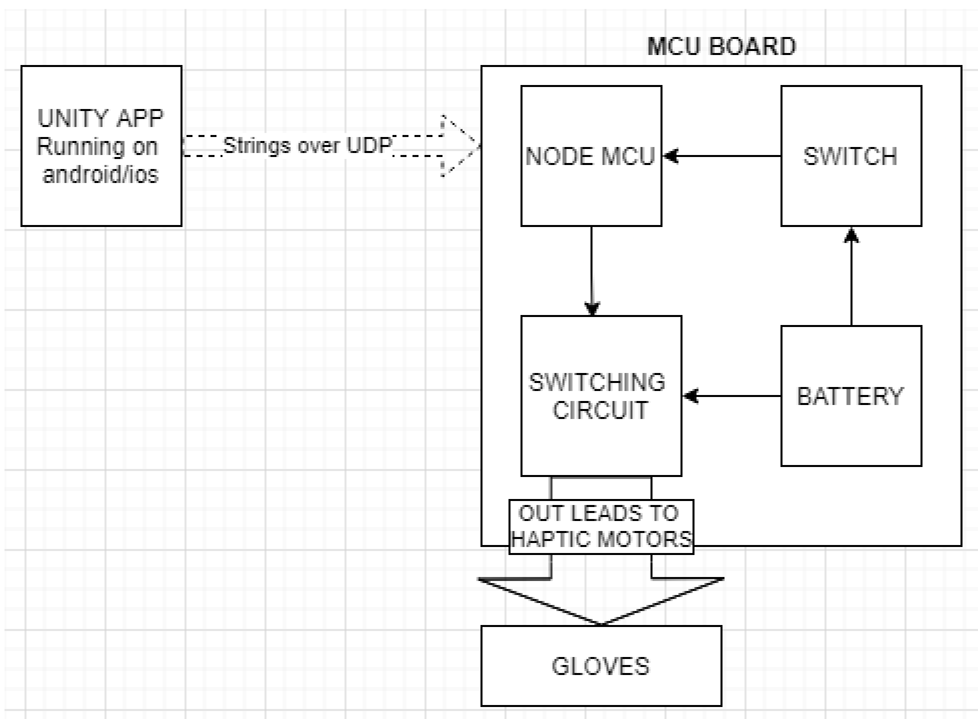



*Figure 2.* **Block diagram of Hardware System**

The above figure shows the block diagram of the hardware system. A switch is used to ON-OFF the system, when the system is powered on the NodeMCU receives 9V from the battery and the inbuilt regulator keeps it down to 3.3V. The NodeMCU powers up and starts searching for the WIFI device to connect. Once the device is connected you can start interacting with the XR world with a mobile device and glove on the other hand. The mobile device sends strings over UDP. These strings are read and sampled in a range that can be read and mapped for the process ahead. Then the control signal is sent to each LRAs switch and from that the LRA actuates and gives haptic feedback to the person wearing the glove. This feedback has different patterns with respect to the different objects with which the person interacts.

# 8. Hardware Design

## 8.1 Hardware Components

### 8.1.1: Node MCU

**NodeMCU** is an open source firmware for which open source prototyping board designs are available. The name "NodeMCU" combines "node" and "MCU" (micro-controller unit). The term "NodeMCU" strictly speaking refers to the firmware rather than the associated development kits. Both the firmware and prototyping board designs are open source. The prototyping hardware typically used is a circuit board functioning as a dual in-line package (DIP) which integrates a USB controller with a smaller surface-mounted board containing the MCU and antenna. The choice of the DIP format allows for easy prototyping on breadboards.

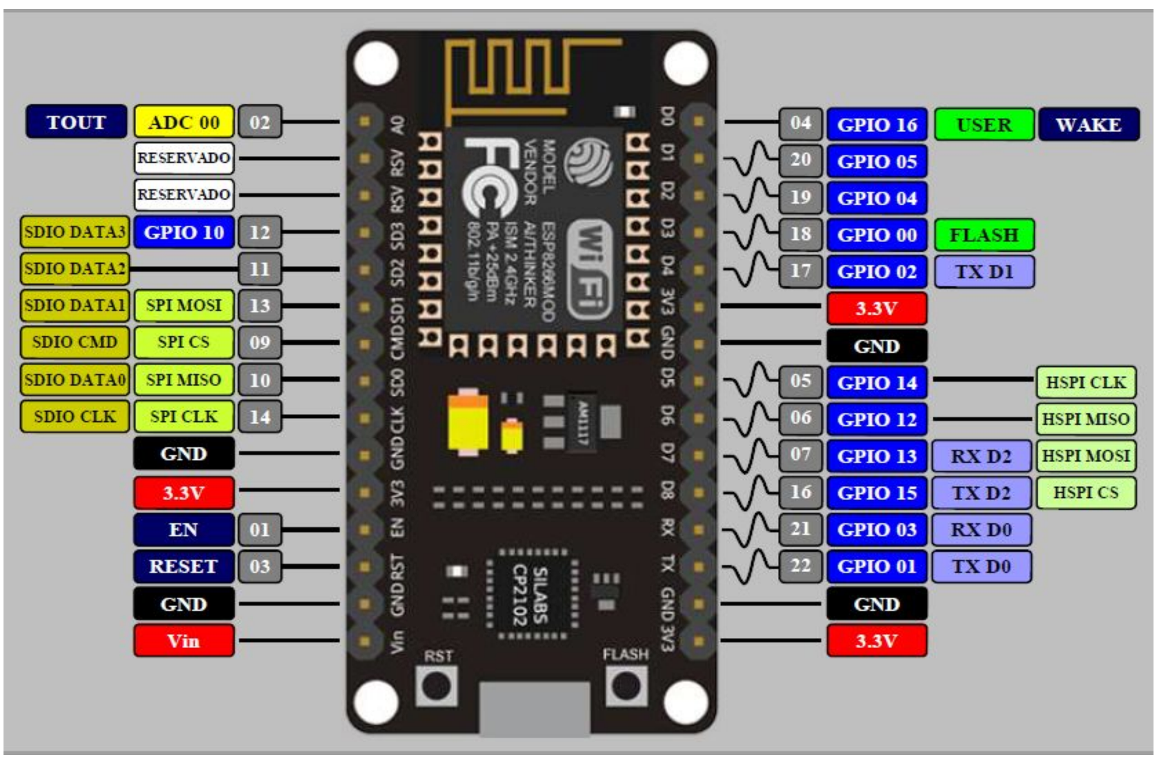



*Figure 3.* **Pinout of NODEMCU Board**

## 8.1.2 LRA (Linear Resonant Actuators)

Linear Resonant Actuator (LRA) vibration motors (also known as linear vibrators). LRA motors are different to Eccentric Rotating Mass (ERM) vibration motors in the way that they work, they are used, and how long they last.

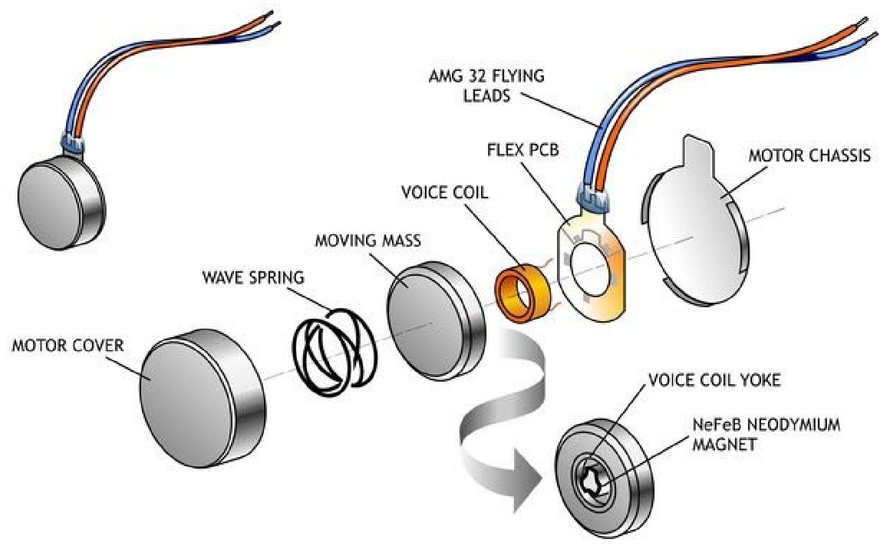



*Figure 4.* **Linear Resonant Actuator**

The figure above shows the general arrangement of parts within a Y-axis LRA vibration motor. Note that the voice coil drive is very similar to that loudspeaker. However, instead of a cone that generates sound pressure waves, there is a mass that generates vibrations.

Attaching a mass to a spring causes a resonance effect. The combination of spring stiffness, mass and magnet/coil size will cause the linear vibrator to have a natural resonant frequency.This natural resonant frequency is where the LRA is most efficient in its operation. Typically for Y-axis vibrators, resonant frequencies are around 175 - 235 Hz, they work on 2.5-6V depending on the model.
Unlike most vibration motors which have an electromechanical commutation, LRA vibration motors are effectively brushless as they use a voice-coil to drive the mass. This means that the only moving parts that are prone to failure are the springs. These springs are modelled with finite element analysis (FEA) and are operated within their non-fatigue zone.

With little mechanical wear, failure modes are restricted to ageing of internal components which results in much longer MTTF failure modes than traditional brushed eccentric rotating mass (ERM) vibration motors.

## 8.1.3 Transistor BC337 and IN4007

A **transistor** is a semiconductor device used to amplify or switch electronic signals and electrical power. Here we used a transistor as a switch because the voltage levels between the NODEMCU and the LRAs were different, also taking into account the current consumption.

A **diode** is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction. We used In4007 Diode as a freewheeling diode. It is connected across an inductor(LRAs) used to eliminate flyback, which is the sudden voltage spike seen across an inductive load when its supply current is suddenly reduced or interrupted. Peak Repetitive Reverse Voltage of 1N4007 is 1000V. RMS Reverse Voltage of 1N4007 is 700V.

## 8.2 Hardware Working

*Figure 5.* **Complete hardware setup**

The above figure shows the complete hardware setup. As you can see the NodeMCU is powered with the 9V battery. For demonstration purposes it is also connected to a laptop with the I2C USB cable.

The setup is quite simple, the LRAs are placed on key points on the hand. These points are near the tip of the thumb, index, middle, ring, pinky finger and one in the groove of the palm. When the person interacts with objects in the AR world wearing this glove, the person will feel the haptic feedback when the respective finger interacts with the object. The haptic feedback may vary from finger to finger or will be the same for all the key touch points. The current consumption of all the LRAs is less than 400mA maximum. The battery can power the system independently for 30 minutes which is what we have tested, this can be easily scaled upwards to 90 minutes.

# 9. Software Design

## 9.1 Technologies used in Software Design:

### 9.1.1 Unity:

**Unity** is a cross-platform game engine developed by Unity Technologies, first announced and released in June 2005 at Apple Inc.'s Worldwide Developers Conference as a Mac OS X-exclusive game engine. As of 2018, the engine had been extended to support more than 25 platforms. The engine can be used to create three-dimensional, two-dimensional, virtual reality, and augmented reality games, as well as simulations and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering and construction.

### 9.1.2 ARFoundation:

**AR Foundation** is Unity's high-level, cross platform API to support Augmented Reality. **AR Foundation** lets you write your app once, and build for either Android or iOS. ARCore Extensions is a package that provides additional ARCore functionality for **AR Foundation.**

### 9.1.3 MediaPipe:

**MediaPipe** is a cross-platform framework for building multimodal applied machine learning pipelines. MediaPipe is a framework for building multimodal (eg. video, audio, any time series data), cross platform (i.e Android, iOS, web, edge devices) applied ML pipelines. With MediaPipe, a perception pipeline can be built as a graph of modular components, including, for instance, inference models (e.g., TensorFlow, TFLite) and media processing functions.

### 9.1.4 InterHaptics:

**Interhaptics** is a development suite to build and create human-like interactions and haptics feedback for VR and AR. We build **Interhaptics** as a cross platform that supports the deployment of your creations to any external devices.

## 9.2 Software Block Diagram:

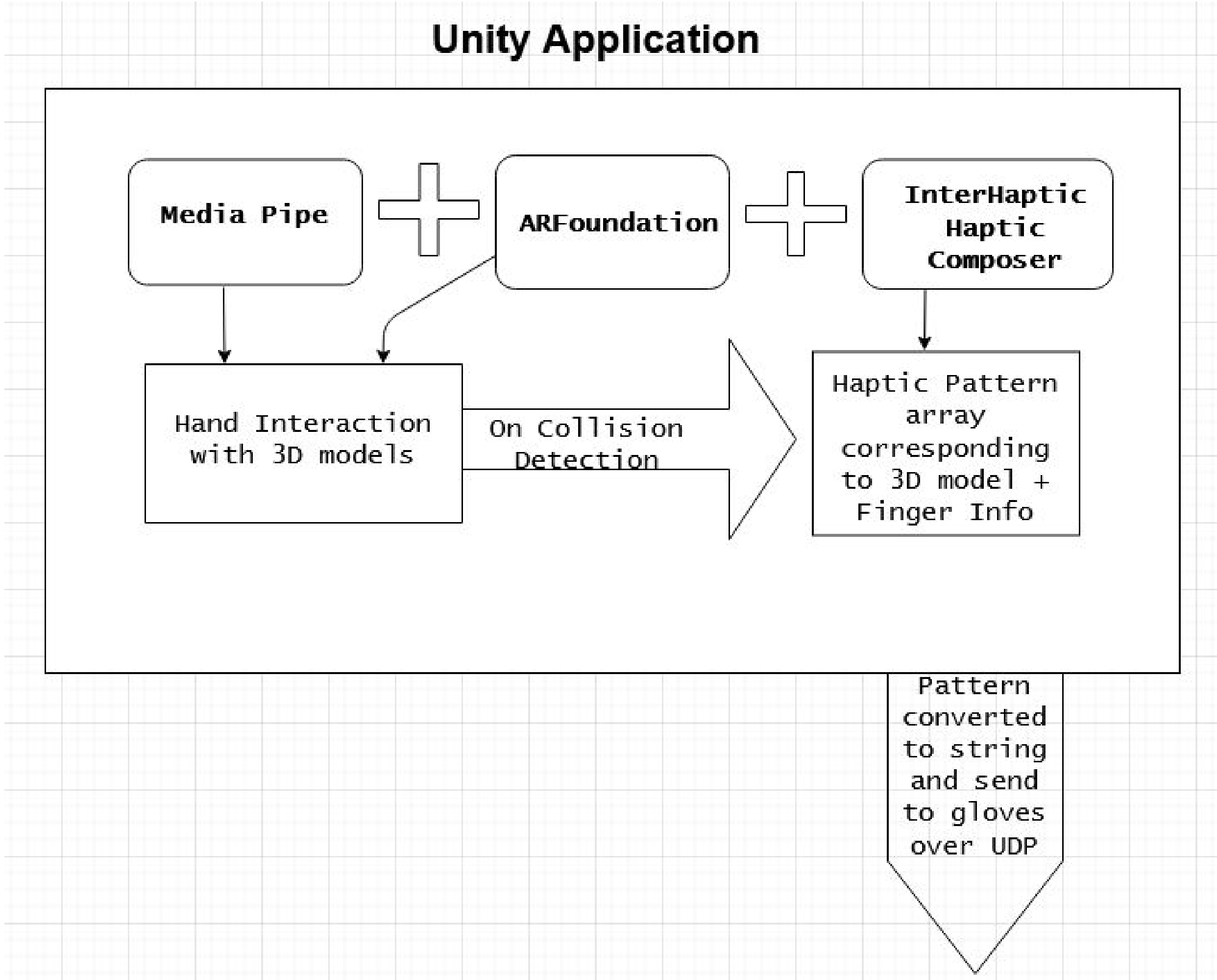



*Figure 6.* **Software block diagram**

## 9.3 Software working:

For the purpose of this project we have developed 2 applications with the same environment one in Augmented reality and one in Virtual reality. Working of both the applications is the same.

Step 1: On opening the application prompts to look for plane surfaces. This step is important as it is helpful in the next step for getting the depth of our detected hand in our next step.


*Figure 7.* **Images of detected plane in VR**

Step 2: Next step is to push our hand on the plane that the AR foundation has detected and press the ok button. Our hand is detected after pressing ok and a skeleton will appear on our hand. Pressing the hand on the plane will help the app understand the depth of our hand w.r.t. The phone.

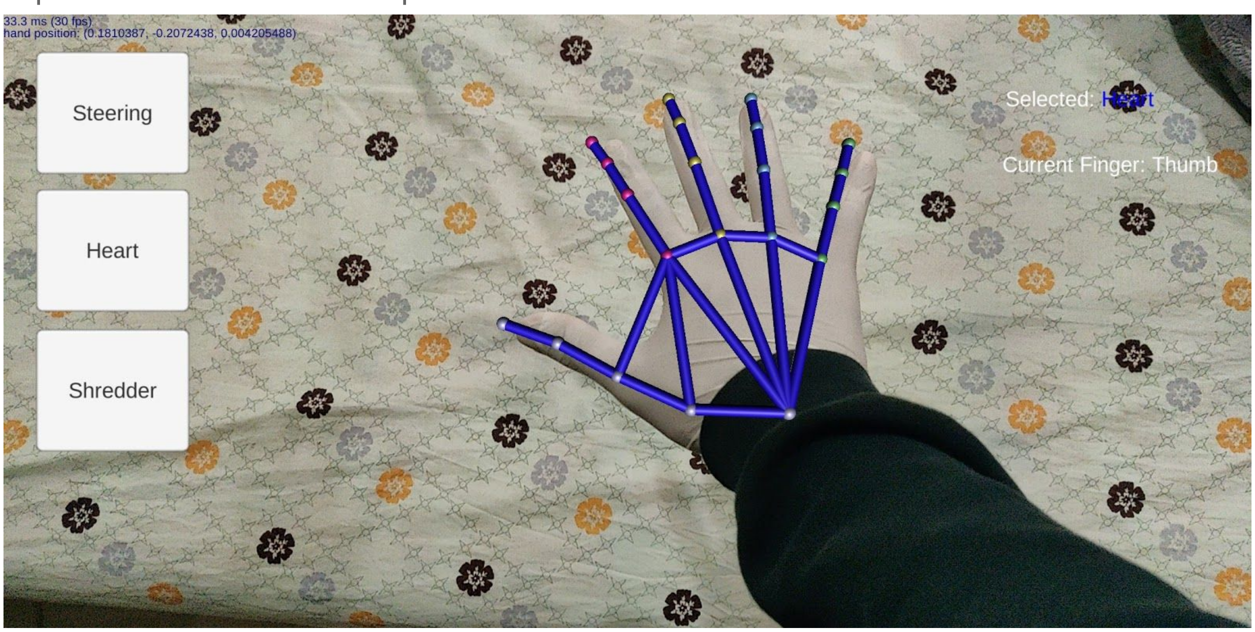



*Figure 8.* **Image of detected hand with 21 point Skeleton**

Step 3: Now select one of the buttons present on Ui. The button will spawn a prefab corresponding to the text on the button. Once selected tap on the detected plane to place that prefab. The prefab will spawn and have a white default material attached to it.

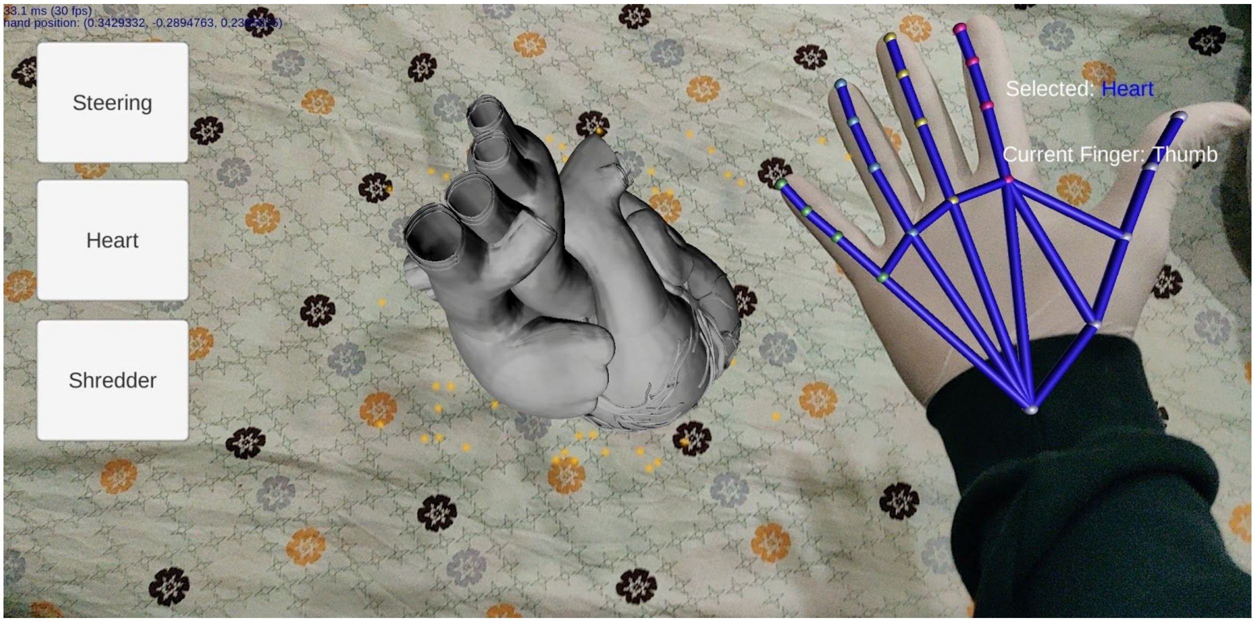



*Figure 9.* **Image of default 3D object**

Step 4: To feel the haptics of the corresponding model user can move the detected hand on the model. When the hand collides with the model a series of haptic patterns or strings(depending on the app) is sent to the glove. Once the hand collides with the 3D object it turns the model's colour to red.

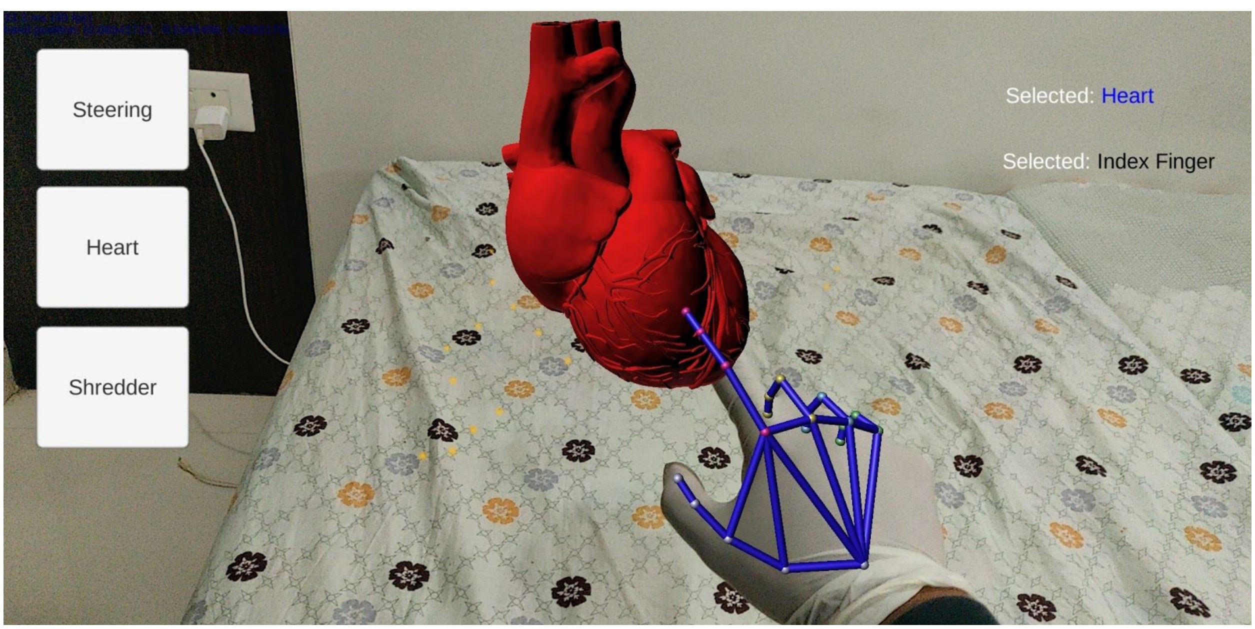



*Figure 10.* **Colour of 3D object changes when touched with Index finger**

### Details to pay attention to:

On the right hand corner user can see what model is currently selected and which part of the hand is colliding with the 3D model in the form of text, for example in the below figure Pinky finger is coming in contact with the Steering model hence only that part of the gloves will receive haptics.

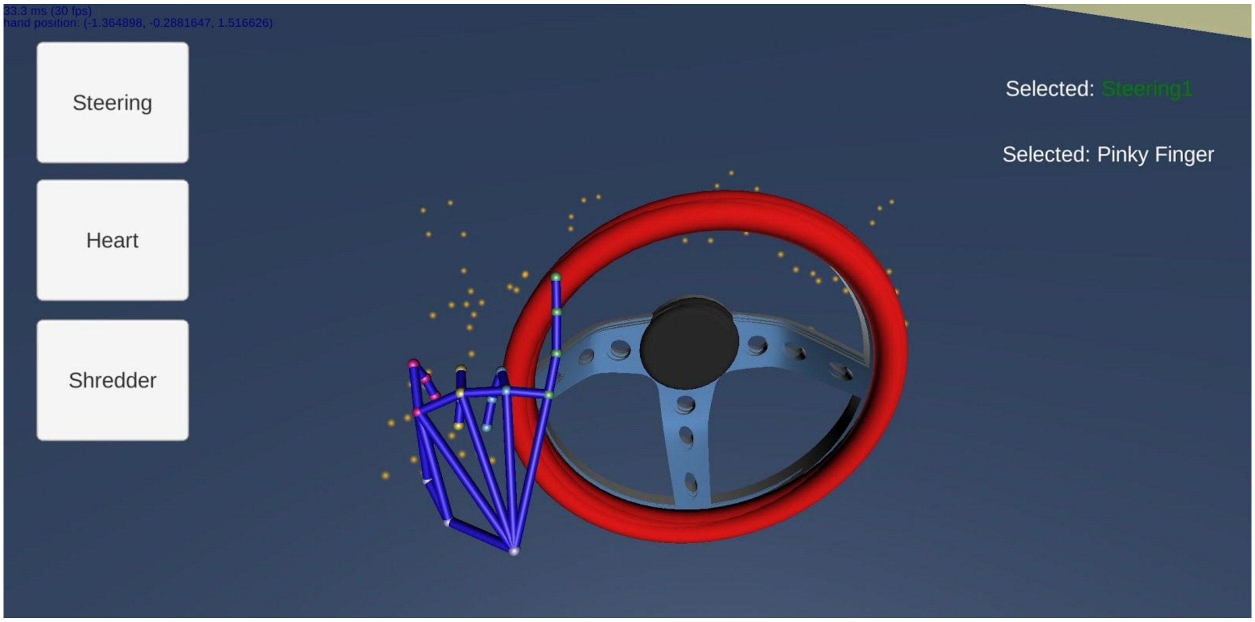



*Figure 11.* **Steering wheel haptics in VR variant of application**

# 10. Implementation

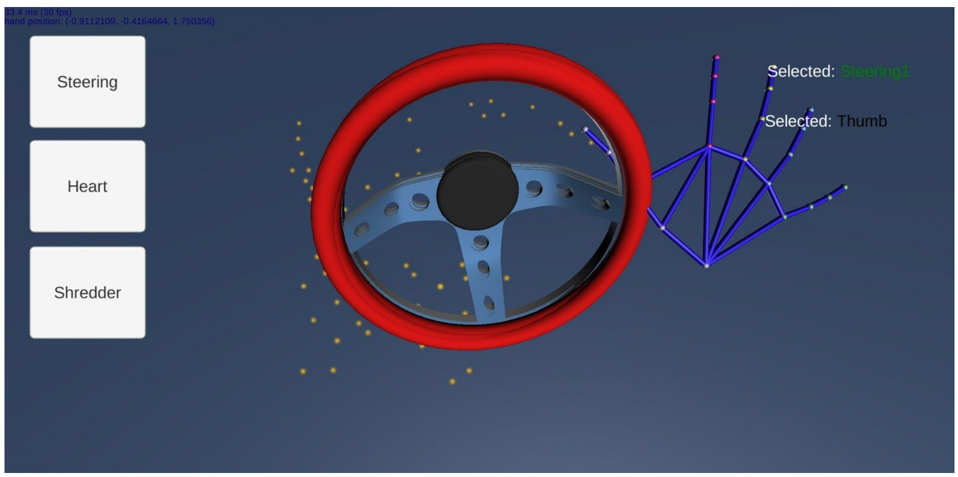
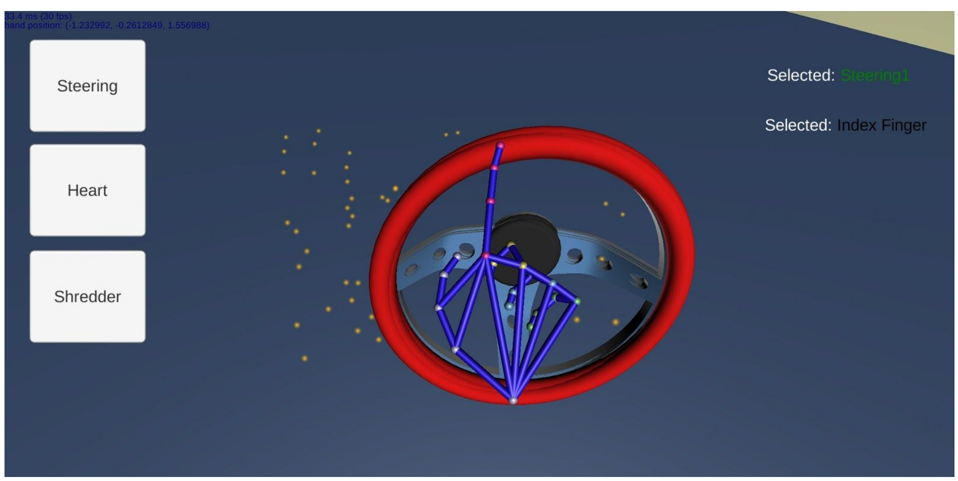
This section contains implementation of the project in AR and VR. The information is in tabular form for easier understanding.

## 10.1 VR Application:

The following table contains snapshots of the working of application in Virtual Reality. The 3D model demonstrated is a Steering wheel. Our agenda is to send engine vibrations felt on the steering wheel to the haptic gloves. The table below shows collision of each finger with the steering wheel object, the application detects which finger has collided with the 3D object and triggers a haptic pattern of engine vibration on that finger in the glove only. When multiple fingers collid at the same time, multiple fingers get triggered to play the pattern at the same time.

**Details:**

1. First text on the right top corner mentions the 3D object that is selected.
2. Second text of the right top corner indicated the finger that collided with the 3D model last.

| Finger | Steering wheel in VR |
|---|---|
| Thumb Finger |  |
| Index Finger |  |

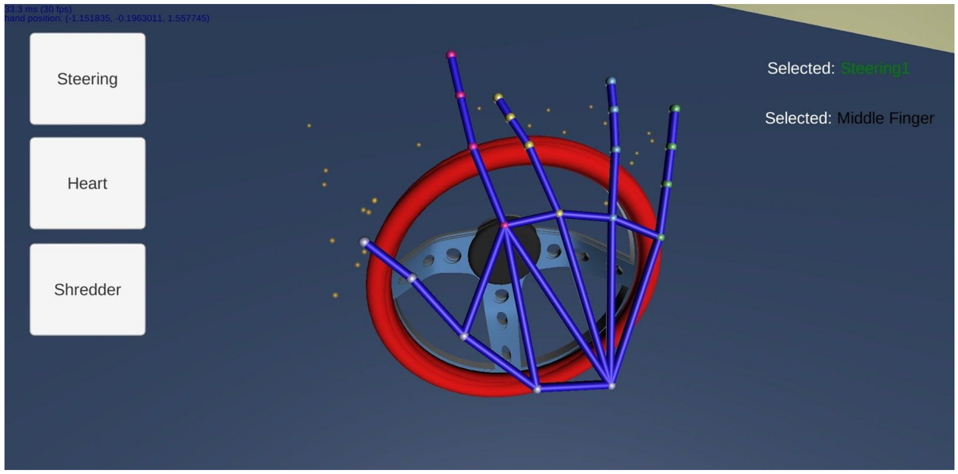
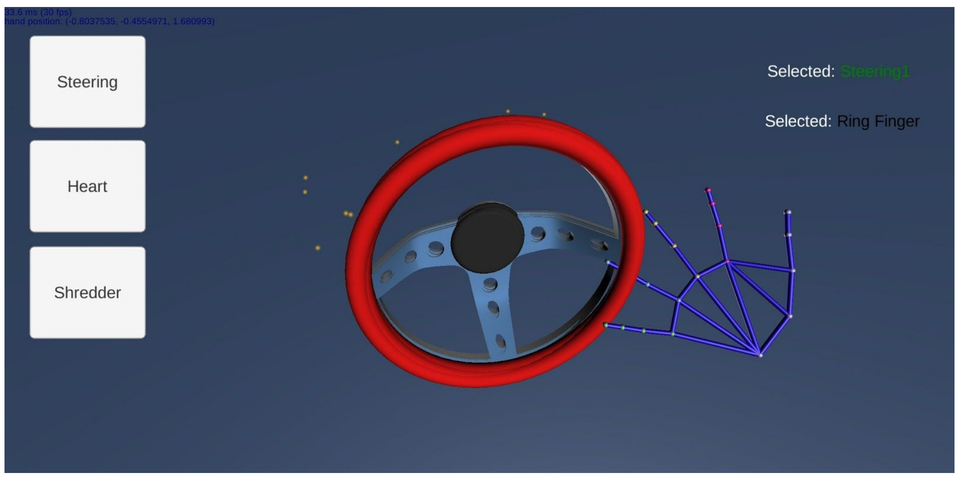
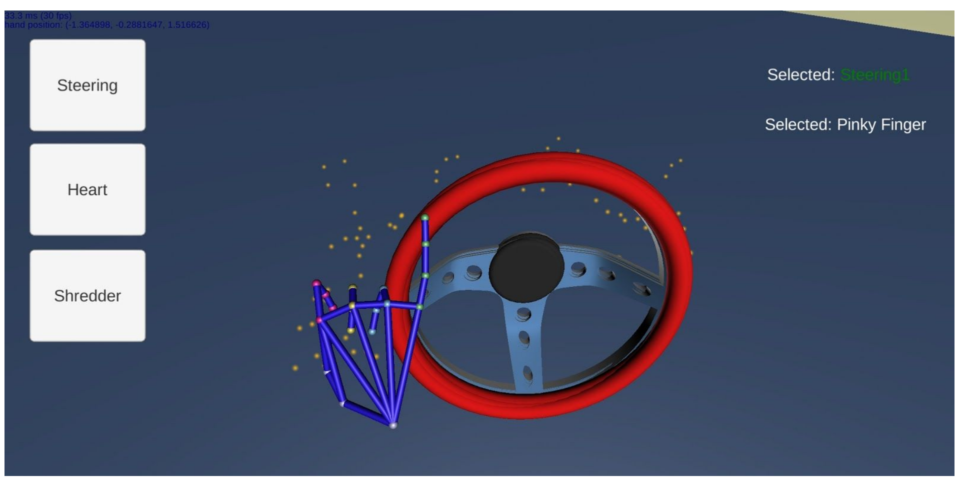
| | |
|---|---|
| Middle Finger |  |
| Ring Finger |  |
| Pinky Finger |  |

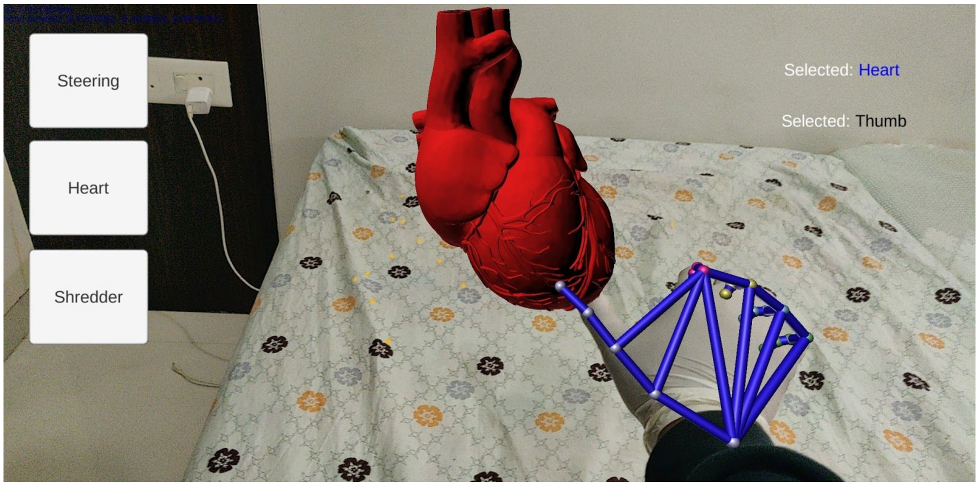
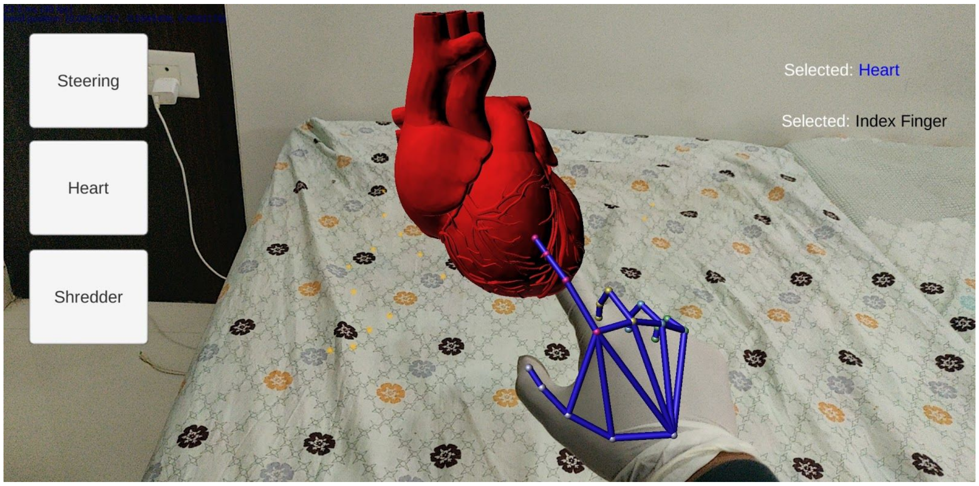
*Table 1.* **VR implementation**

## 10.2 AR Application:

The following table contains snapshots of the working of application in Augmented Reality. The 3D model demonstrated is a Heart. Our agenda is to send Heartbeat when the hand comes in contact with the 3D model. The table below shows collision of each finger with the Heart object, the application detects which finger has collided with the 3D object and triggers a haptic pattern of Heartbeat on that finger in the glove only. When multiple fingers collid at the same time, multiple fingers get triggered to play the pattern at the same time.

**Details:**

3. First text on the right top corner mentions the 3D object that is selected.
4. Second text of the right top corner indicated the finger that collided with the 3D model last.

| **Finger** | **Heart beat model in AR** |
|---|---|
| Thumb |  |
| Index Finger |  |

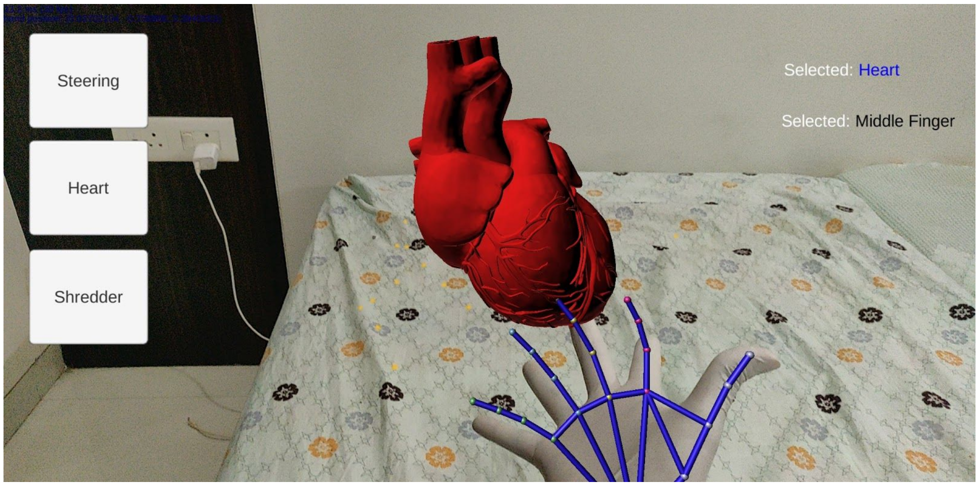
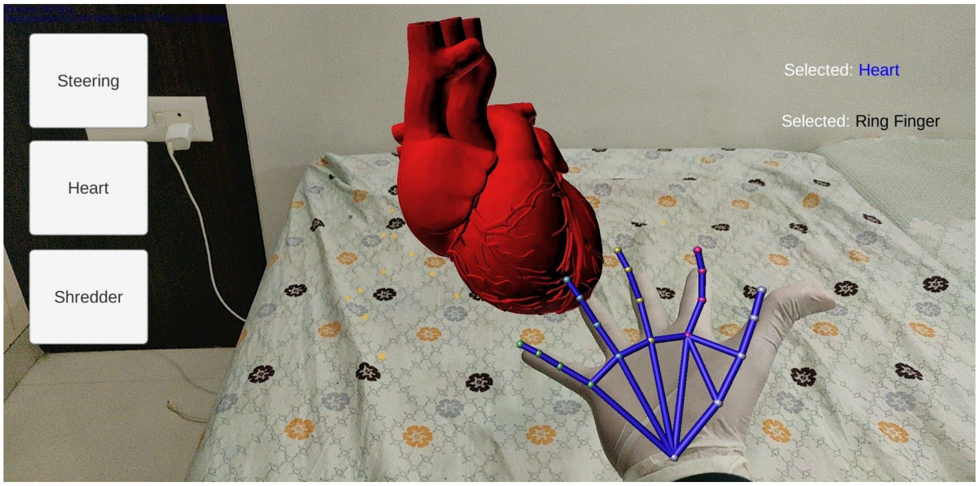
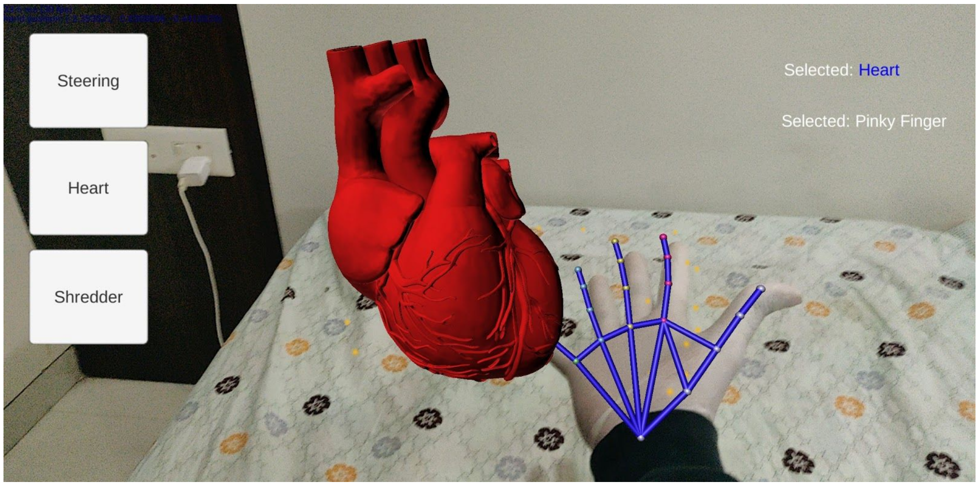
| | |
|---|---|
| Middle Finger |  |
| Ring Finger |  |
| Pinky Finger |  |

*Table 2.* **AR Implementation**

# 11. Result and Conclusion

- The amplitude Control Range of the LRA actuators is from 0-1023.
- Accuracy of 21 point hand tracking in MediaPipe is an average precision of 95.7% in palm detection.
- The gloves give haptic feedback with a 1 millisec delay between each amplitude value.

Our first phase of haptic response glove has produced astonishing results. Our application works at an average **fps of 30** which is an excellent result considering the amount of computation it has to do. The Glove itself has an **amplitude control** which helps us produce **HD haptics.** Even though the prototype had LRA actuators( Scaleable to 21) the outcome was satisfying.

# 12. Costing of the project hardware

| ITEM | PRICE OF ONE PIECE | OVERALL |
|---|---|---|
| LRA | 50 | 300/- |
| NodeMCU | 350 | 350/- |
| BC337 | 6 | 30/- |
| Diode IN4007 | 3 | 18/- |
| Resistor 1Kohm | 2 | 12/- |
| Wires | 10/meter | 120/- |
| Board | 30 | 30/- |
| Polyester Gloves | 40 | 80/- (pair) |
| Battery & Switch | 80 | 80/- |
| | **TOTAL=** | **1020INR/-** |

*Table 3.* **Cost of Component**

# 13. Time scheduling of the project

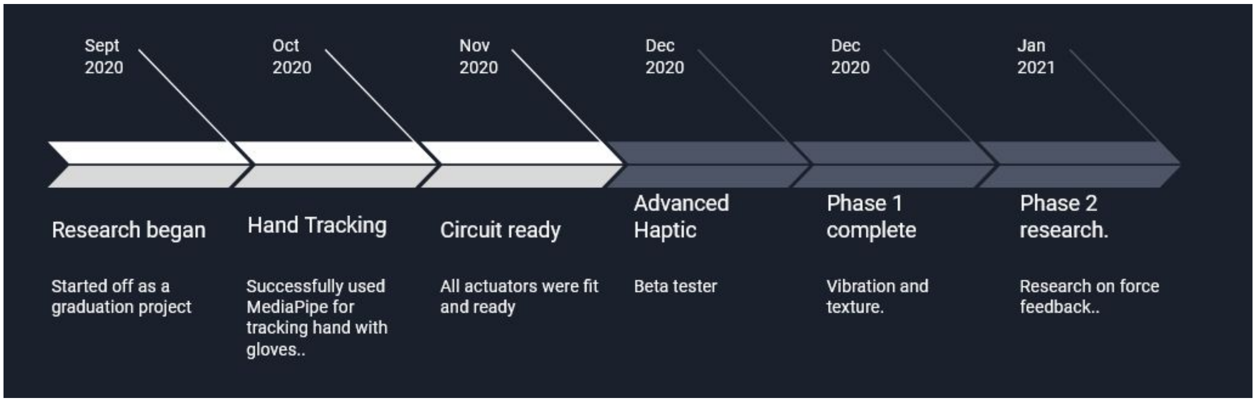



*Figure 12.* **Project timeline & future plan**

# 14. References & Appendix

- https://google.github.io/mediapipe/solutions/hands.html
- https://www.interhaptics.com/resources/docs
- https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@4.1/manual/index.html
- https://developer.android.com/things/sdk/pio/pwm
- https://ipindiaservices.gov.in/PublicSearch/PublicationSearch/Search
- https://www.precisionmicrodrives.com/vibration-motors/linear-resonant-actuators-lras/
- https://www.onsemi.com/pub/Collateral/BC337-D.PDF