VR Force Feedback Gloves Restricting Side to Side Finger Movement Design Document Check

Team 23
Aaron Gros, Yoon Seo Choi, Sunghoon/Sean Kim
TA: Jason Paximadas

Fall 2022
ECE 445

1. Introduction

1.1. Problem

Force Feedback gloves may be an important part of the future of VR given the increased sense of immersion they can provide. However, current commercial force feedback VR gloves like HaptiX [3] or Sense Glove [4] are too expensive for regular consumers and are only targeted towards industry and research. On the other hand, open source force feedback VR gloves like Lucid Gloves [5] are economically accessible to regular consumers as long as they're willing to spend the time to build them. However, they are bulky and don't restrict the finger's side to side movement. The latter would be desired for a greater sense of immersion when for example grabbing an object between the sides of your fingers, or when the friction of an object you're grabbing should prevent you from sliding your fingers.

1.2. Solution

We propose a new design for force feedback VR gloves that are still economically accessible to the regular consumer and that restrict the finger's side to side movement. The result would be that if a user tried to grab an object in VR with the sides of their fingers, this movement would be reflected in VR, and the movement of the fingers would be restricted when they collide with the object in VR.

Our design would use a potentiometer and a servo on each finger, to sense and restrict side to side movement, respectively. It would also have a Dead Man switch to stop the gloves from restricting movement in case of an emergency. The actuators, potentiometers, and Dead Man switch would be connected to a microcontroller(STM32). To share the finger's position and know when to restrict each finger's movement, the microcontroller would communicate over a USB connection with a computer running the VR application. The power for the glove would also be provided by the USB.

1.3. Visual Aid

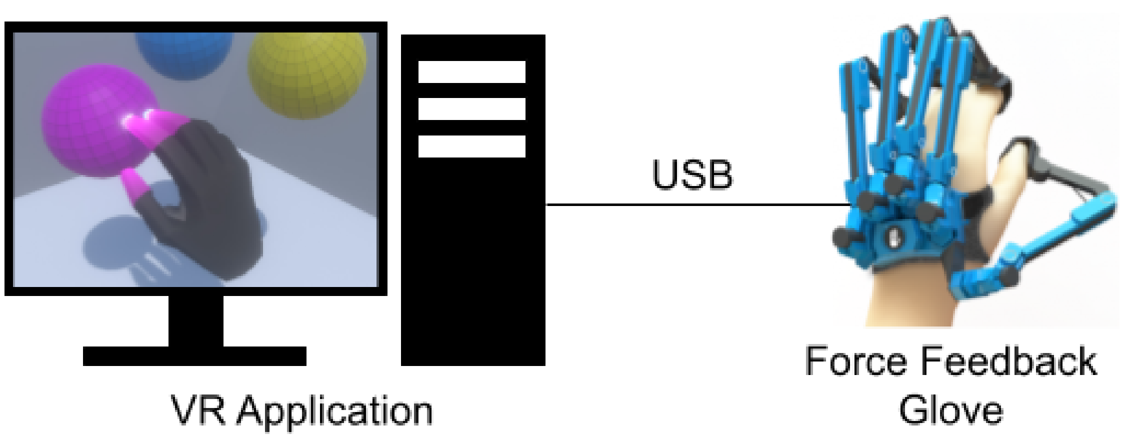

Figure 1. Depicts how the user will interact with the product. Glove image taken from [6] and virtual hand image taken from [9]

1.4. High-Level Requirements

The gloves are able to:

- Accurately track and recreate each finger's angle within +/- 2.5 degrees
- Restrict the finger's side to side movement when they are in contact with a VR object such that the finger's restriction point is within +/- 2.5 degrees of the object's boundary
- Restrict the finger's side to side movement with 1.9 to 4 Kg/cm of torque when the finger collides with a virtual object otherwise with less than 0.5 Kg/cm.

2. Design

2.1. Block Diagram

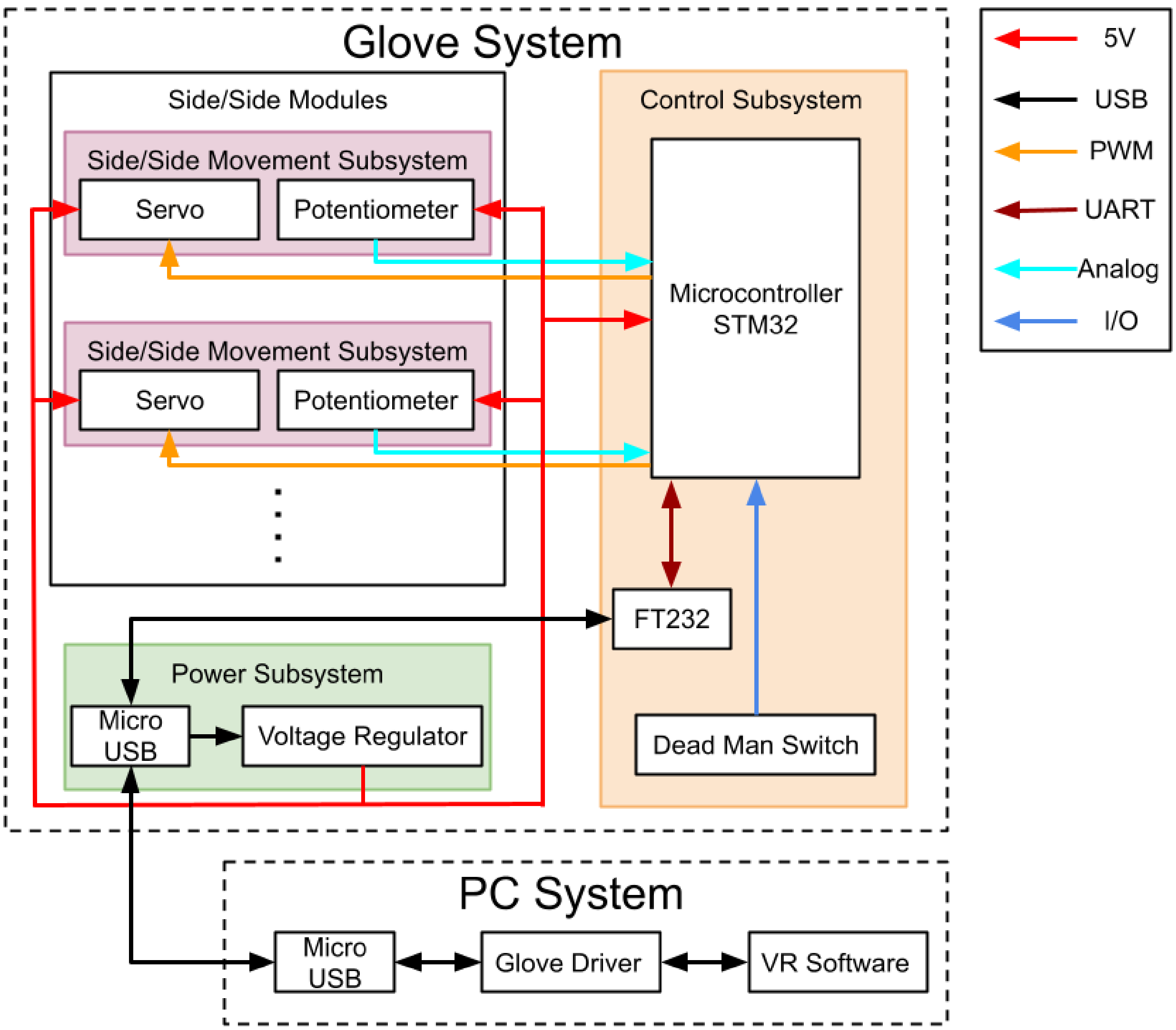

Figure 2. Shows all the different subsystems and how they interact with each other

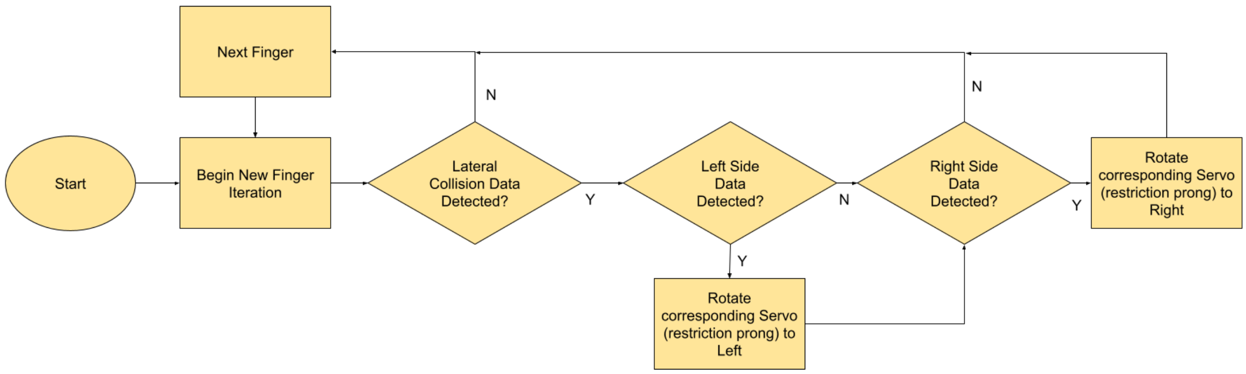

Figure 3. Shows the firmware algorithm for processing the input data from the computer and restricting finger movement if necessary

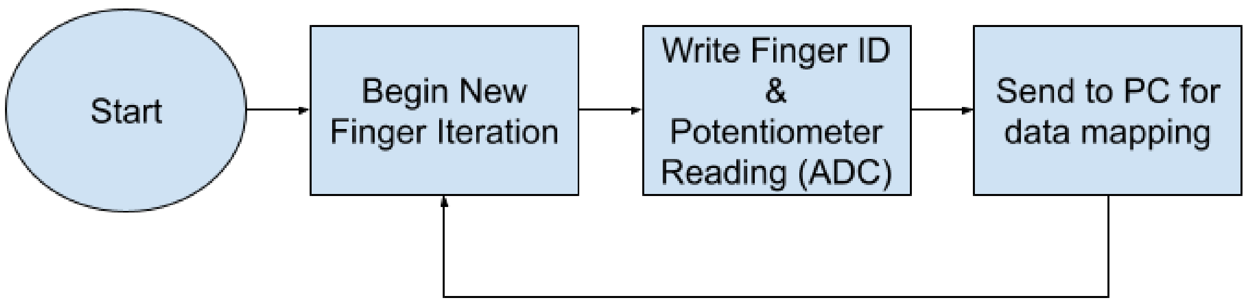

Figure 4. Shows the firmware algorithm for processing the finger's position data and sending it to the computer

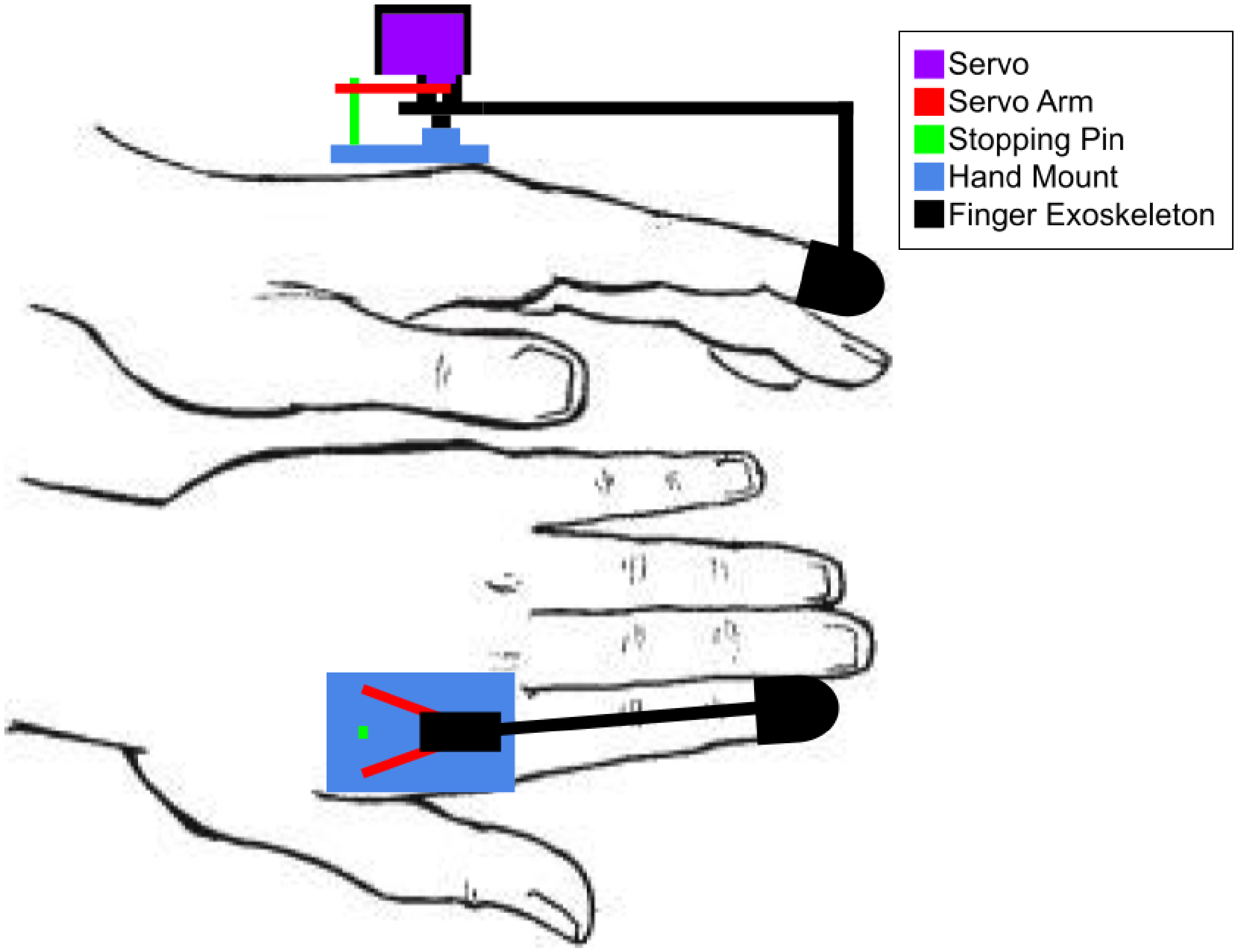

Figure 5. A drawing of the proposed mechanism to restrict the finger's movement. The hand mount and stopping pin are one piece. The servo, servo arms, and finger exoskeleton rotate with the finger. The movement is restricted by moving the servo arm to act as a hard stop against the stopping pin. Hand images taken from [7]

2.2. Subsystems Overview/Requirements

2.2.1. Control Subsystem

The purpose of this subsystem is to control the movement of the actuators, read sensor values, handle the dead man's switch, and communicate with the computer running the VR application. A microcontroller will handle all of this data processing.

Microcontroller

The microcontroller reads the potentiometer values, controls the actuators, and reads the dead man's switch. It also communicates with a computer through UART over a micro USB cable.

Requirements	Verification
1. Must be able to send 4Kb of position data to the computer per second and receive 4Kb of data from the computer per second over UART.	1A. Connect the microcontroller to the computer via a micro USB. 1B. Measure how long it takes to send 4Kb from the microcontroller to the computer and 4Kb from the computer to the microcontroller
2. Must sample each potentiometer at least 30 times per second	2A. Connect 5 potentiometers to the microcontroller 2B. Read the analog signal for each potentiometer 2C. Repeat 29 more times 2D. Measure the time it takes to finish reading the signals.
3. Must sample the dead man's switch at least 2 times per second	3A. Read the digital input switch 3B. Measure how long it takes to finish sampling
4. Must be able to adjust the PWM signal at least 5 times per second	4A. Connect the digital out on the microcontroller to an oscilloscope 4B. Change the PWM signal five times 4C. Check the oscilloscope recording to see if the PWM signal changed five times within a second

Table 1. Requirements and verifications for the potentiometer control module

2.2.2. Power Subsystem

The purpose of this subsystem is to regulate the voltage received from the micro USB to the necessary levels.

Voltage Regulator

The voltage regulator will receive a 5V signal from the micro USB and will need to regulate it to the necessary voltages.

Requirements	Verification
1. Must be able to output 5V +/- 1V from a 5V source	1A. Using an oscilloscope, measure the output voltage and check if it stays within the target.

Table 2. Requirements and verifications for the power module

2.2.3. Side/Side Subsystem

The purpose of this subsystem is to send the angle of the finger to the microcontroller and receive the actuator control signal from the microcontroller.

Actuator

The actuator receives a PWM control signal from the microcontroller.

Requirements	Verification
1. The mechanical design in conjunction with the actuator must have a step size of at most 3 degrees	1A. Increase the PWM 1 at a time until the servo moves. 1B. Measure the change in angle with a potentiometer.
2. While in conjunction with the mechanical design,they must produce a stall torque in between 1.9 to 4 Kg/cm	2A. Set a 2 Kg weight a centimeter away from the mechanical design's pivot point 2B. Set the device such that the force will be perpendicular to the ground an see if the design can hold the weight 2C. Try the Same with a 4 Kg weight and see if it fails.

Table 3. Requirements and verifications for the actuator sub module

Potentiometer

A potentiometer will be located near each knuckle and will measure the angle of each finger. It will send its value to an analog port on the microcontroller.

Requirements	Verification
1. The mechanical design in combination with the potentiometer must measure the finger's angle within +/- 2.5 degrees	1A. Measure the finger's angle with a protractor and compare it to the measurement by the potentiometer 1B. Repeat for a couple of different locations

Table 4. Requirements and verifications for the potentiometer sub module

2.3. Tolerance Analysis

Since these are force feedback gloves they will have to be able to resist a comfortable amount of torque from the fingers. If the actuators are unable to resist the torque from the fingers then when attempting to grab a virtual object your fingers will go through the object and you'll lose your sense of immersion. However, we don't want to pull with too much torque on the fingers as this could hurt the user. Therefore to guarantee this operation we must find the casual torque a finger can apply and also the maximum torque a finger can apply.

After measuring our fingers' strength on *Table 5* we have found that our fingers can comfortably produce 0.2 Nm of torque with side to side movements. When exerting our fingers more we can produce more than 1.9 Kg/cm of torque with side to side movements and less than 4 Kg/cm of torque. Therefore we'll need to design a mechanical design that in conjunction with the actuator can produce a torque between 1.9 Kg/cm and4 Kg/cm.

We also don't want to exert much force when the finger should be able to move freely as this could also break the sense of immersion. To achieve this we measured the easiest force for fingers to exert and it was around 50 g. Since the pinky would have the hardest time with this torque as it's the shortest finger we find the maximum torque allowed using its length. Therefore the maximum torque allowed when the finger should be able to be moved freely must be less than 0.44 Kg/cm.

	Pinky	Ring	Middle	Index	Thumb
Hard Push Right (g)	500	360	650	360	640
Light Push Right (g)	120	100	100	105	170
Hard Push Left (g)	440	500	690	450	630
Light Push Left (g)	170	170	183	200	150
Length (cm)	8.89	10.795	11.43	10.16	11.43
Average Hard Push (g)	470	430	670	405	635
Average Light Push (g)	145	135	141.5	152.5	160
Average Hard Torque (Kg/cm)	4.1783	4.64185	7.6581	4.1148	7.25805
Average Light Torque (Kg/cm)	1.28905	1.457325	1.617345	1.5494	1.8288

Table 5. Calculation of high exertion torque and low exertion torque produced by each finger

3. Cost & Schedule

3.1. Cost

The average EE graduate from ECE at UIUC has a salary of $80,296 [8] and the average CE graduate from ECE at UIUC has a salary of $105,352 [8]. Working 40 hours weekly would result in working 2080 hours per year. Meaning a $38.60/hour wage for EE graduates and a $50.65/hour wage for CE graduates. Following the calculation in *Table 6*, we get a total labor cost of $30,684.

The total cost of our parts is $44.64 as shown in *Table 7,* bringing the total cost of the project to $30,728.64.

	Yoon Seo	Sean	Aaron
$/Hour	38.6	38.6	50.65
Fudge Factor	2.5	2.5	2.5
Hours/Week	12	12	12
Weeks	8	8	8
Individual	9264	9264	12156
Total	30684		

Table 6. Calculation of the labor costs for the project

Description	Manufacturer	Part Number	Link	Quantity	Cost
Microcontroller	STMicroelectronics	STM32F446RET6	Link	1	11.92
Servo	RGBZONE	MG90S	Link	5	3.5
Latching button	DIYhz	SPST Latching Type Dash ON/OFF Push Button	Link	1	2.5
USB to UART IC	FTDI	FT232HQ-REEL	Link	1	3.89
ST-Link STM Programmer	CANADUINO	26146	Link	1	8.43
Micro USB input	Adam Tech	MCR-B-S-RA-SMT-CS14-T/R	Link	1	0.39
Total					44.63

Table 7. Bill of materials for the components that will the connected to the PCB

3.2. Schedule

Week	Task	Person
10/3 - 10/8	Design PCB	Yoon Seo, Sean
	Design 3D printed parts	Aaron
	Order components	Everyone
10/9 - 10/15	Finish designing, print, assemble, and test mechanical design	Aaron, Sean
	Finish designing PCB	Yoon Seo, Sean
	Firmware programming	Yoon Seo
	Order first PCB October 11	Everyone
10/16 - 10/22	Update mechanical design if needed	Aaron, Sean
	Firmware programming	Yoon Seo, Sean
	Driver Programming	Aaron
10/23 - 10/29	Assemble PCB and verify functionality	Sean
	Firmware programing /verification	Yoon Seo
	Driver Programming	Aaron
	Redesign PCB if needed	Yoon Seo, Sean
10/30 - 11/5	Driver Programming	Aaron
	Test functionality of PCB and mechanical design	Sean
	Firmware programing /verification	Yoon Seo
	Order second PCB November 1	Everyone
11/6 - 11/12	VR Environment Building	Aaron
	Firmware programing /verification	Yoon Seo
	If needed update mechanical design	Sean
11/13 - 11/19	VR Environment Building	Aaron
	Firmware programing /verification	Yoon Seo, Sean
11/20 - 11/26	Driver Verification	Aaron, Yoon Seo
	Firmware programing /verification	Yoon Seo, Sean
11/28 - 11/30	Final demo	Everyone

Table 8. Schedule of the weekly tasks required to complete the project

4. Ethics & Safety

Our project in all aspects will adhere to the IEEE and ACM Code of Ethics in the following ways:

ACM CoE 1.1 [1] states that products should be broadly accessible. Our design is built on the idea that technology should be accessible to all consumers at a cheap cost and for all interested individuals to take their ideas and build upon ours for the advancement of our society. To follow through with these ideas we'll make the project open source and choose components that fulfill our requirements but aren't unnecessarily expensive.

In addition to our project's accessibility, we also wanted to emphasize that the VR glove's design prioritizes the safety of its users and its features make sure the device doesn't inflict damage to the user's hand. This follows ACM CoE 2.9 [1] which clearly mentions that we should make sure our design works as it's supposed to and that our safety features are intuitive. To accomplish this we will choose components that can't hurt the user and test our design, especially the actuators. In case of an emergency we'll also design a dead man's switch to disengage the actuators in such a way that it's easily accessible.

Since we'll be building on top of other people's mechanical design and software we feel it's necessary to follow ACM CoE 1.5 [1] and give credit to those whose work we build upon.

Lastly, following IEEE CoE I.5, as engineers, not only is it our responsibility to advance technology and safety implementations but also to have the ability to acknowledge our shortcomings of technical work and to honestly correct these in a professional manner. Our group will focus on creating the best product that is needed for the public, and when we're done implementing our design we will evaluate our design and communicate its strengths and weaknesses.

All of our members in this group are well-versed in these claims and will strive to make this product following these ethical guidelines.

5. References

[1] "ACM Code of Ethics and Professional Conduct" *ACM*. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 15-Sep-2022].

[2] "IEEE code of Ethics" *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 15-Sep-2022].

[3] "Haptic gloves for virtual reality and robotics | HaptX" HaptX https://haptx.com/. [Accessed: 15-Sep-2022].

[4] "VR & Haptic Technology Gloves | SenseGlove | Feel the virtual like it's real" SenseGlove https://www.senseglove.com/. [Accessed: 15-Sep-2022].

[5] "Arduino/ESP32 based DIY VR Haptic gloves. Compatible with SteamVR via OpenGloves" Lucid Gloves https://github.com/LucidVR/lucidgloves. [Accessed: 15-Sep-2022].

[6] L. Beijen, "WANT Chat: met de Sense Glove krijg je letterlijk grip op virtual reality," *WANT*, Jan. 28, 2018. https://www.want.nl/want-chat-sense-glove-vr/. [Accessed: 15-Sep-2022].

[7] "How to draw hands, Side view drawing, Drawing body poses," *Pinterest*. https://www.pinterest.ca/pin/232568768238451837/. [Accessed: 28-Sep-2022].

[8] "Salary Averages," *UIUC ECE*. https://ece.illinois.edu/admissions/why-ece/salary-averages. [Accessed: 29-Sep-2022].

[9] M. Schubert and B. Fox, "Interaction Sprints at Leap Motion: Exploring the Hand-Object Boundary," *Leap Motion Blog*, Dec. 14, 2017. https://blog.leapmotion.com/interaction-sprint-exploring-the-hand-object-boundary/. [Accessed: 29-Sep-2022].