Haptic Feedback Device for Virtual Simulation and Medical Applications

Sarah Ragle, Mechanical Engineering

Mentor: Dr. Nolan Tsuchiya

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Project Objective

In this project, a device called the "VirtuSim Glove" is created, which attempts to simulate the feeling of picking up an object through use of haptics and a virtual reality simulation. The result of the project includes a wearable glove device designed to provide haptic feedback to the user, all of which connects to a VR simulation setup. The overall design of the glove can be seen in Figures 1 and 2, with a closeup of the haptic mechanisms in Figure 3. The individual contributions of this project include designing a way to gain and transmit positional data from the glove to the VR system via sensors.

The research focus of this project is to examine how the proposed device is applicable in the medical field. Research will be conducted to find potential applications in the medical industry. From there it can be determined whether the proposed device in concept would serve a practical purpose.

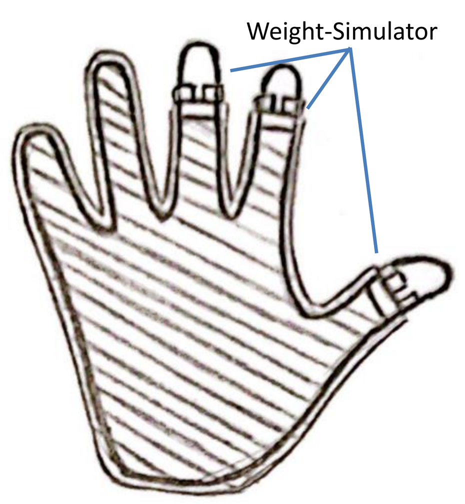

Figure 1: Top view of VirtuSim Glove

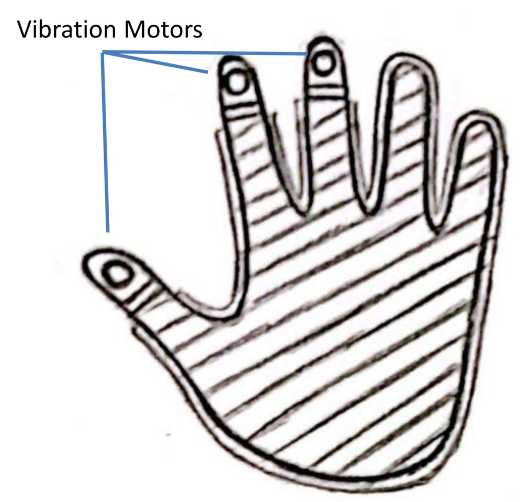

Figure 2: Bottom view of the VirtuSim Glove

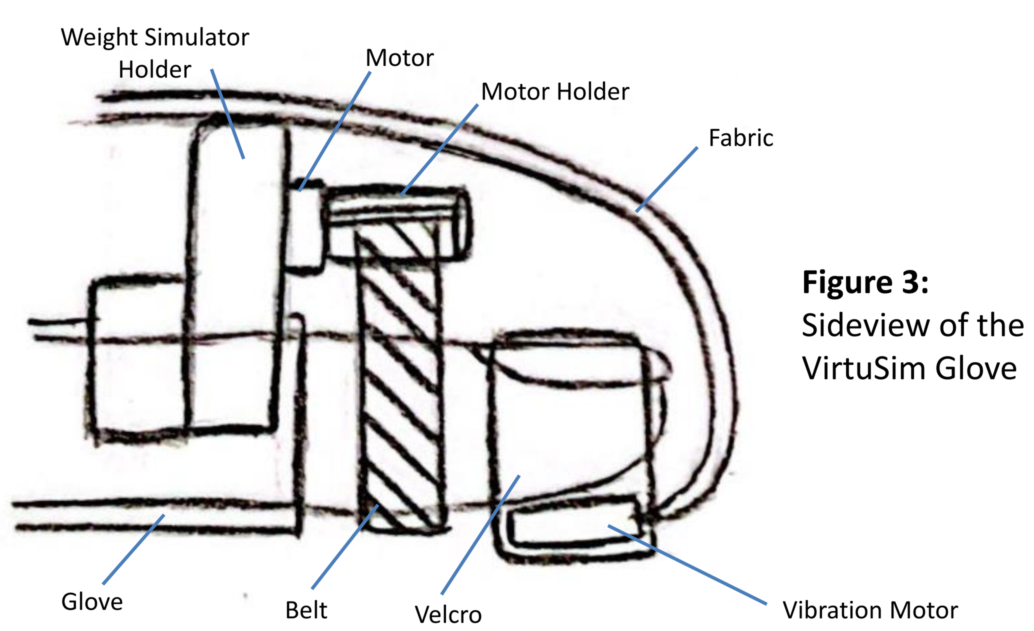

Figure 3: Sideview of the VirtuSim Glove

What is Haptic Feedback?

Haptic feedback, often shortened to haptics, refers to utilizing the sense of touch to communicate additional information to an individual, typically used with technology. The two haptic methods used in this project are vibrotactile haptics and surface haptics. Vibrotactile haptics entails the use of tiny motors to create a vibration sensation, typically used in phones and video game controllers. Surface haptics creates friction across the user's skin, typically done on a touchscreen. [1]

VirtuSim Glove Design

The proposed VirtuSim Glove Device will utilize both vibrotactile haptics and surface haptics to be able to simulate the feeling of grabbing an object in conjunction with a virtual simulation program. As the user moves their hand and fingers, the VR modeled hand will mirror it by receiving information from motion sensors.

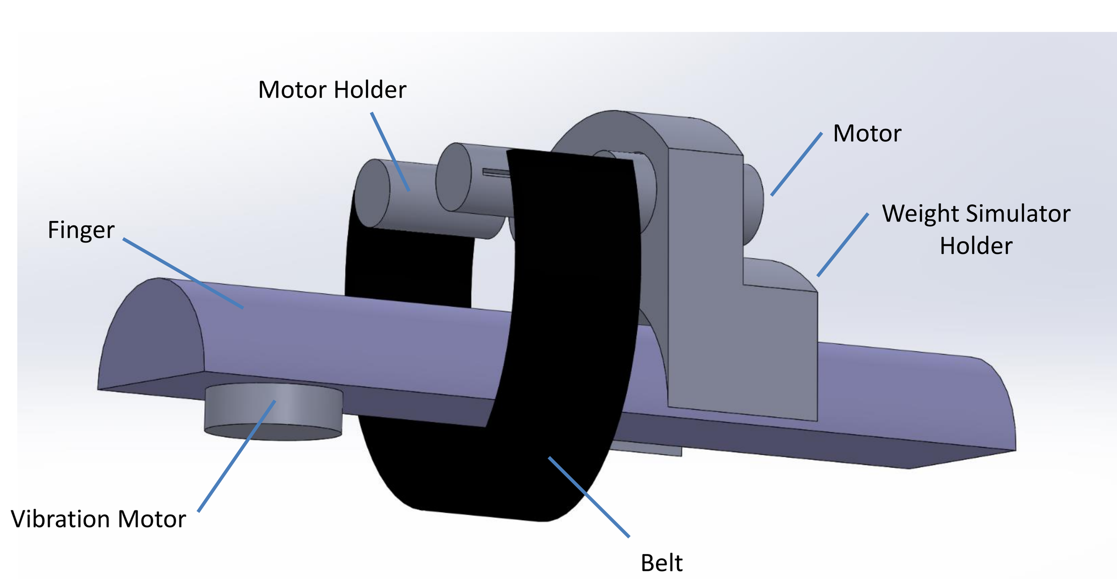

Figure 4: A CAD model of the vibration motor and pulley system, depicted as they will be located on the finger

The user will have the goal of picking up objects in the VR space, and as they do so, will receive haptic feedback via small vibrating motors and a weight-simulating small scale pulley system. The goal of the pulley system is to simulate the feeling of weight that occurs when holding an object and adjust the direction of the frictional sensation depending on the orientation. The vibration motors and pulley systems will be located on three fingers, as they are the most important in grasping objects: the thumb, pointer finger, and middle finger. A CAD model of these haptic mechanisms can be seen in Figure 4 above.

Method 1: IMU Sensor

For the VirtuSim Glove, a method was needed to detect the location and orientation of the fingers in a 3D space, and to transmit that data to Matlab. An Inertial Measurement Unit (IMU) sensor was selected, specifically, the MPU-6050 as seen in Figure 2. It consists of a three-axis accelerometer and a three-axis gyroscope that would allow the user to measure orientation and acceleration.

For implementing the IMU sensor, the first goal was to create a Matlab script that would be able to read and display data from the IMU sensor via the Arduino Uno board. In order to interface with Arduino, a Matlab package was downloaded to allow the data to be imported. Then a Matlab script was composed, allowing for the IMU data to be read, which consisted of the accelerometer data in the x, y, and z direction in m/s2, and the gyroscope data in the x, y, and z direction converted to degrees/s.

The next step was to implement two individual components together, which in this case, was the IMU sensor and the vibration motors. The goal was to write and implement a Matlab script that would intake data from the IMU sensor, and based on its readings, turn on and off a vibration motor. While simple, this test was an effective checkpoint in the project.

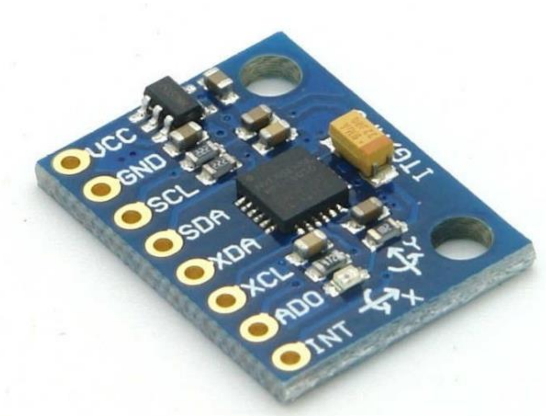

Figure 5: The MPU-6050 IMU Sensor used in the project

Method 2: Leap Motion Controller

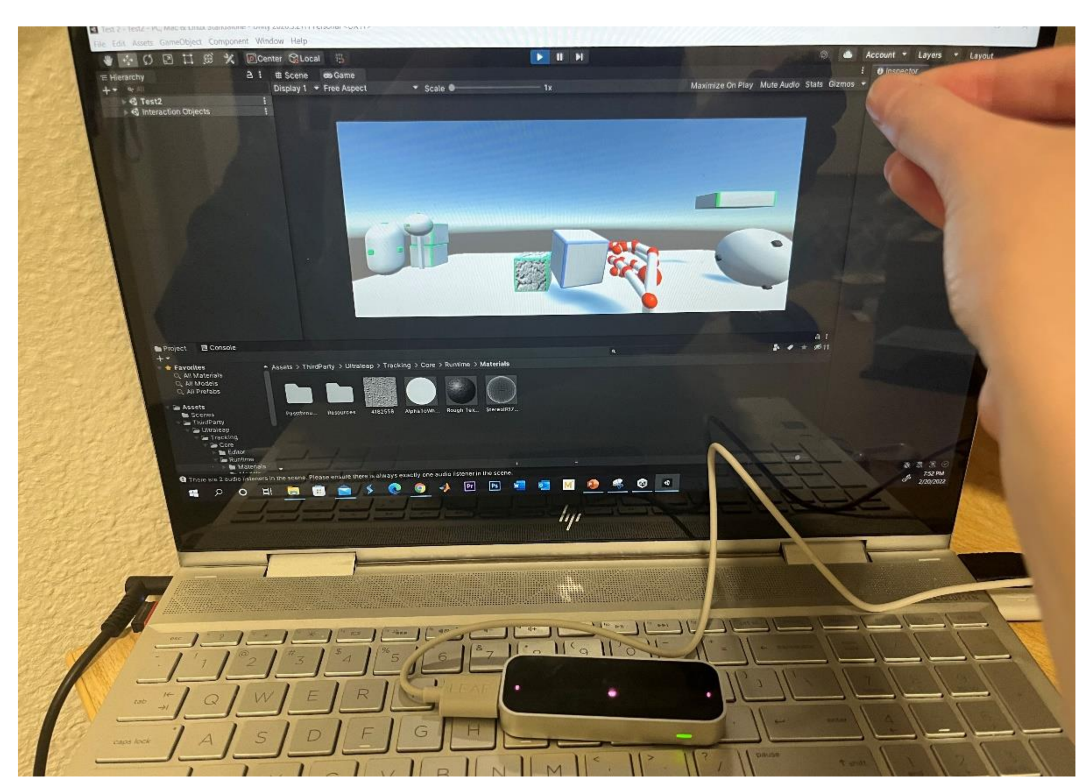

Figure 6: The Leap Motion sensor in action, transmitting positional data to Unity 3D and displaying the virtual hands

It was eventually determined that the processes necessary to convert the IMU data into usable positional data would not fit the timeline of this project. So, it was decided that pre-made sensors would be optimal. Out of all the options, the Leap Motion was selected as it was compatible with the chosen VR software. It also had the added benefit of not requiring a sensor to be attached to the glove device, as it could simply sit on a table below the user's hands, as seen in the Figure 6 to the left.

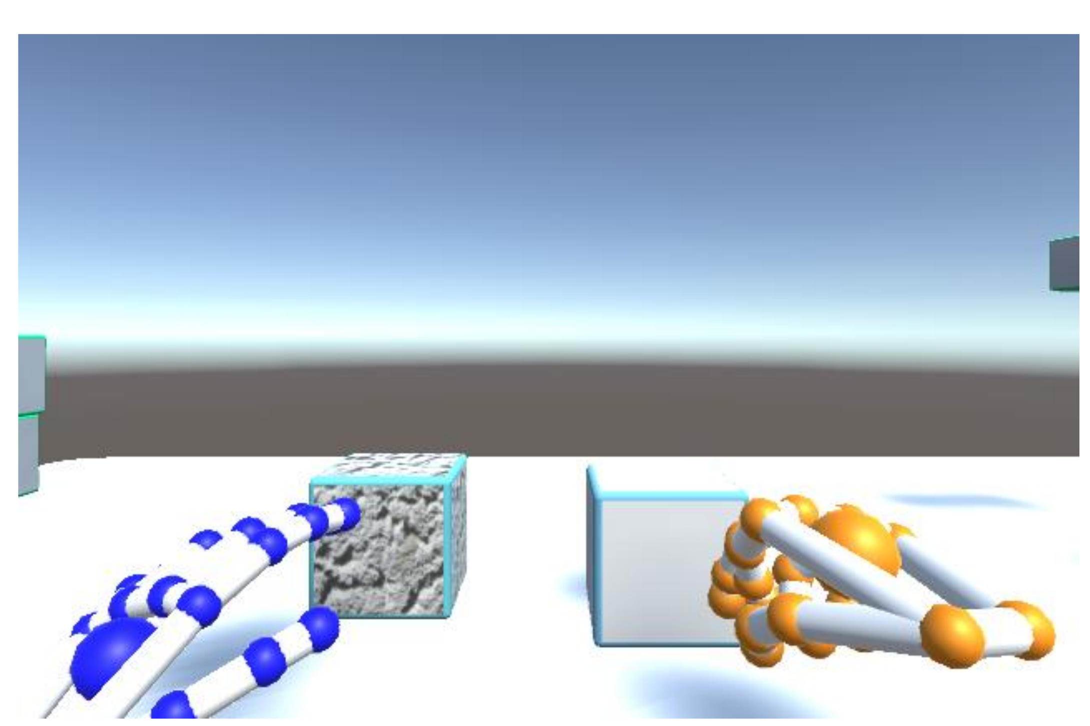

Figure 7: The virtual hands displayed in Unity 3D interacting with virtual objects

Unity 3D was the software chosen that would allow a virtual 3D space to be constructed, where the user could interact with objects, as seen in Figure 7. In relation to the Leap Motion sensor, Unity 3D would allow the virtual hands to appear in the 3D space, and also has the capability to detect and store data related to finger spacing and positioning.

Haptics in the Medical Field

When performing surgeries, touch is a sense that surgeons rely heavily on, for example when distinguishing diseased tissue from healthy tissue. However, there is greater push for Minimally Invasive Surgeries (MIS) as opposed to open surgeries, as they allow for shorter recovery times. Due in part to the loss of haptic feedback, they are extremely difficult for surgeons, but robot-assisted surgeries have improved the ease at which MIS can be performed. It then follows that incorporating haptic feedback into teleoperations could immensely improve their effectiveness. [2]

Surgical bilateral teleoperation systems are one method through which haptics can be incorporated into robot-assisted surgeries. In this configuration, seen in Figure 8, the surgeon is seated at a master console, viewing what is captured at the site of the surgery via a remote imaging system. The manipulations of the surgeon via the master robot are reflected through the slave robot at the site of the surgery. The additional haptic component of this setup is that a force sensor is added so that the forces experienced by the slave robot are measured and reflected back to the master robot, so the surgeon can adjust as needed.

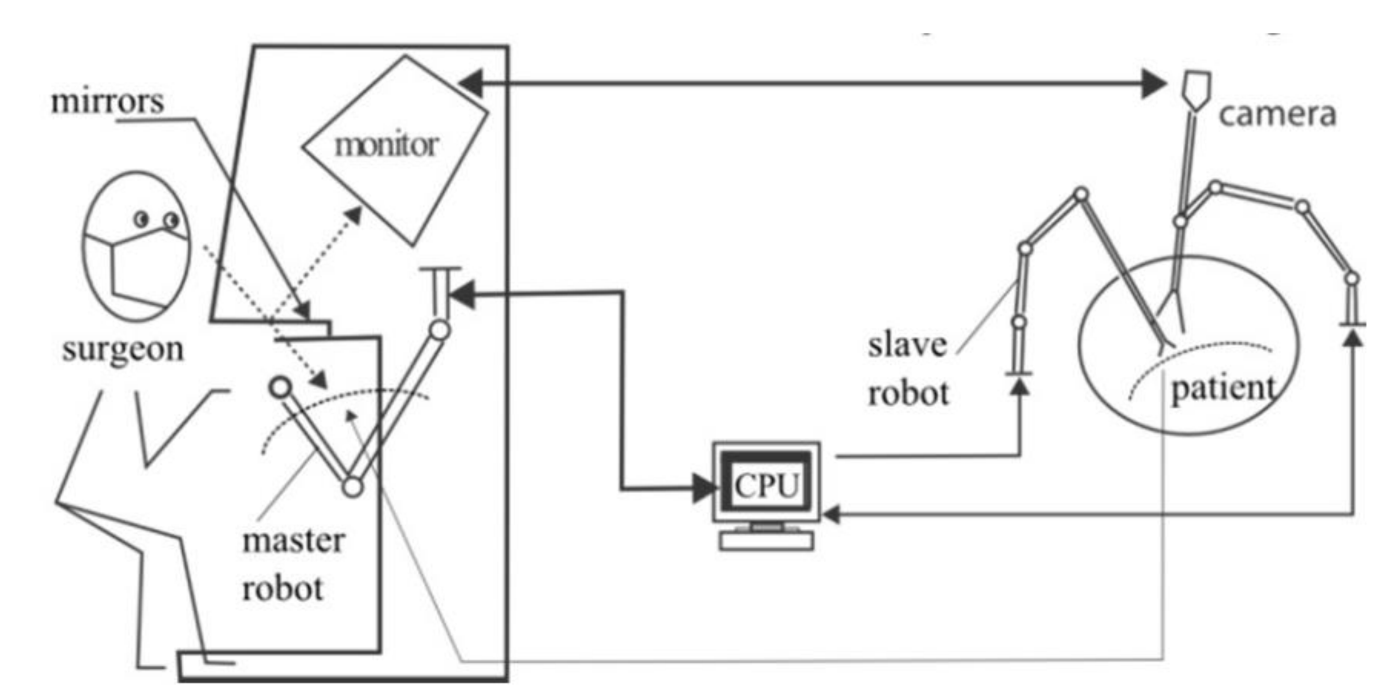

Figure 8: A simplified layout of a surgical bilateral teleoperation system, with feedback being exchanged between the two robots

Another use of haptic feedback in the medical field is in surgery training in VR. Surgical simulators offer a simple solution to allow surgeons in training to practice medical procedures safely, while still obtaining a valuable and accurate representation of the procedure itself through haptics. [2] A wearable glove device would be helpful in both these applications to be able to give the surgeon a more specific haptic response, relative to their individual fingers.

Future Considerations

With this project only partially completed, there are many aspects that will need further work and consideration. With the individual components of the VirtuSim Glove determined, they must then be implemented together. Additionally, a C# script in Unity must be written that allows positional data based on input from the Leap Motion sensor to be interpreted, communicating with the Arduino so that the vibrational motors and pulley-system illicit the proper haptic feedback response on the VirtuSim Glove. Once the glove device is complete, testing must be conducted with several test subjects to determine its feasibility and accuracy in replicating the sensory experience associated with grasping an object. Overall, a device of this type shows promise to be of use in the Medical industry, and VR as a whole.

References

[1] Vander Poorten, E. B., Demeester, E., & Lammertse, P. (2016). (rep.). Haptic Feedback for Medical Applications, a Survey. Retrieved February 20, 2022, from https://silo.tips/download/haptic-feedback-for-medical-applications-a-survey#

[2] Basdogan, C., Giraud, F., Levesque, V., & Choi, S. (2020). (rep.). A Review of Surface Haptics: Enabling Tactile Effects on Touch Surfaces. Retrieved February 20, 2022, from https://arxiv.org/pdf/2004.13864.pdf.