CSE 490V Final Project Proposal

Alex Mastrangelo and Paul Yoo

1 ELEVATOR PITCH

We will create a glove that will use magnetometers to track the position of fingertips with high accuracy and low power. Each point tracked on this glove will be accomplished using a custom pcb that contains magnetometers mounted at a fixed position relative to each other, and possibly an accelerometer. We will then use an optimization technique, or possibly even machine learning to estimate the position of each pcb based on the measurements. To provide the magnetic field that will be measured, we'll either be mounting a permanent magnet or a solenoid onto the user's hand. If everything works correctly, the user should be able manipulate virtual objects through a simulated hand.

2 EXTENDED OVERVIEW

Accurate finger tracking is a significant challenge. Variations in the accuracy of each magnetometer, and noise from the environment reduces tracking accuracy. High accuracy finger tracking is essential for manipulating objects in virtual reality.

The finger tracking scheme cited in references works by using sensors fixed to the hand, and having coils on each finger. Our approach hopes to do the opposite, having a magnet fixed to the hand, and having sensors on each finger. The main advantage of this approach is that the magnet consumes orders of magnitude more power than the sensors, so by using more sensors and less magnets it will reduce the overall power consumption.

However, this comes with the risk of increased error. Off the shelf magnetometer ICs are inconsistent because their 3 axes of measurement are typically misaligned by a few degrees; so by introducing more of these sensors we are introducing more error.

Even then, assuming that we are able to get measurements of reasonable accuracy, we must then convert these measurements into an estimated position. With just 1 magnetometer we get 3 measurements, the B field in the xyz directions. However, because of the symmetry of the magnetic field we are actually only getting 2 measurements; the distance from the magnet and the angle of the magnetometer relative to the magnet [1]. So if we want to get the 3 dimensional position, we must take more measurements.

The approach we wish to explore in our final project is that of combining the multiple magnetometers into 1 sensor. This is accomplished by placing multiple magnetometers onto a single pcb, therefore allowing us to know the position of one magnetometer relative to another. In theory, a scheme like this should give us enough variables to solve for the position, but there are many practical problems that must be solved to make this work well.

2.1 Technical Challenges

- **Challenge 1:** We will construct a model for determining the 6 DOF position and orientation of each pcb, as well as a way to solve it efficiently.
- **Challenge 2:** We will design and construct a custom pcb that integrates all the sensors into one board. These boards will all be hooked into an i2c multiplexer, allowing an arduino to communicate will all boards on the same i2c bus.
- **Challenge 3:** We will convert the 6 DOF position and orientation data into a simulated hand that can physically interact with other objects; and integrate it into Unity.
- **Challenge 4:** We will develop a test level that allows users to manipulate objects using the movements of their fingers.
- **Challenge 5 (Optional):** If we have extra time we may integrate 6 DOF tracking on the entire hand, possible using SLAM or computer vision. This would allow users to move their entire hand in the simulation.
- **Challenge 6 (Optional):** If we have extra time we may integrate haptic feedback strips into the glove, and implement some basic haptic rendering to make the objects feel realistic.

2.2 Key Risks and Mitigations

- **Risk 1:** Misalignment of the 3 axes of each magnetometer (each measurement axis is usually +-5 degrees misaligned) may make finding all 6 DOF too difficult to achieve. A potential mitigation for this would be to use an inverse kinematics joint model, using only the magnitude of the magnetic field to compute the distance from the magnet. Then with the joint model we can estimate a position based on the distance, and the gravity vector provided by the accelerometer.
- **Risk 2:** The predicted position of each finger may be either noisy or inaccurate. As a mitigation we may explore signal processing techniques, and if nothing seems to work then we may pivot to using other approaches to track fingers, and submit a revised final project proposal using that.

3 HARDWARE AND SOFTWARE

This project requires the following hardware.

- [Personal] Arduinos
- [Personal] Permanent/Electro Magnets
- [Personal] Magnetometer ICs
- [Personal] Accelerometer ICs
- [Personal] I2c multiplexer ICs
- [Personal] Custom PCBs

This project requires the following software.

- [Personal] EAGLE
- [Personal] Arduino IDE
- [Personal] Unity

4 TEAM RESPONSIBILITIES

- **Alex Mastrangelo:** Responsible for: (1) creating a python simulation of the magnetic field to test the correctness of the position algorithm, (2) coming up with a collection of sensors to use for tracking, and combining them into one custom pcb, (3) developing Arduino software to stream the sensor data to the users' pc, and (4) contributing to the final project report.
- **Paul Yoo:** Responsible for (1) implementing the virtual hand to interact with objects in Unity, (2) creating the test levels in Unity, (3) exploring and implementing optimization methods to accurately get the 6 DOF of each pcb, possible using ML, and (4) contributing to the final project report.

5 DEVELOPMENT PLAN

- **February 19:** Come up with an algorithm using an optimizer or ML to detect position from magnetometers input.
- **February 20:** Use python and magpylib to create a simulation of magnetic field position algorithm, and demonstrate its correctness with noise and misaligned measurement axes.
- **February 22:** Determine and order the parts necessary to build the position sensor on Digikey.
- **February 22:** Design a custom pcb to house the parts and order it on SeeedStudio Fusion.
- **February 24:** Have hand physical model implemented in Unity.
- **February 28:** Pcbs likely won't have arrived yet, mount ICs onto onto cardboard to demonstrate proof of concept.
- **March 2:** Pcbs have likely arrived, assemble them.
- **March 4:** Have Arduino communicating with all the pcbs and streaming data to pc over a com port into the position algorithm.

- **March 4:** (Optional) Buy haptic strips, and a controller to add to the glove.
- **March 11:** (Optional) Incorporate haptic strips into the glove.
- **March 14:** (Optional) Incorporate a haptic rendering algorithm into Unity.
- **March 14:** Have test level prepared in Unity.
- **March 17:** (Optional) Incorporate a commercial IMU into the glove to track the position of the hand.
- **March 18:** Complete and submit the final report.
- **March 19:** Prepare final project demo, including (optional) poster.
- **March 20:** Participate in the final project demo session.

REFERENCES

1. https://ubicomplab.cs.washington.edu/pdfs/finexus.pdf