Glovesy

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A Technical Document

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Project Title	Glovesy
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ABSTRACT

Glovesy is a wearable computer interfacing device in the form of a glove which will allow the user to interface with their computer by using custom macros or use the device for hand-tracking in VR or AR applications.
Keywords: : Wearables, human-computer interfacing, VR, AR, Arduino

GLOSSARY

1. VR Headset A head-mounted device for use in consuming Virtual Reality Content.
2. AR Headset Similarly to a VR Headset, an AR Headset is a head-mounted device which aims to provide a User with content that is built around their surroundings rather than replace them in the case of a VR Headset.
3. Arduino An Open-Source electronic prototyping platform.
4. ISR Interrupt Service Routine is a software process invoked by an interrupt request from a hardware device.

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Introduction

1.1 Overview

Glovesy is an Arduino based wearable device which will allow the user to interface with their computer, either by using user-defined macros, which will be set up using our program, the Glovesy Configuration Suite, which will allow several gestures do be defined to certain actions within the PC or by allowing the user accurate hand and finger tracking for use in Virtual and Augmented Reality.

Gestures will be defined by a user and mapped to some action on their PC. Actions could include entering a combination of keystrokes, opening an application, raising/ lowering system volume, etc. They will be executed upon the user repeating their chosen gesture.

Motivation

The idea for glovesy came from our analysis of the input devices used in VR/ AR applications. Typically in the case of VR applications, standard input devices mostly come in the form of controllers held in each hand with an array of buttons and some mechanism to provide tracking on the top. AR headsets, generally rely on voice-activated services such, or, the use of a smartphone to interact with the device. In both applications, we agreed that using a glove based input device would provide a more immersive VR gaming experience, and more a more intuitive way of interacting with AR content.

Furthermore, we saw a great learning opportunity with this project. We would be exposed to programming microcontrollers, GUI development and game development to name a few. We also would have the opportunity to make use of some of the skills we developed while undergoing this degree, namely applying linear algebra to a real project.

Research

Overall a significant amount of research was carried out before beginning the development of Glovesy in order to see if our idea would be possible to implement given our current technical expertise and within a reasonable budget.

3.1 Finger Tracking

One of the main components that we carried out research on was how the fingers would be tracked. While we found a number of low-budget ways to track the user's fingers, such as using potentiometers attached to the fingers using fishing line or string, however using this method means that the glove will be much larger and bulkier than using flex sensors. This method also has the downside of the increased chance of snagging due to the fishing line attached to the fingers. In the end, we decided to use flex sensors, as while there are expensive versions of them such as the ones found on Adafruit, it is possible to buy the materials and construct them for much cheaper. Flex sensors are also very low profile and sit flush along the glove, making it feel more natural and reduces the chances of snagging.

3.2 Hand Tracking

When researching methods for tracking the user's hand, while there were a few other options, such as using a HTC Vive Tracker, however this is not only an expensive option, but it also requires at least one HTC Vive Lighthouse for tracker. On top of this, when attached, the tracker is bulky and can easily snag or catch on something due to it's design, especially when using a VR headset, since the user cannot see their sur-

roundings. Instead, the best option we could find was using an 9DoF IMU, specifically the Adafruit LSM6DS33 LIS3MDL, as it was both cheap and small, while also offering accurate accelerometer and gyroscope data.

3.3 Board

When looking for a board to use, there were a number of requirements which had to be satisfied for it to function adequately. Those requirements were:

- the board must have enough analog pins to read data from each of the flex sensors
- the board must have i2c compatibility in order to receive data from the IMU
- the board must be compact in terms of its form factor in order to reduce the bulk of the glove and make it more comfortable to wear

While researching said boards, there were a few boards that fit the requirements, such as the TinyCircuits TinyLily Mini, but we decided to use the Adafruit Feather M0 Bluefruit LE, since it not only meets all the requirements, but is also Bluetooth enable, which would allow us to create a wireless version of the device without needing to purchase new components.

3.4 Game Engines

During research into which game engine to use as the basis for the demonstrations, there were a number of valid options. One of said options being the Godot engine as it is a relatively easy engine to develop for, however, due to the limitations of the engine, it was decided that another engine would be better suited, especially due to difficulty when getting input from non-standard controllers. Another favourable option to use was Unreal Engine as it uses C++ which is a language we both have experience in. However, this option was ruled out due to compatibility issues when developing on linux systems. As such we decided to use Unity as it is a cross-platform game engine, as well as allowing non-standard input devices to be used with relative ease. This, though, was not an ideal

scenario as we have little experience using Unity as well as little experience programming in C#.

3.5 Language for implementing AR Suite

Choosing a language for this aspect of the project was rather straightforward. It had to meet certain requirements. The first requirement was for the language to be statically typed, this is mostly down to personal preference as I have found dynamically typed languages to be cumbersome when working with larger codebases. The next requirement was for the language to be platform agnostic. With all that considered, we settled on Java.

3.6 Build Tool

The choice in build tools came down to two candidates, Maven and Gradle. Having used both in the past, I settled on Gradle as it is typically quick to set up and modify as well as having great support in my Java ide of choice. It also provides some excellent features such as automatically generating a test result site on each build of the project.

3.7 GUI Library

Having settled on Java as the programming language to be used for the AR aspect of this project, we needed to choose a library for GUI development. Requirements for a GUI library mainly came down to the availability of documentation and the ability to create 3D models. While researching libraries, we discovered that Javafx satisfies both requirements.

3.8 Competitors

Upon researching to see if the idea had already been done by a company, or if the idea was even feasible to begin with, we discovered a number of different implementations of the

same idea. A very high fidelity solution to our idea can be found in the Manus VR Primus II, however this very high fidelity solution is very costly at a price of €2,499. Another solution which takes a different approach to the problem is the Senseglove, which is not only very bulky, being much larger than the user's hand, but is also very expensive, at €2,999. A final example is the HAPTX gloves which are once again very bulky, including a backback which must be worn during use.Another downside to all of the aforementioned competitors is their reliance on existing vr systems such as the HTC Vive Trackers, or the Occulus Controllers which not only require the user to have a vr environment set up, but also add bulk to the glove, particularly the Occulus Controllers, alongside being somewhat expensive.

Design

4.1 System Architecture

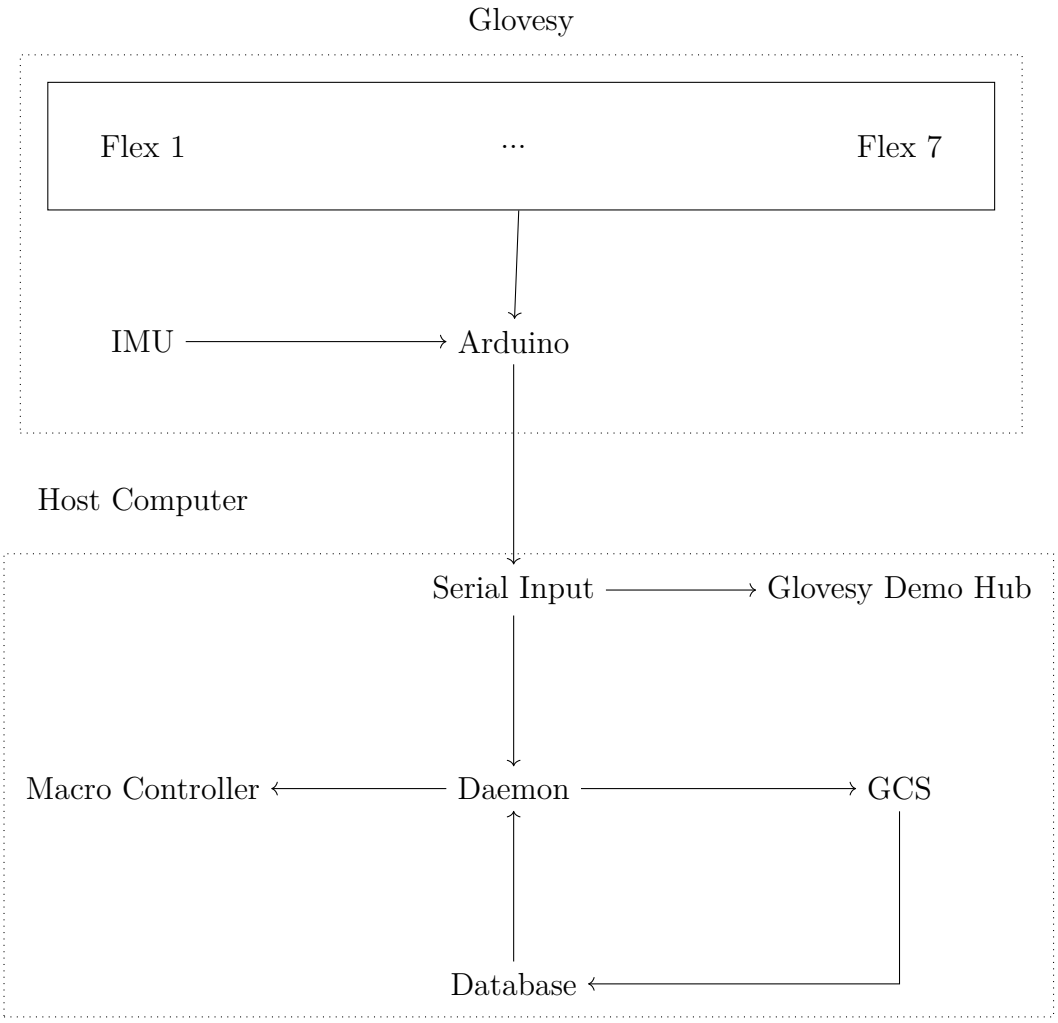

Figure 1: High-Level System Architecture Diagram

4.2 Flex Sensors

The flex sensors are constructing by using 3 layers of velostat, with conductive thread running up along both top and the underside, and is held together using electrical tape. They function by changing resistance according to how much the sensor is bent. Using this resistance, once the sensor is calibrated, the value can be normalized to be between 1.0 and 0.0 depending on how bent the finger is.

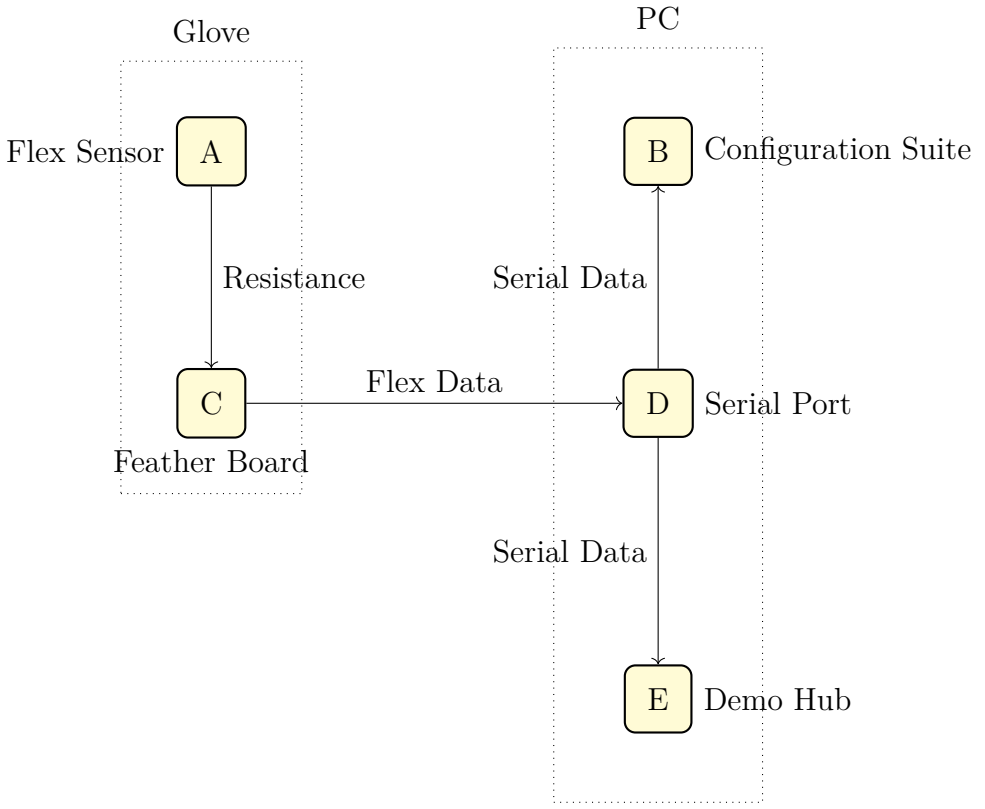

Figure 2: Flex Sensor Data Flow Diagram

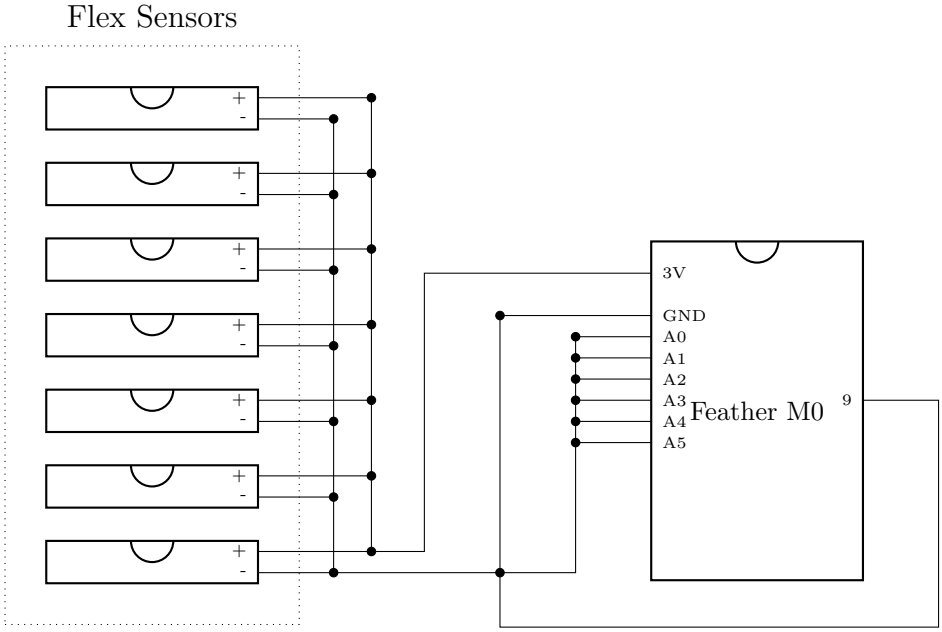

Figure 3: Flex Sensor Circuit Diagram

4.3 IMU

The IMU functions by sending Accelerometer, Gyroscope, and Magnetometer data to the board over I2C, thereby allowing the system to track hand movement and orientation.

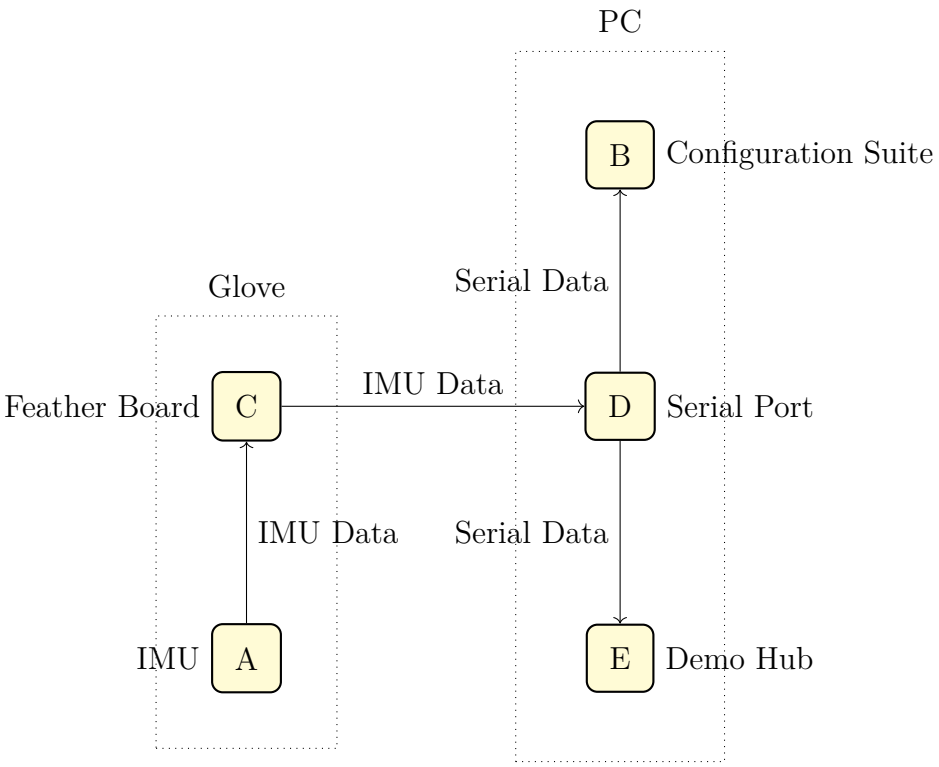

Figure 4: IMU Data Flow Diagram

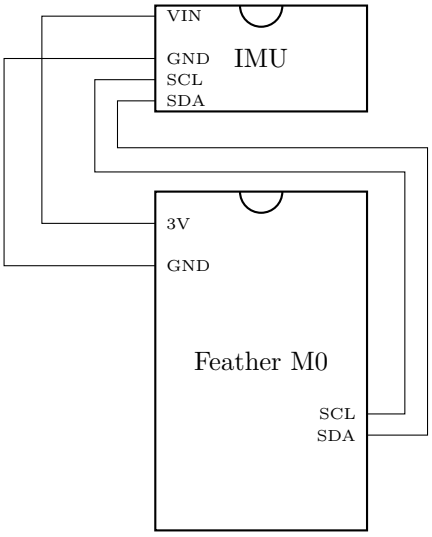

Figure 5: IMU Circuit Diagram

4.4 Board

The board used is the Adafruit Feather M0 Bluefruit LE, which transfers data from the flex sensors and IMU to the PC as comma seperated values over serial communications.

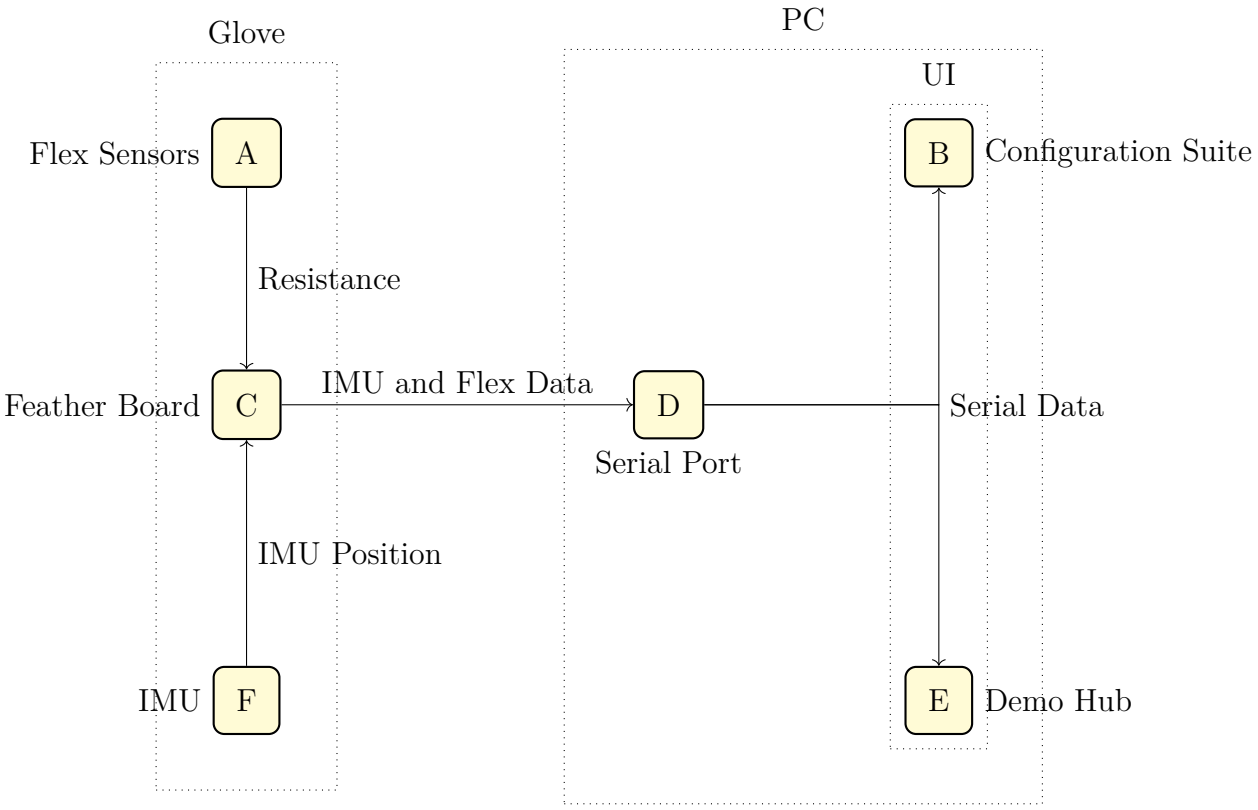

Figure 6: Data Flow Diagram

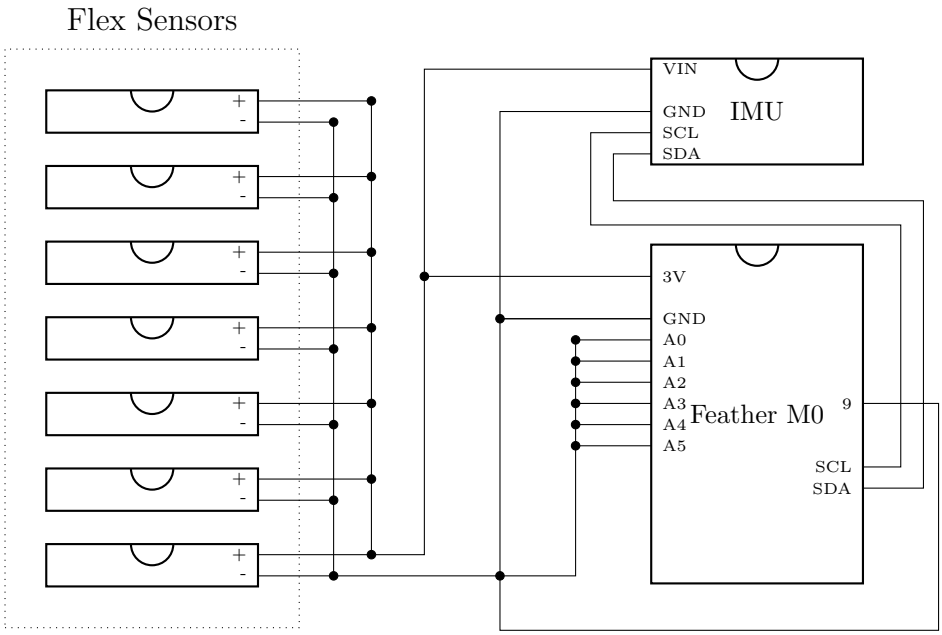

Figure 7: Board Circuit Diagram

4.5 Glovesy Configuration Suite

4.6 Glovesy Demo Hub

Glovesy Demo Hub is a game environment created using Unity which allows the user to use glovesy to interact with a virtual environment. It does this by reading the serial data received from glovesy, and assigning the values received to the in-game representation of the user's hand, allowing them to interact with physics objects.

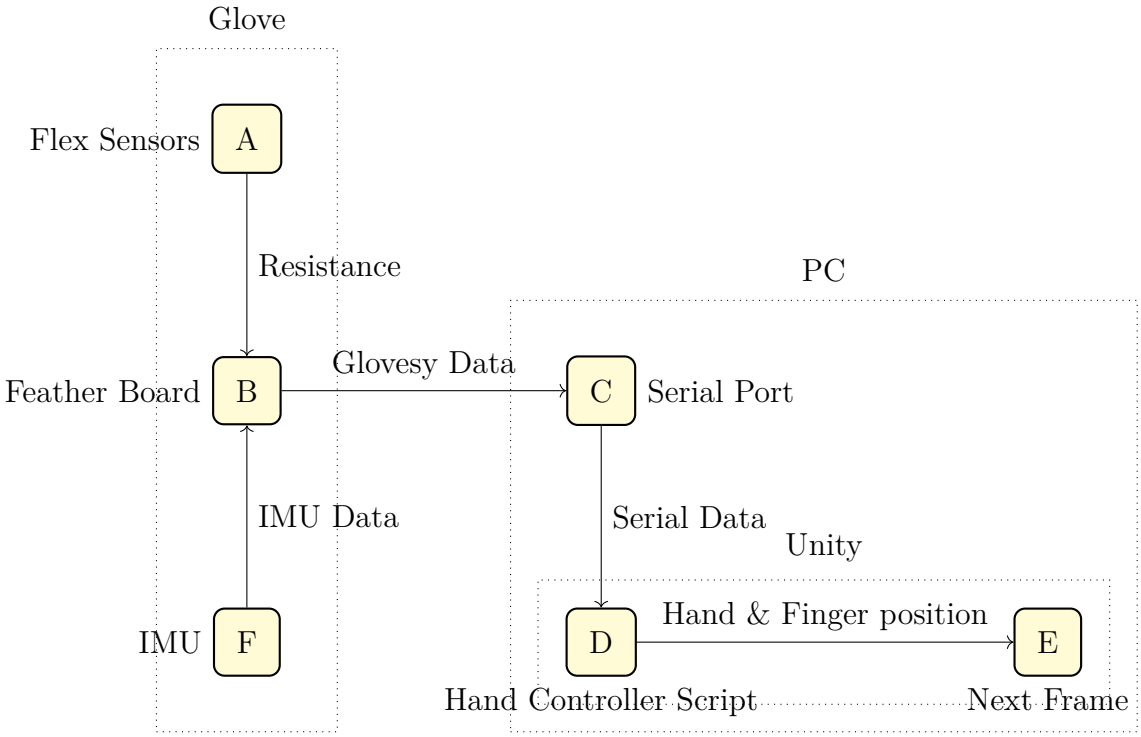

Figure 8: Demo Hub Data Flow Diagram

Implementation

5.1 Flex Sensors

The flex sensors are created by stacking 3 layers of velostat on top of each other and then attaching a conductive thread along the outside of it on both sides. Once this is done its routed through a 4.7kΩ resistor which is connected to ground, and goes to an analog sensor on the board. When this is done, the board will read the voltage by default.

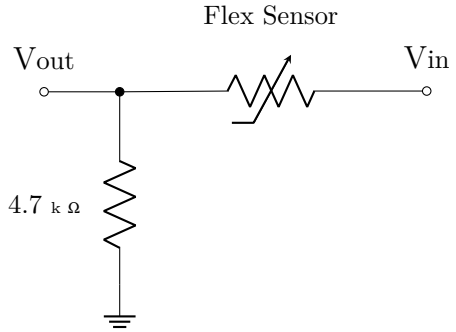

Figure 9: Flex Sensor Resistor Circuit

At this point the value from the flex sensor can be read as shown in Figure 10.

While reading in this method is adequate, we decided to covert the voltage to the corresponding resistance using the code seen in Figure 11.

Once that has been implemented, both can be used to read the resistance of each flex sensor and print it to the serial port using the code in Figure 12.

```
// Read thumb values
Serial.print(analogRead(A4));
Serial.print(",");

// Read Index values
Serial.print(analogRead(A0));
Serial.print(",");
Serial.print(analogRead(A1));
Serial.print(",");

// Read Middle finger values
Serial.print(analogRead(A2));
Serial.print(",");
Serial.print(analogRead(A3));
Serial.print(",");

// Read Ring finger value
Serial.print(analogRead(A5);
Serial.print(",");

// Read Pinky finger value
Serial.print(analogRead(9));
Serial.println();
```

Figure 10: C Code to read voltage from flex sensor

5.2 IMU

In order to use the IMU, we had to use the Adafruit_LSM6DS33 library which can be installed through the arduino IDE. Using this library we can initialise the IMU using the code as seen in Figure 13. Once the IMU has been initialised, gyroscope and accelerometer data can be read and printed to the serial port as shown in Figure 14.

```
float get_resistance(int ADCflex) {
  // Convert value from flex sensor to resistance
  float VCC = 3.3;
  int R_DIV = 4700;
  float Vflex = ADCflex * VCC / 1023.0;
  float Rflex = R_DIV * (VCC / Vflex - 1.0);

  return Rflex;
}
```

Figure 11: C code for conversion from voltage to resistance

5.3 Board

To be able to program the board, we used the Arduino IDE which allowed for easy deployment of the code and easy reading of the serial port, as well as making it very simple and streamlined to install the libraries required to let our device function. The bulk of the coding for the board has already been mentioned in sections 5.1 and 5.2, as all that was left to do was to combine the code for getting the flex data and the IMU data and set the baud rate as can be seen in Figures 15 and 16

```
float get_resistance(int ADCflex) {
  // Convert value from flex sensor to resistance
  float VCC = 3.3;
  int R_DIV = 4700;
  float Vflex = ADCflex * VCC / 1023.0;
  float Rflex = R_DIV * (VCC / Vflex - 1.0);
  return Rflex;
}
// Read thumb values
Serial.print(get_resistance(analogRead(A4)));
Serial.print(",");
// Read Index values
Serial.print(get_resistance(analogRead(A0)));
Serial.print(",");
Serial.print(get_resistance(analogRead(A1)));
Serial.print(",");
// Read Middle finger values
Serial.print(get_resistance(analogRead(A2)));
Serial.print(",");
Serial.print(get_resistance(analogRead(A3)));
Serial.print(",");
// Read Ring finger value
Serial.print(get_resistance(analogRead(A5)));
Serial.print(",");
// Read Pinky finger value
Serial.print(get_resistance(analogRead(9)));
Serial.println();
```

Figure 12: C code to print flex resistance to serial port

```
#include <Adafruit_LSM6DS33.h>

// For SPI mode
#define LSM_CS 10
// For Software-SPI
#define LSM_SCK 13
#define LSM_MISO 12
#define LSM_MOSI 11

Adafruit_LSM6DS33 lsm6ds33;

void setup(void) {
    // Accelerometer
    lsm6ds33.configInt1(false,false,true);
    // Gyro
    lsm6ds33.configInt2(false,true,false);
}
```

Figure 13: Code to initialise the IMU

```
sensors_event_t accel;
sensors_event_t gyro;
sensors_event_t temp;

lsm6ds33.getEvent(&accel, &gyro, &temp);

// Accelerometer and Gyro data
Serial.print(accel.acceleration.x);
Serial.print(",");
Serial.print(accel.acceleration.y);
Serial.print(",");
Serial.print(accel.acceleration.z);
Serial.print(",");
Serial.print(gyro.gyro.x);
Serial.print(",");
Serial.print(gyro.gyro.y);
Serial.print(",");
Serial.print(gyro.gyro.z);
Serial.println();
```

Figure 14: Code to print IMU data to serial port

```
#include <Adafruit_LSM6DS33.h>
// For SPI mode, we need a CS pin
#define LSM_CS 10
// For software-SPI mode we need SCK/MOSI/MISO pins
#define LSM_SCK 13
#define LSM_MISO 12
#define LSM_MOSI 11
Adafruit_LSM6DS33 lsm6ds33;
void setup(void) {
  Serial.begin(115200);
  while (!Serial)
    delay(10);
  if (!lsm6ds33.begin_I2C()) {
    Serial.println("Failed to find LSM6DS33 chip");
    while (1) {
      delay(10);
    }
  }
  // accelerometer DRDY on INT1
  lsm6ds33.configInt1(false, false, true);
  // gyro DRDY on INT2
  lsm6ds33.configInt2(false, true, false);
}
float get_resistance(int ADCflex) {
  // Convert value from flex sensor to resistance
  float VCC = 3.3;
  int R_DIV = 4700;
  float Vflex = ADCflex * VCC / 1023.0;
  float Rflex = R_DIV * (VCC / Vflex - 1.0);
  return Rflex;
}
```

Figure 15: Initialisation of the board

```
void loop() {
  sensors_event_t accel;
  sensors_event_t gyro;
  sensors_event_t temp;
  lsm6ds33.getEvent(&accel, &gyro, &temp);
  Serial.print(get_resistance(analogRead(A4)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(A0)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(A1)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(A2)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(A3)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(A5)));
  Serial.print(",");
  Serial.print(get_resistance(analogRead(9)));
  Serial.print(",");
  Serial.print(accel.acceleration.x);
  Serial.print(",");
  Serial.print(accel.acceleration.y);
  Serial.print(",");
  Serial.print(accel.acceleration.z);
  Serial.print(",");
  Serial.print(gyro.gyro.x);
  Serial.print(",");
  Serial.print(gyro.gyro.y);
  Serial.print(",");
  Serial.print(gyro.gyro.z);
  Serial.println();
}
```

Figure 16: Main loop for the board