Infinity Control Gauntlet

Team 25: Ashish Pabba, Chris Schodde and Ramakrishna Kanungo
TA: Yifan Chen

Table of Contents

Introduction

Objective

For certain applications, the issues with conventional input devices such as the mouse and keyboard are evident. There are numerous such fields that lack a sufficiently intuitive and natural input method, including but not limited to VR technology, video games, CAD/3D modelling, and even basic menu navigation. For example, in the context of 3D modeling and CAD applications, rotation, zooming, and translation are extremely inconvenient actions. Such a lack of intuitiveness can seriously hamper workflows and negatively affect efficiency and accuracy. Therefore, an advancement or breakthrough in this area would be analogous to the invention of the mouse as a point and click device.
Moreover, another source of inconvenience is that most input devices are external and secondary instruments as opposed to extensions of the body, the latter being overwhelmingly preferable. This is evident in the complete replacement of stylus-based touch screens by capacitive touch screens that can be used with fingers.
With these aspects of the problem space in mind, our proposed solution is to engineer a wearable glove that can be used to recognize the hand-based gestures of the wearer to serve as an input device. Such a solution would enable the user to translate specific and precise gestures to a directive/input command. As previously discussed, the applications for this method of input would be significant. Therefore, our objective is to essentially develop a glove that can serve as an immersive and intuitive input instrument with applications in several fields.

Background

Our goal is to attempt to develop a more intuitive, immersive, and natural method of input in the form of a glove that is capable of recognizing gestures. While there are similar products in development or even commercially available from companies such as HTC and Sony, such products are either nascent, niche, or prohibitively expensive. In order to distinguish itself, our glove solution will have to be both reliable and inexpensive. Another possible argument against the pursuit of the development of such a glove is the alternative possibility of using computer vision to track hand/finger movements. However, this solution can be easily dismissed when the field-of-vision requirements, camera costs, and necessary computer vision hardware and software are contrasted with the simplicity of the glove.

High-level requirements list:

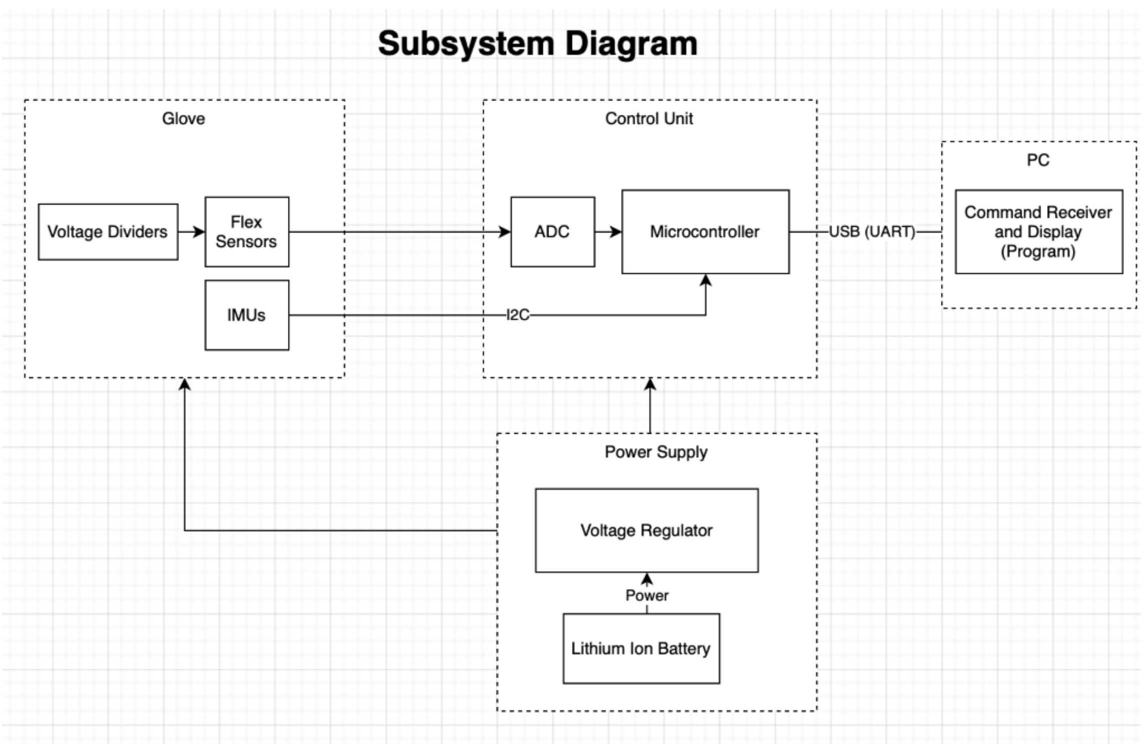
• The orientation of the hand and its fingers, sufficient to cover the range of desired commands, must be known.

• There must be a translation between the orientation of the hand and its fingers, and the commands for the CAD system.

• An interface between the translated commands and the CAD system installed on the target PC must be present.

Design

Block Diagram



Functional Overview

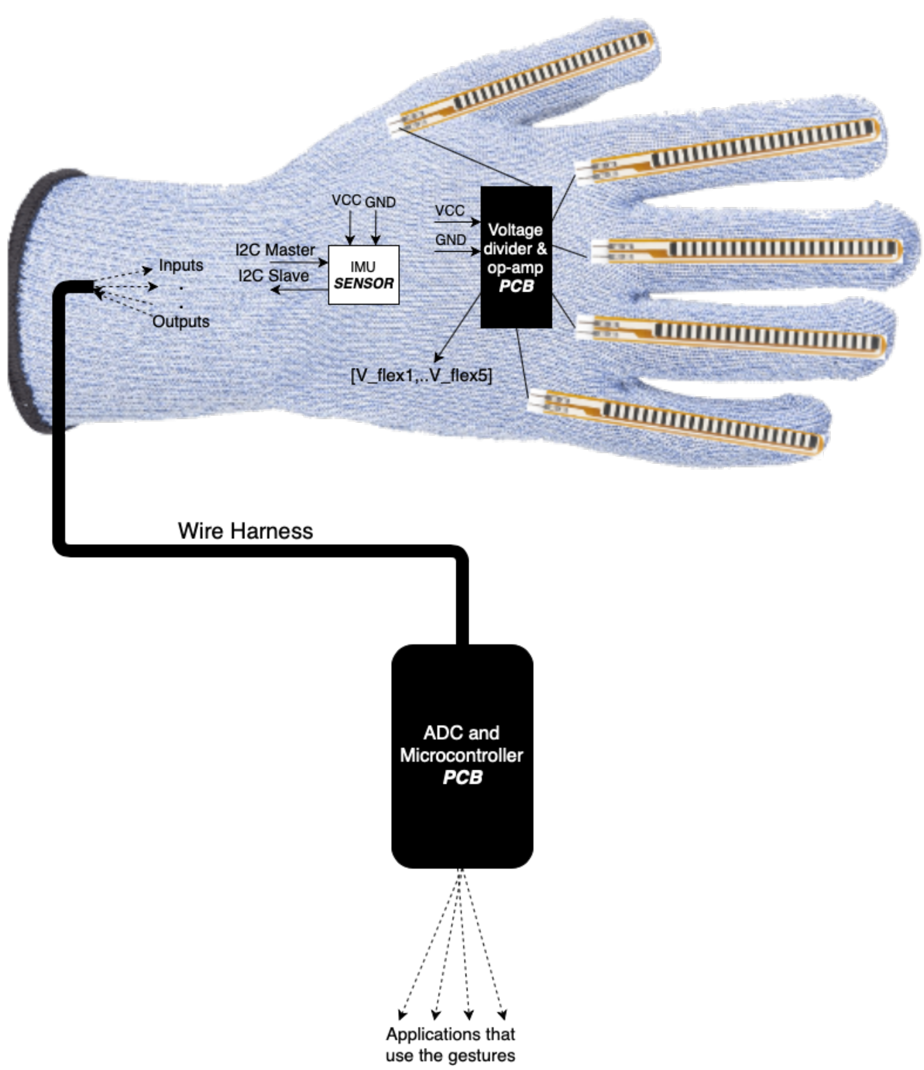
The ***glove subsystem*** encompasses the sensors mounted on the glove that are used to help detect gestures. And since a gesture is just a combination of different motions happening in parallel the aim of the glove subsystem is to provide the control unit, with the microcontroller, data from different types of sensor values that aim to detect a certain motion.

The ***control unit*** consists of the microcontroller and the analog to digital converter. The ADC is used to convert the voltage divider circuit value from the glove subsystem and send the digital output to the microcontroller. The microcontroller is used to interface with the various sensors and detect gestures, these include rotational motion, translational motion and contraction of hand.

The ***power supply unit*** is used to provide power to the various sensors and the microcontroller.

The ***PC unit*** is used to interact with the microcontroller and report the gestures sensed.

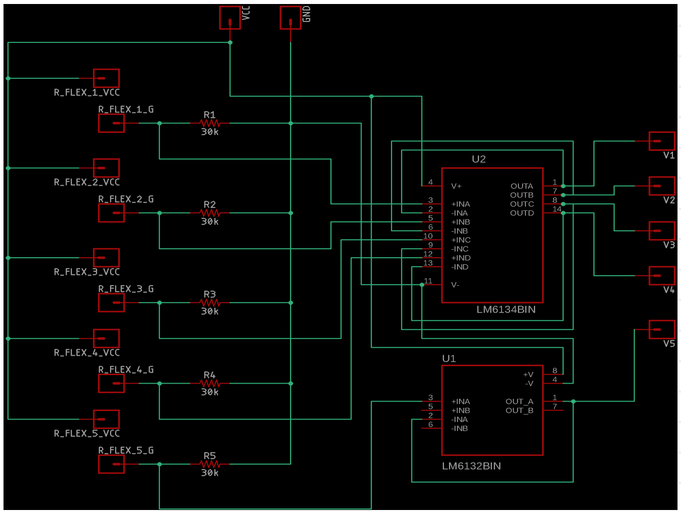
Physical Design

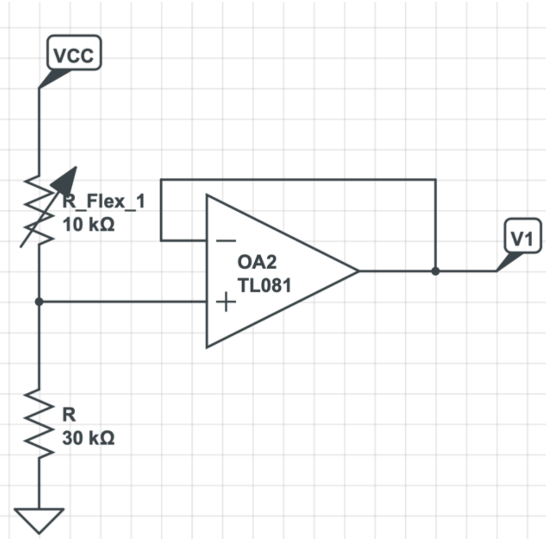


Glove Subsystem

Flex Sensors

The flex sensors are placed to capture the contraction of each of the fingers. The flex sensors are connected to another set of resistors in series to form a voltage divider circuit. The voltage drop is fed to a voltage follower op amp circuit to avoid source impedance. Then this is routed to the control unit.





Requirement	Verification
Get voltage values of 1.2-2.7V from the flex sensor in order to detect finger positions	• Create resistor divider circuit on the breadboard and check the output for multiple different flex sensors • Verify working of through hole op-amp by recreating unity gain buffer on bread board • Vary length of wire and measure output voltage

IMUs

The IMU is used to detect rotational and translational motion. It contains a Gyroscope and an Accelerometer, that can be used to detect the translational and rotational motion experienced by the hand as a whole. It communicates with the control unit using an I^2C interface. Further, adding additional IMUs/standalone accelerometers on the tips of fingers is being explored to enable capturing the rate of change while contracting fingers.

Control Unit

Analog to Digital Converter

The ADC converts the analog voltage values from the flex sensor into digital ones. Since the output expected from the flex sensor is primarily binary, the digital signal doesn't need to have a high resolution. Although since the values of the voltage divider circuit vary from 2-3.5V, a 6-8 bit resolution is optimum. Given that there are 5 voltage values that need to be converted, a 5 channel ADC will be necessary. It would take up less power and area on the PCB as opposed to an 8-bit ADC for each voltage line. The conversion speed and channel switching frequency for the ADC will have to be on the higher side so as to keep all the voltage values read from each of the sensors synchronized.

Microcontroller

The microcontroller needs to support I2C interface to communicate with the IMU's and few GPIO pins to interface with the ADC. A control loop needs to be able to constantly analyze sensor data and output which gesture is being performed. Further, the clock speed needs to be kept in mind since a relatively fast clock is required to do computationally heavy tasks to detect gestures while missing minimal sensor information between two computation cycles. A UART interface with the laptop is also needed since it will be used to display the gesture on the Laptop.

Power Unit

This consists of a battery and VRM. The battery can directly power the resistors since the change in current draw is not very rapid. A VRM is needed to power the microcontroller.

PC

The current goal of the project is to be able to display the various gestures detected by the microcontroller on the PC. This would mean transmitting the data whenever a gesture is detected from the Control unit to the PC. But if possible, these gestures are to be translated into useful and intuitive commands to preview CAD models. This would involve writing windows drivers to send commands to the CAD software to perform certain tasks based on the data being received on the USB UART port.

[SUBSYSTEM NAME]

For each subsystem in your block diagram, you should include a highly detailed and quantitative block description. Each description must include a statement indicating how the block contributes to the overall design dictated by the high-level requirements. Any and all design decisions must be clearly justified. Any interfaces with other blocks must be defined clearly and quantitatively.

Include any relevant supporting figures and data in order to clearly illustrate and justify the design. Typically a well justified block design will include some or all of the following items: Circuit schematics, simulations, calculations, measurements, flow charts, mechanical diagrams (e.g. CAD drawings, only necessary for mechanical components).

You must include a **Requirements and Verifications** table. Please see the R&V page for guidance on writing requirements and verification procedures.

Tolerance Analysis: Through discussions with your TA, identify the block or interface critical to the success of your project that poses the most challenging requirement. Analyze it mathematically and show that it can be feasibly implemented and meet its requirements. See the Tolerance Analysis guide for further guidance.

COVID-19 Contingency Planning: Discuss how you intend to handle the situation where the University transitions to all online classes. How will your overall project change if at all? How will you implement your designs? How will your requirements, verifications, or goals change?

Cost and Schedule

Cost Analysis: Include a cost analysis of the project by following the outline below. Include a list of any non-standard parts, lab equipment, shop services, etc., which will be needed with an estimated cost for each.

- Labor: (For each partner in the project)
  Assume a reasonable salary
  `($/hour) x 2.5 x hours to complete = TOTAL`
  Then total labor for all partners. It's a good idea to do some research into what a graduate from ECE at Illinois might typically make.
- Parts: Include a table listing all parts (description, manufacturer, part #, quantity and cost) and quoted machine shop labor hours that will be needed to complete the project.
- Sum of costs into a grand total

Schedule:

Include a time-table showing when each step in the expected sequence of design and construction work will be completed (general, by week), and how the tasks will be shared between the team members. (i.e. Select architecture, Design this, Design that, Buy parts, Assemble this, Assemble that, Prepare mock-up, Integrate prototype, Refine prototype, Test integrated system).

Discussion of Ethics and Safety:

The weight and positioning of the sensors, PCB boards, and batteries may over time, if care is not taken, cause strain on the operator's hand or abrasions on the skin, potentially resulting in permanent injury. To comply with rule #1 of the IEEE Code of Ethics [1], that we may preserve the health and safety of our users, attention will be given to ergonomic placement of the said components on the hand and wrist, to achieve a balanced, comfortable experience. Additionally, because the user is intended to wear a mounted electrical system, care will be taken to ensure proper insulation of the mounted electrical components and their associated wires, so that no part of the operator physically comes into contact with these components.

Citations:

[1] ieee.org, "IEEE IEEE Code of Ethics", 2020. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 16- Sep- 2020].

Any material obtained from websites, books, journal articles, or other sources not originally generated by the project team