The Glove

Design Review

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1. Introduction

1.1 Statement of Purpose

Motion tracking technology has been largely used in Virtual Reality Game to offer more engaging gaming experience. Most motion tracking devices enable people to observe the movement of their hands and interact with virtual objects. Based on this, our team think that providing haptic feedback to the contacts with virtual objects makes the experience even better.

We plan to mount the servo motors on the glove to control the movement of the fingers/palm. We will incorporate Leap Motion with our glove wirelessly to simulate the signal. Conditions like touching or grabbing the virtual object will output a signal sending to a controller to activate the servo motors and give a haptic feedback to the hand.

1.2 Objectives

- Provide force feedback that is similar to real life experience.
- Skeleton will stop fingers from moving into the virtual object.
- Wireless glove with high portability.
- Low power consumption.
- Well incorporated with Leap Motion.

2. Design

2.1 Block Diagram

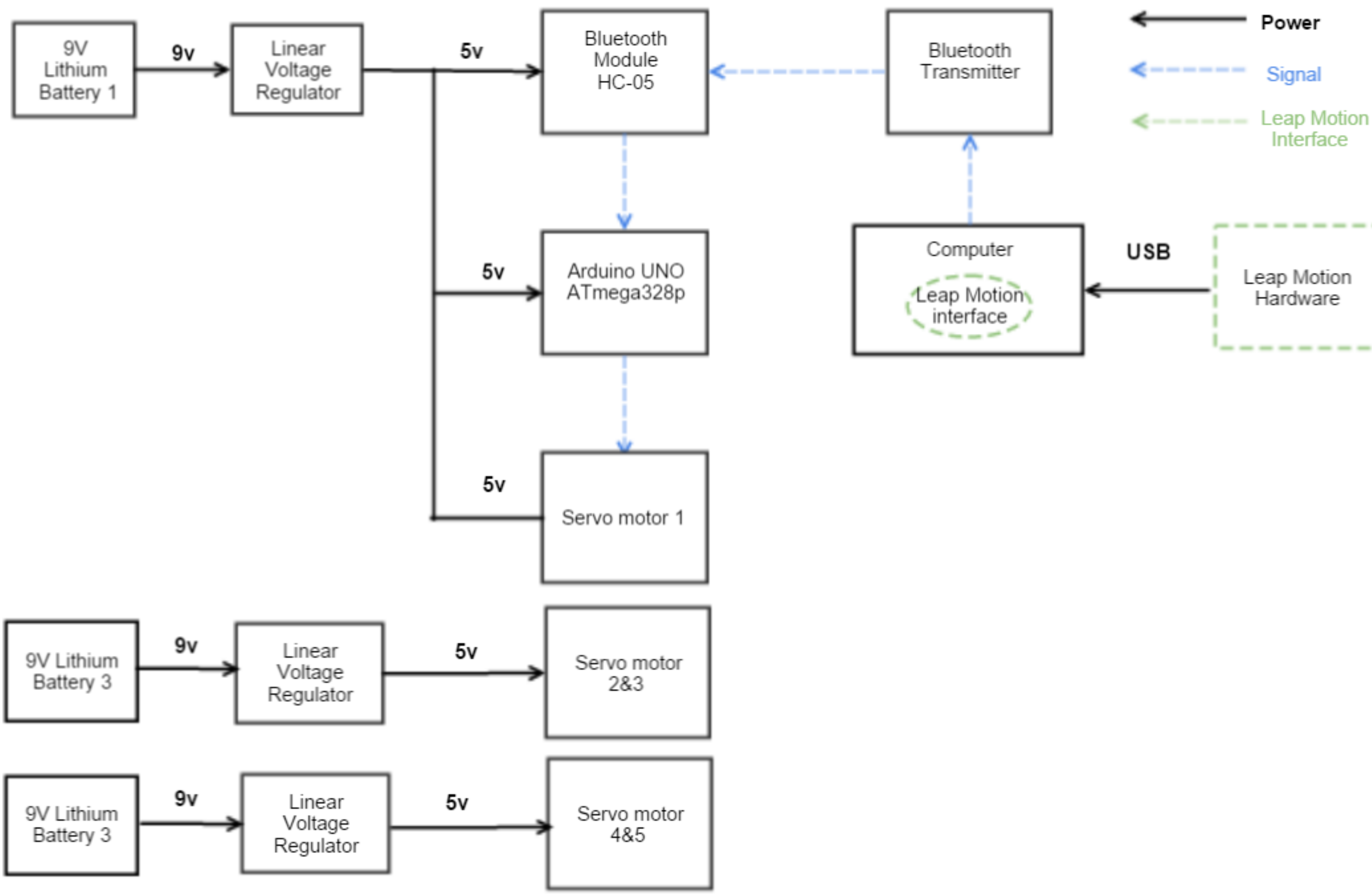


Figure 1

2.2 Block Description & Schematics

2.2.1 Power Supply

We are using three 9v lithium batteries to serve as basic power supply for the device circuits. All the batteries are regulated by a linear voltage regulator to output a 5.0

voltage. The first battery is supplying power for micro controller, Bluetooth and the first servo. The other two batteries are supplying power for two servos each in order to prevent possible battery over discharge.

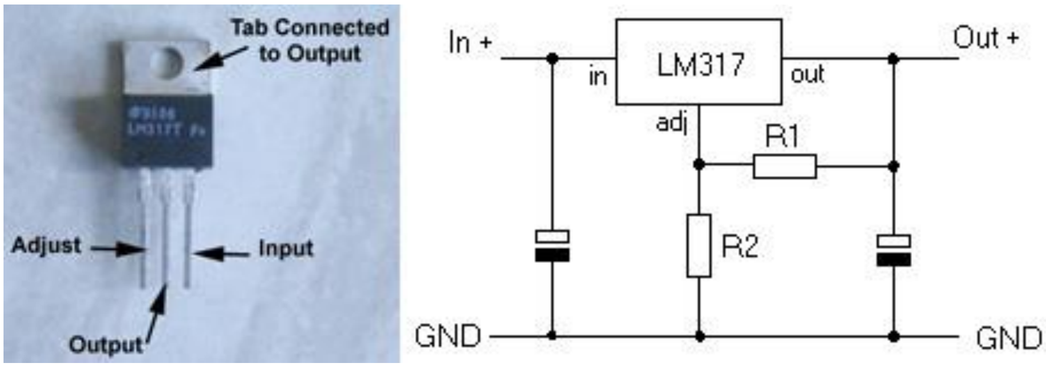


Figure 2

For the linear voltage regulator LM317, the equation is V out= 1.25(1+ (R2/R1)) where R2 is usually 220 or 240 ohms. Since we want an output voltage of 5V, the equation became:

5 = 1.25（1+（240/R1)). Then R1 = 80 ohms. The capacitor on the left is usually set to 0.1 μf and the capacitor on the right is usually set to 1 μf.

2.2.2 ATmega328p

ATmega328P is the heart of the design which is wired to HC-05 (through RX, TX) and servo motors (through PWM pins). It reads the serial data received from HC-05 and uses it as the control signal to program servo motors. It is powered by external 9V lithium battery going through a linear regulator.

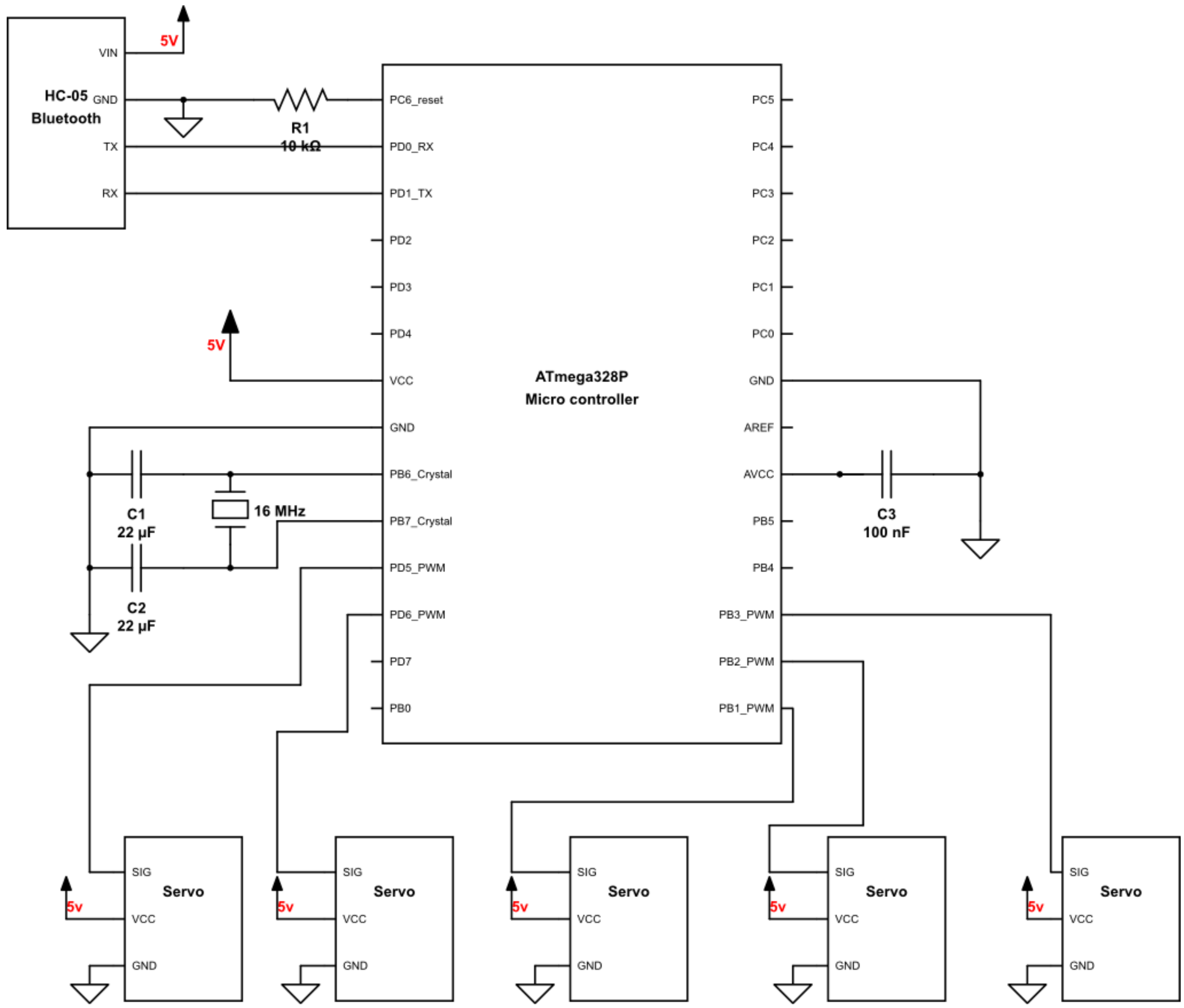


Figure 3

2.2.3 Bluetooth Module HC-05

HC-05 a small Bluetooth module device connecting to ATmega328P (Details in figure 3) which send signal to servo motors. The HC-05 has a breakout board with several pins on it. These pins are used to connect to PCB. Bringing KEY to high level before the power on (AT Command). The STATE tells if they are connects or not.

TX is connected to RX of ATmega328P and RX is connected to TX of ATmega328P for serial communication. The Bluetooth is powered by a 9V lithium battery and a linear voltage regulator.

2.2.4 Servo Motor

In our project we decide to use SG90 micro servo motor. The reason we use this type of motor is because it's cheap and small enough to put on the glove.

The signal pin accepts the control signal which is a Pulse Width Modulation (PWM) signal from the controllers that tell what angle to turn to. The length of the pulse corresponds to the angle the motor turns to.

The pulse width sent to servo ranges as follows: Minimum: 1 millisecond ---> Corresponds to 0 rotation angle. Maximum: 2 millisecond ---> Corresponds to 180 rotation angle. Any length of pulse in between will rotate the servo shaft to its corresponding angle. For example, 1.5 ms pulse corresponds to rotation angle of 90 degree. This is will explained in figure below.

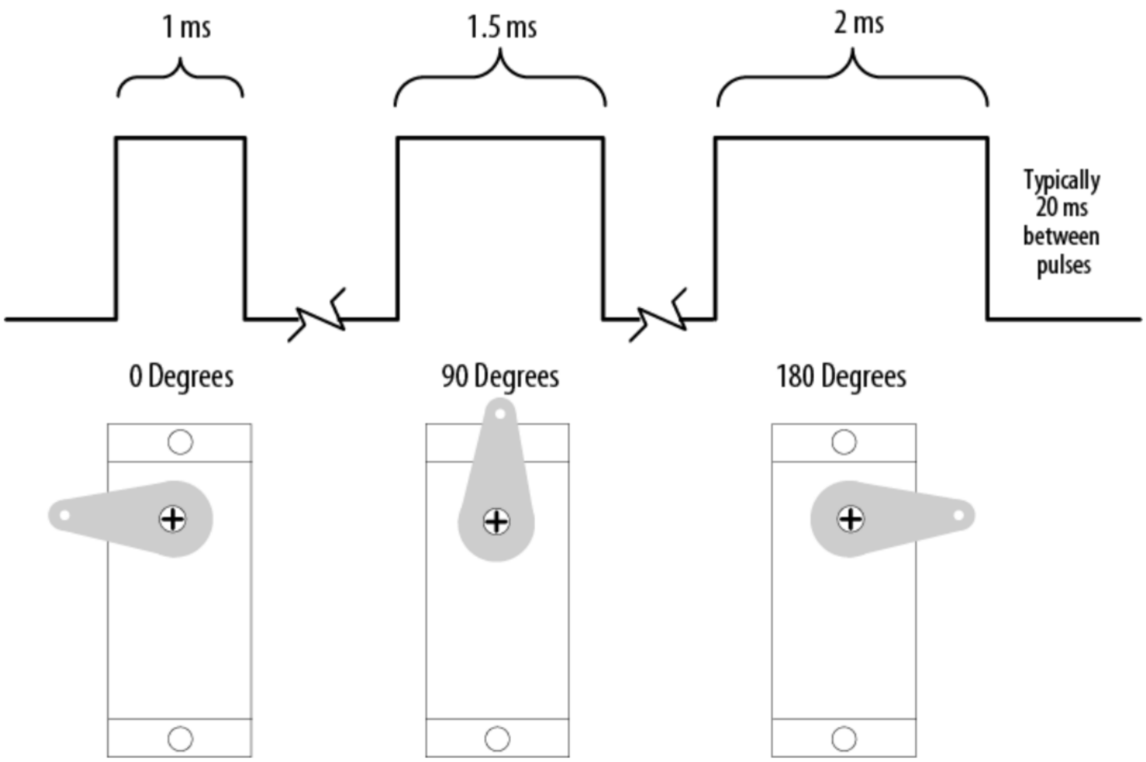


Figure 4

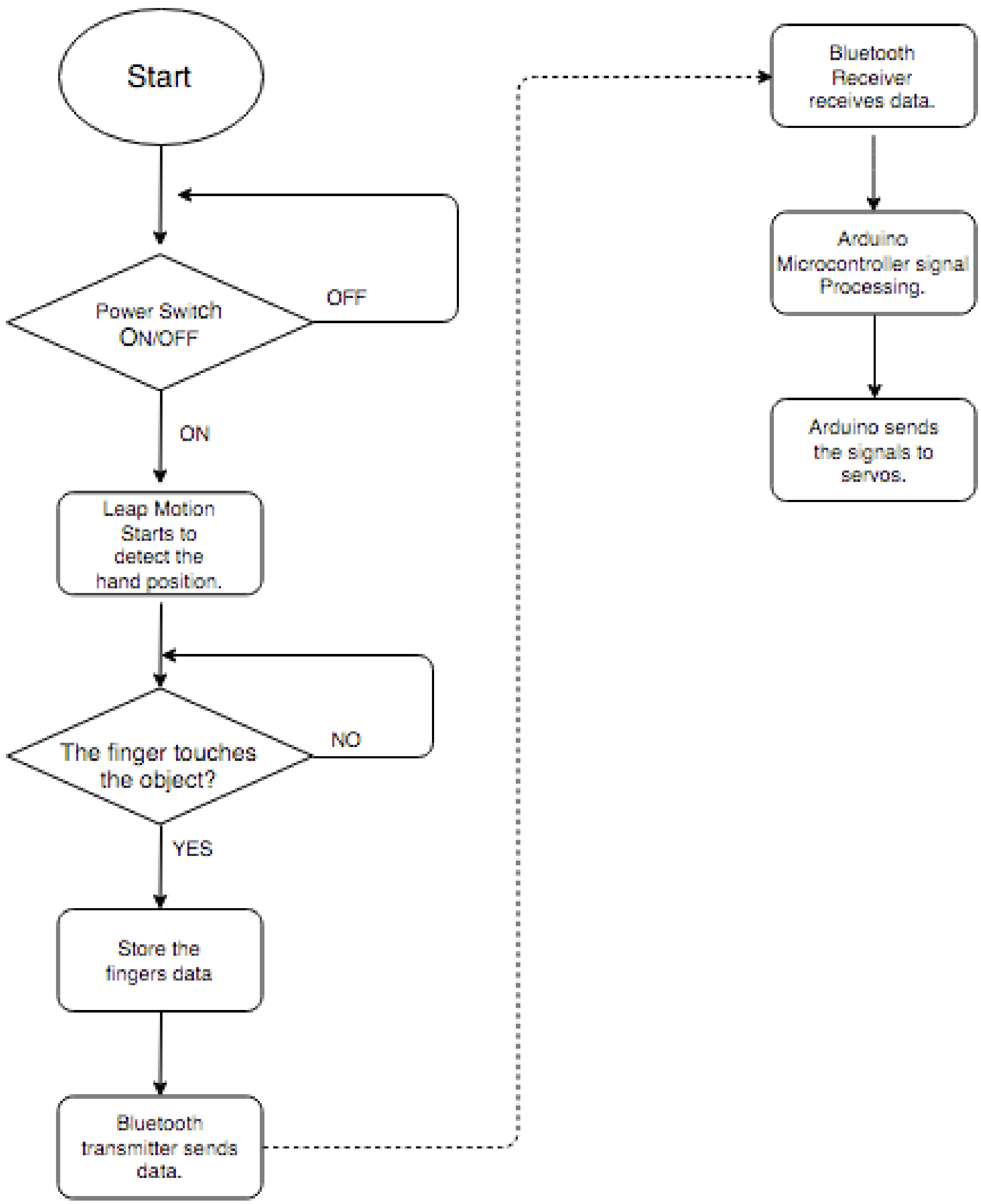
2.2.5 Bluetooth Transmitter in computer

Using computer's Bluetooth or Bluetooth dongle to send data back and forth between PC and microcontroller via Bluetooth module HC-05 transceiver.

2.2.6 Leap Motion Hardware and Interface

Computer will supply 5v to the leap motion controller via USB2.0 cable. On the computer, we will build a virtual environment using c# in the leap motion SDK in which we can read and store the position data of fingertips and curvature of hand into computer. And we will write a c# program to communicate with the microcontroller and deal with the data from the leap motion.

2.3 Flow Chart



3. Requirement and Verification

3.1 Table of Requirement and Verification

Requirements	**Verification**	**Points**
1. **Power Supply** a. All Lithium battery provide 9V +/- 0.25V output voltage. b. Linear Voltage regulator should be able to provide 5V +/- 0.25V output voltage for servo motors. c. Lithium battery and voltage regulator should work properly under a maximum of 500 mA for an hour.	1. **Power Supply** a. Use digital multimeter to measure the output voltage, and it should read 9V +/- 0.25V.(2) b. Use digital multimeter to measure the output voltage after conversion, and it should read 5V +/- 0.25V.(3) c. Connect a 10 ohm resister in the power supply circuit, use a digital multimeter to measure the current and monitor if it reads 500mA +/-25mA for an hour.(5)	10
4. **Bluetooth Transmission** a. The Bluetooth in Laptop should catch the signal from computer program and transmit it to HC-05. b. The Bluetooth transmitter should be able to transmit data within 10 meters. c. The Bluetooth should be able to communicate in baud rate 38400 (bps).	**4. Bluetooth Transmission** a. Transmit 1 and 0 alternatively and program arduino to activate LED when receives 1 and see if the LED is blinking continuously.(4) b. Take the transmitter 9.9 meters away and check whether the system is still working.(5) c. Transmit the date to HC-05 and transmit back to laptop. It should transmit and receive data in 38400 bps.(6)	**15**
3. **Micro controller** a. Pin PD5~6, PB1~3 must output PWM signals with the peak-to-peak voltage of 5V +/-0.5V, 50Hz, 2ms pulse width b. Must read correct data from HC-05 from RX	3. **Micro controller** a. Write test code and use an oscilloscope to check the output of the digital pins to see if it is the corresponding signal.(10) b. Send simple 1 and 0 signal to Bluetooth alternatively at every second and output the signal to a LED tester and see if it's blinking.(15)	25

4. **Servo Motor** a. Battery: Each motor draws 4.8+/-0.2 V voltage from power supply b. Rotation: Servo motor rotates the exact angle corresponding to the signal from microcontroller c. Speed: Servo motor rotates between 20~40 rpm d. Current: Each motor draws 220+/- 20mA current	a. Using voltmeter to connect motor in parallel and measure the voltage. Record the voltage and compare with desired one(5 pts) b. Programing on microcontroller. Giving pulse 1ms; 1.5ms; and 2ms, which will give rotation correspondingly. (5) Giving a force (< 5N) to encounter the servo motor. Record the final position the servo motor is at. (5) c. Using an optical tachometer and verify the speed is fall within this range(5) d. Using ammeter to connect motor in series and measure the current. Record the current and compare with desired one. (5)	25
5.Leap motion: a. The leap motion hardware is compatible with the computer. b. The leap motion app could store the vector data of each finger as a csv file correctly into the computer. c. The leap motion app is able to identify the fingers and curvature of the fingers precisely (+/-5mm the range of errors). d. The app is able to tell whether each finger touches the virtual object correspondingly. Return a five digit binary number with each digit representing each finger. For example, 10000 means only the thumb touches the object.	**5.Leap motion:** a) Set up the leap motion software on the computer and connect the leap motion controller with computer. Test using the motion visualizer within leap motion SDK (and pre-loaded demos). b) Launch the app of the project, place your right hand above the leap motion (palm towards table) with five fingers stretched out. Move your hand in 3 directions of 50mm respectively. Compare the results with those of the csv file. c) Put the right hand above the leap motion within 2 feet, with palm towards the table and fingers stretched out. Record roughly the position of each finger so that one can tell and identify them from the records and compare them with the file. And curve your hand as if it is holding a men’s basketball (4.7inches ~119.38mm), and then compare it to the corresponding values in the file. d) Touch the virtual object with each finger one by one. And the file should output the corresponding number: 10000, 01000,00100,00010,00001.	**25**

3.2 Tolerance Analysis

3.2.1 Power Analysis

The capacity of our battery is 750mAh. To operate all the servos it needs 1100 mA +/- 100mA. ATmega328P and HC-05 draw a total of 100mA maximum.

For battery 1 which powers the microcontroller, Bluetooth and servo1:

Maximum current: 100mA + 240mA = 340mA.

Minimum time: 750mAh / 340mA = 2.2 hrs

For battery 2&3 which power two servo motors:

Maximum current: 240mA * 2 = 480mA.

Minimum time: 750mAh / 480mA = 1.56 hr

If we take the minimum running time for three batteries, our system will be active for at least 1.56 hour.

3.2.2 Bluetooth Transmission Distance

According to the datasheet, the Bluetooth receiver has typically -80dBm sensitivity and up to +0dBm RF transmit power. And as we know that Free-space path loss formula is FSPL (dB) = 20 log10(d) + 20 log10(f) − 27.55 where d is our distance between the transmitter and receiver in meter, and f is the signal's frequency in MHz which is 2400MHz thus 80 = 20 log10(d) + 20 log10(2400) − 27.55 d ≈ 100(m) That means we can use this mouse in 100 meters.

3.2.3Interaction Area of the Leap Motion

The interaction area of our device will be 2 feet above of the controller by 2 feet wide on wach side(150 degree angle), by 2 feet deep on each side(120 degree angle).

The fingertip position data are stored as vectors by the leap motion controller into the computer. And the data are read in mm and accurate to 3 decimal places.

However, to tell whether or not your finger is touching the virtual object, the precision range varies, which we specifically tested during the grab cubes demo. In other words, the precision sometimes could be off, but could be corrected by redoing the movement.

X	Y	Z	Speed
-22.220	184.767	103.636	0.713
16.831	205.137	28.863	2.987
43.414	207.094	17.486	14.291
81.107	202.326	25.675	8.818
109.708	189.766	51.452	4.205

Figure 6

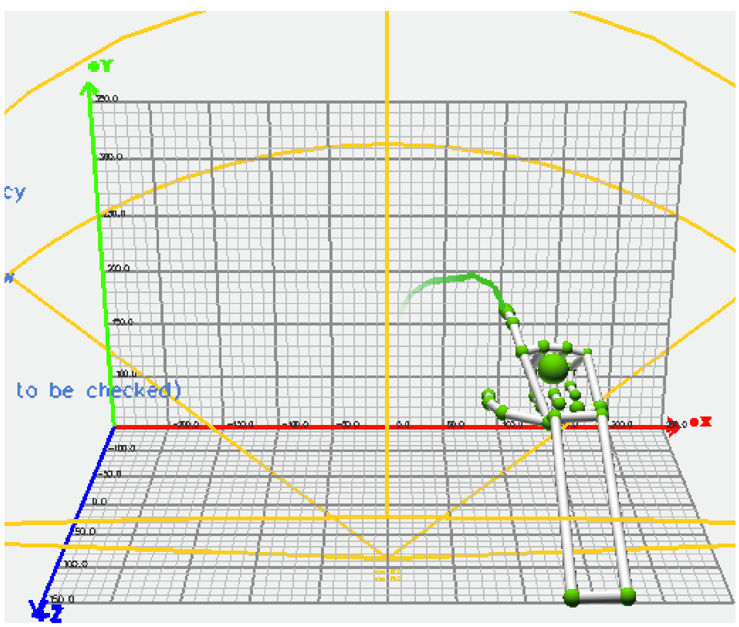


Figure 7

3.2.4 Latency

The latency of the leap motion is about 30milliseconds based on its official site.

3.2.5 Error analysis of fingers propagation in 3 directions

We tested the tracking precision of the leap motion in its x, y, z directions.

group1: fingertip moved in negative y direction with finger straight.

group2: fingertip moved in positive x direction with finger straight.

group3: fingertip moved in positive z direction with finger curves inwards.

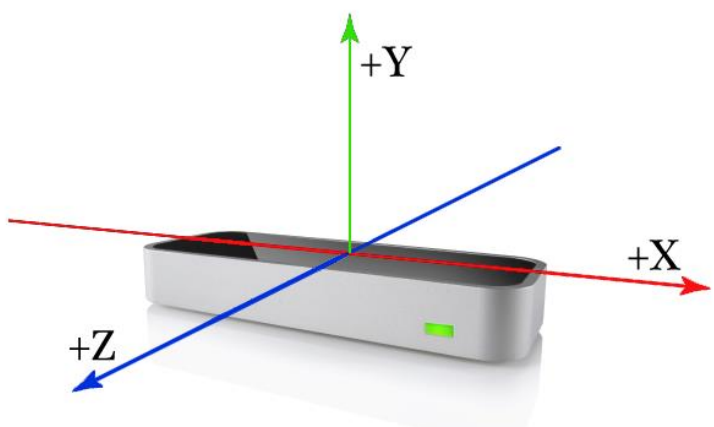


Figure 8

test number	Delta Y(IN Leap Motion)	Actual Distance	Difference	Average
group1(y axis)	175-128=47mm	46mm	1mm	
group1(y axis)	175-136=39mm	46mm	7mm	
group1(y axis)	175-132=43mm	46mm	3mm	3.667mm
group2(x axis)	32+47=79mm	73mm	6mm	
group2(x axis)	50+24=74mm	73mm	1mm	
group2(x axis)	55+24=79mm	73mm	6mm	4.333mm
group3(z axis)	61-26=35mm	35mm	0mm	
group3(z axis)	68-24=44mm	35mm	9mm	

group3(z axis)	55-27=28mm	35mm	7mm	5.333mm

As a result, fingers curving in z axis will cause the most errors with a range of +/-5.333mm than translations in y (+/-4.333mm) and x (+/-3.667mm) directions.

4. Cost and Schedule

4.1 Cost Analysis

4.1.1 Labor:

Name	**Hourly Rate($)**	**Total Hour Invested(hrs)**	**Total($)**
Lei Wang	**25.00**	**225**	**5625.00**
Jiayi Wang	**25.00**	**225**	**5625.00**
Chenhao Wu	**25.00**	**225**	**5625.00**
		675	**16875**

4.1.2 Parts &total:

Items	**Quantity**	**Cost($)**
Microcontroller ATmega328P	**1**	**24.95**
Panasonic Cr2025 Dl2025 3V Lithium	**1**	**1.24**
Parts Express 9V Battery Clip	**3**	**12.06**
American Weight Scale H110	**1**	**7.90**

SparkFun 5V Step-Up Breakout - NCP1402	**1**	**5.95**
Leap motion	**1**	**80.00**
Bluetooth module HC-05	**1**	**8.99**
servo motor SG 90	**5**	**20.00**
Skeleton Component	**/**	**30.00**
Linear Voltage Regulator LM317	**1**	**1.59**
PCB	**/**	**0**
Resistor	**Assorted**	**0**
Capacitor	**Assorted**	**0**
Total		**192.68**
Total with labor		**17,067.68**

4.2 Schedule

WEEK	**TASK**	**DUTY**
Feburary 10th	**Finalize Proposal**	**All**
Feburary 18th	**Prepare Mock Design Review**	**Lei Wang**
Feburary 25th	**Research about Leap Motion interface**	**Chenhao Wu**
Feburary 25th	**Research about bluetooth transmission and servo motor**	**Lei Wang**
Feburary 25th	**Research about microcontroller and skeleton control**	**Jiayi Wang**
March 3rd	**Order leap motion and set up leap motion interface**	**Chenhao Wu**
March 3rd	**Order servo and measure the servo wing length**	**Lei Wang**

March 3rd	**Design the connection of the microcontroller and write skeleton code for arduino; order parts**	**Jiayi Wang**
March 7th	**Design servo motor with the glove & the connection string**	**Lei Wang**
March 7th	**Calculate leap motion latency& error**	**Chenhao Wu**
March 7th	**Redesign pcb with ATmega chip**	**Jiayi Wang**
March 19th	**Progam interface of leap motion and drag out/store the signal from Leap Motion environment**	**Chenhao Wu**
March 19th	**pre-test servo motor & start build into glove**	**Lei Wang**
March 19th	**Finish PCB design**	**Jiayi Wang**
March 26th	**Transmit data to bluetooth module on PCB**	**Chenhao Wu**
March 26th	**Finish servo built-in**	**Lei Wang**
March 26th	**Finish code for microcontroller**	**Jiayi Wang**
April 2nd	**Debug and make sure microcontroller receive data and produce PWM properly**	**Jiayi Wang**
April 2nd	**Post-test servo motor to make sure string, motor and every other components work fine**	**Lei Wang**
April 2nd		**Chenhao Wu**
April 14th	**Prepare Mock demo**	**Lei Wang**
April 21st	**Prepare Demonstration**	**Chenhao Wu**
April 28th	**Prepare Presentation**	**Jiayi Wang**
May 5th	**Lab checkout & Finalize Paper**	**All**

5. Ethics & Safety Analysis

5.1. Safety Analysis

We will use servo to implement the skeleton. Because servo motors allow precise angular positioning of their output shaft, it is possible that the servo motors position our fingers to the places that might hurt ourselves.

We randomly choose 20 people (10 men and 10 women) from campus and test their tolerance with electronic scales by pulling their fingers as much as possible

Note this result may not be comprehensive since we only choose 20 people to do the test. We decide not to average the entire data since, by observing the data, tolerance of women's fingers is generally smaller than tolerance of men's fingers. However, we decide to delete the maximal and minimal values of women's group and then average them only. The average value we calculate is 5.194 N. Here we no longer consider man's data anymore. Therefore, we decide to make the maximal value to be 5N.

We also consider the minimal force that the string must have to be capable of pulling our finger. Actually, since we do all our work in virtual world, we don't actually apply any forces in real life. For example, we can push/grasp/touch objects without push/grasp/touch anything in real world. Therefore, according to Newton's Third Law that for every action, there is an equal and opposite reaction. Since we do not apply any forces in the first place, then the minimal force to pull our fingers is 0N.

For the string, we did an experiment shown below. With unchanged wrist angle, the two extreme opposite positions have different string lengths. The difference is 1.3 cm. Then converting to the angle that the servo motor rotates, which is approximately 74.5 degree.

Conclusion:

The force range is 0N~5N. (Note that we don't need inward force in our project). The range of rotation is 0 ~ 74.5 degree.

Figure9

Figure10

5.2 Ethics Analysis

We commit ourselves to the highest ethical and professional conduct and agree the following:

1. To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

2. To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;

3. To be honest and realistic in stating claims or estimates based on available data;

4. To reject bribery in all its forms;

5. To improve the understanding of technology; its appropriate application, and potential consequences;

6. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

7. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

8. To treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;

9. To avoid injuring others, their property, reputation, or employment by false or malicious action;

6. Reference

1) Figure 1: YouTube channel: https://www.youtube.com/watch?v=XICTT-mTtco

2) Arduino and Bluetooth Connection: http://www.instructables.com/id/Arduino-AND-Bluetooth-HC-05-Connecting-easily/

3) Arduino UNO data: https://www.arduino.cc/en/Main/ArduinoBoardUno

4) ATmega328P:http://www.atmel.com/images/Atmel-8271-8-bit-AVR-Microcontroller-ATmega48A-48PA-88A-88PA-168A-168PA-328-328P_datasheet_Complete.pdf

5) Leap Motion: Leap

6) Battery: http://www.homedepot.com/p/Energizer-9-Volt-Advanced-Lithium-Battery-LA522SBP/202252832

7) Servo motor:

http://www.micropik.com/PDF/SG90Servo.pdf

8) Voltage Regulator: http://www.instructables.com/id/5v-Regulator/

9) HC05 Bluetooth: http://www.robotshop.com/media/files/pdf/rb-ite-12-bluetooth_hc05.pdf