Prosthetic Hand for Typing

ECE 445 Design Document

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1 Introduction

1.1 Objective

In the 21st century, computers are essential in our society for working, learning, and absorbing information. Typing is fundamental to using a computer and current affordable prosthetics cannot be used for typing, so the user has to type with just one hand. This severely reduces efficiency and makes it hard for people with prosthetic arms to work on a computer. While the prosthetics industry is constantly evolving and making revolutionary products, current prosthetics are expensive and not readily available to the public **[1]**. Our goal is to create an affordable solution that improves the typing experience for people with only one hand. We will create a prosthetic hand that allows the user to type by tapping buttons with their feet.

We propose a solution that consists of two main components: a prosthetic hand, and foot buttons that can be used to send signals that control the fingers on the hand. The foot buttons and prosthetic hand will communicate using bluetooth protocol to ensure low latency and good responsiveness. Each time the user taps one of the foot buttons, the corresponding finger on the prosthetic hand will rotate downward and press a key on the keyboard.

The prosthetic hand will be made out of a lightweight metal such as aluminum to ensure that it is easy to move, while still remaining durable and able to mechanically withstand hundreds of hours of usage. The four servos will be mounted adjacent to each other, and we will use bevel gears to change the angle of rotation. An axle will be placed above the motors to allow the bevel gears to rotate in a vertical motion. Attached to each vertical bevel gear will be a metal finger that has a rubber stopper on the end. The servos will be controlled by a microcontroller that will also serve as a communication bridge between the buttons and the hand.

There will be four foot buttons to control the four fingers on the prosthetic hand. There is no need for five buttons and fingers because the thumb is generally used for the space bar, which the user can use their other hand to press. The buttons will be mounted to a base and will be spaced out evenly, so the user does not accidentally press the wrong button. The buttons will act as sensors and will be connected to a microcontroller on the foot button system that will send a bluetooth signal to the microcontroller on the prosthetic hand.

1.2 Background

For patients without health insurance, a prosthetic hand typically costs no less than $5,000 for a purely cosmetic arm, up to $10,000 for a functional prosthetic arm that ends in a split hook, and up to $20,000-$100,000 for an advanced myoelectric arm, controlled by muscle movements with a functioning artificial hand **[2]**. These costs are reduced for patients with health insurance, but the overall price still remains in the thousands. The myoelectric arm is the only arm capable of typing on a keyboard. Even the most expensive prosthetic hands offer only predefined gestures, so BrainCo's recent announcement of a prosthetic hand that works with brain waves and muscle signals allowing the user to train the prosthetic to perform an unlimited number of gestures is a huge stride in the industry **[3]**. The prosthetic hand is reported to cost between $10,000 to $15,000, which is much cheaper than competing prosthetics. This prosthetic would give users the ability to type along with other functionality, but still comes at a high price. Our design does not aim to compete with an advanced prosthetic hand such as the one that BrainCo has created, but serve as an affordable tool for typing. Additionally, our solution can be modified to serve a variety of problems that require similar functionality, such as playing the piano or the tabla.

1.2 Visual Aid

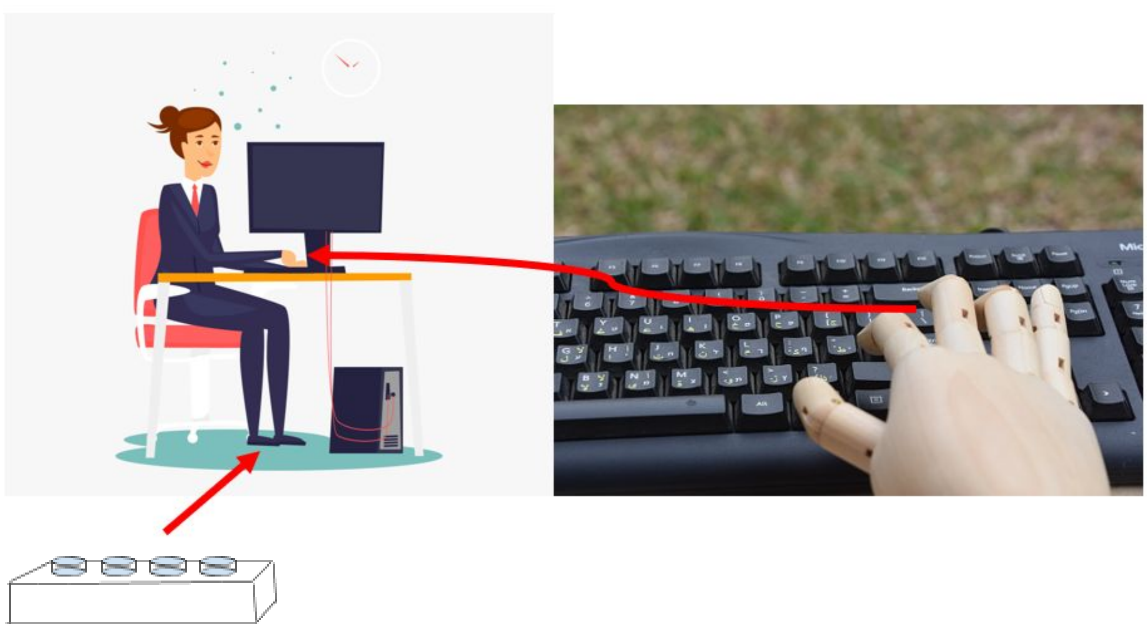

Figure 1. Visual Aid

1.3 High-level Requirements List

- The final design must be affordable and should cost less than $1000 to manufacture.

- The foot-to-finger response time should be less than 0.25s, so the user can comfortably type without noticeable delay.

- A user should achieve a typing speed greater than 25 words per minute when using the system. We want users to be able to type faster than they would be able to with just one hand. The average typing speed for someone with 2 hands is 41 words per minute **[4]**. When we tested ourselves with one hand, our team obtained an average of 25 words per minute.

2 Design

2.1 Block Diagram

The prosthetic hand and foot buttons are the two systems of the device. Both systems will have a battery charger, rechargeable batteries, microcontroller and bluetooth module. The prosthetic hand will have four servo motors and the foot button system will have four buttons. The parts we are planning to use total under $200, so the cost to manufacture the device will be well below the $1000 requirement. The bluetooth module of the foot button system will send a 3-bit signal to the bluetooth module of the prosthetic hand. This signal determines which servo motor will be rotated to initiate a key press. Bluetooth classic transfers data at 0.7-2.1Mbps **[5]** and the device only needs to transfer three bits at a time, which will take much less than 0.25s. The servo motors will be attached on top of the hand and connect to a gear and axle system that will move the fingers to press the keys. This motion will be rather quick as the fingers should be hovering over the keyboard and will not require a large angle of rotation to make the press.

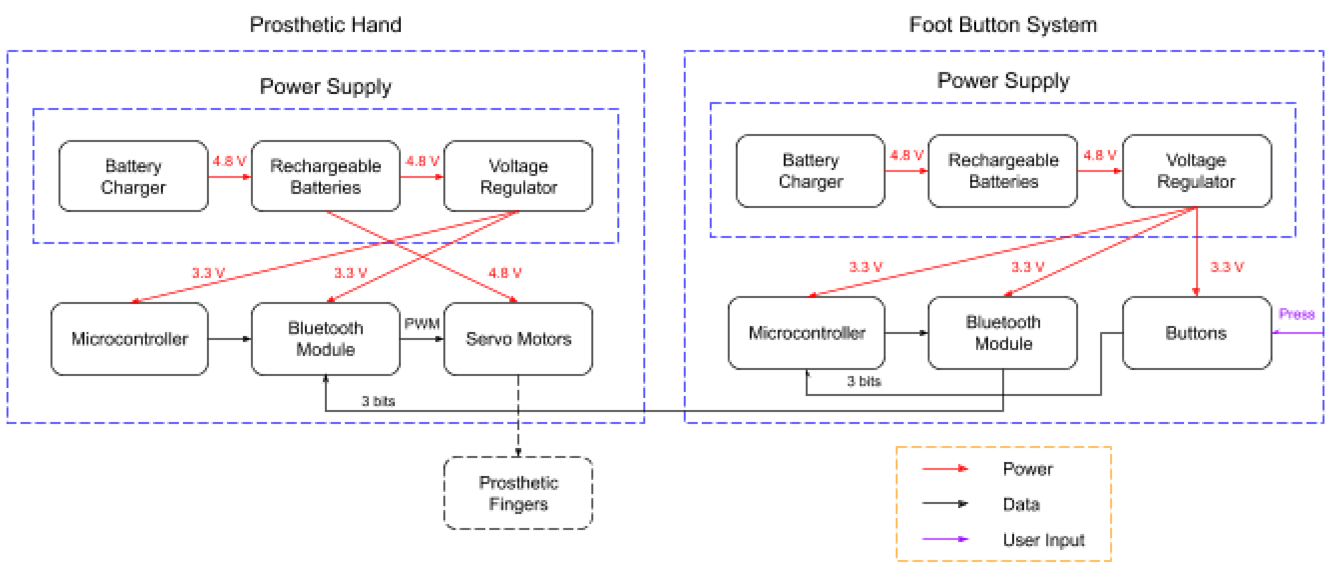

Figure 2. Block Diagram

2.2 Physical Design

The 3D model below is what the mechanical components of the prosthetic hand will look like when put together. The vertically-aligned bevel gears allow the servo motors to be placed side-by-side and minimize the amount of space used. Each servo motor has a width of 19.81mm, so all four together will take up about 80mm when we account for space between each servo motor. The average male adult has hands with a breadth of 3.5 inches, while for females it is about 3.1 inches **[6]**. The prosthetic hand will have similar dimensions to the average hand because 80mm is about 3.15 inches. We want people using the device to feel as if they are typing with two hands, so a prosthetic hand of comparable size to average hands is ideal.

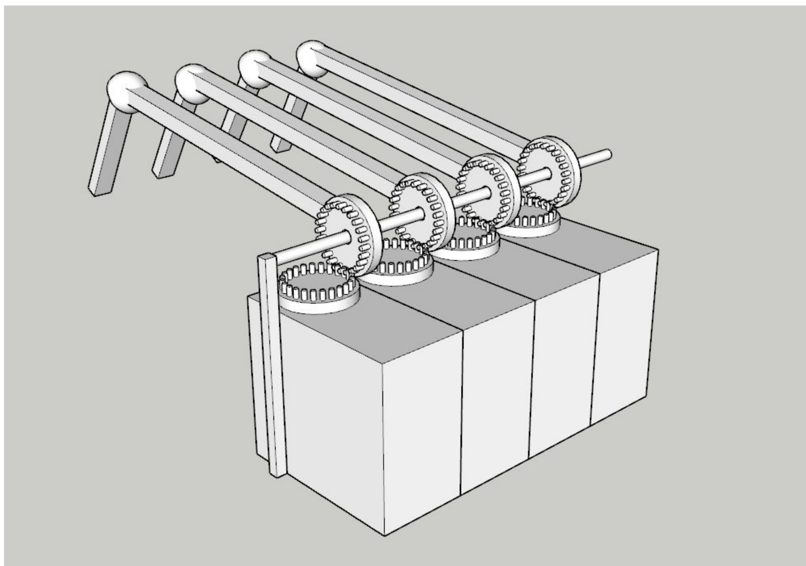

Figure 1. CAD Prosthetic Hand

The 3D model below displays the design of our foot button system. Since the buttons need to be spaced out, we are aiming for a design that is 24” x 6” x 2”. Each button will have a diameter of two inches for easy pressing. We will use momentary push buttons to capture the press from the user.

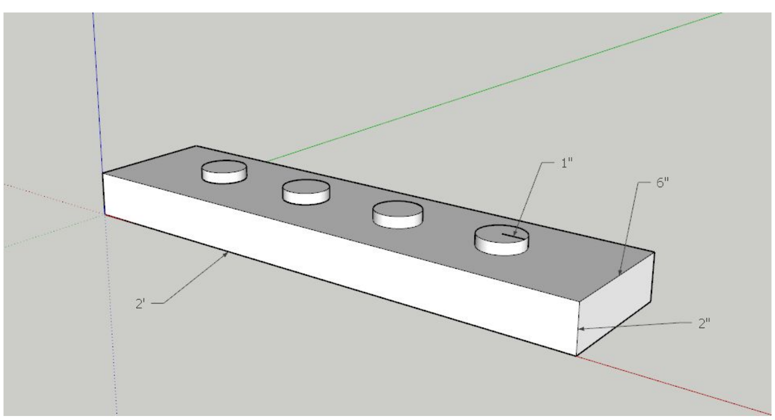

Figure 2. CAD Foot Button System with Ideal Dimensions

The circuit schematics below show fundamental components that will run our prosthetic hand and our foot button system. Both circuits are essentially the same, except that one of the circuits has a Bluetooth slave module and sensors, while the other has a Bluetooth master module and the servos. Note that the voltage regulators are not sources, but rather step-down voltage regulator IC's.

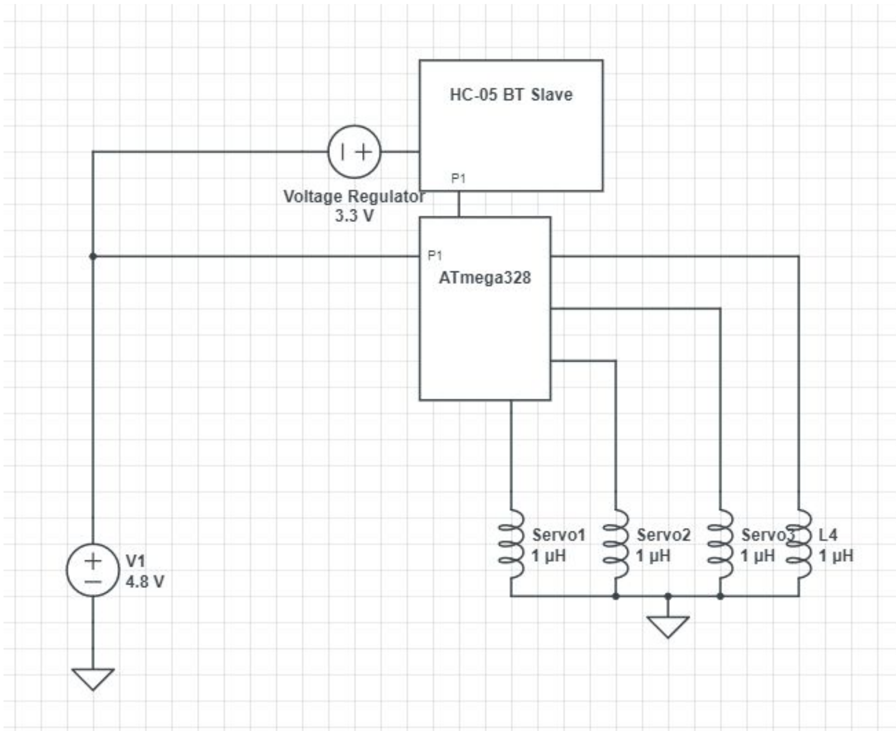

Figure 3. Prosthetic Hand Circuit

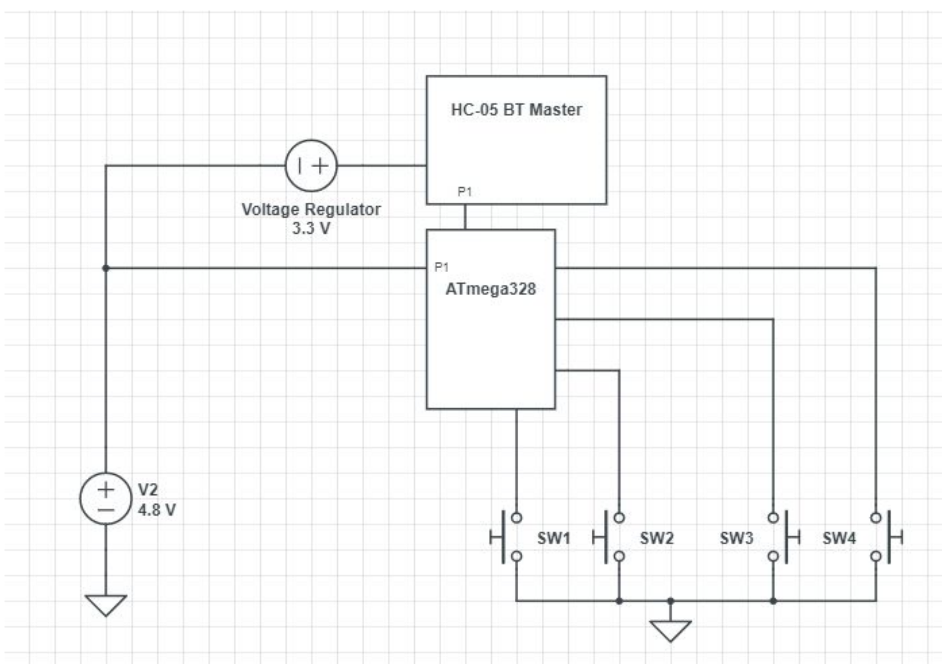

Figure 4. Foot Button Circuit

2.3 Power Supply

2.3.1 Battery Charger

Two battery chargers will be used to charge the two sets of four rechargeable batteries of the prosthetic hand and foot button system. The chargers will be powered by a wall outlet and should be able to fully charge the batteries in 3-5 hours.

Requirement	Verification
1. Each AA battery charges to 1.2V +/- 5% in under five hours	1. A. Place the batteries in the chargers and set a timer for five hours; B. Remove the batteries and use a DMM to verify the voltage of each battery is 1.2V.

2.3.2 Rechargeable Batteries

For each system, we will use four AA NiMH rechargeable batteries that will supply 1.2V each. In series, this will supply the 4.8V needed to operate the servo motors of the prosthetic hand with minimal power consumption. For the prosthetic hand, the 4.8V will feed into the voltage regulator to step down to 3.3V for the microcontroller and bluetooth modules which is enough voltage to run the microcontroller at 8MHz. Our servos have a max current draw of 160mA each, so they will draw at max 640mA from the battery if they are all rotating at the same time, and the microcontroller draws anywhere between 20-80mA. The bluetooth module will draw a current less than 20mA, so the maximum total current draw will be ~700mA/hr. Assuming the servos are only operating half the time, the draw will be closer to 350mA/hr. Since we want our hand to operate for at least three hours at a time, the batteries should have at least 1050-2400mAH of charge. For the foot button system, the 4.8V will feed into the voltage regulator to step down to 3.3V for the microcontroller, bluetooth module and buttons.

Requirement	Verification
1. Outputs at least 4.8V; 2. Stores at least 1.05AH of charge.	1. Place four batteries in the battery holder and connect to a DMM to ensure that the total voltage is at least 4.8V. 2. A. Connect the positive terminal of the battery to a voltage source of 4.8V and negative terminal to ground. B. Discharge the battery at 350mA for three hours. C. Use a DMM to ensure that the battery

	voltage remains about 4.8V

2.3.3 Voltage Regulator

The voltage regulator for the prosthetic hand will step down the voltage from 4.8V for the servos to 3.3V for the microcontroller and bluetooth module. The voltage regulator for the foot button system will step down the voltage from 4.8V to 3.3V for the microcontroller, bluetooth module and buttons.

Requirement	**Verification**
1. Takes a 4.8V input voltage and outputs 3.3V with at least 80mA current at one node.	1. A. Connect a power supply to the regulator and feed in 4.8V; B. Check other pin with a DMM to ensure output voltage is 3.3V +/- 5%.

2.4 Prosthetic Hand

2.4.1 Microcontroller

We will be using the same microcontroller for both of our systems, which is the ATmega328P from the Arduino Uno. The microcontroller will be connected to both a bluetooth module and the four servo motors. It will send PWM signals to the corresponding servo motors whenever the bluetooth module receives a signal from the foot button subsystem.

Requirement	**Verification**
1. Must be able to communicate with the HC-05 Bluetooth module; 2. Must send PWM signal to control servo motors.	1. Connect the HC-05 Bluetooth module to the ATmega328P chip and use the Arduino serial monitor to ensure there is a communication bridge; 2. A. Connect oscilloscope to the analog pins and send PWM signals to those pins B. Check oscilloscope to verify that PWM signals are accurate.

2.4.2 Bluetooth Module

The Bluetooth module we will be using is the HC-05, which will give the ATmega328P bluetooth capability. The HC-05 on the hand will be the slave, and will receive three bit signals from the master on the foot button system. Bluetooth is capable of 0.7-2.1Mbps data transfer rates, which far exceed our requirements.

Requirement	**Verification**
1. The module must be able to receive at least eight 3-bit message bursts per second via SPP protocol.	1. A. Connect HC-05 bluetooth module to Arduino Unos and establish link; B. Send this HC-05 module eight messages per second for 10 seconds, monitoring Arduino serial port to ensure successful retrieval of all messages.

2.4.3 Servo Motors

There will be four HS-311 servo motors mounted to the prosthetic hand, each one controlled by the microcontroller. The servos will rotate a set angle whenever the bluetooth module on the ATmega328P receives a signal from the foot button system. We chose the HS-311 servos because they are reliable and have a travel time of .107°/µsec **[7]**, so they will be able to rotate the 30° required to push a button in about 300µsec.

Requirement	**Verification**
1. Must be capable of a 30° revolution within 10ms of receiving a PWM signal; 2. Must be capable of four 30° revolutions per second.	1. Use a signal generator to generate PWM signals of increasing duty cycle and record the corresponding servo revolution angles; 2. Once we have mapped a duty cycle to angle relationship, send four instructions to rotate the servo +30°, -30°, +30°, -30°, evenly sent over one second and ensure that it follows instructions accurately.

2.5 Foot Button System

2.5.1 Microcontroller

We will be using the same microcontroller for both of our systems, which is the ATmega328P from the Arduino Uno. The microcontroller will be connected to a bluetooth module and the four buttons. When a button is pressed, the microcontroller will receive a 3-bit signal from the foot button system indicating which finger should be moved.

Requirement	Verification
1. Must be able to communicate with the HC-05 Bluetooth module; 2. Must receive 3-bit signal from buttons when pressed.	1. Connect the HC-05 Bluetooth module to the ATmega328P chip and use the Arduino serial monitor to ensure there is a communication bridge; 2. A. Connect oscilloscope to the analog pins and send 3-bit signals to those pins; B. Check the oscilloscope to verify that signals are accurate.

2.5.2 Bluetooth Module

The HS-05 bluetooth module is the same one we will be using on the prosthetic hand, but this one will serve as the master and send three bit signals to the slave on the prosthetic hand whenever one of the buttons is pressed.

Requirement	Verification
1. The module must be able to send at least eight 3-bit message bursts per second via SPP protocol.	1. A. Connect HC-05 bluetooth modules to Arduino Unos and establish link; B. Send eight messages per second from this HC-05 module for 10 seconds, monitoring Arduino serial port to ensure successful retrieval of all messages.

2.5.3 Buttons

We will be using pushbutton switches placed on the surface of the foot button system. To indicate which button has been pressed, a three bit signal will be sent to the microcontroller on the foot button system. The buttons in our cost analysis are 30mm in diameter. To achieve bigger buttons, we will create button caps that are two inches in diameter and attach them to the buttons.

Requirement	Verification
1. Must be comfortably pressable with feet. 2. Must not be able to accidentally press two buttons with the same foot.	1. Measure the diameter of the button to verify it is at least two inches; 2. Press the button to make sure it can be done without hitting another button by mistake.

4 Discussion of Ethics and Safety

While we do not anticipate many safety hazards during this project, we have identified possible sources of danger that we need to keep in mind while working on the project. They include the overheating of servo motors that are being used to drive the fingers, the malfunction of servo motors causing mechanical dysfunction of the fingers which may harm the user of the prosthetic hand, and the improper discharge of batteries being used to power the controllers for our motors and foot buttons. Another potential safety hazard is the material of the prosthetic hand. We plan on using a lightweight metal like aluminum for the hand, which can be sharp or conductive and can cause injury if used carelessly. We can help mitigate some of these dangers by adding a plastic coating or encasing for the hand, which will both insulate the user from the electronics on the hand, as well as make the hand look more aesthetically pleasing.

We have met with the machine shop, and have come up with a design for the hand that will minimize the potential risks to the user. In order to avoid the risk of electric shock, we will only be using 6V to power our entire system - 5V per Arduino microcontroller and 6V to drive the servo motors attached to the hand. By keeping our maximum voltage at 6V, we should never overdrive the servos and avoid most mechanical issues that could arise from servo malfunction. Also, by keeping the voltage relatively low, there should never be enough current in our system to harm the user of the hand. Keeping the voltage low will also help with regulating heat in the system and keeping the hand at a safe operating temperature.

In terms of ethical issues that we might encounter, we do not believe there are not many applicable guidelines from IEEE **[8]**, but these are the most relevant:

1. *to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment;*
9. *to avoid injuring others, their property, reputation, or employment by false or malicious action;*

Some of the ethical guidelines from ACM **[9]** are far more relevant to our project choice, such as:

1.1 *Contribute to society and to human well-being, acknowledging that all people are stakeholders in computing.*
3.7 *Recognize and take special care of systems that become integrated into the infrastructure of society.*

We believe that if we maintain proper caution during the assembly of the hand, we can mitigate the chances of causing harm to the users and their property, and avoid the ethical issues involving harm to the user entirely. Additionally, we will vigorously test the functionality of the prosthetic hand so that we do not accidentally break any keyboards. We assume full responsibility for the product that we put out, and will therefore take every possible step to mitigate the potential for our product to be abused.

We recognize that our product will be used mainly for the improvement of daily life for prosthetic users, and believe that the very spirit of our project echoes the underlying principles behind these codes. We also believe that our project has the potential to become incorporated into the lives of countless amputees and other members of society, and will therefore make every effort to make our product ethical and secure. Through rigorous testing and refinement of our design, we hope to achieve a product that will give prosthetics users more functionality and help make computers more efficient for them.

5 Citations

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