Prosthetic Hand for Typing

Team 1: Rahul Krishnan, Rohil Hatalkar, Vaidotas Marcinkevicius
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TA: Dhruv Mathur

Introduction

Objective

While the prosthetics industry is constantly evolving and making revolutionary products, current prosthetics are both expensive and not readily available to the public. The prosthetics that are available to the public do not have all the functionality that a person in the 21st century needs - for instance, most prosthetics cannot be used for typing on a keyboard and so the user has to type with just one hand, which severely reduces efficiency and makes it hard for people with prosthetic arms to work on a computer. Our goal is to improve upon the typing experience by creating a prosthetic typing device.

We propose a solution that consists of two components: a prosthetic hand, and foot pedals that can be used to send signals that control the fingers on the hand. We hope that with a little practice, the user can achieve typing speeds that are comparable to that of an average person.

It should be noted that a few alternate solutions currently exist. One handed keyboards could solve our problem, however these are rare, expensive, and do not pose a typing advantage over regular keyboards. Additionally, our solution can be modified to serve a variety of problems, such as playing the piano or the tabla.

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 or more for an advanced myoelectric arm, controlled by muscle movements, with a functioning artificial hand **[1]**. For patients with health insurance, these costs are reduced, but the overall price remains in the thousands. Additionally, the functionality of these hands are often limited. Currently, the most suitable prosthetic arm design is the Hero Arm which has a three motor design. Our design will be flexible and lightweight. Since it serves a singular purpose, one could consider the arm as a tool for typing rather than a limb replacement device.

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 500ms, so the user can comfortably type with minimal delay.
- Our target typing speed is 25 words per minute. We want the user 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 **[2]**. When we tested ourselves with one hand, our team attained an average of 25 words per minute, so that is the target to beat.

Design

Block Diagram

The prosthetic hand and foot pedals are the two systems of the device. Both systems will have a rechargeable battery, Arduino microcontroller and bluetooth module. The prosthetic hand will have 5 servo motors and the foot pedal system will have 5 buttons. The parts we are currently considering total around $135, so the cost to manufacture the device should be well below the requirements. Bluetooth classic transfers data at 1-3 Mbps **[3]** and the device only needs to transfer 5 bits at a time, which will take much less than 500ms. The servo motors will be attached to the knuckles of the fingers, so that when rotated they can press the key. This motion will be rather quick as the fingers should be hovering over the keyboard and will not require a large angle to make the press. The buttons on the foot pedal system will be at least two inches in diameter, as to promote quickly pressing buttons with our feet with limited error.

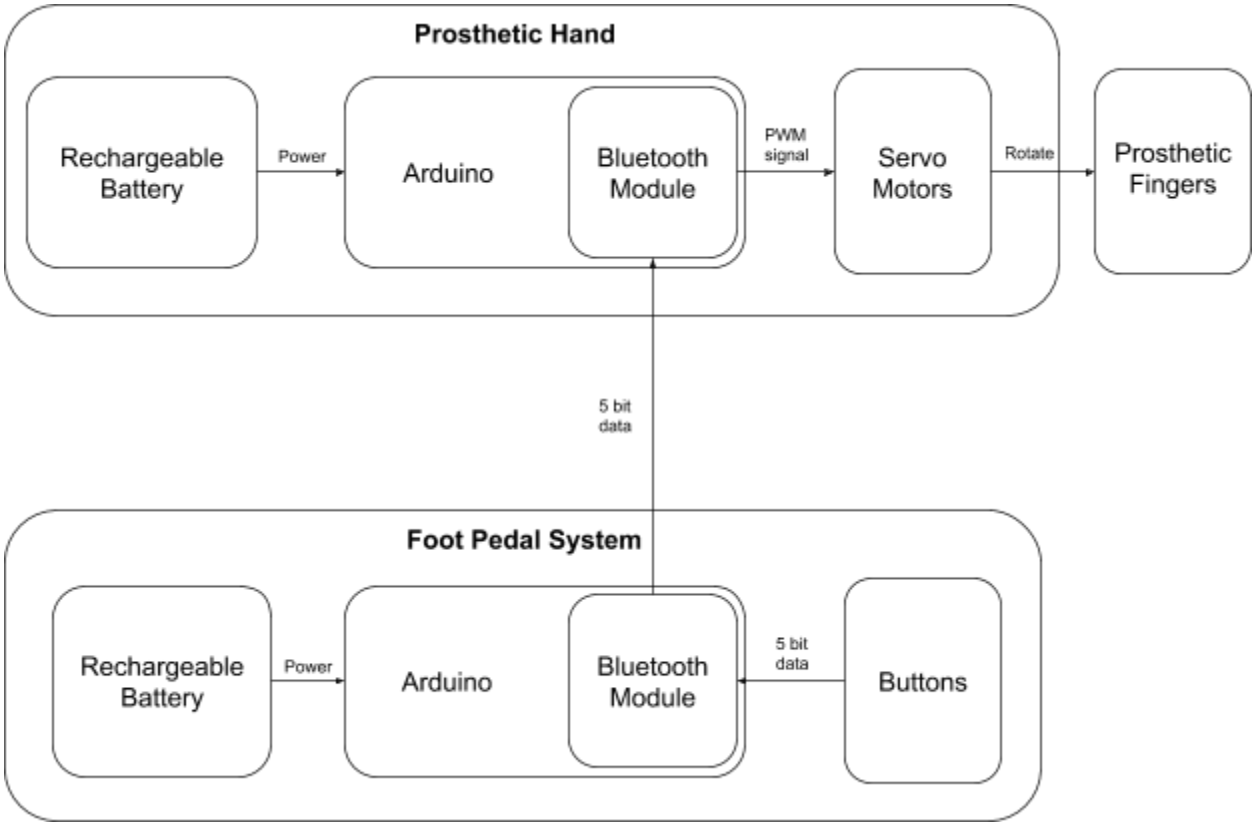
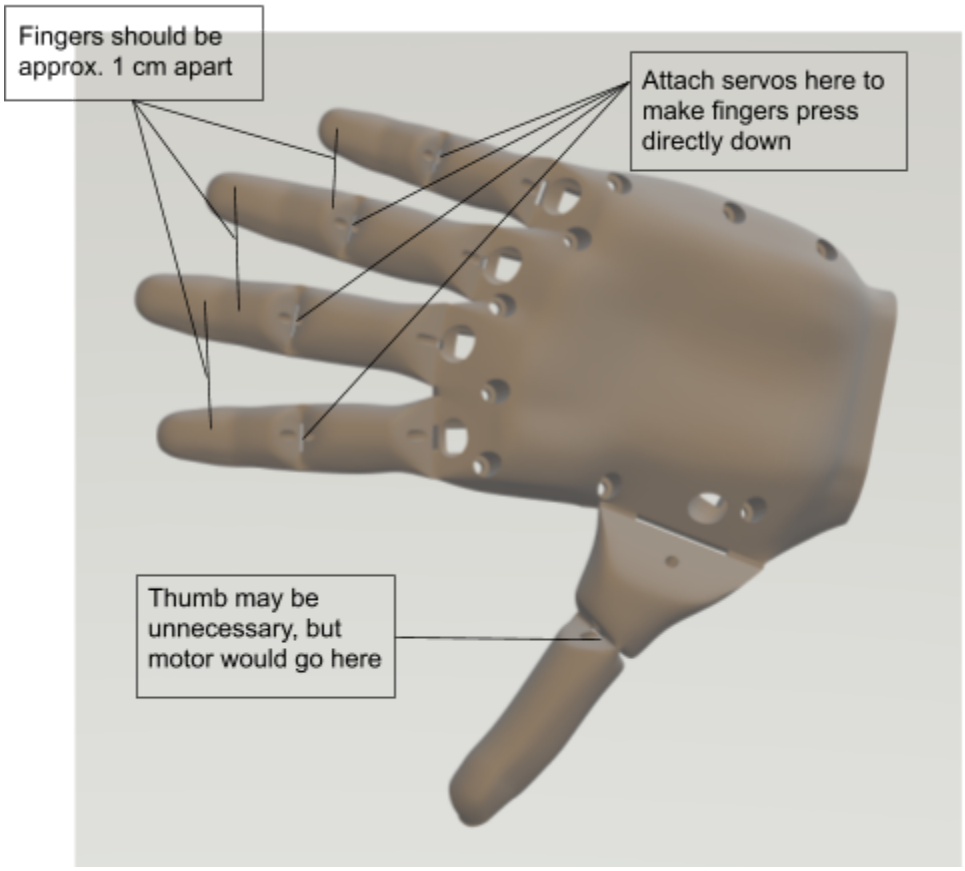


Figure 1. Block Diagram

Physical Design

For the physical design of our prosthetic hand, we are planning on having the machine shop create us a metal hand based on the design we have outlined. The hand will have fingers that are approximately 1 inch apart so that the fingers line up with the keys on the keyboard. The fingers will be separate from the hand and will be attached to servo motors at the end of each knuckle. Once the Arduino on the prosthetic hand receives the 5 bit signal from the foot pedal system, it will send a PWM signal to the servo motors allowing the fingers to rotate and press the keys.



Functional Overview

Foot Pedal System

Buttons:

Five buttons will be placed on the top of the foot pedal system corresponding to the fingers of the hand. When the user presses the button with their toe, the corresponding binary signal will be sent to the prosthetic hand that will complete the press on the keyboard.

- Requirement 1: The buttons should be easily pressable and at least two inches in diameter, so a toe can comfortably press the button.
- Requirement 2: The buttons have to be spaced out well, so multiple buttons are not pressed simultaneously.

Arduino:
The Arduino will take note of which of the 5 buttons is pressed and send a binary signal from the the foot pedal system to the prosthetic hand using the bluetooth module.

- Requirement 1: The Arduino must be able to support bluetooth.
- Requirement 2: It should have at least five I/O ports.

Bluetooth Module:
The bluetooth module on the foot pedal system must be able to send a 5 bit signal to the prosthetic hand quickly and with low latency. We do not want to limit the capability of the user, so we will assume a rate of 120 words per minute. If we would like to achieve a rate of 120 words per minute, with an average of 5 letters per word, the minimum time between key presses would need to be 60 seconds / 600 letters typed = 0.1 seconds/letter. We will aim to have the time from button pressed to key pressed to be well below this time.

- Requirement 1: The bluetooth module will require a range of 1.5 meters as we consider that to be the maximum height of a table.
- Requirement 2: The bluetooth transfer signal time along with the servo motor movement time should take less than 500ms.

Battery:
We will use rechargeable batteries to power the Arduino, bluetooth module, and five buttons. The battery will have to supply a voltage of at least 5V as that is the operating voltage for the Arduino. Therefore, we will keep all of our buttons below that voltage. The battery will be charged using a micro USB cable. Our preliminary design will simply use four AA rechargeable batteries to get 6V of power.

- Requirement 1: The battery should be at least 5V.
- Requirement 2: It must be able to power five buttons, and bluetooth capability for 6-8 hours.

Prosthetic Hand
Servo Motors:
Five motors will be attached to the joints of each finger. When the bluetooth module receives the binary signal from the foot pedal system, the Arduino will send a PWM signal to the servo motor that will rotate a specific angle to press the key.

- Requirements: 1200 rpm. If our prosthetic is capable of up to 120 words per minute, then the user should be able to comfortably type at all speeds under 120 wpm . Assuming an average of 5 letters per word, 600 letters per minute need to be pressed. Using the servos to rotate back and forth, they should be making two “revolutions” per letter. Therefore 600 letters per minute * 2 rotations per letter = 1200 rpm.

Arduino:
The Arduino on the prosthetic hand will receive a binary signal from the foot pedal system using the bluetooth module. It is then responsible for running the program to send a PWM signal to rotate the servo motors, so keys can be pressed.

- Requirement 1: The Arduino must be able to support bluetooth.
- Requirement 2: It should have at least five I/O ports.

Bluetooth Module:
The bluetooth module on the prosthetic hand must be able to receive a 5 bit signal from the foot pedal system and handle it quickly. This module needs to work in concordance with the servo motors at a speed of less than 500ms. Therefore, we will target the bluetooth module to take 250ms from button press to beginning of motor movement.

- Requirement 1: The bluetooth module will require a range of 1.5 meters as we consider that to be the maximum height of a table.
- Requirement 2: The bluetooth transfer signal time along with the servo motor movement time should take less than 500ms.
- Requirement 3: The signal should always be processed by the hand, so simultaneous presses should be buffered.

Battery:
We will use rechargeable batteries to power the Arduino, bluetooth module, and five servo motors. The battery will have to supply a voltage of at least 5V as that is the operating voltage for the Arduino. Therefore, we will keep all of our servo motors below that voltage. The battery will be charged using a micro USB cable. Our preliminary design will simply use four AA rechargeable batteries to get 6V of power.

- Requirement 1: The battery should be at least 5V.
- Requirement 2: It must be able to power five servo motors and bluetooth capability for 6-8 hours.

Risk Analysis

The most volatile block in our design will be the Bluetooth module that we incorporate into our Arduino for wireless data transfer. We want the latency between foot pedal presses and finger movements to be consistent and below 500ms, which is entirely a function of how fast our Bluetooth modules can communicate with each other. Since the maximum listed bitrate of Bluetooth is between 1-3 Mbps **[3]**, and the instructions we will be sending are only a few bits, the module should theoretically have no problem communicating with low latency, but we need to physically test the module before we will know if the latency is good enough for use. If we cannot achieve low latency with the module we have chosen, we may need a more expensive module with a more recent version of Bluetooth.

While we anticipate the Bluetooth latency being an issue, as long as the distance between the foot pedals and prosthetic hand remains constant, there should not be much issues with inconsistent latency. Since the maximum distance between the foot pedals and the prosthetic hand will never be more than 10 meters, and as long as the Bluetooth module is capable of transferring data at a minimum rate of 1 Mbps, we should be able to prevent any latency issues between the pedals and the hand.

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 pedals. Another potential safety hazard is the material of the prosthetic hand. We plan on using metal for the hand, which can be sharp or conductive and can cause injury if used carelessly.

We will review the design that is created by the machine shop, and coat it in rubber/sand down the edges if necessary. In order to minimize chances of injury, we will only be using 5V to power the Arduinos and less than 1.5V per servo motor which should ensure that the motors do not reach dangerously high speeds, no matter what signal the motors receive.

In terms of ethical issues that we might encounter, we do not believe there are not many applicable guidelines from IEEE, 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 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 a keyboard when typing. 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.

References

[1] “How Much Does a Prosthetic Arm Cost?” *CostHelper*, health.costhelper.com/prosthetic-arms.html

[2] “Average Typing Speed Infographic.” *Ratatype*, www.ratatype.com/learn/average-typing-speed

[3] “Bluetooth Basics.” *Bluetooth Basics*, learn.sparkfun.com/tutorials/bluetooth-basics/all