Foot Keyboard

Team 42 - ECE445 - Spring 2020 - Project Proposal

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1. Introduction

1.1 Objective

There are nearly two million people in the United States currently living with limb loss and around 185,000 more amputations occur each year [1]. In order to help those facing limb loss, there are prosthetics amputees can purchase. While very useful tools, prostheses are limited when it comes to finger dexterity and many have a limited set of gestures they are programmed to do. The Universal Declaration of Human Rights states in Article 19 that everyone has the right, “to seek, receive and impart information and ideas through any media and regardless of frontiers” and Section 32 expands that to include the Internet as a human right [2]. Being able to connect to the internet with a computer is crucial to our society today. But, current prostheses greatly hinders the ability for amputees to use computers. We propose a device that will allow those with hand or arm loss who may or may not own a prosthetic to perform keyboard functions with their feet.

Our solution would consist of a keyboard that is built to be operated by only a person’s feet. Because people are typically much less dexterous with their toes, we will not be using a conventional array of buttons, each corresponding to a letter. The top of our keyboard will have two large grip pads, one for each foot, that can be pushed in any direction. The left foot will serve as a group selector, with each direction selecting a group of keys. The right foot will then select a single key from that group of letters to input. We also have a button to toggle between uppercase and lowercase letters. Allowing for eight directions per foot plus the neutral center position and the case switch button, we can achieve up to 162 unique inputs. This enables us to easily map all 107 unique keystrokes a standard keyboard can perform. As memorizing the various inputs will take some time, we will also design a cheat sheet that can be placed on a desk (where a keyboard would normally be) so the user can quickly identify what foot positions they need for each key.

1.2 Background

Prosthetic technology has been greatly improving over recent years in terms of availability and affordability. However, even relatively affordable prosthetics made of 3D printed materials still can cost above 5,000 dollars which is still a rather high price point for a device many amputees require to do simple daily tasks [3]. Even if someone has a prosthetic it does not guarantee them the ability to type as many, especially the more affordable bionic arms use pre-programmed gestures. Typing requires many different gestures and is not realistic to be programmed to the arm. There are prostheses that can be controlled using brainwaves on the market such as the one designed by BrainCo earlier this year [4]. However, it is reported to cost around 10,000 dollars which is not accessible for many people as well as a high price if someone needs it to be able to use the computer. These factors rule out using a prosthetic as an affordable means for using a computer.

In terms of non-prosthetic solutions, there are mouse alternatives for people who do not have the capabilities of using a regular mouse such as the Shortcut HID, but besides using hand/arm prosthetics there are not really any alternative keyboard input methods for an amputee to use [5]. An alternative keyboard-like device many people use is text to speech software to translate spoken commands to keystrokes. There are limitations to text to speech as it may be prone to inaccuracies and the software does not allow for function keys such as ctrl or alt [6]. If an amputee wants to perform keyboard commands, they are effectively limited to purchasing expensive prosthetic hands or arms. Our design aims to provide those who do not have the means to afford an expensive prosthetic the freedom to type and use a computer on their own.

At the start of Spring 2020, Project Team 1 designed a prosthetic hand to type on a standard keyboard. The design consisted of a hand prosthetic and a set of four buttons to be pressed by the user's toes. Each of the toe buttons corresponded to the prosthetic's four fingers on the keys. The prosthetic was designed for a user who did not have the use of only one hand, so it is expected that the user typed normally with their other hand. This design eliminates the need for any external device to connect to the computer. It also allows for the user to feel like they are typing with two hands as most people do because they can see two hands in front of them when they are typing. The tradeoffs of this design are that the prosthetic cannot move it's fingers vertically to press the characters above or below the initial position. It also cannot be used by someone who does not have neither their left nor right hands. While our solution does not simulate two handed typing, it does not require the use of hands at all enabling double amputees to have access to a computer as well. We also map all standard keyboard characters to the feet and can be typed in a much more natural motion of moving the entire foot than individual toes.

1.3 High-Level Requirements List

1. The keyboard must be able to replicate the 95 unique characters and 12 function keys found on a standard compact keyboard using the user's feet.

2. The polling rate of the keyboard must be at least 100 Hz.

3. The keyboard microcontroller is able to send the correct key to the computer.

2. Design

2.1 Block Diagram

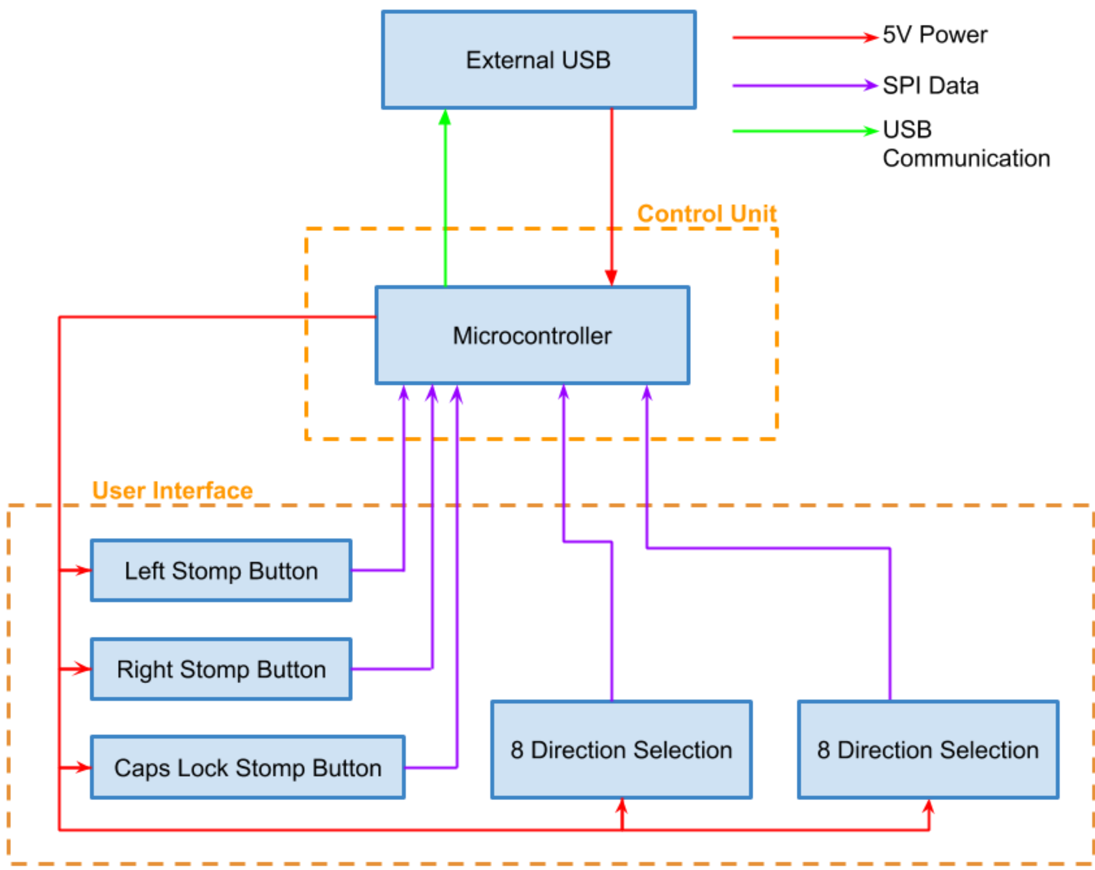

Fig 1: Block Diagram: The user interface gets the user input from the analog stick like device the user controls with their feet. The control unit will convert the user input to a keystroke and then execute the keypress on a computer.

Our design has two main subsystems, the user interface and the control unit. Through the user interface the user can provide their keyboard inputs by using the two 8 direction selection modules. Each of these consist of a set of switches which when active will determine the user's selection for a group of characters as well as a center stomp button for additional inputs. The external stomp button allows the user to alternate between capital and lowercase letters. The control unit is responsible for converting the user input to the respective character or function key as well as sending a signal to the computer via USB to execute the key press.

2.2 Physical Design

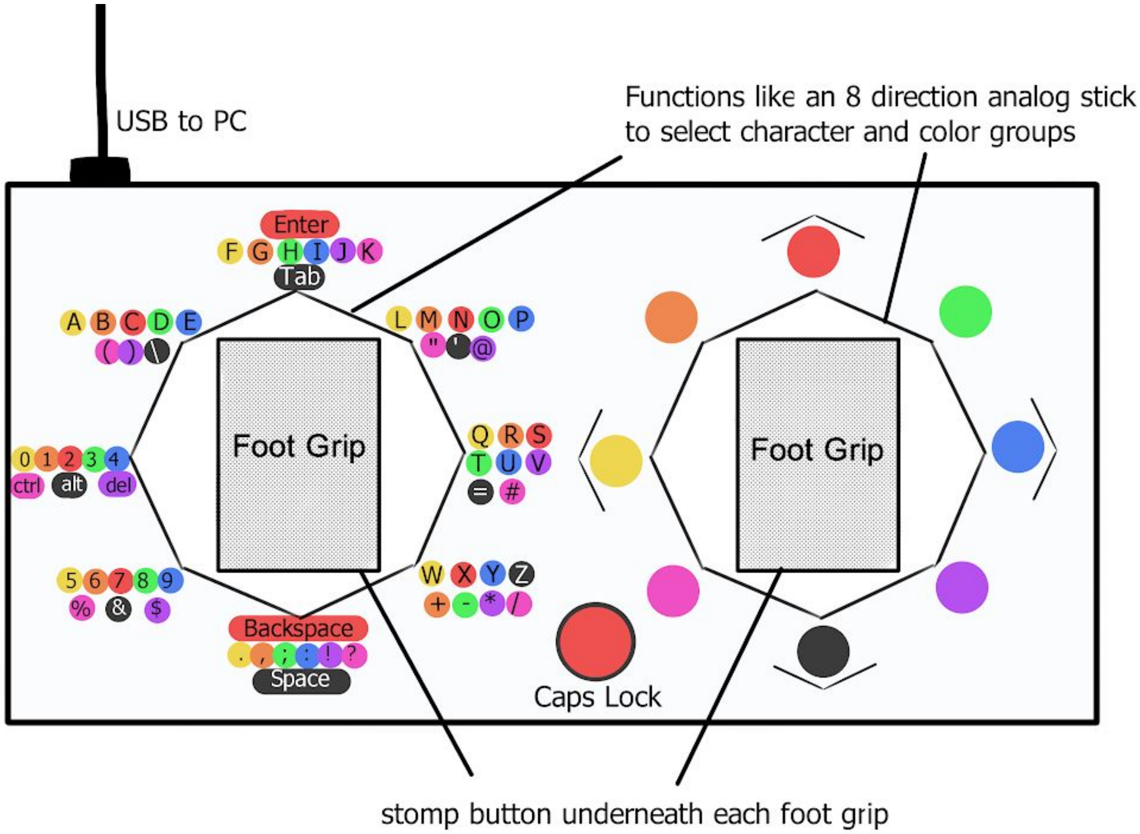

Fig 2 Physical Design: Characters are placed in character groupings which are controlled by the left foot and each character is also in a color group controlled by the right foot. In order to make a selection both feet need to select a character group. Arrow keys can be controlled by pressing down on the left foot grip and then each right foot direction corresponds to arrow key directions. Capital and lowercase letters are toggled through the "Caps Lock" stomp button.

Each foot will control a large eight direction analog stick like device. Each left foot position will control a group of characters (ex. A, B, C, D, E, (,), \) and the right foot will select a specific character from that group. When the user slides their foot to any of the eight directional positions a signal will be sent to the control unit of which group has been activated. Only when both feet have made their selections will a signal be sent to the computer to display the character input. In order for the user to toggle between capital and lowercase letters there is an external caps lock stomp button. The user will also have a cheat sheet that can be placed on a desk to help identify which groups each character is in.

2.3 User Interface

2.3.1 Functional Overview

The user interface consists of 16 switches, eight for each foot which are switched when the user moves their foot to one of the eight directional positions. The switches will be placed radially around the moving foot pads and actuate when the pad has fully moved in a direction. There are also three stomp buttons, one under each foot grip when in the neutral position and one externally to allow for additional keystrokes such as the arrow keys and caps lock. Only if both left and right feet have made a selection will a signal be sent to the computer to do the selected action.

8 Direction Selection

Each of the eight directions the user can move the foot grip has a switch which will determine if that directional input is active or not. The signal from the 8 direction selection will be sent over SPI to the microcontroller.

Stomp Buttons

Three stomp buttons are used to switch functionality of the direction selection to other inputs such as arrow key control and acting as the caps lock key on a standard keyboard. Signals from the stomp buttons will also be sent over SPI to the microcontroller.

2.3.2 Block Requirements

8 Direction Selection

Requirement 1: The foot pads can support the weight of a human leg and still operate.
Requirement 2: The foot pads return to center when the user removes their foot.
Requirement 3: Pushing the foot pad fully in any direction will always engage one of the foot switches.

Stomp Buttons

Requirement: The foot stomp buttons can function without breaking under the weight of a human leg.

2.4 Control Unit

2.4.1 Functional Overview

A microcontroller is required to communicate between the keyboard and the computer. The microcontroller will take and compile the inputs from the user interface to determine which character has been selected. Once selected, the microcontroller must send a signal to the computer via USB behaving as a standard USB keyboard would. The microcontroller would also receive power from the computer to power the device.

2.4.2 Block Requirements

Requirement 1: Identify the correct keystroke when both foot controllers have selected groups.
Requirement 2: Send a signal to the PC when a character has been selected.
Requirement 3: Must have enough memory to store all keyboard input mappings.
Requirement 4: Must have a polling speed that allows for a complete scan of the user interface in 10ms.

2.5 Risk Analysis

Likely, the hardest part of the project will be properly setting up and maintaining a USB keyboard interface with the computer. There will be many edge cases we must consider such as ensuring the device is hot pluggable and begins working immediately with the driver software we create. We also need to account for operating system specific functionality and adjust the device's operation accordingly. Another thing that we need to focus on is if we are sending the right characters as inputs. The device differentiate between certain characters that have different behavior such as ctrl and alt which must have their function saved for the next keypress.
We'll have to use durable hardware and design for the stomp buttons or foot pads so that they don't wear down quickly during normal use.

3. Ethics and Safety

There are a few safety hazards that must be taken into consideration with our product. As the device will be out of sight of the user, it must not have any sharp edges or otherwise dangerous surfaces that the user could unknowingly injure themselves on. The user should be able to apply significant force to any part of the frame without it harming them. As an additional precaution, the frame should not be made of a material that could break or shatter under significant weight. Because we have moving parts, we must ensure the foot pads and stomp buttons cannot pinch the user's feet at any point in their range of motion. Thus for the safety of the users our project must comply with IEEE Code of Ethics #9 [7]:

"*to avoid injuring others, their property, reputation, or employment by false or malicious action;*"

Since our product caters to the people who are unable to use the keyboard with their hands, we must be realistic in stating claims about the features and success of the product, in accordance with IEEE Code of Ethics #3 [7]:

'to be honest and realistic in stating claims or estimates based on available data'.

We will make sure we vigorously test our product to get a better accuracy of the success of our product.

For the success of this product we will consider all the constructive criticism and suggestion on improving the performance which adheres to the IEEE Code of Ethics #7 [7]:

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

4. Citations and References

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