Concept and Functional Specifications Document

Sign Language Assistance

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Submitted to:

Professor Blinder

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Introduction

With advances in technology there are many different ways to communicate with people around the world no matter the language they speak. However this is not as easily done with American Sign Language (ASL).

Sign language serves as a vital medium of communication for individuals with hearing impairments, yet its comprehension remains a significant challenge for those unfamiliar with its intricacies. In response, this project endeavors to create an innovative device that bridges this communication gap by translating sign language alphabet gestures into a user-friendly graphical interface. The device, composed of a 3D-printed hand model capable of mimicking sign language gestures and a Raspberry Pi-powered system, integrates advanced software algorithms for gesture recognition, speech recognition, and text-to-speech conversion. Through this endeavor, we aim to facilitate inclusive communication, enhance accessibility for individuals with disabilities, and contribute to the advancement of assistive technology.

This project's significance lies in its potential to revolutionize communication accessibility for individuals with hearing impairments, fostering inclusivity and social integration. By developing a device that translates sign language into a visual learning GUI, we aim to empower both sign language users and non-users to engage in meaningful interactions. Moreover, this endeavor aligns with broader efforts to advance assistive technology, emphasizing the importance of innovation in addressing societal challenges and promoting inclusivity for all individuals, regardless of their abilities.

Project Organization

Task	Hardware	Software	Research & Assistance	
Assigned Team Member	Matthew Frazier	Oluwadamilare Ajayi	SungWon Lee	

Table 1

Concept

3a.Title

Sign Language Assistance

3b. Problem:

For a majority of the hearing disabled community access to proper ASL tools is hard to come by. Even translation tools that are available are not interactive and engaging. Just having someone who understands ASL is not enough for a full conversation between someone who is hearing disabled and someone who is not. To allow for easier and interactive communication between the two we have designed Sign language Assistance

3c. Project Description and Functions

This project utilizes a Raspberry Pi 4 to take in user speech and translate it into ASL. Along with the Pi the main components will consist of a touch screen, microphone, and 3D printed robotic hand. Combining these components will allow us to take user speech, break each word down into single letters, and have the hand sign each letter spelling it in ASL.

The screen will display a graphical user interface, GUI, that has all the letters of the alphabet as individual buttons. These buttons will also be able to trigger the robotic hand as it will sign each letter when pressed. Another button on the GUI will be the record button that will activate the microphone for a short period of time to allow the Pi to record speech using the connected microphone. The screen will also display the current letter it is signing in a text box.

To show accurate hand signals we will utilize a robotic hand. The hand itself will be put together by 3D printed parts. The fingers will be attached by a strong fishing line to servo motors. There will be one motor for each finger to allow them to bend at different angles for the appropriate hand signals. There are also two servo motors in the wrist to control the X and Y directions of the hand. Attached to the hand will be an elbow joint also controlled by a motor, which will allow the arm to turn upside down as some ASL signs are with the hand facing the floor.

3d. Originality

While there are a lot of translation softwares out there now as technology advances and AI becomes more widely used, the closest anything comes to our project is speech to images.

Functional Specifications

In designing a device to translate sign language alphabet gestures into a visual learning GUI, a comprehensive set of functional specifications guides the development process. These specifications delineate the core functionalities and performance requirements necessary for achieving the project's objectives effectively.

Gesture Recognition
A fundamental aspect of the device is its ability to accurately recognize and interpret sign language gestures. The gesture recognition system must be capable of distinguishing between various hand movements corresponding to different letters of the alphabet. To achieve this, the system employs computer vision algorithms and machine learning techniques to analyze images captured by a camera mounted on the device. Through robust training and testing procedures, the gesture recognition algorithm is optimized to achieve high accuracy and reliability in detecting and classifying sign language gestures.

Speech Recognition and Text-to-Speech Conversion
In addition to recognizing hand gestures, the device incorporates speech recognition and text-to-speech conversion functionalities to facilitate two-way communication. Upon receiving voice input through a microphone, the system employs advanced speech recognition algorithms to transcribe spoken words into text. Subsequently, the text-to-speech conversion module synthesizes the transcribed text into audible speech output, allowing for seamless communication between users of the device and individuals proficient in spoken language. The integration of these features enhances the device's versatility and utility, enabling users to engage in interactive dialogues beyond the realm of sign language interpretation.

Graphical User Interface (GUI)
Central to the device's user experience is the graphical user interface (GUI), which serves as the primary medium for displaying sign language alphabet gestures and corresponding spoken words. The GUI is designed to be intuitive, visually engaging, and accessible to users of all proficiency levels. Through the integration of interactive elements and user-friendly navigation controls, the GUI facilitates seamless interaction with the device, empowering users to explore and learn sign language alphabet gestures at their own pace. Moreover, the GUI accommodates customization options, allowing users to adjust settings, preferences, and display configurations to suit their individual needs and preferences.

In essence, the functional specifications of the project encompass the core capabilities and performance requirements essential for developing a device that transcends communication barriers and promotes inclusivity for individuals with hearing impairments. Through the integration of advanced technologies and user-centric design principles, the device endeavors to empower users to engage in meaningful interactions and foster greater understanding and acceptance within diverse communities.

Research

5a. Research topics:

1. Struggles of hearing impaired individuals.
2. Similar projects to what we had planned to clear up originality
3. Speech to text - How it works and possible open source options
4. Human hand anatomy
5. Open Source human hand STL models

5b. Research sources:

Research was done to see if there was a similar project being developed. At the time the results of the research was there are apps that display this in 2D.

Some of reasons why we decide to do this project

Advantages & Disadvantages of Sign Language. (2022, May 14). The Classroom | Empowering Students in Their College Journey. https://www.theclassroom.com/advantages-disadvantages-of-sign-language-12084066.html

Wolmark, M. (2023, September 2). *79 Hearing loss statistics: How many deaf people in the U.S.?* https://www.goldenstepsaba.com/resources/hearing-loss-statistics#:~:text=It%20is%20estimated%20that%20approximately,deaf%20people%20in%20the%20U.S.

World Health Organization: WHO. (2021, March 2). WHO: 1 in 4 people projected to have hearing problems by 2050. *World Health Organization*.

https://www.who.int/news/item/02-03-2021-who-1-in-4-people-projected-to-have-hearing-problems-by-2050

Related project

Hackster.io. (2022, January 7). *Recognizing Speech with a Raspberry Pi*. https://www.hackster.io/petewarden/recognizing-speech-with-a-raspberry-pi-50b0e6

Instructables. (2017, September 15). *3D printed robotic hand with Bluetooth control*. Instructables. https://www.instructables.com/3D-Printed-Robotic-Hand/

5c. Research results:

Research done to look at similar hand designs that can be used for this purpose. An open source hand was found in the form of stl. files that would be perfect for our project. Insert link

According to research by the World Health Organization (WHO), an estimated 466 million people worldwide suffer from disabling hearing loss, constituting approximately 6.1% of the global population, with one-third of individuals over the age of 65 affected. Projections indicate that by 2050, this number could soar to over 900 million globally. In the United States, the National Institute on Deafness and Other Communication Disorders (NIDCD) reports that approximately 2 to 3 out of every 1000 children are born with detectable hearing loss in one or both ears. Additionally, about 15% of Americans aged 18 and over experience some degree of hearing difficulty, which often leads to communication limitations, language accessibility issues, and societal stigmatization.

To address these challenges, assistive devices have been developed, but their widespread adoption is hindered by limited production lines and high costs. To overcome these barriers, we propose leveraging microcontrollers and 3D printing technology to create an affordable educational assistive device. Building upon existing innovations such as robotic hands controlled by microcontrollers and speech-to-text translation libraries, our solution integrates these functionalities to cater specifically to the educational needs of the deaf community.

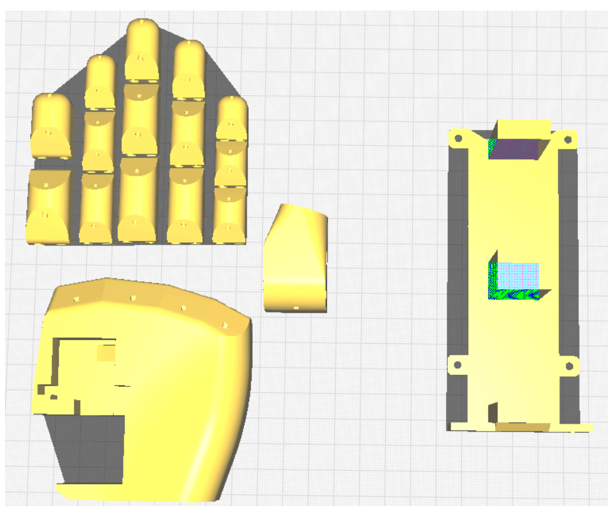
Hardware

Raspberry Pi (***Fig. 1***)

10” touchscreen (***Fig. 2***)

Microphone (***Fig. 3***)

Servo Motor (***Fig. 4***)



3D Printed Hand (STL. file) (***Fig. 5***)

6a. Top Level Diagram

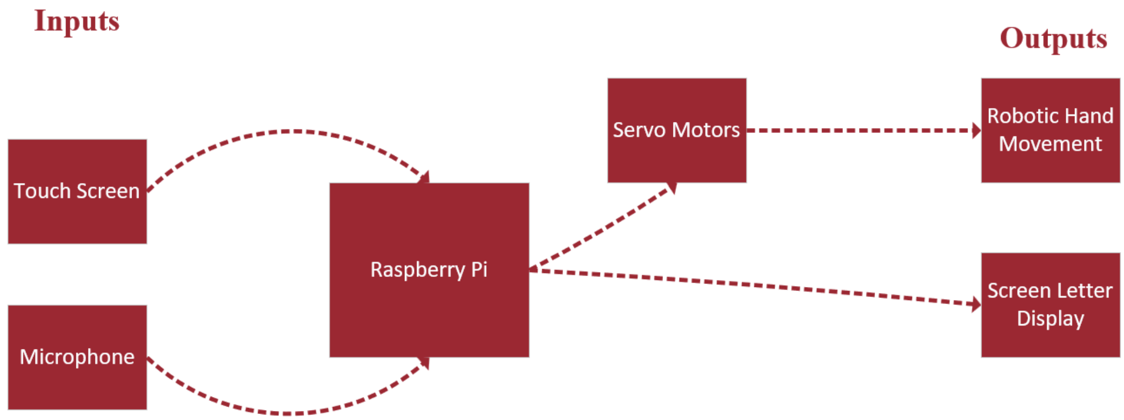


Fig. 6

At the top level diagram we can see the order that all the components will interact. The user will have two choices when it comes to input, selecting a letter on the touch screen or speaking into the microphone. From there the pi will process this and select the correct hand sign. After the letter is chosen it will have two outputs, one displayed on a text box on the screen and the servo motors creating the hand signal.

6b. 2nd Level Diagram

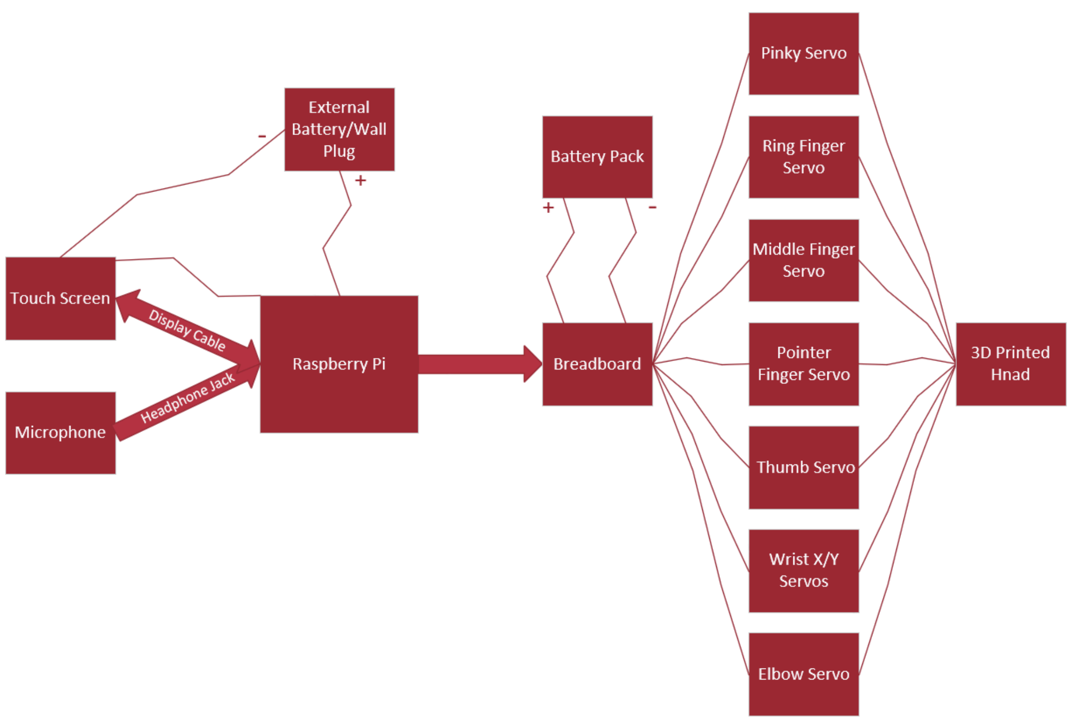


Fig. 7

With the 2nd level we get a look into how the different components are connected. The pi is the main point of contact for all components, it is where the processing will take place. The touch screen will use a display cable and both send and receive data to and from the pi. The pi will receive a button selection from it, whether that be start voice recording or a letter selection. When the pi either receives a letter selection or breaks the speech down into individual letters, the letter it is currently signing will be displayed on the touch screen. This two way travel of data is represented by the double arrow connecting the screen to the pi in Fig 2. The microphone only gives input to the pi when the record button is pressed on the GUI.

After the pi processes the information it then sends information to several servo motors. These motors will be connected to a separate power source to not draw too much power from the pi. Depending on the letter that is selected, different motors will be told to switch to certain positions while others might not move. In turn this will move the 3D printed parts that make up the hand and form the hand signs.

Software

7a. Flow Chart with Subroutines and Descriptions

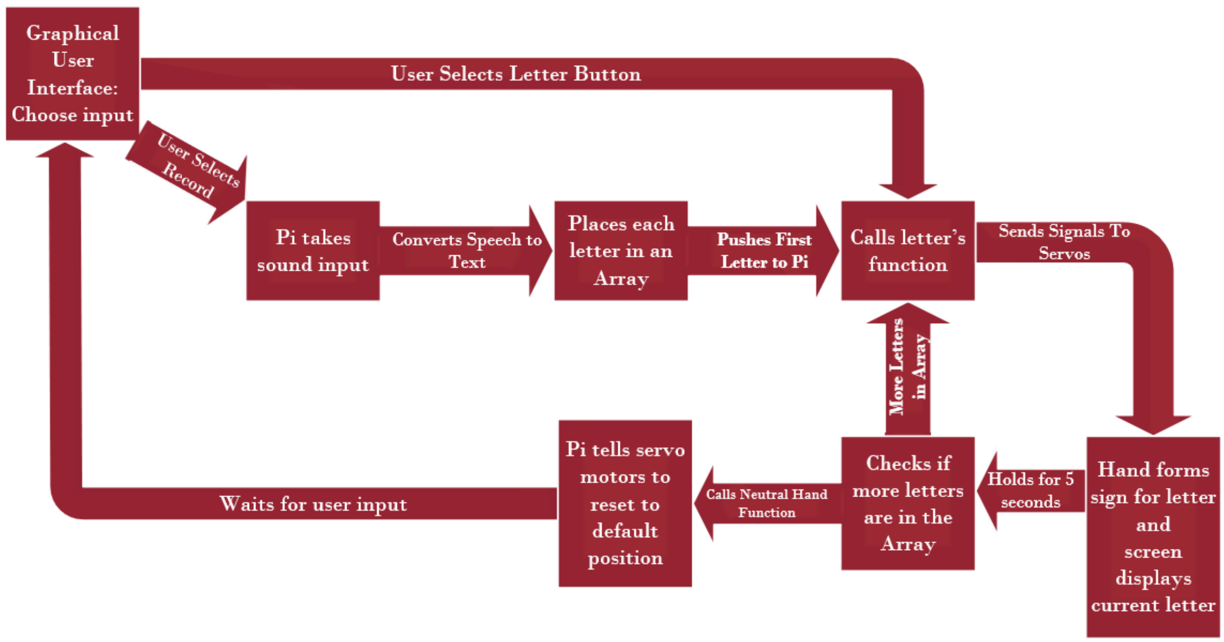


Fig. 8

For the software section of this the user will be greeted by a GUI that has a multitude of options. There are twenty six buttons each with a different letter on them that the user can click on. If the user presses one of those buttons the pi will call on the function of that letter. Each letter's function will be pre programmed with the required hand movements to make the appropriate sign. After that sign is made and the servos lock in place for 5 seconds the hand will reset to a neutral position and be ready for the next import from the user.

If the user selects a record, the microphone will activate for 5 seconds. The pi will take the voice recording and process that into a string, or a line of text. A function will break the string apart letter by letter and store them within an array, or a list. The pi will load and remove the first letter from the array, which will be the first letter of the word, and execute the appropriate function tied to that letter. It then checks to see if the array is empty or if there are still more letters left to sign. If the array has more letters it will move on to the next letter, repeating this process until there are none left. If there are no more letters left to sign it resets and waits for the next user input.

7b. Language

The language this project is done in will be python, this is because it is the most compatible language to use for the pi. In python designing the GUI will be made easier as it has a built in library that allows for GUI building. The pulse width modulation functions will also be compatible with the servo motors used. All of this makes python the best choice for the project development and running of the device to go smoothly.

7c. Platform

For the easiest compatibility between GUI, hardware, and code, this project will run on the PI OS. This is the standard to be installed on the PI, as it is a mini computer and PI OS is its operating system.

Project Plan

8a. Gantt Chart

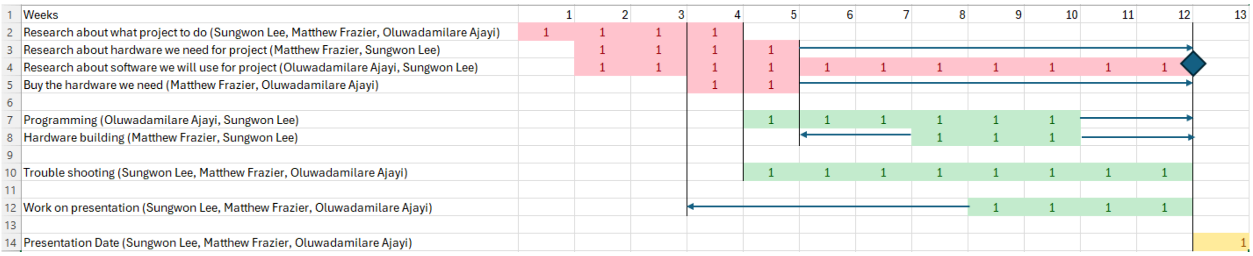


Fig. 9

8b. Work Breakdown

- **Week 1~3:** Research about what project will be appropriate to use for senior project (Sungwon Lee, Matthew Frazier, Oluwadamilare Ajayi)
- **Week 4~6:** Research about hardware and software that will be used for the project (Sungwon Lee, Matthew Frazier, Oluwadamilare Ajayi)
- **Week 5~10:** Start programming for GUI and control microcontroller (Oluwadamilare Ajayi, Sungwon Lee)
- **Week 5~12:** Troubleshoot every problem that we face while working on the project
  (Sungwon Lee, Matthew Frazier, Oluwadamilare Ajayi)
- **Week 8~10:** Assemble the parts that been printed out from 3d printer and other hardware that has been delivered
  (Matthew Frazier, Sungwon Lee)
- **Week 9~12:** Organize the research we have done for this project and troubles we've been face while working on project and prepare the presentation
  (Sungwon Lee, Matthew Frazier, Oluwadamilare Ajayi)
- **Week 13:** Presentation date
  (Sungwon Lee, Matthew Frazier, Oluwadamilare Ajayi)

8c. Deliverables

- GUI tested separately (code)
- Hand functionality tested separately
- Speech to text tested separately
- Parts will be added one at a time and tested separately
  - Mic and speech to text
  - Screen and hand motions
- All components combined and tested together

8d. Possible Problems

- Small servo motors don’t have enough torque to pull fingers
- High torque servo motors might need external power supply
- Time to print out parts take longer than expected
- Some parts broke while assembling
- Error of microcontrollers
- Microphone can’t clearly pass the sound to software so it might miss translate
- Drop the device and crack the touch screen, microcontroller, and servo motors

8e. Expected and Worst Case Costs

Expected Costs

Hardware	Price
20kg Servo Motor X3	$40.77
SG90 Micro Servo Motor X7	$16.99
3D Printer Filament X2	$29.99
Microphone	$16.99
Touch Screen	$68.99
Fishing Wire	$5.99
Hinges X2	$5.67
Glue gun & Glue Stick	$9.99
Raspberry Pi	$76.49
Arduino Uno	$27.60
Bread Board	$8.99

Table 2

Worst Case Costs

Hardware	Price
20kg Servo Motor X18	$244.62
SG90 Micro Servo Motor X7	$16.99
3D Printer Filament X4	$59.98
Microphone	$22.99
Touch Screen X2	$137.98
Fishing Wire	$5.99
Hinges X2	$5.67
Glue gun & Glue Stick	$9.99
Raspberry Pi X2	$152.98
Arduino Uno X2	$55.20
Bread Board	$8.99
External Power Supply X10	$69.50
AA Battery X20	$18.48

Table 3

Appendices

9a. Acronyms and Definitions

1. ASL: American Sign Language
2. Pi: Raspberry Pi
3. GUI: Graphical user interface
4. AI: Artificial intelligence
5. STL: stereolithography (file used for 3D printing)

9b. Parts list

- 3D printed hand(filament) x1
- Raspberry pi 4 x1
- Microphone x1
- 20 kg/cm Servo motor x3
- Servo motor x7
- Fishing line real x1
- Arduino uno x1
- Break board x1
- Touch screen x1
- Hinges x2