ECE 445
Senior design project laboratory
Design document

TOOL THAT TRANSLATES PRINTED TEXT TO BRAILLE

Team No. 76

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1. Introduction

1.1 Problem

According to the World Health Organization, currently there are around 39 million people who are legally blind around the world. Right now there are not many resources available for people who can only read braille to read physical written text from a book or magazine, and those that are available are very expensive.

1.2 Solution

Our solution is to create a tool that can be placed over printed text and translate it to braille so that blind people can read it. This tool will be divided into two parts that will be connected between each other through several wires that will transmit power and data.

The first part will be a handheld device with a camera to recognize the letters in a word. The user would hold this handheld device with one hand and place it on top of written words.

The second part will be a box that will contain the pcb with the microprocessor and an external battery module. It will receive the images taken by the camera, process them to recognize every letter on the word and finally output on top in braille the characters of that word one by one using pins that can be pushed up and down to create braille characters.

The person using this device will place one of their fingers on top of the moving pins used to create the braille characters to read the printed text.

After showing all the braille characters in a word, the user can simply move to the next word for it to be shown in braille.

1.3 Visual Aid

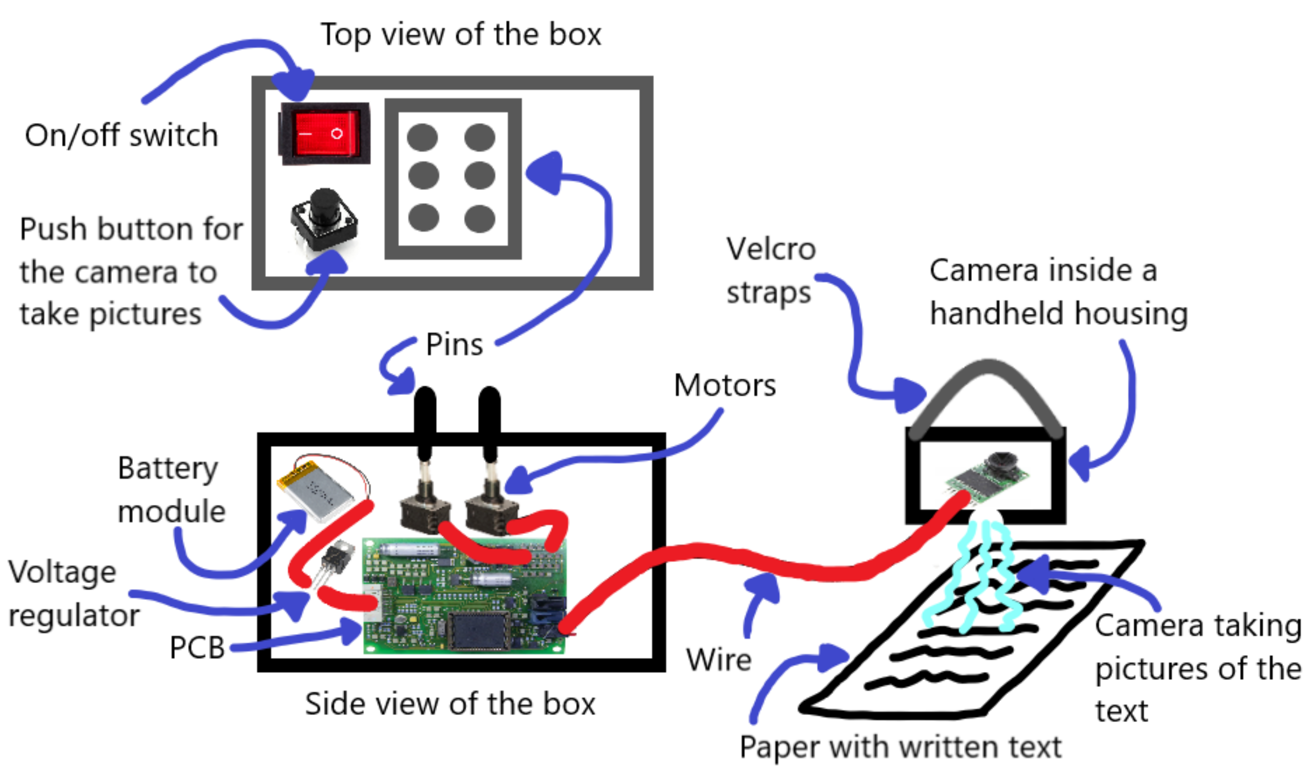

Figure 1. High-level overview of our design

1.4 High-level Requirements

We aim to accomplish these three high-level requirements:

- Text character to braille display accuracy is at least 90%.
- Battery life lasts 8 hours for an all-day battery life.
- All pins extend to 0.35$\pm$0.1 cm high in less than 1 second.

2. Design

2.1 Block Diagram

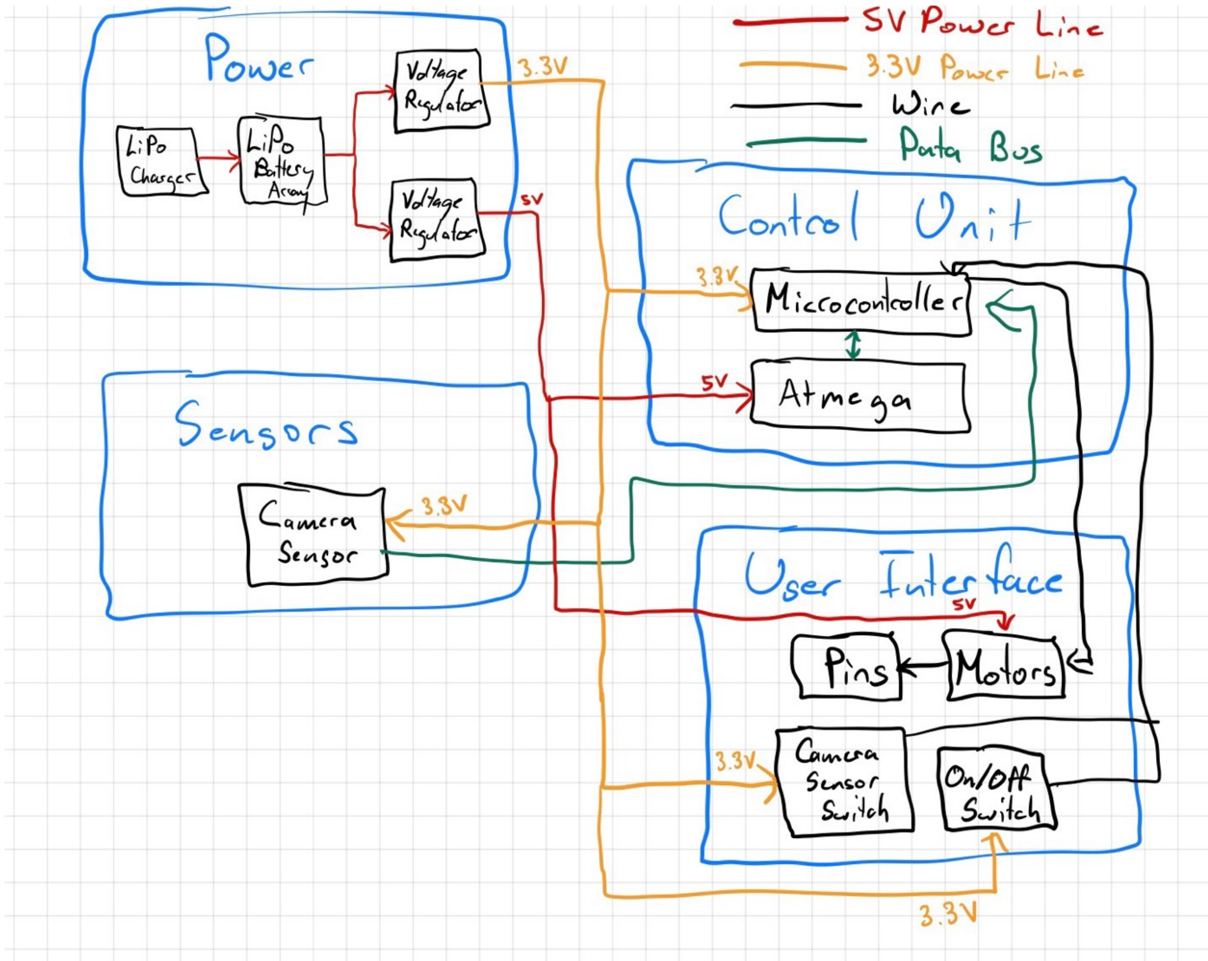

Figure 2. Block diagram

2.2 Physical Diagram

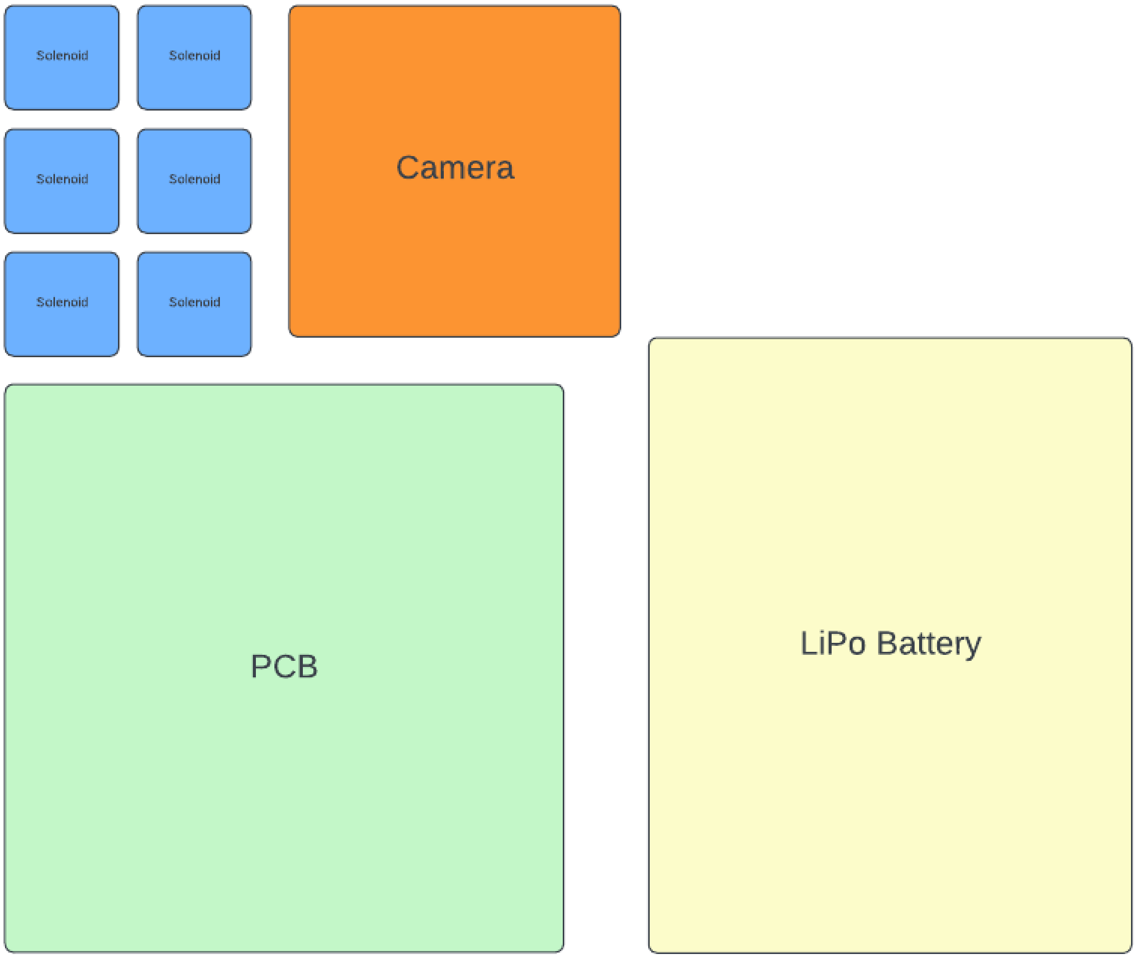

Figure 3. Physical diagram of the project

The physical diagram as drawn above is a sketch to show what the placement of our part might look like from above. The size is 12 cm across and 10.5 cm down. We have estimated the PCB size to be 6 cm x 6 cm, as we haven't finished the PCB design yet, and this will give us an idea of what to fit our PCB design down to.

2.3 Subsystem Overview

2.3.1 Power Management Subsystem

The power module will power the whole system and:

1) Be lightweight for ease of transporting
2) Powerful enough to sufficiently power the whole system
3) Have theoretical “all-day” battery-life (at least 8 hours)

The power module will consist of an array of Lithium Polymer (LiPo) batteries and charger encased in a plastic housing. The current energy need is unknown (volts/amps/watts), thus the exact “dimensions” of the battery array is unknown. A charging module will be added in order to evenly distribute charge across the batteries to ensure optimal battery health.

Some downsides to such a battery module would be that LiPo batteries require extra care in their recharge cycles as they must be evenly charged, and also not overcharged. Further, LiPo batteries can become hazardous if punctured, and such a safety hazard would have to be addressed through the design of the casing.

2.3.2 Sensor Subsystem

A handheld housing will have a camera sensor attached to it, which would be transmitting image data to the microcontroller. The housing will have to be ergonomic to hold and made of some lightweight material, like plastic. We may additionally add some way for the user to attach the housing (e.g. velcro straps) for convenience.

2.3.3 Control Unit Subsystem

A custom PCB will be designed in order to connect all other subsystems. The PCB would connect the pin motors for the braille “display”, the handheld housing containing the camera sensor, and the external battery module in order to power all the other components. The PCB would also control the recharging of the battery module to ensure optimal battery health.

The Atmega microcontroller will take images from the camera sensor to process the text characters in the image. The image processing, or more specifically the OCR (Optical Character Recognition), will be done through open source computer vision and machine learning libraries such as OpenCV or Tesseract. The microcontroller will also control the solenoids that will drive our pins to form braille characters.

The Atmega microcontroller will interface with the microcontroller used in our custom PCB as a more powerful chip may be required for better OCR performance.

2.3.4 User Interface Subsystem

Solenoids controlled by the microcontroller will be used to move up and down 6 small bars through holes made on top of the box to form braille characters. The bars required to form each character in braille will move up and down in a synchronous way so that the user can read them with their finger.

2.4 Subsystem Requirements

2.4.1 Power Management Subsystem

Requirements	**Verifications**
The Voltage regulator will limit the Voltage to the correct value for each system component.	Use an oscilloscope to measure voltage through voltage regulators under normal operation. Expected measurement should be 3.3 ± 0.1V and 5.0 ± 0.2 V
The Power Management Subsystem will be able to safely charge the battery	The voltage regulator increases the voltage to 5 V and can be used to charge the LiPo battery. The voltage can be measured during testing using a voltmeter to ensure there is the expected voltage.

Table 1. Power management subsystem requirements and verifications

2.4.2 Sensor Subsystem

Requirements	**Verifications**
The camera must be able to take at least a 480p resolution photo and send the data to the Control Unit system whenever the take photo button is pressed.	The OCR testing software receives 480p resolution photos on photo button press.

Table 2. Sensor subsystem requirements and verifications

2.4.3 Control Unit Subsystem

Requirements	**Verifications**
The ML algorithm on the microprocessor must be able to analyze image data and convert to character texts with 90% accuracy rate.	The OCR testing suite will use a test dataset of 480p resolution images of characters, the ML algorithm will be run against this dataset to determine its accuracy.
The character text data is converted into signals that are sent to the motors to form Braille characters for all 63 Braille characters	Test software will be written in order to replicate converted signals from the ML algorithm. All 63 Braille character signals will be sent to the motors one by one and the correct formation will be verified by eye.

Table 3. Control unit subsystem requirements and verifications

2.4.4 User Interface Subsystem

Requirements	**Verifications**
The Motors must be able to lift the pins 0.35±0.1 cm high and to lower them in less than 1 second when forming the braille characters.	Measure rise height when all solenoids are powered on, and use a ruler to check height.

Table 4. User interface subsystem requirements and verifications

2.5 Tolerance analysis

The Image-to-Text-Character recognition aspect of the project poses a risk to a successful completion of the project. At a high level, this project aims to make data more accessible by translating it into a different form. However, the integrity of the data depends on the accuracy of the translation from image data into text characters. Thus, a malfunctioning image-data-to-text-character translation would prove fatal to the success of the project. However, the feasibility of this component is definitely possible as there are many open source libraries that have trained machine learning models that simulate this very process.

In order to fulfill the 90% accuracy high-level requirement, a testing platform must be developed in order to quantify the image-to-text-character translation accuracy. There would be two levels of testing platforms to rigorously test for this requirement.

The first level platform would be developed in software. The measurement of accuracy would be done by creating a testing dataset: images that have been labeled with the text-character that it is displaying. Instead of feeding images from the camera sensor, images would be fed from this testing dataset. Then, the number of times the output of the Optical Character Recognition (OCR) library fails to output the same character as the image label would be noted. A simple division between the number of images the OCR library successfully translated to text by the total number of images would give us a rough accuracy estimate of the OCR library.

The second level platform would use the actual image sensor. A small subset of characters would be printed out on paper and other surfaces. The second level platform software would take the inputs from the image sensor (which is shown one physical printed character at a time) and output the recognized character which then would be noted. The accuracy would be determined by the number of characters successfully recognized, divided by the total number of characters tested.

3. Cost and Schedule

3.1 Labor cost

To carry out this project we would expect a salary of around 30 $/hour.
Each team member will work an estimate of 60 hours on their own to complete their work.
That means that we would expect a total salary of around 30 $/hour * 2.5 * 60 hours = $4500 per team member.
If we multiply this salary times the number of people in the team we get a total amount of $4500 * 3 people = **$13500 in labor cost**.

Work Type	Samuel's Hours	Seungyeop's Hours	Alejandro's Hours
PCB design	10	0	20
Soldering	10	0	10
OCR Programming	0	20	0
Debugging	20	20	10
Writing reports and documentation	20	20	20

Table 5. Hours to be spent by each team member on each work type

The machine shop in UIUC will be used while carrying out this project. According to their webpage [3], their cost is $38.17/hour. Our project should take around 1 to 2 hours for the machine shop to complete, as we only need them to dig some holes into the boxes where the components will be placed.
Therefore, the total cost for the UIUC machine shop should be $38.17 * 1.5 hours = **$57.26**

The total parts cost, as seen on table 6 is **$66.92**

Therefore, the total cost of the project is equal to:

Total cost = labor cost + UIUC machine shop cost + parts cost = $13500 + $57.27 + $66.92 = = **$13624.19**

3.2 Parts Cost

Description	**Manufacture**	**Part #**	**Quantity**	**Total Cost ($)**
Solenoid	Sparkfun	ROB-11015	6	29.70
Atmega32u4 microcontroller	Atmel	32u4	1	5.22
Camera	Olimex	OV7670	1	5.70
Battery	Adafruit	328	1	14.95
3V regulator	Texas Instruments	TPS70630DBVT	1	0.93
5V converter	Murata Power Solutions	MEE1S0305SC	1	7.51
On/Off switch	ZF	SRB22A2DBBN N	1	1.41
Camera button	Adafruit	1439	1	1.50
Total				**66.92**

Table 6. Parts cost

3.3 Weekly schedule

Week	Samuel	Seungyeop	Alejandro
02/27	Circuit and PCB Design	Research and explore best fit OCR libraries	Circuit schematic and PCB design
03/06	Solenoid and microchip module and PCB design	OCR integration programming	Power module design and PCB design
03/13	-	-	-
03/20	Build and test the first prototype, solder and test the solenoid and micro chip modules	Integrate prototype and debug OCR code	Build and test the first prototype by soldering and testing the power module with the PCB
03/27	Fix problems with microchip and solenoid design	Debug OCR code	Fix potential problems in the power module and the PCB (design a new PCB if necessary)
04/03	Build the final Design and test it. Solve any issues	Write up OCR test suites and set up physical tests as well.	Build the final design and test it. Solve any potential issues
04/10	Final adjustments for mock demo and testing	Final adjustments for mock demo and testing	Final adjustments for mock demo and testing
04/17	Final Adjustments for final demo and testing	Final Adjustments for final demo and testing	Final adjustments for final demo and testing
04/24	Final paper	Final paper	Final paper
05/01	Final paper	Final paper	Final paper

Table 7. Suggested weekly schedule

4. Ethics and Safety

We will mainly follow the IEEE Code of Ethics [2] while carrying out our project. The main aspects to take into account are:

- Image data must be collected onto the system in order to carry out the translation to text characters. Image data is sensitive and private information. We feel strongly about maintaining the privacy of users and protecting the integrity of the image data. All image data that is collected will be localized only to the system, and never shared on the internet. This way, we will minimize the number of access points to the data, lowering the risk of a data leak. The image data will also periodically be deleted to preserve space on the system, and also again lower the risk of a data leak.

- We will ensure good teamwork, treating everyone in an equal manner and with respect. We have created a shared Google drive folder to make sure that all team members have access to all the project related documents.

- Further, we will keep the user's safety as the top priority. Our project uses Lithium Polymer (LiPo) batteries in the power subsystem. LiPo batteries are notorious for being a potential safety and fire hazard when punctured, mishandled, or charged in a way that is not intended. Therefore, it would be our responsibility to avoid such a safety risk as much as possible. We would address this through the design of the power subsystem housing, and the way that the battery charging system is designed. The housing will be built to withstand everyday abuse, and the charging system will be programmed to avoid mischarging of the batteries.

- As a device that aims to provide better accessibility for the visually impaired, we recognize the consequences of having an inaccurate reading of real-world data. A user may depend on the accuracy of the data that is read in order to inform decisions in their life, potentially life threatening decisions. To minimize this risk, we will try to make our device as accurate as possible.

5. References

[1]. WHO. “Blindness and vision impairment” (2022), [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment (visited on 02/09/2023).

[2]. IEEE. “”IEEE Code of Ethics”.” (2020), [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html (visited on 02/09/2023).

[3]. Machine Shop, School of Chemical Sciences at UIUC. [Online]. Available: https://scs.illinois.edu/resources/cores-scs-service-facilities/machine-shop (visited on 02/23/2023).

[4]. Salary averages. The Grainger college of engineering. [Online]. Available: https://ece.illinois.edu/admissions/why-ece/salary-averages (visited on 02/23/2023).