Braille translator - Samanya

Design Document

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1 Introduction

1.1 Objective:

One thing most people may take for granted is their ability to read the simplest of things, like; menus, magazines, newspapers and more. While braille is available for people who cannot see, it can be difficult for them to even find books printed for them, so these everyday items are almost never available. It is thought that every year, in the United States alone, 75,000 people will become blind in some capacity [1]. Most people may believe that advances in technology will lead to improved lifestyle and opportunities for the blind. This is actually a myth, and it has been found that most blind people who rely on their ears and technology end up being deficient in other areas when in school and the work environment [1]. Substituting reading and writing with technology may seem like a good thing but think about how technology has affected people who have full sight. Instead of having to go get a newspaper, or to the library, we have access to the same things at our fingertips. We didn't replace reading and writing for ourselves, if anything we have further integrated these activities in our lives.

This is where we would like to make a difference. Our goal is to be able to help blind and visually impaired people to be able to read items that fully abled people can. We would like to make a device that blind people would be able to bring to places like restaurants, libraries and classes. This device will enable them to read text written on most flat surfaces by producing a braille version of it in real-time. We can help the blind community by developing this portable device.

1.2 Background:

There has been enormous progress in the field of developing products to help the disabled, especially in helping the blind with reading using braille [3]. However, there is no such product to help the blind and visually impaired read menus as most restaurants don't keep a braille version available. This can be discouraging as they become dependent on others to read the menu to them, which is not always feasible. Our solution to this problem is to develop a handheld device that one can place over a sheet of paper or menu. his device will then take a picture of the underlying text using the camera and will use OCR to convert the digital text to scanned text which will then allow us to convert the captured text to braille. The converted braille message will then appear on the refreshable braille display above and the user will be able to read the text in braille.

The concept for this product was designed by our friend Abhijoy Nandi[9] who is majoring in Industrial Design at the University of Illinois Urbana Champaign and wanted to see this device ultimately being used in restaurants by visually impaired beings to be able to read menus and also other texts from papers like flyers, textbooks, posters, etc. We hope that this device ultimately eases the day to day tasks of the visually impaired.

1.3 Visual Aid:

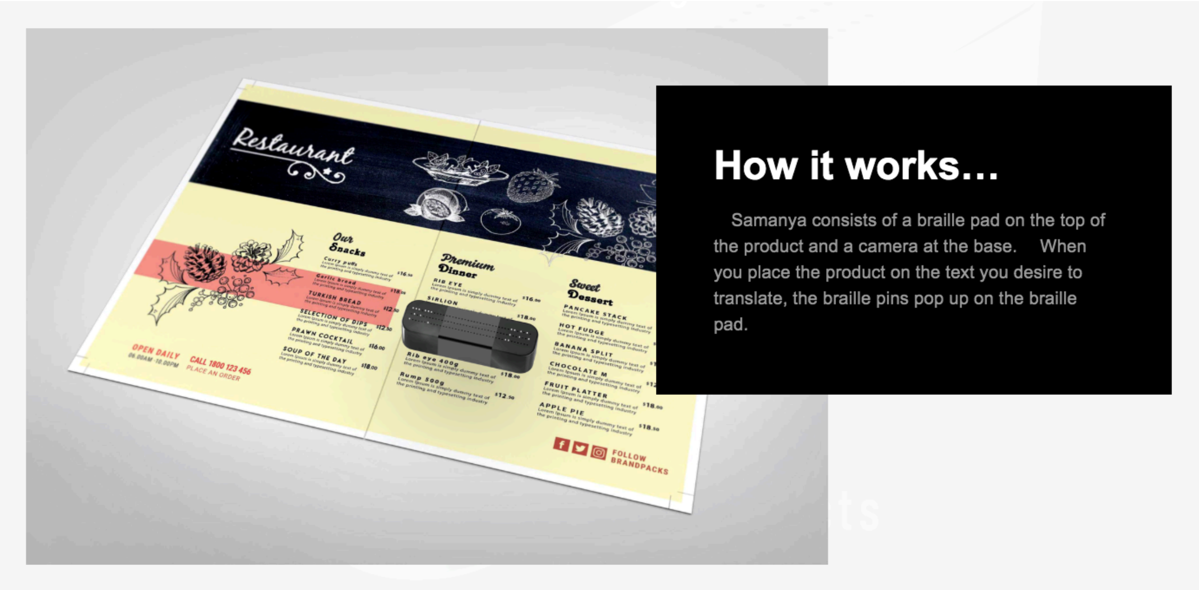

Figure 1: A visual representation of the working of the braille translator named Samanya

1.4 High Level Requirements:

- The device is able to detect a button press and trigger the camera to capture an image
- The device is able to convert the captured image into strings of up to 32 characters about 80% of the time
- The device is able to display a string of characters in braille 4 characters at a time

2 Design

In order for this device to function, it will need to have: a power supply unit, an image capture unit, a processing unit, an input unit and a braille display unit. The power supply unit will ensure that the correct amount of power is safely delivered to all components. The image capture unit will ensure that the device can capture an image. The input unit is responsible for receiving user input and sending it to the processor. The braille display unit is responsible for displaying braille characters using solenoids (This part has been abstracted since it will need solenoids fitted on to a metal plate to be done at the machine shop.) The processing unit is responsible for maintaining accurate functionality for all other units. Additionally, the microcontroller unit is also responsible for converting the captured image to a string.

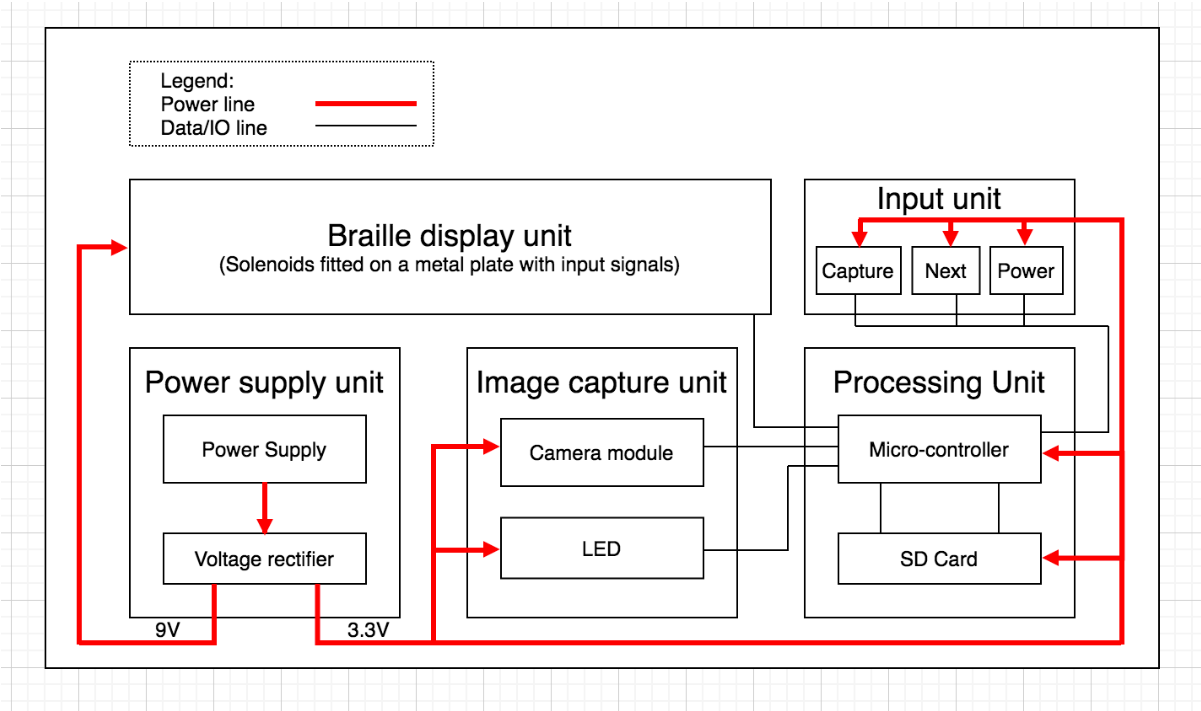

Figure 2: High level block diagram for braille translator device

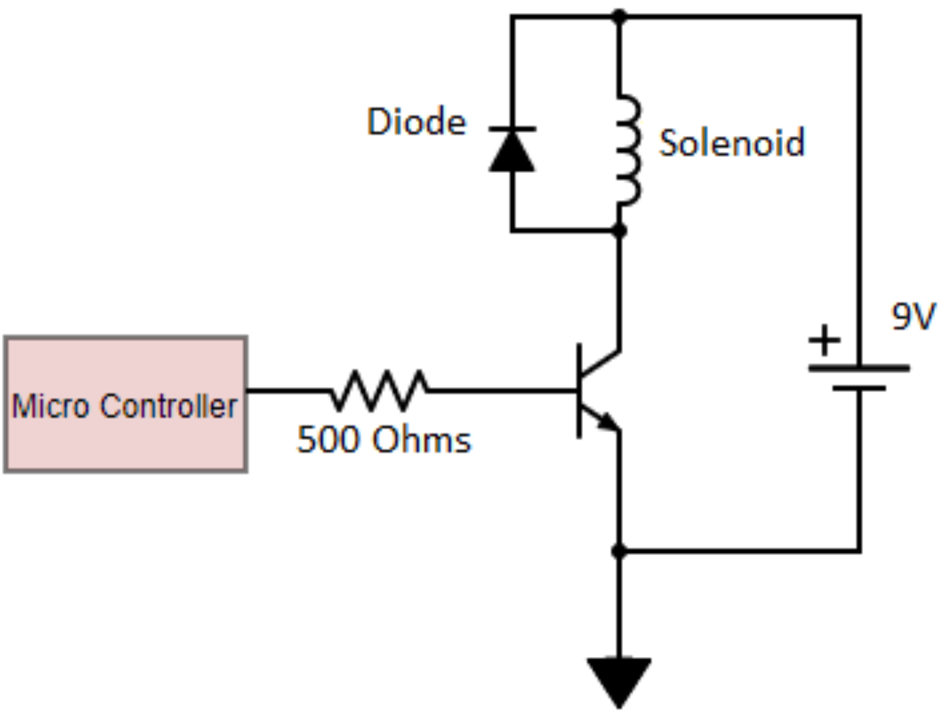

Figure 3: Circuit Diagram for each Solenoid in Braille Display Unit

Figure 3 describes the circuit diagram for the setup of the braille display. To show this circuit diagram, we have laid out how we plan to setup each solenoid in our device. Note that there will be 25 such solenoids connected in parallel to the power supply shown in figure 3. The transistor allows us to control the state of the solenoid with an I/O signal from the microcontroller.

One of the design choices we made was to display only 4 braille characters at a time. The reasoning behind this is based on the cost factor of building a prototype with a larger number of characters and is covered in section 3 Cost analysis in this document.

2.1 Physical Design:

Figure 4: The physical design of the braille translator

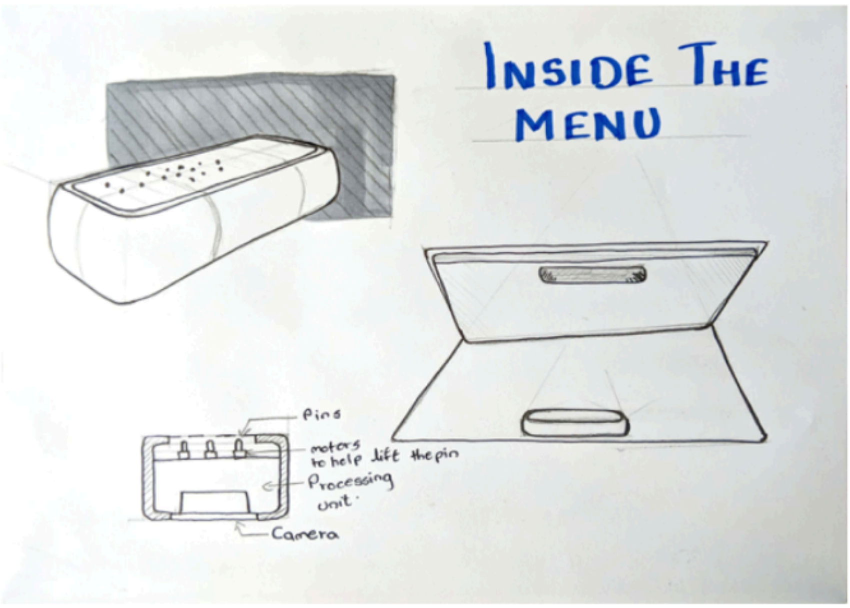

Figure 5: Sketches of the product concept

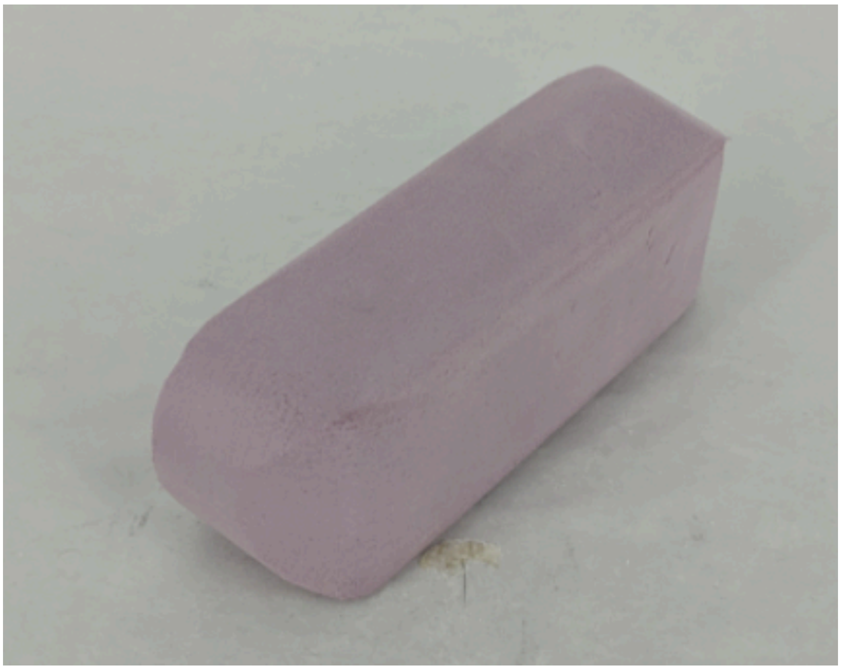

Figure 6: Physical concept development using pink foam

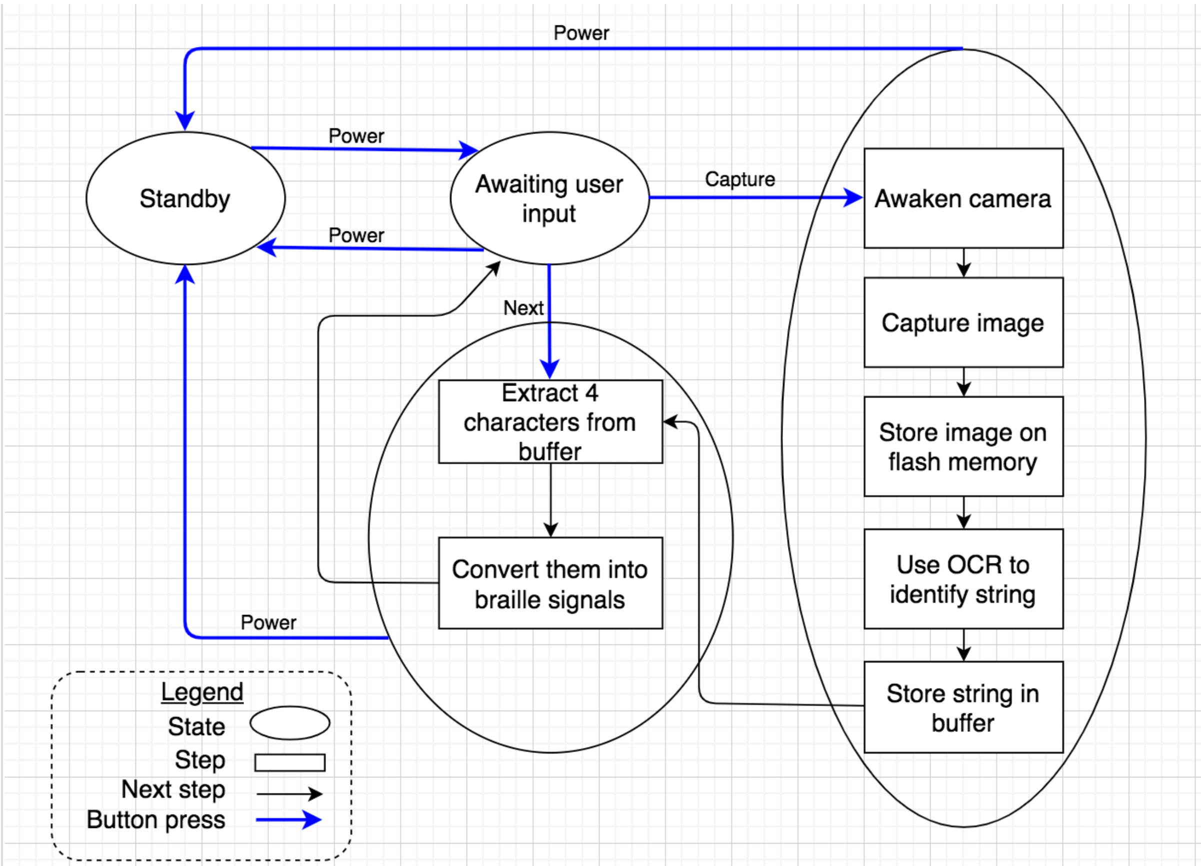

Figure 7: State machine diagram for software setup

Note: If a button is pressed outside of the "awaiting user input state", the machine will attempt to jump to step one of that particular state. For instance, if the "Next" button is pressed during execution of the one of the "capture state" steps, the machine will skip current instructions and jump to the first step of the "next state".

2.2 Power Supply Unit:

This unit will supply power to the entire device safely and ensure a consistent flow of voltage across all components. It will provide the circuit with 3.3V and the majority of our power will be consumed by the 25 solenoids in our braille display unit to move up and down and also by the microcontroller.

2.2.1 Wall Socket input (Power supply):

We will be using a wall socket power supply to power our system because we need to supply 9 volts in order to power our solenoids. We will also be using voltage regulators to supply the other blocks of our system [7].

Requirements	Verification
Must supply 3.3 V for microcontroller, camera and SD card reader.	1. Power the device on. 2. Measure the voltage at the camera input.
Must supply 9 V to the solenoids in parallel, providing the current to be a max of 10 amps, 0.4 amps for each solenoid.	1. Plug the device into a socket. 2. Run the voltage through the Braille Display Unit. 3. Use a multimeter to read the voltage across the solenoids on the bread board

2.2.2 Voltage Stabilization:

For this portion, we want to implement a component that safeguards the other circuit components from short circuits and prevents voltage fluctuation. We also need to decrease the input voltage for certain components, in order to do this, we will need a regulator.

Requirements	Verification
Voltage regulator that supplies 3.3 V from the original 9 V input for the microcontroller, camera and SD card reader.	1. Build a basic circuit with the regulator and some resistors. 2. Plug the power into the wall and run it through the circuit. 3. Measure the voltage at the output pin with a multimeter to verify.

Have a voltage rectifier that can take the AC power from the wall and convert it to 9 V DC.	1. Plug the power into the wall. 2. Apply the voltage to a circuit with a resistor. 3. Use an oscilloscope to verify the voltage at the beginning of the circuit is 9 V and that it has been converted to DC

2.3 Image Capture Unit:

This unit will be responsible for capturing an image in a dimly lit setting since the device will prevent most of the light from falling onto the underlying sheet. However, a constraint that we have right now is that our camera has a focusing range of 30 cm to infinity. This implies that the device would be required to be held at least 30 cm away from any object whose text we want to interpret.

2.3.1: Camera Module:

The camera module will be fixed in place so that it can take a picture when the processing unit sends out a signal to this unit. The camera module will consist of a camera sensor that has 3280 X 2464 active pixels that reads at 21 fps and a focusing range of 30 cm [6]. The camera module will also consist of an LED with enough power to allow the camera to take a picture in dim lighting.

Requirements	Verification
The camera should be able to take a small (4.6 mm) picture and send it to the microcontroller through an I2C interface.	We can verify that the microcontroller receives the image through the I2C interface: 1. Use an oscilloscope to verify the proper operation of the microcontroller. 2. May need to look at signals ranging from DC to up to high speed clocks and data signals. 3. Verify that microcontroller has received the picture and the OCR software is ready to decipher the text in the image.
Operating voltage between 3.0V to 3.6V	1. Power the device on. 2. Measure the voltage at the camera input using an ammeter.

2.3.2: LED:

An LED will be placed near the camera so that the device can capture images in the enclosed space. We need to make sure to provide the correct amount of light so that there is no glare. A glare could potentially cause problems in detecting a letter, and therefore displaying the wrong words.

Requirements	Verification
The LED must be able to light up the target area for our picture the point where we can detect letters are present.	1. Have the device take a picture. 2. Verify that the OCR can detect letters.
The LED should draw less than a certain threshold of power.	1. Power the LED by turning on the power source 2. Measuring the current being drawn by the LED using an oscilloscope

2.4: Processing Unit:

This unit will be responsible for interpreting user inputs, processing the state machine and providing control signals to most of the other components in this device.

2.4.1: Microcontroller:

We plan to use a microcontroller chip that can handle the operation of the entire device ensuring that there is no visible delay between the user input and the machine's output.
The microcontroller will be the 32-bit STM32F427AIH6[5] and will communicate with the camera module using a I2C interface. It will run the OCR (Optical Character Recognition) software and interface with the braille display unit after converting the image to text.

Requirements	Verification
Operating voltage between 1.7V to 3.6V	To check that the operating voltage is between 1.7V to 3.6V we: 1. Connect the multimeter probe to the multimeter and we observe the correct polarity 2. Set the multimeter function to measure a DC voltage as we require a DC current

	3. Connect the probes to the output terminal and try to measure the output voltage of the power supply by reading the value on the multimeter and ensure it is between 1.7V and 3.6V.
Receive image from the camera through I2C interface	The microcontroller should be able to receive a picture captured from the camera sensor and this can be verified by: 1. Using an oscilloscope to measure the operation of the microcontroller
Successfully run OCR (Optical Character Recognition) software	The microcontroller should be able to successfully run the OCR software to convert the text in the captured image to actual text: 1. If the microcontroller successfully converts image to text, then we can observe the solenoids moving up displaying braille characters.

2.4.3: SD Card storage:

Considering the size of the image to text conversion library, we need to add an SD card to supplement the 256kB program memory storage available on the microcontroller [8].

2.5: Input unit:

This unit will be responsible for taking the input from the user and relaying the information back to the processing unit. Each button will be connected to the processing unit with one wire and will help the user to be able to control the device. To make it easier for a blind person to know which button is which, we will place them on different parts of the device. This way they can't mistake a button for a different button.

2.5.1: Power Button Input:

We will have a power button so that the system will be able to be powered on and off. It will easily toggle the power as long as the device is plugged into the wall.

Requirements	Verification
We need the power button to power the system up and down when pressed	1. Plug the device into the wall. 2. Press the button 3. See if the status indicating solenoid moves up. Or 4. Check to see if the correct signal was passed.

2.5.2: Next Button Input:

We will have a button to control when we want the next string of characters to be displayed. We need this because we will have a limited number of characters for the prototype. This will help the reader to be able to read an image that has many words on it.

Requirements	Verification
This button needs to send a signal saying to move to the next four characters	1. Have the device powered on. 2. Press the button 3. See if the correct signal was passed to the microcontroller 4. Or see if new characters are displayed

2.5.3: Capture Button Input:

We will need to have a button that will be a signal for the device to take a new picture of the desired text. Once it is pressed, the new image will be taken, and the text will begin to be converted to braille.

Requirements	Verification
This button needs to send a signal to the processor so that it knows to take another picture.	1. Power the device on. 2. Press the button. 3. Verify that the correct signal was sent to the microcontroller.

2.6: Braille Display Unit:

This unit will be responsible for displaying braille output for the user to read the converted text. We will need it to be able to properly display the correct dots that the image processing unit has determined.

2.6.1: Braille display metal plate:

This portion will consist of 24 solenoids for the braille letters. Each braille character consists of 6 pins and we plan to display 4 characters for our proof of concept due to a constraint on the cost of each solenoid. 25 solenoids alone cost $100 when purchased from American suppliers. The cost comes down to around $25 when fc however the shipping time goes up to two months which is not acceptable for this class.

Requirements	Verification
The 24 solenoids (for the characters) should be independently controllable	1. Attach the 24 input pins from the solenoids to a breadboard. 2. Setup transistor and diode circuit in the same row as each of the solenoids as described in figure 3. 3. Supply 9v across the breadboard 4. Supply each of the transistors with a positive signal individually to test if the solenoids operate independently.
The solenoids need to switch up and down in a minimum of 3 seconds.	1. Retain the circuit setup from above. 2. Record the time it takes for the solenoids to toggle between the two positions

2.6.2: Status indicator (Single solenoid):

Our device needs a status indicator to indicate that the device is either powered on or off. Since our user base largely comprises people who are visually impaired, we cannot use an LED as a status indicator. Instead, we are moving ahead with a single solenoid pin that will indicate if the device is powered on or off. If the solenoid is up, it means that the device is powered on and the user can proceed to press the capture button and get the braille text.

Requirements	Verification
The status indicator solenoid should be independently controllable	1. Attach the single solenoid input pin from to a breadboard. 2. Setup transistor and diode circuit in the same row as each of the solenoids as described in figure 3. 3. Supply 9v across the breadboard 4. Supply each of the transistors with a positive signal individually to test if the solenoids operate independently.
The solenoid needs to switch up and down in a minimum of 3 seconds.	1. Retain the circuit setup from above. 2. Record the time it takes for the solenoids to toggle between the two positions

2.7 Risk Analysis:

The functionality of our device depends heavily on the image capture and conversion process. Therefore, it is very important that we find a camera that can take an image at a close enough distance while also maintaining clarity in the image taken. If the camera component fails to take a picture close to the sheet of paper, then we will have to alter our design to reposition that came and ensure that image quality is not compromised.
Another major risk factor in the design of our project is the conversion of image to a string of characters. Since we plan to use the micro-controller for this part of the process, we need to ensure that the microcontroller can perform this conversion within 3s so that the first iteration of this proof-of-concept is user friendly and does not display a significant lag in the processing of new images.
The solenoids that we plan to use for this project also pose a threat to the successful completion of our project as each one has a significant power and current requirement. This means that the refreshable braille display itself will consume more power than the rest of the device. If we cannot solve the issue of the power supply in an appropriate manner, then we may not be able to complete this project in time.

3 Tolerance Analysis:

The imaging distance that we plan to use for our camera is approximately 12cm. Our idea is that we should be able to position the camera 12cm above the sheet of paper without sacrificing image quality. In order to understand this part, we need to analyze if using the selected camera is going to allow for this or not. The following figure demonstrates how the working distance can be calculated.

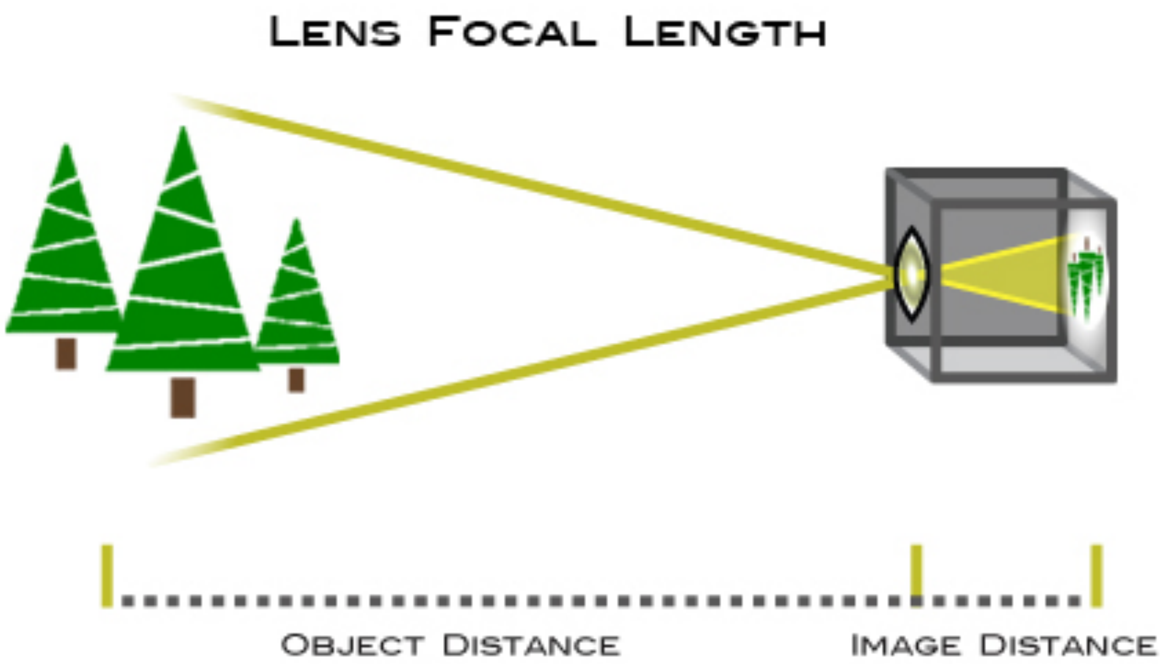

Figure 8: Calculating object distance s_1, requires knowledge of image distance s_2 and focal length f [10]

$$\frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f}$$

Given that the focal length of the selected camera is 1.55mm (f) and the desired distance between object and focal point is approximately 120mm (s_1). Using this formula, we see that if the image sensor is placed approximately 1.57mm away from the image sensor, we should be able to position the camera 12 cm away from the sheet of paper and extract good quality images. However, if that approach fails, we can attempt to add an additional lens to correct for the imaging distance.

4 Cost Analysis

We assume our labor costs to be around $50 per hour and we also assume that the device will take a total of 100 hours to design and develop assuming 3 people are working to design the product.

Description	Manufacturer	Part #	Qty	Unit cost	Total cost
Push type solenoid	Delta Electronics	DSOS-0416-09D	25	$4.8	$100 (bulk)
Camera	Leopard Imaging	LI-IMX219-MIPI-FF-NANO-H145	1	$28.75	$28.75
Micro-controller	STMicroelectronics	STM32F427AIH6	1	$13.45	$13.45
SD card port	Samtec Inc.	HSEC8-130-01-S-DV-A	1	$4.88	$4.88
Power supply wall socket	Phihong USA	PSA10F-050(P)-R	1	$12.56	$12.56

Total cost of purchasing parts: $159.64 (+taxes)
Estimated labor cost at machine shop (Initial - R&D): 12 hours * $25/hour = $300
Estimated labor cost at machine shop (Continual - Production): 4 hours * $25/hour = $100
Estimated labor cost of teammates (R&D): 3 * $50/hour * 2.5 * 100 hours = $37,500
Estimated labor cost of teammates (Production): 3 * $50/hour * 2.5 * 1.5 hours = $562.5

Total estimated cost for research and development of the product: $37,959
Total estimated cost for production of the product: $822

5 Proposed schedule

Dates	Aayush	Matt	Ashmita
02/24 - 03/02	Speak to machine shop regarding selected parts for the product	Place order for the selected parts after speaking to the machine shop	Design state machine for the functionality of the device
03/03 - 03/09	Design eagle PCB schematic along with all the components	Verify eagle PCB schematic with peers and Tas	Research microcontroller functionality and how to program the selected component
03/10 - 03/16	Submit PCBway order (by 03/11)	Design the boot and standby procedure for machine	Design each individual section of different features of the state machine
03/17 - 03/23	Research software libraries to use for OCR	Implement voltage rectifier circuit on a breadboard	Test voltage rectifier circuit
03/24 - 03/30	Manual testing of each of the individual components to understand functionality	Design the text to braille conversion function	Provide solenoids to machine shop and specific constrains on the braille display component
03/31 - 04/06	Test state machine functionality on microcontroller	Add image to text conversion function calls to existing state machine	Add text to braille conversion function calls to existing state machine
04/07 – 04/13	Solder components to PCB	Attach camera to device	Test functionality of attached components
04/14 – 04/20	Prepare for mock demo	Prepare for mock demo	Prepare for mock demo

6 Safety and Ethics

One safety issue that can arise while working on this project is that spilling water or other liquids on the device could cause a short circuit and ruin the components. This is a risk because our project idea is to be used at places like restaurants where everyone would have a drink on the table. We believe that finding a rubber casing for the device will make it safer to use for this scenario.

Another potential safety concern related to the use of a battery in this device. The first issue would be that the battery could leak. A battery leak could be harmful to the user because, for example, lithium ion batteries may release harmful gasses that can potentially harm people [2]. One solution is for us to use batteries that are leak resistant. The next issue that could come from the battery, is that we could electrocute ourselves while working on the project. This is a persistent concern when working with electronics and circuits. One good precaution to take to avoid this from happening is to make sure the system is powered down before you attempt to change something. Also, we will be having some sort of surge protection to protect our device from voltage fluctuations.

One ethical issue we see with this project is that there are similar projects that are being worked on [2]. While there are other projects that our attempting to help the blind to be able to read better, our project is meant as a portable solution for public places. We intend to develop this project idea in a unique manner and will strive to make our design exactly how we have stated.

7 References:

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