Braille Machine Design Document

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***Abstract*—This paper contains design details and analysis of the Braille Machine.**

I. Introduction

The preliminary research was represented with the proposal document, so this document will be focusing on application such as needs assessment, design parameters, costs, analysis, and plans for testing.

II. Needs Assessment

A. Client/Customer Definition

- Clients are among the "deaf-blindness" group which is a group of individuals who have both significant hearing and vision.
- Clients are low-income individuals who can't afford expensive braille Machines.
- Clients are in Canada's English-speaking area or other English-speaking countries.
- Clients have the ability to read braille fluently.

According to [1] , total deaf-blindness individuals in Canada are approximately 466,420. Based on research in 2021: "Less than 10% of blind people read braille. There should be less than 46,642 deaf-blind individuals in Canada who could read braille as it is even harder for deaf-blinded to learn and remember braille. Customers are client themselves or someone who is close to the customer

B. Challenges

It is extremely hard and low in efficiency for those individuals to communicate with a healthy English speaker, especially in terms of receiving information. English speakers have to either use tactile language or use tactile fingerspelling. [2] As a result, English speakers would be less likely to talk with those individuals and they would generally face mental problems due to loneliness. [3] However, if the communication efficiency could improve, there will be more individuals willing to communicate with the deaf-blinds and it would help them mentally. [3] Our group is trying to design a machine that allows English speakers to input words using a keypad or a keyboard and the machine could generate braille on a plane board for those blind deafs to read.

C. Sources

- In a ted talk called "DeafBlind: Blind But Not Blind", JeanLynn, who identifies as deaf-blind explained her communication barriers as she is unable to see facial expressions, body language, or hear vocal intonations. It is difficult for her to fully understand the context of the conversation due to her disability. As a result, she relies heavily on written text for communication but is unable to access visual information such as text on signs, menus, or non-verbal cues, which can be isolating and frustrating. [4]
- Pradip Sinha explained his difficulty of communicating with strangers as a deaf-blind when he is not able to write words or perceive colours. He stated that communicating with strangers leads to a lot of misunderstanding and causes low efficiency in communication. [5]
- In the book Three days to see written by Helen Keller who is deaf-blind Helen explained of feeling isolated and cut off from the world as a deaf-blind. She expresses why deaf-blindness limits her from expressing herself and understanding others. [6]

D. Competitive Landscape

- Assistive Technology Market: This landscape is a combination of other companies and organisations that develop assistive technologies for disabled such as HumanWare, Freedom Scientific, and Perkins Solutions. These companies have Braille Displays and Braille Notetakers that have more functions. However, the prices are high and not affordable for many deaf-blinds who have low income. Therefore the braille machine has to be cheaper than those designs to succeed in the competitive market. [7]
- Tactical sign languages: This landscape is a combination of all the tactical sign languages that are currently used in society such as Pro-tactile ASL. It is very convenient for two individuals who are fluent in these languages to communicate. However, it took a long time for someone with no previous experience to learn these languages. Therefore, the braille machine has to be easy to use and learn to succeed. [8]
- Consumer Behaviour: This landscape is a system of behaviours and preferences of the target customer base. According to research, average speed for adults who read braille are 70-100 words per minute and print readers can read 200-300 words per minute. However, different individuals have different speeds of reading and braille learners have a slower reading speed. Therefore, the braille machine should be able to customize the speed of displaying between 50 to 300. [9]

E. Requirement Specification

- The machine should not break if one finger applied less than 10 N on it.
- The output board has 6 dots that move upwards and downwards to display braille.

- The speed of displaying braille should be a minimum of 50 words per minute.
- The speed of displaying braille should be a maximum of 300 words per minute.
- The display speed (50-300 letters per minutes) is proportional to resistance that the potentiometer is provided linearly.

III. Analysis

A. Design

Servo motor are motors that can twist to specific angles from 0 to 180 degrees. In the design there are 6 servo motors. Each servo motor contains two parts: a movable piston and a constraint. The constraint also has two parts: a triangle wooden frame that is tied to the servo motor and the constraint for the piston glued to the wooden frame. The constraint is hollow so the piston can move freely inside it, and the wooden frame ensures stability. This part is designed to be removable and replaceable. The piston contains three parts: the piston, a rubber band, and a string. The piston, as mentioned, moves in the constraint, and it is also connected with the constraint by a rubber band. When no external force is acting on the piston, the rubber band brings the piston up. However, when the servo motor pulls the string, the piston will be pulled down. If the servo motor goes back to its original position, meaning no tension acting on the piston, the rubber band immediately brings the piston up again.

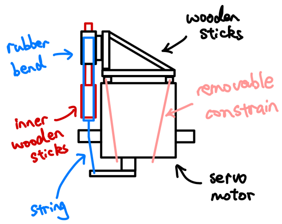

Fig. 1. Side of the servo motor

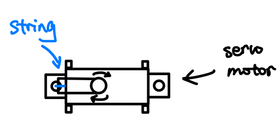

Fig. 2. Bottom of the servo motor

As the image shows, the product contains six servo motors with the exact same structure. The back of the servo motor is nailed to the main wooden frame, and between each of them, there will be wooden blocks isolating them to ensure they are stable and have equal distance.

Looking at the top of the machine. There are six holes allowing the pistons to come out, one potentiometer, and two push buttons. The potentiometer controls the displaying speed, and the two buttons forward actions: show again and pause. All the wiring will be hidden in the mainframe or along the sides of it and eventually connected to the STM32 board. This part should use approximately 25 IO ports. Another component is the keypad, which allows users to type in letters, and it is directly connected to the STM32 board, using 6 IO ports. The USB port is used for programming and power supply.

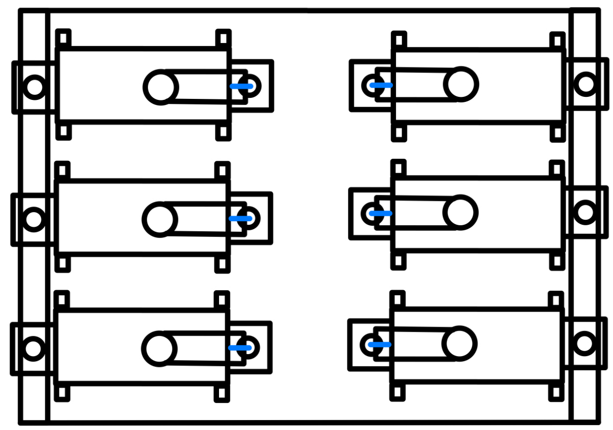

Fig. 3. Bottom of the machine

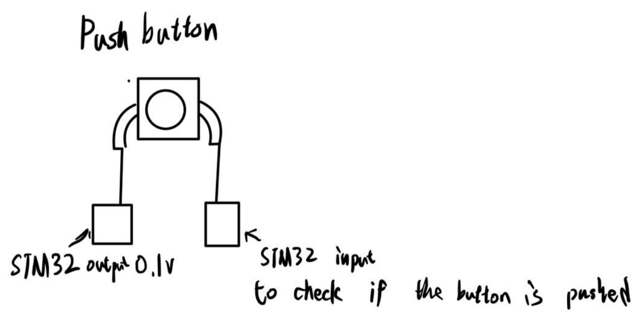

Fig. 4. Push button

There are two push buttons on the design, one is for replay sentence and the other is for pause. Each push button is connect to STM32 I/O ports to check if it is pressed.

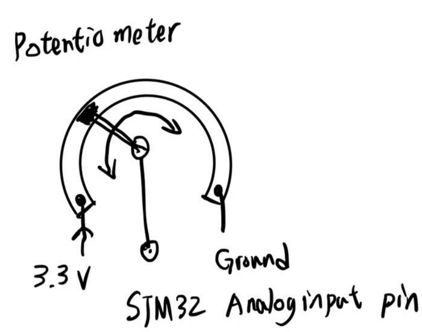

Fig. 5. Potentiometer

There is a potentiometer on the design that change the speed of displaying as twisting. Three pins on the potentiometer are connect to power, analog input, and ground respectively.

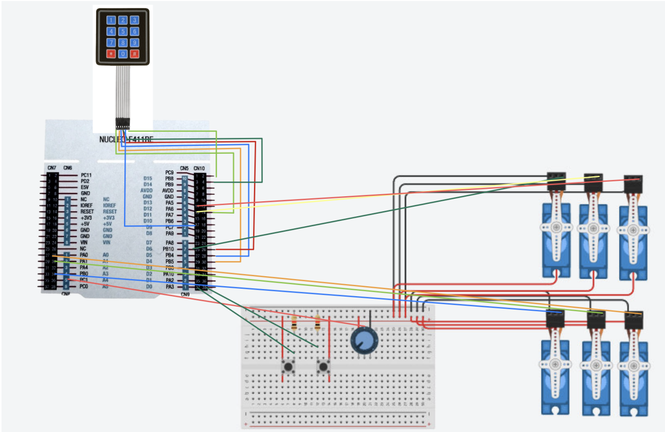

Fig. 6. Schematic

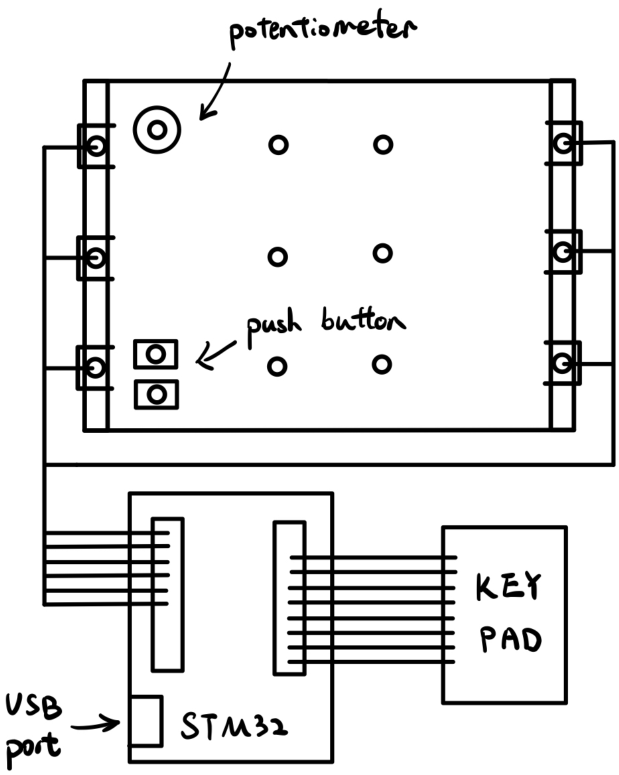

Fig. 7. Full image of the machine

B. Scientific or Mathematical Principle

1) Ohm's law:

$$V = IR$$

In a circuit, Voltage(V) is jointly proportional to current(I) and device resistance(R). Current can be calculated by $I = V/R$ and Resistance can be calculated by $R = V/I$. [10] In the machine, we want to design a customised function that allows customers to change the speed of displaying. To realise this function, we will use a circuit with a 10k potentiometer. The side pins of the potentiometer are connected to the power pin that outputs the $3.3v$ and ground pin of STM32 respectively and the middle pin of the potentiometer connected to analog pins on STM32. The analog in pin on STM32 will receive voltage between $0v$ to $3.3v$ depending on how much the potentiometer is turned. Using Ohm's law, Total current is total voltage/total resistance

$$I = \frac{V}{R} = \frac{3.3v}{10000\mho} = 0.00033A$$

To calculate the resistance of the potentiometer, subtract the total voltage by voltage detected then divide by total current

$$R = \frac{3.3v - V}{0.00033A}$$

2) Trigonometry:

$$\cos(\theta) = \frac{adjacent}{hypotenuse}$$

Trigonometry describes the relationship between angle and three sides of a triangle. [11] We will be using this maths principle to design the braille display. In the display system, we will use 6 servo motors for each dot. The angle of the servo motor turning directly relates to the height of the dot and trigonometry has to be used in order to calculate the height of the dot. Using the trigonometry and pythagorean theorem, we can derive the cosine law which is

$$c^2 = a^2 + b^2 - 2(a)(b)\cos(\theta)$$

At the original position, the length of the string is $x = 12mm$; the motor spinning radius is $r = 8mm$; and their sum is $22mm$. Then the motor spins to form a triangle, meaning x and r are no longer on the same line, but on a triangle instead. Since the braille dot needs to go down $2mm$, and the new x would become $14mm$. Now we have all three variables, so we can sub them back to the formula and yield

$$14^2 = 8^2 + 20^2 - 2(8)(20)\cos(\theta)$$

Then we can find$\theta = 33°$, which is the parameter we will set to the motor in the software.

3) Pythagorean Theorem:

$$c^2 = a^2 + b^2$$

It is used to find out the length of a side for a right angle triangle based on the other two sides. [12] The piston is subjected to be perpendicular to the back of the servo motor, which forms a 90 degree angle. In order to make it work stably, we added another piece of wood stick connecting their ends to form a right triangle, because triangle is the most stable geometric shape. From measure, we know that height $a = 10mm$ and base $b = 15mm$. Based on the Pythagorean theorem and some formula manipulation, the length of the hypotenuse side is findable, being

$$c = \sqrt{10^2 + 15^2} = 18mm$$

IV. Cost

A. Manufacturing Cost

- 6 SG90 Servo motor: manufactured by TowerPro, United States. Retail by Amazon, Canada. 30$
- STM32 board: manufactured by STMicroelectronics; Switzerland. Retail by Wstore, Canada. 35$

- 20 male to female jumper wires: manufactured by DUZ-FOREI, China. Retail by UWaterloo retail store, Canada. 15$
- Wood sticks:manufactured by Comfy Package, China. Retail by UWaterloo retail store, Canada. 4$
- Rubber bands: manufactured by Officemate, United States. Retail by Amazon, Canada. 2$
- Hot Glue Gun Stick: manufactured by Gorilla, United States. Retail by Amazon, Canada. 5$
- Most of the product are from North America, so the shipping cost is generally low.

Most of the products are from North America, so the shipping cost is generally low. All the materials are basic and cheap. Not many technologies are required for manufacturing and glue guns have a long life cycle with cheap cost. Therefore the manufacturing wouldn't be very high.

B. Implementation Cost

After the you opening the package, they need to plug in the usb port to the stm32 board for power supply. The product will automatically reset the motors, and then you can type in the letters for the blind-deaf to read. When you finish using the product, you need to unplug the usb to cut the power supply.

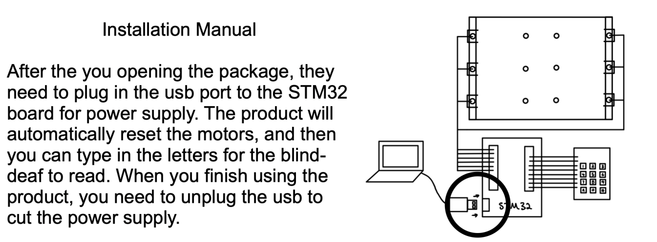

Fig. 8. Installation manual preview

To display the letters, you need to find its corresponding number first. For example, "1" is responsible for "ABC", "2" is responsible for "EFG", etc. You press that button once for the first letter, twice for the second, thrice for the third. After finishing pressing the letter, you need to press the pound key to tell the machine that it can display that letter and start to record the next one.

If you no longer uses the product, they should take out the STM32 board, servo motor, and keypad, because they are e-wastes that require special treatment. Otherwise, it might cause pollution to the environment.

V. RISKS

A. Energy Analysis

1) STM32 Voltage Compatibility:

- The STM32 has an operating voltage range of $1.71v$ to $3.6v$. [13]
- The $3v$ provided by the adapter falls within this voltage range, ensuring compatibility for the STM32.

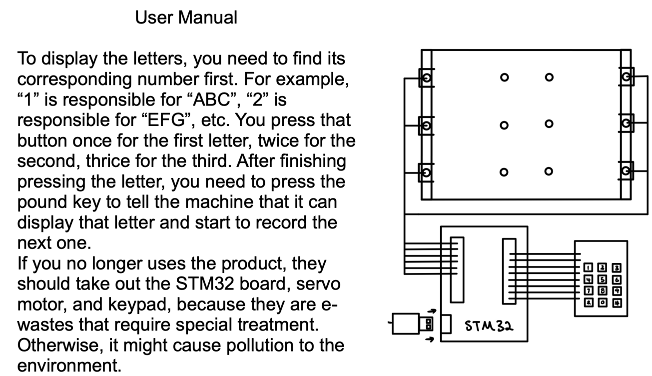

Fig. 9. User manual preview

Fig. 10. AC/DC Adapter

2) Servo-Motor Compatibility:

- The servo-motor SG90 operates within a voltage range of $3v$ to $6v$. [14]
- The STM32 is capable of powering the servo-motor, ensuring that the motor functions properly and safely within its specified voltage range.

3) Rubber Bands and Elasticity:

- The design incorporates 6 rubber bands, each with an elastic coefficient (k) of $k = 1.6\frac{N}{m}$.
- At maximum contraction, the change in position $\triangle x = 2mm = 2 \times 10^{-3}m$.
- Using the formula for elasticity potential energy $U = \frac{1}{2}k\triangle x^2$, the energy for each rubber band is calculated to be $0.0192mJ$.
- The maximum energy for all 6 rubber bands is $0.0192mJ$, which falls well within the specified $500mJ$ range.

B. Risk Analysis

- There might be potential environmental problems if disposes of the product is incorrect. The e-waste like servo motors required special processes to handle. If it is processed like other normal wastes, it is harmful to the environment.
- Since all components in the product are designed to be replaceable, users might be more careless as there are always available substitutions to fix that. This will lead to a rise in demand for substitutions and wastes of broken parts, such as servo motors, rubber bands, and wood.

- The product might break if it is misused, and this might lead to exposure of wires or short circuits. These might cause the product to be overheated and burn the wooden components. Also, although the circuit is designed to work at a low voltage, there is no guarantee of leaking electricity after damaging some core components.
- When the user presses the baillie dots too hard, it might break the mechanics inside the machine. If the product got hit by a strong force, it might also lead to similar consequences.

For the safety aspect, overheating caused by short circuits might cause fire and hurt people. If people do not break and replace the components too frequently or do not dispose of them correctly, it will lead to an increase in e-wastes, leading to potential environmental issues.

VI. Testing and Validation

A. *Force Tolerance Test*

- Ensure the machine can withstand a force of less than 10 N applied by one finger without breaking.
- Set up the machine, a glass block with a 10 N weight, and a ruler.
- Measure the height of each dot without any applied force and record the value.
- Place a wooden block on the machine's surface and display 100 words.
- Observe the dots through the glass block during the display.
- After the test, verify that the dot heights remain unchanged. If they do, the test is passed.

B. *Display Accuracy Test*

- The machine has an output board with 6 dots that move up and down to display Braille.
- Connect the machine to a computer, test program, and a camera.
- Ensure room temperature is between 10°C to 50°C, and humidity is between 0% to 60%.
- Face the camera towards the machine, set the speed to a minimum, and start recording.
- Display all 26 letters in Braille.
- After the display, verify if all 26 letters were successfully displayed by reviewing the recorded video. If there are no errors with the dots, the test is passed.

C. *Minimum Display Speed Test*

- The machine should display Braille at a minimum speed of 50 words per minute.
- If the machine passed the previous test, set up the machine, a multimeter, and a timer.
- Ensure room temperature is between 10°C to 50°C, and humidity is between 0% to 60%.
- Set the potentiometer to 0 resistance, verified by the multimeter.
- Display 300 random words at the minimum speed while timing. The time should be around 6 minutes.
- Check if the time captured is within a tolerance of 10%. If it is, the test is passed.

D. *Maximum Display Speed Test*

- The machine should display Braille at a maximum speed of 300 words per minute.
- If the machine passed the previous test, set up the machine, a multimeter, and a timer.
- Ensure room temperature is between 10°C to 50°C, and humidity is between 0% to 60%.
- Set the potentiometer to 10k resistance, verified by the multimeter.
- Display 1800 random words at the minimum speed while timing. The time should be around 6 minutes.
- Check if the time captured is within a tolerance of 10%. If it is, the test is passed.

E. *Potentiometer-Related Speed Test*

- The display speed (50-300 letters per minute) is proportional to the potentiometer's resistance linearly.
- Set up the machine, a timer, and a multimeter.
- Ensure room temperature is between 10°C to 50°C, and humidity is between 0% to 60%.
- Test various resistance values of the potentiometer from 0 to 10k ohms in 1k increments.
- Display 300 letters and time using the timer for each resistance value.
- For each test, check if the time is within a tolerance of 10% based on the formula: 300 / (50 + 0.025 * ohms of the potentiometer) minutes. If it is, the test is passed.

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