Diversifying Optical Technology (DOT.)

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Background:

In a world where information is abundant but accessibility is unequal, people with disabilities often find themselves facing daily challenges that would otherwise go unacknowledged by those without disability. In daily interactions, sight is critical, as it is the most powerful method of absorbing information in our environment. However, that is not the case for many. According to the World Health Organization, around 40 million people in the world are blind, while another 250 million have some form of visual impairment (*The International Agency for the Prevention of Blindness*, 2022). For Visually Impaired People (VIPs), these obstacles require inventive modifications to standards so that those with disabilities can navigate and thrive in a society that often overlooks their needs.

What is Braille?

Braille is a modification to the standard alphabet that is composed of raised dots arranged in specific patterns within cells. Braille involves a series of characters that are used by visually impaired individuals to translate letters into an accessible format. Braille can represent letters, numbers, punctuation, and even musical symbols.

The braille alphabet is based on a three-by-two-cell configuration. Each Braille letter of the alphabet is formed using one or more of the dots in the Braille cell. Braille has two forms: known as Grade One and contracted Braille, Grade Two, for saving space. Grade One braille is more commonly used for reading signs and brief labels and notes. Grade Two braille is used in most novels and magazines, as it takes less space (ConnectCenter, 2017).

Braille is read by passing one's fingertips over the characters on a "Braille tablet," or the 3x2 rectangle of raised points in a specific configuration representing individual letters or words. Since its inception, Braille has been adapted to almost every known language (Roth & Fee, 2010).

Significance of Braille

By using Braille, blind people can review and study the written word without relying on sighted readers. They can become aware of conventions in a language, such as spelling, punctuation, and footnotes. Braille provides blind individuals with a wide range of reading materials. However, these materials are often very bulky, costly, and limited in offering a wide variety of texts that a visually impaired person can read (Library of Congress, 2023). While fewer than 10 percent of 1.3 million people who are legally blind are Braille readers, access to Braille enhances knowledge and accessibility for the younger visually impaired population (*National Federation of the Blind*, 2009).

Moreover, the outside world contains a lot of visual information conveyed through text, such as signage. Things like advertisements, signs, menus, etc, often don't have a braille translation, which leaves visually impaired people reliant on audio or able-bodied people to assist them.

In the development of this study, the goal is to facilitate the challenges or alleviate limitations a VIP may face through a device that employs optical character recognition (OCR). We believe that through a translation device that can convert text to a tactile braille format, VIPs can gain access to a greater range of writing, allowing them to become more self-reliant.

A Text-to-Braille Translation Device

This project is aimed at improving the amount of information a VIP can receive from their environment through an engineered text-to-Braille translation device. This device will employ optical

character recognition (OCR) to extract text characters from an image captured from an Arduino-powered camera. In the past, several studies have utilized OCR technology for assistive devices aimed at helping VIPs (Yoo & Baek, 2022). In this device, the OCR technology will extract text. The translated Braille information will be outputted to the assistive device, a portable configuration of braille characters, allowing users to move to the next phase through a button.

To achieve that goal, this device would require the user to first align the device with a piece of text in front of it. The output would be a line of braille configurations on the device that the user can run their fingertips over to read the translated phrase.

Current Braille Translation Technologies

While there are existing assistive devices for helping visually impaired persons (VIPs) with daily tasks, devices aimed at increasing accessibility for text-to-braille remain limited and highly costly. The most common braille translation technologies are centered on translating computer documents into braille files that can later be printed on a braille printer or sent to a braille display. While it is useful for accessibility purposes, the obvious limitation is the medium, as such translations are only compatible with a computer interface. Costs also become a limiting factor of the technology, as these braille translation software are priced at around $895, and braille printers are among the thousands range (*American Foundation for the Blind*, 2024).

Our focus is a portable device that can translate text-to-braille, in real-time, from any surface, such as from a sign, book, computer screen, etc, and then provide the user a way of physically reading that translation on a braille surface. Through extensive market research, we have found three competitors whose products are by our objective.

Design Concept:

This device employs Microsoft's OCR to extract text characters from an image captured from a connected camera, as visualized in Figure 1. The translated Braille information from the OCR will be outputted to the device's portable configuration of braille characters, allowing users to interpret the translated message.

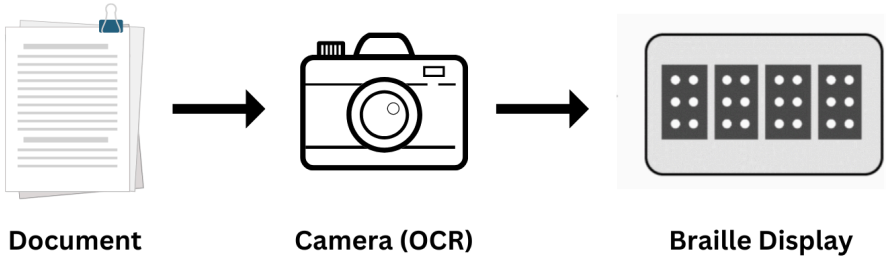

Figure 1. Text acquisition and display

This design concept employs electromechanical refreshable Braille modules for the refreshable Braille display. The key component of this design is a cam actuator, which consists of an eccentric cam with a magnet embedded in it. This complex is rotated to two stable positions in a 180° rotation by an

electromagnetic that changes its polarity. The rotation of the cam causes a braille dot to be lifted up or lowered down. A visual of the braille cell construction using the cam actuator is pictured in Figure 2. The frame of this device will be designed using Computer Assisted Design (CAD) in Fusion360 and Onshape, and 3D printed using an FD3D and SLA printer. All electrical designs will be constructed using a custom PCB board except the main microcontroller board which will be the ESP32-S3 Board with camera, optical image recognition, WiFi, and Bluetooth dependencies. Lithium-ion battery batteries will be added to ensure the device can sustain power whilst being portable.

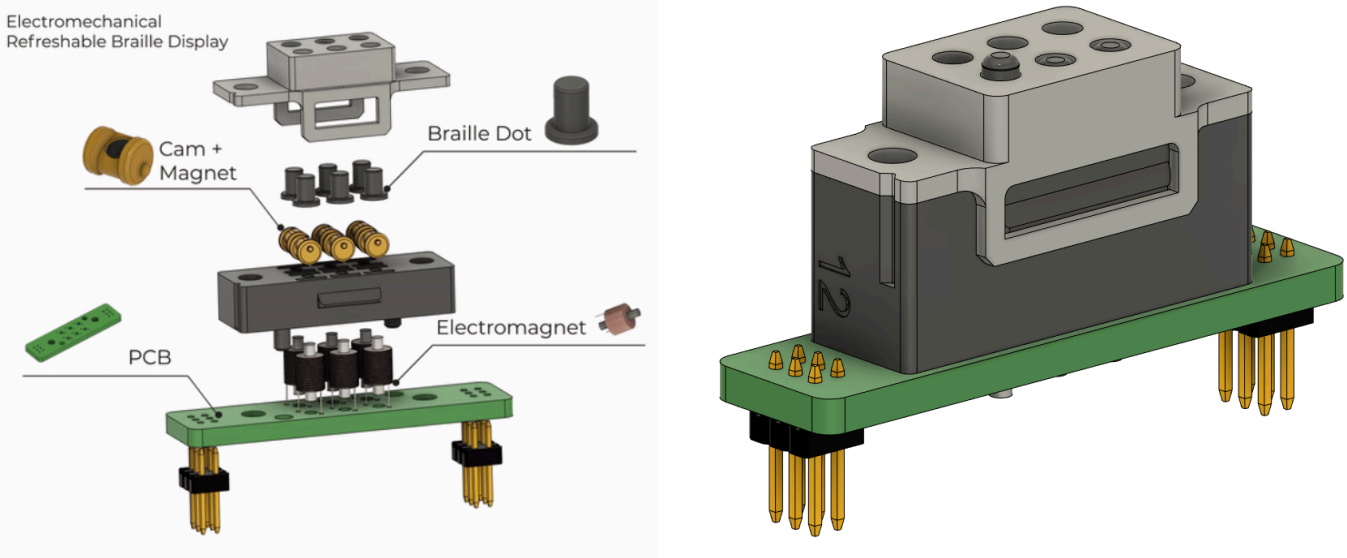

Figure 2: Braille Cell Construction (not including main PCB board or Arduino)

Resources Needed and Budget: Based on our requirements, our design shall not exceed a budget of $200. For the materials listed below, funding and materials will be provided by the Massachusetts Academy of Math and Science and WPI. The total materials for the design sum to **$131.78**, meeting our requirement.

Table 1: Materials for Design Concept

Item	Supplier	Catalog Number	Quantity	Unit Price	Total price	Link To Product
Ferrite Core	Fair-Rite Products Corp.	1934-1516-ND	90	$0.18	$8.96	https://www.digikey.com/en/products/detail/fair-rite-products-corp/3067990831/8599513
Pitch Pin Headers	Adam Tech	2057-HPH2-B-06-UA-ND	30	$0.50	$13.08	https://www.digikey.com/en/products/detail/adam-tech/HPH2-B-06-UA/9831288?s=N4IgTCBcDa4AwFYDsBaAEgBTWFAhFcAbCgKoCCKAcgCIgC6AvkA

Neodymium Disc Magnets	NeoMagnets	N/A	100	$0.19	$18.99	https://themagnetbaron.com/products/100pcs-1-32-x-1-64-rare-earth-disc-magnets
Lithium Ion Polymer Battery - 3.7v 1200mAh	Adafruit	258	1	$9.95	$9.95	https://www.adafruit.com/product/258
USB-C Battery Circuit	Adafruit	4410	1	$5.95	$5.95	https://www.adafruit.com/product/4410
ESP-32 S3 Board	FireBeetle	DFR0654	1	$19.90	$19.90	https://www.dfrobot.com/product-2676.html
Camera	Mouser Electronics	5838	1	$14.95	$14.95	https://www.adafruit.com/product/5838
PCB boards	PCBWay	N/A	16	around $1	$35	pcbway.com

Solenoid Winding tool						
Drill Chucks	Amazon	B07MCZDRBR	2	$4.49	$8.99	https://www.amazon.com/Ximimark-Electric-Fixture-Adapter-0-5mm-3-2mm/dp/B07MCZDRBR
4mm shaft gearbox DC motor	Adafruit	4639	1	$12.50	$12.50	https://www.adafruit.com/product/4639

Shipping and Assembly costs	$6.99 from DigiKey, $3.99 from TheMagnetBaron, $20 from PCBWay, $14 DFRobot					
Total					**$193.25**	

Alternate (cheaper due to avoiding extra shipping costs)

Item	Supplier	Catalog Number	Quantity	Unit Price	Total price	Link To Product
Ferrite Core	DigiKey	1934-1516-ND	90	$0.18	$8.96	https://www.digikey.com/en/products/detail/fair-rite-products-corp/3067990831/8599513
Pitch Pin Headers	DigiKey	2057-HPH2-B-06-UA-ND	30	$0.50	$13.08	https://www.digikey.com/en/products/detail/adam-tech/HPH2-B-06-UA/9831288?s=N4IgTCBcDa4AwFYDsB

						aAEgBTWFAhFcAbCgKoCCKAcgCIgC6AvkA
Neodymium Disc Magnets	TheMagnetBaron	N/A	100	$0.19	$18.99	https://themagnetbaron.com/products/100pcs-1-32-x-1-64-rare-earth-disc-magnets
Lithium Ion Polymer Battery - 3.7v 1200mAh	Amazon	B07BTV5Q6F	1	$9.49	$9.49	link
Adafruit Micro-Lipo Charger for LiPoly Battery with USB Type C Jack	PiHut	ADA4410	1	$4.93	$4.93	https://thepihut.com/products/adafruit-micro-lipo-charger-for-lipoly-batt-with-usb-type-c-jack?variant=31257709248574
FireBeetle 2 ESP32-S3 with Camera	PiHut	DFR0975	1	$16.17	$16.17	https://thepihut.com/products/firebeetle-2-esp32-s3-with-camera?variant=42474279600323
Adafruit OV5640 Camera Breakout - 120 Degree Lens with Autofocus	PiHut	ADA5838	1	$12.19	$12.19	https://thepihut.com/products/adafruit-ov5640-camera-breakout-120-degree-lens-with-autofocus?variant=42833949458627
PCB boards	PCBWay	N/A	16	around $1	$35	pcbway.com

Solenoid Winding tool						
Drill Chucks	Amazon	B07MCZDRBR	2	$4.49	$8.99	https://www.amazon.com/Ximimark-Electric-Fixture-Adapter-0-5mm-3-2mm/dp/B07MCZDRBR
4mm shaft gearbox DC motor with an encoder	Adafruit	4639	1	$12.50	$12.50	https://www.adafruit.com/product/4639

Shipping and Assembly costs	$6.99 DigiKey, $3.99 TheMagnetBaron, $20 PCBWay, $14 DFRobot, $7.44 PiHut (Intl Standard, 3-10 working days)
Total	**$192.72**

Considering the cost of the parts necessary to make this device, and the unavailability of these parts at Mass Academy and WPI, it is not possible for us to access or fund these parts ourselves. We have looked for the cheapest options wherever we can, and we need money from this grant to pay for the parts listed above, which are crucial to our project. The net cost of this product (around $190) includes parts that are not directly included in the final product but are necessary for the fabrication of the device (such as shipping and materials for the solenoid winder).

Pros: This mechanism offers a novel approach to representing Braille characters. Once the Braille is lifted due to the cam actuator and the pin has rotated into its stable position, the force of a finger cannot drive it back down. Thus, this acknowledges the need for protrusion force of the braille pin and demonstrates a net lower power consumption, as the electromagnet doesn't need to be powered once the pin has been lifted.

Cons: If more cells are added up, the time to change the state of one pin can increase marginally (±100ms).

Potential Future Additions: In the future, Wi-Fi and Bluetooth connectivity for seamless integration with smartphones, tablets, and other devices will be implemented. Audio futures will be implemented through Bluetooth and speaker components. The electromagnetic component can be paired to the audio feature to allow users to seamlessly read braille while listening to the audio. Moreover, a USB port will also be added for data transfer and more charging applications.

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