Background

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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 (WHO), 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 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 (Library of Congress, 2023).

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 variety 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 accessibility, and autonomy (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 alleviate the 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.

Braille Literacy

Adolescents comprise a large number of the visually impaired community. WHO estimates that 1.4 million children worldwide are blind, 17.5 million suffer from moderate to severe visual impairment, and 18.9 million have general visual impairment (American Foundation for the Blind, 2024). For adolescents, learning Braille from a young age aids with literacy, as braille is a much better way to understand punctuation, grammar and spelling than audio (Braille Works, 2023). Braille literacy has major implications on future life outcomes for a VIP, as literacy affects an individuals health, lifespan, wellness, and socio-economic status. According to Braille Works, it was found that the unemployment rate of VIP adults is around 70%. Conversely, 90% of employed VIPs can read and write (Braille Works, 2023). Evidently, Braille literacy has a direct correlation to employment for VIPs. The link between braille usage and employment outcomes was echoed by a survey conducted in 2018 that found adults who used braille at least once a week have higher employment rates (65% versus 45%) (Bell and Silverman, 2018).

Despite the well-documented importance of Braille literacy, the Braille literacy of students with visual impairments stands at around 10% (Braille Works, 2023). This discrepancy is correlated to a lack of qualified teachers to instruct students in Braille literacy. Early exposure to Braille is crucial, and in order to master Braille, students need ample, daily practice. They also need individualized feedback, which is difficult for teachers with high caseloads to support (Hoskin et al., 2022).

Based on a lack of Braille literacy, there should be more cost-effective assistive Braille devices for VIP adolescents. These devices should be engineered with the VIP youth in mind. In a study investigating the effectiveness of technology for braille literacy education for children it was found that technology for braille literacy education for children should provide real-time auditory and tactile feedback and be easy to use, motivational, and engaging (Hoskin et al., 2022).

A Text-to-Braille Translation Device

This project is aimed at improving the amount of information a VIP can receive from their environment as well as enhances Braille literacy 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 phrase through a button.

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 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 options 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 in accordance with our objective.

Market Research

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Competitor 1: Tactile

Tactile is a device designed by MIT undergraduates in 2017 and is currently not for sale (Petronzio, 2017). This device never went to a market testing stage, but an analysis of its components is important, as it has a similar function to the proposed device.

Designed by a team of students during a 15-hour MIT "hackathon," Tactile is a text-to-Braille translation device. It contains 30 Braille tablets attached to the top of a roughly brick-sized block with a camera on the underside. The device takes pictures of flat, written text, scanned on the bottom of the device, and sends them to a microcontroller that converts the image to text, then to Grade 1 Braille, and ultimately displays the Braille on the tablets.

While this device is targeted to be "portable" and "handheld," its usability is hindered because of its size. Despite the device being smaller and more cost-effective than current Braille machines, modifying the device to make it even smaller could make it more accessible and functional outside the home. For example, designing a device that uses fewer Braille tablets would make it more portable. Furthermore, adding the ability to adjust the position of the camera would make users able to place their hands in multiple positions and take pictures of text in their surroundings, not just on written text on a table. Adding a mechanism for the device to automatically know if the user is done with the line, as well as a text-to-audio feature would not only make the device easier to use on a day-to-day basis, but it would also expand the device's audience.

Even though this project has not been updated since 2017, no other competitors currently perform the basic function of translating text to Braille.

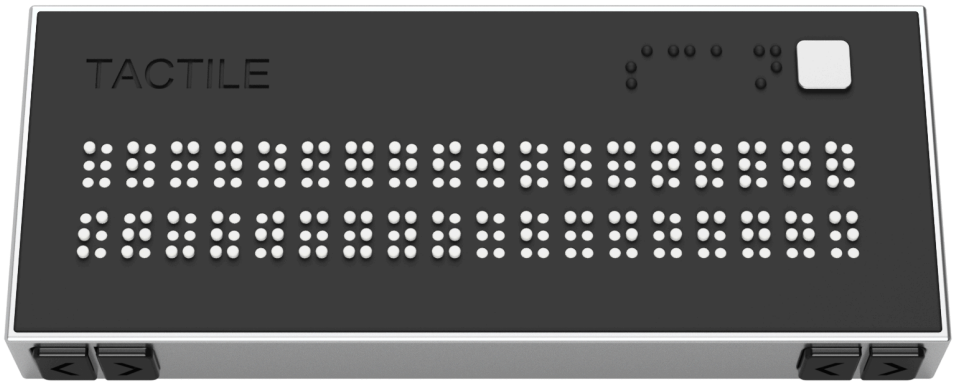

Figure 1: Top Face Image of the Tactile Device. The white pegs move up and down to display Braille characters for users to move their fingers across the board and read the Braille (Petronzio, 2017).

Competitor 2: Braille Print Books

Braille books provide the VIP with a way of expanding their literary intellect the same way standard books do for someone without visual impairment. Braille books can be found in libraries, making it a cost-effective option. However, libraries only have a limited amount of Braille books, much less than the standard books the library holds.

Braille books are often quite bulky as well, tripling or quadrupling in size. For example, the book *Harry Potter and the Deathly Hallows* weighs 1.15 pounds normally but weighs 12 pounds in printed Braille (Amazon, 2024). The greater weight makes it harder to carry the books outside of the home and difficult to store within the home.

Figure 2: Image of Braille version of *Harry Potter and the Deathly Hallows* (Reddit, 2017)

If a library cannot provide a Braille book, it can be quite expensive for a VIP to purchase. While a typical print book may cost $25, a Braille version may cost upwards of $200, depending on the size of the novel. Combined with the sheer lack of Braille books in comparison to regular books, current Braille printed books are inaccessible to many visually impaired individuals, resulting in significant barriers to accessing essential information and enjoying literature. Our device, in contrast, would not have the user conform to what has already been translated but instead give the user limitless possibilities to what can be read by actively translating new material in a quick and efficient manner.

Competitor 3: Brailliant

While some devices may already convert text screens on computers to Braille, they often cost a minimum of $2000. For example, the Brailliant B1 20X Braille Display costs about $2200. The portable device connects to a phone or computer via Bluetooth and prints the text in Braille on the surface of the device (Humanware, 2024).

Brailliant helps users read e-books on iOS and Android devices but is financially inaccessible to many. Additionally, the device is unable to read text that is not electronic, making it difficult to function outside of the home or for physical media. Adding a camera element to the device can allow users to understand the text in their surroundings, giving users a better understanding of their environment.

Figure 2: Top Face View of Brailliant Device (Humanware, 2024).

Competitor 4: TWM651236U (Patent)

The patented Braille board for blind and sighted people primarily serves as a device to teach sighted people to read Braille (廖克熙, 2023). However, its tactile capabilities make it convenient for a visually impaired person to read Braille. As Braille requires a thorough and comprehensive understanding of different phonetic symbols, the device attempts to facilitate the fluency and learning of Braille.

The Braille board has both tactile and visual recognition functions. The device is moderate in size and easy to operate. It requires Braille cards inserted in the device for the user to read. For visually impaired people, they can touch the raised pegs to read the Braille card that was placed behind. For sighted people, the board has a visualization unit that translates the Braille into the traditional alphabet.

While the device is portable, it is unable to display text that has not already been converted to Braille. As there is a severe limit on the amount of text that has been converted to Braille, this device has limited applications. The Braille must be in the exact paper size and format the board supports, which restricts its usability outside of the home.

Using a camera to automatically read text and convert it to Braille will allow the device to be used on numerous different types and formats of text, increasing the utility and practicality of carrying the device outside the home to perceive the surroundings.

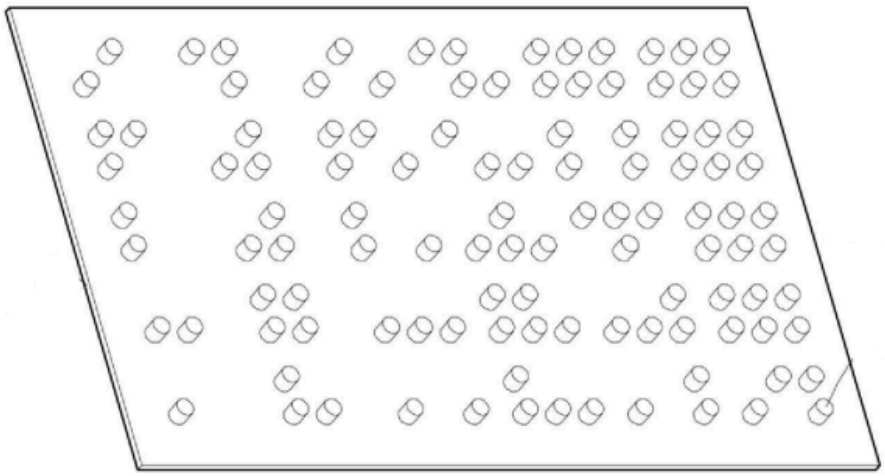

Figure 3: Braille Board Structure. The Braille card would be inserted between the grooves of the board, allowing users to use the surface to touch and read the Braille (廖克熙, 2023).

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