

# Arduino Uno-based automated text-to-braille converter using the 6-dot system: An assistive technology solution

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## Abstract

This study employed a developmental evaluative experimental research design to develop an Arduino Uno-based automated text-to-Braille converter to assist visually and auditory impaired individuals in learning and reading Braille. Additionally, it serves as a tool for converting printed materials into Braille for accessibility. The device has several key components, including an Arduino Uno Board, breadboard, MOSFETs, jumper wires, power supply, ESP32 Camera, solenoids, rectifier diodes, and polywood for structural support. Due to the lack of available respondents, researchers conducted direct observations based on predefined research problems. When performing a test on whether the accuracy of text-to-Braille conversion is affected by the different text contrasts, ranging from high to medium to low contrast. Out of 5 attempts, respectively, the high contrast resulted in 100%, the medium contrast resulted in 80%, and the low contrast resulted in 20%. Findings indicate that the device efficiently converts various text formats into Braille. However, certain factors, such as text contrast, image quality, and character recognition accuracy, may affect conversion precision. These limitations highlight areas for improvement in future designs. To enhance performance, researchers recommend using a higher-resolution camera for improved image processing and a Raspberry Pi to eliminate reliance on a laptop, making the device more portable. Integrating AI-based character recognition could also significantly refine text-to-Braille conversion accuracy, ensuring more transparent and precise translations. Future studies may also explore optimizing the device's hardware and software components to improve efficiency and accessibility. These advancements may contribute to a more reliable, user-friendly tool for Braille education and accessibility.

**Keywords:** text-to-Braille converter, visually impaired, visual auditory impaired, Arduino Uno, 6-dot system

## **Arduino Uno-based automated text-to-braille converter using the 6-dot system: An assistive technology solution**

### **1. Introduction**

In this current era, where technology continues to develop to make everyone's lives easier, supportive technologies have emerged to aid individuals with disabilities. Among these supportive technologies brought by technological advancements, text-to-braille converters have become a helpful tool for individuals with disabilities, especially those with visual and hearing impairments. According to the Assistive Technology Industry Association (ATIA), new tools, including software, instruments, and devices, improve the daily lives of persons with disabilities. It is developed to accommodate different individuals who require different tools. According to research conducted by Lupetina (2022), the usage of talking books, audiobooks, and recorded lessons has increased due to technological advancements; however, when a blind person learns through listening, their brains do not function as synaptically as they would if they were reading and writing in braille. Reading and writing are essential skills that improve cognitive function in people who engage in them.

Braille is a reading system for blind people that uses characters of raised dots to represent the letters of the alphabet (Braille Works, 2024). Blind people use Braille language, which is determined by a fashion of a system of reading and writing that serves as a communication bridge between the blind and the sighted. The Braille method, also known as white writing, was created 150 years ago and has become the reading and writing alphabet most used by blind people worldwide (Dharme & Karmore, 2015). Braille is an effective way of reading and writing for many blind individuals. Still, not every printed text has a Braille translation, making written text less accessible for the visually impaired. Students with visual impairments have far lower reading comprehension levels. Blind kids' ability to read print material is nearly gone. Students who are blind can read embossed text due to the Braille device, which improves their learning (Hussain et al., 2023). This study only shows that with the help of technology, even if a person has a disability, it will never obstruct them from keeping up with their surroundings, especially in their education. As cited by Lupetina (2022), for a blind child in the reading and writing acquisition process, using braille to read and write is fundamental for the child's cognitive development. This statement shows that braille language has a more positive effect when developing a person's cognitive function, teaching them how to read and write using braille.

According to data from the Department of Health (cited in the Senate of the Philippines, 2022), 54,533 visually and/or deaf individuals are registered in the Philippines as of March 2022. Due to the Philippines still being a developing country, there are limited innovations that could cater to visually and visually impaired individuals. Although assistive technology is available for them, it is expensive, leading to limited access for low-income individuals. Some assistive devices were also highly technical, requiring individual training, which could be a hindrance for people who are not experienced with technology.

This study developed a text-to-braille system to aid individuals with visual problems and also individuals with both visual and auditory impairments. This device was programmed using the Arduino Uno program. Due to the flexibility of this platform, this machine can be made possible using specific components such as solenoids and a camera. In this project, the researchers sought an effective technique for converting printed text to braille. Visually and hearing-impaired individuals need to have accessibility to ensure that they can participate and be knowledgeable in their surroundings without barriers. It allows them to access education, information, and daily activities without relying on others. When the world is accessible to all persons with disabilities, particularly visually and hearing-impaired individuals, it promotes inclusivity and helps them complete various everyday tasks (Pamuji et al., 2023). This project aims to close this gap by creating an automatic text-to-braille converter built on an inexpensive and easy-to-use Arduino Uno Board and an ESP32 camera and make Braille technology more accessible, enabling blind individuals to engage more fully in educational, communication, and even daily

**Statement of the Problem** - This study aimed to develop an Arduino Uno-based automated text-to-braille converter that shall assist persons with disabilities, particularly those with visual and visual-auditory impairments, in reading inaccessible text by scanning and converting it into braille. Specifically, it sought to answer the following questions: (1) What is the level of performance of the automated text-to-braille converter in terms of ability to scan text, ability to convert scanned text into braille, and ability to display and recognize the braille output accurately? (2) What is the level of accuracy of the automated text-to-Braille converter in converting scanned text into a Braille display in terms of text contrast, font type, and document type? (3) Is the accuracy of Braille conversion affected by text contrast, font type, and document type?

**Significance of the Study** - This study aims to help blind and visually-auditory impaired individuals by making Braille easy to use with an Arduino Uno-based automated text-to-Braille converter. This may prove significant to the following: To visually impaired and visually-auditory impaired individuals, this study may help individuals who have visual impairments and visual-auditory impairments. Individuals who are both blind and deaf may benefit from this study by making Braille easier to use. This enabled them to read Braille faster and more thoroughly, increasing their enjoyment of reading. The findings of this study benefited individuals who were not interested in using Braille. They learned how Braille worked by understanding the position of dots. This study also helped learners realize the practical use of Braille in everyday life, emphasizing the importance of learning this skill. This study's findings benefited individuals who knew how to use Braille. They learned more about how this technology improved traditional Braille instruction, potentially leading to more effective teaching methods. The community benefited from this study by becoming aware of the challenges visually and hearing-impaired individuals face. They also learned how people with disabilities used the Braille system, through which they gained more knowledge in using this code. To future researchers, this study shall determine how much money they would spend on developing this technology. They will also receive information and insight into designing and making this technology more effective, benefiting those visually or auditorily impaired. Their understanding of code and how it works will also expand.

**Scope and Delimitation of the Study** - This study focused on making an automated text-to-braille system using an Arduino Uno Board and an ESP32-Camera that automatically converts printed text into braille using a built-in camera. The researchers developed the product for individuals with visual and visual-auditory impairments with wider Braille reading options. The product development was conducted from December 2024 to March 2025. The product evaluation was conducted from March 6-7, 2025, and assessed the device's performance and versatility when converting text in different formats. The Arduino Uno-based text-to-braille converter is limited only to the 6-dot braille system. All research processes involved were done in San Jose, Occidental Mindoro. Due to the unavailability of the direct respondents, the study relied on observation-based evaluation to assess the converter's performance. The researchers developed and examined the device's performance and versatility to aid the needs of visually impaired and visually-auditory impaired individuals.

## 2. Methodology

**Research Design** - In this study, the automatic text-to-braille converter was developed and evaluated using a developmental evaluative experimental research design. While the experimental method examined the device's effectiveness in scanning, converting, and displaying text, the developmental side concentrated on improving the device based on performance evaluations. The effectiveness of the converter in helping people with visual impairments was measured and examined methodically using a quantitative research approach.

**Data Gathering Procedure** - The researchers conducted a series of procedures to test the product's effectiveness, aligning with the research questions and variables. These procedures encompass various methodological approaches to ensure comprehensive data collection and analysis. This process served as the study's framework, guiding the systematic assessment of the product and contributing significantly to the study's

overall validity and objectivity. The tests were conducted on March 6-7, 2025, to maintain consistency. The researchers conducted the testing at San Jose, Occidental Mindoro, which included experiments and observations. Each stage of the testing process was carefully monitored, with data cautiously recorded and analyzed.

**Research Process: Stage 1 Preparation and Gathering of Materials** - The materials that were used to produce the Automated Text-to-Braille Converter are as follows: a.) For Braille Display: 12v Solenoids, Arduino Board, and Polywood Sheet; b.) For Automated Text-to-Braille Converter: ESP32-Camera, Breadboard, Jumper Wires, Resistors, Power Supply, Barrel Plug, N-Channel MOSFETs, Rectifier Diode. The physical components required to build the product were bought through online stores, mainly from MakerLab Electronics, while the polywood for the device's housing was bought from Citi Hardware. Thus, the total amount spent purchasing all the materials was Php 4,310.

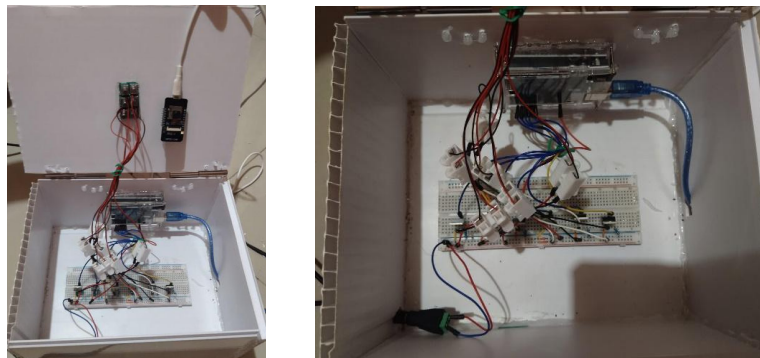


Figure 1: Actual Image of the Arduino Uno-Based Text-to-Braille Converter

**Stage 2: Construction and Development of Product** - Figure 1 shows the final output of the automated text-to-Braille converter with various components that work together to produce the desired result. Every element was connected to the breadboard and the Arduino Uno based on the Tinkercad prototype. After the product's construction, the researchers inserted the programmed code into the Arduino IDE. The experiments were then conducted after the product's construction was finished. The product's construction took 1 week, while the coding process took 2 days.

**Stage 3: Experimental Stage, Observation, and Data Recording** - After the machine had been developed, an experiment was conducted to test the device's overall performance. The researchers tested the performance of the Automated Text-to-Braille Converter through a series of experiments, including testing whether the Automated Text-to-Braille Converter can effectively scan and display the printed text in Braille. The researchers scanned a printed text using the ESP32-Camera. The recognized characters were run through the Arduino IDE program, converting them from recognized characters into text. The text was encoded in the researchers' programmed code, converting the scanned text into recognizable braille using solenoids as a display. After testing the product, the researchers conducted a series of experiments based on the study's statement of the problem. The researchers tested the ability of the product to scan and recognize printed text using the camera, as well as its performance in processing text in varied conditions. The experiments took 2 days to finish.

**Statistical Treatment of the Data** - In this study, the researchers applied descriptive statistics using weighted means to evaluate the performance and effectiveness of the converter. This involves calculating the frequency percentage of successful conversions to assess the converter's capability to scan, convert, display, and recognize Braille output. This provides an overview of how well the converter scans the text, processes text into Braille, and displays output accurately. Additionally, the simple mean was also used to determine the converter's accuracy level in converting scanned text into braille. It involves calculating the average frequency percentage based on test criteria, such as single characters, short words, and sentences in text contrast, font, and document type. Furthermore, inferential statistics through regression analysis are also applied to determine whether the text contrast, font type, and document type affect Braille conversion accuracy.

### 3. Results and Discussions

**Table 1**

*Mean level of performance in terms of text scanning.*

| No. of Trials | No. of Successful Scans | Percentage (%) |
|---------------|-------------------------|----------------|
| 1             | 1                       | 20%            |
| 2             | 1                       | 20%            |
| 3             | 1                       | 20%            |
| 4             | 1                       | 20%            |
| 5             | 1                       | 20%            |
| Total         | 5                       | 100%           |

*Legend: 1=successful, 0=unsuccessful*

Table 1 presents the data gathered through the researchers' observations and their respective results interpreted as 1 for successful conversion and 0 for unsuccessful conversion. Based on the average of the collected data, the converter has an average of 100%. The converter scans the text successfully on five consecutive trials conducted by the researchers themselves. Based on the results of the researcher's observations, the Automated Text-to-Braille Converter is an effective assistive tool for scanning text. The results show that the Automated Text-to-Braille Converter has high reliability and accuracy and successfully scans text without errors. The results also aligned with prior research, including Saitwal (2024), which stated that the level of accuracy for OCR ranges from 96% to 99% when the scanned text is of high quality and well-structured, but this level of accuracy can easily be affected when the quality of the image is poor and poorly structured.

**Table 2**

*Mean level of performance of the Automated Text-to-Braille Converter in terms of converting text into braille and accuracy in text-to-braille conversion*

| Test Criteria             | No. of Successful Trials |       |       |       |       | % of Successful Trials | Verbal Description |
|---------------------------|--------------------------|-------|-------|-------|-------|------------------------|--------------------|
|                           | Trial                    | Trial | Trial | Trial | Trial |                        |                    |
|                           | 1                        | 2     | 3     | 4     | 5     |                        |                    |
| Single Characters         | 1                        | 1     | 1     | 0     | 1     | 80%                    | Good               |
| Short words (3-5 letters) | 1                        | 1     | 1     | 1     | 1     | 100%                   | Excellent          |
| Sentences                 | 1                        | 1     | 1     | 1     | 1     | 100%                   | Excellent          |
| <b>Total</b>              |                          |       |       |       |       | <b>93.33%</b>          |                    |

| Test Criteria             | No. of Successful Trials |       |       |       |       | % of Successful Trials | Verbal Description |
|---------------------------|--------------------------|-------|-------|-------|-------|------------------------|--------------------|
|                           | Trial                    | Trial | Trial | Trial | Trial |                        |                    |
|                           | 1                        | 2     | 3     | 4     | 5     |                        |                    |
| Single Characters         | 1                        | 1     | 1     | 0     | 1     | 80%                    | Good               |
| Short words (3-5 letters) | 1                        | 1     | 1     | 1     | 1     | 100%                   | Excellent          |
| Sentences                 | 1                        | 0     | 1     | 1     | 1     | 80%                    | Good               |
| <b>Total</b>              |                          |       |       |       |       | <b>86.67%</b>          |                    |

*Legend: 1=successful, 2=unsuccessful. 90-100% = Excellent, 70-89% = Good, 50-69% = Fair, Below 50% = Poor*

Table 2 displays the data gathered by the researchers in testing the product's performance in converting texts into braille. These data were collected through five trials of scanning single characters, five trials of scanning short words (3-5 letters), and five trials of scanning sentences. For single characters, there is only one unsuccessful conversion. All trials are successful for short words (3-5 sentences). There is no unsuccessful trial for sentences, and all of the texts are successfully converted into braille. The data gathered from the conducted observation resulted in a percentage of 80% out of 5 attempts when scanning single letters that have a similar structure to other letters in the alphabet, such as N, M, L, and I. These results are mainly because of the low 2MP resolution of the ESP32. This situation aligned with the research of Saitwal (2024), which stated that the resolution and quality of the image can easily affect the performance of the optical character recognition program. Meanwhile, the other variables resulted in 100% out of 5 attempts when converting short words with 3-5 letters and another 100% out of 5 attempts when converting simple sentences. These results are also aligned with the research of Shokat et al. (2020), which stated that the system is affected by special actions, such as uppercase and lowercase letters, that can easily affect the system's usability.

Furthermore, the data are collected through observation to assess the level of accuracy of the converter's performance. The data were observed by scanning with five trials each in single characters, short words (3-5 letters), and sentences. For single-character recognition, the converter achieved an accuracy rate of 80%, with 4 out of 5 trials successfully converting the characters. This suggests that the software is generally reliable in recognizing individual characters but is still prone to occasional errors. The converter demonstrated 100% accuracy for short words, successfully converting all five trials. This indicates that the OCR system is highly effective when processing short words, likely because they provide more contextual information than isolated characters, reducing the misinterpretation. The consistent accuracy in this category suggests that the software performs best when dealing with brief and well-defined text segments. However, for complete sentences, the accuracy rate dropped back to 80%, with 4 out of 5 sentences being correctly transcribed. This decline suggests that OCR struggles with longer and more complex text structures. These findings align with the research of D et al. (2020), which stated that OCR software frequently produces errors in its output. When the transcription of the text is inaccurate, mistakes vary from a single wrong character to a whole word, and as a result, sentences are not correctly transcribed.

Table 3 contains the weighted mean after conducting a test on whether the accuracy of text-to-Braille conversion is affected by the different text contrasts, ranging from high to medium to low contrast. The high contrast (black text on a white background) resulted in 100% out of 5 attempts, while the medium contrast (gray text on a white background) resulted in 80% out of 5 attempts, while the low contrast (light text on a white background) resulted in 20% out of 5 attempts. This result indicates that different text contrasts affect the accuracy of the automated text-to-Braille converter, which aligns with the research of Saitwal (2024). His study stated that high-quality and well-structured images result in 96%-99% accuracy when scanned by an optical character recognition program. In contrast, low-quality and poorly structured images will have significantly lower accuracy compared to the image with higher quality.

**Table 3**

*Mean level of accuracy of the Automated Text-to-Braille Converter in terms of text contrast, font type, and different document types.*

| Test Criteria |          | No. of Successful Trials |       |       |       |       | % of Successful Attempts | Verbal Description |
|---------------|----------|--------------------------|-------|-------|-------|-------|--------------------------|--------------------|
|               |          | Trial                    | Trial | Trial | Trial | Trial |                          |                    |
|               |          | 1                        | 2     | 3     | 4     | 5     |                          |                    |
| High          | Contrast |                          |       |       |       |       |                          |                    |
| (100%         | Contrast | 1                        | 1     | 1     | 1     | 1     | 100%                     | Excellent          |
| Level)        |          |                          |       |       |       |       |                          |                    |

|                                   |          | No. of Successful Trials |   |   |   |   | % of Successful | Verbal Description |
|-----------------------------------|----------|--------------------------|---|---|---|---|-----------------|--------------------|
| Medium Contrast (50% Level)       | Contrast | 0                        | 1 | 1 | 1 | 1 | 80%             | Good               |
| Low Contrast (25% Contrast Level) | Contrast | 0                        | 0 | 0 | 0 | 1 | 20%             | Poor               |
| <b>Total</b>                      |          |                          |   |   |   |   | <b>66.67%</b>   |                    |

| Test Criteria | No. of Successful Trials |       |       |       |       | % of Successful Attempts | Verbal Description |
|---------------|--------------------------|-------|-------|-------|-------|--------------------------|--------------------|
|               | Trial                    | Trial | Trial | Trial | Trial |                          |                    |
|               | 1                        | 2     | 3     | 4     | 5     |                          |                    |
| Serif         | 0                        | 1     | 1     | 1     | 1     | 80%                      | Fair               |
| Script        | 0                        | 1     | 0     | 0     | 0     | 20%                      | Poor               |
| Decorative    | 1                        | 0     | 1     | 0     | 0     | 40%                      | Poor               |
| <b>Total</b>  |                          |       |       |       |       |                          | <b>46.67%</b>      |

| Test Criteria     | No. of Successful Trials |       |       |       |       | %   | Verbal Description |
|-------------------|--------------------------|-------|-------|-------|-------|-----|--------------------|
|                   | Trial                    | Trial | Trial | Trial | Trial |     |                    |
|                   | 1                        | 2     | 3     | 4     | 5     |     |                    |
| Physical Books    | 1                        | 0     | 1     | 0     | 1     | 60% | Fair               |
| Handwritten Notes | 1                        | 1     | 1     | 0     | 0     | 60% | Fair               |
| Text in Images    | 1                        | 1     | 1     | 1     | 0     | 80% | Good               |
| <b>Total</b>      |                          |       |       |       |       |     | <b>66.67%</b>      |

*Legend: 1=successful, 0=unsuccessful. 90-100% = Excellent, 70-89% = Good, 50-69% = Fair, Below 50% = Poor*

In this observation, the researchers tested three different font styles: serif, script, and decorative. Among the tested fonts, the serif font style achieved an 80% success rate, with 4 out of 5 attempts resulting in accurate conversion. Serif fonts, characterized by small strokes or extensions at the ends of letters, are generally designed for readability, which likely contributed to the high accuracy rate. The serif font style exhibited the lowest accuracy, with only a 20% success rate across five attempts. Script fonts, which mimic cursive handwriting, often feature connected letters and varying stroke thicknesses, making them difficult for OCR-based systems to distinguish. The results of this observation aligned with the study conducted by Alsumait and Al-Osaimi (2016), who studied how different fonts and text spacing influence readability, demonstrating that easily distinguishable letter forms help readers quickly identify characters, reducing cognitive strain and enhancing reading efficiency. Poorly designed fonts with ambiguous letter shapes can slow down scanning and increase errors in text recognition.

Moreover, the researchers tested different documents, including physical books, handwritten notes, and image text. The results revealed that text in images had the highest success rate (80%), meaning that the scanned text was correctly transformed into Braille in four trials. This implies that optical character recognition (OCR) software can recognize text extracted from photographs more readily. This is probably because of the high contrast, legible typefaces, and well-organized layouts that make the text easier to read. On the other hand, the success rate for handwritten notes and physical books was 60%, meaning that only three out of five experiments produced a completely accurate Braille conversion. A pocketbook and a children's tale were among the physical

books examined; these might have had differences in font styles, text clarity, or print quality that impacted OCR performance. The results of these findings can be related to a study conducted by Lamba and Madhusudhan (2023), who explored optical character recognition errors in text documents, noting that faded text, speckled backgrounds, and shadowed text can lead to mistakes such as joined words, misspellings, and character insertions.

**Table 4**

*Correlation analysis on the Level of the text-to-Braille conversion accuracy to the text contrast, font type, and document type*

| Independent Variable | Dependent Variable             | R-value | R <sup>2</sup> (Effect Size) | P-value | Interpretation  |
|----------------------|--------------------------------|---------|------------------------------|---------|-----------------|
| Text Contrast        | Accuracy of Braille Conversion | 0.911   | 0.830                        | 0.713   | Not Significant |
| Font Type            | Accuracy of Braille Conversion | 0.654   | 0.428                        | 0.333   | Not Significant |
| Document Type        | Accuracy of Braille Conversion | 0.866   | 0.750                        | 0.166   | Not Significant |

\*Significant at  $p < 0.05$       Not Significant at  $p\text{-value} > 0.05$

Table 4 summarizes the key findings of the correlation analysis on the level of the text-to-braille conversion accuracy concerning the text contrast, font type, and document type. Each sub-variable was assessed through regression analysis to determine its significance to the level of accuracy of the Braille conversion. Each variable was statistically treated through a confidence level of 95%, requiring a p-value of less than 0.05 to be labeled significant. The computed R-values are also included in the table, indicating a positive or negative correlation. The relationship between the Braille conversion accuracy and text contrast garnered a p-value of 0.713, making the ties statistically insignificant. The computed R-value of 0.911 suggests a strong positive correlation between the two variables. This supports past studies that signify that character recognition relies heavily on text contrast since it affects readability and visual resolution (Chen & Muhamad, 2022)—establishing the fact that high contrast improves the capacity to see tiny details because color and text-background polarity affect visual resolution, significantly when contrast levels drop. However, due to the p-value result indicating that the relationship is not statistically significant, the findings are likely to happen by chance or due to the variability.

The correlation between the font type and accuracy resulted in a p-value of 0.178, more significant than 0.05, making the relationship statistically insignificant. The calculated R-value of -0.654 further proves the relationship is insignificant, suggesting that there is little to no difference between font types concerning the accuracy of text scanning and braille conversion. In a similar study by Arditi (2018), it is stated how font readability affects memory retention and comprehension, emphasizing that clear, well-spaced fonts enable smoother eye movement across text, preventing misinterpretations caused by letter confusion. The finding suggests that the level of accuracy of braille conversion is not regarded as a specific font type as long as there is a clear, well-spaced format. The relationship between the variables, level of Braille conversion accuracy, and document type resulted in a p-value of 0.783, making the relationship statistically insignificant. However, the computed R-value of 0.866 suggests that certain document types increase the level of accuracy of Braille conversion. The statistically insignificant interpretation of the p-value implies that the findings are likely due to chance or the number of test trials. Similarly, Bengali OCR, developed by Rabby et al. (2024), caters to diverse document types, including handwritten and typewritten texts, and works identically to the Arduino Uno-Based Automated Text-to-Braille converter, allowing versatility in its performance.

#### 4. Conclusions

Based on the findings, the following were concluded about the following research problems: The Arduino automated text-to-Braille converter performed well in recognizing the text and converting it into Braille—high

contrast resulted in more accuracy than low contrast. The font type and document type do not affect the accuracy of the text-to-braille converter when scanning and converting text into braille. The text contrast, font type, and document type have no significant effect on the accuracy of Braille conversion.

**Recommendation** - Based on the results and findings of the study, the researchers suggest the following topics for future research: The researchers recommend that future developers of this product may improve the OCR algorithm to detect a greater variety of typefaces and document formats. Text recognition can be enhanced by using higher-resolution cameras or image enhancement techniques, especially for handwritten or low-contrast texts. The researchers recommend that device manufacturers and innovators maximize the Braille output mechanism by improving the hardware design and utilizing more accurate actuators. This will enhance the device's dependability by resolving sporadic pin alignment and reaction time irregularities and guaranteeing a more precise and responsive Braille display. The researchers recommend that schools and organizations assist people with visual impairments using cutting-edge processors like the Raspberry Pi or Intel Edison to improve their systems. Processing photos more quickly and enabling machine learning models for improved text recognition and Braille conversion can improve performance. With this update, a laptop would no longer be required, increasing the device's portability and accessibility in learning environments. The researchers recommend that developers include a feature that saves and refreshes recently scanned documents. This would eliminate the need for users to repeatedly scan a text or document, enhancing both the accessibility and functionality of the device. By implementing this feature, the device would become more efficient and user-friendly. The researchers recommend that future researchers directly test the converter with visually impaired people. To obtain crucial input for enhancing the converter's usability, functionality, and practicality in real-world applications. Future research can also look into integrating AI to improve text recognition, test the device's longevity to see how well it works over time, and consider adding a text-to-speech function for multimodal accessibility.

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