# Voice-to-Braille Translation System for Promoting Braille Learning

Ian Herrera*, Juan J. Carreras, and Rutilio Nava

Biomedical Engineering, Faculty of Engineering, Universidad Modelo, Mérida, México
Email: 15222025@mode1o.edu.mx (I.H.); 15221815@modelo.edu.mx (F.B.L.); rutilio.navam@modelo.edu.mx (F.C.L.)
*Corresponding author

Manuscript received November 27, 2023; revised December 25, 2023; accepted January 4, 2024; published March 26, 2024

***Abstract*—The Braille system is vital for deafblind individuals, aiding their education and communication. However, Braille learning often relies on educator support. This paper outlines the development of a Braille printer converting voice input to Braille using an old ink printer to enhance communication to deafblind. The process includes designing the prototype, modifying the mechanism, and creating the control system. The innovation tackles key issues by enabling real-time voice-to-Braille translation, thereby enhancing communication. Repurposing materials and utilizing an existing printer infrastructure reduce costs and environmental impact, thus promoting sustainability. This approach has the potential to transform education and communication for the deafblind, fostering independence, cost-effectiveness, and environmental responsibility. The results demonstrate the effective operation of the mechanism, as it seamlessly translates voice input into accurate Braille output.**

***Keywords*—braille printer, deaf blindness, biomedical engineering, education**

## I. Introduction

The Braille system, developed by French educator Louis Braille in the 19th century, remains a cornerstone of literacy for people with visual impairments [1]. Despite its historical significance, the modern Mexican population faces significant challenges related to disability, as evidenced by a reported prevalence of 5.7%, with a notable increase in visual-auditory disabilities [2].

This educational dilemma is particularly pronounced for the 466,178 individuals with visual and hearing impairments among the 7 million people with disabilities, significantly impacting their quality of life and educational independence, especially in the context of Braille education [3]. Braille instruction is a skill that is taught to adults with visual impairments and participate in rehabilitation programs, offering an alternative to printed content. Despite this, it is estimated that less than 10% of people with blindness can read braille [4]. Traditional methods of teaching Braille present challenges in terms of time, the need for dedicated instruction, and the specialized skills required of both educators and learners [5].

These challenges are compounded by the prohibitive cost of Braille embossers, which limits private ownership and hinders the democratization of Braille education [6]. In response, this work envisions the development of an affordable, accessible device capable of translating natural speech into Braille. This innovation aims to promote autonomous learning, especially for those who may struggle with acquiring Braille literacy skills later in life, such as the elderly population [7, 8].

## II. Literature Review

The literature on braille education and assistive technology for the visually impaired provides a solid foundation for our research. Existing studies underscore the continued relevance of Braille in education [1], while also highlighting the challenges posed by traditional teaching methods and the high cost of Braille embossers [2, 6].

Technological solutions, particularly those incorporating Automatic Speech Recognition (ASR) technology, are emerging as a potential way to address these challenges and provide an innovative approach to Braille education [8]. The literature review thus positions our study at the intersection of historical significance, current challenges, and emerging technological opportunities in the field of Braille education for the visually impaired.

## III. Materials and Methods

This project involves the meticulous adaptation of an old printer into a real-time transcription device adapted to convert oral speech input into Braille text. The critical hardware components include:

Reused Components:

- Ink cartridge: Positioning for the solenoid actuator, salvaged from the original printer;
- Printer Casing;
- Sheet Feeder;
- Paper Support;
- Output Tray Extension;
- Paper Feed Rollers;
- Control Panel;
- Buttons;
- Printing Motor;
- Conveyor Belt;
- Toothed Belts and Toothed Belt Pulleys: Used for precise linear motion.

New Components:

- DC Motors: Two DC motors for X-axis and Y-axis control;
- Stepper Motor: Used for precise movement control;
- Push-pull Solenoid Actuator: Used for Braille dot embossing;
- AC-to-DC Adapter :12V 2A for power supply;
- Arduino Uno Microcontroller: Central control unit;
- Laptop: Equipped for natural language processing;

During the reconfiguration phase, components intrinsic to inkjet printing were systematically removed. This included ink cartridges, toner pads, ribbon cable, control circuits, printer battery, and the upper assembly housing the scanner and associated circuits. Conversely, salvageable components such as the printer casing, sheet feeder, paper support, output tray extension, paper feed rollers, control panel, buttons, printing motor, and conveyor belt were retained. The printing headboard, stepper motor governing its movement, and rewiring were meticulously executed to align with the new operational objectives.

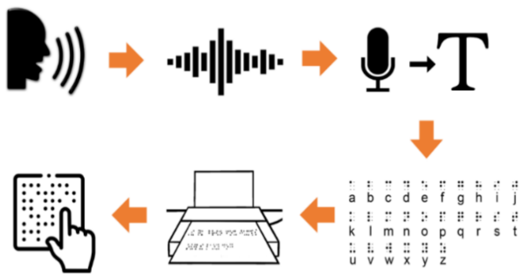


Fig. 1. Voice processing diagram.

The operational architecture revolves around the precise control of motor movements performed by the Arduino Uno microcontroller. The X-axis, which controls the horizontal movement of the print head across the paper, is controlled by a 24V DC motor. Meanwhile, the Y-axis motion for printing on individual rows is controlled by a stepper motor. The solenoid actuator, strategically positioned within the print head, provides the force necessary to emboss Braille dots onto the paper.

To achieve precise linear motion for Braille character printing, toothed belts and pulleys have been strategically mounted on the axes of motion. This mechanical arrangement efficiently converts the rotational force generated by the motors into precise linear motion.

The printer's central control hub is the Arduino Uno microcontroller. It interfaces with the computer and runs Python code for voice input processing. Voice input captured by a microphone is processed and translated into Braille by the Python code. The Arduino code then interprets the Braille characters and meticulously coordinates motor movement, solenoid activation, and paper printing synchronization. This coordination is critical to ensuring an accurate Braille representation of the original voice input, as well as the precise linear motion required for flawless Braille character printing.

Central control is provided by an Arduino Uno, which receives signals from the computer via Python code. The computer, equipped with a microphone, captures the voice, and the Python code transcribes and translates this voice into the Braille language shown in Fig. 1. The Arduino code interprets the Braille letters and coordinates motor movement, solenoid activation, and paper printing synchronization.

Comprehensive testing was crucial in determining the Voice-to-Braille Printer's optimal functionality and accuracy. The test battery included critical assessments such as a

### A. *Mechanical Functionality Test*

The test was overseen and conducted under the supervision of the Arduino microcontroller, which directed and controlled the assessment process, ensuring precise movements of the prototype's X and Y axes.

Commands facilitated by the Arduino were used to execute and measure meticulously controlled movements with the goal of achieving precise alignment between the head unit and paper positioning mechanisms to ensure accurate Braille dot configuration.

The evaluation involved controlled movements at varying speeds, each directed by the Arduino with great attention to detail and measured to determine their accuracy. This facilitated a thorough examination of the system's performance across varying operational conditions.

### B. *Assessment of Braille Quality*

The main aim was to guarantee accurate and readable Braille output, rendering this appraisal an indispensable measure in affirming the quality of the Braille text generated.

A meticulous analysis of the printed sample was conducted to assess the formation of Braille dots. The primary objective was to achieve accuracy and clarity, crucial for upholding the readability of Braille text. The intensive assessment focused on ensuring the precision of Braille dot formation to enhance comprehensibility for the target audience.

A comprehensive analysis was conducted on the complete printed sample to ascertain the precise depiction of Braille characters.

### C. *Alignment and Spacing Test*

This assessment involved printing multiple lines of Braille and ensuring precise spacing without overlap or inadequate separation, following the guidelines set by the Braille Authority of North America [9].

The aim was to maintain clear and accessible Braille text. The assessment was conducted immediately after the mechanical test. Meticulous analysis based on the principles of objectivity, comprehensibility, logical structure, conventional structure, clear objective language, formatting, formal register, balanced language, precise word choice, and grammatical correctness ensured a well-organized and spaced layout with a focus on readability and adherence to established Braille standards.

### D. *Translation Accuracy Test*

This involved a meticulous evaluation of the accuracy of the Braille transcription process from voice input to output. The primary objective was to validate the transcription's correctness and fidelity, aligning with international Braille transcription standards.

The assessment thoroughly examined the precision of the transformation from vocal input to Braille output. Significant focus was given to verifying the accuracy and fidelity of the transcription in accordance with the recognized global standards for Braille.

Each stage of the transcription process was rigorously evaluated to ensure accuracy and compliance with international Braille standards. The examination focused on verifying the transcription's precision, ensuring the Braille output accurately reflected the spoken input, adhering to established conventions, and maintaining coherence and dependability in the resulting Braille text.

The thorough evaluation of the transcription process, which adhered to international Braille standards, was crucial in verifying the accuracy and reliability of the Braille output. This meticulous assessment upheld the importance of fidelity and consistency for individuals who rely on Braille as a means of accessing written information.

### E. Printing Speed Test

The printer's speed underwent an extensive evaluation, taking into account the outcomes of the prior mechanical functionality test. The objective was to attain an efficient printing process while still upholding high-quality Braille dot production.

The assessment comprised insights from the mechanical functionality test, striving to balance the printer's efficiency with the production of high-quality Braille dots. The goal was to guarantee that the printer's velocity did not undermine precision, lucidity, or adherence to Braille protocols. This was verified in the evaluation of mechanical functionality.

This evaluation confirms the efficient speed of the printer while maintaining the quality of Braille dot production, highlighting the significance of accessibility and readability. Other components of the printer system have the potential to enhance both speed and quality.

### F. Noise Test

The system was subjected to varying noise levels to simulate different environmental conditions. The tests were conducted in scenarios mimicking typical office noise to louder public spaces.

The assessments involved the following scenarios:

Closed Environment: Elevated Noise Level: Four individuals engaged in loud conversation while one individual spoke closely into the microphone, dictating words. This simulated a noisy office setting.

Closed Environment: Lower Noise Level: Like the previous setting, but with individuals conversing at a lower volume, yet in closer proximity to the microphone. This represented a quieter office environment.

Open Environment: Crowded Setting: Testing conducted in an open area with a significant number of people, where an individual spoke near the microphone. This scenario simulated a public space with a larger crowd.

Each scenario aimed to test the system's performance in varying noise conditions. The objective was to assess the system's ability to accurately capture and transcribe voice input into Braille amidst different noisy environments.

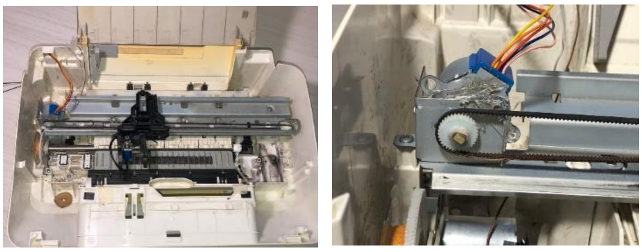
## IV. Result and Discussion

Fig. 2(a) and Fig. 2(b) display the proposed device's external profile and the modification made to the upper part of its casing to create an open space for viewing its interior during operation.

(a) (b)

Fig. 2. (a) Printer casing; (b) Internal observation panel of the printer.

The integrated stepper motor in the printer mechanism enables precise and controlled movements of the marking awl for sheet marking. As shown in Fig. 3(a) and (b), the motor is controlled by an Arduino board, which drives a conveyor belt to guide the awl smoothly along a low-resistance rail.

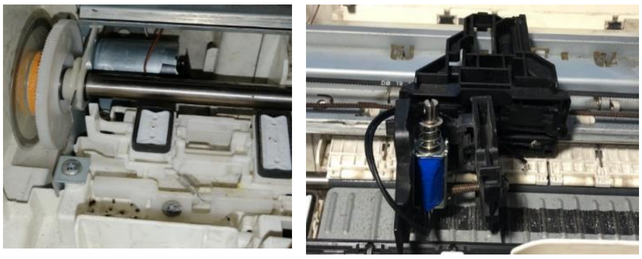


(a) (b)

Fig. 3. (a) Top view of the x-axis movement mechanism; (b) x-axis stepper motor.

Fig. 4(a) and Fig. 4(b) exhibit the DC motor operating in tandem with the pre-existing printer gear system, as it moves the sheet alongside the solenoid mount responsible for paper marking. Only minor modifications were made to this component of the system.

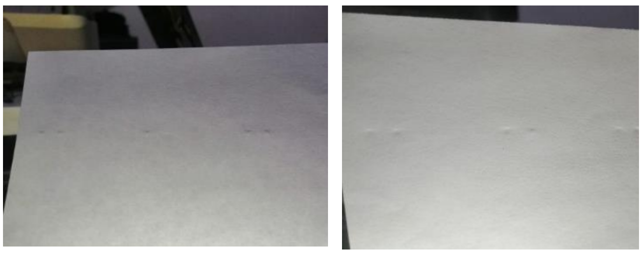
The mechanical testing results incontrovertibly confirm the system's outstanding precision, achieving accurate Braille dot placement on paper and validating the mechanical proficiency of the prototype. This thorough and exact analysis, carried out and monitored by the Arduino, confirmed the system's ability to fulfill the demanding criteria necessary for precise Braille character embossing.



(a) (b)

Fig. 4. (a) Gear system; (b) Solenoid Mounting.

Some work was conducted on designing and constructing the solenoid mounting responsible for marking the sheet. Similarly, the code functions by effectively coordinating each motor, enabling the prototype to operate adequately. The code now includes additional features that allow the user to input text directly from the computer console and translate it into Braille. Fig. 5(a) and Fig. 5(b) display various parts of the printing tests.



(a) (b)

Fig. 5. (a) Initial printing test; (b) Post adjustment printing.

The expenses involved in developing the prototype's components are itemized in Table 1. Thanks to its focus on sustainability and the refurbishment of electronic components, as well as the use of a foundational structure for modifications, there has been a substantial decrease in manufacturing costs.

Table 1. Hardware prices

| Component | Quantity | Unit Price (MXN) | Total $ (MXN) |
|---|---|---|---|
| Arduino UNO | 1 | $ 350 | $ 350 |
| Stepper Motor | 1 | $ 80 | $ 80 |
| Duplex Cable | 1 (m) | $ 15 | $ 15 |
| Resistor | 2 | $ 3 | $ 3 |
| Dual H Bridge | 1 | $ 55 | $ 55 |
| Breadboard | 1 | $ 30 | $ 30 |
| Solenoid | 1 | $ 250 | $ 250 |
| | | **Total** | $ 783 |

To evaluate the printing efficiency of the device, the system was tested in a controlled, silent environment. The results were outstanding, with a 100% accuracy rate in transcribing voice input into Braille. The absence of ambient noise contributed to the optimal performance of the system, which precisely captured and transcribed voice commands.

However, in louder public spaces, where noise levels are higher, the system's performance decreased, achieving a transcription accuracy of only 36%. Significant background noise negatively impacted the system's capacity to capture and interpret voice input accurately, leading to lower transcription precision.

The findings reinforce that the system functions optimally in quiet or less noisy environments, ensuring impeccable transcription results. In noisy conditions, especially those that simulate crowded or loud public settings, the accuracy of the system in transcription of voice commands into Braille decreased significantly. Test results in noisy environments demonstrate the difficulty the system faces in identifying the specific portion of audio that requires processing. As a result, it translates different conversation fragments simultaneously (see Table 2).

Table 2. surrounding sound efficiency

| Scenario | Number of errors | Efficiency |
|---|---|---|
| Quiet Site | 0 | 100% |
| Loud Site | 64 | 36% |

Due to the design of the printer, the formation of each character can vary in terms of the time and number of motions required to complete it. The printer speed test took individual measurements of the time required for each different character, including letters, punctuation, and special characters. Similarly, the time taken to complete various words was measured. This data was then averaged to provide a general time frame for the printing process. In order to improve print quality and prevent inconsistencies, it was necessary to introduce a variable delay in milliseconds after the marking of each point shown in Tables 3 and 4.

The tests conducted indicate significant progress in the development process; however, it is clear that additional efforts are needed to achieve the precision and accuracy required for proper Braille writing.

The prototype is able to produce prints, although they do not fully meet the required specifications due to the fact that the motors used have more power than necessary to achieve precise millimeter marking. As for the diameter and height of each dot, this is due to the fact that the punch used in the prototype has a very blunt tip.

Table 3. Average print time

| Letter | Printing time (s) | Letter | Printing time (s) | Letter | Printing time (s) |
|---|---|---|---|---|---|
| **a** | 3.2 | l | 8.48 | v | 12.49 |
| **b** | 5.59 | m | 8.31 | w | 11.46 |
| **c** | 4.42 | n | 11.02 | x | 11.2 |
| **d** | 6.89 | ñ | 13.41 | y | 13.63 |
| **e** | 6.01 | o | 10.07 | z | 12.52 |
| **f** | 6.78 | p | 9.62 | . | 6.03 |
| **g** | 9.67 | q | 12.37 | : | 7.35 |
| **h** | 8.43 | r | 11.09 | , | 4.64 |
| **i** | 5.94 | s | 8.53 | ; | 7.34 |
| **j** | 8.65 | T | 11.12 | ? | 8.65 |
| **k** | 7.00 | u | 11.28 | ! | 9.84 |
| **Capital Follows** | 7.08 | Number Follow | 12.41 | Space | 1.52 |
| **Taking paper in** | 5.68 | Taking paper out | 3.24 | Average time | 7.75 |

Table 4. Average print time

| Sample | Time | Sample | Time |
|---|---|---|---|
| Adventure | 1:23.19 | Nightmares | 1:32.85 |
| Butterfly | 1:19.71 | Outstanding | 1:15.28 |
| Celebrated | 1:31.02 | Puzzlement | 1:30.91 |
| Direction | 1:22.02 | Quotations | 1:14.03 |
| Equipment | 1:36.81 | Resistant | 1:0763 |
| Forgotten | 1:14.35 | Stationary | 1:27.34 |
| Glamorous | 1:36.22 | Thankful | 1:07.63 |
| Happiness | 1:31.37 | Unhealthy | 1:29.39 |
| Insurgent | 1:27.37 | Vibrantly | 1:24.81 |
| Judgment | 1:32.56 | Whimsical | 1:2.22 |
| Knowledge | 1:18.79 | Excavation | 1:17.17 |
| Landscape | 1:31.79 | Youthfully | 1:35.12 |
| Meditation | 1:20.93 | **Average** | **1:25.76** |

The Braille quality tests conducted indicate significant progress in the development process as shown in Table 5: the Braille dots showed good formation resulting in accurate and readable Braille output; however, in the alignment and spacing test, it is evident that additional effort is needed to achieve the precision and accuracy required for proper Braille writing.

The prototype is capable of producing prints, although they do not fully align to the required specifications because the motors used have more power than necessary to achieve accurate millimeter marking. As for the diameter and height of each dot, this is due to the fact that the punch used in the prototype has a very blunt tip, as shown in Fig. 6.

Table 5. Measurement comparation according to Braille Authority of North America

| Measurement | Required (mm) | Obtained (mm) |
|---|---|---|
| Dot Base Diameter | 1.5–1.6 | 1.89 |
| Distance Between two dots in the same cell | 2.3–2.5 | 4 |
| Distance between corresponding dost in adjacent cells | 6.1–7.6 | 7.6 |
| Dot height | 0.6–0.9 | 0.6 |
| Distance Between corresponding dots from one cell directly below | 10.0–10.2 | 10.0 |

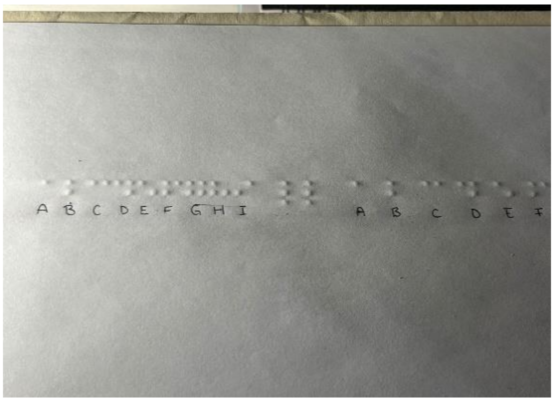



Fig. 6. Printing showcase.

## V. Conclusion

This paper presents the process of creating a portable and affordable technological device capable of converting spoken discourse into Braille writing by adapting an outdated printing device. While the proposed system succeeds in receiving audio input, interpreting it, and performing a physical transcription on paper, the lack of printing precision necessitates further research and refinement to improve print quality and optimize performance in terms of speed.

Efforts to improve print speed are emphasized. The average time to produce a character is 7.75 s, and the average time to type a 10-character word is 85.76 s. The goal is to reduce errors in audio interpretation and improve signal processing time to achieve more efficient communication.

In terms of print quality, certain measurements and distances between each dot must be maintained to ensure legibility. The device falls short of the required precision for the distance between two dots in the same cell, measuring 4 mm instead of the required 2.5 mm. Similarly, the diameter of each dot is 1.89 mm instead of the required 1.6 mm. Further development of the system is planned.

The efficiency of receiving and interpreting audio signals is 100% in a quiet environment. However, this efficiency drops to 36% in a noisy environment. Its use is recommended in a quiet environment. Similarly, efforts are being made to improve the system's ability to accurately identify the voice intended for translation.

In summary, this automated printer streamlines and improves the process by eliminating the need for a person to manually translate content from speech to Braille. In addition, it provides a tangible and portable way to communicate information, which is particularly useful in situations where electronic devices may not be feasible or convenient.

We believe this printer has the potential to improve education, communication, and information availability for people who are deafblind. It simplifies the learning, reading, and writing processes for braille users by providing direct speech-to-braille translation and real-time printing capabilities. In addition, we are committed to the continuous improvement of both the software and hardware components of the device.

In essence, this effort to create a printer capable of transcribing spoken language into Braille and producing it on a sheet of paper serves as a prime example of how technology can improve the quality of life for people who are deaf-blind. This paper provides guidance for individuals who wish to develop novel tools in this area. By ensuring universal access to information and communication, regardless of visual ability, it has the potential to foster a more inclusive and progressive society.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

IH conducted research and data collection, and developed the prototype code, contributing to its assembly and testing. JC, took charge of writing the paper, played a major role in assembling the prototype, and conducted functional tests. RN provided guidance and the python code on the paper and approved the prototype. All authors endorsed the final version.

## References


[1] S. C. Mackenzie, *Braille Writing in the World,* Paris: UNESCO, 1954. (in Spanish)

[2] F. J. Villalobos-Piña, M. S. Esparza-Gonzáles, and J. J. Muñoz-Correa, "Braille printer design from dot matrix printer," *Conciencia Tecnológica*, vol. 56, 2018. (in Spanish)

[3] INEGI, Population and Housing Census 2020 (INEGI), 2020. (in Spanish)

[4] N. Martiniello, L. Haririsanati, and W. Wittich, "Enablers and barriers encountered by working-age and older adults with vision impairment who pursue braille training," *Disability and Rehabilitation*, pp. 1–16, 2020. doi:10.1080/09638288.2020.1833253

[5] K. Duarte-Barón, J. X. Pabón, R. Claros, and J. J. Gil, "Design and construction of a device to facilitate learning of the braille reading and writing system," *Engineering and Competitiveness*, vol. 18, no. 1, pp. 77–90, 2016. (in Spanish)

[6] E. R. Hoskin, M. K. Coyne, S. C. D. Dobri, M. J. White, T. C. Davies, and S. D Pinder, "Effectiveness of technology for braille literacy for children: A systematic review," *Disabil Rehabil Assist Technol*, 2022. (in Spanish)

[7] C. Simón, E. Ochaíta, and J. A. Huertas, "The Braille system: Bases for teaching and learning," *Communication, Language & Education*, vol. 28, pp. 91–102, 1995. (in Spanish)

[8] P. D. Villavicencio-López, "Electronic alphabetic learning device voice to braille translator," *Technical University of Ambato*, 2022.

[9] Braille Authority of North America. (2009). Size and spacing of braille characters. [Online]. Available: https://brailleauthority.org/size-and-spacing-braille-characters