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作品名稱	EIBraille: An Electromagnetic Field-Powered Braille Training Device with Development of Printed Circuits and Algorithms for Visually Impaired Individuals
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就讀學校　The Prince Royal's College
指導教師　Rungkan Wangboon
作者姓名　Sataporn Thanapanyakul
Siwakorn Suwannahong
Punnawit Ponnirun

作者照片

A PROJECT REPORT ON

“ EIBraille: An Electromagnetic Field-Powered Braille Training Device with Development of Printed Circuits and Algorithms for Visually Impaired Individuals ”

Submitted by:
Sataporn Thanapanyakul
Siwakorn Suwannahong
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A Project Report Submitted for the partial fulfillment of the requirement of Taiwan International Science Fair 2025 supervised by Ministry of Education, Taiwan and organized by National Taiwan Science Education Center

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Project name :	EIBraille: An Electromagnetic Field-Powered Braille Training Device with Development of Printed Circuits and Algorithms for Visually Impaired Individuals
Student name:	Siwakorn Suwannahong , Punnawit Ponnirun, Sataporn Thanapanyakul
Advisor:	Rungkan Wangboon, Krittipong Wachirangkul
School:	Prince Royal 's College
Address:	117 Kaewnawarat Road Wat Ket Subdistrict mueang district Chiang Mai Province
Phone	053242038 **Fax** 053241132
Project duration:	from 15/01/2024 to 30/06/2024

Abstract

Visual impairment ranks among the top three disabilities globally, with affected individuals projected to increase from 39 million in 2015 to 115 million by 2050. Despite this growing prevalence, over 95% of visually impaired individuals face difficulties in learning Braille (AFB, 2022). In Thailand, the issue is compounded by limited resources, with only 48 schools for the blind serving 6.5% of visually impaired children, alongside a shortage of trained teachers and prohibitively expensive Braille displays.

To address these challenges, the **EIBraille Box** was developed as a cost-effective and accessible tool enabling visually impaired individuals to practice Braille independently. The device utilizes electromagnetic field generation based on Lenz's Law and electromagnetic induction, employing copper coils and varying currents to drive a Braille dot display mechanism controlled by a microcontroller.

Results show the device achieves an average display rate of 30–120 milliseconds per cell and a Braille dot-changing frequency of 3–20 cycles per second. The production cost is reduced from 11,660 USD to 87 USD—over 130 times more affordable—while maintaining performance comparable to traditional mechanisms. Additionally, the device integrates with a web application aligned with the Ministry of Education's curriculum to enhance learning.

The EIBraille Box is planned for deployment across 48 schools affiliated with the Northern School for the Blind. Plans include extending access to individuals unable to attend schools via alternative distribution channels.

This project stores high capacity to achieve global reach by partnering with the World Blind Union, extending its services to rural areas and ensuring access for underprivileged communities. This effort seeks to promote literacy among the blind on a worldwide scale.

This innovation strives to enhance equity for the visually impaired by enabling blind individuals to participate in inclusive educational environments alongside their peers. It aims to eradicate the challenges of illiteracy and ensure equitable access to quality education.

Acknowledgements

The successful completion of the project, *"EIBraille: A Self-Learning System for Teaching Braille Reading for the Visually Impaired through Multi-Gate Algorithm and Artificial Intelligence,"* was made possible through the support and contributions of several individuals and organizations.

We would like to extend our deepest gratitude to the Thailand National Software Contest(26th edition), organized by the National Science and Technology Development Agency, for their generous grant, which provided essential resources for this project.

Special thanks are due to:

- Rungkan Wangboon, project advisor, for her comprehensive guidance, valuable suggestions, and wiseful feedback, which greatly contributed to the development and refinement of this project.
- Krittipong Wachirangkul, of the Technology Excellence Program, for his expert advice and support in the development and practical application of the EIBraille Box.
- Professor Rati Wongsathan, from Northeastern University, for his detailed assistance and technical expertise in magnetic conduction and the overall project framework.
- Professor Wachira Hannkla, from the School for the Blind under the Royal Patronage of Her Majesty the Queen, Chiang Mai Province, for his insightful guidance, provision of essential information, and facilitation of cooperation for practical project implementation.

We also extend our gratitude to the faculty of the Technology Excellence Program, as well as our families, friends, and team members, for their steadfast encouragement and support in various aspects of the project.

Finally, we would like to acknowledge Prince Royal's College for generously providing the facilities, equipment, and tools required for this project's successful completion.

Project Development Team

Objective

The primary objective of this project is to enhance Braille literacy among visually impaired individuals by developing an innovative learning tool that combines affordability, portability, and advanced technology. The project specifically aims to:

1. Enable visually impaired students to read Braille with accurate pronunciation and spelling through the use of the **EIBraille web application**.
2. Provide an affordable and portable solution with the **EIBraille Box**, a Braille display device that is 130 times more cost-effective than traditional devices.
3. Utilize **AI integration** to simplify lesson accessibility and deliver personalized learning experiences anytime, anywhere.
4. Ensure secure data storage and processing using a **cloud-based system** that complies with **PDPA standards**, safeguarding user privacy.
5. Increase access to essential educational tools for visually impaired individuals, thereby promoting inclusivity and reducing barriers to learning.

Project Objectives and Scope

The *EIBraille* project aims to enhance access to education for visually impaired students aged 7–12, whether they were born visually impaired or lost their vision due to genetic conditions or accidents. By utilizing EIBraille's Braille teaching aids in conjunction with an innovative Braille display device, this project addresses the challenges of illiteracy and inequality in accessing education. The compact, portable design of the device, coupled with a significant reduction in production costs (from 5,830–11,660 USD to approximately 87 USD per device, a 130-fold decrease), ensures its affordability and accessibility.

Key Objectives

A. For the Visually Impaired:

1. Equip students with basic Braille reading skills aligned with the Ministry of Education's curriculum.
2. Provide the ability to independently learn Braille anytime and anywhere.
3. Improve quality of life by enabling individuals to integrate more effectively into society and perform daily activities with confidence.

B. For Educators in Schools for the Visually Impaired:

1. Enhance the capacity to monitor and support a greater number of students within the same time frame.
2. Enable detailed assessment of each student's learning progress and development.
3. Reduce the burden of producing teaching materials, allowing educators more time to focus on discipline and behavioral support.

C. For Government and National Agencies:

1. Reduce the budget required to procure Braille display devices (from 5,830–11,660 USD per device to approximately 87 USD).
2. Enable the Ministry of Education to distribute over 20,000 Braille teaching devices within the same budget, significantly increasing resource availability.
3. Alleviate educational inequality by bridging the gap between visually impaired and sighted students, promoting inclusivity nationwide.

Introduction

According to the **Vision Loss Expert Group (2018)**, the number of visually impaired individuals is expected to triple, rising from 39 million to over 115 million by 2050. This increase is largely due to the growing population of elderly individuals aged 60 and above, projected to reach 901 million, doubling within the next 40 years. As age progresses, common eye conditions such as macular degeneration, cataracts, and glaucoma become prevalent. Additionally, other contributing factors to vision loss include accidents, hereditary conditions, infections, and complications from severe diseases.

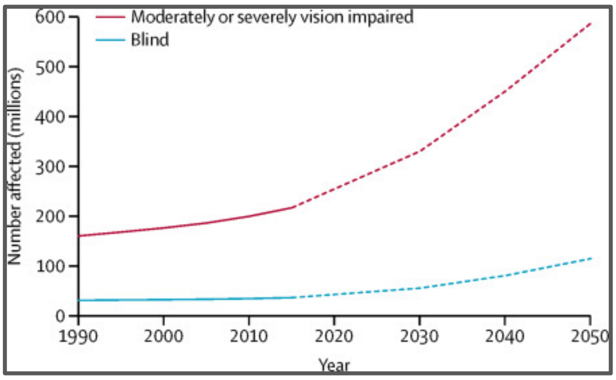


Figure 1. Increase of visually impaired individuals by 2050

Source https://www.thelancet.com/journals/langlo/article/PIIS 2214-109 X(17)30293-0/

The **World Health Organization (WHO)** recognizes visual disability as a major global issue, with over 360 million people worldwide experiencing challenges, particularly in accessing information. Visual impairment is classified into two main types:

1. **People with Low Vision**: These individuals cannot have their vision corrected with standard glasses, contact lenses, medication, laser treatments, or general surgery. Common causes include eye conditions such as glaucoma, retinal diseases, corneal and optic nerve disorders, as well as brain-related diseases. While their vision may not lead to complete blindness, they can still read enlarged text in regular language. However, it is essential to teach them Braille and provide audio-based learning to enhance their accessibility.

Figure 2: Education for people with low vision

2. **People with Visual Impairments (Totally Blind):** These individuals have lost their vision to such an extent that they cannot perceive anything visually or have no eyesight at all. For them, it is essential to teach Braille as a means of reading and provide audio-based lessons as the primary form of learning.

Figure 3: Education for blind people in Europe and Asia

However, over 95% of people with visual impairments, or approximately 34.2 million individuals globally (according to the **American Foundation for the Blind**, 2022), are unable to read or write Braille. This is largely due to a shortage of trained educators and the lack of accessible learning materials, such as Braille books, which require expensive printers. As a result, schools for the blind are often limited in the number of students they can accommodate. Additionally, the implementation of core curricula in education has led to an increase in the volume of Braille textbooks, making each book significantly larger and heavier. This creates challenges in terms of portability, particularly for visually impaired children under the age of 10.

Figure 4
Special case Braille book printing device costs 40,810 USD from the blind school

Figure 5
Standard braille book printing device costs 5,830 USD from blind school

To address the challenges outlined above, the development team has conceived the creation of a software solution called EIBraille, a web-based Braille learning system enhanced by AI. The system, or Electronic Interface Braille Portable Learning System, has been designed to overcome the difficulties faced by the visually impaired, aligning with the findings of Phatthira Klin Lekha (2013), who explored the media exposure behaviors and needs of the visually impaired, particularly concerning audio learning. Klin Lekha's study revealed that traditional television media often fails to cater to the specific needs of the visually impaired, as it lacks interactive features and does not engage them in a participatory way. This finding supports the research of Chitwa Nichkul (1999), who emphasized the need for media and services that are accessible to the blind, to facilitate practical life skills and self-development.

Recognizing these longstanding issues, the development team has focused on creating Braille learning materials for the visually impaired, with a dual-system approach involving both software and hardware components. These systems work in tandem to provide an effective learning channel for visually impaired individuals.

1) Learning Media Software System

The software system consists of three key components:

1. **Voice Command System**: This system converts user voice input into text, which is then used for lessons. The development team has selected **Google Speech-to-Text** from Google Cloud due to its high accuracy and robust database storage capabilities. This system is divided into three main sub-systems:
    - **Thai Consonant Recitation System**: Enables pronunciation practice for Thai consonants.
    - **Question and Answer System**: Allows for interactive exercises and assessments during lessons.

- **Interaction with the EIBraille Web Application**: Facilitates smooth interaction between the voice command system and the EIBraille platform, ensuring seamless operation from start to finish.

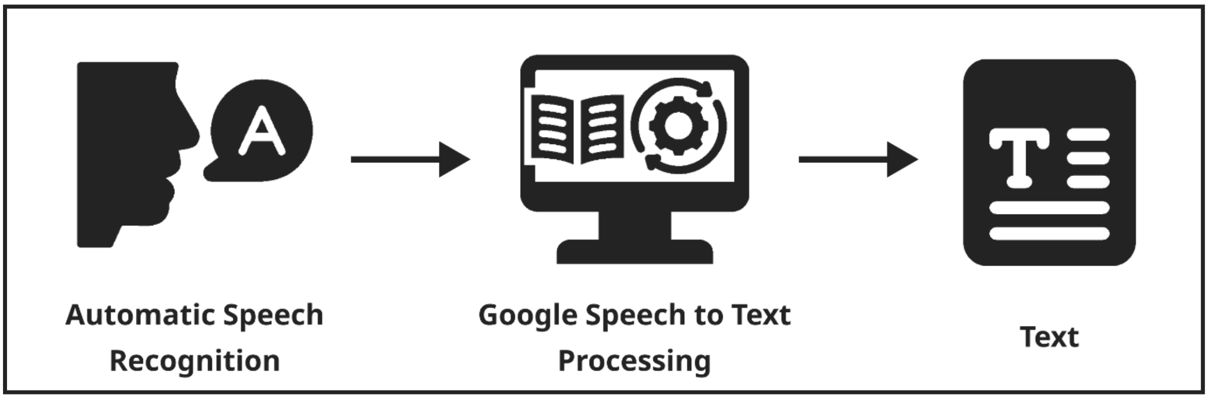


Figure 6. Flowchart of Speech to Text operation from Google Cloud.

2) Identification system To verify the identity of visually impaired students before each session, and to prepare data for system entry, the development team has chosen to implement a facial recognition system. The system utilizes the K-Nearest Neighbors (KNN) algorithm, which is known for its simplicity, small data processing requirements, and high accuracy.

To create a user account, the system requires the user to take a photo of their face, ensuring that their neck is positioned straight in front of the web application's camera. This process involves capturing three images, which are then uploaded to Firebase to generate a unique 7-digit username or user ID. For future logins, users can conveniently authenticate using their face and username.

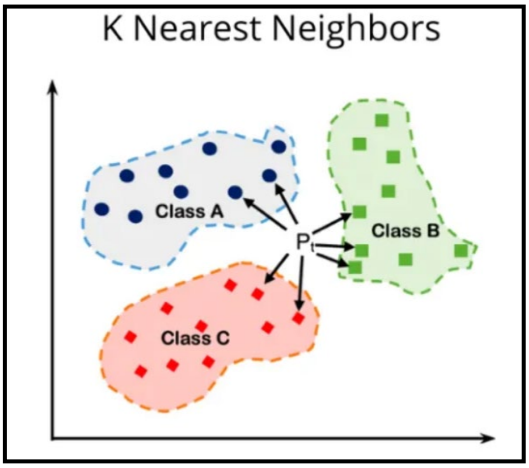


Figure 7 K Nearest Neighbors with A B C as user accounts.

Source https://medium.com/@sachinsoni600517/k-nearest-neighbours-introduction-to-machine-learning-algorithms-9dbc9d9fb3b2

3.1) Database System for Storing Student Data and Internal System Changes in the Web Application

The development team selected Firebase as the primary database for EIBraille due to its extensive features and suitability for the project. Firebase is a NoSQL database, ideal for storing data in JSON format, which aligns with EIBraille's needs.

3.2) Realtime Database

The Realtime Database enables instantaneous data updates, ensuring that changes are immediately reflected and sent back to users. This system is particularly beneficial for applications requiring rapid updates and real-time monitoring.

- The Realtime Database is used to control devices integrated with ESP32.
- It processes octal codes and converts them into text format for lesson displays while simultaneously rendering the output in Braille format on the hardware device.

This seamless integration of real-time data handling and hardware functionality enhances the learning experience for visually impaired users by providing dynamic and accurate feedback during lessons.

Related Terms

1. **Accuracy**: The precision of AI calculations measured using a Confusion Matrix.
2. **Pneumatic**: Compressed air delivered through pipes to generate mechanical energy for devices.
3. **Solenoid**: An electromagnetic device that converts electrical energy into mechanical movement.
4. **Cell**: A unit in a Braille display device, consisting of 6 raised dots to form Braille characters.
5. **Ferrite Magnetic Coil**: An induction device that creates a magnetic field when current flows through a coil.
6. **Arduino NANO**: A small development board with an ATMega328 microcontroller, like Arduino Uno.
7. **Microcontroller**: A compact processor capable of processing data, making decisions, and executing control programs independently.
8. **Braille Display**: A hardware device that converts text on a screen into Braille characters.

Research Objectives

1. **Develop tools and technologies for visually impaired learners:** Innovate and enhance devices to address learning challenges, improving usability and integrating advanced features.
2. **Improve learning quality and efficiency:** Create accessible and effective teaching aids, making lessons easier to understand and more engaging for visually impaired students.
3. **Reduce the cost of Braille displays:** Research affordable production methods and materials to make Braille displays more accessible to students and schools.
4. **Increase access to knowledge:** Develop inclusive learning media, such as digital platforms and interactive tools, to empower visually impaired students.
5. **Reduce educational inequality:** Bridge gaps between visually impaired and general students by creating affordable, innovative tools that promote equal learning opportunities.

Experimental Methodology

Step 1: Data Study, Analysis, and Problem-Solving Design Target Objectives:

1. Understand the challenges faced by visually impaired individuals in depth.
2. Conduct a root cause analysis to uncover the underlying issues.
3. Design targeted, effective, and innovative solutions to address these challenges.

Operational Steps:

1. Preliminary Study:
    - Research the daily challenges of visually impaired individuals: Focus on barriers such as access to education, employment, communication, and routine activities.
    - Collect and analyze information from diverse sources: Gather data from research articles, academic documents, websites, and reports that focus on visual impairments to understand the root causes and nature of the problem.
    - Document and summarize findings: Compile and organize insights from the gathered data to outline the specific problems identified for visually impaired individuals.

No.	Conclusion	society	economy	thinking	learning	References
1	The use of Braille has declined over time due to various factors, but technology can help promote its use by connecting visually impaired individuals to the same resources as those with normal vision. This integration can improve opportunities for a more inclusive life. To make this possible, additional training for teachers is essential, ensuring visually impaired individuals have equal opportunities to learn and succeed.	✓	✓		✓	Clark, Jill. "The importance of braille in the 21st century ." Journal of South Pacific Educators in Vision Impairment 7.1 (2014): 24-29.

No.	Conclusion	society	economy	thinking	learning	References
2	Increased access to digital books has given visually impaired individuals much-needed independence, allowing them to read for both entertainment and education. While read-aloud features help with many types of content, they are not always suitable for technical texts, songs, or graphics, as they may not promote a deeper understanding. As a result, many Braille readers prefer electronic Braille display devices. However, the high cost of these devices remains a significant barrier.		✓		✓	A. Russomanno , S. O'Modhrain , RB Gillespie and MWM Rodger, "Refreshing Refreshable Braille Displays," in IEEE Transactions on Haptics, vol. 8, no. 3, pp. 287-297, 1 July-Sept. 2015.
3	- Braille is an essential tool for the visually impaired, enabling them to access literacy and promoting intellectual freedom, equal opportunity, and personal safety. It can be learned at any age, even by those who only have partial vision. - Since the 20th century, the use of Braille and literacy rates have declined, primarily due to a shortage of qualified Braille teachers and the rise of sound technology. -	✓		✓	✓	Cibes Lift Thailand. (nd). * Braille What is and history . Retrieved from https://www.cibeslift .co.th /blog/ what-is-braille-and-how-to-read-it-with-its-history-and-origins/ #:~ :text= % E 0% B 9%82% E 0% B 8% 94% E 0% B 8% A 2
4	The most pressing issue for people with visual impairments is the difficulty they face in daily life. While recent advancements in science and technology, such as vision assistance tools for the blind, have made progress, affordable assistive technologies for visually impaired individuals, especially those living in isolation, have remained insufficient for many years.	✓	✓			Sarkar, R., Das, S., Roy, S. (2013). SPARSHA: A Low Cost Refreshable Braille for Deaf-Blind People for Communication with Deaf-Blind and Non-disabled Persons. In: Hota , C., Srimani , PK (eds) Distributed Computing and Internet Technology. ICDCIT 2013.

No.	Conclusion	society	economy	thinking	learning	References
5	Language and thought are closely connected. As mentioned, there is a chain reaction between the two: individuals with high proficiency in language often demonstrate enhanced thinking abilities. This relationship creates a continuous cycle where language skills directly contribute to cognitive development. Therefore, learning at least one language is crucial for fostering the thinking process.			✓	✓	Chulalongkorn University . (2010).* Project report Voice for people Disability See *. Retrieved from https://curadio. chula.ac.th/ Images/Class-Onair / th / 2010/ th - 2010-09-23. pdf
6	Braille display technology has remained largely unchanged for over 35 years, which is surprising given advancements in other assistive technologies. To revolutionize Braille displays, innovations could focus on making them more affordable, compact, and versatile, with dynamic tactile feedback and improved durability for enhanced interaction with Braille and tactile graphics.	✓	✓		✓	A. Russomanno, S. O'Modhrain, RB Gillespie and MWM Rodger, "Refreshing Refreshable Braille Displays," in IEEE Transactions on Haptics, vol. 8, no. 3, pp. 287-297, 1 July-Sept. 2015.
7	- Only 10% of the 1.3 million visually impaired people can read Braille, and only 10% of blind children are learning it. - Around 75,000 people lose their vision each year, a number that is expected to grow, which will increase the illiteracy rate for Braille. - The current situation is concerning, with over 70% of blind adults unemployed and 50% of blind high school students dropping out. There is also a lack of qualified Braille teachers— in 2003, only 6,700 teachers served 93,600 blind students.	✓	✓		✓	National Federation of the Blind. (2009). Braille literacy report. National Federation of the Blind. https://nfb.org/ images/ nfb /documents /pdf/braille_ literacy_report _ web.pdf

Table 1: Record of Issues and Articles Related to Visual Impairment and Braille

1.2 Define the Scope of the Problem

1. Research and Discussion with Educational Experts The researched information and issues were discussed with educational experts, including Professor Watchira Hannkla at the Northern School for the Blind under the Royal Patronage of Her Majesty the Queen in Chiang Mai Province. Interviews were conducted to collect additional information about the in-depth problems that visually impaired people face in their learning and daily lives.

Conclusions from the Consultation: The number of visually impaired people who do not know Braille is steadily increasing. Among a sample of 100 students, only two people could read Braille. The issues identified are:

- (1) Lack of teaching aids and Braille books
- (2) Insufficient number of teachers

Many visually impaired people starting to learn Braille require a lot of interaction during their learning process due to physical limitations. However, due to the small number of teachers, learning is not individualized, and comprehensive student care is not provided. Although Braille is essential for communication in the lives of visually impaired people, the availability of Braille display technology is crucial.
However, most Braille display devices have limited accessibility, and their cost is around 400,000 baht per unit. There is also a lack of teaching materials, and supervision is needed throughout the learning process.

2. **Post-Interview Analysis After the interview**, the data and advice from the experts were analyzed, combined with in-depth study data gathered in section 1.1. The scope of the problem was summarized as follows: Current Braille display technology does not meet the needs of the user group in terms of learning Braille.
3. **Consultation with Professor Chotiphong Phongsriwat,** The Braille display problem was then consulted with Professor Chotiphong Phongsriwat, an expert in Electrical Power Engineering, to examine the mechanisms of Braille displays and their suitability for use.
4. **Study of Parameters Affecting the Usability of Braille Displays** A study of parameters affecting the usability of Braille displays was conducted.
5. **Study of Different Braille Display Technologies** Various Braille display technologies and mechanisms were studied to compare them in terms of parameters and qualitative usage, and the results were organized in a table format.

Image 1 Consultation with Professor Watchira Hannkla on the 24th of April 2024 15:00-17:00

Image 2 Consultation with Professor Chotiphong Phongsriwat on the 25th of April 2024 15:00-17:00

Engineering goals		Actuators				note
parameter	target	Solenoid	Piezoelectric	Shape memory metal	Pneumatics	
quantity (Cell)	> 8	45	5	4	1	Braille standards 1 word 8 Braille characters
Braille button height (mm)	0.5	0.5	0.5	0.5	0.5	ISO standards 17049:2013 0.3mm – 0.7mm
diameter Braille (mm)	1 - 1.7	1.5	1	0.7	1.5	ISO 17049:2013 standard 1.0mm-1.7mm
Distance between Braille dots at positions 1 and 2 (mm)	2.2 - 2.8	2.5	3	2.13	2.5	ISO 17049:2013 standard 2.2mm – 2.8mm
Distance between Braille dots at positions 1 and 4 (mm)	2 - 2.8	2.5	3	2.37	2.5	ISO 17049:2013 standard 2.0mm-2.8mm
Cell Distance (mm)	5.1 - 6.8	6.8	6	3.27	6	ISO 17049:2013 standard 5.1mm – 6.8mm
Energy consumption (W/ hr)	1	6.1	0.2	0.4	0.001	
Heat transfer (°C)	< 42	75 - 80	Room Temp	68 - 73	42	
Cell button pressure (N)	> 0.49	15	0.39	2.4	0.18	
Display speed (ms)	200	33	20	1000	210	
Machine size (cm2)	< 15	24 x 5	32 x 10	24 x 6	24 x 3	

Table 2 Analyzing and Setting Parameters for actuators

Actuators	Strength	Weakness
Solenoid	Compact size and high pressure, low cost, lightweight, potential for further development	High heat release, potential inaccuracy due to magnetic attraction.
Piezoelectric	Very small size, lightweight, high sensitivity, no heat release	Expensive, very energy-intensive.
Shape memory metal	Light weight, Small size	Slower rendering rate than other mechanisms, requires thermal energy to change states, leading to frequent maintenance.
Pneumatics	High sensitivity, precise, no heat release	Requires frequent maintenance due to the use of a pressurized valve to push the button, which can be dangerous. It is expensive and noisy during operation.

Table 3: Comparison of actuators potential

Discussion of Results

From the comparison in Table 2 and Table 3, it is evident that the goal of creating a Braille display device can be achieved by utilizing solenoid-based cells to display Braille characters, as this aligns well with most engineering objectives when compared to other mechanisms. However, there are still three areas that have not yet met the set goals:

1. Energy Consumption
2. Heat Transfer
3. Braille Display Size

To address these issues and create a Braille display that meets the engineering goals, a new mechanism design will incorporate Ferrite Magnetic Coils inside the solenoid. This design modification is expected to solve the current problems and achieve a functional and efficient Braille display.

1.3 Simulation Design:

Target:

1. The lifting force of the raised button in the display must exceed 0.05 newtons.
2. The diameter of the protruding button must be 0.08 centimeters.
3. The height of the raised buttons from the contact surface should be between 0.03 - 0.07 centimeters.
4. The distance between raised buttons in each cell should be between 0.2 – 0.4 centimeters.
5. The distance between cells should be between 0.51 – 0.68 centimeters.
6. Reduce energy consumption by 8 times.
7. Reduce the size of the display to 10cm x 11cm.

Operational Procedure:

1. Study the working principles of Braille displays and the mechanisms of Braille button displays.
2. Analyze and design problem-solving approaches using the data collected from research studies and expert interviews, focusing on the electromagnetic induction mechanism combined with the UMGo Algorithm to encrypt base 2 for accurate display of Braille raised buttons.
3. Cell Prototype Design for Displaying Braille Buttons: 3.1. Study and understand the principles of electromagnetism, force, and motion calculations. 3.2. Study the prototype mechanism for displaying Braille raised buttons, referring to the Flip-Latching Structure mechanism.

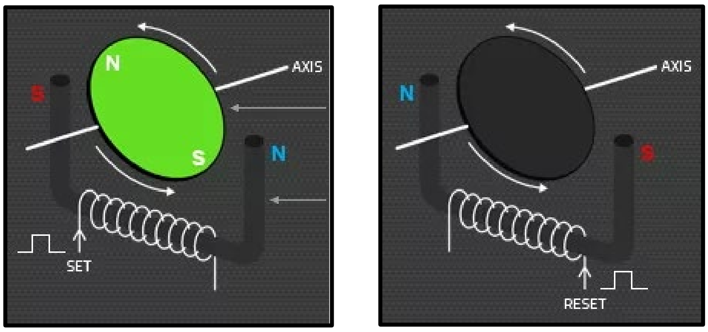


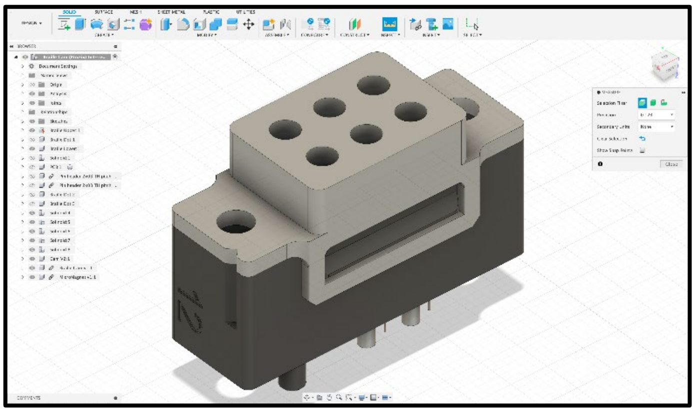
Image 1 : visualization of flip latching structure before and after electrical charge

3.1 Calculate the lift force required to flip the pivot point that will push the Braille button, which has a diameter of 0.08 centimeters, by determining the torque.

$$\tau = B \cdot I \cdot A \cdot \sin(\theta)$$

The equation of relation between torque and magnetic field

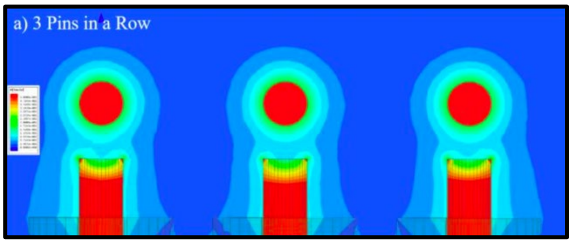
3.2 **Prototype Design for the Braille Display Cell** Design the prototype cell for displaying Braille embossed buttons in alignment with goals 2, 3, 4, and 5.



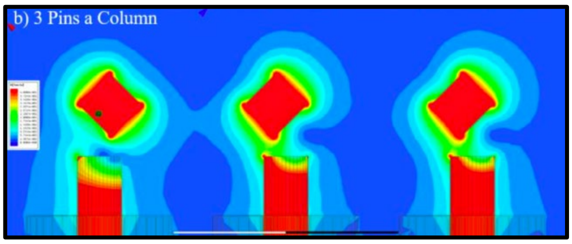
Prototype Image of the Braille Display Cell Buttons using Autodesk Fusion 360.

3.3 Calculate the appropriate magnetic flux density (Tesla) for usage in the cell, ensuring the spacing between Braille buttons does not exceed 0.4 centimeters as targeted, to prevent magnetic field interference.

3.4 Simulate the data obtained from the calculations using COMSOL to create a model, allowing for clear observation and analysis of the results.



Micromagnet without interference



Micromagnet with interference

4. Cell Control Circuit Board with Braille Display Button

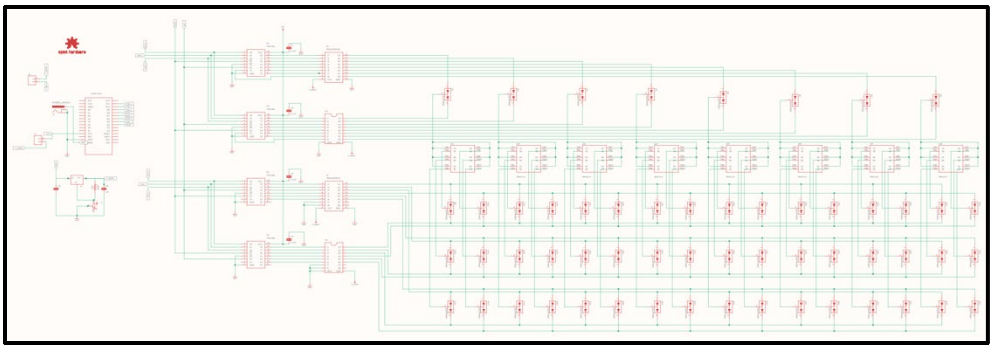
4.1 Study the basic circuit design by understanding the principles of electronic devices and their circuit connections.

4.2 Investigate and apply the use of binary data conversion (Binary Encoder) to implement the UMGo Algorithm for controlling 48 display points with 8 signal channels, while reducing energy consumption to meet target 6.

4.3 Design a truth table based on the logic of the UMGo Algorithm.

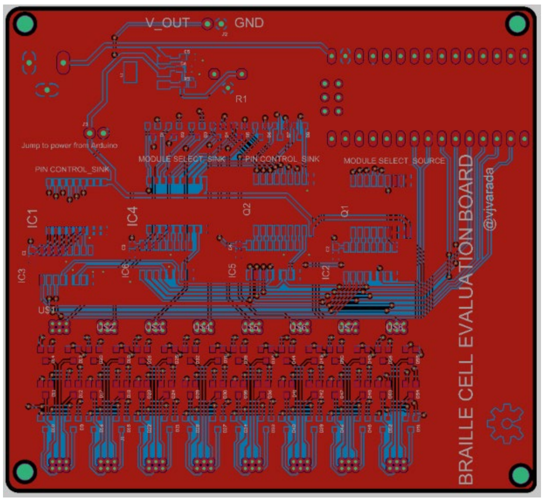
4.4 Study the ICs and components to be used on the circuit board according to the design specifications.

4.5 Draft the schematic of the circuit board using Altium Designer and EasyEDA.



Outline Schematic view for the circuit board

4.6 Design the PCB layout by specifying the location of each component and the routing of copper traces.Use a two-layer design to minimize the size of the device, in line with the 7th goal.

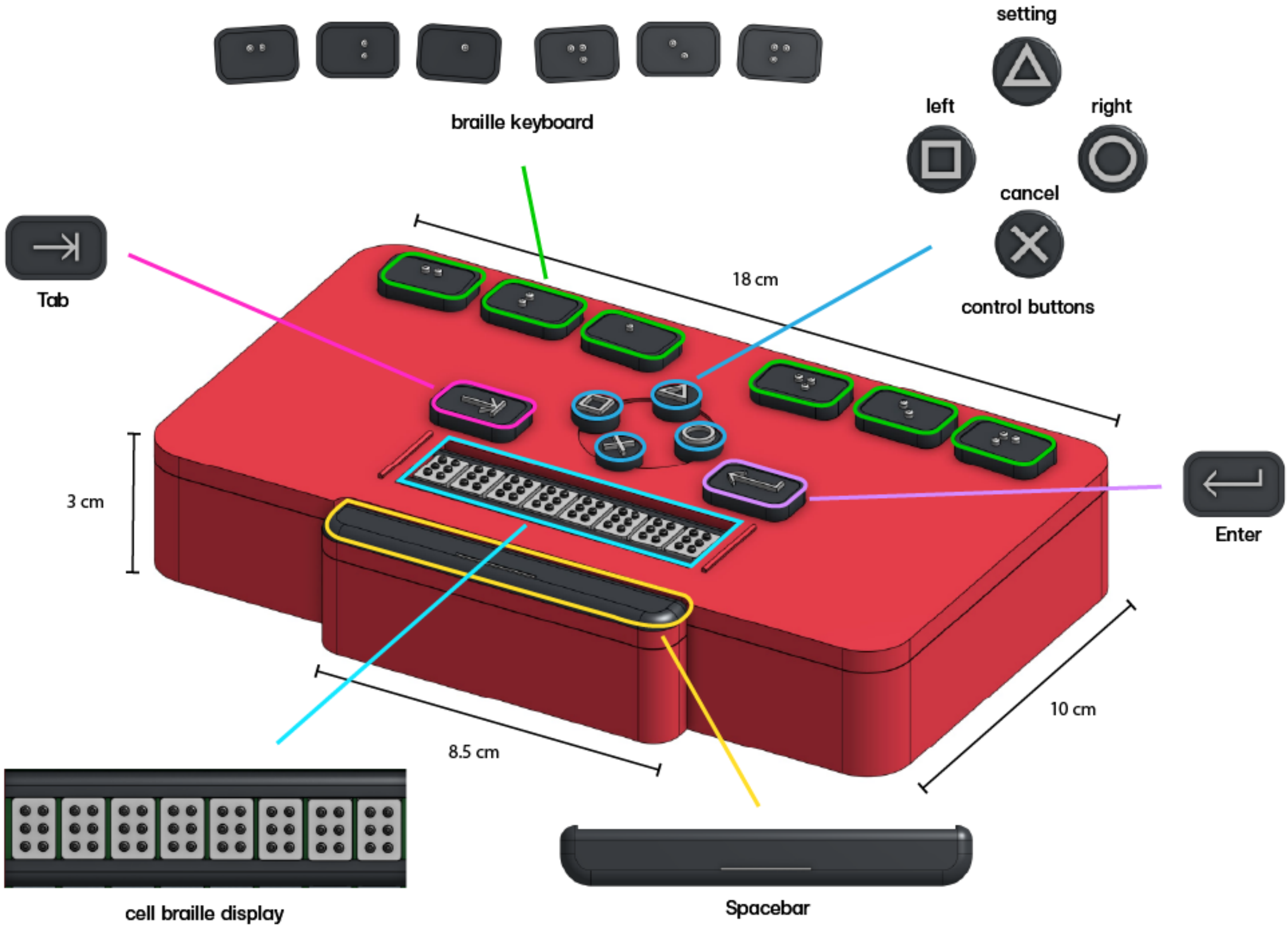


2-layer PCB circuit board designed with Altium designer

5. Design a Braille Display Box Use Autodesk Fusion 360 for the design.

5.1 Design the input section of the Braille display box to comply with ISO 19028 (Braille display standard).

5.2 Design the Braille display box with dimensions: width 10 cm, length 11 cm, and height, ensuring it meets the size requirements as outlined in target 7.



Prototype of Braille display (EIBraille-Box)

Experiment 2: Development of a Low-Cost Braille Display Suitable for Beginners, Maintaining Equivalent Performance and Meeting Set Goals.

Experiment 2.1: Development and Testing of a Prototype Braille Display Cell Using a Ferrite Magnetic Coil Mechanism, Offering Low Cost While Maintaining Comparable Efficiency to Current Models

Problem The prototype Braille display cell designed with a Ferrite Magnetic Coil mechanism will be capable of functioning as intended, as outlined in section 1.3.

Hypothesis The designed prototype Braille display cell will function as intended when all items in section 1.3 are correctly implemented.

Experimental Preparation Steps:

1. **Creation of the Prototype Cell:**
   1.1. Import the CAD file of the cell prototype designed for displaying Braille buttons and print the model using a 3D resin printer.
   1.2. Wrap copper wire around a Ferrite rod to create the Ferrite Magnetic Coil ensuring it fits into the slot of the printed prototype cell.
   1.3. Assemble the Ferrite coil rod into the prototype cell box.
2. **Preparation of Related Equipment:**
   2.1. Prepare a force gauge (Lead Force Meter) to measure the force in the cell display mechanism.
   2.2. Connect a multi-meter (current and temperature meter) to the Ferrite Magnetic Coil to monitor the electrical parameters.
   2.3. Prepare a DC power supply for testing the operation at 5V voltage and 150mA current.

Experimental Procedure:

1. **Testing the Braille Display Cell:**
   - 1.1 Supply 5V power using a DC power supply, activating one display cell with 6 raised dots for 3 minutes.
   - 1.2 After 3 minutes of power supply, allow a 30-second break before supplying power again.
   - 1.3 Repeat steps 1.1 – 1.2 for 10 rounds.
2. **Recording the Accuracy of the Display Mechanism (%):**
   - 2.1 Observe the cell display to verify if the number of raised dots matches the intended display according to the power supply.
   - 2.2 Record the observation results until all power supply cycles are complete.
3. **Recording the Display Speed (Milliseconds):**
   - 3.1 Use a timing device to measure the time taken for the Braille display buttons to appear.
   - 3.2 Measure the mechanical voltage when powered by the DC supply.
   - 3.3 Record the time obtained from the measurement.
   - 3.4 Repeat steps 3.2 – 3.3 until all power supply cycles are complete.
4. **Recording the Temperature During Display Operation (°C):**
   - 4.1 Use a multimeter to measure the temperature around the mechanism after each power cycle.
   - 4.2 Record the temperature readings obtained.
   - 4.3 Repeat steps 4.1 – 4.2 until all power supply cycles are complete.
5. **Recording the Braille Display Pressure of the Mechanism (N):**
   - **5**.1 Connect the force gauge to the raised area of the Braille display mechanism.
   - 5.2 Measure the mechanical voltage when powered by the DC supply.
   - 5.3 Record the pressure values obtained from the measurement.
   - 5.4 Repeat steps 5.2 – 5.3 until all power supply cycles are complete.
6. **Calculate the variance of different variables. (σ)**

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \mu)^2}{N}}$$

Variance formula

σ = *Variance*
μ = *Median*
N = Amount of times experimented
X_i = Result value i

Discussion of Results

From the Braille display cell operation test, it was observed that the cells developed using Ferrite Magnetic Coils met the target for speed, pressure, and accuracy. However, a subsequent issue was identified with the temperature of the mechanism, which exceeded the set target. Despite this, the Ferrite Magnetic Coil Braille display cell was able to meet the overall goals as set out in the design specifications.

Chapter 2.2: Testing for the Optimal Number of Turns of the Copper Coil to Drive the Ferrite Magnetic Coil Mechanism

Problem After testing in Section 2.1, it was observed that the mechanism using ferrite rod coils met the target efficiency parameters set in Section 1.3. However, it was found that the mechanism generated an average high temperature of 83°C. Since the Braille display is intended for prolonged use, the challenge lies in determining the optimal number of copper wire turns to wind onto the Ferrite Magnetic Coil. The goal is to create the required electromagnetic force while minimizing power consumption.

Target 1. The length of the Ferrite Magnetic Coils should not exceed 1 cm.
2. Minimize the heat generated through electromagnetic induction as much as possible.
3. The embossed display mechanism must maintain the same display performance.

Hypothesis Optimal winding count at 120 cycles for ferrite magnetic coil is designed to generate an appropriate magnetic field for display purposes while minimizing temperature increase as much as possible.

Development Process:

1. Study basic concepts of magnetic field generation, electrical conductivity, and the relationship between various factors affecting electromagnetic force, heat generation, and power consumption.

2. Apply the acquired knowledge to design the most suitable Ferrite Magnetic Coils for the display, specifying the use of cylindrical ferrite rods with a cross-sectional diameter of 0.1 centimeters and a length of 1 centimeter, in accordance with the display box designed to meet the goals outlined in Section 1.3

3. Research for necessary formulas for determining the optimal amount of coil binding turns

- Magnetic force formula

$$F = \frac{\vec{B}^2 A}{2\mu_0}$$

F = Magnetic Force (N)
$\vec{B}$ = Magnetic Flux Density (Tesla)
A = Cross sectional area of Ferrite
μ_0 = *Permeability constant of air*

- Solenoid magnetic flux formula

$$\vec{B} = \frac{\mu \cdot N \cdot I}{L}$$

$\vec{B}$ = Magnetic Flux Density (Tesla)
μ = Permeability of Ferrite Rod
N = Number of copper coil turns
I = Electric Current(Amp)
L = *Length of Ferrite Rod*

Combine the two equations To calculate the number of turns of copper coil per magnetic force.

$$F = \frac{\mu_0 A (N \cdot I)^2}{2L^2}$$

μ = Permeability of Ferrite Rod
N = Number of Copper Coil Turns
I = Electric Current(Amp)
L = *Length of Ferrite Rod*

F = Magnetic Force (N)
A = Cross Sectional Area Ferrite
μ_0 = Permeability Constant of Air

Enter the equation in Section 4 and create a graph to observe the relationship between various variables using MATLAB.

Relation formula of magnetic force and coil binding count

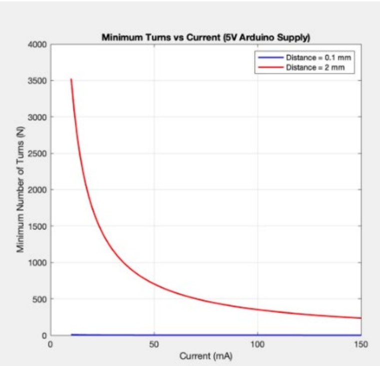


Figure 1 Relation of copper coil and Electric coil

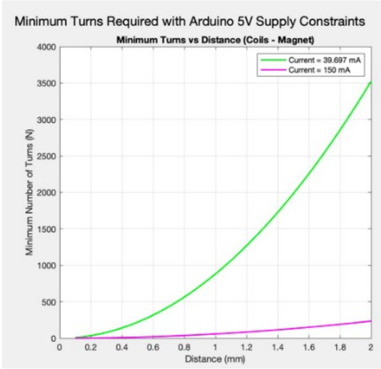


Figure 2 relation between the number of coil turns and the distance between the micromagnet and the ferrite rod.

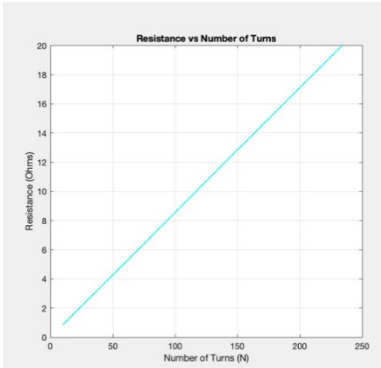


Figure 3 relations between the number of coil turns and the resistance value.

8. From the graph in Section 2, it was found that the micromagnets are designed to meet the operational targets specified in Section 1.3. The distance between the micromagnet and the ferrite rod is 1.6 mm, and the coil has 150 turns, as calculated.
9. When calculating the resistance generated by the coil using the formula, it was found that with 150 turns, the coil has a resistance of 13 ohms. This is sufficient for a voltage of 5V and a current of 150mA from the Arduino Nano V3.
   - Resistance of ferrite magnet formula

$$R = \frac{\rho \cdot N \cdot C}{A}$$

$\vec{B}$ = Magnetic Flux Density(Tesla)
ρ = Resistance of Cu
N = Number of Copper Coil Turns
C= Length of Ferrite Magnet
A = Cross Sectional Area of Ferrite

10. The temperature of the Braille display must not exceed 42°C. Therefore, the ferrite rod used must have the least electric current (I) and resistance (R), with the electrical power (P) being directly proportional to the product of these variables, as expressed in the equation:

$$P \propto I^2R$$

P = Resistance of Cu
I = Electrical Current(mA)
R = Resistance of Copper coil (R)

Relation formula of Electrical Power and Electrical Current and Resistance

11. Experiment to Verify the Calculation of the Number of Turns of Copper Coil Windings To validate the accuracy of the current (mA), magnetic flux density (T), and thrust (N), the following steps will be performed:
    - 11.1 Connect the ferrite rod wrapped with copper coil to a power supply (DC Supply) providing a voltage of 5V and a current of 150mA (representing pressure and power from an Arduino NANO V3).
    - 11.2 Measure the magnetic flux density (Tesla) using a Gauss Meter and record the value over the area above the ferrite rod.
    - 11.3 Measure the current flowing through the ferrite rod (in mA) using a multimeter, measuring across the circuit of the ferrite rod.
    - 11.4 Measure the lifting force (N) generated by the ferrite rod using a force gauge (Force Gauge).
    - 11.5 Repeat the process, varying the number of turns of the copper coil from 1 to 150, and record the results in the table.

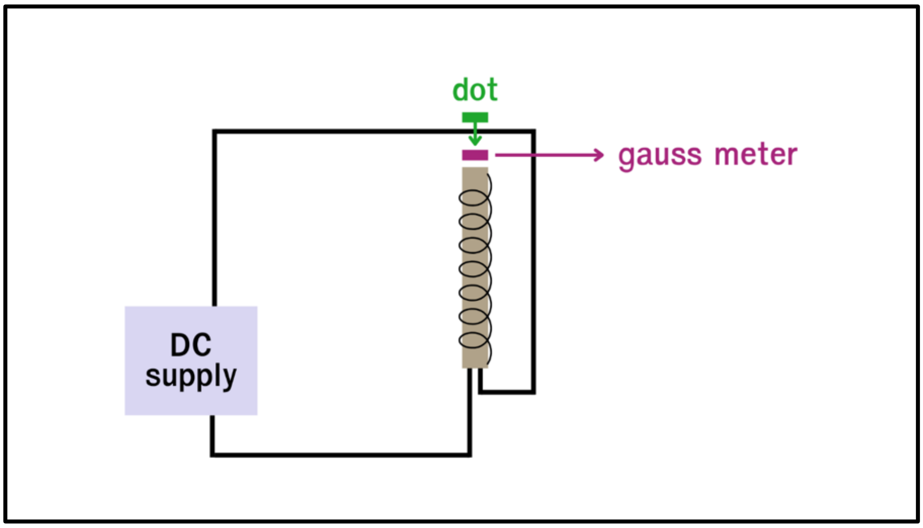


Figure 4 Experimental Process

Experiment 3: Identifying the Most Optimal Braille Display Design to meet target engineering goals

Experiment 3.1: Identifying the Most Suitable Braille Display Control System

Problem: Which type of circuitry system should be used to control the 8 Braille display buttons, ensuring the ability to manage the entire circuit and control all display cells simultaneously?

Hypothesis Construct the printed circuit board (PCB) by designing the integrated circuit specifically for controlling multiple microcontrollers, enabling the simultaneous control of all 8 Braille display cells across the entire circuit

Development Process

1. Design and Creation of Display Control Circuit:
   - 1.1. Study the fundamental concepts of electrical circuits, logic gates, voltage, and current.
   - 1.2. Design schematic diagrams for each control method.
   - 1.3. Create a printed circuit board (PCB) to control the Braille display buttons.
   - 1.4. Select the appropriate microcontroller, install and connect all control circuits on the PCB, and program the microcontroller to manage the display cells.
2. Design and Fabrication of the Mechanism Structure:
   - 2.1. Design the display mechanism structure using Autodesk Fusion 360, incorporating the principles of joint rotation and force applied by the Ferrite Magnetic Coils.
   - 2.2. Print the model using a 3D resin printer and adjust the dimensions for proper fitting.

Testing Procedure:

1. Test the functionality of the circuit by controlling all 8 Braille display buttons simultaneously. Measure and record the performance, focusing on button stability and display accuracy. Perform the test for 5 minutes to evaluate the system's stability.

2. Analyze the results by comparing the performance of the circuit under each control method. Assess the controllability of the 8 Braille display buttons simultaneously.

3. Summarize the experimental findings to determine the most suitable microcontroller for controlling the Braille display buttons. Provide recommendations for potential improvements or future developments in the control method.

3.2 Which concept is most suitable for reducing the number of output ports required to control the display cells, ensuring that only one microcontroller is necessary for operation?

Problem : To accurately and precisely display Braille buttons, a microcontroller with a single output port is required to control each raised point. However, with a total of 48 raised points, a single output port from one microcontroller is insufficient for proper operation.

Hypothesis : The development of a multi-gate algorithm using binary character encoding (Encoder String to Binary) could reduce the number of output ports required from the original 48 channels to only 8 channels, enabling control by a single microcontroller.

Development Process:

1. Design the Algorithm
   1.1 Design a Multi-gate Algorithm that encodes data from letters into binary numbers.
2. Circuit Board Design
   2.1 Design a printed circuit board to control cell operation through a program using
   EasyEDA.
   2.2 Test the working program of the microcontroller in a simulation environment (Simulator).
   2.3 Order the production of the printed circuit boards (PCBs) from JLCPCB.
   2.4 Connect the microcontroller and ICs to the printed circuit board.

Experimental Procedure:

1. Retrieve datasets from the database (Firebase) using the microcontroller on the printed circuit board.
2. Test the display functionality of all 8 cells, which will show information pulled from the database.
3. Record the display data from the first character to the last character. Repeat the test until all 5 data sets have been displayed.

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【評語】100052

1. The topic is very suitable for humanity's needs. Even though the proposed training device may be beneficial to visually impaired person, the complexity and effectiveness of the system in terms of development and implementation need to be analyzed.
2. In the conceptual flow presented in Figure 6, since speech recognition was utilized as input, why not directly utilize voice output?
3. For user identification, biometric identification following specifications defined by the FIDO alliance was recommended.
4. Given the planned voice input, what is the necessity of a braille keyboard?
5. In addition to CAD and 3D drawing, the authors are advised to present a real product and discuss its functionality.
6. In addition to describing the engineering process of this research work and some survey of other works, it would be good (also required) to present the innovation of this work. A comparison of the proposed system with existing state-of-the-art methods should be provided in the

introduction so the advances, contributions, and novelty of the approach can be identified.

7. It would be good to include an experimental evaluation that consolidates the proposed idea.