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Portable American Sign Language System using RF Signals and IoT Technology for Deaf-Blind People

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ABSTRACT

The Internet of Things (IoT) has revolutionized connectivity, enhancing accessibility to devices and information. This advancement addresses challenges faced by deaf-blind individuals, such as slow learning and memory issues. A new ASL learning kit has been developed to address these challenges, featuring physical and interactive elements for an engaging experience. Two learning methods are available: one involves RFID sign language cards tapped on an RFID reader, triggering an LCD visualizer with ASL alphabets and videos; the other method uses a Braille-embedded keyboard to provide audio feedback through ESpeak for ASL gestures. This ASL learning kit aims to boost the interest and effectiveness of deaf-blind students in learning ASL and Braille.

1. Introduction

Sign languages, which are essential for deaf and blind communication for centuries, serve about 15 million individuals globally with speech, hearing, and vision challenges was reported both by Dhake *et al.,* and Vijayalakshmi *et al.,* [1,2]. While various sign languages exist, American Sign Language (ASL) stands out as the most widely used as depicted by Choudhary *et al.,* [3]. Additionally, Braille is crucial for blind individuals to engage with society, especially for reading and writing. The Braille system consists of a maximum of six dots, categorized into three levels: Grade 1 for beginners, Grade 2 for intermediate users, and Grade 3 for advanced users based on Kavalgeri *et al.,* [4]. This project primarily focuses on Grade 1 Braille for beginners.

In Deaf-Blind ASL learning, innovative methods have emerged according to both Dhake *et al.,* and S. Nižetić *et al.,* [5,6]. Sign Language Recognition devices are helpful nowadays, however they have limitations according to Padmalatha *et al.,* [7]. To meet diverse Deaf-Blind needs, alternative approaches are vital. The proposed ASL education system, aimed at young learners, uses RFID cards,

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visuals, and physical interactions, offering an inclusive learning experience beyond gesture demonstration. Continued research should focus on developing inclusive ASL tools, enabling individuals with varying abilities to effectively learn and communicate through ASL.

Braille education faces challenges in achieving interactivity and resource availability as stated by Salim *et al.,* [8]. Traditional methods involve small groups, thus limiting the interaction in view of both by Silvia *et al.,* and Duarte *et al.,* [9,10], while resource scarcity hampers learning. Therefore, more solutions must be brought up to enhance interaction as well as to develop more resource accessibility. Technologies like the Braille attachment keyboard and Raspberry Pi can create engaging environments. Digital resources and assistive technicality expand material availability, thus improving the Braille learning experience [11]. Addressing these issues enhances outcomes for those relying on Braille for reading and writing, making learning more engaging and accessible accordingly.

Improvements are needed in the ASL education system, especially for children with reference to Humphries *et al.,* [12]. In Malaysia, interactive tools for deaf-blind children are lacking as indicated by Nasir *et al.,* [13]. While Malaysian Sign Language (BIM) is predominant, ASL knowledge exists due to international interactions and online resources. Innovative methods can make learning enjoyable and improve retention as revealed by Warren *et al.,* [14]. Dr. Erica Warren stresses visualization for academic achievement. To overcome ASL education limitations, investing in tools, resources, and methods for deaf-blind children is crucial. Creating an interactive, fun, and visual learning environment can significantly enhance the ASL education system, thus benefiting sensory-impaired children's outcomes.

The proposed system enhances deaf-blind children's learning by integrating RFID cards and a reader for them to grasp basic ASL education. Tapping the cards activates audio and video ASL displays. The system is also paired with a Braille keyboard connected to a Raspberry Pi for tactile feedback from learners. This adaptable approach facilitates learning anywhere, fostering engagement and inclusivity among typically-abled peers. Through a blend of visualizations, physical interactions, and interactivity, it creates an inclusive ASL education environment, promoting continuous learning and meaningful connections within the deaf-blind community and beyond, as well as exemplified by Rajasekar *et al.,* [15].

Presently, there is a deficiency in interactive technology that enables individuals with vocal, verbal, and visual impairments to acquire a new language through a voice interface. To deal with it, this work has two main contributions: First, it aims to create an interactive and engaging method for learning Sign Language using low-cost IoT technology, combining Raspberry Pi and Arduino microcontroller. Secondly, the project focuses on designing a software interface for attractive ASL visualization. In this paper, Section 2 reviews related studies, while Section 3 elaborates on the system design. Section 4 presents and discusses the results, and Section 5 provides the conclusion.

2. Methodology

This section reviews additional literature related to the research domain. Dr. Lynell Burmark, an education consultant emphasizing visual literacy, highlights the significance of connecting words, thoughts, and ideas with images while ideas that are not connected to an image will enter one ear, travel through the brain, and exit the other ear as evidenced by Hodgdon *et al.,* [16]. She suggests that information presented with visuals can have a more lasting impact and better retention compared to text alone, as depicted in Figure 1.

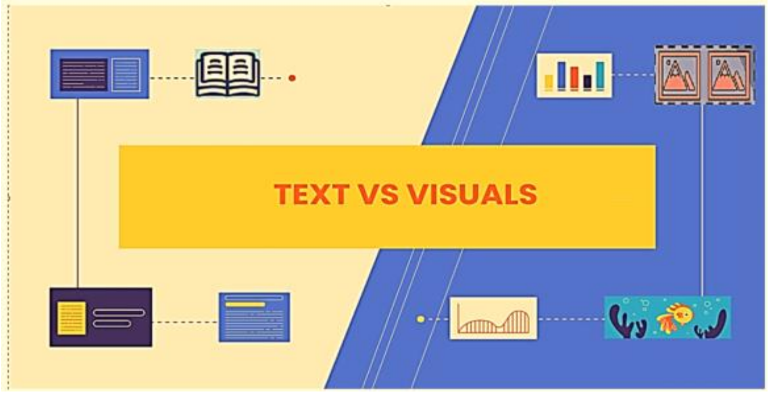

Fig. 1. Text vs Visuals

Words are processed in short-term memory, limited to about seven pieces of information, while images are quickly stored in long-term memory. Some educators struggle to create engaging learning environments, but students benefit from mastering basic alphabets before delving into sign languages. An interactive learning kit with physical activities can make this initial learning enjoyable, especially for children. A portable kit can educate both younger and older generations effectively, utilizing memorable visual representations for alphabets and sign languages as reported by Pinola *et al.,* [17].

Currently, there's a lack of interactive technology for vocally, verbally, and visually impaired individuals to learn a new language with a voice interface. They often rely on traditional or online methods, which lack practical engagement. Additionally, Braille content creation tools are costly as outlined by Shalini *et al.,* [18]. There's a gap in technology allowing various impairments to use Braille in one single platform. Sophisticated data-crunching software and sensor-based sign language tools help deaf and blind individuals integrate into society as disclosed by Jyothi R *et al.,* [19]. Users wear gloves with resistors and sensors for hand movements, improving gesture clarity and accuracy. However, the challenge remains in obtaining comprehensive sign language datasets for machine-learning support considerably.

The study as introduced by Suwito *et al.,* [20] found that Raspberry Pi with a touchscreen LCD significantly aids in learning alphabets and sign languages. Another study as stated by Noor *et al.,* [21] highlighted the effectiveness of a storybook reading program for teaching youngsters to recognize and spell words correctly. The study conducted by Syahrul *et al.,* [22] also anticipates educational media that will assist blind children in learning English words and character pronunciation interactively. The authors of Waghela *et al.,* [23] proposed a versatile Braille system supporting all levels of Braille encoding, usable by both beginners and advanced users for typing purposes. Some systems employ letter-to-letter conversion, as presented by Aarthi *et al.,* [24]. Mini-DC motors are used in Braille pads for compactness and ease of use. Additionally, the authors of Pawar *et al.,* [25] also introduced a real-time motion detection device with gesture recognition using a webcam. This study aims to enhance learning with a Raspberry Pi and LCD, complemented by flash card RFID tags, voice recognition (ESpeak), and a Braille keyboard. This integrated platform supports normal, deaf, and blind students in their teaching and learning process. Table 1 shows the comparison of previous related research articles.

Table 1
Comparison of previous related research articles

No	Project Title	Ref	Technique used
1	Portable Alphabet Learning Device	[20]	-Raspberry Pi with LCD and Python programming language
2	Teaching and Learning Module on Learning Disabilities (LD) using RFID Technology	[21]	-RFID tags, RFID readers and database
3	Design of an interactive learning media to pronunciation characters and English words for blind children	[22]	-Raspberry 3, Voice recognition system (Espeak) and Braille Keyboard
4	Braille Keyboard and printer interfaced	[23]	-Arduino Braille Keyboard Speaker
5	Braille Based Mobile Communication for Deafblind People	[24]	-Braille pad, Microcontroller, GSM Module and Braille Driver
6	Gesture Language Translator Using Raspberry Pi	[25]	-Camera Module, Gesture Input and Raspberry pi
7	Proposed system	-	-Raspberry PI with LCD display and Python programming Language, Flash card RFID tags, voice recognition system (Espeak) and Braille Keyboard

3. System Design

This section discusses the results obtained from the surface pressure measurement study. The effects of angle of attack, Reynolds number and leading edge bluntness are discussed in the next sub section. This section outlines the methodology for achieving the project objectives. By referring to Figure 2, the central component is the Raspberry Pi Model 4b, boasting a 4GB SD RAM, 2.4GHz and 5.0GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE, and Gigabit Ethernet. The Python, with C/C++ support serves as the main programming language. The project integrates RFID technology, specifically the RFID Smart ID Card Reader EM4001, capable of 125-kHz in frequency and features a USB interface for reading the first 10 RFID digits. The Python code interfaces with the RFID card so that tapping it on the reader triggers a Sign Language Visualizer on the LCD, thus catering to the needs of the deaf and blind users.

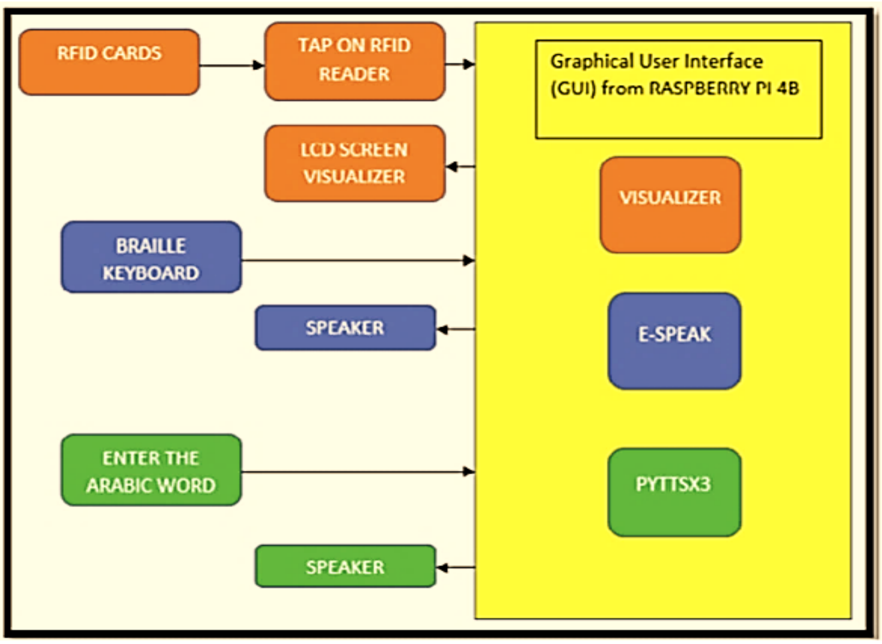

Fig. 2. Block diagram of the modified system

The Braille keyboard, designed for blind users, features Braille keys and operates at a frequency of 2.4GHz with a range of up to 10 meters in distance. When a child presses the Braille keyboard's alphabets, the system responds with a corresponding sound. ESpeak, a software used for text-to-speech conversion in LINUX, is implemented to achieve this process. ESpeak is versatile and supports multiple languages, thus making it a valuable tool in this context. The third method involves using Tkinter software, specifically the pyttsx3 engine, designed for individuals without physical impairments and focused primarily on the Arabic language. It is a Python text-to-speech engine enabling the system to read Arabic letters and produce corresponding sounds through the speaker. The users input Arabic words from an image and click the "Speak Now" button to hear the corresponding pronunciation.

This project has two parts. Figure 3 shows three elements respectively: the Raspberry Pi, Braille keyboard, and the RFID reader with tapping cards. The first part is the ASL Visualizer. It is activated when RFID cards tap the Reader, thus displaying ASL on the screen using a .csv file to link RFID serial numbers to corresponding alphabet details as shown in Figure 4. The second part is the i8 mini wireless Braille keyboard. Pressing the Braille dots from A to Z triggers speaker outputs via the ESpeak software on the Raspberry Pi module.

Fig. 3. Project Designation

```
No,RFid,User
1,0001104901,A
2,0001026668,B
3,0001097153,C
4,0001022085,D
5,0001098815,E
6,0001189803,F
7,0001160519,G
8,0001147313,H
9,0001157091,I
10,0001123968,J
11,0001030507,K
12,0001156470,L
13,0001039975,M
14,0001033960,N
15,0001147596,O
16,0001153419,P
17,0001161120,Q
18,0001030220,R
19,0001133097,S
20,0001190060,T
```

```
21,0001137556,ONE
22,0001102146,TWO
23,0001039424,THREE
24,0001109462,FOUR
25,0001197803,FIVE
26,0001096668,SIX
27,0001129055,SEVEN
28,0001060273,EIGHT
29,0001077264,NINE
```

Fig. 4. Database.csv file for Python coding to fetch RFID data

In the project's operation, as depicted in Figure 5's flowchart, the device functions in two ways. When a visually impaired child taps an RFID card on the reader, it checks card validity. Valid cards trigger visual output on the LCD screen, while invalid cards require tapping a new one (for maintenance purpose). Alternatively, using a Braille keyboard fetches output from the ESpeak software. Inputting a wrong character prompts retries from the user. For customization, children must retype a word from an image and click "Speak Now." If the Arabic word matches, a corresponding sound is produced via the pyttsx3 software; otherwise, the process restarts. This project is focused on teaching American Sign Language and basic Braille to children aged from 6 to 8 years old. It utilizes a low-frequency RFID system that requires close contact for card detection. The project aims to innovate and create a more engaging and effective learning system for these children.

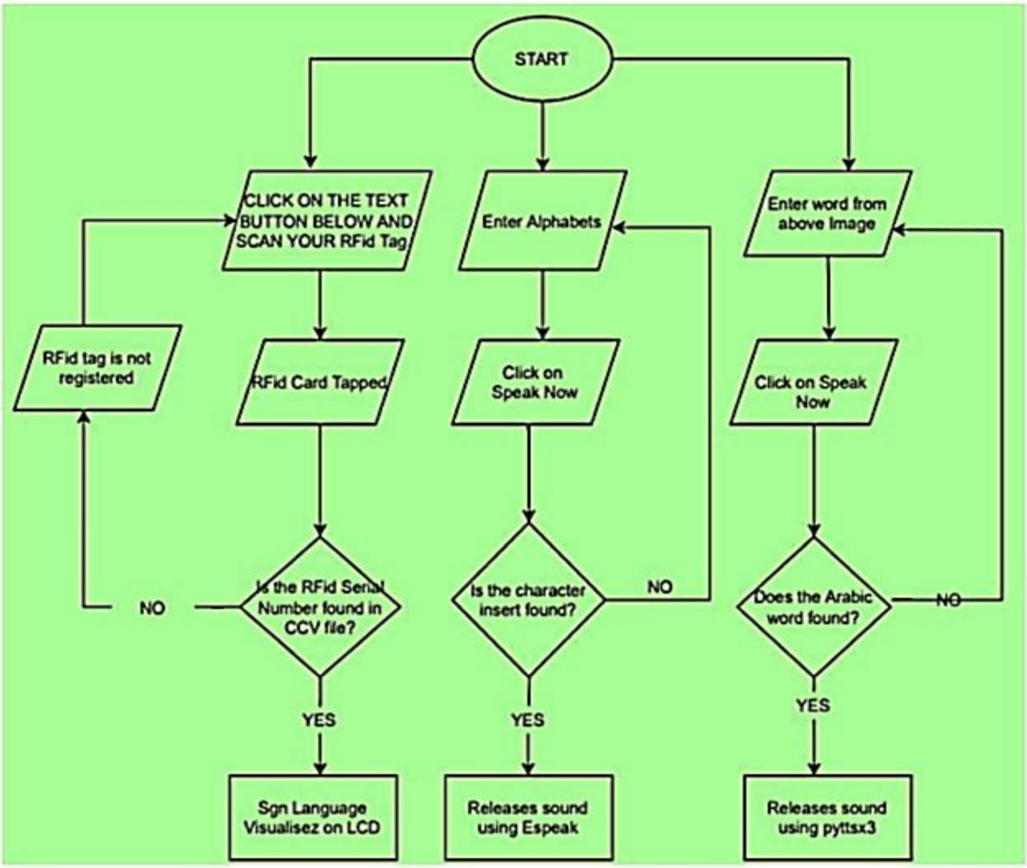

Fig. 5. Flowchart of the entire proposed system

4. Results

A VNC viewer enables remote control of the Raspberry Pi from a laptop. To set up the visualizer, the Raspberry Pi is connected to a power source. When the RFID reader and Braille wireless keyboard is plugged in as well, the running code is executed thus producing a corresponding visualized output as shown in Figure 6. This paper benchmarks advanced ASL implementation, as shown by Radzi Ambar *et al.,* [26], but focuses on improving ASL learning for children aged from 6 to 8 years old. The project customizes the learning experience, enhancing ASL recognition and speech, with Arabic as the chosen language for a dynamic, portable language learning solution.

The modified approach starts with the user tapping a card in a designated box, displaying the Sign Language name ("Sign Language A") and its ASL gesture image on an LCD screen. If the RFID reader fails, an "RFID not registered" error appears, prompting children to retry or choose another card. The second part involves a Braille-to-speech function, where typing a character and pressing "Speak Now" button triggers the speech pronunciation as shown in Figure 7. These changes aim to create an engaging and interactive learning experience for young children, enhancing their ASL recognition and speaking abilities. Visual representations and auditory feedback featured by the system also improve their language understanding and engagement.

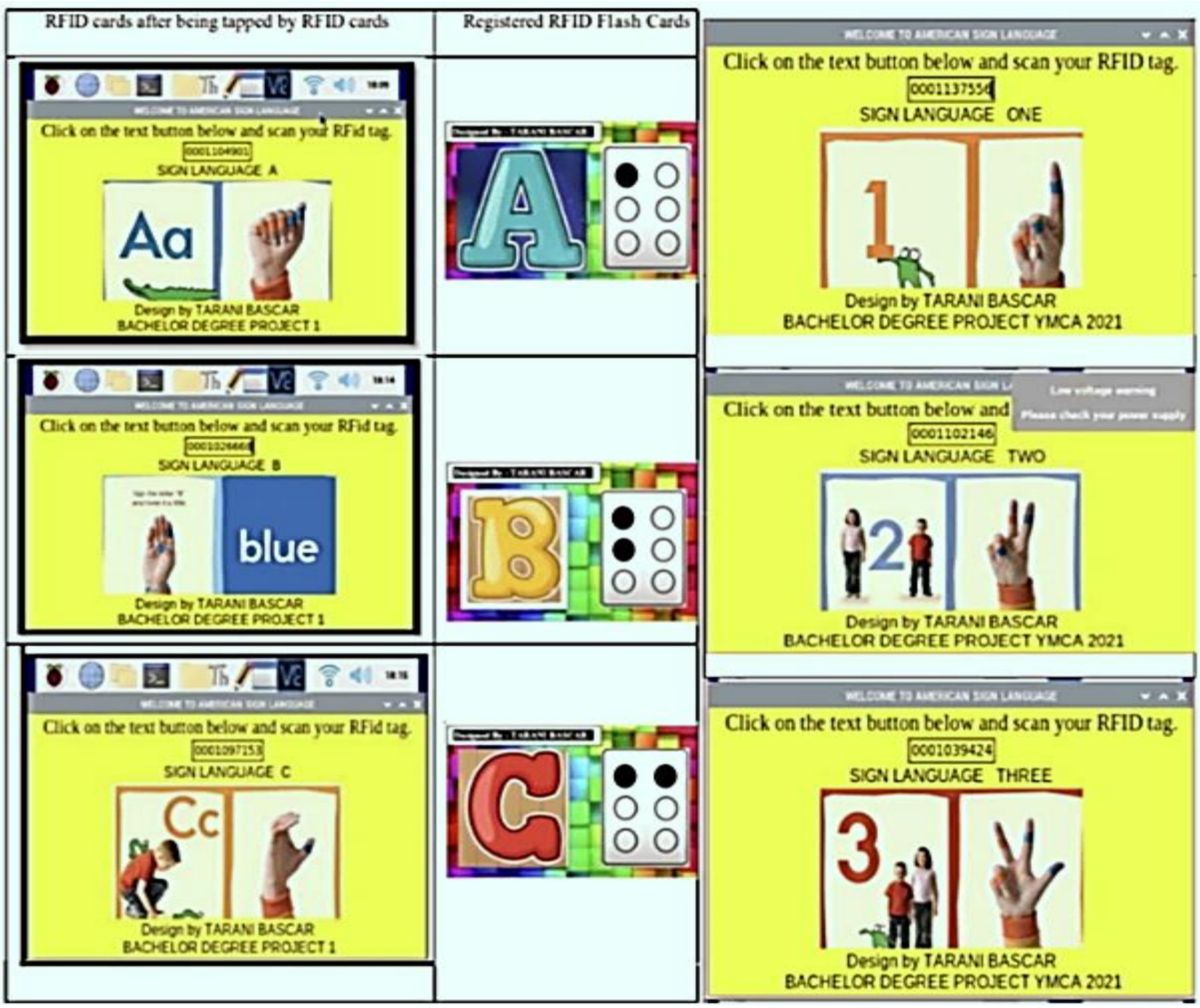

Fig. 6. Graphical Interface of the proposed system

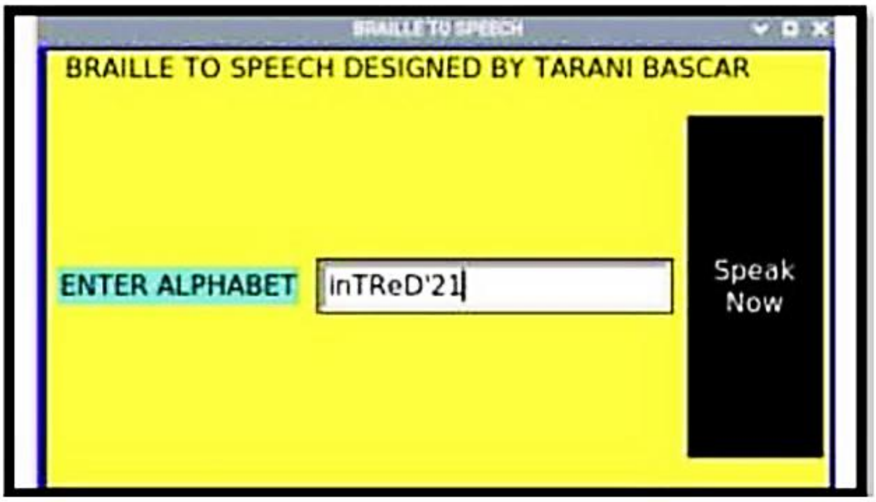

Fig. 7. Braille to speech conversion

A case study on November 24, 2021, involved two deaf-blind students and a YMCA teacher in Brickfields, Malaysia. The aim was to implement the ASL learning project in the real-time environment. Three methods were employed. The first method utilized RFID cards tapped on a reader, thus displaying ASL visualization on a projector via wireless connection as shown in Figure 8. Some students participated remotely using laptops, accessing the project's device for ASL learning as shown in Figure 9.

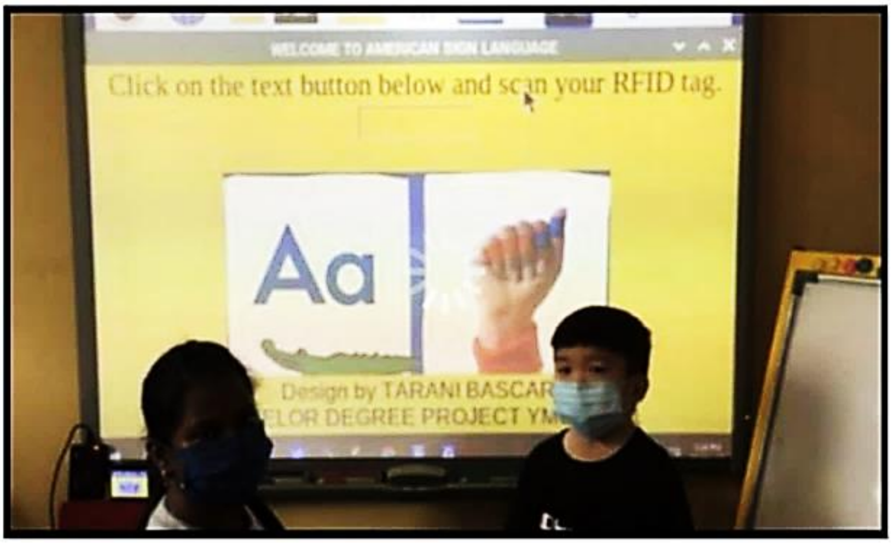

Fig. 8. Children tap and showing the sign language through the external projector

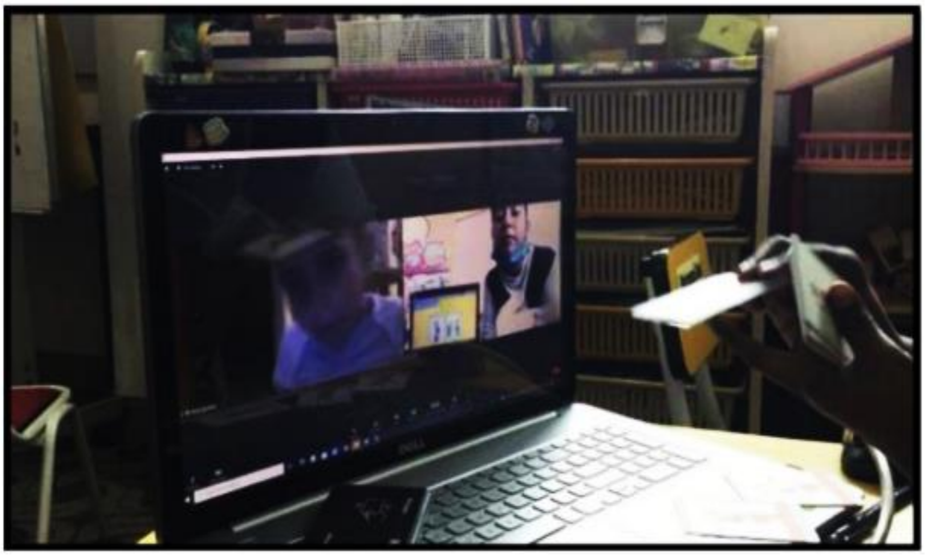

Fig. 9. Children learning the ASL 4. Conclusions remotely through ASL visualizer

Figure 10 illustrates a child learning ASL through Braille keyboard to speech system using a dedicated Raspberry Pi device, thus promoting tactile-based ASL comprehension. Users' feedback from the association revealed the children are excited and committed towards learning ASL with RFID cards, thus emphasizing more physical interaction. The students also found the project device aided their ASL comprehension effectively. This case study confirms the successful project implementation, showcasing positive engagement and learning outcomes for the deaf-blind students.

Fig. 10. Braille to speech practical

Beyond ASL and Braille, this prototype supports language learning, focusing on Arabic language for typically abled children. It presents Arabic words for children to input via the provided interface and offers voice speech for feedback as shown in Figure 11. The evaluation results, as seen in Table 2, highlight the system's versatility as a dominant language learning tool. Although the sampling is limited, these preliminary findings provide insights into the system's functionality and performance improvement, thus laying the foundation for understanding its operation accordingly under current conditions.

Table 2
Number of error occurred

ASL	Number of Error
A	0
B	0
C	0

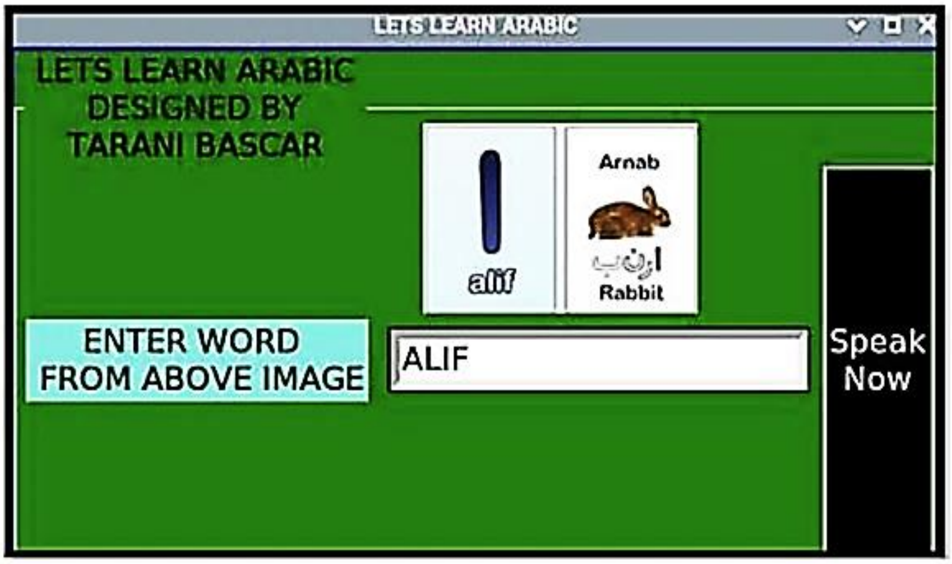

Fig. 11. GUI display when the student has entered the Arabic word

5. Conclusions

This project aims to visualize American Sign Language (ASL) and improve educational opportunities for deaf-blind children. It integrates RFID card interfacing with the Python programming language to provide basic ASL learning through visualization and includes a Braille-to-speech function for Braille effective learning. Despite its innovative approach, challenges like ASL gesture interpretation accuracy persist due to the complexity and user-specific nuances. Addressing these issues with introduction to advanced gesture recognition algorithms and machine learning could enhance accuracy and expand the sign vocabulary recognition considerably. Overall, this project represents a significant advancement in assistive technology for the deaf-blind community.

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