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Interactive Braille Communication System for the Visually and Hearing Impaired

Garachetla Pradeep Reddy, Gaddam Chandraprakash, Nallavalli Harshavardhan, Busmalla Manish

Department of ECE, Hyderabad Institute of Technology and Management, Hyderabad, India

Ch.Shanti Priya

Assistant Professor, Department of ECE, Hyderabad Institute of Technology and Management, Hyderabad, India

ABSTRACT: With the rapid advancements in technology, enhancing accessibility for individuals with disabilities is a vital objective. This paper presents a cost-effective and easy-touse Braille display system designed specifically for visually impaired users. The system operates through Bluetooth, allowing users to send text from their smartphones or computers. An Arduino-based controller decodes each character and activates six servo motors, controlled by a PCA9685 module, to form Braille patterns. The system displays each character sequentially and resets after each word to maintain clear communication.

In addition to the Braille text display, the system incorporates a **to-do list feature**. Users can add tasks via voice commands such as "add to-do," and the system saves these tasks on an SD card for future retrieval. Furthermore, the system includes **health monitoring** capabilities, measuring vital signs like temperature and heart rate. These health parameters are transmitted to a caregiver using a GSM module, ensuring timely alerts for user safety. The design is portable, power-efficient, and scalable, making it wellsuited for real-world applications.

KEYWORDS: Voice-to-Braille Conversion, Assistive Technology for Visually Impaired, Arduino Driven Braille Display, Speech Recognition in Braille Systems.

I. INTRODUCTION

Blindness is [1] regarded as one of the most challenging disabilities, as it severely limits an individual's ability to interact with their surroundings independently. When combined with hearing impairment, the condition becomes even more complex, as the two most essential senses for perceiving external information are compromised. Individuals who are both blind and deaf face substantial barriers in communication, mobility, and day-to-day living, often requiring specialized tools to bridge the gap between themselves and the world around them.

For such individuals, tactile systems like Braille become a crucial medium for understanding information and expressing themselves.

However, traditional Braille systems are largely static and rely on printed materials, which do not support dynamic or real-time interactions. In modern contexts where instant communication is a norm, there is a growing demand for responsive and affordable assistive devices tailored for people with dual sensory loss.

This work presents the development of an interactive assistive device designed to support communication for individuals who are both blind and deaf. The proposed system leverages Bluetooth technology to receive voice input from a paired mobile device. The spoken words are processed by a microcontroller and translated into corresponding Braille characters, which are physically represented using an array of servo motors. These motors are arranged according to the Braille cell pattern and are managed through a PCA9685 driver for precise control.

To ensure that users are not isolated in emergency situations or when assistance is needed, the device incorporates a GSM module. This allows critical information, such as emotional wellbeing, to-do reminders, or alerts, to be sent directly to a caretaker or family member. This dual functionality enhances both communication and safety.By utilizing cost-effective and widely available hardware components such as Arduino boards, servo controllers, and GSM





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modules, the system remains accessible and practical for everyday use.

II. LITERATURE REVIEW

Authors	Technique	Methodology	Pros	Cons
Gousiya	Python-based	Uses	-Helps visually impaired to	-Needs .png Braille images
Begum,	speech	SpeechRecognition	translate speech to	for letters
N. Musrat	recognition and	library for capturing	Braille with ease	-Needs a PC or device for
Sultana,	text- toBraille	and converting speech	-Utilizes open-source Python	execution
D. Hinduja	conversion using	to text, processes text	libraries	-Might have problems with
et.al [2]	libraries like	using Python scripts.	-Checks Braille script by	lengthy or cacophonous
	SpeechRecognitio	Converts text to Braille	scanning - Can support multiple	speech inputs (reportedly to
	n, NumPy,	using pre-saved .png	languages in the	be improved in the future)-
	Matplotlib,	images of Braille	future	Needs
	PyAudio, and	letters. Utilizes		.png Braille images for letters
	PyTorch	Matplotlib to display		
	5	Braille, NumPy for		
		processing, and		
		PyTorch for potential		
		deep learning		
		improveme		
		nts. Allows scanning		
		Braille script		
		to check accuracy.		
S. Venkat	Gesture-	Makes use of Speech	-Gesture-controlled cloud-based-	-Real-time object detection
Ragavan,	controlled, cloud-	Recognition library to	mobile application based on AI,	and spatial reference -
A. H. Tarun	based mobile app	record and interpret	DL, NLP, and language	Multilingual narration
et.al[3]	using AI, DL,	speech into text.	translation for realtime	(native language support) -
	NLP, and	interprets text using	navigation	Portable mobile-based
	language	Python programs.		solution
	translation for	Interprets text to		-Leverages latest cloud and
	realtime	Braille utilizing pre-		AI technologies - Gesture
	navigation.	saved.png pictures of		control provides hands-free
		Braille characters.		interaction
		Uses Matplotlib for		
		displaying Braille.		
		NumPy for		
		computations, and		
		PyTorch for potential		
		deep learning		
		optimization. Can scan		
		Braille		
		writing to test		
		correctness.		





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B. Gopinath, S.	Speech & Text to	Employs Raspberry Pi-Multi-disability support (blind, Raspberry Pi Zero can have
Nagarathinam.	Braille using	Zero with speech-to-deaf, and deafblind) processing speed constraints
M	Raspherry Pi Zero	text and text- toBraille-Bi-directional. Speech \leftrightarrow Braillein real- time operations - Wi-
Alagumeenaaks	and NodeMCU	$randram$ software $A \leftrightarrow Text$ Fidenendency restricts
hi et a[4]	with bi-	NodeMCU
III CLA[4]	directional	(FSD826 hardware (NodeMCU) Several input modes (speech
		(ESI 620 mardware (NouciviCO, -Several input modes (speech,
	(Draille to text	6) Kaspberry Pi Zero) - Ottersbraine, push buttons) can
		racinitates with violation (bone conduction) complicate
	and speech) and	Fi communication withreedback for partially hearing-Bone conduction not
	boneconduction	a web server users effective for completely deat
	feedback	Facilitates bi-
		directional interaction
		where speech/text
		inputs are translated to
		Braille (through
		solenoids) and Braille
		inputs (through push
		buttons or image
		scanning) are translated
		to text/speech. A
		piezoelectric
		transducer also offers
		boneconduction
		vibration feedback for
		nartially-hearing
		nsers
Kausar et al. [5]	Deen Learning for	Proposed a two-stage Extremely precise Braille Needs large computational
	Braille Character	approach employing character recognition resources for training
	Recognition	deen learning for Very efficient with reduced Dependent on image quality
	(CNNbased)	Braille recognition computational expanse due to for preprocessing
	(CININDASCU)	Initially the the second secon
		initially, they inverted residual offer
		amplated
		employed
		employed imag
		employed imag e preprocessing
		employed imag e preprocessing methods like
		employed imag e preprocessing methods like alignment,
		employed imag e preprocessing methods like alignment, enhancement, and
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second
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		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational burden low while
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational burden low while ensuring accuracy. The
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational burden low while ensuring accuracy. The model was tested and
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational burden low while ensuring accuracy. The model was tested and trained using English
		employed imag e preprocessing methods like alignment, enhancement, and noise removal to preprocess Braille images. In the second stage, they used a light- weight CNN model where normal DenseNet201 layers were substituted with Inverted Residual Blocks (IRBs) to keep the computational burden low while ensuring accuracy. The model was tested and trained using English and Chinese Braille





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		prediction t (0.01s–0.03s) and more than accuracy.	times a 95%	
Gangaiah et al. [6]	IoT-based Smart Speaking Device for Mute People (Gesture Recognition)	Uses ges recognition w subjects execute defined f movements. gestures are captured by ser wired into NodeMCU ESP microcontroller, w sends informa wirelessly to a mo app coded with App Inventor. system trans gestures into word voice using C++ and cloudbased for real- communication. device is made to worn on the h allowing for mo and convenient use mute indivice without an intermediary.	sture-Employing gesture-based vherecommunication for mute pre-individuals hand-Facilitates communication The without the use of an interpreter -C++ based, with integrated Nod nsorsMCU ESP8266 and MIT App afor simple connectivity and 8266setup which ation obile MIT The slates ls or code APIs -time The o be hand, obile e for duals	-Depends on correct gesture recognition for proper utilization - May not function properly in noisy or chaotic environments e-Needs extra hardware (Node MCU and wearable) -Relying on users being able to execute gestures properly





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III. METHODOLOGY

Components Overview

1. Arduino Uno:

The Arduino Uno (fig no:1) is an open-source microcontroller board based on the ATmega328P chip.



Fig:1

It is widely used in embedded systems and prototyping due to its ease of programming, rich library support, and broad compatibility with various sensors and modules. It features 14 digital I/O pins (6 of which can be used for PWM), 6 analog input pins, a USB interface for programming, and a 16 MHz clock speed. The Uno serves as the central processing unit in many DIY projects, handling data input, processing logic, and output control.

2. Heartbeat Sensor:

The heartbeat sensor(fig no:2) (often based on photoplethysmography or PPG technology) detects the pulse rate by measuring changes in blood volume through a light sensor



Fig:2

When placed on a fingertip or earlobe, it emits light and detects its reflection or absorption by blood vessels, allowing the Arduino to compute the heart rate. This sensor is widely used in health-monitoring systems.





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3. Temperature Sensor:



Fig:3

Temperature sensors like the LM35 or DS18B20 (fig no:3) are used to measure ambient or body temperature. The LM35 provides an analog voltage output proportional to temperature in Celsius, while the DS18B20 offers digital output and supports multiple sensors on a single data line using the 1-Wire protocol. These sensors are useful in health and environmental monitoring applications.

4. GSM Module (SIM800L):

The SIM800L GSM module (fig no:4) is a compact cellular module capable of sending and receiving SMS, making voice calls, and connecting to GPRS networks. It communicates with the Arduino via serial communication and requires a SIM card to operate.



Fig:4

This module is ideal for IoT projects where remote data transmission or mobile communication is needed, such as sending health alerts or location-based updates.

5. 9G Micro Servo Motors: The 9G micro servo (fig no:5) is a lightweight and compact servo motor commonly used in hobby robotics and control systems. It operates on a PWM signal and provides precise angular motion (typically 0–180 degrees). These motors are suitable for applications that require controlled movement, such as actuating Braille dots or mechanical arms in automation projects.



Fig:5





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6. Ultrasonic Sensor (HC-SR04):

The HC-SR04 ultrasonic sensor (fig no:6) is used to measure distance by emitting high- frequency sound waves and detecting the echo reflected back from nearby objects. It consists of a transmitter and a receiver and measures distance using the time delay of the echo. It is commonly used in obstacle detection, level monitoring, and proximity-sensing applications.



Fig:6

7. HC-05 Bluetooth Module:

The HC-05 (fig no:7) is a popular Bluetooth module designed for wireless serial communication. It operates in the 2.4 GHz frequency band and supports both master and slave modes. The module communicates with microcontrollers via UART (serial communication) and is ideal for short-range, low-power applications. It enables wireless data transfer between the Arduino and devices like smartphones, tablets, or other microcontrollers, making it essential for Bluetooth-based projects.



3.1 System Architecture

The system is based on a microcontroller (Arduino Uno) that coordinates all the actions. The core idea is to enable the user to interact with the device through voice commands, which are then converted into Braille output. The output is displayed on a motorized Braille display, which uses servo motors controlled by a PCA9685 driver. In parallel, the system uses a GSM module to notify a caretaker about the user's emotional state, health issues, or important tasks. The overall system architecture involves three main subsystems:

- Speech Input System: Captures speech through Bluetooth.
- Braille Output System: Displays the captured speech as Braille.
- Caretaker Notification System: Sends updates to the caretaker via GSM.

3.2 Braille Output via Servo Motors

The main feature of the system is the translation of text into Braille. Once the Arduino processes the text, it needs to display it in Braille. This is achieved through a servo based Braille display. The system uses six servo motors, each

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representing a dot in the Braille cell. These motors are controlled using a PCA9685 servo driver connected to the Arduino.

When the system receives a command to display a word or phrase, it processes each letter and translates it into its Braille representation. For each letter, the corresponding servo motors rotate to the correct positions to represent the Braille dots for that character. The servo motors then return to their default position, preparing for the next letter or character.

For example, if the system is instructed to display the letter "A", the first servo motor rotates to the required position to represent a raised dot, while the other motors remain in their default positions. After displaying the character, the motors return to their initial state, and the next letter is processed in a similar manner.



IV. RESULTS

Fig:8

The developed assistive communication system demonstrated reliable performance across its key functionalities. In controlled conditions, the Bluetooth-based voice input interface accurately recognized commands such as "display time," "add to-do," and "show to-do list." The voice recognition operated with high precision in quiet environments, while in noisy settings or with unclear speech, its accuracy declined slightly, occasionally requiring the user to repeat commands. Despite these minor limitations, the system remained responsive and consistent in most practical scenarios. The Braille output mechanism, which uses six servo motors managed through a PCA9685 driver, effectively translated the recognized speech into corresponding Braille characters. Each servo motor responded precisely, raising and lowering the dots to form accurate tactile representations of letters. The characters were displayed sequentially, with a brief delay of approximately 1 to 2 seconds between each letter. Although this delay was acceptable for short sentences, reducing the interval could improve the speed of interaction, particularly for longer messages. Nevertheless, the tactile feedback provided by the Braille display was consistent and easily perceivable by users.

The GSM module integrated into the system functioned effectively to notify the caretaker of important events. When triggered by specific actions, such as emotional alerts or additions to the to-do list, the module sent real-time SMS notifications to the caretaker's mobile device. These messages were delivered promptly and were clearly structured, enabling the caretaker to respond appropriately and without delay. The communication between the user and the caretaker added a layer of safety and support, particularly in scenarios where timely intervention could be crucial.

Overall, the seamless integration of Bluetooth based voice input, Braille tactile output, and GSM-based caregiver notification resulted in a robust and user-centric solution. The system successfully enabled individuals who are both blind and deaf to receive and interact with spoken information while maintaining a channel for caregiver support. This practical and accessible design contributed to enhanced communication, improved autonomy, and increased safety for users facing dual sensory challenges.

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V. FUTURE SCOPE

This project serves as a foundation for further innovation in assistive communication technologies for individuals who are both blind and deaf. Future improvements may include the implementation of more advanced speech recognition systems that can function effectively in noisy surroundings and understand various accents and regional languages. Offline voice processing could be added to improve functionality in areas with limited internet access.

The Braille output module can be enhanced to support continuous text display, possibly by incorporating dynamic Braille cells or a sliding mechanism to reduce the delay in reading longer messages. Additional features, such as a tactile user interface for menu navigation or response selection, could further increase user independence.

Integration with wearable technology is another potential direction, allowing for more discreet and portable communication. Furthermore, cloud-based data storage could enable caregivers to monitor usage history or receive detailed updates, supporting proactive care. Expanding compatibility with mobile applications would also allow users and caretakers to interact with the system remotely, improving convenience and accessibility.

VI. CONCLUSION

The assistive system developed in this project provides an effective communication bridge for individuals with dual sensory disabilities. By incorporating speech input through Bluetooth, tactile Braille output using servo motors, and real-time caregiver notifications via GSM, the device ensures a responsive and supportive communication environment. The system accurately interprets spoken commands, converts them into tactile Braille characters, and notifies caregivers promptly during important interactions. Its straightforward design and affordable components make it a practical solution for widespread use. Most importantly, it empowers users with greater independence, allowing them to access information and seek support without relying on constant human assistance.

This work highlights the potential of integrating simple electronic modules into meaningful assistive tools. With future enhancements, such systems can become more intelligent, interactive, and tailored to meet the diverse needs of the blind and deaf community.

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