Journal of
Communication Engineering & Systems
https://journals.stmjournals.com/joces
ISSN: 2249-8613 (Online)
ISSN: 2321-5151 (Print)
Volume 15, Issue 3, 2025
September–December
DOI (Journal): 10.37591/JoCES
Review JoCES

Gesture Vocalizer Using Arduino

Tuneer Sen Sarma[1,*], Rupendra Singh Chahar[2]

Abstract

Science and technology have been an indispensable part of our lives, driving innovation and transforming the way we communicate. Communication barriers between the hearing-impaired and the hearing population pose significant challenges in daily interactions. Sign language, a primary mode of communication for the deaf and mute communities, is not universally understood by the general public. This research work presents a novel system for real-time sign language to speech conversion, aiming to bridge this communication gap. The system utilizes flex sensors and an accelerometer mounted on a glove to detect finger bending and hand movements corresponding to specific sign language gestures. These sensor readings are processed through conditional logic programmed into the Arduino to match predefined sign patterns, which are then converted into audible speech via a speaker module. This approach eliminates the need for complex machine learning models, making the system cost-effective, efficient, and easier to implement. The design emphasizes real-time performance, portability, and ease of use, offering a practical solution for enhancing communication between signers and non-signers and fostering greater inclusivity in society.

Keywords: Sign language, arduino, flex sensors, sound glove, accelerometer, deaf, mute, real-time performing

INTRODUCTION

Communication is a fundamental aspect of human interaction, enabling individuals to express thoughts, emotions, and ideas. However, for individuals who are hearing or speech impaired, communication can pose significant challenges in a predominantly verbal world. Sign language, a visual language that uses hand gestures, facial expressions, and body language, serves as an essential communication medium for the deaf and mute community. Despite its effectiveness within that community, a major barrier persists in communicating with individuals who do not understand sign language. Bridging this communication gap is crucial for fostering inclusion, accessibility, and empowerment. In recent years, technological advancements have opened up new possibilities for developing assistive devices that can translate sign language into text or speech. Such innovations can dramatically improve communication and social integration for individuals with hearing and speech disabilities. This research focuses on designing and implementing a low-cost, wearable glove-based system that can recognize hand gestures corresponding to sign language and convert them into audible speech. The system leverages commonly available components such as Arduino microcontrollers, flex sensors, an accelerometer, and a Bluetooth module to provide a portable and efficient solution. The proposed system consists of a glove embedded with flex sensors and an accelerometer to capture finger bending and hand orientation, respectively. Flex sensors measure the degree of bending in each finger, while the accelerometer detects the motion and position of the hand in space. The sensor data is processed by an Arduino microcontroller, which compares the input

***Author for Correspondence**
Tuneer Sen Sarma
E-mail: Tuneersensarma9@gmail.com

[1]Student, Department of Electronics and Communication Engineering, Echelon Institute of Technology, Haryana, India
[2]Assistant Professor, Department of Electronics and Communication Engineering, Echelon Institute of Technology, Haryana, India

Received Date: June 28, 2025
Accepted Date: August 06, 2025
Published Date: September 22, 2025

Citation: Tuneer Sen Sarma, Rupendra Singh Chahar. Gesture Vocalizer Using Arduino. Journal of Communication Engineering & Systems. 2025; 15(3): 14–25p.

values against predefined gesture templates to identify specific sign language symbols or words. Once recognized, the corresponding message is transmitted wirelessly via a Bluetooth module to an external device, such as a smartphone or computer [1]. A text-to-speech (TTS) application then converts the message into audible speech, completing the translation process. This system aims to be affordable, lightweight, and user-friendly, making it accessible to a broader population in both urban and rural settings. One of the key advantages of this glove-based approach is its adaptability. Unlike computer vision-based systems that rely heavily on cameras and controlled environments, sensor-based gloves can function effectively in diverse lighting and background conditions. Moreover, they offer a more private and real-time experience, which is essential for practical, everyday use [2]. Another important consideration is the use of an open-source microcontroller like Arduino, which makes the system highly customizable and scalable. Users can modify gesture mappings or add new signs as needed, enabling personalization for regional sign language dialects or individual preferences. The system also promotes the integration of low-power wireless communication through the HC-05 Bluetooth module, ensuring seamless interaction with mobile devices without the need for cables or external hardware [3]. This research also explores the challenges associated with gesture recognition, such as sensor calibration, gesture overlap, and latency in response time. Through systematic testing and iterative development, the prototype aims to achieve a high level of accuracy and reliability. In future iterations, the incorporation of machine learning algorithms could further enhance the system's ability to recognize complex or dynamic gestures, expanding its vocabulary and usability. In summary, this study presents a practical, wearable solution for real-time sign language to speech conversion, contributing to the broader field of assistive technology. By combining the flexibility of microcontroller platforms with affordable sensor technology, this project offers a promising step toward breaking communication barriers for the hearing and speech impaired [4].

The ultimate goal is to foster more inclusive communication in society, where every individual, regardless of physical limitations, has the tools to be heard and understood. The inspiration for this project stems from a personal experience that highlighted this communication barrier. I once witnessed a situation in a public place where a hearing-impaired individual struggled to explain their needs to a service provider who had no knowledge of sign language. The frustration and helplessness on both sides left a lasting impression on me. It made me realize how a simple technological intervention could make a profound difference in such situations. This moment sparked a desire to create a device that would allow sign language users to communicate more freely and independently, without relying on an interpreter or facing misunderstanding (Figure 1). The goal of this project, therefore, is not just to apply engineering principles but to make a meaningful social impact through innovation.

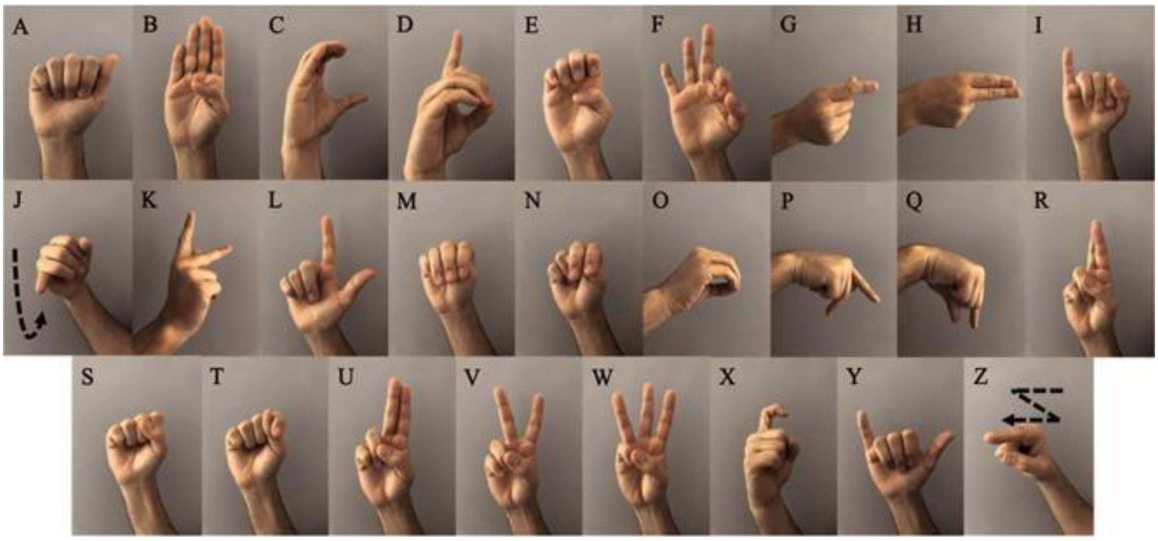

Figure 1. American sign language (ASL).

LITERATURE REVIEW

Over the years, several efforts have been made to bridge the communication gap between sign language users and non-signers through technology. Communication is a fundamental human need, one that connects us, allows us to share ideas, express emotions, and participate in society. For individuals who rely on sign language, this connection can be difficult to maintain in a world largely oriented toward verbal communication. The communication gap between sign language users and non-signers continues to pose challenges in education, healthcare, employment, and daily interactions. To bridge this divide, researchers and developers have turned to technology, experimenting with various methods such as vision-based systems, sensor-embedded gloves, and hybrid models that combine the strengths of both.

One of the earliest breakthroughs in this field was the DataGlove, developed in the 1980s. It employed fiber-optic sensors to detect finger movements and laid the foundation for modern gesture-recognition systems. However, due to its high cost and bulkiness, it was inaccessible for everyday users and remained confined to labs and research settings.

As sensor technology evolved, glove-based systems became more affordable and user-friendly. These gloves typically integrate flex sensors, accelerometers, and gyroscopes to accurately capture finger bends and hand movements. A significant contribution in this space came from Kadam and Pawar who designed a cost-effective glove system that converted hand gestures into text on a display [5]. While functional, the absence of speech output meant that communication still lacked spontaneity and emotional expression.

Gopalakrishnan *et al*. took a similar approach for recognizing basic gestures from Indian Sign Language (ISL) [6]. Their system used Arduino and flex sensors to display predefined messages on an LCD. Though affordable and useful for educational purposes, it was limited by a small vocabulary and lacked audio output, which are critical components for real-time, natural interactions.

In parallel, vision-based systems that use cameras and image processing gained popularity. These systems, like the one developed by Ong and Ranganath leverage machine learning to identify hand gestures without any physical contact [7]. Such solutions allow for a more intuitive user experience but are heavily influenced by environmental factors such as lighting conditions, background clutter, and the need for significant computational resources. These challenges limit their effectiveness in real-world, mobile, or outdoor scenarios.

To improve user mobility and comfort, Bluetooth-enabled systems began to emerge. Shaikh *et al.* designed a smart glove that sent gesture data wirelessly to an Android device for text-to-speech conversion [8]. This step toward integrating audio output brought systems closer to real conversational tools. However, issues such as gesture overlap and inadequate recognition of dynamic gestures still hindered fluid communication.

Recognizing the need for better accuracy, Yap *et al*. combined data from flex sensors and accelerometers to distinguish between similar signs [9]. Their hybrid method improved gesture detection but depended on external processing units, which compromised portability and user independence.

More recent advancements have turned to machine learning and neural networks for interpreting complex gestures. Kumar *et al*. applied supervised learning algorithms to improve recognition accuracy [10]. These models show great potential but come with their own set of trade-offs, namely, the need for large datasets, long training times, and powerful processors, which can increase cost and reduce accessibility for the average user.

Despite all these innovations, existing systems often fall short in delivering a seamless, inclusive communication experience. Some are too expensive for widespread use, others are not portable, and many lack real-time audio output, a key feature for truly bridging the gap between deaf and hearing individuals.

This project seeks to address these gaps by developing an affordable, portable, and real-time speech-generating glove. It uses Arduino, flex sensors, an accelerometer, and Bluetooth to convert hand gestures into audible speech. Designed with empathy and practicality in mind, this system aims not just to recognize gestures, but to give voice to those who cannot speak, enabling more natural conversations, fostering social inclusion, and ultimately empowering individuals with speech and hearing impairments [11].

DESIGN METHODOLOGY

The working methodology of this project involves the design, development, and testing of a wearable glove system capable of translating hand gestures, representing sign language, into audible speech. The system is structured around a modular approach comprising five core stages: hardware setup, sensor data acquisition, gesture recognition, wireless data transmission, and speech output [12]. The methodology adopted ensures the seamless integration of both hardware and software components to enable real-time communication. The goal is to create a cost-effective, portable, and reliable wearable glove that can interpret hand gestures in real-time and convert them into spoken language. The design is user-centric, focusing on simplicity, accuracy, and ease of use (Figure 2).

COMPONENTS USED

The development of the sign language to speech conversion glove involves the integration of several hardware components, each playing a critical role in sensing, processing, and communicating data. The main components used in this project include the Arduino Uno, flex sensors, accelerometer, HC-05 Bluetooth module, and a glove as the base platform. Below is a comprehensive explanation of each component and its function within the system [13].

Arduino Uno

Function

The Arduino Uno acts as the brain of the system. It processes input data from all sensors, performs logic-based gesture recognition, and communicates the results to an external device via Bluetooth.

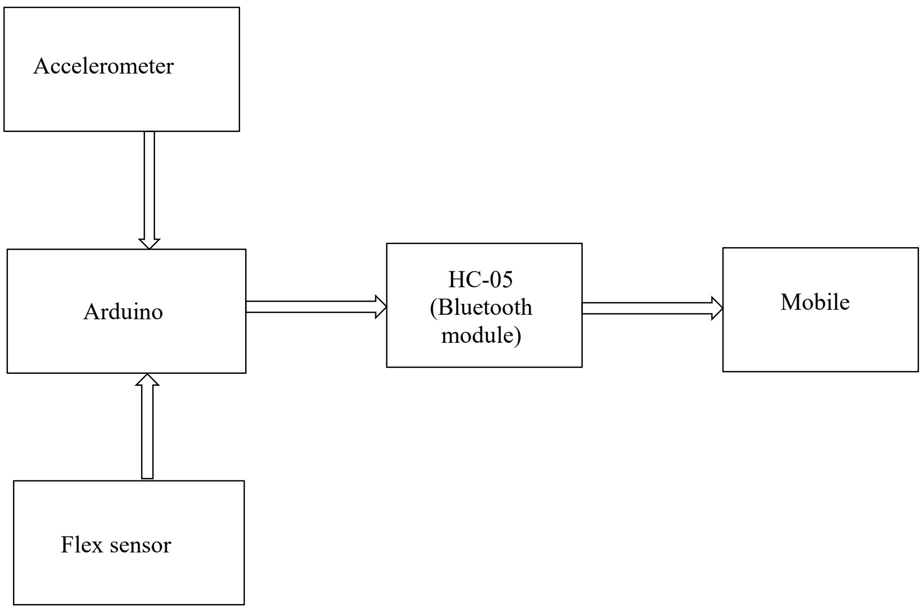

Figure 2. Block diagram.

Working Principle

The Arduino Uno is a microcontroller board based on the ATmega328P (Figure 3). It features 14 digital input/output pins, 6 analog inputs, a USB connection for programming, and operates at a clock speed of 16 MHz. In this project, the analog inputs are used to read voltage values from the flex sensors and the accelerometer [14]. The Arduino continuously monitors sensor values, compares them against predefined gesture thresholds, and upon recognizing a valid gesture, sends the corresponding text data to a Bluetooth-connected device. Its compact size, versatility, and low power consumption make it ideal for wearable technology.

Flex Sensors

Function

Flex sensors are used to detect the bending or flexing of each finger. They help determine the finger positions, which are essential in interpreting specific hand gestures.

Working Principle

A flex sensor is a variable resistor that changes its resistance based on the amount of bend applied (Figure 4). In its default, unbent position, the sensor has a baseline resistance (typically 10 kΩ). As the sensor is bent, the resistance increases proportionally.

These resistance changes are converted into voltage values using a voltage divider circuit and read by the Arduino’s analog pins. The readings are then mapped to specific finger postures: straight, semi-bent, or fully bent. By attaching one flex sensor to each finger, the glove can identify unique gesture patterns based on finger positions [15].

Accelerometer (e.g., MPU6050)

Function

The accelerometer captures the orientation and motion of the hand in three-dimensional space, providing additional data to distinguish between similar finger configurations.

Working Principle

An accelerometer is an electromechanical device that measures acceleration forces acting on it in multiple axes (usually X, Y, and Z). These forces can be static (like gravity) or dynamic (caused by movement). The ADXL335, for example, is a 3-axis analog accelerometer that outputs voltages proportional to acceleration in each axis. The MPU6050 combines a 3-axis accelerometer and a 3-axis gyroscope, providing more comprehensive motion data (Figure 5) [16]. In this system, the accelerometer helps identify the orientation of the hand (tilt left/right, forward/backward) to supplement the flex sensor readings, especially for gestures where finger positions alone are not distinctive.

Figure 3. Arduino UNO.

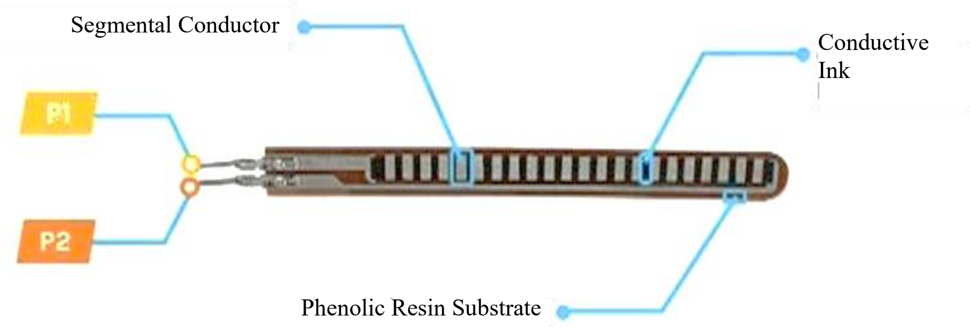

Figure 4. Flex sensor.

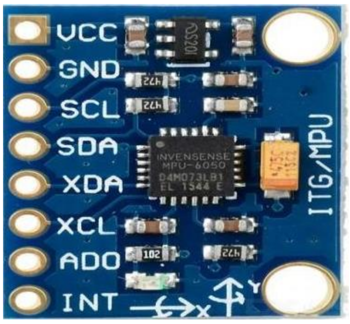

Figure 5. MPU6050.

HC-05 Bluetooth Module

Function

The HC-05 Bluetooth module is used for wireless communication between the Arduino and a mobile phone or other Bluetooth-enabled device. It transmits the recognized gesture's corresponding word or phrase as text.

Working Principle

The HC-05 module operates over a 2.4 GHz frequency and supports serial communication using UART (Universal Asynchronous Receiver/Transmitter). It can be configured as a master or slave device; in this project, it typically operates in slave mode, waiting for a Bluetooth-enabled device (like a smartphone) to initiate a connection [17]. Once paired, the Arduino sends gesture recognition results as serial text data to the mobile device. On the receiving end, the mobile device uses a text-to-speech application to vocalize the received message. This component ensures wireless, real-time conversion of gestures into speech without physical connectivity (Figure 6).

Glove (Wearable Platform)

Function

The glove serves as the physical base to mount and organize all sensors in a natural and ergonomic manner, allowing users to make sign language gestures comfortably.

Working Principle

The glove is a simple wearable piece, typically made of cotton, neoprene, or other flexible fabrics, that fits snugly around the user's hand (Figure 7). Each flex sensor is securely attached to a finger, running along the length from the fingertip to the wrist. The accelerometer is generally fixed near the back of the palm, and the Arduino board, battery, and Bluetooth module are mounted on the wrist area, often in a small, 3D-printed or plastic casing. The glove allows users to perform gestures naturally while ensuring that the sensors remain stable and accurately capture motion and flex data. Proper alignment and secure attachment are essential to minimize noise in the sensor data and improve the accuracy of gesture recognition.

Journal of Communication Engineering & Systems
Volume 15, Issue 3
ISSN: 2249-8613 (Online), ISSN: 2321-5151 (Print)

Power Supply

Function

Provides power to the entire system, making it portable and independent from external power sources.

Working Principle

The glove system is powered by a 9 V battery or a compact rechargeable lithium-ion battery (Figure 8). Voltage regulators or shields can be used to ensure the Arduino receives a stable 5 V power supply. Portable power ensures the system's usability in real-world scenarios where a power outlet is not available.

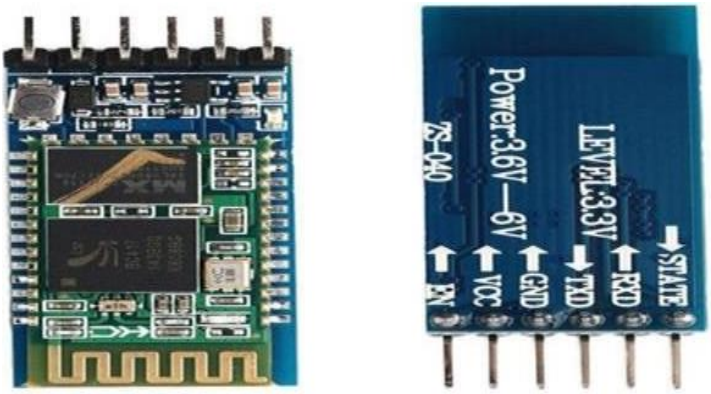

Figure 6. Bluetooth module (HC-05).

Figure 7. Glove (NEPRENE).

Figure 8. 9 V battery.

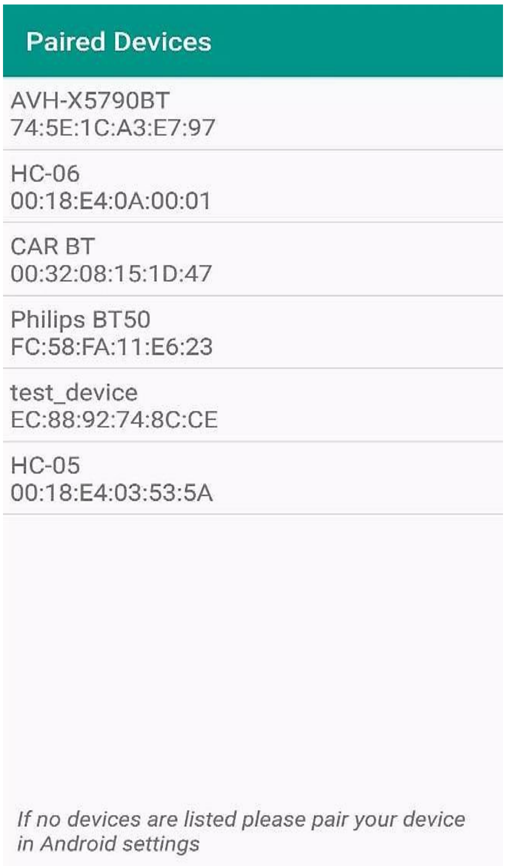

Figure 9. App interface.

Arduino Bluetooth Text to Speech Conversion App

The integration of Arduino, HC-05 Bluetooth module, and a Text-to-Speech mobile app completes the final and most critical stage of the gesture-to-speech pipeline, delivering the spoken output to the listener (Figure 9).

CIRCUIT DIAGRAM AND WORKING

The circuit for the sign language to speech conversion glove involves integrating multiple sensors and modules with an Arduino Uno microcontroller. At the heart of the system lies the Arduino Uno, which acts as the central controller. It receives input signals from the flex sensors and accelerometer, processes them, and sends the output text corresponding to the identified gesture via the HC-05 Bluetooth module to a smartphone for text-to-speech (TTS) conversion [18, 19]. Each of the five flex sensors, mounted on the fingers of the glove, is used to detect the degree of bending of the fingers. These sensors are analog resistive components whose resistance increases when bent. To make the flex sensors compatible with the Arduino's analog input, a voltage divider circuit is used for each sensor. One end of each flex sensor is connected to the 5 V supply on the Arduino, while the other end is connected to both a 10 kΩ resistor and an analog input pin (A0 to A4). The opposite end of the resistor goes to ground (GND). This configuration converts changes in resistance into measurable voltage changes, which the Arduino reads to determine finger positions. The analog values from these pins help the microcontroller interpret specific hand gestures. In addition to finger positions, the glove also needs to understand hand orientation and motion, which is achieved using an accelerometer module, commonly either the ADXL335 or the MPU6050 [20]. The ADXL335 provides analog outputs corresponding to the X, Y, and Z axes of motion [21]. These outputs are connected to analog pins on the Arduino (e.g., A5, A6, A7). Alternatively, if an MPU6050 is used, it communicates via I2C protocol, so its SDA and SCL pins are connected to Arduino pins A4 and A5, respectively. The accelerometer is powered by connecting its VCC pin to 3.3 or 5 V (depending on the module) and the GND pin to

Arduino's ground. This sensor adds contextual awareness, such as whether the hand is facing up or down, which enhances gesture recognition accuracy. The processed output from the Arduino is then sent wirelessly to a smartphone using the HC-05 Bluetooth module. This module uses UART (serial) communication to interface with the Arduino. The HC-05's TX (transmit) pin is connected to the RX (pin 0) of the Arduino, while the RX (receive) pin of the HC-05 is connected to the TX (pin 1) of the Arduino through a voltage divider circuit [22]. This voltage divider is necessary because the Arduino transmits at 5 V, while the HC-05 operates safely at 3.3 V on its RX pin. A typical voltage divider uses two resistors (e.g., 1 and 2 kΩ) to reduce the voltage to a safe level for the Bluetooth module. To power the entire system, two options are available. For testing and programming, the Arduino can be powered directly via USB from a computer or a power bank. For standalone use, a 9 V battery can be connected either through the barrel jack or to the Vin and GND pins. This makes the system fully portable and wearable. In a practical application, the battery can be mounted on the glove or worn on the arm for ease of use. Once the Arduino identifies a gesture, it sends the corresponding phrase (e.g., "Hello" or "Thank you") as a text string to the HC-05. The Bluetooth module then transmits this text to a paired smartphone. On the smartphone, a Text-to-Speech app receives the text and immediately converts it to audible speech using the phone's built-in TTS engine [23]. This seamless communication chain, from gesture detection to audible output, enables real-time, hands-free communication for individuals with speech impairments. In summary, the circuit combines flex sensors for finger detection, an accelerometer for motion sensing, a Bluetooth module for wireless data transfer, and Arduino as the processing core (Figure 10). The integration of these components ensures a smooth, reliable, and cost-effective method of converting sign language into audible speech [24].

FUTURE IMPROVEMENTS AND ENHANCEMENTS

Integration of Machine Learning for Gesture Recognition

Currently, the system uses fixed threshold values to interpret gestures. By integrating machine learning algorithms, particularly gesture classification models (e.g., decision trees, SVM, or even neural networks), the glove can learn from user-specific hand movements and improve accuracy over time. This will also allow for dynamic gesture training, where the glove adapts to different users' finger flexibility and gesture styles [25].

Wireless and Compact Design

To make the glove more wearable and less bulky, future versions can replace Arduino Uno with a smaller microcontroller like Arduino Nano, ESP32, or Seeeduino XIAO. Using wireless charging and integrated Li-ion battery management systems can further improve portability and user comfort.

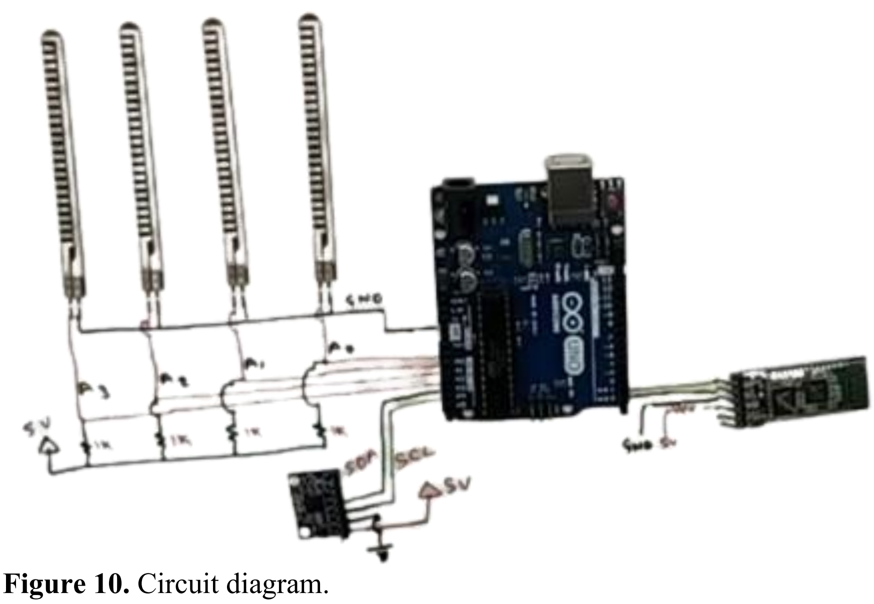

Figure 10. Circuit diagram.

Bidirectional Communication (Speech-to-Sign)

The current glove converts sign language to speech only. In the future, adding a speech-to-sign language feature using speech recognition and a small screen or vibration patterns could create a two-way communication bridge between deaf and non-deaf individuals, enhancing inclusivity [26].

Use of Advanced Sensors (IMUs and Force Sensors)

Instead of basic flex sensors, more advanced sensors like Inertial Measurement Units (IMUs) or force-sensitive resistors (FSRs) can provide multi-axis motion tracking and pressure detection. This would allow recognition of more complex gestures and even full sign language alphabets or sentences.

Cloud Connectivity and Data Logging

Incorporating IoT capabilities (via ESP32 or similar modules) would allow the system to log gesture data to the cloud, enabling gesture tracking over time, remote monitoring, or even real-time translation in conferencing tools like Zoom, Google Meet, etc. [27].

Multilingual Text-to-Speech Output

Currently, the output is in a single language. Future versions can include a language selection feature in the smartphone app, enabling the spoken output in multiple languages. This enhances communication for users in diverse linguistic environments.

Gesture-to-Text Display

For environments where voice is not practical (e.g., noisy areas [28]), adding a small OLED or LCD display on the glove or the phone screen to show the recognized gesture as text can be helpful for silent visual communication.

Haptic Feedback System

To provide confirmation of recognized gestures to the user, vibration motors can be added to the glove. This gives real-time haptic feedback, confirming that a gesture has been successfully recognized and transmitted [29, 30].

Better Smartphone App UX and Voice Personalization

Future iterations of the mobile app can offer features like:

- Custom voice selection;
- Speed and pitch control;
- Gesture configuration panel; and
- Voice assistant integration.

This improves the user experience and makes the system more customizable.

Support for Full Sign Language Grammar

Current systems usually recognize isolated words. By combining gesture sequence tracking and temporal analysis, future designs can recognize full phrases and sentences, adhering to actual sign language grammar (like ASL or ISL), making communication more natural and accurate [30, 31].

CONCLUSION

The Sign Language to Speech Conversion Glove designed in this project offers a practical and affordable solution to help bridge the communication gap for individuals with hearing or speech impairments. By combining flex sensors, an accelerometer, Arduino, and a Bluetooth module, the glove accurately detects hand gestures and converts them into audible speech using a smartphone-based TTS app. This system demonstrates how low-cost hardware and simple design can be used to create meaningful assistive technology. While the prototype currently supports a limited set of gestures,

REFERENCES

1. Dupire J, Boude Y. Lessons from Helen Keller: How to Make the Comics Accessible?. In Association for the Advancement of Assistive Technology in Europe conference (Vol. 242). 2017 Sep 11.
2. Jhunjhunwala Y, Pooja S, Pradnya P, Jyoti W. Sign language to speech conversion using arduino. International Journal of Recent Innovation in Engineering and Research January-2017 (URIER). 2017 Jan; 37–44.
3. Vijayalakshmi P, Aarthi M. Sign language to speech conversion. In 2016 IEEE international conference on recent trends in information technology (ICRTIT). 2016 Apr 8; 1–6.
4. Bansode A. Flex sensor based glove to control wheel chair and sign language translator for speech impaired people. Available at SSRN 3632705. 2020 Feb 22.
5. Kadam SR, Pawar SN. Development of Cost Effective Motion Capture System based on Arduino. In 2020 IEEE Fourth International Conference on Computing Methodologies and Communication (ICCMC). 2020 Mar 11; 1–6.
6. Khetavath S, Sendhilkumar NC, Mukunthan P, Jana S, Gopalakrishnan S, Malliga L, Chand SR, Farhaoui Y. An intelligent heuristic manta-ray foraging optimization and adaptive extreme learning machine for hand gesture image recognition. Big Data Min Anal. 2023 Apr 7; 6(3): 321–35.
7. Ong SC, Ranganath S. Automatic sign language analysis: A survey and the future beyond lexical meaning. IEEE Trans Pattern Anal Mach Intell. 2005 Jun 1; 27(06): 873–91.
8. Karim S, Shakir M, Sheikh A, Memon S, Mustafa H, Kumar V. A Novel Eye-Tracking Device Designed with a Head Gesture Control Module. EAI Endorsed Trans Scalable Inf Syst. 2022 Jan 1; 9(34): e10.
9. Khoh WH, Pang YH, Ooi SY, Yap HY. Spatiotemporal spectral histogramming analysis in hand gesture signature recognition. J Intell Fuzzy Syst. 2021 Mar 2; 40(3): 4275–86.
10. Kumar R, Kalinathan L, Murugan JM. Enhancing Real-Time Gesture Recognition Systems for Virtual Reality Applications Using Deep Learning Techniques. In International Conference on Data & Information Sciences. Singapore: Springer Nature Singapore; 2024 May 24; 263–272.
11. Karthiga E, Fathimal MS, Gowthami N, Madura P, Babu MP. Sign Language to Speech Using Arduino Uno. In National Conference on Biomedical Signal and Image Processing (BSIP-2018), Proc IJSPR. 2018 Mar; 53–55.
12. Jhunjhunwala Y, Pooja S, Pradnya P, Jyoti W. Sign language to speech conversion using arduino. International Journal of Recent Innovation in Engineering and Research . 2017 Jan; 2(01):37–44.
13. Chandra KR. Smart glove for sign language translation using Arduino. Doctoral dissertation, Bachelor’s thesis. ANIL Neerukonda Institute of Technology and Sciences, Andhra University, Visakhapatnam. 2021.
14. Cameron N, Cameron N, Pao P. Arduino Applied. New York, NY, USA: Apress; 2019.
15. Saggio G, Orengo G. Flex sensor characterization against shape and curvature changes. Sens Actuators A: Phys. 2018 Apr 15; 273: 221–31.
16. Teradal MK, Karwa MM, Nikhil M, Kumar N, Raihan MR. Design and simulation of MEMS based capacitive accelerometers for crash detection and airbag deployment in automobile. Int J Eng Res Technol. 2021; 10(8): 100–21.
17. pavanakp1904. (2024). Basics of Bluetooth Module. [Online]. LearnElectronics India. Available from: https://www.learnelectronicsindia.com/post/basics-of-bluetooth-module?srsltid=AfmBOoov7mbXvahwjeNpKeDWr5pKS0mhINwZYnROCvlbqOOp5zvDNeWj.
18. Warren JD, Adams J, Molle H. Arduino for robotics. In: Arduino robotics. Berkeley, CA: Apress; 2011 Jul 14; 51–82.
19. Sharma A, Panda S, Verma S. Sign language to speech translation. In 2020 IEEE 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT). 2020 Jul 1; 1–8.
20. Abougarair AJ, Arebi W. Smart glove for sign language translation. Int Rob Auto J. 2022; 8(3): 109–17.

21. Al Rakib MA, Rahman MM, Anik MS, Masud FA, Rahman MA, Islam S, Abbas FI. Arduino Uno based voice conversion system for dumb people. European Journal of Engineering and Technology Research. 2022 Apr 11; 7(2): 118–23.
22. Abraham A, Rohini V. Real time conversion of sign language to speech and prediction of gestures using Artificial Neural Network. Procedia Comput Sci. 2018 Jan 1; 143: 587–94.
23. Mundewadi SA, Dindore PN, Kamurti LB, Arole KV, Gurav VV. Sign language to speech conversion and home automation. Int Res J Mod Eng Technol Sci. 2023;05(01): 249–51.
24. Shaheen H, Mehmood T. Talking gloves: Low-cost gesture recognition system for sign language translation. In 2018 IEEE Region Ten Symposium (Tensymp). 2018 Jul 4; 219–224.
25. Chandra MM, Rajkumar S, Kumar LS. Sign languages to speech conversion prototype using the SVM classifier. In TENCON 2019-2019 IEEE Region 10 Conference (TENCON). 2019 Oct 17; 1803–1807.
26. Kumar DN, Madhukar M, Prabhakara A, Marathe AV, Bharadwaj SS. Sign Language to Speech Conversion—An Assistive System for Speech Impaired. In 2019 IEEE 1st International Conference on Advanced Technologies in Intelligent Control, Environment, Computing & Communication Engineering (ICATIECE). 2019 Mar 19; 272–275.
27. Pandey U, Kumar V, Kaushik S, Kumari M. IoT-assisted gesture-to-audio conversion system for enhancing accessibility in speech-impaired users. In 2024 IEEE 5th India Council International Subsections Conference (INDISCON). 2024 Aug 22; 1–5.
28. Sparsha U, Priyanka M, Mukthashree S, Kiran KN. System for sign language to speech conversion. In 2024 IEEE International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE). 2024 Jan 24; 1–4.
29. Arif A, Rizvi ST, Jawaid I, Waleed MA, Shakeel MR. Techno-talk: An american sign language (asl) translator. In 2016 IEEE International Conference on Control, Decision and Information Technologies (CoDIT). 2016 Apr 6; 665–670.
30. Arvind S, Gayatri CH, Kumar GA, Krishna R. Sign Language Conversion into Text and Speech using Flex Sensors. In 2024 IEEE International Conference on Intelligent Algorithms for Computational Intelligence Systems (IACIS). 2024 Aug 23; 1–6.
31. Al Othaina N, Al Shammari S, Ghonim H, Shehadeh M. Sign language translator. Salmiya (KW): American University of Kuwait; 2024. p. 14–35.

