

Real-Time Sign Language to Speech Conversion Glove Using Arduino and Wearable Sensors

Fardeen Khan^{1*}, Rupendra Singh Chahar²

Abstract

This research work presents the design and development of a low-cost, wearable glove system for real-time sign language to speech conversion. The system employs an Arduino microcontroller integrated with flex sensors and an accelerometer to accurately detect hand gestures. The system translates hand gestures into audible speech through Bluetooth communication, enabling seamless interaction for hearing-impaired individuals. By converting sign language into speech in real-time, it significantly enhances communication accessibility and promotes greater independence. This device bridges the gap between hearing-impaired users and others by providing a practical, immediate way to express and understand sign language. Its real-time translation fosters smoother conversations, making everyday interactions easier and more inclusive. Overall, the technology supports improved social integration and empowerment for individuals with hearing impairments. Its compact design ensures portability, while the use of widely available components keeps costs low. This innovative approach offers a practical and efficient solution to bridge communication gaps, improving the quality of life and social inclusion for users with hearing impairments. The design emphasizes portability, affordability, and adaptability, offering a practical solution for bridging the communication gap between sign language users and the general public. Future iterations may incorporate machine learning algorithms to enhance gesture recognition accuracy and expand the system's vocabulary.

Keywords: Sign language, Arduino, flex sensors, accelerometer, assistive technology, speech synthesis, wearable technology

INTRODUCTION

Communication is a fundamental human need, yet individuals with hearing or speech impairments often face significant barriers in a predominantly verbal world. Sign language serves as a vital communication medium for the deaf and mute community (Figure 1). However, its limited understanding among the general population creates a communication gap that hinders inclusion and accessibility. This research addresses this challenge by developing a wearable glove system capable of translating sign language gestures into audible speech in real-time [1].

*Author for Correspondence

Fardeen Khan
E-mail: khanfardu786@gmail.com

¹Student, Department of Electronics and Communication Engineering, Echelon Institute of Technology Haryana, India

²Assistant Professor, Department Electronics and Communication Engineering, Echelon Institute of Technology Haryana, India

Received Date: July 05, 2025
Accepted Date: August 11, 2025
Published Date: September 04, 2025

Citation: Fardeen Khan, Rupendra Singh Chahar. Real-Time Sign Language to Speech Conversion Glove Using Arduino and Wearable Sensors. Research & Reviews: Journal of Space Science & Technology. 2025; 14(3): 10–18p.

This research is inspired by a real-life observation of a hearing-impaired individual struggling to communicate in a crowded public setting. The difficulty and frustration experienced during this encounter served as a powerful reminder of the communication barriers faced by many people with disabilities [2]. It highlighted the urgent need for assistive technologies that not only address practical challenges but also promote dignity, autonomy, and social integration [3].

Beyond its primary function, the proposed system has broader implications. It can serve as an

educational tool to teach sign language to non-signers, thereby encouraging more people to learn and engage with the deaf community. Additionally, it opens the door for future innovations in human-computer interaction, rehabilitation, and inclusive technology design [4]. By combining electronics, software, and empathy-driven design, this project represents a step toward a more inclusive society, one where technology serves to connect people, rather than divide them.

The proposed system leverages readily available and cost-effective components, including an Arduino microcontroller, flex sensors to detect finger bending, an accelerometer to capture hand orientation, and a Bluetooth module for wireless communication. This combination enables a portable, efficient, and customizable solution for sign language translation [5]. The system aims to empower individuals with hearing impairments by providing a means to communicate more effectively and independently in various social and professional settings. The inspiration for this project stems from witnessing the communication struggles faced by a hearing-impaired individual in a public setting, highlighting the potential for technology to make a meaningful social impact [6].

In conclusion, the wearable sign language translation glove aims to be more than just a technological solution; it aspires to be a bridge for understanding, an enabler of communication, and a tool for empowerment. Through continued research, development, and community engagement, this system has the potential to transform the way we think about communication accessibility and contribute meaningfully to the lives of those who rely on sign language as their primary mode of expression.

LITERATURE REVIEW

Numerous research efforts have focused on developing sign language recognition systems using various technologies. Early systems, such as the DataGlove, utilized fiber-optic sensors but were limited by high costs and accessibility. Vision-based systems, employing cameras and image processing, offer contactless interaction but are susceptible to environmental factors like lighting and background noise. Sensor-based glove systems have emerged as a promising alternative, offering portability and robustness.

A study by Mundewadi *et al.* proposed a glove-based system using flex sensors and an accelerometer to convert gestures into text [7]. Further, Shaheen and Mehmood developed a system using Arduino and flex sensors to identify basic Indian Sign Language (ISL) gestures [8].

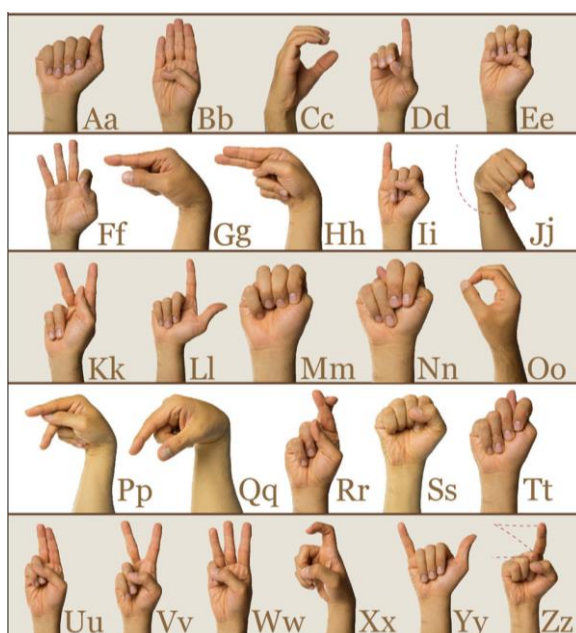


Figure 1. American sign language (ASL).

A study by Chandra *et al.* designed a smart glove with Bluetooth connectivity for text-to-speech conversion on an Android device. A study emphasized the importance of combining sensor inputs to increase accuracy [9]. An integrated supervised learning algorithms to train gesture recognition models was presented by Kumar *et al.* [10].

These previous works have contributed significantly to the field, but many existing solutions lack real-time audio output, require expensive components, or are constrained by environmental dependencies [11]. This project builds upon prior research by developing an affordable, portable, real-time speech-generating glove using Arduino, flex sensors, an accelerometer, and Bluetooth, offering an integrated system that can function in various environments.

DESIGN METHODOLOGY

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 (Figure 2). 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.

COMPONENTS USED

Arduino Uno

Function

The Arduino Uno acts as the brain of the system. It processes data from all sensors, performs logic-based gesture recognition, and communicates the results to an external device via Bluetooth (Figure 3).

Working Principle

The Arduino Uno is a microcontroller board based on the ATmega328P. It features 14 digital input/output pins, 6 analog inputs, a USB connection for programming, and operates at a clock speed of 16 MHz [12]. In this project, the analog inputs are used to read voltage values from the flex sensors and the accelerometer. 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.

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. 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.

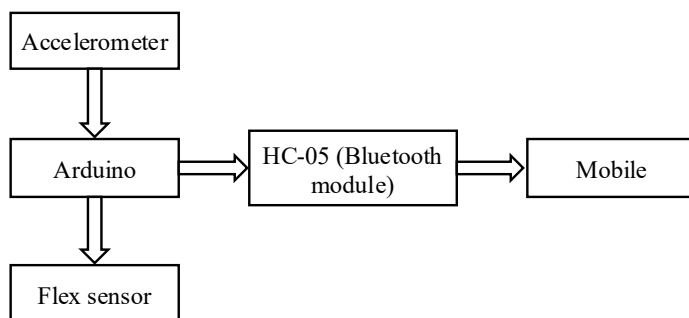


Figure 2. Block diagram.

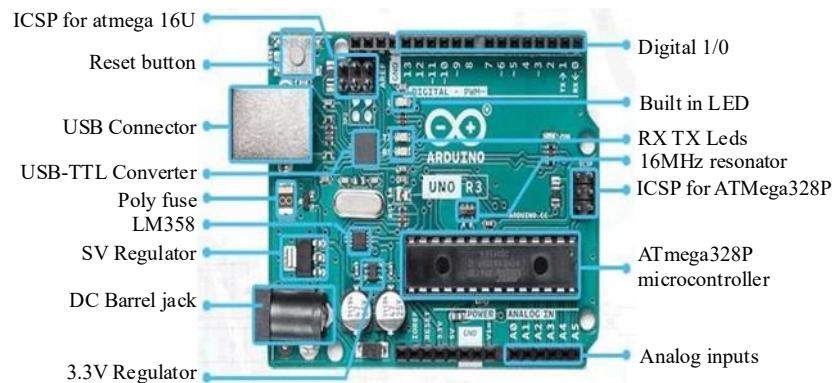


Figure 3. Arduino Uno.



Figure 4. Flex Sensor.

Flex Sensors

Function

Flex sensors are used to detect the bending or flexing of each finger (Figure 4). 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. In its default, unbent position, the sensor has a baseline resistance (typically 10 k Ω) [13]. 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 p.

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 (Figure 5).

Working Principle

An accelerometer is an electromechanical device that measures acceleration forces acting on it in multiple axes (usually X, Y, and Z) [14]. These forces can be static (like gravity) or dynamic (caused by movement). 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.

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 (Figure 6). It transmits the recognized gesture's corresponding word or phrase as text.

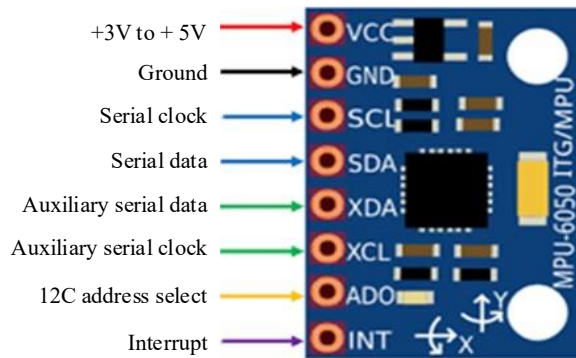


Figure 5. MPU6050.

Bluetooth Module HC-05 (ZS-040) Pinout

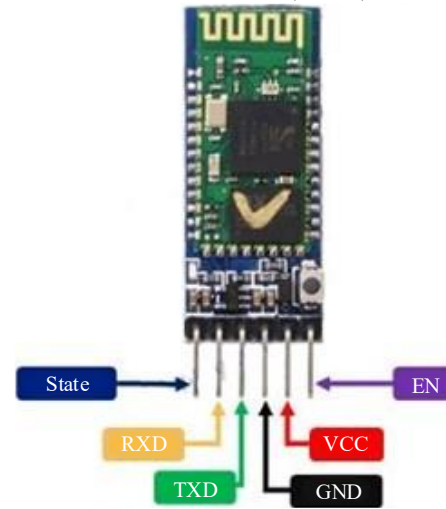


Figure 6. Bluetooth Module (HC-05).



Figure 7. Gloves.

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.

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 (Figure 7).

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. Each flex sensor is securely attached to a finger, running along the length from the fingertip to the wrist.

Power Supply

Function

Provides power to the entire system, making it portable and independent from external power sources (Figure 8).

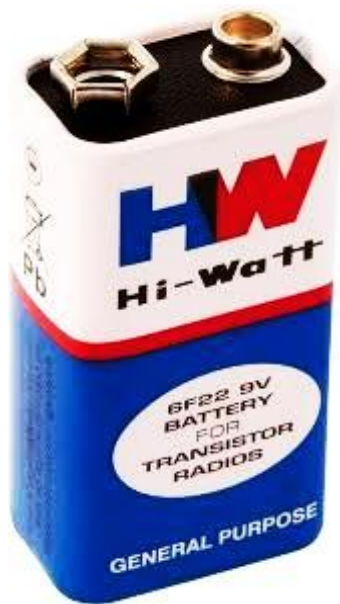


Figure 8. 9 V Battery.

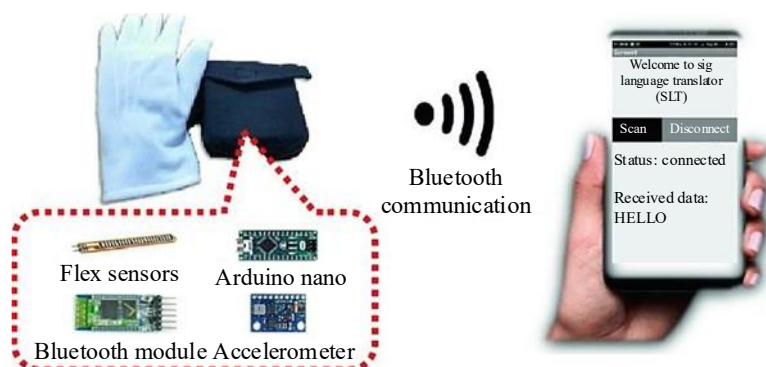


Figure 9. App Interface.

Working Principle

The glove system is powered by a 9 V battery or a compact rechargeable lithium-ion battery. Voltage regulators or shields can be used to ensure the Arduino receives a stable 5 V power supply.

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.

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.

Key Connections

Flex Sensors and Arduino

The flex sensors are connected to the analog input pins of the Arduino. Each flex sensor is placed on the fingers, with one wire connected to an analog movement of the hand. For example, the accelerometer can differentiate between upward, downward, or lateral movements of the hand.

By combining the data from the flex sensors and the accelerometer, the Arduino can detect more complex gestures and dynamic signs, such as directional or compound signs, which may require specific hand movements in addition to finger bending.

Data Processing and Gesture Recognition (Arduino)

- Once the Arduino receives data from the flex sensors and accelerometer, it processes this data using the gesture recognition algorithm. This algorithm checks the values from the sensors against a predefined set of sign language gestures.
- If the data matches a particular gesture, the system identifies the sign and maps it to a corresponding word or phrase in the English language (or other languages).

Accelerometer and Arduino

The accelerometer (e.g., MPU6050) is connected to the Arduino via I2C.

- After the Arduino processes the gesture, it communicates with an external device (smartphone, tablet, or computer) via Bluetooth. The HC-05 Bluetooth module is responsible for sending the processed data wirelessly to the device.
- The external device can then convert the gesture into a spoken word using text-to-speech (TTS) technology. This is typically achieved by using a speech synthesis app or software on the device. The device communicates with sensors or controllers using Inter-Integrated Circuit (I²C) communication. The SDA (data) and SCL (clock) lines are used to transfer information between the microcontroller and peripheral devices.

Outputting the Translated Speech (External Device and Speaker)

- Pins of the accelerometer are connected to the corresponding SDA and SCL pins on the Arduino (e.g., A4 and A5 on Arduino Uno).

The accelerometer also requires power connections, with VCC connected to the 5 V pin and GND connected to the ground (GND) pin of the Arduino.

Bluetooth Module and Arduino

The Bluetooth module (e.g., HC-05) is connected to the Arduino through serial communication (TX/RX). The TX pin of the HC-05 is connected to the RX pin of the Arduino, and the RX pin of the HC-05 is connected to the TX pin of the Arduino.

- Once the device receives the sign language gesture data, it processes the data (such as converting the sign to a word in text form) and uses speech synthesis to generate an audible output. This output is played through the speaker connected to the device.
- In this way, the user's hand gestures are transformed into audible speech, which can be understood by hearing individuals, facilitating communication between sign language users and non-sign language speakers.

The Bluetooth module also requires power, with VCC connected to 5 V and GND connected to ground.

Speaker and Bluetooth Module

The speaker is connected to a smartphone, tablet, or computer through a Bluetooth connection. Once the sign language gestures are translated into text, they are converted into speech for seamless communication.

Power Supply

Translation glove is the integration of machine learning (ML) algorithms to improve gesture recognition. Currently, the glove uses a set of predefined gestures. A rechargeable battery (e.g., Li-Po battery) is connected to the power input of gestures and sensor data to map sign language gestures to spoken words. The Arduino and the other components ensure the system is portable faults. However, this approach can be limited by the system's ability to recognize. Typically, a voltage regulator is used to ensure that the voltage levels remain stable and appropriate for each component.

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. While the prototype currently supports a limited set of gestures, future enhancements can make it more adaptive, accurate, and user-friendly. Overall, this project highlights the potential of wearable technology to promote accessibility and inclusion, paving the way for improved connectivity. While the glove's wireless communication module already supports Bluetooth, further enhancing its integration with modern devices could significantly improve the user experience, further enhancing the system's integration with modern devices could significantly improve the user experience. For instance, linking the glove to a smartphone app or a pair of smart glasses would allow users to view the spoken translation in real-time, either as subtitles on the phone or directly in the user's field of vision through augmented reality (AR) glasses. This would create a hands-free experience for the user, enabling them to engage in conversations without having to rely on a separate speaker or external display. Smart glasses, equipped with transparent displays, could overlay translated text onto the wearer's environment, allowing them to maintain eye contact with the person they are communicating with, thus making conversations more natural and engaging.

REFERENCES

1. Karthiga E, Fathimal MS, Gowthami N, Madura P, Babu PG. Sign language to speech using Arduino Uno. In: National Conference on Biomedical Signal and Image Processing (BSIP-2018) Proceedings. 2018; 53–5.
2. Chandra KR, Suhruth V, Patnaik K, Sandeep M, Prasad A. Smart glove for sign language translation using Arduino. Bachelor's thesis. Visakhapatnam, India: ANIL Neerukonda Institute of Technology and Sciences; 2021.
3. Vishal D, Aishwarya H, Nishkala K, Royan BT, Ramesh T. Sign language to speech conversion. In: 2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC). 2017; 1–4.
4. Abougarair AJ, Arebi W. Smart glove for sign language translation. *Int Rob Auto J.* 2022; 8(3): 109–17.
5. Al Rakib MA, et al. Arduino Uno based voice conversion system for dumb people. *Eur J Eng Technol Res.* 2022; 7(2): 118–23.
6. Abraham A, Rohini V. Real time conversion of sign language to speech and prediction of gestures using Artificial Neural Network. *Procedia Comput Sci.* 2018; 143: 587–94.
7. Suman SK, Shekhar H, Mahto CB, Gururaj D, Bhagyalakshmi L, Patra PS. Sign language interpreter. In: Kumar A, Mozar S, Haase J, editors. *Advances in Cognitive Science and Communications: Selected Articles from the 5th International Conference on Communications and Cyber-Physical Engineering (ICCCE 2022)*, Hyderabad, India. Singapore: Springer Nature; 2023. p. 1021–31.
8. Shaheen H, Mehmood T. Talking gloves: Low-cost gesture recognition system for sign language translation. In: 2018 IEEE Region Ten Symposium (TENSYP). 2018; 219–24.
9. Chandra MM, Rajkumar S, Kumar LS. Sign languages to speech conversion prototype using the SVM classifier. In: IEEE TENCON. 2019; 1803–1807.

10. 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; 272–5.
11. 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; 1–5.
12. Sparsha U, Priyanka M, Mukthashree S, Kiran K. System for sign language to speech conversion. In: 2024 IEEE International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics (IITCEE). 2024; 1–4.
13. Arif A, Rizvi STH, 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; 665–70.
14. Arvind S, Gayatri C, 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; 1–6.