SMART GLOVE FOR SPEECH AND HEARING DISABILITIES

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Abstract:

The Smart Glove system is an innovative assistive device developed to support individuals with speech and hearing impairments by translating hand gestures into audible speech. This project integrates flex sensors, an MPU6050 sensor (accelerometer and gyroscope), and an ESP32 microcontroller, which captures and processes real-time gesture data. The processed data is transmitted wirelessly via Wi-Fi to a connected smartphone or web interface, where it is converted into voice output, enabling effective communication. The system supports the recognition of sign language gestures, reducing communication barriers and enhancing accessibility. Features such as gesture customization, data logging, and wireless operation improve the usability and flexibility of the system. Leveraging the capabilities of the ESP32 and sensor technologies, the Smart Glove promotes independence, ease of interaction, and social inclusion for differently abled users.

Keywords: *Smart Glove, ESP32 Microcontroller, Accelerometer Gyroscope, Flex sensors, Gesture recognition, Speech Output, Text Output, Assistive Technology*

1. INTRODUCTION

Assistive technologies play a vital role in improving the quality of life for individuals with disabilities, particularly those with speech and hearing impairments. Communication barriers often limit their ability to interact effectively with others, leading to social isolation and reduced independence. In recent years, wearable systems capable of recognizing hand gestures have emerged as practical tools to address these challenges. Among these, Smart Gloves that interpret sign language or hand movements into speech are gaining significant attention for their potential to enhance real-time communication.

This paper presents the development of a cost-effective, lightweight Smart Glove designed to assist individuals with speech and hearing impairments by converting hand gestures into audible speech. The glove integrates flex sensors and an MPU6050 sensor (accelerometer and gyroscope) to accurately detect finger bending and hand orientation. These signals are processed by an ESP32 microcontroller, selected for its efficient performance and built-in wireless communication capabilities. The interpreted gestures are transmitted to a connected smart device for voice output, enabling seamless interaction with others. According to the Indian Census and reports by the National Association of the Deaf, over 1.8 million people in India are deaf and mute, highlighting the urgent need for accessible communication aids.

The proposed system offers a low-cost solution, with an estimated prototype cost of approximately ₹3,500–₹4,000, making it accessible for wider adoption, especially in resource-constrained environments. By combining gesture recognition with speech output in a wearable format, the Smart Glove serves as a practical assistive tool to promote inclusion, independence, and effective communication.

The paper "Smart System with Artificial Intelligence for Sensory Gloves" describes a smart glove integrated with multiple sensors and wireless communication, including web-based output. The system emphasizes real-time gesture recognition and responsive feedback, which aligns with the goals of the proposed glove. It highlights the potential of embedded systems for accurate gesture detection and remote output display. [1].

Bello et al. introduce Captain Glove, a system that utilizes capacitive sensors and inertial sensors such as the MPU6050 to perform real-time gesture recognition using on-device edge processing. The recognized gestures are wirelessly transmitted and displayed via mobile or web interfaces, demonstrating the effectiveness of wearable gesture-based systems. [2]

The work by Tashakori et al., Machine Learning-Powered Stretchable Smart Textile Gloves, focuses on a glove equipped with stretchable flex sensors and IMUs to recognize complex hand movements. The system uses a Wi-Fi-enabled microcontroller to process and visualize gesture data in real time. [3].

This paper presents a fully integrated Smart Glove system that converts hand gestures into real-time audible speech using a connected smart device. The proposed design emphasizes low cost, portability, and ease of implementation, making it suitable for real-world applications. By using commonly available components such as flex sensors, the MPU6050 sensor, and the ESP32 microcontroller, the system offers an affordable solution for individuals with speech and hearing impairments. Additionally, features like gesture customization and real-time voice output enhance communication, accessibility, and user independence beyond prior research efforts.

2. BLOCK DIAGRAM

The block diagram for smart glove for speech and hearing disabilities is as shown in Fig.1.

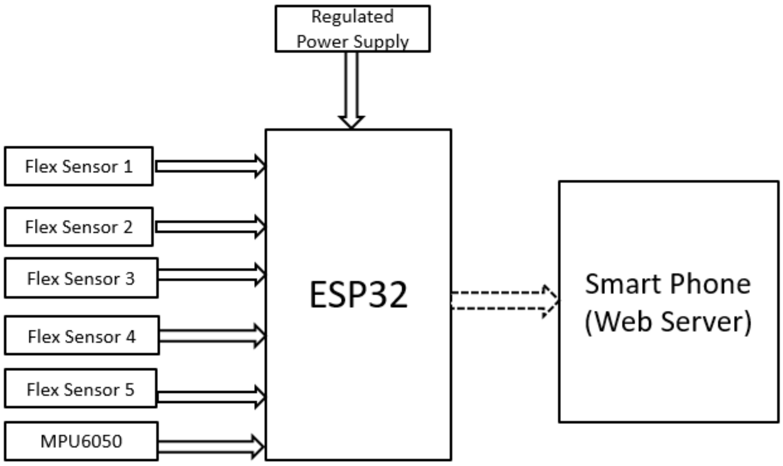


Fig.1. Block Diagram

Regulated Power Supply: The power supply provides the required voltage and current to the ESP32 microcontroller and connected sensors. It ensures continuous operation of the smart glove system.

Flex Sensors (1–5): Five flex sensors are attached to each finger to detect bending or finger movement. They generate analog voltage signals proportional to finger curvature. These values are sent to the ESP32, which compares them with calibrated data to recognize specific gestures or finger combinations, enabling accurate hand gesture interpretation.

MPU6050 Sensor: The MPU6050 is a 6-axis motion tracking device combining a 3-axis accelerometer and 3-axis gyroscope. It detects orientation, rotation, and movement of the hand. Communicating via I2C protocol, it sends digital motion data to the ESP32. This data is essential for interpreting dynamic gestures involving hand tilting or shaking.

ESP32 Microcontroller: ESP32 acts as the central processing unit. It collects data from all flex sensors and the MPU6050, processes it using Embedded C logic to detect gestures, and hosts a local web server. It generates predefined gesture-based messages and transmits them wirelessly to a smartphone connected to its access point.

Wi-Fi Communication Protocol: The ESP32 uses Wi-Fi to create a local access point. The smartphone connects to this network, enabling wireless communication. Gesture messages are served via HTTP requests on a web interface. This eliminates the need for wired connections and provides real-time gesture-to-text updates accessible through a standard web browser.

Smartphone (Web Server Interface) The smartphone functions as the output interface by connecting to a web server hosted on the ESP32 microcontroller. Upon establishing a connection via the IP address 192.168.4.1, the smartphone fetches the recognized gesture messages from the ESP32. These messages are then displayed on the screen in real time. Additionally, the system employs the JavaScript Speech Synthesis API to convert the textual messages into audible speech. This approach enables seamless gesture-to-voice communication, providing an effective assistive solution for individuals with speech and hearing impairments.

When a differently disabled person wears the Smart Glove, the flex sensors and MPU6050 accelerometer embedded in the glove detect specific hand gestures corresponding to commands. These sensor signals are continuously monitored and processed by the ESP32 microcontroller, which interprets the gesture patterns in real time. Once a valid gesture is detected, the ESP32 uses its built-in Wi-Fi module to transmit the processed data to a connected smart device or web-based application. This application then converts the gesture data into corresponding voice and text output, allowing the user to communicate with others effectively. The entire system is powered by a Power Supply and a rechargeable battery module, ensuring uninterrupted operation during prolonged use. This integrated setup provides a reliable, portable, and user-friendly assistive communication tool, combining gesture recognition, wireless connectivity, voice synthesis, and text features to improve the quality of life and independence of differently abled individuals.

3. HARDWARE MODULE

The hardware module is shown in the Fig.2.

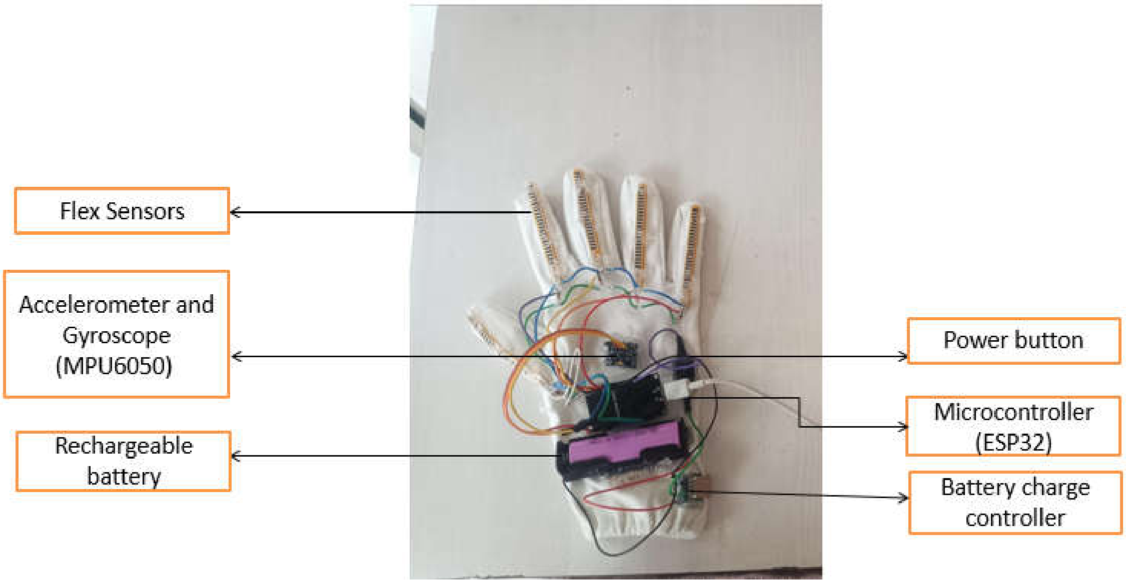


Fig.3. Smart Glove

A rechargeable battery powers the Smart Glove system, and its output is regulated by a battery charge controller to ensure safe and stable operation. A power button is included to turn the glove on or off as required. Once powered on, the ESP32 microcontroller, which features built-in Wi-Fi, manages all input processing, communication, and gesture recognition functions. The glove is equipped with Flex Sensors on each finger to detect finger bending, and an MPU6050 sensor is used to measure the orientation and motion of the hand through accelerometer and gyroscope data. These sensor inputs are read by the ESP32, which processes the signals to identify specific hand gestures mapped to words or phrases. When a valid gesture is recognized, the ESP32 uses its Wi-Fi capability to send the interpreted message to a connected smartphone or web application, where it is converted into audible speech output, enabling real-time voice communication. This helps individuals with speech or hearing impairments to express themselves effectively. The rechargeable battery allows for portable, uninterrupted operation, while the battery charge controller ensures the system is protected from overcharging and voltage fluctuations. The design is compact and wearable, integrating all components seamlessly on the glove. This smart glove system thus provides an efficient and wearable assistive technology solution that includes gesture detection, wireless speech transmission, and power management, offering enhanced communication for differently abled users in real-time

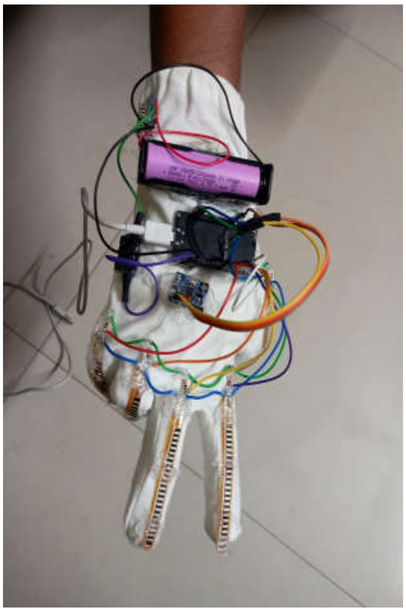
3.2 HARDWARE COMPONENTS

1. Flex sensor
    - **Resistance Range:** ~10 kΩ (flat) to ~30–50 kΩ (fully bent)
    - **Bend Angle Range:** 0° to 180°
    - **Operating Voltage:** 0–5V
    - **Length:** Typically, 2.2 inches or 4.5 inches
    - **Sensitivity:** Resistance increases with bending
    - **Durability:** Up to 1 million flex cycles
2. MPU6050 (Accelerometer + Gyroscope)
    - **Type:** 6-axis IMU (3-axis accelerometer + 3-axis gyroscope)
    - **Communication Protocol:** I2C
    - **Operating Voltage:** 3.3V–5V
    - **Gyroscope Range:** ±250, ±500, ±1000, ±2000 °/s
    - **Accelerometer Range:** ±2g, ±4g, ±8g, ±16g
    - **Resolution:** 16-bit ADC for each channel
    - **Sampling Rate:** Up to 1 kHz
3. ESP32 Microcontroller
    - **Processor:** Dual-core Ten silica Xtensa LX6 (up to 240 MHz)
    - **Operating Voltage:** 3.3V
    - **Flash Memory:** 4 MB (varies by module)
    - **RAM:** 520 KB SRAM
    - **Wi-Fi:** 802.11 b/g/n (2.4 GHz)
    - **Bluetooth:** v4.2 BR/EDR and BLE
4. Rechargeable Battery – Main Specification
    - **Type:** 3.7V Lithium-ion battery
    - **Capacity:** 1200–2000 mAh
    - **Output Voltage:** 3.7V DC
    - **Charging Voltage:** 4.2V (via TP4056 module)
    - **Recharge Cycles:** Up to 500 cycles

4. TESTING AND RESULTS

CASE 1: When the user opens their index and middle fingers and keeps the ring, little, and thumb fingers closed**,** the glove recognizes this specific hand gesture. The flex sensors on the fingers detect the bending, while the ESP32 microcontroller processes the sensor data. Once the gesture is matched, the glove sends the message “Have a Nice Day” to a connected phone through Wi-Fi**.**

For example, a student who cannot speak or hear wears the glove. When they see a friend, they perform the gesture, and the phone displays the message. The friend reads it and smiles. Similarly, a person at a shop can express gratitude using the same gesture, allowing smooth and polite interaction.

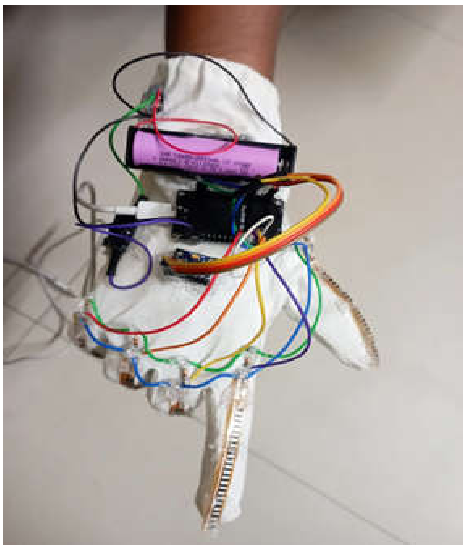


4.1(a) Have a nice day

4.1(b) Output “Have a nice day”

CASE 2: **“I am Lonely”**, When the user closes all fingers except the thumb, the smart glove detects this unique hand gesture. The flex sensors measure the bending of each finger, and the ESP32 microcontroller reads the data. Once the pattern matches the programmed gesture, the glove sends the message “I am Lonely” to a connected phone via Wi-Fi**.**

For example, a student with speech and hearing disability is feeling left out in class. They wear the glove and show the gesture. The phone immediately displays “I am Lonely”**,** allowing teachers or friends to understand their feelings and include them in activities



4.2(a) I am lonely

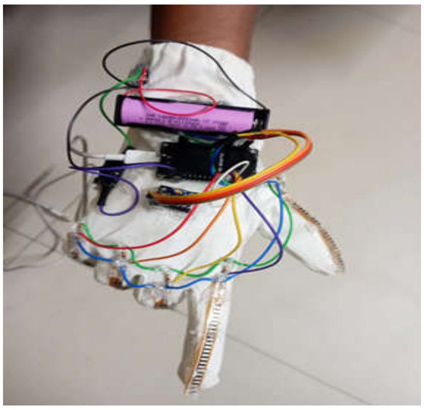
4.2(b) Output “I am lonely”

CASE 3: “Stop” gesture is performed by opening all five fingers fully. The flex sensors detect the straight position of each finger, and the ESP32 microcontroller identifies the gesture. It then sends the message “Stop” to the phone via Wi-Fi. For example, a hearing- and speech-impaired person is walking in a public place and notices a child running toward a busy road. Since they cannot shout or call for help, they quickly

Raise the fingers. .

The smart glove detects this gesture using the flex sensors, processes it through the ESP32**,** and instantly sends the message "Stop" to their connected phone. The phone displays the message clearly, and they show it to a nearby adult or passer-by. This quick action prevents a possible accident.

During a friendly chat, a person who can’t speak or hear wants to gently pause the conversation. They open all five fingers to make the “Stop” gesture. The smart glove picks it up and shows **“Stop”** on their phone. Their friend sees the message, understands, and pauses making the moment smooth and respectful.



4.3(a) Stop

4.3(b) Output is “Stop”

CASE 4: "It's Super" When a person bends their index and thumb slightly (about 15°) and keeps the other three fingers open, the smart glove understands this as a special gesture. The flex sensors feel the finger positions, and the ESP32 chip processes this pattern. Once recognized, the message "It's Super" is sent to their phone using Wi-Fi. It's a simple way to express joy or appreciation without saying a word.

Imagine a student who can't speak wants to thank their friend for helping in class. They show the "It's Super" gesture. Instantly, the message pops up on their phone screen. The friend reads it, smiles, and feels appreciated. It turns a small moment into something meaningful and that's the magic of the smart glove.

For Example, at home, a child with speech disability finishes a puzzle. They show the "It's Super" gesture using the glove. The phone displays the message, and their parent praises them happily.

4.4(a) Its super **4.4(b)** "output will be "its super

CASE 5: "Hello. How Are You?" When all five fingers are fully open, the smart glove recognizes it as a greeting gesture. The flex sensors detect that none of the fingers are bent, and the ESP32 processes this data to send the message "Hello, how are you? I haven't seen you in a long time" to a connected phone via Wi-Fi. This gesture helps people with speech and hearing disabilities start conversations easily and naturally.

For example, a student sees an old friend at college after months and performs the open-hand gesture. The glove displays the greeting message on the phone, and the friend smiles, happy to reconnect.

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4.5(a) hello. How are you?

4.5(b) Output will be “Hello. How are you”

CASE 6: “Need medicine.” When the middle and ring fingers are open and the thumb, index, and little fingers are slightly bent (15°)**,** the glove detects this unique gesture. The flex sensors read this specific pattern, and the ESP32 processes it to send the message “Need medicine” to the phone via Wi-Fi. It helps user’s express health needs easily.

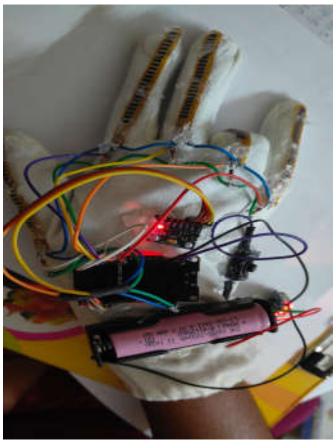
For example, a student with speech disability has a headache in class. They show the gesture, and the phone displays “Need medicine.” The teacher understands and offers help. At home, the user feels unwell and shows the gesture. The family sees the message and responds quickly.

4.6(a) Need medicine

4.6(b) Output will be “Need Medicine”

CASE 7: "Call someone" When the ring finger is bent at a 15° angle and the thumb, index, middle, and little fingers are fully open**,** the smart glove recognizes it as a signal to request help. The flex sensor on the ring finger detects the slight bend, while the others show full extension. The ESP32 microcontroller compares this unique combination with stored patterns and sends the message "Call someone" to the connected phone through Wi-Fi. This gesture allows the user to quickly ask someone nearby to make a call, especially in situations where they can't speak.

For example, a person with speech disability feels unwell at the bus stop and uses the gesture. The phone displays "Call someone," prompting a bystander to assist. In another case, a student with hearing and speech challenges wants to speak to a parent after school. They show the gesture, and the teacher reads the message, then helps make the call.



4.7(a) Call Someone.

4.7(b) output will be "Call Someone".

Smart glove Results & Testing Table

The gesture recognition table outlines various hand and finger movements that the Smart Glove is designed to detect and interpret. Each gesture is associated with specific angles or positions of the fingers or hand, which are captured using flex sensors and motion sensors. Based on these inputs, the glove generates corresponding output messages that reflect common phrases or expressions used in daily communication. These include greetings like "Good Morning," responses such as "You're welcome," requests like "Where are you?" or "I need food," and alerts such as "I am in pain" or "I'm in danger." The table also includes examples explaining the real-life context in which each message can be used. This gesture-to-speech mapping allows differently abled users to express themselves clearly and effectively through natural hand movements, enhancing their ability to communicate independently.

S.No	Gesture	Gesture Description	Output Message	Example
1	Hand tilted right & back	angleX > 90 & angleY > 40	You're welcome	To politely respond or acknowledge someone
2	Tilted upward in Z-axis	angleZ > 180	Where are you	To ask for someone's presence or location
3	Tilted left side	angleY < -100	Put it down	Used to request placing something down
4	Hand tilted downward and right	angleX < -90 & angleY > 40	It's time to eat	Used when requesting food or mealtime attention
5	Tilted downward and Z-rotated	angleX < -90 & angleZ > 150	Hello. How are you?	Greeting someone after a long time
6	All fingers bent (>15 difference from base)	All flex sensors: thm, ind, mid, rng, sm > 15	I am scared	Expressing fear/discomfort
7	Mid, ring, and little bent	mid > 15, rng > 15, sm > 15	I am lonely	Sharing feeling of being left out or alone
8	Index, mid, ring, little bent	ind > 15, mid > 15, rng > 15, sm > 15	I need water	Asking for water
9	Thumb,index,little bent	thm > 15, ind > 15, sm > 15	I am happy now	Expressing happiness
10	Mid and ring bent	mid > 15, rng > 15	Have a great day	Positive wish to someone
11	Index only bent (above 30)	ind > 30	It's Super	Expressing appreciation or joy
12	Middle only bent (above 30)	mid > 30	Need medicine	Asking for medicine when feeling sick
13	Ring only bent (above 30)	rng > 30	Call someone	Requesting someone to make a call
14	Waving-like gesture (little finger bent)	sm(small finger) > 30, others < 15 (open)	Good Morning	Used to greet someone in the morning in a friendly way
15	All fingers open	All flex sensors ≈ baseline	Hello. How are you?	Greeting someone

5. CONCLUSION

This paper presented the design and implementation of a low-cost, wearable Smart Glove system aimed at assisting individuals with speech and hearing impairments. By integrating flex sensors, an MPU6050 sensor, and an ESP32 microcontroller, the glove effectively recognizes hand gestures and translates them into real-time audible speech through a smartphone interface. The system demonstrated consistent performance across multiple test cases, with accurate gesture recognition and responsive voice output. Its portable design, ease of use, and affordability (₹3,500–₹4,000) make it a practical solution for real-world applications. The Smart Glove enhances communication, promotes social inclusion, and holds promise for future development in assistive technology.

6. ACKNOWLEDGMENT

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