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SIGN GLOVES

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***Abstract*— The SignGloves project presents a wearable assistive technology designed to bridge the communication gap between individuals with speech or hearing impairments and the general public. This smart glove system utilizes an ESP32 microcontroller to capture and process hand gestures associated with sign language. Integrated with various sensors (such as flex sensors), the glove interprets the unique finger and hand positions corresponding to different signs.**

The recognized gestures are then mapped to pre-recorded voice outputs stored on the APR33A3 voice playback module, which delivers real-time audio responses. The ESP32, with its powerful processing capabilities and built-in wireless communication, ensures efficient gesture detection and smooth system operation. This project aims to provide an affordable, portable, and user-friendly solution for real-time sign-to-speech translation, enhancing communication accessibility for the hearing and speech impaired.

Keywords: flex sensors, ESP32, APR33A3 voice module, I2C LCD display.

1. *Introduction*

Communication is a fundamental human need, yet individuals with speech or hearing impairments often face significant barriers in expressing themselves to those who do not understand sign language. Communication is the activity of conveying information through the exchange of thoughts, messages or information as by speech, visuals, signals, writing or behaviour. According to the World Federation of Deaf, there are around 72 million deaf, mute or deaf-mute people in the world today and while many of them can communicate with each other through sign language, there is a linguistic wall between them and people who can speak and write but don't know sign language.

The "Sign Gloves" project aims to address this challenge by creating a wearable assistive device that can translate sign language into both speech and text, making communication more inclusive and accessible. This project leverages modern embedded technology to bridge the gap between sign language users and the general public.

2 Hardware Architecture

2.1 ESP32 Microcontroller

The ESP32 serves as the system's processing core. Its dual-core processor, high-resolution ADC channels, and integrated Bluetooth/Wi-Fi enable efficient sensor data acquisition and processing. The ESP32 reads analog signals from the flex sensors, interprets gesture patterns, and controls output modules.

Fig.1 – Block Diagram

2.2 Voice Playback Module (APR33A3)

This module stores pre-recorded audio corresponding to recognized gestures. Upon receiving a trigger from the ESP32, it plays the associated voice message, providing immediate auditory feedback.

Fig.2 – APR33A3

2.3 Flex Sensors

Flex sensors are resistive elements whose resistance varies with bending. Each finger on the glove is fitted with a flex sensor that outputs an analog voltage proportional to the finger's bend angle. The sensors provide continuous, fine-grained data essential for distinguishing different signs.

Working Principle: When straight, the sensor exhibits a baseline resistance (~10 kΩ). Bending increases resistance (up to ~40 kΩ at 90°), creating a measurable voltage change.

Fig.3 – flex sensor

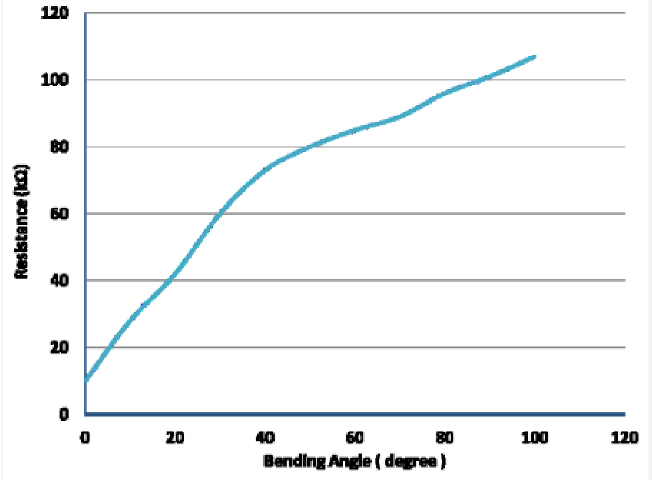

Fig.4 – flex sensor bending angle and resistance value

2.4 LCD Display

An I2C LCD displays the textual translation of the recognized sign, facilitating communication in noisy environments or for users who prefer visual feedback.

Fig.5 - I2C LCD Display

2.5 Supporting Components

Additional hardware includes power management circuitry, resistors for sensor interfacing, connectors, and a speaker for audio output, all integrated into a wearable glove.

3 Block Diagram

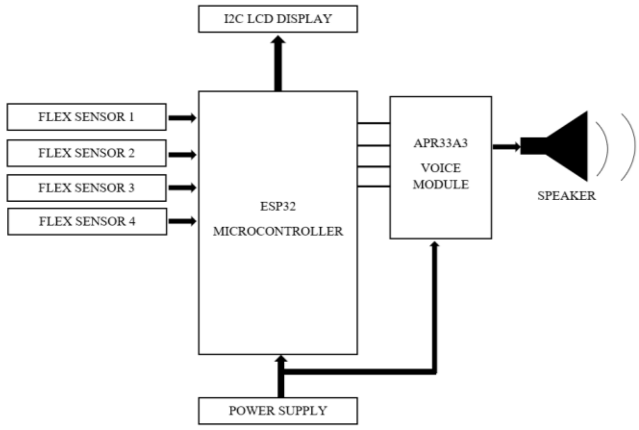

Fig.6 – Block Diagram

The Sign Gloves system consists of six main functional blocks, which together form the overall gesture recognition and communication pipeline. Figure X (to be included) depicts the block diagram of the system. Below is a comprehensive explanation of each subsystem:

3.1 Flex Sensors – Input Stage

The major input mechanism of the glove is made up of four flex sensors (Flex Sensor 1 through Flex Sensor 4), which are each mounted on a corresponding finger. They are variable resistors whose resistance varies with bending. The mechanical movement of finger flexion is thus translated to an analog electrical signal.

Each sensor is connected in voltage divider form, producing a variable voltage output that depends on resistance. These analog voltage signals are then read through the ESP32 microcontroller's ADC (Analog-to-Digital Converter) pins, and they provide the basis for detecting gestures.

3.2 ESP32 Microcontroller – Processing Unit

The ESP32 is the processing unit that interprets sensor readings and controls system output. It has several GPIO pins and ADC channels that can interface directly with the flex sensors, I2C display, and voice module.

Once it receives the analog signals from the sensors, the ESP32 analyzes them based on a set of predetermined threshold values or classification logic to determine a specific gesture. Each detected gesture is translated to a corresponding predefined sentence (for example, "I am feeling hungry"). According to the recognition outcome, the ESP32 also triggers both visual and audio outputs at the same time.

3.3 I2C LCD Display – Visual Feedback

The recognized gesture is communicated textually through a character LCD module interfaced via the I2C protocol. The I2C communication reduces wiring complexity to a great extent by using only two lines—SCL (Serial Clock) and SDA (Serial Data)—saving precious GPIO resources on the ESP32.

The LCD module shows the interpreted message in real time, giving instant visual feedback to the user as well as surrounding people, improving accessibility and interaction.

3.4 APR33A3 Voice Module – Audio Output

For auditory output, the ESP32 provides a digital control signal to the APR33A3 voice playback module. This microchip is designed to store and play back a number of pre-recorded voice messages from internal memory or external EEPROM. Activated, the voice module plays out a pre-selected audio message in response to recognized gesture, allowing users with speech disabilities to express themselves vocally in real time.

3.5 Speaker – Sound Emission

An 8-ohm Dayton Audio CE50MP-8 speaker is plugged into the APR33A3 module output. It translates the electrical audio signal into intelligible, audible speech. This audible output is particularly convenient in social or public settings where auditory communication is desirable or necessary.

3.6 Power Supply – Energy Management

The system is driven by a single power source, commonly a USB interface or rechargeable lithium-ion battery pack. All the parts are made to run effectively under a voltage range of 3.3V to 5V. Proper voltage regulation circuits are used to provide safe operation and power stability, making the glove robust and portable.

3.7 System Workflow Overview

The workflow step by step of the Sign Gloves system is provided below:

1. Gesture Initiation: The user initiates a hand gesture while wearing the glove.
2. Signal Acquisition: Finger bending is detected by flex sensors and analog signals are transmitted to the ESP32 microcontroller.
3. Gesture Interpretation: The ESP32 interprets the input data and identifies the corresponding gesture.
4. Dual Output Generation:

Visual: The corresponding sentence is displayed on the I2C LCD screen.

Audio: ESP32 activates the APR33A3 voice module, which speaks out the related audio clip through the speaker.

This combined process enables the system to act as an effective and easy-to-use assistive communication device, providing immediate feedback in visual as well as auditory formats.

4 System Methodology

The Sign Gloves project is a wearable assistive device intended to fill the communication gap for people with speech or hearing disabilities. It converts hand movements into both spoken words and real-time text output, thus making it easy to interact socially in different social settings. The system uses a collection of flex sensors, an ESP32 microcontroller, an I2C LCD display, and an APR33A3 voice playback module. All the parts function in unison to translate gestures and provide user-friendly multimodal feedback. The functional building blocks of the system are elaborated below.

4.1 Gesture Detection using Flex Sensors

The glove is equipped with flex sensors, usually one for each finger, to track finger and hand motion. Four flex sensors are implemented in this prototype to recognize individual gestures. Each flex sensor acts as a variable resistor whose resistance increases as the sensor is flexed. The changes in resistance are integrated into voltage divider circuits, generating varying analog voltage levels proportional to the amount of finger flexion.

These analog voltages are input into the Analog-to-Digital Converter pins of the ESP32 microcontroller. These captured values are representative of varying bending angles of fingers, which get mapped to certain hand gestures in terms of pre-specified messages.

4.2 Signal Processing through ESP32 Microcontroller

The ESP32 microcontroller serves as the system's central processing unit. It reads all the analog data from all the flex sensors simultaneously and processes them using either threshold logic or machine learning models (depending upon the implementation) to determine the gestures.

To illustrate, individual gestures are coded as below:

Finger 1 bent → "I am not feeling well”

Finger 2 bent → "I am feeling hungry"

Finger 3 bent → "I need to go to restroom"

Finger 4 bent → "Give me some water"

As soon as a gesture is detected, the ESP32 triggers two simultaneous responses:

It transmits the associated text message to an I2C LCD display.

It makes the APR33A3 voice playback module play the pre-recorded audio message associated.

4.3 Visual Output using I2C LCD Display

The acknowledged gesture is at the same time shown on a 16x2 or 20x4 character LCD display connected through the I2C communication protocol. The I2C interface needs only two lines—SDA (data) and SCL (clock)—reducing the number of GPIO pins on the ESP32.

The display gives real-time visual feedback to the user and surrounding people, verifying the system's understanding of the gesture. It increases transparency and reliability of communication.

4.4 Audible Output through APR33A3 Voice Module and Speaker

For voice output, the ESP32 provides a signal to the APR33A3 voice playback module. This module is capable of storing and playing back several audio messages stored in its onboard memory or an external

EEPROM. On power-up, the correct voice clip is played via a mini speaker (such as Dayton Audio CE50MP-8), providing clear and understandable speech output.
This sound feature is especially useful in situations where visual information may not be ideal or convenient, such as loud public places or in the case of people who are unfamiliar with sign language.

4.5 Power Supply Design

The Sign Gloves system draws power from a single, battery-mounted power supply like a USB power adapter or a rechargeable lithium-ion battery pack. All the components work efficiently under a range of 3.3V to 5V, promoting compatibility and power efficiency.
The power routing architecture that minimizes power loss supports mobility and extended battery life and makes the gloves highly applicable for extended daily use without regular recharging.

4 Advantages

• Enables individuals with hearing or speaking disabilities to communicate effortlessly.
• Translates hand signs into voice and text in real-time.
• Displays text on LCD and communicates via a speaker – both sound and visual responses.

5 Result

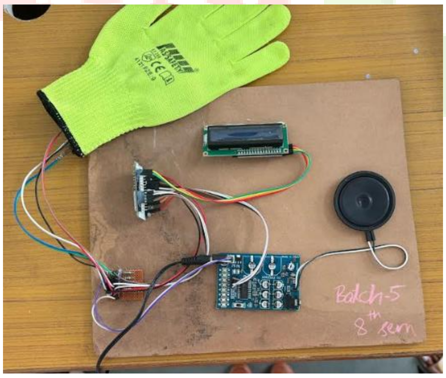

Fig.6 – prototype

During testing of the prototype, we have tested it for the coded signs. The test results were almost accurate. We tested it for the words like,
If finger 1 is bent → "I am not feeling well"
If finger 2 is bent → "I am feeling hungry"
If finger 3 is bent → "I need to go to restroom"
If finger 4 is bent → "give me some water"

6 Conclusion

In conclusion, Sign Gloves project has significant potential to make a meaningful impact in areas like accessibility, wearable technology, and human-computer interaction. By integrating the ESP32 and APR33A3 voice module, it offers exciting opportunities for real-time sign language translation, gesture recognition, and voice feedback, making communication easier for hearing-impaired individuals. With advancements in AI, machine learning, and IoT, Sign Gloves can evolve to provide smarter, more accurate, and more customizable features, expanding its use across healthcare, education, and smart home ecosystems. The future of Sign Gloves holds promising possibilities, and its continued development can drive inclusivity and bridge communication gaps for many.

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