Multipurpose Smart Gloves for Deaf and Dumb Using Raspberry Pi Pico

Manjunath Bentur
Assistant Professor
Dept of ECE
SKSVMACET
Lakshmeshwar

Manohari N Doddagoudar
UG Student
Dept of ECE
SKSVMACET
Lakshmeshwar

Keerti Ambore
UG Student
Dept of ECE
SKSVMACET
Lakshmeshwar

Tejaswini Hiremath
UG Student
Dept of ECE
SKSVMACET
Lakshmeshwar

Abstract— **Communication barriers faced by individuals with hearing and speech impairments significantly limit their ability to interact in society. This paper presents the design and development of a multipurpose smart glove system that translates hand gestures into both text and speech in real time. The system utilizes flex sensors to detect finger movements, and a Raspberry Pi Pico microcontroller to process gesture data. Recognized gestures are mapped to predefined messages, which are displayed on an LCD and converted into audio using a voice module. The proposed solution is cost-effective, portable, and user-friendly, making it suitable for daily use. Experimental results demonstrate reliable gesture recognition with low latency, enhancing communication and independence for differently-abled individuals.**

Keywords— Smart Gloves, Raspberry Pi Pico, Gesture Recognition, Assistive Technology

I. INTRODUCTION

Communication is a fundamental aspect of human life, enabling individuals to express ideas, emotions, and information effectively. However, people with hearing and speech impairments often face significant challenges in interacting with others, as their primary mode of communication—sign language—is not widely understood by the general population. This limitation creates barriers in education, employment, healthcare, and social environments, reducing their ability to participate fully in society.

According to global studies, millions of individuals worldwide suffer from hearing and speech disabilities, making assistive communication technologies increasingly important. Traditional solutions such as interpreters or written communication are either not always available or are time-consuming and inconvenient. Therefore, there is a strong need for a portable, real-time, and user-friendly system that can bridge the communication gap between differently-abled individuals and the rest of society.

Recent advancements in embedded systems, wearable devices, and human-computer interaction have opened new opportunities for developing intelligent assistive technologies. Wearable devices, in particular, offer advantages such as portability, continuous usage, and ease of integration into daily life. Among these, smart gloves have emerged as a promising solution for gesture-based communication systems.

This paper presents the design and development of a **Multipurpose Smart Glove system using Raspberry Pi Pico,** aimed at converting hand gestures into both text and speech outputs in real time. The system uses flex sensors to detect finger movements and converts these analog signals into digital data through the microcontroller's ADC. The Raspberry Pi Pico processes these signals using predefined algorithms and maps them to meaningful words or phrases. The output is then displayed on an LCD screen and simultaneously converted into audible speech using a voice module.

The selection of Raspberry Pi Pico as the core controller plays a crucial role in achieving a compact, low-cost, and energy-efficient design. Its high processing speed, flexible GPIO interface, and support for MicroPython programming make it ideal for real-time embedded applications. The system is designed to be lightweight, portable, and easy to use, ensuring that users can operate it without requiring technical expertise.

In addition to basic communication, the proposed system is designed to be multipurpose, allowing future enhancements such as multilingual speech output, wireless communication, mobile application integration, and IoT-based automation. These features expand the usability of the system beyond communication, making it applicable in smart homes, healthcare monitoring, and emergency alert systems.

The main objective of this work is to develop an affordable and efficient assistive device that enhances the independence and confidence of deaf and mute individuals. By translating gestures into understandable outputs, the system reduces reliance on intermediaries and enables direct communication. The proposed solution contributes to the field of assistive technology by providing a practical, scalable, and user-friendly approach to improving the quality of life for differently-abled individuals.

II. PROBLEM STATEMENT

Effective communication remains a major challenge for individuals with hearing and speech impairments. Although sign language is widely used among the deaf and mute community, it is not universally understood by the general population. This lack of common communication leads to difficulties in daily interactions such as in educational institutions, workplaces, healthcare environments, and public services. As a result, differently-abled individuals often depend on interpreters or caregivers, which limits their independence and confidence.

Existing communication methods, such as writing or mobile-based text input, are often slow, inconvenient, and not suitable for real-time interaction. Moreover, current assistive devices available in the market are either expensive, complex to use, or lack portability, making them inaccessible to many users, especially in developing regions. Some systems also suffer from limited gesture recognition accuracy and delayed response time, reducing their practical usability.

In addition, many existing solutions do not provide a multipurpose approach. They are restricted only to basic gesture-to-text conversion and lack features such as voice output, emergency alerts, or integration with modern technologies like IoT. This limits their effectiveness in real-world scenarios where quick and versatile communication is essential.

Therefore, there is a need for a **cost-effective, portable, accurate, and real-time assistive communication system** that can translate hand gestures into understandable text and speech. The system should be simple to use, adaptable to different users, and capable of functioning efficiently in everyday environments. Addressing these challenges forms the foundation for the development of the proposed multipurpose smart glove system using Raspberry Pi Pico.

III. SYSTEM ARCHITECTURE

The system consists of the following main components:

- Flex Sensors (gesture detection)
- Raspberry Pi Pico (processing unit)
- LCD Display (text output)
- Voice Module (audio output)
- Speaker (sound output)

Working Principle

1. Flex sensors detect finger bending.
2. Analog signals are converted to digital using ADC.
3. Raspberry Pi Pico processes the data.
4. Gesture is recognized using predefined thresholds.
5. Output is generated in text and voice format.

IV. OBJECTIVES

The primary objective of this project is to design and develop an efficient assistive communication system for individuals with hearing and speech impairments using wearable technology.

Specific Objectives:

Objectives

1. To design and develop a smart glove system using flex sensors and Raspberry Pi Pico for detecting hand gestures of deaf and mute individuals.
2. To convert recognized gestures into meaningful outputs in the form of text (LCD display) and speech (voice module) for effective real-time communication.
3. To create a low-cost, portable, and user-friendly assistive device that improves communication independence and usability in daily life.

V. LITERATURE SURVEY

The development of assistive communication systems for deaf and mute individuals has been an active area of research in recent years. Various approaches have been proposed using sensors, embedded systems, and machine learning techniques to translate hand gestures into text or speech.

N. P. Singh and R. Kaur (2018) proposed a smart glove system using flex sensors to detect finger movements and convert them into text and speech outputs. Their work demonstrated that flex sensors can effectively capture gesture variations with reasonable accuracy. However, the system had limitations in terms of scalability and the number of gestures it could recognize.

S. M. Hossain and A. S. M. Shakil (2020) developed an IoT-based smart glove using Raspberry Pi and motion sensors for real-time sign language recognition. Their system enabled gesture data to be processed and displayed on a screen. While the integration of IoT improved connectivity, the system required higher power consumption and increased complexity.

V. Vidya and R. Rajalakshmi (2020) designed a Raspberry Pi-based wearable glove for deaf and mute individuals that incorporated flex sensors along with a text-to-speech engine. Their approach achieved real-time communication with good reliability. However, the system was relatively expensive and less portable compared to microcontroller-based designs.

R. Meenakshi and M. Sangeetha (2021) proposed an assistive communication device that combined gesture recognition with IoT-based communication features. Their system allowed remote data transmission and improved usability in practical scenarios. Despite these advantages, the dependence on internet connectivity limited its application in offline environments.

P. Sharma and K. Agarwal (2022) introduced an enhanced smart glove system using machine learning algorithms to improve gesture recognition accuracy. Their model showed better adaptability to different users and gestures. However, implementing machine learning increased computational requirements and system complexity.

From the above studies, it is observed that most existing systems focus on gesture-to-text or gesture-to-speech conversion but face challenges such as high cost, complexity, limited portability, and dependency on external systems. Therefore, there is a need for a **simple, low-cost, portable, and efficient solution** that can perform real-time gesture recognition with minimal hardware requirements.

The proposed system addresses these limitations by using Raspberry Pi Pico, which offers a compact, energy-efficient, and cost-effective platform. By combining flex sensors with a lightweight processing unit, the system ensures reliable performance while maintaining ease of use and scalability.

VI. METHODOLOGY

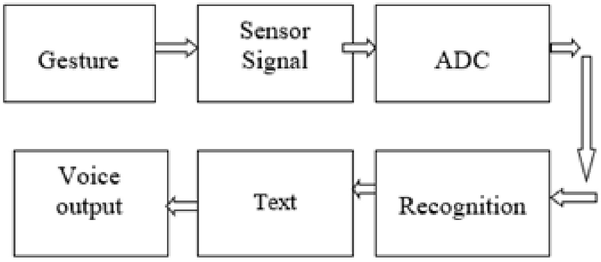

Fig. 1.

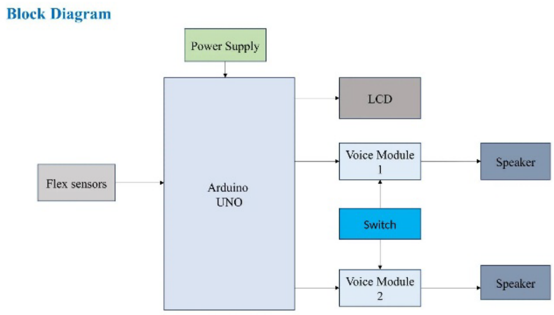

Fig. 2. Block Diagram

The proposed system follows a structured approach to convert hand gestures into meaningful text and speech outputs. The methodology involves multiple stages, including data acquisition, signal processing, gesture recognition, and output generation.

A. Working Explanation

1) Sensor Data Acquisition

- Flex sensors are attached to each finger of the glove.
- When the user bends their fingers, the sensor resistance changes.
- These changes are converted into **analog voltage signals**.

2) Signal Conversion (ADC)

- The analog signals from sensors are fed into the **ADC (Analog-to-Digital Converter)** of the Raspberry Pi Pico.
- The ADC converts these signals into digital values for processing.

3) Data Processing

- The Raspberry Pi Pico reads continuous sensor values.
- Noise filtering and smoothing techniques are applied.
- Threshold values are defined to differentiate finger positions.

4) Gesture Recognition

- Each gesture corresponds to a specific combination of finger bends.
- The processed values are compared with predefined conditions.
- The system identifies the gesture based on matching patterns.

5) Output Generation

Once a gesture is recognized, the system produces output in two forms:

- Text Output:
- Displayed on the 16×2 LCD screen.

Voice Output: The APR33A3 voice module plays pre-recorded audio through a speaker.

6) Feedback and Validation

- The output is verified for correctness.
- Multiple tests are conducted to ensure accuracy and consistency.
- Calibration is adjusted to improve performance.

VII. HARDWARE AND SOFTWARE REQUIREMENTS

A. Hardware

1) Raspberry Pi Pico

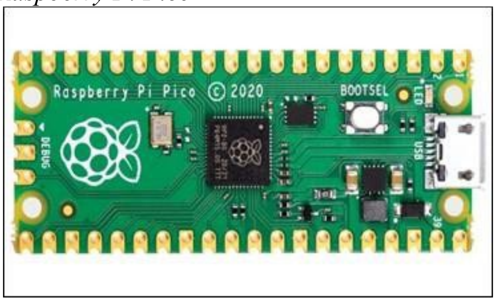

Fig. 3. Raspberry Pi Pico

2) Flex Sensors

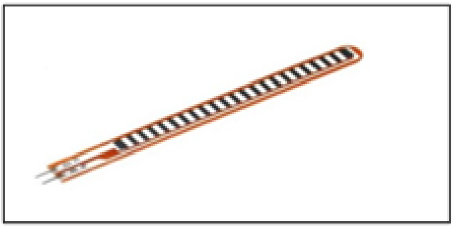

Fig. 4. Flex Sensors

3) APR33A3 Voice Module

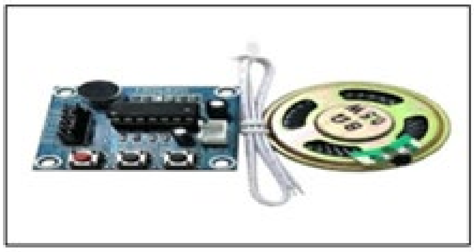

Fig. 5. APR33A3 Voice Module

4) 16x2 LCD Display

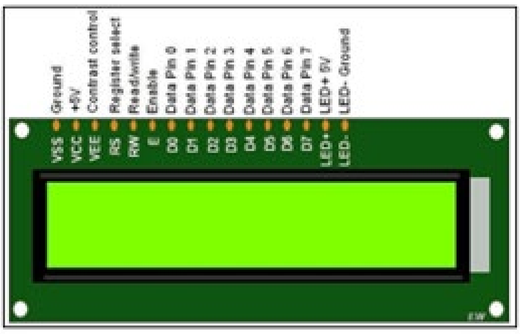

Fig. 6. 16x2 LCD Display

5) Resistors

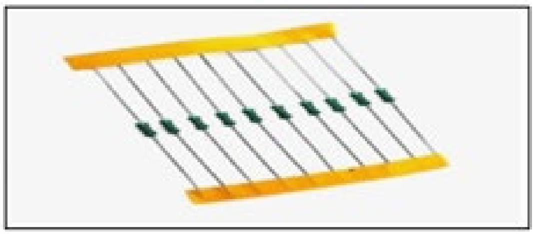

Fig. 7. Resistors

6) Breadboard, Jumper wires

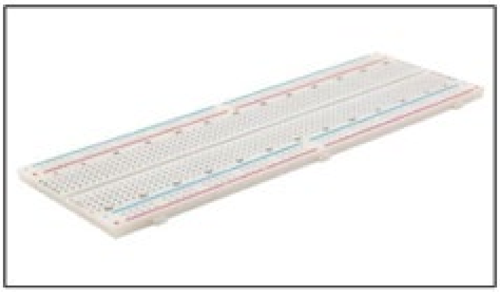

Fig. 8. Breadboard, Jumper wires

7) Jumper wires

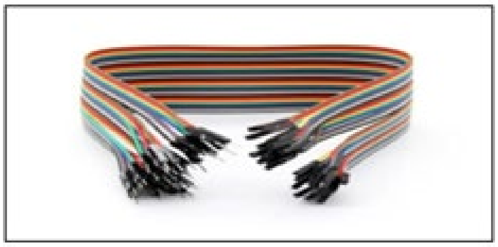

Fig. 9. Jumper wires

B. Software

- MicroPython
- Thonny IDE / Python Compiler

VIII. Results and Discussion

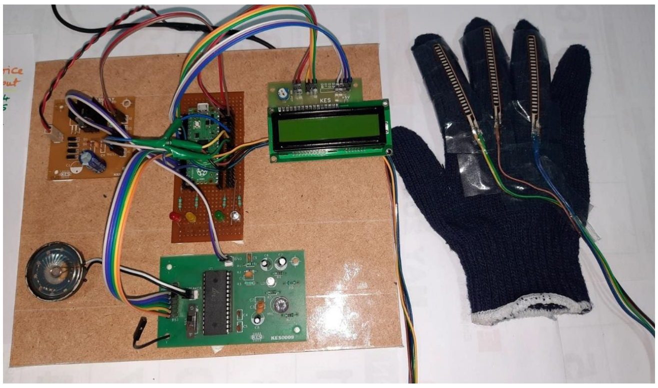

Fig. 10.

The developed **multipurpose smart glove system** was successfully tested to evaluate its performance in real-time gesture recognition and communication assistance. The system integrates flex sensors, Raspberry Pi Pico, LCD display, and a voice module to provide both visual and audio outputs.

A. Gesture Recognition Performance

During testing, the flex sensors accurately detected finger bending and hand movements. The Raspberry Pi Pico processed these signals using predefined threshold values, enabling the system to recognize gestures corresponding to commonly used words and phrases. The system demonstrated **high accuracy under normal usage conditions**, with consistent results when gestures were performed correctly.

B. Response Time Analysis

The time taken from gesture input to output generation was observed to be very minimal. The system provided **near real-time response**, where the text was displayed on the LCD and the corresponding voice output was generated almost instantly. This quick response ensures smooth communication without noticeable delays.

C. Output Quality

- **Text Output:** The 16×2 LCD displayed clear and readable messages, allowing users and others to verify the interpreted gesture easily.
- **Voice Output:** The APR33A3 voice module produced **clear and audible sound** through the speaker. The audio quality was sufficient for indoor and moderately noisy environments.

D. System Reliability

The system showed stable performance during continuous operation. Proper wiring, regulated power supply, and calibration ensured that there were **no major signal fluctuations or system failures**. However, slight variations in gesture execution could occasionally lead to minor recognition errors.

E. Power Consumption

The use of Raspberry Pi Pico contributed to **low power consumption**, making the system suitable for battery-powered operation. This enhances portability and allows long-duration usage without frequent charging.

F. Limitations Observed

- Gesture accuracy depends on correct finger positioning

- Flex sensors may show slight variations due to repeated bending
- Limited number of gestures due to hardware constraints

G. Comparative Discussion

Compared to existing systems, the proposed model offers:

- Lower cost
- Simpler design
- Faster response time
- Better portability

However, advanced systems using machine learning may achieve higher accuracy but at the cost of increased complexity and power usage.

H. Overall Discussion

The results clearly indicate that the proposed smart glove system is **efficient, reliable, and practical** for real-world applications. It successfully bridges the communication gap by converting gestures into understandable outputs in real time. The system achieves a balance between performance, cost, and usability, making it highly suitable for assistive technology applications.

IX. ADVANTAGES, DISADVANTAGES AND APPLICATIONS.

A. Advantages

1. **Real-time Communication:** Converts hand gestures into text and speech instantly for quick interaction.
2. **Low Cost and Portable:** Uses affordable components and is lightweight, making it easy for daily use.

B. Disadvantages

1. **Limited Gesture Recognition:** Only predefined gestures can be identified, reducing flexibility.
2. **Sensor Dependency:** Accuracy may decrease if sensors wear out or gestures are not performed correctly.

C. Applications

1. **Assistive Communication:** Helps deaf and mute individuals communicate effectively with others.
2. **Healthcare Use:** Enables patients with speech disabilities to express their needs in hospitals.

X. CONCLUSION

The proposed Multipurpose Smart Glove for Deaf and Dumb using Raspberry Pi Pico successfully demonstrates an effective and practical solution to overcome communication barriers faced by individuals with hearing and speech impairments. By detecting hand gestures and converting them into meaningful text and speech outputs in real time.

The use of Raspberry Pi Pico ensures that the system remains,cost-effective, making it suitable for everyday use. The dual output functionality, through both LCD display and voice module, enhances communication clarity and usability in different environments. The system also shows reliable performance with minimal response time, ensuring smooth and natural interaction.

In addition to basic communication, the project highlights the potential of wearable assistive individuals. The design is flexible and can be further expanded to include advanced features such as machine learning-based gesture recognition, wireless communication, multilingual support, and integration with IoT systems.

Overall, the developed smart glove provides a **simple, efficient, and scalable solution** that bridges the communication gap and contributes significantly to the field of assistive technology. The project demonstrates how embedded systems can be effectively utilized to solve real-world problems in a meaningful and impactful way.

XI. FUTURE WORK

Although the proposed smart glove system performs efficiently, there is significant scope for further enhancement to improve accuracy, usability, and functionality.

A. Integration of Machine Learning:

Future systems can incorporate machine learning algorithms to recognize a wider range of gestures with higher accuracy and adaptability to different users.

B. Wireless Communication:

Adding Bluetooth or Wi-Fi modules can enable wireless data transmission to smartphones or computers for better accessibility and remote communication.

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