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SMART GLOVE FOR HEARING AND SPEECH IMPAIRED

[#1]**Mrs.L. Padmalatha,** *Department of ECE*
[#2]**M. Pallavi,** *Department of ECE*
[#3]**M. Reshma Teja Sri,** *Department of ECE*
[#4]**P. Viswa Chaitanya Yadav,** *Department of ECE*
[#5]**M. Sai Surya Nithik,** *Department of ECE*
Seshadri Rao Gudlavalleru Engineering College,India

ABSTRACT: Communication can be difficult for people with hearing and speech disabilities, especially when interacting with individuals who are not familiar with sign language. To address this problem, this paper presents the design and development of a wearable smart glove that translates specific hand gestures into both speech and text. The system uses four flex sensors placed on the glove to sense the bending of the fingers and detect different gesture patterns. An Arduino Nano collects the sensor readings, while an ESP32 module processes the data and manages wireless communication. When a gesture is identified, the system produces a corresponding voice message through a speaker and also sends the related text to an Android application. The glove is built using low-cost and easily available electronic components, making it practical for real-world use. Overall, the proposed device provides a compact and user-friendly solution that helps reduce the communication gap between speech-impaired individuals and others without relying on camera-based recognition systems.

Keywords—*Smart Glove, Gesture Recognition, Flex Sensors, Arduino Nano, ESP32, Assistive Technology, Speech Output.*

1. INTRODUCTION

Communication is an essential part of everyday life, helping people express their thoughts, needs, and emotions. However, individuals with hearing and speech impairments often find it difficult to interact with others, especially when the other person does not understand sign language. While sign language is an effective means of communication within the deaf community, it is not widely known by the general public. As a result, many people with these disabilities face obstacles in academic environments, workplaces, and social situations.

Reports from international health organizations show that millions of people worldwide experience different levels of hearing loss. This highlights the need for supportive technologies that can make communication easier between sign language users and those who are unfamiliar with it. Developing simple and practical assistive devices can significantly improve independence and social inclusion.

Over the years, researchers have introduced various systems to convert hand gestures into text or speech. These solutions mainly fall into two categories: vision-based systems and wearable sensor-based systems. Vision-based approaches use cameras along with image processing and machine learning algorithms to identify gestures. Although these methods can provide good recognition accuracy, their performance is

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affected by lighting conditions, camera angles, and complex backgrounds.

Wearable devices, such as smart gloves, provide another effective solution. Instead of using cameras, these gloves rely on sensors to directly detect finger movements. Because they do not depend on visual input, they can function reliably in different environments and also offer better privacy to the user.

In this project, a smart glove is designed using flex sensors, an Arduino Nano, and an ESP32 module. The system captures finger bending movements, processes the data, and converts recognized gestures into predefined speech and text messages. This approach aims to simplify communication for individuals with speech impairments and help them interact more comfortably with others.

2. RELATED WORK

In recent years, researchers have proposed several techniques to recognize sign language gestures and convert them into readable text or audible speech. Most of these solutions are based on two main approaches: vision-based systems and wearable sensor-based devices.

Vision-based systems use cameras to capture hand movements, and the captured images are processed using computer vision algorithms to identify different gestures. Some studies have implemented gesture recognition using smartphone cameras along with machine learning techniques such as k-Nearest Neighbors or deep learning models like Convolutional Neural Networks. Although these systems can achieve good recognition accuracy, their performance is often affected by external factors such as lighting conditions, camera position, and background complexity. In addition, users must keep their hands within the camera's visible range, which can sometimes restrict natural movement during communication.

To overcome these challenges, researchers have also developed wearable solutions. Smart gloves equipped with sensors can directly measure finger movements without relying on cameras. Flex sensors are widely used in such designs because they change their resistance when bent,allowing finger movements to be detected and converted into electrical signals that can be processed by a microcontroller.

Some advanced smart glove systems combine flex sensors with motion sensors such as accelerometers and gyroscopes to capture both finger bending and hand orientation. While these additional sensors can improve gesture detection accuracy, they also increase the overall complexity and cost of the system.

The system proposed in this work focuses on a simpler and more practical approach. By using flex sensors together with an Arduino Nano and an ESP32 module, the device can detect predefined hand gestures and convert them into speech and text outputs. This design reduces hardware complexity while still providing an effective communication aid for people with speech impairments.

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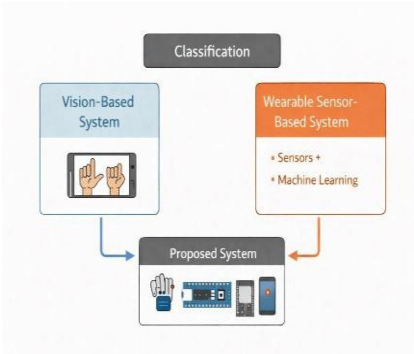

Figure 1: Syntax of sign language

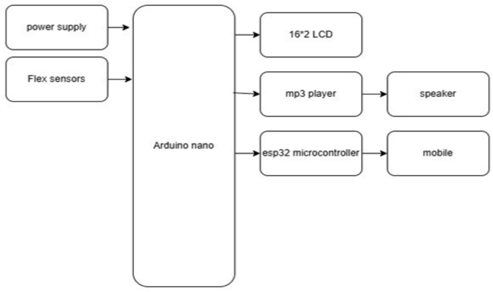

Figure 2: Block diagram of the device with an illustrate layout of the components

3. SYSTEM ARCHITECTURE

The smart glove system is made up of several main components that work together to detect gestures and produce output messages. These components include four flex sensors, an Arduino Nano, an ESP32 module, a speaker, an Android application, and a power supply.

Flex sensors are attached to four fingers of the glove. These sensors change their resistance when the finger bends. By placing them in a voltage divider circuit, the change in resistance can be converted into a voltage signal.

The Arduino Nano reads these analog voltage values through its analog input pins. After collecting the sensor readings, it sends the data to the ESP32 module using serial communication.

The ESP32 acts as the main processing unit of the system. It analyzes the sensor values and compares them with predefined threshold levels to identify the performed gesture. Once a gesture is recognized, the ESP32 generates a corresponding output message.

The system then provides two types of output. A voice message is played through a speaker, and the same message is also sent to an Android application so it can be displayed as text.

4. IMPLEMENTATION

The smart glove system operates by continuously monitoring the bending of the fingers using flex sensors attached to the glove. Each sensor produces a variable resistance depending on the degree of finger movement. These resistance variations are converted into voltage signals through voltage divider circuits.The Arduino Nano reads the analog voltage values from the sensors through pins A0 to A3. These values represent the bending levels of the index, middle, ring, and little fingers. The collected sensor data is transmitted to the ESP32 microcontroller through serial communication.

The ESP32 processes the received sensor values and compares them with predefined threshold ranges stored in the program. When the sensor values match a particular gesture pattern, the corresponding message is selected.

Once a gesture is identified, the ESP32 triggers the audio output module to play a predefined voice message through the speaker. At the same time, the recognized message is transmitted wirelessly to the Android application using Bluetooth or Wi-Fi communication.

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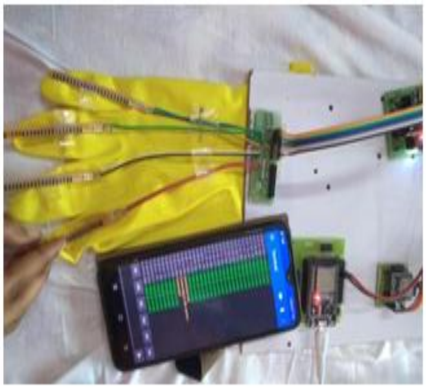
5. RESULTS AND DISCUSSION

The smart glove system was developed and tested to evaluate its ability to recognize hand gestures and convert them into meaningful outputs. During testing, the flex sensors successfully detected the bending of the fingers and produced different analog values based on the finger positions. These values were read by the Arduino Nano and transmitted to the ESP32 module for processing.

Sensor Pin	Flex Sensor	Analog Value Condition	Generated Message	Audio Track No.
A0	Flex Sensor 1	700 – 950	HI	1
A0	Flex Sensor 1	< 700	I AM FINE	2
A1	Flex Sensor 2	700 – 950	Hello	3
A1	Flex Sensor 2	< 700	I Need Medicine	4
A2	Flex Sensor 3	700 – 920	I Need Food	5
A2	Flex Sensor 3	< 600	I Need to Go to Washroom	6
A3	Flex Sensor 4	700 – 920	My Name Is	7
A3	Flex Sensor 4	< 600	I Need Go to Bed	8

Table 1: Flex Sensor–Based Message Generation



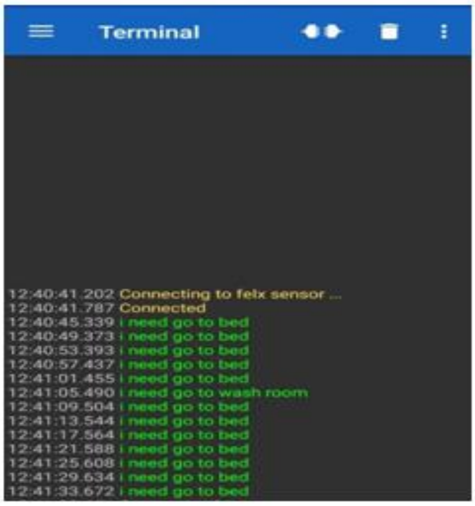
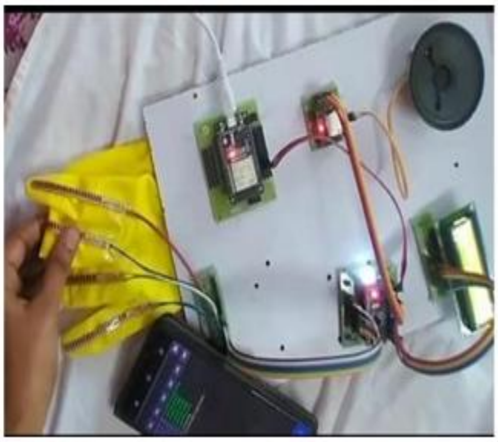


Figure 3: The Fig shows the display on the screen that “I NEED GO TO BED”, this text is displayed whenever the above gesture is made.



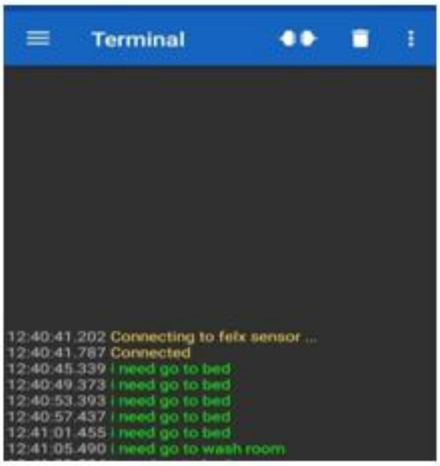


Figure 4: The Fig shows the display on the screen that “I NEED WASHROOM”, this text is displayed whenever the above gesture is made.

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The ESP32 compared the received sensor readings with predefined threshold ranges stored in the program. When the values matched a specific pattern, the system identified the corresponding gesture and generated the appropriate message. The detected message was then played through the speaker as a voice output and also sent to the Android application as text.

The system responded quickly to gesture inputs, allowing messages to be generated almost immediately after a gesture was performed. The sensor readings were stable and consistent during repeated trials, which helped improve the accuracy of gesture recognition. No major hardware or software issues were observed during the testing process.

Overall, the experimental results show that the proposed smart glove can effectively recognize simple finger gestures and convert them into speech and text messages. The system provides a practical and low-cost communication aid that can help individuals with speech impairments express basic needs and interact more easily with others.

6. CONCLUSION

This project presented the development of a smart glove that helps people with hearing and speech impairments communicate more easily. The system uses flex sensors to detect finger movements, an Arduino Nano to read the sensor values, and an ESP32 module to process the data and produce output messages. When a gesture is detected, the system converts it into both speech and text.

The prototype showed that simple hand gestures can be successfully recognized and translated into meaningful messages. The system uses low-cost components and does not require cameras or complex processing, which makes it easy to use and affordable.

In the future, the system can be improved by adding more gesture commands and improving the accuracy of gesture detection. Additional sensors or advanced processing methods can also be used to make the communication system more efficient. Overall, the smart glove provides a useful assistive technology that can help reduce communication difficulties for speech-impaired individuals.

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AUTHOR BIOGRAPHIES

M. Pallavi, M. Reshma Teja Sri, P. Viswa Chaitanya Yadav,
M. Sai Surya Nithik are final year undergraduate students pursuing a Bachelor of Engineering in the Department of Electronics and Communication Engineering at Seshadri Rao Gudlavalleru Engineering College, India.

Mrs.L. Padmalatha holds M. Tech and PhD qualifications and serves as Professor and Head of the Department of Electronics and Communication Engineering at Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru, Andhra Pradesh 521356, India. His scholarly interests encompass embedded systems design, digital signal processing, and applied computer vision.

