Dex-Link

Ajay Kumar Yadav[1], Tarun[2], Ankit[3], Aryan Verma[4], Arun Panchal[5]
[1]*(Assistant Professor) ECE Department, R.D. Engineering College Ghaziabad, Uttar Pradesh*
[2,3,4,5] *ECE Department, R.D. Engineering College Ghaziabad, Uttar Pradesh*

***Abstract:* This research paper presents a dual-system setup designed to facilitate efficient communication and automation using gesture-based input and voice output. The system comprises two distinct units: a hand/wrist-mounted system and a home-mounted box system. The hand-mounted system features four potentiometers, an ESP32 microcontroller (ESP32-A), a DF Player Mini, a DAC, a speaker, a battery, and a linear voltage converter. It is responsible for detecting gestures through potentiometer input and producing corresponding voice outputs. The system supports twelve distinct cases, with seven voice outputs generated locally and five commands transmitted wirelessly to the home-mounted box system.**

The home-mounted box system, featuring a second ESP32 microcontroller (ESP32-B), a DF Player Mini, a DAC, a speaker, a battery, a linear voltage converter, an OLED display, and a two-channel relay, executes automation tasks such as controlling electrical appliances and broadcasting SOS alerts. The OLED display provides real-time feedback on the executed commands. This paper details the system architecture, component integration, communication protocol, and performance analysis of the dual-system setup, highlighting its practical applications for assistive communication and smart home automation.

***Keywords:* Assistive technology, Smart Hand Attachment, Gesture recognition, Automation, ESP32, Potentiometers, 9V Battery**

INTRODUCTION

Advancements in wearable and smart home technologies have paved the way for innovative solutions that bridge communication and automation. In this context, the presented dual-system setup aims to combine gesture-based communication with home automation, enhancing user interaction through voice output and wireless control. The hand/wrist-mounted system, equipped with four potentiometers, serves as the primary input device, detecting hand gestures and generating corresponding voice outputs. Seven of these outputs are directly played through the hand-mounted speaker, while the remaining five commands are wirelessly transmitted to the home-mounted box system.

The home-mounted box system further extends functionality by automating household tasks via relay control and delivering voice feedback. An OLED display on the home unit provides visual feedback, displaying the executed commands and alert messages. One of the key features of the system is the SOS alert mechanism, which prioritizes safety by broadcasting a repetitive alert message through the home speaker. By leveraging ESP32 microcontrollers for wireless communication and real-time processing, the dual-system setup offers a robust and practical solution for assistive communication and home automation.

LITERATURE REVIEW

Several research studies have explored gesture recognition-based communication systems. Early models used wired gloves embedded with flex sensors, which converted hand movements into digital signals. However, these devices frequently lacked features like portability, real-time processing, and reliance on external systems. Recent advancements have introduced wireless solutions incorporating Bluetooth and Wi-Fi connectivity. The application of artificial intelligence (AI) to enhance gesture interpretation accuracy has also been the subject of research. However, these approaches have faced challenges related to computational cost, power consumption, and limited vocabulary recognition.

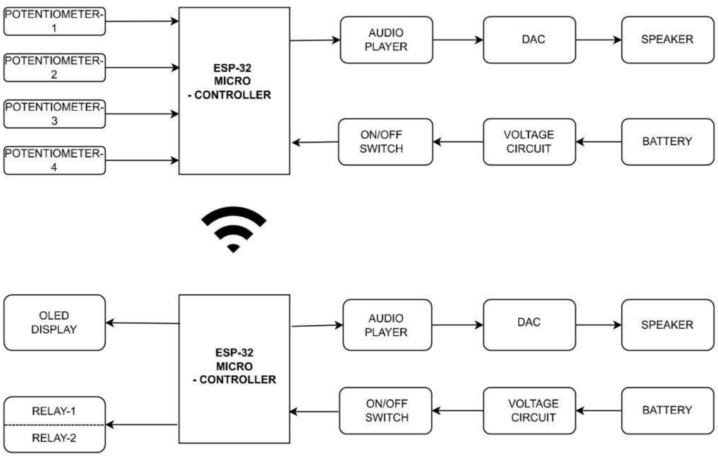
- A study by Kaur et al. (2020) presented a sign language glove that used flex sensors and an Arduino-based system to recognize predefined gestures and convert them into speech. While effective, the system was limited by its dependence on predefined gestures and lacked automation features.
- Similarly, Zhang et al. (2018) developed an Arduino-based sign language recognition system that relied on accelerometers and gyroscopes to detect movement patterns. This method improved flexibility but required high

computational power, making real-time processing a challenge.

- Another notable study focused on computer vision-based gesture recognition, utilizing deep learning models to classify hand signs. While this approach achieved high accuracy, it required a controlled environment with proper lighting, making it less practical for real-world applications.

Our proposed system addresses these shortcomings by employing a lightweight, wearable design with an ESP32-based controller that processes gestures efficiently. The addition of IoT capabilities further enhances the system's usability, allowing for seamless integration with automation control systems. Unlike previous studies that focused solely on communication, our design integrates home automation, enabling users to control electronic appliances through simple hand gestures. Furthermore, by replacing traditional flex sensors with potentiometers, our system reduces the overall cost and increases durability, making it more accessible to a wider range of users. Real-time voice output is provided by a speaker module integrated into the system, eliminating the requirement for an external display or mobile application. Overall, while previous research has contributed significantly to gesture recognition technology, our approach enhances usability, affordability, and practicality. The Dex-Link stands out as a good solution that combines automation control with communication assistance to make everyday tasks easier for people with speech and hearing impairments.

SYSTEM DESIGN AND METHODOLOGY



Components

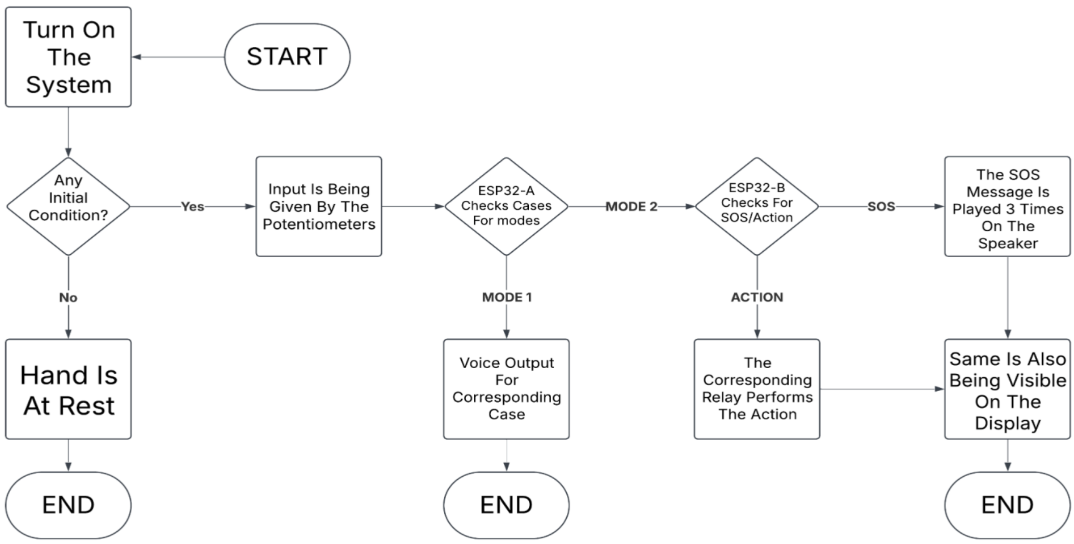
Hand/Wrist-Mounted System (ESP32-A)

1. ESP32 Microcontroller (1x) - Acts as the main processing unit, handling gesture recognition and wireless communication.
2. Potentiometers (4x) - Detect hand and finger movements by varying resistance, generating analog signals for gesture input.
3. DFPlayer Mini (1x) - Plays pre-recorded audio files based on received commands for voice output.
4. Digital-to-Analog Converter (DAC) (1x) - Converts digital audio signals from the microcontroller into analog signals for the speaker.
5. Speaker (1x) - Outputs the voice response or message after processing the gesture command.
6. Battery (1x) - Powers the hand-mounted system, typically a Li-ion or Li-Po battery for portability.
7. Linear Voltage Converter (e.g., AMS1117) (1x) - Regulates the battery voltage to a stable level suitable for the ESP32 and other components.
8. Capacitors (Assorted values) - Smooth out voltage fluctuations to ensure stable power supply.
9. Jumper Wires (As needed) - Provide electrical connections between components.

10. PCB or Breadboard (1x) - Used to assemble and connect the components securely.
11. Enclosure (1x) - Protects the electronics and makes the system wearable on the wrist or hand.

Home-Mounted Box System (ESP32-B)
1. ESP32 Microcontroller (1x) - Receives commands from the hand unit, processes them, and controls home automation.
2. DFPlayer Mini (1x) - Plays voice responses or SOS alerts upon receiving specific commands.
3. Digital-to-Analog Converter (DAC) (1x) - Converts digital audio data to analog signals for clear sound output.
4. Speaker (1x) - Delivers audio notifications, relay status updates, or SOS alerts.
5. Battery (1x) - Powers the home-mounted system, generally with higher capacity for longer usage.
6. Linear Voltage Converter (e.g., AMS1117) (1x) - Ensures a stable voltage supply for consistent operation.
7. Capacitors (Assorted values) - Filter voltage noise and stabilize the power input.
8. OLED Display (1x) - Provides visual feedback by displaying the current command or system status.
9. 2-Channel Relay Module (1x) - Controls two electrical appliances (like lights or fans) by switching them on or off.
10. Jumper Wires (As needed) - Facilitate wiring and connectivity between components.
11. PCB or Breadboard (1x) - Holds and connects components securely.
12. Enclosure (1x) - A compact housing that protects the components and allows easy installation at home.

Working Principle



The proposed dual-system device operates through gesture recognition and wireless communication to achieve voice output and home automation. The system is divided into two primary units: a hand/wrist-mounted system (ESP32-A) and a home-mounted box system (ESP32-B). The fundamental principle of the device lies in interpreting potentiometer inputs as gestures and translating them into predefined actions, either locally or remotely via wireless transmission.

Hand/Wrist-Mounted System (ESP32-A)
The hand-mounted system is equipped with four potentiometers that act as gesture input devices. These potentiometers are strategically positioned to detect hand or finger movements, providing 12 unique combinations (or cases). The potentiometer outputs are fed to the ESP32-A, which processes the analog signals and maps them to specific commands.

Among the 12 cases:
- 7 Cases trigger voice outputs locally through the DFPlayer Mini and DAC, producing audio feedback via a small speaker mounted on the hand unit.
- 5 Cases correspond to home automation commands and SOS alerts, which are wirelessly

transmitted to the home-mounted system via Wi-Fi communication using the ESP32's built-in wireless module.

Home-Mounted Box System (ESP32-B)

The home-mounted system receives wireless data packets containing the command signals from the hand-mounted system. On receiving a command, ESP32-B performs one of the following tasks:

1. Voice Output (for automation acknowledgment): The command is processed, and the appropriate audio file is played via the DFPlayer Mini, DAC, and speaker.
2. Relay Activation/Deactivation: Four of the five remote commands control relay switches to turn household appliances (like lights or fans) on or off.
3. SOS Alert: The fifth command triggers an SOS voice message, which is repeated three times to ensure the alert is noticeable.

The OLED display on the home unit shows the currently executed command or alert message, providing visual feedback to the user.

Wireless Communication

The communication between ESP32-A and ESP32-B is established using Wi-Fi, where the hand-mounted unit acts as a client and the home-mounted unit acts as a server. Commands are sent as structured data packets and are decoded at the receiver end to perform the respective actions.

Limitations of previous Research

Technology	Limitation
Flex Sensor - based systems	Expensive and easily Damaged
Vision-Based Recognition	Requires powerful processing and lighting can affect the results
Our Approach (Potentiometer)	limited to predefined gestures

Comparison with the existing technology

Previous technologies for gesture recognition primarily relied on expensive flex sensors or complex vision-based systems. Our approach provides a balance between affordability, accuracy, and usability.

Various research studies have focused on developing assistive technologies for deaf and mute individuals. Many of these solutions incorporate gesture recognition, speech synthesis, and automation control, yet they differ significantly in terms of accuracy, cost, usability, and technological implementation. In this section, we compare our Dex-Link with

1. Flex Sensor-Based Gloves:
   a. Highly accurate but expensive and prone to sensor wear over time.
   b. Limited flexibility and can be uncomfortable for prolonged use.
   c. No direct home automation control.
2. Vision-Based Gesture Recognition:
   a. Requires an external camera, making it non- portable.
   b. Accuracy drops in low-light conditions.
   c. High computational requirement, making it impractical for real-time applications.
3. AI-Based Gesture Recognition:
   a. Achieves high accuracy but requires extensive training data.
   b. Computationally expensive, requiring powerful processing hardware.
   c. May require cloud connectivity, leading to privacy concerns.

Advantage of our proposed system

1. Cost-Effective Solution:
   i. Uses inexpensive potentiometers instead of costly flex sensors.
   ii. Reduces hardware complexity while maintaining high accuracy.
2. Highly Portable and User- Friendly:
   i. Designed as a wearable device with a rechargeable battery.
   ii. Can be used indoors and outdoors without dependency on external hardware like cameras.
3. Integrated Home Automation:
   i. Allows users to control household appliances with simple gestures.
   ii. Compatible with IoT devices, enhancing accessibility and convenience.
4. Real-Time Gesture Recognition:
   i. Processes hand movements instantly and converts them into speech or automation commands.
   ii. No significant latency in communication.

Our approach enhances existing research by offering a cost-effective, portable, and feature-rich assistive technology that integrates gesture-based communication with home automation. The combination of affordability, ease of use, and IoT integration makes it a promising solution for individuals with speech and hearing impairments.

Unique aspects of this project

To stand out from previous technologies, this project can incorporate the following unique features:

- Custom Gesture Learning – Future AI models could allow users to train the system with their own unique gestures.
- Haptic Feedback – Vibration motors can be added to provide feedback to the user for improved interaction.
- Wireless Connectivity – Bluetooth/Wi-Fi connectivity can enable app integration and remote device control.
- Multilingual Voice Output – Expanding language options can make the device more inclusive.

By incorporating these features, the Dex-Link can revolutionize accessibility technology for the deaf and mute community.

CONCLUSION

The Dex-Link offers a cost- effective, efficient, and highly functional solution for speech-impaired individuals, allowing them to communicate seamlessly through gesture-to-voice translation. By integrating home automation, the system enhances accessibility and independence, making daily activities easier.

Future improvements such as AI-based recognition, mobile app integration, and cloud-based voice processing can further extend its utility, making it a revolutionary assistive technology for real-world applications.

Compared to previous research, our approach offers several advantages, including affordability, real-time processing, portability, and IoT integration. The use of an ESP32 microcontroller ensures fast response times and seamless wireless connectivity, making the device versatile and highly functional in everyday scenarios.

Future advancements such as AI-based gesture learning, extended gesture recognition capabilities, and cloud connectivity will further enhance the system's usability and adaptability. By refining its design and expanding its applications, the Dex-Link can become a mainstream assistive technology, empowering individuals with disabilities to communicate more effectively and control their environment with greater ease.

Ultimately, this research contributes to the ongoing development of assistive technology, paving the way for innovative solutions that promote inclusivity and accessibility for the differently-abled community.

FUTURE SCOPE

Although the Dex-Link already offers valuable functionalities, several enhancements can be introduced:

- AI-Powered Gesture Learning – Implementing machine learning models to recognize custom gestures.
- Bluetooth & Wi-Fi Connectivity – Enabling synchronization with mobile applications for greater control.
- Cloud-Based Speech Processing – Allowing real-time processing for dynamic voice synthesis.
- Enhanced Home Automation – Expanding compatibility with IoT devices and smart home ecosystems.
- Facial Expression Recognition – Combining gesture recognition with facial tracking for more effective communication.

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