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Sign Recognition for Disabled People

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Abstract
Sign recognition for disabled people is an innovative assistive technology developed to reduce communication barriers between hearing- and speech-impaired individuals and the wider community. Communication is essential in daily life, yet many people with disabilities experience difficulties because sign language is not commonly understood. This research proposes an intelligent real-time gesture recognition system that interprets hand signs and converts them into readable text and audible speech.The proposed model uses computer vision, image processing, and machine learning techniques to identify hand gestures captured through a camera. Input images are preprocessed using noise removal, background separation, and contrast enhancement methods to improve recognition accuracy. Relevant gesture features such as hand contour, orientation, finger positions, and movement patterns are extracted and supplied to a trained classification model for sign identification.Once a gesture is recognized, the system instantly translates it into text and speech output, allowing smooth interaction between disabled users and non-sign-language users. The system is designed to be affordable, portable, and user-friendly, making it suitable for educational institutions, hospitals, offices, and public spaces. Experimental results indicate that the proposed approach achieves reliable recognition accuracy under normal lighting conditions.This work contributes to inclusive communication by empowering disabled individuals with greater independence and social participation. Future improvements may include multilingual speech generation, larger vocabulary support, and mobile deployment for wider accessibility.
Keywords: *Sign Language Recognition, Assistive Technology, Machine Learning, Computer Vision, Gesture Detection, Speech Synthesis, Disability Support, Human-Computer Interaction.*

Introduction

Communication is one of the most essential aspects of human life, enabling individuals to express thoughts, needs, and emotions. However, people with hearing and speech impairments often face major difficulties when interacting with others because sign language is not widely understood by the general public. This communication barrier can affect education, employment, healthcare access, and social inclusion. To address this challenge, technology-driven solutions have become increasingly important in supporting inclusive communication systems.

The proposed project, Sign Recognition for Disabled People, is designed to create an intelligent platform that recognizes hand gestures and converts them into understandable text and speech outputs. The system aims to assist hearing- and speech-impaired users by enabling them to communicate effectively with people who are unfamiliar with sign language. By using image processing, machine learning, and real-time gesture analysis, the proposed model provides a practical and accessible communication tool.The major objective of this work is to develop a reliable gesture recognition system capable of accurately identifying predefined hand signs under real-world conditions. The system uses a camera to capture gesture images, preprocesses them to remove noise and improve clarity, extracts relevant features such as hand shape and orientation, and classifies the gestures using trained learning models. Once recognized, the corresponding meaning is displayed as text and can also be spoken through an audio output module.This project also focuses on affordability, user convenience, and portability so that it can be adopted in homes, schools, hospitals, offices, and public service centers. The overall report is organized in a systematic manner, covering problem definition, literature review, methodology, implementation, testing, results, and future enhancements. This chapter provides the foundation for understanding the motivation, goals, and structure of the proposed system.

Literature Survey

Recent advancements in assistive communication technologies have significantly improved interaction opportunities for people with disabilities. Researchers have explored both vision-based and sensor-based gesture recognition systems to convert sign language into meaningful outputs. These developments have combined machine learning, wearable sensors, and embedded processors to improve recognition accuracy, speed, and real-time usability. Modern solutions are increasingly focused on portability, low power consumption, and practical deployment in daily environments.Early studies in gesture recognition concentrated on camera-based systems that used image processing techniques to detect and classify hand movements. Rautaray and Agrawal presented a detailed survey of vision-based hand gesture recognition methods for human-computer interaction. Their work highlighted the importance of segmentation, feature extraction, and classification algorithms in achieving accurate recognition. It also established performance standards related to real-time response and system robustness.Further research introduced wearable sensor technologies to overcome the limitations of vision systems, particularly under poor lighting and background complexity. Ahsan and colleagues proposed a gesture recognition framework using flex sensors and surface electromyography signals. Their findings demonstrated that sensor-based systems can provide reliable gesture detection even when user hand positions vary. Such approaches are highly beneficial in mobile and uncontrolled environments.With the growth of artificial intelligence, deep learning techniques have also been integrated into gesture recognition platforms. Li and Wang developed a wearable hand gesture recognition system using neural network models to classify a larger vocabulary of signs. Their study reported improved accuracy and faster recognition when compared with conventional machine learning methods. It also showed that compact controllers such as ESP32-based platforms can support intelligent processing efficiently.

System Analysis and Design

The Sign Recognition for Disabled People system is developed to support individuals with hearing and speech impairments by enabling easier and faster communication. In everyday situations, many disabled individuals experience difficulty expressing their thoughts, needs, and emotions to others, particularly when people around them do not understand sign language. This creates a communication barrier that can affect personal independence and social participation. The proposed system offers a smart technological solution by translating hand gestures into readable text and audible speech.The system uses cameras or sensing devices to capture user gestures and processes the inputs through image processing and machine learning techniques. Since the model operates in real time, users receive immediate responses without noticeable delay. The design emphasizes simplicity and accessibility so that users with minimal technical knowledge can operate the device comfortably. This solution can be applied in homes, healthcare centers, educational institutions, workplaces, and public service environments. The primary objective is to improve communication efficiency, accessibility, and quality of life for disabled individuals.

Key Features of the System

The proposed system incorporates several important features that improve usability and performance. One of the major features is real-time gesture recognition, which allows users to communicate instantly through natural hand movements. Recognized gestures are converted into text messages displayed on an LCD or screen and can also be transformed into speech using an audio output module. This dual-output mechanism helps both hearing and non-hearing users interact effectively.The system is designed to function under varying environmental conditions such as different lighting levels and complex backgrounds. It also supports two-way communication by converting spoken words into text for deaf users. An emergency alert feature can be integrated to send notifications or messages to family members, caretakers, or emergency contacts. Wireless connectivity through Bluetooth or internet-based services further enhances remote communication capabilities. The platform is portable, energy-efficient, and easy to use, making it practical for day-to-day applications. Additionally, the architecture is flexible enough to allow the inclusion of new gestures and language support in future versions.

Conceptual Requirements of the System

For effective operation, the system requires a set of conceptual and functional elements. It must receive input data in the form of hand gestures and optional voice signals. A structured dataset or predefined gesture patterns is necessary to train and validate the recognition model. The system should continuously capture incoming signals, preprocess them, and compare extracted features with stored templates or learned classes.A user-friendly interface is essential so that users can interact with the system easily. Fast processing speed is required to ensure real-time communication, while high recognition accuracy is necessary to avoid misunderstandings. Reliability across different environments and users is another important requirement. Since the device may be used in mobile conditions, energy efficiency and portability are also critical factors. Proper synchronization between input acquisition, processing modules, and output devices ensures smooth performance. These requirements collectively support accurate, responsive, and practical communication assistance.

Main Components of the System

The system consists of four major functional units: input, processing, storage, and output. The input unit includes components such as cameras, flex sensors, or microphones that capture gestures and voice commands from the user. These devices collect raw data and forward it for analysis.The processing unit acts as the core of the system and may consist of a microcontroller such as ESP32 or an embedded computing board. It receives input signals, performs preprocessing, extracts gesture features, and executes the recognition algorithm. This unit controls the overall system workflow and decision-making process.The storage unit is responsible for maintaining gesture datasets, trained models, predefined messages, and optional audio files. Memory modules such as SD cards or internal flash storage can be used to retrieve data quickly and support future updates.The output unit includes displays, speakers, or mobile interfaces. Once a gesture is recognized, the corresponding message is shown as text and can also be spoken aloud. This helps bridge communication between disabled users and the general public effectively.

Data Handling and Processing Concepts

The system follows a structured data processing pipeline to achieve accurate sign recognition. Initially, gesture data is captured using a camera or sensor device and converted into digital input signals. The raw data then undergoes preprocessing steps such as noise removal, background filtering, resizing, and normalization to improve quality and consistency.After preprocessing, the system extracts meaningful features such as finger positions, palm orientation, contours, motion trajectories, and spatial relationships. These features are then compared with stored gesture templates or passed through a trained machine learning classifier to identify the intended sign. If a valid match is found, the gesture is recognized and translated into text or speech output.This sequence is repeated continuously in real time, enabling smooth and uninterrupted communication. Efficient data handling reduces errors, minimizes delay, and improves system responsiveness. The architecture also supports future model retraining and dataset expansion, allowing improved recognition performance over time. Overall, the proposed framework ensures fast, accurate, and scalable gesture-to-language conversion for practical use.

Core Techniques and System Intelligence

This chapter presents the principal techniques used in the proposed Sign Recognition for Disabled People system. The framework combines gesture sensing, pattern recognition, machine learning, and embedded intelligence to translate user actions into meaningful outputs. The system is designed to process incoming data efficiently and generate responses with high accuracy and low latency. By integrating multiple computational methods, the model becomes capable of understanding user gestures and converting them into text, speech, or alert messages. The overall objective is to provide an intelligent communication platform that performs reliably in real-time environments.

Gesture Recognition Technique

Gesture recognition is the central operation of the proposed system. Hand signs are captured through flex sensors mounted on a glove or through a camera-based input module. These gestures are transformed into digital signals representing finger positions, hand orientation, and movement characteristics. The collected data is then processed to extract meaningful features that uniquely represent each gesture.The extracted features are compared with predefined gesture templates or trained machine learning models. If the detected pattern matches a stored reference, the corresponding message is generated. The recognition engine is designed to tolerate slight variations in hand movement, finger bending, and gesture speed, ensuring that users are not required to perform gestures with perfect precision. Since recognition is performed continuously, the user can communicate naturally without interruption. This technique forms the core functionality of the system by converting physical gestures into understandable outputs.

Algorithms Used

The proposed model uses several algorithms to improve recognition performance. A pattern matching algorithm compares incoming sensor values or image features with previously stored templates. When the similarity level exceeds a defined threshold, the associated output is selected. This method is computationally efficient and suitable for embedded platforms such as ESP32.Basic machine learning algorithms are also employed to improve adaptability and accuracy. By learning from multiple gesture samples, the system becomes more robust to user-specific variations. This enables better classification performance than rigid rule-based systems.Signal processing methods are used to refine raw input values before recognition. Noise reduction, normalization, smoothing, and calibration improve the quality of sensor readings and enhance system stability. Together, these algorithms create an efficient and intelligent recognition framework.

Performance Metrics

The proposed Sign Recognition system is evaluated using important performance indicators such as Recognition Probability (RP) and Response Rate (RR). Recognition Probability measures how often the system correctly identifies a performed gesture. Higher signal quality and stable sensor readings generally increase this probability.

Prec=Pr(Valuesensor∈Thresholdtarget)P_{rec}=Pr (Value_{sensor}\in Threshold_{target})Prec =Pr(Valuesensor∈Thresholdtarget)

For multi-finger gestures, recognition may require simultaneous threshold satisfaction across several sensors.

Prec=Pr(⋂i=15Valuesensor,i∈Thresholdtarget,i)P_{rec}=Pr\left(\bigcap_{i=1}^{5} Value_{sensor,i}\in

Threshold_{target,i}\right)Prec=Pr(⋂i=15 Valuesensor,i∈Thresholdtarget,i)

Response Rate indicates the speed at which the system converts a gesture into final output. Faster response times are critical for natural communication. The visual output rate depends on processing and display time, while audio response depends on processing and speech trigger delay.

RRvisual=1Tprocess+TdisplayRR_{visual}=\frac{1}{T_{process}+T_{display}}RRvisual=Tprocess+Tdisplay1

RRaudio=1Tprocess+Taudio_triggerRR_{audio}=\frac{1}{T_{process}+T_{audio_trigger}}RRaudio=Tprocess+Taudio_trigger1

These metrics indicate that the proposed ESP32-based wearable system provides faster responses than many conventional vision-based systems due to lower computational overhead.

Software Requirements

The proposed system uses suitable programming tools, libraries, and mobile applications for implementation. These components support sensor data processing, wireless communication, and output generation.

Arduino IDE

Arduino IDE is the main development platform used to write, compile, and upload programs to the ESP32 microcontroller. It supports required libraries for sensors, displays, audio modules, and communication protocols. It also provides debugging and serial monitoring tools.

Arduino Bluetooth Controller

The Arduino Bluetooth Controller mobile application provides wireless communication between a smartphone and ESP32. It supports text commands and voice terminal functions. Spoken words can be converted into text and transmitted to the system through Bluetooth. This helps enable two-way communication for hearing-impaired users.

Telegram Bot (Emerrrbot)

Telegram Bot is used for emergency alert communication. When danger gestures such as HELP or DANGER are recognized, the ESP32 sends an alert message to caregivers through the Telegram Bot API. It also confirms system online status and supports remote monitoring.

Hardware Requirements

ESP32 Microcontroller

The ESP32 acts as the central controller of the system. It reads sensor values, executes recognition logic, and controls output devices such as displays and speakers. It offers high speed, wireless connectivity, and multiple GPIO pins.

Flex Sensors

Flex sensors are used as the main gesture input devices. One sensor can be placed on each finger to measure bending angles. These sensors generate analog values corresponding to finger movement.

DFPlayer Mini with SD Card

DFPlayer Mini is used for audio output. It stores speech files on an SD card and plays voice messages corresponding to recognized gestures. This enables spoken communication.

LCD Display 16×2

The LCD module displays recognized gestures as text messages. It provides clear visual output for communication.

OLED Display

The OLED display offers high-contrast text visibility and consumes low power. It uses I2C communication, reducing pin usage on the ESP32.

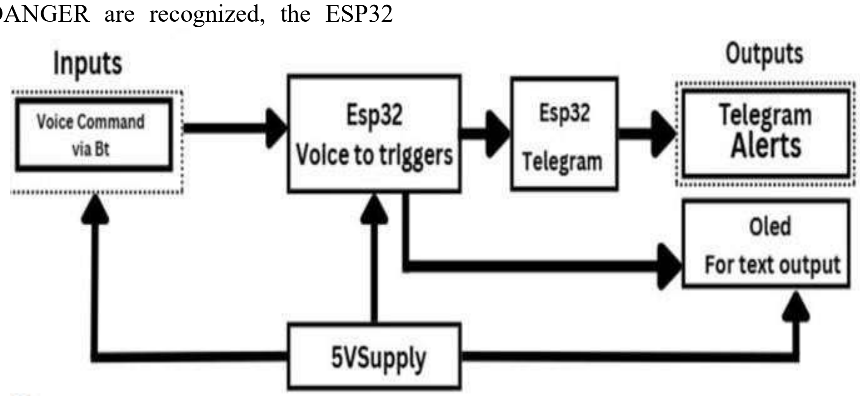
Other Components

Additional components include connecting wires, breadboard, batteries, resistors, and wearable glove structures. These parts support circuit connections, portability, and stable operation.

5.3 Conclusion

The chosen hardware components provide accurate sensing, efficient processing, and reliable output generation. They are compatible, low-cost, and suitable for real-time wearable communication systems.

Software and Hardware Implementation Working Methodology



Block Diagram of Sign Recognition for disabled people

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Initially, the ESP32 initializes all modules including Wi-Fi, Bluetooth, sensors, and display units. Once connected, it confirms readiness through status messages.Voice inputs from a smartphone application are converted into text and transmitted via Bluetooth. The ESP32 processes received commands and checks for emergency keywords such as HELP or DANGER.When emergency conditions are detected, the Telegram Bot sends alert notifications to caregivers instantly. At the same time, recognized messages are displayed on the OLED screen for hearing-impaired users.A stable power supply supports all modules including the controller, displays, and sensors. The complete system is optimized for fast response, reliability, and practical real-time communication.

Applications

The proposed Sign Recognition for Disabled People system offers a wide range of practical applications across social, educational, healthcare, and technological environments. In educational institutions, the system can support hearing-impaired students by enabling smoother communication with teachers and classmates. Real-time conversion of hand gestures into text or speech helps create a more inclusive classroom environment and improves learning participation.In domestic environments, the system can be integrated with smart home platforms to control appliances such as lights, fans, televisions, and security devices through predefined gestures. This provides greater independence and convenience for users with physical or speech limitations. Gesture-based home automation can significantly improve accessibility in everyday life.Healthcare and rehabilitation centers can also benefit from the proposed system. Patients who temporarily lose speech ability due to surgery, neurological disorders, or trauma can use gesture recognition to communicate their needs with doctors and caregivers. The system may also assist therapists in monitoring motor recovery and rehabilitation progress through hand movement analysis.Public service applications include deployment in automated kiosks such as ATMs, railway ticket counters, hospital reception desks, and information terminals. By allowing gesture-based interaction, these systems can become more accessible for users with hearing or speech impairments.

Results and Discussion

Results

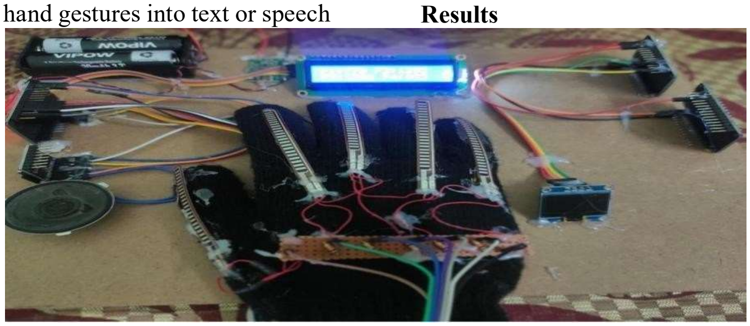

Fig 1 Hardware Implementation

Fig 2 OLED Visual Output showing "hello

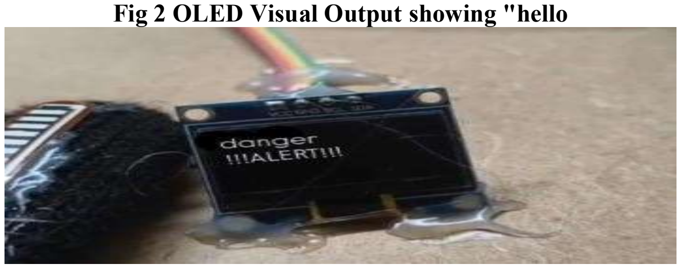

Fig 3 OLED Emergency Alert showing

Fig 4 Alerts via Telegram (Emerrrbot)

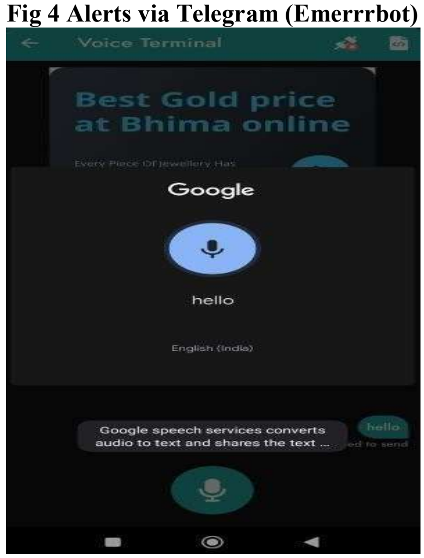

Fig 5 Speech-to-Text Voice Terminal

The proposed Sign Recognition System was implemented and experimentally evaluated to verify its effectiveness in converting hand gestures into meaningful outputs. The developed prototype successfully recognized predefined gestures and generated corresponding text, speech, and emergency notifications in real time. Testing confirmed that the wearable glove integrated with flex sensors accurately captured finger-bending movements and transmitted them to the ESP32 controller for processing.The visual output module displayed recognized words such as “Hello,” “Water,” “Hungry,” and “Bye” clearly on the OLED or LCD screen. This validated the system’s ability to support immediate text-based communication for hearing-impaired users. The speech module also converted recognized gestures into audible responses, thereby helping interaction with individuals unfamiliar with sign language.Emergency communication functions were also successfully demonstrated. When gestures associated with distress, such as “HELP” or “DANGER,” were detected, the system generated warning messages and transmitted alerts through the Telegram bot interface. This feature confirmed the usefulness of integrating IoT communication with assistive technology for user safety.Speech-to-text functionality was additionally tested using Bluetooth voice input. Spoken words captured through the mobile application were converted into text and displayed to support two-way communication between hearing and hearing-impaired individuals. Overall, the results indicate that the proposed system can effectively bridge communication gaps through a combination of wearable sensing, wireless connectivity, and embedded intelligence.

Discussion

The experimental findings demonstrate that the proposed approach is practical, reliable, and suitable for assistive communication applications. The use of flex sensors mounted on a wearable glove allowed accurate detection of finger positions corresponding to specific gestures. These sensor readings were processed efficiently by the ESP32 microcontroller, resulting in low response time and smooth real-time performance.The system showed strong accuracy for predefined gestures including common daily expressions such as greetings, requests, and basic needs. Signal preprocessing methods such as filtering, calibration, and normalization contributed significantly to reducing sensor noise and improving recognition consistency. The coordination among the glove, controller, display unit, speaker, and alert system confirmed stable end-to-end integration.One of the major strengths of the proposed design is portability. Unlike camera-based recognition systems that require fixed positioning and favorable lighting conditions, the wearable glove can function in diverse environments with lower computational complexity. It also operates with modest power requirements, making it more practical for continuous personal use.

Conclusion

This work presented a wearable Sign Recognition System designed to improve communication for individuals with speech and hearing impairments. By integrating flex sensor technology with the ESP32 microcontroller, the proposed model captures hand gestures and translates them into text and speech outputs in real time. The system offers an affordable and efficient alternative to expensive vision-based recognition platforms.Performance testing confirmed that the prototype provides dependable gesture recognition, rapid response, and useful communication assistance in daily scenarios. The generated outputs through display and audio modules support direct interaction between disabled users and the general public. In addition, emergency alert features improve user safety by allowing quick communication with caregivers.Compared with conventional camera-based systems, the sensor-based design offers lower processing requirements, portability, and offline functionality through onboard storage. Although the current vocabulary is limited and requires calibration, the overall results show that the system is a promising assistive technology solution capable of enhancing independence, confidence, and social inclusion.

Future Scope

Several opportunities exist for improving the proposed system in future research. The gesture library can be expanded to support complete sign languages and more expressive communication. Machine learning and deep learning methods may be introduced to improve recognition accuracy and adapt to individual user behavior over time.Hybrid multimodal systems that combine wearable sensors with cameras, speech recognition, or eye-tracking can further improve robustness under challenging conditions. Integration with IoT environments may allow users to control household devices, security systems, and smart appliances through gestures. Miniaturized electronics and ergonomic glove designs can also improve comfort during prolonged use.Future developments may additionally include multilingual speech synthesis, mobile application support, cloud-based analytics, and personalized training modules. These enhancements can transform the proposed prototype into a scalable next-generation communication platform for disabled communities.

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