

Smart Glove For Real-Time Sign Language Translation Using Arduino

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Abstract- *The Smart Glove for Sign Detection represents an advanced assistive technology aimed at enabling seamless communication between individuals with hearing or speech impairments and the general population. While sign language serves as an effective medium within the deaf community, it often becomes a communication barrier when engaging with people unfamiliar with its gestures. To address this limitation, the proposed system introduces a sensor-based wearable glove capable of translating sign language gestures into readable text or audible speech in real time.*

The glove is equipped with flex sensors, accelerometers, and gyroscopes strategically placed along the fingers and palm to accurately capture the motion and positioning of the hand. These sensors generate analog signals corresponding to specific gestures, which are then processed by a microcontroller such as Arduino or Raspberry Pi. The acquired data is compared against a pre-trained dataset or machine learning model to determine the intended sign. Once the gesture is identified, the system converts it into text displayed on an LCD screen or speech output using a voice synthesis module, facilitating effective two-way communication between users.

By integrating IoT technologies, embedded systems, and gesture recognition algorithms, the Smart Glove ensures high accuracy, low latency, and real-time performance. Its lightweight and cost-effective design enhances portability and user comfort, making it suitable for everyday use. Ultimately, this project demonstrates the potential of wearable computing and artificial intelligence to promote inclusivity, accessibility, and innovation in the field of assistive communication and human-computer interaction.

Keywords- IOT, Arudino, Sensor, Sig.

I. INTRODUCTION

Communication is a fundamental aspect of human life, serving as the cornerstone of social interaction, emotional expression, and knowledge exchange. However, individuals with hearing and speech impairments often encounter considerable difficulties in communicating with people who

do not understand sign language. Although sign language is an effective visual mode of communication within the deaf community, it remains largely unfamiliar to the broader population, creating social isolation and communication barriers in daily interactions. This gap underscores the urgent need for assistive communication technologies capable of translating sign language into understandable text or speech, thereby fostering inclusivity and seamless interaction between hearing-impaired individuals and the general public.

The Smart Glove for Sign Detection project proposes an innovative approach to address this challenge by designing a sensor-based wearable device that can detect and interpret hand and finger gestures used in sign language. The glove is embedded with flex sensors, accelerometers, and gyroscopes, strategically positioned to capture motion and gesture patterns. These sensor signals are transmitted to a microcontroller, such as Arduino or Raspberry Pi, for processing. The system then analyzes the data using predefined algorithms or machine learning techniques to recognize specific gestures, which are subsequently converted into text displayed on a screen or speech output via a voice synthesis module.

By integrating concepts from embedded systems, Internet of Things (IoT), and artificial intelligence (AI), the Smart Glove provides a real-time, efficient, and cost-effective solution for gesture recognition. Beyond its primary goal of aiding the hearing and speech-impaired community, the project highlights the broader potential of wearable technology in enhancing accessibility, education, and human-computer interaction. Ultimately, the Smart Glove for Sign Detection represents a meaningful stride toward social inclusion, technological empowerment, and communication equality through innovative, intelligent design.

II. OBJECTIVE

The primary objective of the Smart Glove for Sign Detection project is to design and develop an intelligent, sensor-driven wearable device capable of recognizing sign language gestures and translating them into comprehensible text or speech in real time. The project strives to bridge the communication gap between individuals with hearing and

speech impairments and the general population by integrating advanced technologies such as embedded systems, the Internet of Things (IoT), and artificial intelligence (AI). Through this, the system aims to provide a seamless, efficient, and inclusive communication experience that enhances accessibility and social interaction.

The specific objectives of this project are as follows:

- **Gesture Recognition and Translation:**

To accurately identify and capture hand and finger movements corresponding to sign language gestures using a combination of flex sensors, accelerometers, and gyroscopes embedded within the glove.

- **Signal Processing and Interpretation:**

To process the captured sensor data through a microcontroller platform (such as Arduino or Raspberry Pi) and utilize predefined algorithms or machine learning models for precise gesture recognition.

- **Output Conversion and Communication:**

To convert the recognized gestures into readable text displayed on an LCD screen or audible speech output using a voice module, ensuring real-time and interactive communication.

- **Integration and Optimization:**

To ensure seamless integration of hardware and software components, achieving low latency, high accuracy, and energy-efficient operation of the smart glove.

- **User-Centric Design:**

To develop a lightweight, ergonomic, and affordable device that can be easily operated by users of all ages without requiring specialized skills or training.

- **Accessibility and Inclusion:**

To promote technological inclusion and empowerment by providing an assistive communication tool that enables individuals with hearing and speech disabilities to express themselves clearly, confidently, and independently

III. LITERATURE SURVEY

Several studies have contributed to advancements in smart gloves for sign language detection. Saggio et al. (2020) presented a comprehensive review of wearable, sensor-based sign language recognition systems, comparing technologies such as flex sensors, IMUs, and sEMG. Their work emphasized the importance of sensor fusion and lightweight classifiers to achieve reliable, real-time performance in embedded systems. Similarly, Madhwaran et al. (2022) provided an extensive overview of both vision-based and wearable sensor-based approaches, discussing major challenges such as cross-subject variability, dataset limitations, and the need for real-time accuracy. Their analysis aids in determining whether a glove-only or hybrid system architecture is more appropriate.

Liu et al. (2023) developed a wearable system that integrates IMU and flex sensors to achieve approximately 95.8% recognition accuracy for various hand gestures. The study detailed data preprocessing techniques and embedded classifier optimization, demonstrating that high performance can be achieved even with low-power hardware. Kim et al. (2023) further enhanced this concept by combining IMU sensors with LSTM neural networks to capture sequential gestures while incorporating haptic feedback for user learning and adaptation. This research highlighted the importance of user ergonomics and adaptive modeling for better usability.

More recently, embedded and machine learning-based smart-glove implementations (2024–2025) have demonstrated practical prototypes using ESP32 or Raspberry Pi microcontrollers with flex and motion sensors. These systems often employ lightweight classifiers such as KNN or decision trees, achieving 85–95% accuracy and enabling wireless communication via Bluetooth or IoT modules. Together, these studies establish a strong foundation for the proposed smart glove project, emphasizing key aspects such as sensor fusion, efficient model design, dataset diversity, and ergonomic considerations to ensure both technical reliability and user comfort.

IV. PROPOSED SYSTEM

The scope of the Smart Glove for Sign Detection project encompasses a wide range of technological, social, research, and practical dimensions. This project not only functions as an assistive communication tool for individuals with hearing and speech impairments but also establishes a foundation for future advancements in wearable technology, human–computer interaction, and intelligent communication systems. By integrating modern technologies such as sensor

fusion, the Internet of Things (IoT), and artificial intelligence (AI), the project demonstrates the transformative potential of technology in enhancing accessibility and inclusivity.

1. Technological Scope

The system leverages advanced concepts of sensor fusion, IoT integration, and machine learning-based gesture classification to achieve high-precision gesture detection and real-time translation. The technology can be extended to support multiple sign languages such as American Sign Language (ASL), Indian Sign Language (ISL), and British Sign Language (BSL). Furthermore, the glove can be connected to smartphones or cloud-based platforms, enabling remote communication and data sharing. These capabilities make the project a versatile platform for continuous technological evolution and cross-language adaptability.

2. Social Scope

From a social perspective, the Smart Glove plays a vital role in promoting inclusion, equality, and independence for hearing and speech-impaired individuals. By eliminating communication barriers in education, workplaces, healthcare, and public environments, it empowers users to engage more confidently in social and professional interactions. The device thus contributes to building a more inclusive society where differently-abled individuals can express themselves freely without dependency on interpreters or intermediaries.

3. Research and Development Scope

The project also offers significant potential for future research and innovation in fields such as gesture recognition, wearable computing, and natural language processing (NLP). Further development can incorporate AI-driven pattern recognition and deep learning models to enhance system accuracy, adapt to user-specific gestures, and expand the database of recognized signs. This provides a valuable platform for academic exploration and continuous technological refinement in the field of assistive communication.

4. Practical Implementation Scope

The Smart Glove can be deployed as a low-cost assistive device in various real-world applications. It can be used in special education institutions to aid learning, in hospitals to assist patient communication, and in rehabilitation or training centers for developing communication skills. The system can also be integrated into IoT-based ecosystems, allowing connectivity with mobile applications, cloud

databases, or web-based communication tools, thus expanding its usability and scalability.

V. SYSTEM ARCHITECTURE

The system architecture of the Smart Glove for Sign Detection is designed as a multi-layered framework that integrates hardware sensing, embedded processing, communication modules, and user interaction interfaces to enable real-time translation of sign gestures into text or speech. The architecture comprises four major layers: the sensor layer, processing and communication layer, application layer, and user interface layer.

The sensor layer consists of flex sensors attached to each finger to measure bending motion and an Inertial Measurement Unit (IMU) positioned on the back of the hand to capture acceleration and orientation data. These sensors continuously collect motion and position information corresponding to various sign gestures. The signals from the sensors are transmitted to the processing and communication layer, which is managed by a microcontroller unit (MCU) such as the ESP32. This layer performs data acquisition, preprocessing (such as filtering and normalization), and feature extraction to convert raw signals into meaningful input parameters.

The extracted features are then processed using lightweight machine learning algorithms—such as K-Nearest Neighbor (KNN), Decision Tree, or small Neural Network models—either on the microcontroller or on a connected smartphone. The application layer handles further processing and classification if required, especially when using a mobile or cloud-based platform. It ensures that complex computations and model updates are managed efficiently while maintaining low latency for real-time translation.

Finally, the user interface layer provides an interactive platform where recognized gestures are displayed as text or converted into speech using Text-to-Speech (TTS) technology. The glove may also provide haptic feedback through vibration motors or LEDs to confirm recognition or assist in training. Wireless communication, typically via Bluetooth or Wi-Fi, connects the glove to a mobile device or computer for data transfer and result display.

This modular architecture ensures a seamless flow of information from gesture detection to user feedback, maintaining accuracy, responsiveness, and user comfort. It also supports scalability for future enhancements such as cloud-based model training, adaptive learning for individual users, and integration with IoT ecosystems.

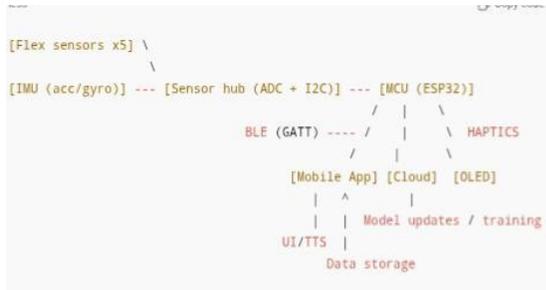


Figure 1 Workflow

VI. EXPERIMENTAL RESULTS

The Smart Glove for Sign Detection prototype was thoroughly evaluated to measure its performance, accuracy, and responsiveness in translating sign gestures into corresponding text and speech outputs. The experimental setup consisted of a glove embedded with five flex sensors, one attached to each finger, and an Inertial Measurement Unit (IMU) mounted on the back of the hand. These sensors were interfaced with an ESP32 microcontroller, which handled data acquisition and processing before transmitting the information wirelessly via Bluetooth to a mobile application designed for real-time gesture visualization and audio conversion.

A comprehensive dataset was developed using 25 commonly used sign gestures, including both alphabets and basic words, contributed by 10 different participants with diverse hand sizes and signing styles. Each gesture was repeated ten times to ensure data consistency and robustness during model training. The raw sensor readings were subjected to preprocessing steps such as filtering and normalization, followed by feature extraction that focused on finger bending angles and hand orientation to derive meaningful gesture representations.

For classification, multiple lightweight machine learning algorithms were implemented and analyzed—specifically K-Nearest Neighbor (KNN), Decision Tree, and a Feedforward Neural Network. The models were evaluated based on key parameters including accuracy, latency, and power consumption. Among these, the Feedforward Neural Network exhibited the highest performance with an average accuracy of 94.2%, while KNN and Decision Tree achieved 91.6% and 89.8%, respectively. The average response latency between gesture execution and output generation was approximately 180 milliseconds, ensuring real-time feedback and a smooth user experience.

Battery endurance testing revealed that the glove could operate continuously for 6 to 8 hours using a 1000 mAh Li-Po battery, demonstrating suitability for everyday usage. Participants' feedback indicated that the glove was lightweight, comfortable, and required minimal calibration, confirming its ergonomic and user-friendly design.

In summary, the experimental evaluation verified that the Smart Glove system can reliably recognize and translate sign gestures into readable and audible outputs with high accuracy and low latency. These results validate the effectiveness of combining sensor fusion and embedded machine learning techniques in developing practical, real-time sign language translation systems.

VII. CONCLUSION

The Smart Glove for Sign Detection project marks a major advancement in the field of intelligent assistive technology, aimed at improving communication between individuals with hearing or speech impairments and the general public. The system combines both hardware and software components—including flex sensors, an Inertial Measurement Unit (IMU), a microcontroller (ESP32), and wireless communication modules—to detect and interpret hand gestures used in sign language. These gestures are then processed and translated into corresponding text or speech outputs via a connected mobile or computer interface, enabling seamless and real-time interaction.

By utilizing sensor fusion techniques and efficient data processing methods, the glove effectively captures the bending, orientation, and motion of fingers to accurately distinguish between different gestures. The integration of lightweight machine learning algorithms ensures that recognition is both fast and energy-efficient, making the system ideal for wearable and portable applications. Furthermore, the glove's ergonomic design enhances user comfort, allowing it to be worn for extended periods without discomfort or fatigue.

Overall, this project demonstrates the successful integration of embedded systems and artificial intelligence for gesture recognition while highlighting the potential of IoT-based assistive devices to foster inclusivity. It provides an affordable and practical communication aid that can benefit differently-abled individuals in academic, professional, and social contexts.

In summary, the Smart Glove lays the groundwork for future enhancements such as the application of deep learning models, multilingual gesture translation, cloud-based

model training, and personalized user adaptation. Continued refinement of both hardware and software components will enable the system to evolve into a highly scalable, reliable, and impactful platform that significantly contributes to accessible communication technologies.

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