MITRA: AN ASSISTIVE GESTURE GLOVE FOR INDIAN SIGN LANGUAGE

Project Reference No.: *49S_BE_4326*

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Keywords:

Indian Sign Language (ISL), Smart gloves, Flex sensors, MPU6500, Bluetooth communication, Short Messaging Service (SMS)

Introduction:

Communication is something most of us don't even think about, but for a person who depends on sign language, every conversation can become a struggle. When others cannot understand their signs, they are left unheard. That simple gap inspired the creation of the 'Mitra: An Assistive Gesture Glove for Indian sign language', a small attempt to make everyday communication easier and more natural for people with hearing or speech impairments. The glove uses an ESP32-WROOM-DA module at its core, because it is reliable, fast, and lightweight enough to be part of something worn on the hand. The mobile side of the system is built as a simple web app and later packaged into an Android application using Cordova/Capacitor, allowing it to run smoothly on the kind of phones most people in India already use. What matters most is the experience it creates. When a person makes a gesture and sees it instantly appear as text on their phone, it gives them a sense of independence that many of us never pause to appreciate. It helps them talk to a shopkeeper, ask a question in class, or simply express a thought to someone they love without feeling left out or misunderstood. This project may be small in terms of hardware and code, but it carries a larger purpose. It is about giving people a chance to be heard, understood, and included. More than technology, it is a step toward dignity and connection for those who have waited long for both.

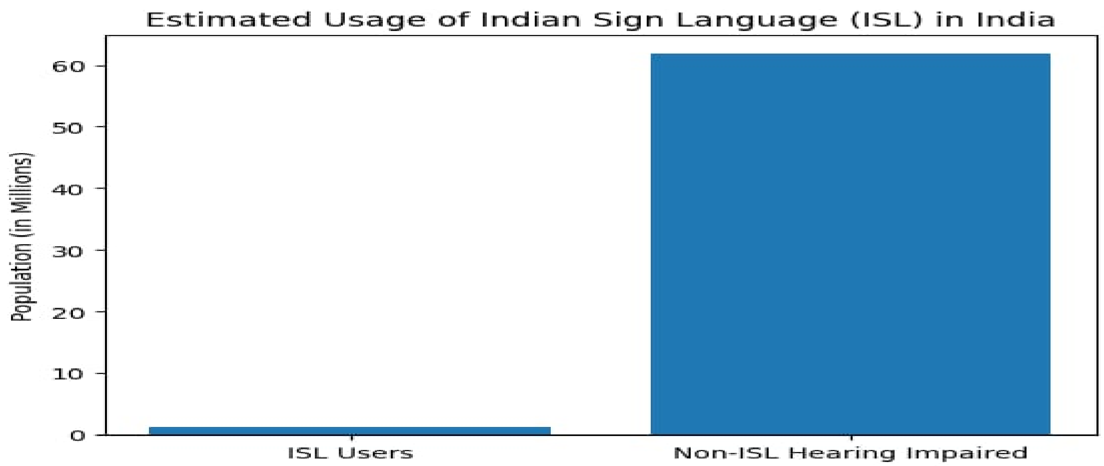

Figure 1: Estimated usage of Indian Sign Language(ISL) in india

Objectives:

1. To develop a gesture glove as a wearable assistive device for the hearing and speech impaired.
2. To develop a dedicated mobile application that translates Indian Sign Language (ISL) gestures into regional text and speech, enabling smooth two-way communication.
3. To create an ISL dataset to train the ML model for the gesture glove.
4. To optimize gesture recognition models for ISL, ensuring higher accuracy and real-time performance suitable for practical usage and education use cases.

Methodology:

1. The different stages involved in the development of the Smart Gesture Glove were hardware implementation, software development, and system integration. Each stage has contributed to the final result of real-time gesture detection and voice translation for ISL.
2. The project's basic idea was to design a portable, low-cost glove that would be able to recognize common ISL hand signs and translate them into readable text and spoken audio in multiple Indian languages. This would solve the problem of communication faced by hearing and speech-impaired individuals and help them interact more easily in everyday situations.
3. The software development started with the development of the interface written in React using Vite, designed in Visual Studio Code. For the purpose of speeding up the process of preliminary development, the AI-assisted platform called Operative.sh was utilized in creating the first version of the interface. This interface would display recognized gestures and play audio feedback.

4. Once the web version was complete, we used Capacitor to turn it into an Android application; this allowed us to create an installable .apk file. Various plugins were integrated for added functionality, including:
    - Capacitor TTS for converting the recognized text into audio.
    - Cordova Bluetooth Serial for communication between the glove and the mobile app.
    - Cordova SMS for message-related features.
5. Permissions such as Bluetooth, SMS, Internet access, Nearby Share, and Location were granted to the application. This ensured reliable communication between the glove and the smartphone. The final mobile application was able to show the recognized gesture, play the output audio, and maintain stable Bluetooth data exchange.
6. The hardware structure of the system was based on the ESP32 microcontroller, selected for its dual-core performance and integrated Wi-Fi and Bluetooth support. The use of an MPU-6500 IMU tracked hand motion and orientation with its accelerometer and gyroscope, respectively. In order to capture the bending of the fingers, flex sensors were placed over each finger, and their analog readings were collected through the ADC pins on the ESP32. All components are compactly fitted on a universal PCB with removable sockets, thus making the design modular and easy to maintain. It was powered by using micro-USB cable, making it lightweight and comfortable to wear.
7. For this purpose, a machine learning model was implemented using TensorFlow Lite to allow gesture recognition. Real-time data from the sensors was obtained and recorded for 400 samples of each of the 15 chosen ISL gestures. These readings of 11 sensor values each were stored in a .csv file and later transformed into a C header (.h) file in hexadecimal format containing the trained model. The model was then deployed on the ESP32 using Arduino Cloud due to its fast compilation and management of libraries. Of course, a few key libraries were included: FastIMU for sensor calibration and TensorFlow Lite for performing inferences with the model. The accuracy achieved by this model was approximately 91%, which was a promising start toward making predictions based on gestures in real time with a microcontroller.
8. Hardware and software were put together in the final stage. The ESP32 processed live sensor data continuously and matched it to a gesture using the trained model. A detected gesture was sent to a mobile app over Bluetooth as a text label. A configuration file called gestures.json was used by the app to map each label to its corresponding word. The detected word was then displayed on the screen and converted into speech using TTS. The app supported various Indian languages, including Hindi, English, Kannada, Tamil, Telugu, and Bengali, making the system all-inclusive and easy for any user in the country.

9. These processes together yielded a workable, user-friendly system that could interpret ISL gestures and provide actual speech output in real time.

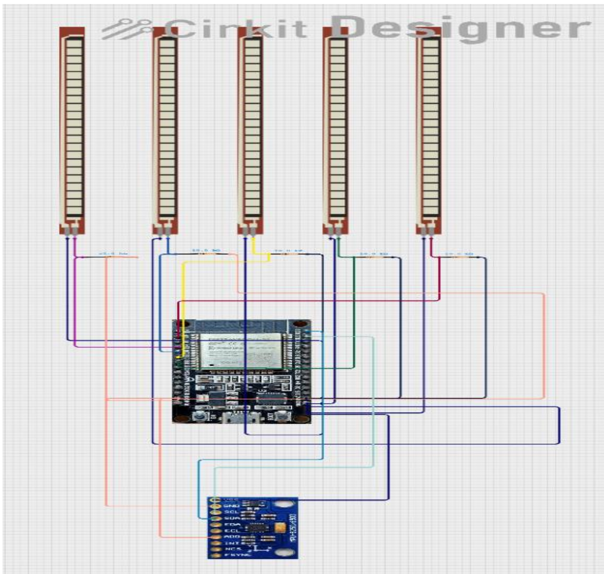

Figure 2 - Circuit simulation of the Smart Gesture Glove

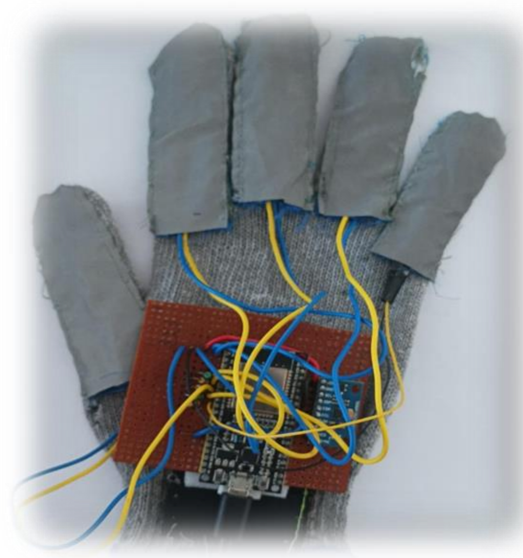

Figure 3 - Smart Gesture Glove for right-handed users

Result and Conclusion

1. The developed MITRA gesture glove prototype was successfully tested for real-time gesture recognition and usability. The system demonstrated reliable performance in detecting predefined Indian Sign Language (ISL) gestures and transmitting the recognized output to a mobile application via Bluetooth communication. The ESP32-based system, integrated with flex sensors and an MPU-6500 IMU, effectively captured hand movements and processed them for gesture classification.
2. The prototype achieved an overall recognition accuracy of approximately 88%, with simpler gestures showing higher accuracy compared to dynamic ones. The response time for gesture-to-text conversion was observed to be around 1–2 seconds, ensuring smooth interaction. Stable Bluetooth communication was maintained within a range of 3–5 meters, suitable for practical usage scenarios. The system also provided additional features such as text-to-speech output and emergency SMS support, enhancing its usability.
3. In conclusion, the MITRA system validates the feasibility of a low-cost, portable, and user-friendly assistive device for individuals with speech and hearing impairments. While minor limitations such as occasional misclassification and delay exist, the overall performance demonstrates strong potential for real-world

application, with scope for further improvements in accuracy, responsiveness, and gesture coverage.

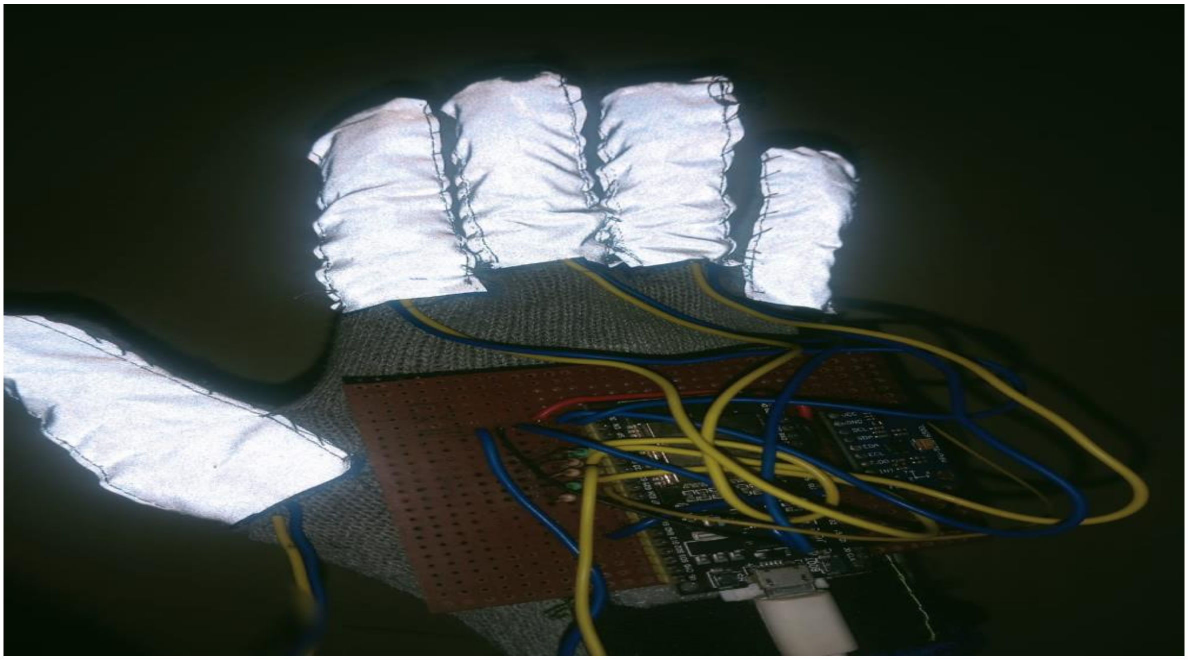

Figure 4 - The Gesture “All Clear” performed

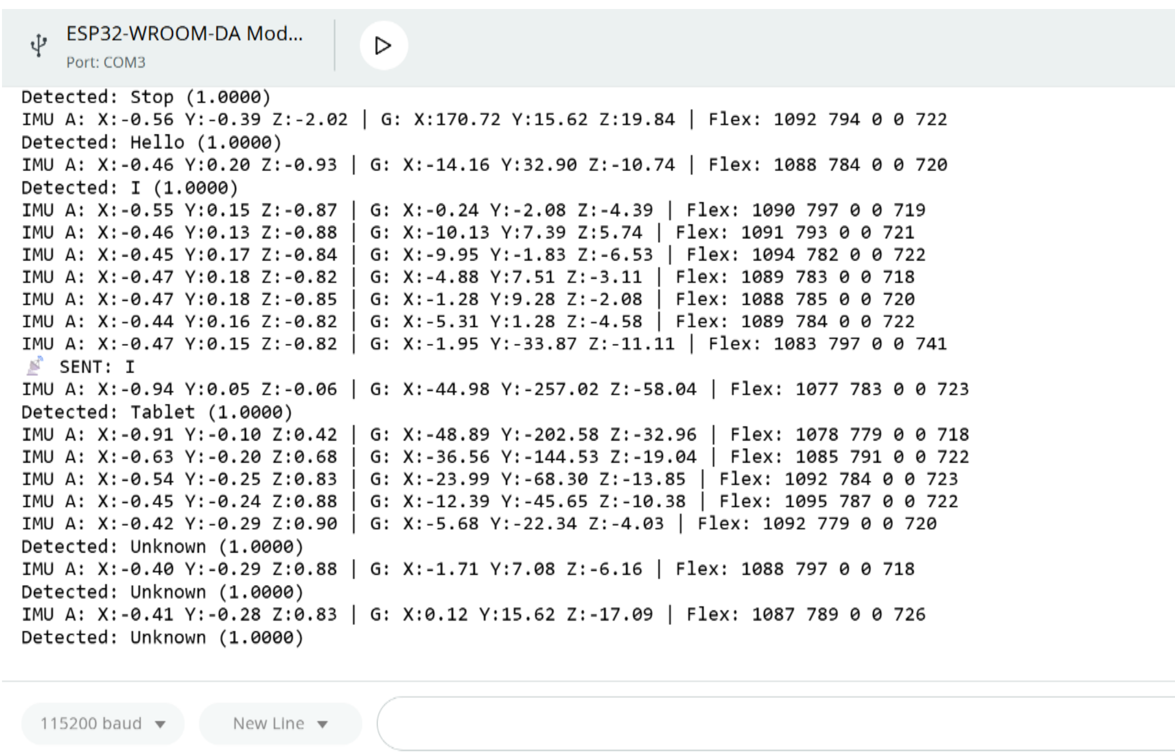

Figure 5 - Serial monitor recording sensor values and detecting the corresponding gesture

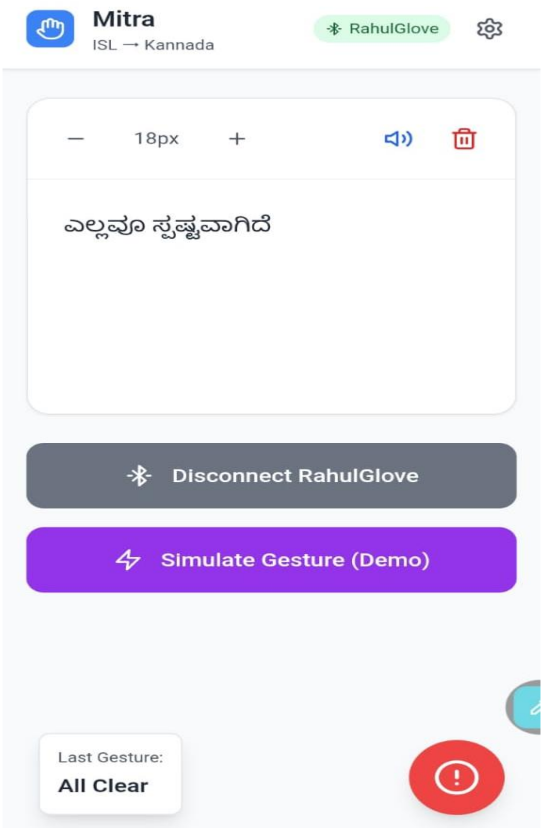

Figure 6 - Translation on app in regional language (Kannada)

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Future Scope:

The future scope of this project includes:

1. Incorporate machine learning algorithms to improve gesture recognition accuracy.
2. Enhance adaptability of the system to suit different users.
3. Optimize power consumption to increase efficiency and battery life.
4. Reduce the size of electronic components to make the glove more compact and comfortable.
5. Continuously refine the system to develop it into a full-fledged assistive communication tool.
6. Enable real-time, two-way communication for smoother interaction.
7. Improve user confidence and independence through better usability and performance.