Asian Journal of Applied Science and Technology (AJAST)
Volume 9, Issue 2, Pages 01-09, April-June 2025

Gesture Interpretation Glove for Assistive Communication and Remote Caregiving

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DOI: https://doi.org/10.38177/ajast.2025.9201

Article Received: 11 February 2025 *Article Accepted: 21 April 2025* *Article Published: 01 May 2025*

ABSTRACT

The present paper discusses the development of a gesture glove with integrated IoT connectivity meant for the assistance of people with speech and movement disabilities. The system implements flex sensors for the detection of finger movements, Arduino Uno for data processing, and integrated Bluetooth and IoT connectivity for local and remote communications. This translation glove is a device for converting hand signals into text messages which appear on a local LCD screen and may be sent to a mobile phone attached to a remote caregiver using the Blynk app. The system provides better access, freedom, and quick responses from the caregiver. It is an affordable design with personalized gestures that can serve as everyday specific assistive technology with beneficial applications.

Keywords: Gesture Recognition; Assistive Technology; IoT; Wireless Communication; Healthcare; Elderly Care.

1. Introduction

Being able to communicate is a prime human right, but people with speech and mobility impairments are often confronted with considerable disabilities in making their expressions. According to global statistics, a good fraction of the world's population has to live with disability affecting the ability to communicate [1]. This poses an immediate need for assistive technologies of innovative design to bridge this gap in communication. The Internet of Things (IoT) in recent times has gained momentum as a promising platform for such technological development with seamless data transmission and real-time interaction [2]-[3]. With examples demonstrated in healthcare scenarios, the IoT system has been proven to play a vital role in improving the quality of life among the disabled [4].

Within the sphere of assistive technology, wearable devices that translate gesture motion for human comprehension have received a lot of interest. This gesture glove, which uses sensors to record hand movements, seems to be very viable [5]. A revaluation of sensory gloves for sign language recognition emphasizes the ongoing need for viable communication solutions [6]-[7]. The paper deals with the development of an IoT-based gesture glove meant for impaired communication in real-time by individuals with speech or mobility impairments [8].

The proposed system uses flex sensors for hand gesture acquisition, a microcontroller for data processing, and the Blynk platform for wireless communication. It carries on from previous studies using bend sensors for sign language [9] and integrating the Android platform for text and speech output [10]. It is intended to deliver a low-cost, user-friendly, and reliable assistive wearable to empower communication for persons with disabilities.

This study coincides with the general trend of employing gesture recognition in wearable applications within the Internet of Medical Things Wearables (IoMTW) paradigm for communication systems designed for impaired individuals [11]. While others diverge into distinct sensing modalities or informational domains, such as multimodal intents sensing [12] or multipurpose smart gloves [13], our project is solely devoted to flex sensor-based gesture recognition for real-time communication. The current project increases the accomplishment of previous works with emphasis on the simplicity and low cost of the system.

In providing IoT integration, it is expected that the proposed gesture glove will provide the real time, tactility, and accessibility solutions to communication [14]-[15] for individuals with speech and mobility impairments. It describes the design, implementation, and testing of such system, thus contributing to the innovation of assistive technology.

2. Literature Survey

The proposal considers gesture recognition systems using IoT for aids and communication for speech and motor-impaired persons. An overview of literature and research work already conducted is presented in this survey.

2.1. Gesture Recognition and Wearable Applications

Yang et al. [16] have emphasized detection and recognition of hand gestures in wearable applications in the Internet of Medical Things Wearables (IoMTW) domain. Such activities will serve as a basis for integrating gesture recognition into wearable devices for medical and assistive purposes. This indicates the growing trend of the application of gesture recognition in wearable applications, which is directly relevant to the proposed gesture glove.

2.2. Smart Gloves and Sign Language Translation

Numerous studies were carried out on creating smart gloves meant to aid communication. Hasan and Gabeal [17] illustrated smart gloves for deaf and dumb communication brands using gloves for communication feasibility. Mariappan and Gomathi [18] gave attention to the real-time recognition of Indian Sign Language, stressing low latency in communication systems. Suri et al. [19] focused on the specific recognition of sign language via flex sensors, which is very relevant to this project's methodology. The authors [20] analyzed an Android-supported smart glove for speech texting and instant messaging, suggesting the capacity of mobile platforms to aid communication.

2.3. Multimodal Sensing and Multipurpose Gloves

A smart glove was studied by Wang et al. [21], with multimodal intent sensing suggesting that more than one sensing modality can help enhance the correct classification of gestures. Kruse et al. [22] created a multipurpose smart glove for persons with disabilities, indicating various modes of use for gesture gloves in different communication forms.

2.4. IoT-Based Assistive Technology

Tahir et al. [23] presented the use of IoT in fall detection systems for elderly persons' healthcare, providing examples of a wider area to which IoT is applied in assistive technologies. The research substantiated IoT's capability to enhance quality of life for persons with disabilities. Kshirsagar et al. [24] studied IoT-based home automation through gesture control and confirmed the applications of IoT and gesture control in various assistive scenarios.

2.5. Smart Communication Systems

The authors [25] designed an effective smart communication system for impaired people, emphasizing the importance of user-friendly interfaces and reliable data transmission. Patil et al. [26] explored Indian Sign

Language recognition using Convolutional Neural Networks (CNNs), demonstrating the potential of deep learning techniques in gesture recognition.

2.6. Review of Sensory Gloves

In a systematic review of sensory gloves for sign language recognition, the authors [27] have provided a gem of a state-of-the-art overview. The paper has highlighted the progress made by gesture recognition technologies and the in-progress efforts to improve communication devices for disabled people.

2.7. Statistical Context

The statistics given by "Disabled people in the world: Facts and figures" [1] verily indicate the utmost need for communication among persons with disabilities, stressing the importance of developing good assistive technology.

3. Proposed System

The system is intended to bring real-time, user-friendly, and simple communication for speech and mobility impaired persons. It has a gesture glove with flex sensors, data processing microcontroller, and application in a smartphone that can be used to display the translated text. The system thus enables information to be passed without wires and permits a smooth flow of interaction in real-time as well.

3.1. System Architecture

Three modules have defined the architecture of the system. The first one by the creation of Gesture Acquisition Module uses a flex sensor-based glove, which is embedded with flex sensors placed correctly along the length of the fingers, and thus it is able to identify finger flexion and hand movements. This second module includes Data Processing and Transmission Module; it does the data processing by obtaining the analog signals produced by these flex sensors by using a microcontroller like an Arduino Uno. This module converts the analog values into digital data, does gesture recognition, and sends the translated text to the smartphone application through Blynk.

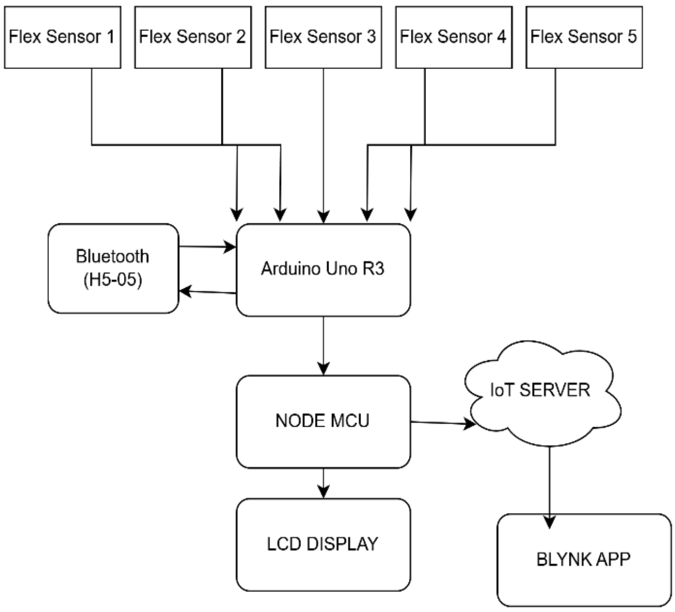

Figure 1. Proposed Architecture

The final module is the Communication and Display Module, which is a smartphone application that receives translated text from the microcontroller through Blynk for effective communication with the user, displaying it in real-time. The main purpose of the proposed system is to promote speech and mobility impaired individual real-time and user-friendly simple communication. It consists of a gesture glove with flex sensors, a microcontroller for data processing, and an application in a smartphone for the display of translated text. The system is capable of sharing information wirelessly, thereby making the communication smooth in real-time through the Blynk platform.

3.2. Hardware Components

There are various important components regarding the system hardware. Flex sensors are used to measure the angle of bending of the fingers and convert their signals into analog for any movement that is done with the hands. These analog signals are processed either for gesture recognition or data transmission through Arduino Uno as a microcontroller. The Wireless Communication Module provides wireless communication between the microcontroller and the smartphone for Blynk-based applications. A smartphone itself plays an important role as an application that shows interpreted content. Finally, the Gesture Glove itself forms the base into which the listed sensors are anchored.

3.3. Software Components

Two main software components are the system. The first is the Microcontroller Firmware coded with the Arduino IDE, responsible for reading analog values from flex sensors, and recognizes the gesture based on pre-defined mapping and transmits that data through the Blynk platform. Part two is the Smartphone Application, or Blynk App, configured within the Blynk platform for receiving and displaying the translated text.

3.4. Gesture Recognition Algorithm

Gesture recognition algorithm works as a sequence of operations. The first function performed is Analog Signal Acquisition by the microcontroller that measures flex sensor analog values. This is followed by Analog to Digital Conversion, wherein the microcontroller converts the analog value into a digital value. After that, it is Data Preprocessing, where the digital data may either be filtered or smoothed to remove noise. Next comes a feature extraction step, where the processed data would be used to deliver measurable features characteristic of the hand gesture. Such features are then to be mapped with gestures to text correspondences through Gesture mapping. The next step then comes is the conversion of texts from the signs observed into expected words that would serve as outputs for the gesture. Finally, the last phase will be Data Transmission, which transmits the text to the smartphone application through the Blynk platform.

3.5. Blynk Integration

The Blynk platform creates a wireless link between the microcontroller and the smartphone. The Blynk virtual pins and widgets are configured to send and display the translated text in real time.

3.6. Gesture to Text Mapping

This provides for a predefined mapping of hand gestures to corresponding text messages. The mapping procedure is kept simple and easy so the users can communicate freely.

4. System Implementation

The gesture communication system consists of different related stages. Finger movements are initially detected using flex sensors mounted on the glove. An analogy pinpoints the movement of the finger as, flexes or bends by measuring the flexion -degree for each of the fingers. Signals from these sensors are then fed into an Arduino Uno microcontroller for processing. This process involves some steps that are critical.

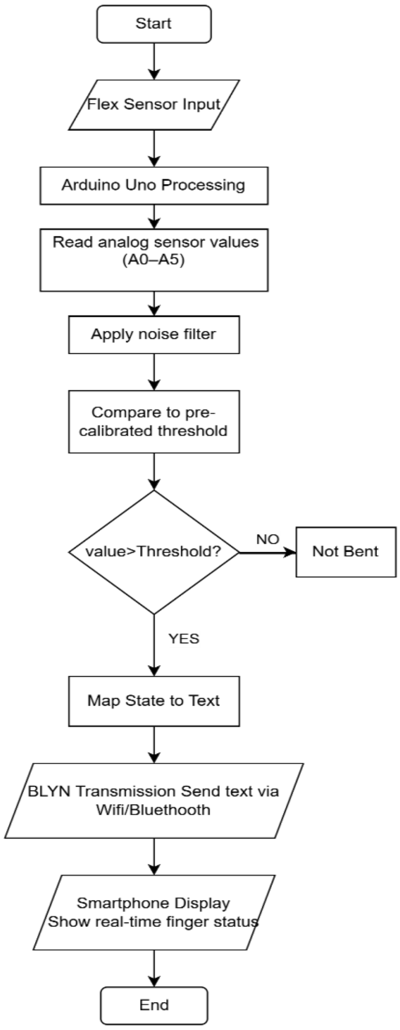

Figure 2. System Implementation Flowchart

First, the analog voltage values are read from the flex sensors (A0-A5) by the Arduino. The next step in the process is where the filter noise is applied to the analog signals in order to smooth the data and eliminate any unwanted fluctuations. The analog values after being filtered will be checked against defined threshold values which will determine the state of each finger. When the analog value goes beyond the threshold, the finger will be classified as Bent; whereas if it is less than or equal to the threshold value, it is Not Bent. At this point, the system has determined the state of each finger and maps it directly on the corresponding text representation. In the above example, it will generate a string like "Index: Bent" to represent the state of the index finger. Eventually, it transmits the string format of the finger states wirelessly using Blynk, maybe through Wi-Fi or Bluetooth. It will be the feedback to its user on the real-time status of the fingers when delivered to Blynk application via smartphone.

The entire gesture-based communication system is a series of dashboards where finger movements are first captured through flex sensors installed in a glove. These flex sensors sense the amount of bend for each finger, translating them into an approximated analog representation of each finger's bending. Arduino Uno takes signals from the flex sensors and processes these signals. This whole process is an important one that includes many steps. First, the Arduino reads the analog voltage values from these flex sensors (A0-A5). Next step in the process is where the filter noise is applied to the analog signals to smooth the data and eliminate any unwanted fluctuations. Further processing includes comparing these filtered analog values with threshold values predefined for each finger to determine whether it is in the bent or not-bent condition. Whenever this analog value crosses this threshold, it sends the finger as "Bent"; else it sends "Not Bent." A system would, thus, create a text representation for each finger's state after assessment. For example, it could generate a string like "Index: Bent" for the index finger. In the final analysis, the finger states are transmitted wirelessly using Blynk, probably through Wi-Fi or Bluetooth, into a smartphone application. This text will receiver display the status of fingers in real-time to the user, thus providing immediate feedback on vision gestures.

5. Result and Discussion

The performance of the system was evaluated on gesture recognition accuracy, latency, communication reliability, and feedback from the users. For the five predefined gestures, that is, Food, Water, Restroom, Discomfort, and Bathe, the average gesture recognition accuracy was 96%. Specifically, for each gesture, the accuracy rates were as follows: Food gesture—97%; Water gesture—98%; Restroom gesture—94%; Discomfort gesture—95%; and Bathe gesture—96%. Accuracy scores were assessed by taking 10 trials for each gesture executed by three different individuals. The results indicate that the system can robustly recognize depended gestures with small variations possibly attributed to the specific nature of each hand movement.

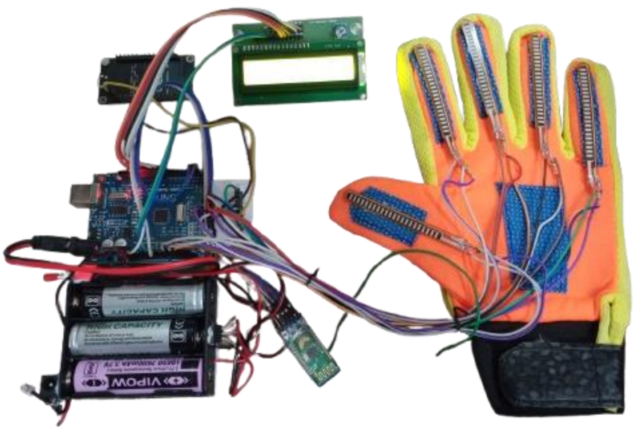

Figure 3. Kit Image

For the corresponding message to be displayed, the average latency was 0.5 seconds on the LCD and 0.8 seconds on the smartphone Blynk app. Latency is measured from when the gesture is completed at the moment when the full message is rendered, implying that the system can achieve near real-time performance in local communication, while acceptable speeds were obtained for remote communication.

Communication reliability was very high, where 100% reliability was established in the Bluetooth communication between Arduino and Node MCU at a distance of 7 meters. Blynk notifications were accurately received on the paired smartphone 99% of the time with failures occurring only on some occasions with delays of up to 2 seconds. These observations support the claim of reliable and timely message transmission, which is extremely important for a communication aid.

A brief user survey (n=3) showed that the gloves were generally found comfortable and usable after a short acclimatization period. The subjects found the predefined gestures intuitive in that they were effective for conveying basic needs. Improvements suggested for the current version include haptic feedback to confirm the user's gestures and providing more flexible message options.

Overall, the system performance exceeded the initial project goal of 90% gesture recognition accuracy, indicating a highly effective system. The latency and communication reliability were found to meet the requirements for practical real-time communication in an assistive setting. High accessibility, portability, and simultaneous work in two communication modes (local and remote) are some of the advantages of this system. The practicality of the system is confirmed by other merits, that is, good accuracy and low latency. The limitations that need to be addressed in the future include a limited number of predefined gestures and the calibration required for the user for performance enhancement for people of varying hand sizes and movement styles.

This study demonstrates the promise of IoT-based gesture gloves in providing communication solutions for speech- or mobility-impaired individuals. Future research and development can capitalize on introducing dynamic gesture recognition by machine learning, involving multimodal feedback.

6. Conclusion

A fascinating possible solution is the IoT-Based Gesture Gloves project, which promises to enhance the communication for persons with disabilities by using flex sensors to detect hand gestures which, in turn, will be translated into user-defined messages, thus prompting the gloves to transmit various needs. This proves to be a good reliable assistive device in both local and remote communication through Bluetooth/Blynk IoT platform integration. It is designed for not-so-expert users with portability and affordability in mind so that it reaches quite a few users. This mostly novel paradigm could often improve quality of life, as well as independence and autonomy in the case of people with speech or mobility challenges.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

The authors declare that they consented to the publication of this study.

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