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Design and Implementation of an Assistive Smart Glove for a Sign Language Recognition System

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Abstract— ***The prevalence of hearing impairment poses significant challenges to effective communication and social integration between hearing and hearing impaired people in the world. The use of assistive smart glove helps impaired people to interact effectively with others. This research work design and implement an assistive smart glove device to recognize Alphabets of American Sign language. The designed system incorporates an ESP32-S microcontroller, accelerometer with flex sensors to detect user hand gestures. The flex sensors were used to detect the degree of bending in the fingers, while the accelerometer measures the orientation of the hand. The data collected through the flex sensors and accelerometer, are then processed using ESP32-S to obtain digital signals. The signals obtained from correct gestures signed by experts are set as predefined rules to classify specific gestures. Subsequently, translating the recognize gesture into text through a mobile application via WiFi module and later converted into voice output. This prototype has been tested for its feasibility in converting American Sign Language Alphabets (A-Z) into text and voice output.*** **The system provides a real-time translation of alphabet gestures** ***and achieves an average recognition accuracy of 91.20%. The system has high accuracy, adaptability, and efficiency make it a valuable contribution to the field of human-computer interaction.***

Index Terms— ***Sign Language Recognition, ESP32-S Microcontroller, Flex Sensor, Accelerometer and Human-Computer Interaction***

I. INTRODUCTION

Communication is a fundamental aspect of human interaction, it allows individuals to express their thoughts, emotions, ideas and desires [1], [2]. However, for individuals who have hearing impairment, communication might be difficult for them, specifically for those who use sign language as means on interaction. Communication through sign language involves the use of hand movements, facial expressions, and body language to convey information [3]. There is wide communication gap between hearing impaired and hearing people, this leads to social isolation, reduced access to education, and fewer employment opportunities for individuals who are deaf or hearing impaired, further marginalizing this community[4], [5]. The World Health Organization (WHO) reported that by 2050, nearly 2.5 billion people worldwide will experience some degree of hearing loss, with at least 700 million requiring hearing rehabilitation services [6]. This projection underscores the growing global burden of hearing impairment and highlights the urgent need for innovative solutions to bridge the communication gap between deaf or hearing impaired individuals and the hearing population. Traditional methods of communication, such as the use of sign language interpreters, are not always available, even when available, quite expensive to hire an interpret, particularly in low-resource settings or in situations requiring real-time interaction. As a result, there is a pressing need for technological solutions that can facilitate seamless communication between sign language users and those who do not understand sign language.

In recent years, advancements in wearable technology has opened new possibilities for addressing this challenge. Wearable devices, such as smart gloves, have emerged as a promising solution for sign language recognition and translation. These devices are equipped with sensors that capture hand movements and gestures, which are then processed and translated into spoken or written language [7], [8]. The use of smart glove-based on sensors can provide a real-time, portable, with no complex data processing is needed and user-friendly solution for sign language recognition, enabling deaf and hearing-impaired individuals to communicate more effectively with the hearing people. The aim of this research is to design and implement an assistive glove specifically for recognizing American Sign Language (ASL) alphabets (A to Z). This glove utilizes flex sensor technology to detect hand movements and finger positions, translating these ssgestures into corresponding letters of the alphabet. By focusing on the recognition of ASL alphabets, the project seeks to provide a foundational tool that can facilitate basic communication for individuals who are deaf or have hearing impairment. The significance of this research lies in its potential to empower users by enabling them to communicate basic thoughts and forms the basis for spelling out words and names, thereby enabling deaf individuals to express themselves more fully and engage in conversations that require precise communication. Furthermore, it creates a bridge between the hearing and non-hearing communities, allowing for more inclusive interactions in various social settings, such as schools, workplaces, and public spaces. The rest of this paper is organized as follows. Related work is presented in Section II.

Section III describes design methodology. Result and discussion are presented in section IV. Finally, Section V presents conclusion and future work.

II. RELATED WORK

There are two approaches used in sign language recognition; vision-based and sensor-based. Various researchers [1], [4], [5], [9] have reviewed and discussed methods used in achieving these approaches. This section review literatures on sensors-based sign language recognition systems.

A system for Arabic Sign Language recognition was designed in [10]. It used depth sensors to capture information about hand movements and used machine learning algorithms for gesture classification. Similarly, [11] system used a magnetic positioning system for recognizing static gestures associated with the American Sign Language (ASL) alphabet. The system employed magnetic sensors to capture the spatial coordinates of hand movements, which were then processed through machine learning algorithms to classify gestures accurately. The performance of this system was evaluated, achieving high accuracy rates of 97% on 24 ASL alphabets.

[12] implemented a smart glove for sign language, addressing the communication gap between deaf individuals and hearing people. The designed system was based on sensors that employed potentiometers to detect the bending of fingers, combined with an accelerometer and gyroscope to capture hand orientation and movement. These sensors converted hand gestures into analog signals, which were then processed using machine learning algorithms to translate the gestures into speech in real-time. The system achieved its primary objective by translate hand gestures of sign language into spoken words, facilitating seamless communication. The performance of the smart glove was evaluated based on its ability to accurately recognize and translate hand gestures into speech, providing a practical device for deaf individuals to communicate effectively with others. The system outputs the translated signs via a display as text and a speaker as sound, enhancing its utility in real-world communication scenarios.

[13] introduced a wearable smart glove system designed for real-time pose and gesture classification. The proposed system utilized a conductive knit-based resistive sensor network and an accelerometer to capture hand motion data, processed in real-time using a pre-trained LSTM neural network on a low-profile microcontroller. Designed for detecting 12 American Sign Language (ASL) letters and 12 ASL words in real time, the system employs a leave-one-experiment-out cross-validation methodology, achieving 96.3% classification accuracy for segmented examples and 92.8% correct rolling predictions during real-time streaming trials.

[14] system focused on enhancing community interaction for the deaf and mute through the design and implementation of a smart speaking glove (SSG) based on an embedded system. The system used flex sensors to measure finger bending and an accelerometer to determine hand position and movement. An Arduino Nano microcontroller processes the sensor data, and a Bluetooth module transmits the translated text to a smartphone. The designed system was tested and evaluated with deaf participants to recognize American Sign Language (ASL) signs and its effectiveness in facilitating communication. The prototype achieves 90% accuracy, with a significantly lower cost compared to previous prototypes.

[15] developed a glove based and machine learning gesture recognition for game control. The designed aimed at creating a low-cost smart glove that accurately captures and classifies dynamic hand gestures for human-computer interaction. The designed of the prototype includes five flex sensors, five force sensors, and an inertial measurement unit (IMU). The data collected through sensors were to classify dynamic gestures using a convolutional neural network (CNN) with three two-dimensional convolutional layers and ReLU activation. The performance was evaluated based on classification accuracy, precision, and recall, with the CNN achieving an accuracy of 90%. The glove effectively captures dynamic gestures for game control, demonstrating its potential for applications in Virtual Reality (VR)/ Augmented Reality (AR) environments. The study contributes to the field of gesture recognition and wearable technology by providing a cost-effective approach that can be used in various limited applications.

III. METHODOLOGY

The system is designed for recognition of alphabets in American Sign Language recognition (ASL). It is divided into two main components: hardware implementation and software development for seamless integration and operation. The hardware components consist of five (5) flex sensors, an accelerometer (ADXL 335), and an ESP32-S microcontroller. The flex sensors detect finger bending, while the accelerometer captures palm orientation and motion. A battery module of 3000mAh with output voltage of 3.7V powers the entire system. These components work together to recognize different hand gestures corresponding to ASL alphabets. The software part involves the development of a mobile application that communicates with the hardware to process and display recognized gestures. The mobile application not only provides a visual representation of the detected sign but also generates an audio output to assist with communication. The block diagram in Fig. 1 shows the overview of the designed system.

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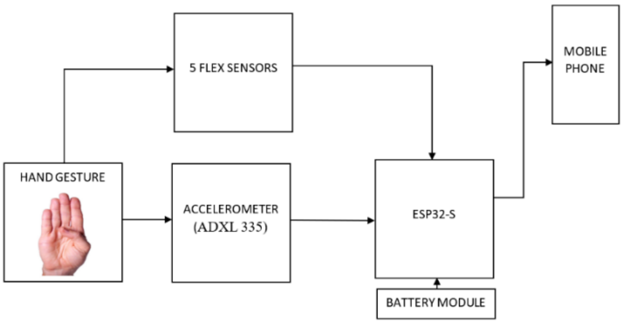

Fig. 1. Block diagram of the system

A. Hardware Design and Implementation

The design and implementation of major hardware components for the system are discussed below.

1. ESP32-S

The ESP32-S is a microcontroller that serves as the central processing unit of the designed system. It is responsible for reading data from the flex sensors and accelerometer, processing the data, and transmitting it wirelessly to the mobile phone. The ESP32-S features built-in Analog-to-Digital Conversion (ADC) pins, which are used to read the analog signals from the sensors. It also includes Bluetooth and Wi-Fi capabilities, enabling seamless wireless communication with the mobile phone. The microcontroller operates at 3.3V, GPIO pins on the ESP32-S are assigned to connect the flex sensors, accelerometer, and other peripherals, making it a versatile and efficient choice for this application. Figure 2 shows the diagram of ESP32 used in this designed system.

Fig. 2. ESP32-S microcontroller

2. Flex Sensors

The flex sensors in this design are resistive sensors that change their resistance when bent, making them ideal for measuring the degree of finger bending. In this design, five flex sensors are used, with one sensor placed on each finger to act as variable resistors. Each flex sensor is integrated into a voltage divider circuit, where one end is connected to a 3.3V supply and the other end is connected to a fixed resistor of 100kΩ. The midpoint of this circuit is linked to an ADC pin on the ESP32-S microcontroller, allowing the analog voltage signals to be read and processed. These voltage signals, which vary based on the bending of the fingers, are calibrated to map the resistance range of each flex sensor to specific finger bending angles. The flex sensors are securely attached to the fingers of the glove, ensuring they bend smoothly with finger movements and provide accurate data for gesture recognition. Fig. 3 shows the diagram of five (5) flex sensors used in the design.

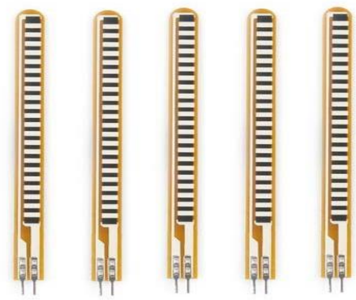

Fig. 3. Flex sensors

3. Accelerometer (ADXL 335)

The ADXL 335 accelerometer is used to measure the orientation and movement of the hand in three axes (X, Y, Z). This component provides analog outputs for each axis, which are connected to the ADC pins of the ESP32-S for data acquisition. The accelerometer operates at 3.3V, so its VCC pin is connected to the 3.3V output of the ESP32-S. The accelerometer is typically mounted on the back of the hand or wrist to capture the overall movement and orientation of the hand, complementing the data from the flex sensors for comprehensive gesture recognition. Fig. 4 shows the diagram of accelerometer.

Fig. 4. Accelerometer ADXL 335

4. Battery Module

The battery module is essential for powering the entire system, including the ESP32-S, flex sensors, and accelerometer. A rechargeable battery, 3.7V of 2000mAh was used in the system designed. The runtime of the system depends on the battery capacity and the total current draw. The battery module can supply a runtime power for about 5 hours provided all peripherals are in active mode. The equation to determine the runtime (hours) of the battery is given in equation (1).

$$Runtime\ (hours) = \frac{Battery\ Capacity\ (mAh)}{Total\ Current\ Draw\ (mA)} \quad (1)$$

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The hardware implementation of the glove-based sign language recognition system involves integrating various components to capture hand gestures, process, and transmit hand gesture data into mobile application with the following hardware components; flex sensors, an ADXL335 accelerometer, and an ESP32-S microcontroller. This section discusses hardware implementation of the system.

The hardware components were configured by mounting five flex sensors on a glove, one for each finger, to measure bending variations. The ADXL335 accelerometer was attached to the back of the hand to detect motion and orientation changes. These sensors provided analog signals, which were then converted into digital form using the ADC (Analog-to-Digital Converter) of the ESP32-S as shown in circuit diagram in figure 5. The flex sensor readings determined whether a finger is straight or bent, while the accelerometer captured hand tilts and directional movements. Fig. 6 shows complete hardware design of the system.

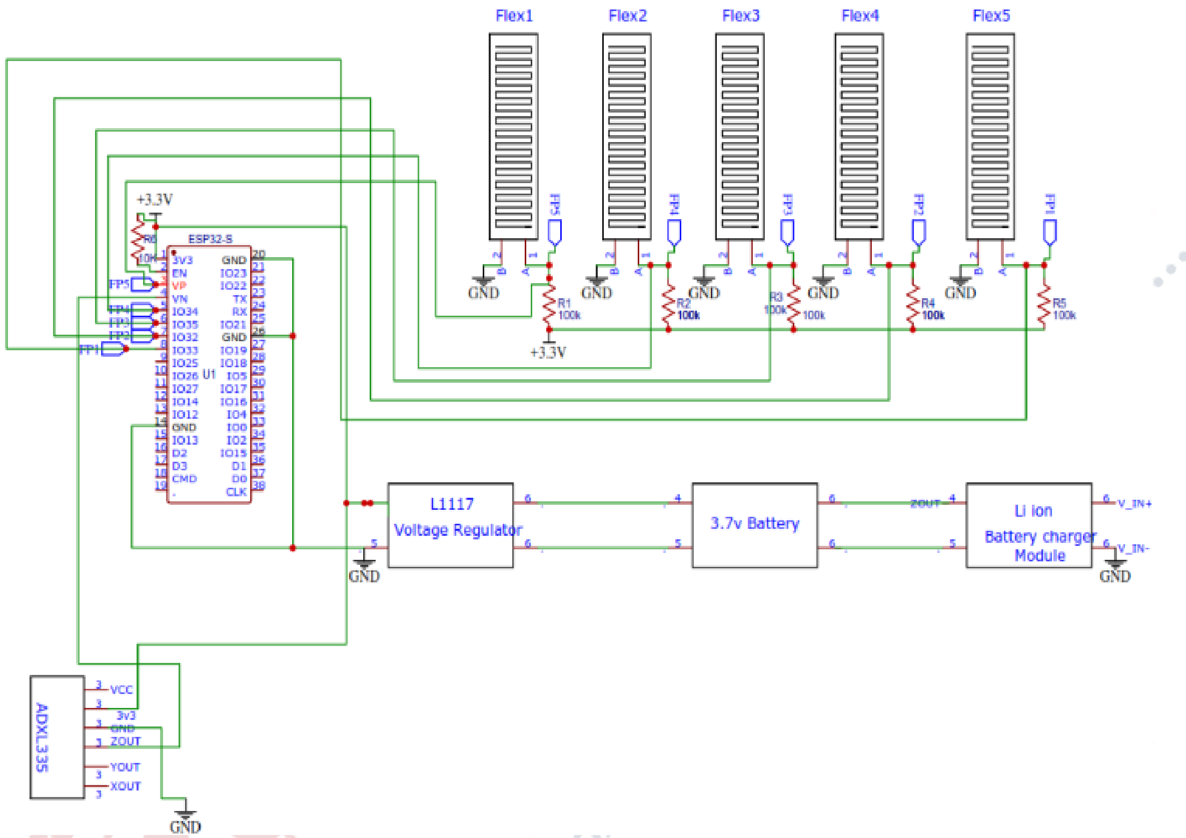

Fig. 5. Circuit Diagram of the Designed System

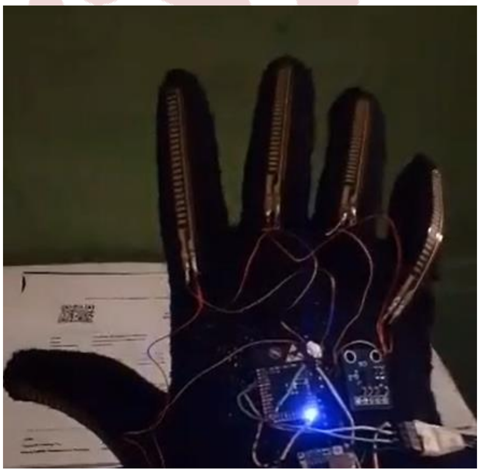

Fig. 6. Complete Hardware Design

Once the sensor data was processed, the recognized gesture was transmitted wirelessly to a mobile device via Wi-Fi for display. The mobile application displayed the recognized letter in real-time and provided an audio output of the corresponding sign gesture using text-to-speech. This feature enhanced accessibility, allowing both hearing and non-hearing individuals to understand the signed gestures through visual and auditory feedback.

B. Software Implementation

The software implementation comprises the programming of ESP32-S microcontroller and development of mobile application for the system.

1. Programming ESP32-S Microcontroller

The ESP32-S microcontroller is programmed in C++ to manage flex sensor inputs, which produce analog signals that

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are converted into digital signals using an Analog-to-Digital Converter (ADC) of ESP32-S. These digital signals represent the output from the flex sensors and were used for gesture recognition based on predefined rules for each sign, determined by experts signer multiple times to get accurately predefined values. During setup, the system calibrates the sensors to establish baseline values, ensuring accurate readings. The microcontroller uses conditional logic to compare the digital signals from the flex sensors to these predefined rules, recognizing a gesture if the values match within a set threshold. Recognized gestures are transmitted to a smartphone via Wi-Fi for text and audio output, enabling real-time communication. An asynchronous web server serves real-time sensor data and recognized gestures over HTTP endpoints, while serial debugging is included for monitoring sensor values and system performance. This approach ensures reliable gesture recognition and seamless integration between the smart glove and the smartphone. Fig. 7 shows the flex sensors outputs when the fingers and hand orientation are stationary, while Fig. 8 shows flex sensors outputs when the fingers and hand orientation are in motion.

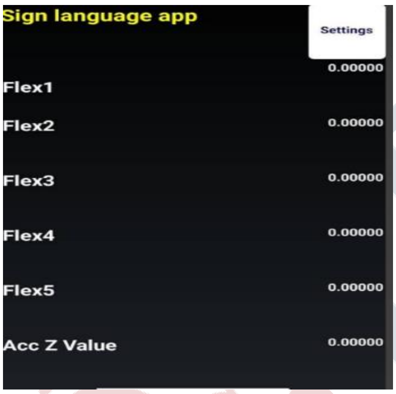

Fig. 7. Flex sensors output when fingers not moving

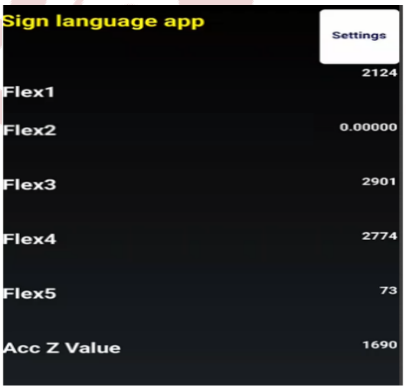

Fig. 8. Flex sensors when finger is moving

2. Mobile Application Development

The mobile application was created using Java for Android and Android SDK. The user interface (UI) design was a key area of focus, as it needed to be intuitive and user-friendly to effectively interact with the smart glove. The mobile application featured robust WiFi data reception capabilities, facilitating real-time data exchange with the smart glove. Fig. 9 below shows some of the alphabets of American sign language recognized by the designed system and displayed on mobile application.

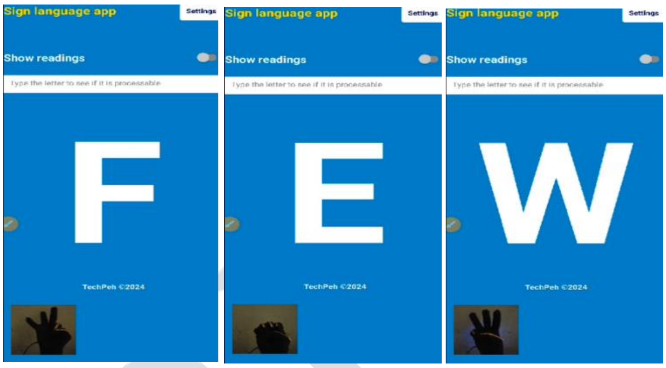

Fig. 9. Alphabets Recognition using Data glove on Mobile Phone

IV. RESULT AND DISCUSSION

The system performance was evaluated using 10 sign language experts to test the design. Each participant signed all the alphabets, and the number of correctly recognized signs was recorded. The chart in Fig. 10 below shows the recognition accuracy for each participant, illustrating the effectiveness of the smart glove in capturing and interpreting hand gestures. The chart shows that all 10 attempts to sign alphabets ‘A’, ‘B’, ‘H’, ‘L’, ‘R’, ‘V’, and ‘W’ were recognized correctly, while 7 attempts out of 10 attempts were recognized correctly for alphabet ‘O’. The system achieved an Average Recognition Accuracy (ARA) of 91.20% using equation (2) given below.

$$ARA\ (\%) = \frac{\sum Recognition\ Accuracies}{Total\ Number\ of\ Gestures} \qquad (2)$$

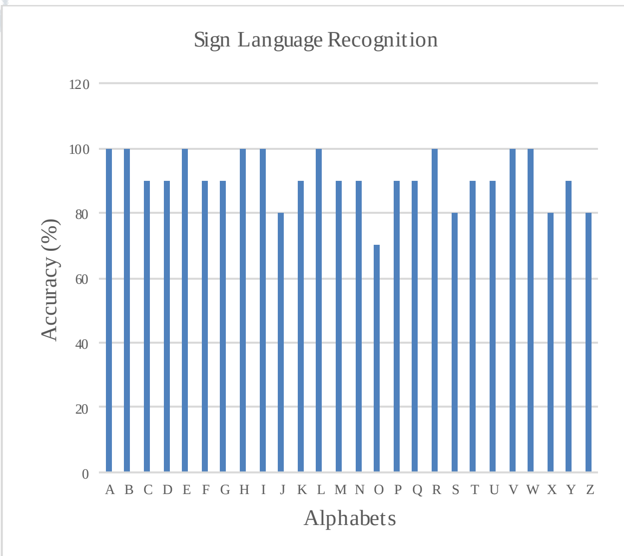

Fig. 10. Sign Language Recognition Accuracy Chart

Overall, the high recognition accuracy demonstrates that the smart glove system is effective in translating sign language into text. The slightly lower accuracy for the alphabet 'O' indicates that further calibration and algorithmic refinement may be needed to better differentiate between similar gestures.

V. CONCLUSION

The smart glove design employing a rule-based approach for sign language recognition has proven to be effective, with an average recognition accuracy of 91.20% during testing with 10 sign language experts. The system accurately interpreted most signs, demonstrating its potential to facilitate communication and teaching for the deaf and hearing-impaired community. However, some challenges were encountered, such as a lower recognition accuracy for some alphabets, which pointed to limitations in the current rule-based algorithm in handling ambiguous or closely resembling gestures. To address these shortcomings and enhance the system's performance, future work will focus on integrating machine learning methods with the rule-based approach to better handle gesture variability and improve overall accuracy. Furthermore, expanding the gesture dataset by including additional signs, dynamic gestures, and capturing a diverse range of signing styles will make the system more adaptable.

REFERENCES

[1] I. A. Adeyanju, O. O. Bello, and M. A. Adegboye, "Machine learning methods for sign language recognition: A critical review and analysis," *Intell. Syst. Appl.*, vol. 12, p. 200056, Nov. 2021, doi: 10.1016/j.iswa.2021.200056.

[2] A. Esposito, A. M. Esposito, and C. Vogel, "Needs and challenges in human computer interaction for processing social emotional information," *Pattern Recognit. Lett.*, vol. 66, pp. 41–51, Nov. 2015, doi: 10.1016/j.patrec.2015.02.013.

[3] S. Srivastava, S. Singh, Pooja, and S. Prakash, "Continuous Sign Language Recognition System Using Deep Learning with MediaPipe Holistic," *Wirel. Pers. Commun.*, vol. 137, no. 3, pp. 1455–1468, Aug. 2024, doi: 10.1007/s11277-024-11356-0.

[4] M. A. Ahmed, B. B. Zaidan, A. A. Zaidan, M. M. Salih, and M. M. B. Lakulu, "A review on systems-based sensory gloves for sign language recognition state of the art between 2007 and 2017," *Sens. Switz.*, vol. 18, no. 7, 2018, doi: 10.3390/s18072208.

[5] U. Gautam, M. E. Asgar, R. Ranjan, C. Narayan, and HMRITM, "A REVIEW ON SIGN GLOVES FOR DUMB AND DEAF PEOPLES USING ESP32," *Int. J. Eng. Appl. Sci. Technol.*, vol. 8, no. 2, pp. 303–308, Jun. 2023, doi: 10.33564/IJEAST.2023.v08i02.046.

[6] World Health Organization (WHO), *World Report on Hearing*, 1st ed. Geneva: World Health Organization, 2021. Accessed: Sep. 02, 2025. [Online]. Available: https://www.who.int/publications/i/item/9789240020481

[7] S. A. E. El-Din and M. A. A. El-Ghany, "Sign Language Interpreter System: An alternative system for machine learning," *2nd Nov. Intell. Lead. Emerg. Sci. Conf. NILES 2020*, no. Ml, pp. 332–337, 2020, doi: 10.1109/NILES50944.2020.9257958.

[8] A. Ji *et al.*, "Dataglove for Sign Language Recognition of People With Hearing and Speech Impairment via Wearable Inertial Sensors," *Sensors*, vol. 23, no. 15, p. 6693, 2023, doi: 10.3390/s23156693.

[9] M. J. Cheok, Z. Omar, and M. H. Jaward, "A review of hand gesture and sign language recognition techniques," *Int. J. Mach. Learn. Cybern.*, vol. 10, no. 1, pp. 131–153, 2019, doi: 10.1007/s13042-017-0705-5.

[10] M. A. Almasre and H. Al-Nuaim, "A comparison of Arabic sign language dynamic gesture recognition models," *Heliyon*, vol. 6, no. 3, p. e03554, Mar. 2020, doi: 10.1016/j.heliyon.2020.e03554.

[11] M. Rinalduzzi *et al.*, "Gesture Recognition of Sign Language Alphabet Using a Magnetic Positioning System," *Appl. Sci.*, vol. 11, no. 12, p. 5594, 2021, doi: 10.3390/app11125594.

[12] A. Aryal, B. Gyawali, D. Aryal, and R. Shrestha, "Design and Implementation of Smart Glove for Sign Language Vocalization," *Int. Res. J. Innov. Eng. Technol. IRJIET*, vol. 6, no. 6, pp. 94–98, 2022, doi: https://doi.org/10.47001/IRJIET/2022.606012.

[13] J. DelPreto, J. Hughes, M. D'Aria, M. De Fazio, and D. Rus, "A Wearable Smart Glove and Its Application of Pose and Gesture Detection to Sign Language Classification," *IEEE Robot. Autom. Lett.*, vol. 7, no. 4, pp. 10589–10596, Oct. 2022, doi: 10.1109/LRA.2022.3191232.

[14] M. Badawi, S. Elaskary, and Z. Ahmed, "Enhancing community interaction for the Deaf and Dumb via the design and implementation of Smart Speaking Glove (SSG) Based on Embedded System," *Int. J. Telecommun.*, vol. 03, no. 02, pp. 1–11, Nov. 2023, doi: 10.21608/ijt.2023.325318.

[15] A. Filipowska *et al.*, "Machine Learning-Based Gesture Recognition Glove: Design and Implementation," *Sensors*, vol. 24, no. 18, pp. 6157–6157, Sep. 2024, doi: 10.3390/s24186157.