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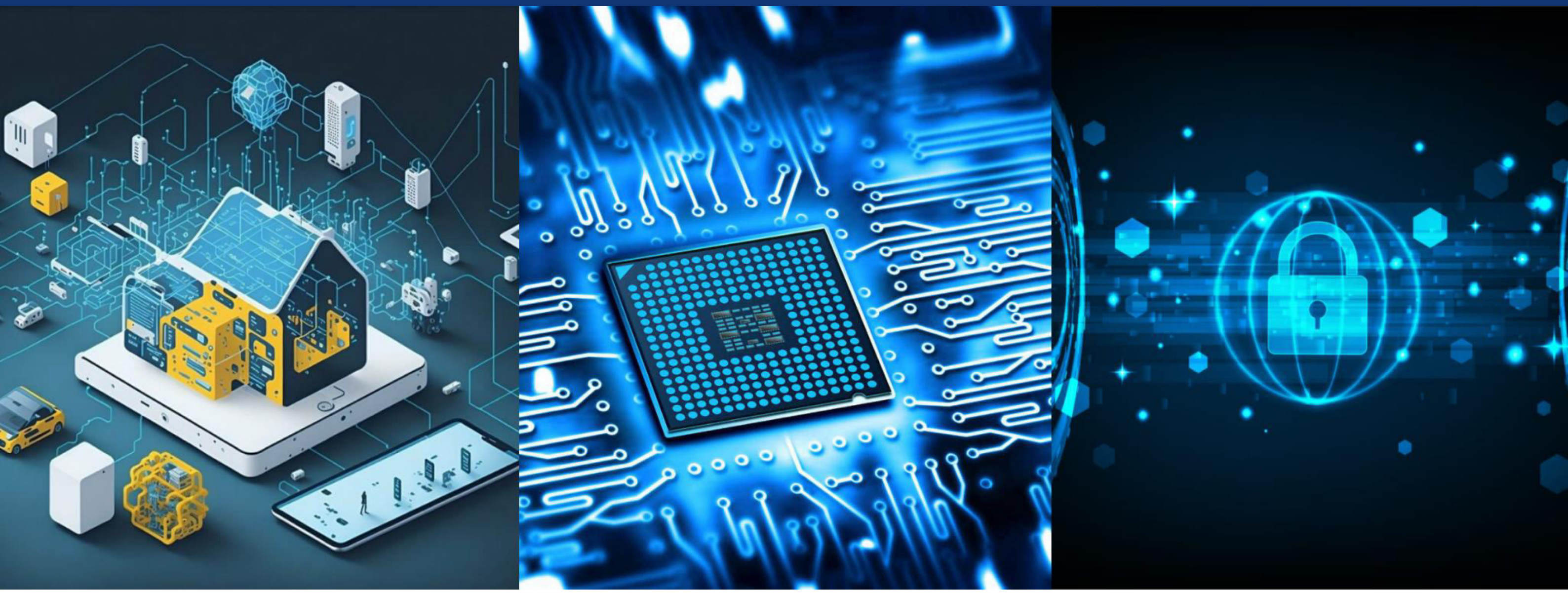

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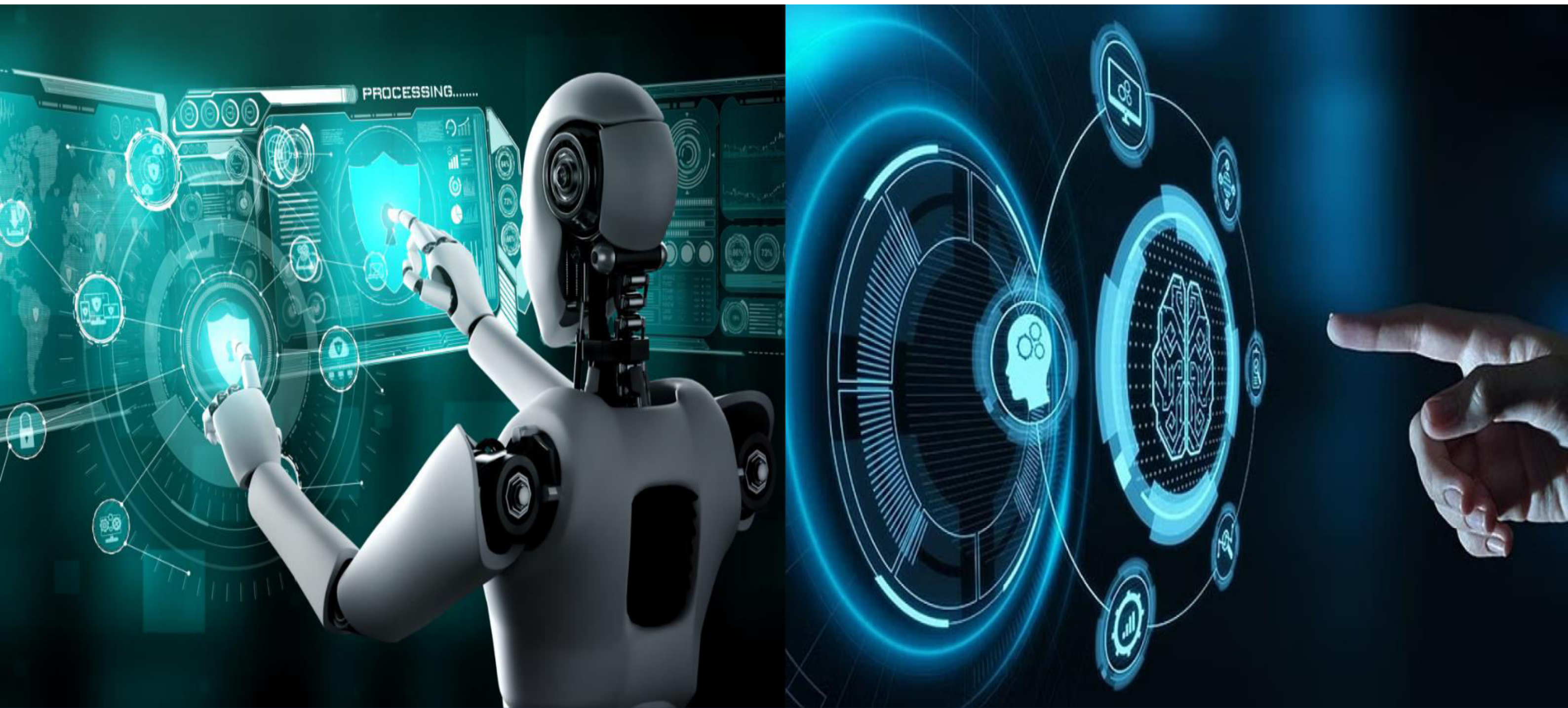

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Smart Glove for Gesture to Speech Translation

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ABSTRACT: Communication between speech-impaired people and normal individuals is often difficult because sign language is not widely understood. The Smart Glove for Gesture to Speech Translation project is designed to solve this problem by converting hand gestures into audible speech. The system uses a glove embedded with flex sensors and motion sensors to detect finger and hand movements. These sensors capture the gestures made by user and send the data to a microcontroller. The microcontroller processes the gesture data and identifies the corresponding words or sentences. The recognized gesture is converted into speech using a text-to-speech module and played through a speaker. This system helps speech-impaired individuals communicate more easily and effectively with others. The proposed device is portable, easy to use, and can improve social interaction and independence for people with communicate disabilities

KEYWORDS: Smart Glove, Gesture Recognition, Gesture-to-Speech Translation, Assistive Technology, Sign Language Communication, Embedded Systems, Flex Sensors, Microcontroller (Arduino), Real-Time Communication, Text-to-Speech (TTS)

I. INTRODUCTION

Communication is one of the most essential aspects of human life, enabling individuals to share ideas, emotions, and information effectively. However, people with speech and hearing impairments often face significant challenges in communicating with others, especially with those who are not familiar with sign language. Sign language is a powerful and expressive means of communication, but its understanding is limited to a small portion of the population. This creates a major communication gap between differently-abled individuals and the general public.

To address this issue, assistive technologies have been developed to bridge the gap and improve accessibility. One such promising solution is the development of a smart glove for gesture-to-speech translation. This system aims to convert hand gestures, commonly used in sign language, into audible speech in real time, thereby enabling effective communication between users and listeners without requiring knowledge of sign language.

The proposed smart glove integrates multiple sensors, including flex sensors and motion sensors, to detect finger bending and hand movements. These sensors capture the physical gestures and convert them into electrical signals. A microcontroller processes these signals and maps them to predefined gestures stored in the system. Once a gesture is recognized, it is translated into corresponding text, which is then converted into speech using a text-to-speech module. The generated audio output is played through a speaker, allowing others to understand the intended message.

II. RELATED WORK

In [1] Kim et al. A real-time sensor-based gesture recognition system was developed for assistive communication. The system uses embedded sensors, such as flex sensors and motion sensors, to capture hand movements and gestures accurately These sensor signals are processed by an embedded system or microcontroller to quickly recognize predefined gestures. The real-time processing ensures that the system responds instantly, reducing delay in communication This approach improves both response time and accuracy, making the interaction faster and more reliable. In [2] Feng Wen et al. Developed a gesture-to-speech conversion system using microcontrollers and text-to-speech modules. The system captures gesture data and maps it into predefined outputs, which are converted into speech.

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In [3] Saisandeep et al. Introduced a smart glove embedded with flex sensors and accelerometers to detect finger bending and hand orientation. The system provides accurate gesture recognition and efficient real-time processing. However, frequent calibration of sensors is required to maintain accuracy. Several researchers have focused on wearable smart gloves for gesture recognition. Flex sensors measure the degree of finger bending, while accelerometers capture motion and orientation In [4] Basha et al. The focus was on integrating multiple sensors with a microcontroller to improve gesture recognition systems. Sensors such as flex sensors, accelerometers, and motion sensors are used to capture detailed hand movements and send signals to the microcontroller for processing.The integration of multiple sensors helps the system achieve reliable and low-latency communication, meaning gestures are recognized quickly and accurately in real time.

In [5] Kanwal et al. Proposed an AI-based gesture recognition system using machine learning and IoT technologies. The system improves recognition accuracy and supports complex gesture patterns. However, it requires high computational resources and large datasets for trainingAI improves gesture recognition accuracy by learning complex patterns, while IoT enables smart connectivity between devices. In [6] In the study by Kumar et al. A vision-based gesture recognition system was developed using cameras and image processing techniques. Instead of using wearable devices like gloves, the system captures hand gestures through a camera and processes the images to recognize different gestures.The main advantage of this system is that it eliminates the need for wearable hardware, making it more convenient and non-intrusive for users. It allows natural interaction without physically wearing any device.However

In [7] Patel et al. Designed a wearable smart glove for translating sign language into speech and text. The system improves communication accessibility for differently-abled individuals. However, it supports a limited number of gestures. Once the gesture is identified, it is converted into corresponding text and then into speech using a Text-to-Speech (TTS) module. This system significantly improves communication for differently-abled individuals, especially those who are deaf or mute, by allowing them to express their thoughts in an understandable way. In [8] Ahmed et al. Developed text-to-speech systems that convert recognized text into natural-sounding speech. TTS modules are essential in gesture-to-speech systems as they enable real-time audio output..In gesture-to-speech translation systems, TTS plays a very important role because after the hand gestures are recognized and converted into text, the TTS module produces voice output

In [9] Singh et al. Emphasized the importance of flex sensors in detecting finger movements. Their study highlighted that proper sensor calibration is essential for improving accuracy and reliability.Flex sensors, along with accelerometers, play a crucial role in capturing precise hand gestures in smart glove systems. studied the use of flex sensors for detecting finger movements. Their work highlights the importance of sensor calibration for accuracy. In [10] Sharma et al. Implemented a low-cost gesture-to-speech system using Arduino and a voice module. The system is simple, portable, and easy to use. However, its performance depends on sensor accuracy and calibration. When a user performs a gesture, the sensors capture the movement and send signals to the Arduino. The microcontroller processes these signals and matches them with predefined gestures.

In [11] Roy et al. A low-cost smart glove system was developed to improve communication for individuals with speech or hearing impairments. The system uses wearable glove technology embedded with sensors to detect hand gestures and convert them into meaningful outputs such as text or speech.The main focus of this system is cost-effectiveness, portability, and real-time performance. In [12] Ahmed et al.A Text-to-Speech (TTS) system was developed to support assistive communication technologies. The system converts input text into natural-sounding speech using speech synthesis techniques.This technology plays a key role in systems like gesture-to-speech translation, where recognized gestures are first converted into text and then into audio output. The generated speech is clear and human-like, which helps in effective communication.

In [13] In the study by V. Gupta et al. A gesture-based human-computer interaction (HCI) system was developed to improve the way users interact with electronic devices. The system uses sensors or vision-based techniques to detect human gestures and convert them into commands that a computer can understand.This approach reduces the need for traditional input devices like keyboards and mice, making interaction more natural and user-friendly. In [14] In the work by T. Nguyen et al. An advanced wearable gesture recognition system was proposed for modern assistive communication. The system uses improved sensor technologies and advanced algorithms to accurately detect and interpret hand gestures.It focuses on key aspects such as portability, high accuracy, and real-time performance, making it suitable for everyday use.

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III. PROPOSED ALGORITHM

The development of the Smart Glove requires a synergy between ergonomic hardware design and a robust logical framework to ensure high accuracy in gesture recognition.

A. Design Considerations

To ensure the device is practical for daily use by individuals with speech impairments, the following design criteria were established:

Ergonomics and Weight: The glove must be lightweight and made of breathable material (e.g., spandex or cotton) to prevent user fatigue and perspiration during extended wear.

Sensor Placement: Flex sensors are positioned precisely over the interphalangeal joints of each finger. The accelerometer is mounted on the dorsal (back) side of the hand to accurately capture pitch and roll without obstructing movement.

Power Efficiency: Since the device is portable, the system is designed to operate on a low-voltage Lithium-ion battery. The algorithm incorporates "Sleep" states when no movement is detected to conserve energy.

Signal Integrity: To prevent electromagnetic interference (EMI) and signal noise from the flexible wiring, pull-down resistors are utilized in the voltage divider circuits for the flex sensors.

B. Description of the Proposed Algorithm

The proposed algorithm operates on a "Capture-Compare-Convert" logic. It translates continuous analog inputs from the hand into discrete digital voice outputs through the following logical flow:

Step 1: Data Acquisition & Normalization: The microcontroller reads five analog inputs (S1to S5) from the flex sensors and three inputs from the accelerometer (A_x,A_y,A_Z). Because sensor resistance varies slightly with temperature and wear, the algorithm performs a dynamic normalization:

Step 2: Gesture Encoding: The normalized values are converted into a "Hand-State Vector." For example, a fully bent finger is assigned a logical '1', and a straight finger a logical '0'. A simple gesture like "Point" might be represented as [1,0,1,1,1] (only the index finger is straight).

Step 3: Pattern Matching (Thresholding): The algorithm compares the current Hand-State Vector against a look-up table stored in the EEPROM. To account for human variability, a tolerance threshold (±10%) is applied.

Step 4: Hysteresis & Debouncing: To avoid "stuttering" (multiple triggers for one gesture), the algorithm requires the hand to maintain a position for a minimum of 400 milliseconds before confirming the gesture.

Step 5: Output Generation: Upon a successful match, the microcontroller sends a command to the TTS module (e.g., Emic 2 or WTV020-SD) via Serial communication to announce the specific string (e.g., “I need water”, “I need help”, “I need food”, I need emergency”)

IV. PSEUDO CODE

The software logic is designed to handle continuous analog signals and translate them into stable digital outputs using the following procedure:

Algorithm: Gesture-to-Speech Processing

BEGIN

Step 1: Initialize system components
    Initialize flex sensors
    Initialize accelerometer
    Initialize microcontroller
    Initialize LCD display
    Initialize voice module and speaker

Step 2: Set threshold values for all sensors

Step 3: Start continuous monitoring

WHILE (system is ON)

Step 4: Read sensor values
    Read flex sensor data (F1, F2, F3, F4,)
    Read accelerometer data (X, Y, Z)

Step 5: Convert analog data to digital values using ADC

Step 6: Process sensor data
    Determine finger bending positions

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Determine hand orientation
Step 7: Compare with predefined gesture patterns
IF (gesture == Pattern 1) THEN
Text = "I NEED WATER"
ELSE IF (gesture == Pattern 2) THEN
Text = "I NEED HELP"
ELSE IF (gesture == Pattern 3) THEN
Text = "I NEED FOOD"
ELSE IF (gesture == Pattern 4) THEN
Text = "I NEED EMERGENCY"
ELSE
Text = "UNKNOWN"
END IF
Step 8: Display output
Show Text on LCD
Step 9: Convert text to speech
Send Text to voice module
Generate speech output
Step 10: Play audio through speaker
END WHILE
Step 11: End system
END

V. SIMULATION RESULTS

The proposed smart glove system was tested through simulation and prototype implementation to evaluate its performance in gesture recognition and speech conversion. The simulation focused on analyzing sensor inputs, gesture matching accuracy, and response time.

Observed Results:

- The system successfully detected and recognized multiple predefined gestures such as I need water, I need Help, I need food, I need emergency
- Sensor readings showed clear variation between different finger positions, enabling accurate gesture differentiation.
- The microcontroller correctly mapped sensor values to corresponding gesture patterns with minimal error.
- The text-to-speech module generated appropriate audio output for each recognized gesture.
- The response time of the system was fast, typically within a fraction of a second, ensuring real-time communication.

Performance Analysis:

- Accuracy: The system achieved good accuracy for predefined gestures when sensors were properly calibrated.
- Response Time: Real-time performance was observed with negligible delay between gesture input and speech output.
- Reliability: Stable performance was maintained under normal operating conditions.

Limitations Observed:

- Slight variations in sensor readings could affect gesture recognition accuracy.
- Overlapping gestures with similar finger positions may cause misclassification.
- Performance depends on proper calibration of sensors.

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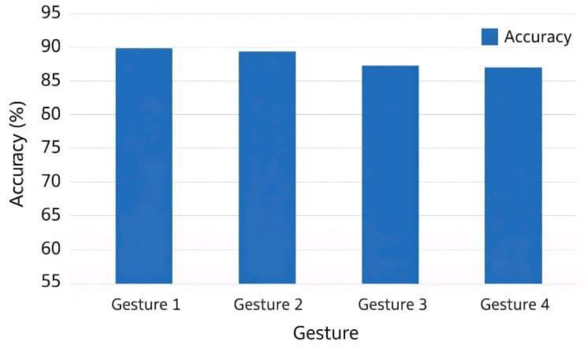

Figure 1: Gesture Recognition Accuracy

The system achieves an accuracy of approximately 85%–95%, especially for simple gestures. Minor errors may occur due to variations in finger positioning or hand size, but proper calibration improves performance. Overall, the system is efficient, reliable and suitable for real-time assistive communication shown in fig:1.

Output of the Smart Glove System

The developed smart glove system successfully converts hand gestures into both text and speech output. In the implemented prototype shown in the image, flex sensors attached to the glove detect finger bending and send signals to the microcontroller shown in fig:2 and fig:3

- When a user performs a gesture:
- The flex sensors capture finger movements
- The Arduino microcontroller processes the signals
- The recognized gesture is displayed on the LCD screen
- Simultaneously, the voice module and speaker generate audio output
- For example, when a predefined gesture is performed, the LCD displays a message such as:

"I NEED HELP"

Figure 2: Output Of Smart Glove for Gesture to Speech Tranlstion

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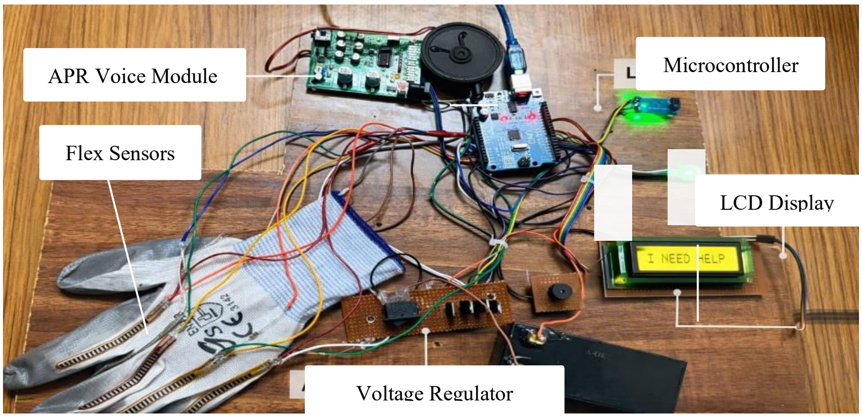

Figure 3: Output Of the Smart Glove System

VI. CONCLUSION AND FUTURE WORK

The proposed smart glove system provides an effective solution for communication between speech-impaired individuals and the general public. By using flex sensors and motion sensors, the system accurately detects hand gestures and converts them into meaningful text and speech output. The integration of a microcontroller and voice module enables real-time performance with minimal delay.The system is portable, cost-effective, and easy to use, making it suitable for daily communication. The simulation and testing results show that the glove can recognize predefined gestures with good accuracy and reliability. Overall, this project successfully demonstrates how assistive technology can improve the quality of life and independence of differently-abled individuals.

In the future, the smart glove system can be enhanced by integrating advanced technologies such as artificial intelligence and machine learning to improve gesture recognition accuracy and enable dynamic learning of new gestures. The system can be expanded to support a larger set of gestures and vocabulary, making communication more expressive and flexible. Wireless communication features like Bluetooth or Wi-Fi can be added to connect the glove with smartphones, allowing text display and data sharing through a mobile application. Additionally, incorporating multi-language speech output will make the system usable for a wider range of users. Further improvements can focus on reducing the size of components to make the glove more compact, lightweight, and comfortable for long-term use. Cloud integration can also be implemented to store gesture data and update the system efficiently, making it more intelligent and adaptable over time.

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