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Assistive Sign Language Communication System

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Abstract: *Most sign language interpretation systems rely on vision-based techniques that require cameras, high computational resources, and controlled environments, which limit their usability in real-world assistive scenarios. This work proposes an Internet of Behavior (IoB)–driven assistive sign language detection system that interprets finger bending behavior as a primary communication signal.*

The system employs a four-finger flex sensor configuration to capture continuous behavioral motion data, which is processed directly at the edge using an ESP32 microcontroller. Instead of transmitting raw data for cloud analysis, the behavioral patterns are locally mapped to predefined semantic outputs, enabling low-latency and privacy-preserving gesture translation.

A distinctive feature of the proposed model is its dual-channel communication framework, where the interpreted message is simultaneously rendered on a local LCD interface and transmitted via Bluetooth to an online application, allowing both immediate and remote interaction. By reducing sensor count, avoiding camera dependency, and emphasizing behavioral data processing, the system achieves a cost-efficient, portable, and socially deployable assistive solution..

Keywords*:* Internet of Behavior, Flex Sensors, ESP32, Edge Processing, Sign Language Detection, Assistive Communication, Bluetooth, LCD Display

I. INTRODUCTION

Communication is a major challenge for speech- and hearing-impaired individuals due to the lack of awareness of sign language among normal people. To overcome this problem, this project presents an IoB-based Assistive Sign Language Detection System that converts finger movements into text. The system uses flex sensors to detect finger gestures, which are processed by an ESP32 microcontroller. The recognized gestures are displayed on an LCD and also sent to an online application through wireless communication. The proposed system is low-cost, portable, and provides real-time communication support, helping disabled individuals interact easily with society.

1.1 Background

Sign language is a behavior-based communication method using finger movements.
Most existing systems use camera-based vision techniques, which are computationally heavy, privacy- intrusive, and environment-dependent.
Internet of Behavior (IoB) focuses on capturing human behavioral data (finger bending) instead of visual information.
Flex sensors and embedded controllers enable edge-level, real-time gesture interpretation without cloud dependency.
This background motivates a behavior-centric, sensor-based assistive communication system.

1.2 Contribution of This Work

• Proposes a behavior-centric (IoB) sign language interpretation model based on finger bending patterns, avoiding camera-based vision systems.
• Implements a minimal four-flex-sensor architecture, reducing hardware complexity and power consumption.

• Performs real-time edge processing on ESP32, enabling low-latency and privacy-preserving gesture translation.
• Introduces a dual-channel output mechanism (LCD + online application via Bluetooth) for local and remote communication.

II. PROPOSED METHODOLOGY

The proposed system consists of one main modules:

1. Assistive sign language communication System

1.1 System Architecture

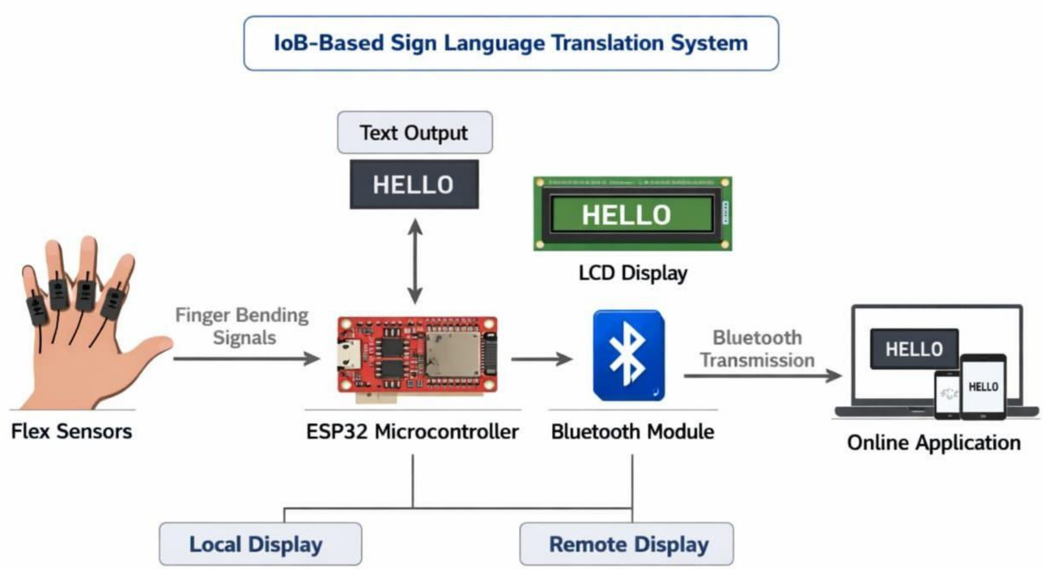
The system consists of four flex sensors attached to fingers to capture finger bending behavior. Sensor outputs are interfaced with an ESP32 microcontroller, which acts as the edge processing unit. ESP32 processes sensor data and maps behavioral patterns to predefined semantic outputs.
The interpreted output is displayed locally on an LCD module.
Simultaneously, the processed data is transmitted via Bluetooth to an online application for remote access.

1.2 Workflow

1. Finger movements generate analog signals from the flex sensors.
2. ESP32 acquires and digitizes sensor values.
3. Behavioral data is processed and matched with stored gesture patterns.
4. Corresponding text output is generated in real time.
5. Output is shown on the LCD and sent to the online application via Bluetooth.

1.3 Block Diagram Description

The proposed system is composed of multiple functional blocks working together to translate finger movements into meaningful text.



Flex Sensor Block:
Four flex sensors are placed on the fingers to sense bending behavior. Each sensor produces an analog signal proportional to the finger movement.

ESP32 Processing Block:
The ESP32 microcontroller receives analog signals from the flex sensors and converts them into digital values. It processes these values at the edge by mapping finger bending patterns to predefined sign language gestures.
LCD Display Block:
The processed output text is displayed on an LCD module, enabling immediate local communication between the disabled user and nearby individuals.
Bluetooth Communication Block:
ESP32 transmits the interpreted text data wirelessly via Bluetooth to an online application for remote viewing.
Online Application Block:
The online application receives the translated message and displays it in real time, extending communication beyond physical proximity.

1.4 Algorithm for AI Self Braking System

1. Behavior-Based Sign Language Detection
2. Initialize ESP32, flex sensors, LCD display, and Bluetooth module.
3. Read analog values from the four flex sensors.
4. Convert sensor readings into digital values using ESP32 ADC.
5. Normalize and analyze finger bending patterns.
6. Compare processed values with predefined gesture thresholds.
7. Identify the corresponding sign language output.
8. Display the translated text on the LCD.
9. Transmit the output to the online application via Bluetooth.
10. Repeat the process continuously for real-time operation.

III. SYSTEM REQUIREMENTS

3.1 Hardware Requirements

- ESP32 Microcontroller – Edge processing and communication.
- Flex Sensors (4 units) – Finger bending detection.
- LCD Display (16x2 or similar) – Local output display.
- Bluetooth Module – Wireless data transmission to online application.
- Jumper Wires – Connections between components.
- Power Supply / USB Source – To power the ESP32 and peripherals.

3.2 Software Requirements

- Arduino IDE
- Online application

IV. LITERATURE SURVEY

Several studies have addressed sign language recognition, but most rely on camera-based vision systems. For example, image-processing approaches using convolutional neural networks (CNNs) provide high accuracy but require controlled lighting, complex computations, and high-power devices. These systems also pose privacy concerns because they continuously capture visual data.
Other studies use sensor gloves with multiple flex sensors to detect hand gestures. While accurate, these designs often use 5–10 sensors, increasing hardware cost, calibration complexity, and power consumption. Additionally, many existing systems provide single-channel output (either LCD or app), limiting communication reach.

Recent research in IoB (Internet of Behavior) emphasizes capturing behavioral data for real-time interpretation. However, there is limited work combining low-sensor, edge-processing, privacy-preserving, and dual-output systems for assistive sign language translation.

V. RESULT AND ANALYSIS

Parameter	Result
Gesture Detection	Accurate
Processing	Real-Time
Output	Dual-Display
Communication	Successful
Privacy	Preserved

The system successfully detects finger bending gestures using four flex sensors with high consistency. ESP32 processes the behavioral data at the edge, enabling real-time translation of gestures to text.

The LCD display shows the translated text instantly for local communication.

The online application receives the data simultaneously via Bluetooth, demonstrating remote accessibility. Compared to camera-based systems, the setup is low-cost, portable, and privacy-preserving, with minimal latency.

VI. APPLICATIONS

- Assistive communication for hearing and speech-impaired individuals. Educational tools for teaching and learning sign language.
- Remote communication in workplaces or public areas without sign language knowledge. Smart IoB-based interaction systems in hospitals, schools, and social platforms.

VII. FUTURE SCOPE

- Expand to full-hand gestures using additional sensors for more complex signs.
- Integrate machine learning algorithms to adapt to individual behavioral patterns.
- Develop a multi-lingual online application for global accessibility.
- Include haptic feedback for two-way interaction.
- Integrate with IoT ecosystems for smart home or public communication interfaces.

VIII. CONCLUSION

This work presents a behavior-centric IoB-based sign language detection system using four flex sensors, ESP32, LCD, Bluetooth, and online application. The system is low-cost, privacy-preserving, portable, and capable of dual-channel communication. By interpreting finger bending behavior in real time, it provides a practical solution to bridge the communication gap between disabled and normal individuals. The approach demonstrates that minimal-sensor, edge-processed systems can be effective alternatives to vision-based methods.

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