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Design and Development of a Flex Sensor-Based Sign Language to Text and Speech Conversion System

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Abstract - Communication between sign-language users and people unfamiliar with sign language can be difficult when an interpreter is unavailable. This paper presents a wearable sign-language translation prototype that detects finger positions using five flex sensors mounted on a glove. An Arduino microcontroller reads the analog sensor values, applies sensor-specific thresholds, and converts the five bent/straight states into a 5-bit code. The code is mapped to one of 32 predefined English words. The recognized text is transmitted to a paired mobile device through an HC-05 Bluetooth module, while selected gestures activate pre-recorded audio through ISD voice modules and a speaker. The prototype demonstrates text transmission for the predefined gesture set. Audio output is implemented for five selected messages because of the memory constraints of the ISD modules. The system provides a low-cost, portable approach to assistive communication. Further work is required to expand the vocabulary, evaluate recognition accuracy across users, and improve support for continuous and dynamic signing.

Key Words: Sign language translation, flex sensor, Arduino, gesture recognition, Bluetooth, assistive technology.

1. INTRODUCTION

Sign language enables people with hearing or speech impairments to communicate through structured hand gestures. Communication can become challenging when the other person does not understand the sign language being used. A compact translation device can help reduce this barrier by converting selected hand gestures into text and audible messages.

This work describes a glove-based system that uses five flex sensors, one for each finger, to capture bending states. An Arduino processes the sensor readings and maps each combination to a predefined English word. The translated word is sent wirelessly to a mobile device using Bluetooth. For a limited set of gestures, an ISD voice module and speaker provide pre-recorded audio output.

2. PROBLEM FORMULATION AND OBJECTIVES

A communication gap exists between sign-language users and people who do not understand sign language, particularly when an interpreter or dedicated support is unavailable. The project addresses this issue by developing a portable system that senses finger movements and produces understandable outputs. The objectives are to detect hand gestures using five flex sensors, process the readings on an Arduino and map the patterns to predefined words, display converted text on a mobile device through Bluetooth, and provide voice output for selected gestures.

3. SYSTEM DESIGN AND METHODOLOGY

3.1 Hardware architecture: Five flex sensors are fixed to the fingers of a glove. Each sensor forms part of a voltage-divider arrangement and produces an analog signal that varies with finger bending. The sensors are connected to Arduino analog input pins A0–A4. An HC-05 Bluetooth module is connected to the microcontroller for wireless transmission. ISD voice modules and a speaker are used for selected pre-recorded audio messages. A regulated power source supplies the circuit.

3.2 Gesture acquisition and encoding: During operation, the Arduino repeatedly reads the five analog sensor values using *analogRead()*.

Each reading is compared with its corresponding empirically selected threshold. A value above the threshold is treated as a bent finger (binary 1), while a value below the threshold is treated as an unbent finger (binary 0). The five binary states are combined to form a 5-bit gesture code. Since five bits provide $2^5 = 32$ possible combinations, the code can represent 32 predefined gesture patterns.

3.3 Word mapping and Bluetooth transmission: The generated gesture code is used as an index in a predefined word array containing 32 English words. The documented vocabulary includes “Hello,” “Yes,” “No,” “Thank You,” “Please,” “Stop,” “Help,” “Water,” and “Hospital.” The Arduino sends the corresponding word through the Bluetooth serial connection. The implementation uses the SoftwareSerial library and a communication rate of 9600 baud. A paired mobile device receives and displays the transmitted text through a Bluetooth terminal application.

3.4 Audio output: For five selected gesture codes, the Arduino activates the corresponding ISD voice module through digital output pins. The module plays its stored recording through the speaker. The five audio messages documented in the project are “Hello,” “Yes,” “Good,” “Thank You,” and “Stop.” Audio output is therefore available for a subset of the 32 text-mapped gestures.

4. IMPLEMENTATION

The control program is developed in C++ using the Arduino Integrated Development Environment (IDE). The flex sensor pins and their thresholds are defined in arrays. In each loop cycle, the program reads the sensors, determines the bent or straight state of each finger, and combines the states into a gesture code. The code selects the corresponding word from the gesture-word array. To avoid repeatedly transmitting the same word, the program compares the current message with the previously transmitted message. When a new message is detected, the word is sent through Bluetooth. The program also checks whether the gesture belongs to one of the five audio-enabled codes and, if so, triggers the appropriate ISD module.

5. RESULTS AND DISCUSSION

The project report documents a prototype that maps five flex-sensor states to 32 predefined gesture codes. Sensor readings are classified using individual thresholds, and the resulting code is converted into an English word. The report includes flex-value testing and a graph showing readings before bending, threshold values and readings after bending. Text transmission was demonstrated using a Serial

Bluetooth Terminal application, with received words including “Hello,” “Yes,” “No,” “Good,” “Please,” “Stop” and “Thank You.”

The report also documents audible output through five ISD modules. Because of the memory constraints of the modules used, only five selected gesture messages are available as pre-recorded audio, even though the text-mapping logic supports 32 gestures. The project report describes stable operation and low response time, but it does not provide a numerical recognition-accuracy measurement or a measured latency value. These performance metrics should be established through further testing rather than assumed.

6. LIMITATIONS AND FUTURE ENHANCEMENTS

The current design recognizes a fixed set of 32 combinations based on five binary finger states. It does not establish recognition of dynamic signs that depend on movement, hand orientation, facial expression or two-handed gestures. Audio output is limited to five messages. Sensor thresholds may also require calibration for different users and glove fittings. Future work can expand the audio vocabulary, add calibration for individual users, evaluate recognition accuracy with multiple participants, and measure response time under different operating conditions. Additional motion or orientation sensors and more advanced classification methods may be explored. A dedicated mobile application with sentence formation and improved speech output could also improve usability.

7. CONCLUSION

This paper presented a glove-based sign-language translation prototype using five flex sensors and an Arduino microcontroller. The system converts finger-bending patterns into 5-bit codes representing 32 predefined gestures, transmits the corresponding English words to a mobile device through Bluetooth, and provides pre-recorded audio for five selected gestures using ISD modules and a speaker. The implementation demonstrates the feasibility of a compact, low-cost assistive communication aid for a limited set of predefined gestures. Broader vocabulary, user-wise calibration and quantitative performance evaluation are important next steps.

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