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Sign Language Translation Device

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I. Abstract

This paper presents the design and implementation of a wearable translator device that converts hand gestures into spoken and textual communication. Flex sensors are placed on a glove to measure finger bending, and their analog outputs are processed by an Arduino Nano microcontroller. Pre-recorded voice messages stored on an SD card are played through a DFPlayer Mini module and a compact DC speaker, while an LCD screen displays text corresponding to the detected gesture. The device further supports PLC interfacing for ex- ternal control. Experimental evaluation demonstrates reliable gesture recognition and real-time output performance suitable for assistive applications. The system offers an affordable and portable translation aid for users who rely on sign language.

II. Keywords

sign language, flex sensors, DFPlayer Mini, Arduino Nano, gesture recognition, PLC interfacing.

III. Introduction

Individuals with hearing or speech impairments frequently rely on sign language to communicate. However, most people outside special education environments are unfamiliar with sign gestures, creating a communication barrier in public and social settings. Assistive devices that convert gesture-based communication into speech or text can reduce this gap and improve accessibility.

Recent developments in flexible wearable sensors and glove-based gesture systems provide a promising direction for real-time gesture recognition. Wong et al. developed a wearable bending sensor glove for hand motion capture and demonstrated the benefits of stretchable sensing materials in capturing finger articulation [1]. Similar research on flexible sensor gloves for gesture recognition has been reported by fang et. al., where multiple sensors were integrated to detect finger postures [2]. Studies also show that micro-controller-based gesture systems can be interfaced with embedded neural networks for recognition tasks [3]

In this work, flex sensors are used to detect bending motion due to their simple electronic interface, small size and cost-effectiveness. The Arduino Nano platform provides sufficient ADC channels and processing capability to classify gestures in real time [4]. A DFMini Module is employed for audio output and enables low-latency playback of pre-recorded messages [5]. The proposed system integrates these modules into an af- fordable sign language translation device intended for assistive communication and basic gesture-controlled automation.

IV. LITERATURE REVIEW

Gesture recognition technologies generally fall under two categories: vision-based systems and sensor-based systems wearable systems. Vision-based systems utilize cameras, image processing, and machine learning algorithms to detect gestures, but they require high computation and controlled lighting conditions,lighting conditions, limiting portability. Sensor-based gloves overcome these limitations by directly capturing finger movement, offering compact and embedded-friendly designs

Soft bending and resistive stretch sensors for glove-based motion tracking have been proposed in earlier research, demonstrating feasibility for real-time gesture acquisition [1]. Flexible data gloves capable of multi-sensor integration and curvature detection continue to evolve, achieving higher resolution and stability in gesture capture [2]. There are some advanced classification algorithms like LSTM neutral networks, which can be implemented on microcontrollers, It shows the

l accuracy in wearable gesture translation [3]
Existing systems typically focus on detecting gestures but often lack integrated speech or automation capabilities. A tranlation device that provides both audio and visual output, during supporting external control through PLC integration can extend the utility of wearable gestures systems to broader communication and assistive domains.

V. SYSTEM ARCHITECTURE

The device has four main parts are as follows: sensing the hand gesture, processing the signals, giving audio and display output on LCD screen, and connecting to PLC. The working starts when the flex sensors change their voltage. The microcontroller reads these changes, processes them, and the products sound and text on the screen.

A. Gesture Sensing Unit

Flex sensors convert finger bending into proportional resistance changes, A voltage divider network containing fixed resistors converts these resistance changes into voltage signals readable by the microcontroller's analog inputs.

B. Processing Unit

An Arduino Nano is the device which collect and process the sensor data. The device platforms analog-to-digital conver- sion, applies filtering and threshold comparision, and activi- ties corresponding output modules. Documentation confirms its suitablity for compact embedded applications and sensor interfacing [4].

C. Output Unit

Pre-recorded audio files stored on a micro-SD card are played via DFPlayer Mini, a lightweight MP3 playback module with serial control capability [5]. Text output is displayed on a character LCD simultaneously.

D. PLC Interfacing

A PLC use for the hand gestures to control outside machines or systems. The microcontroller sends digital signals that the PLC can read and use.

VI. HARDWARE IMPLEMENTATION

The device has these parts: flex sensors, resistors, jumper wires, and Arduino Nano, a DFPlayer Mini with an SD card, an LCD screen, a small speaker, and a PLC connection.

A. Flex Sensors

Flex sensors are placed on the glove to measure finger bending, similar to earlier glove-based research [1], [2].

B. Threshold Calibration

By setting the threshold limits helps the device to read gestures correctly.

C. Serial Commands

Serial commands are used to control DFPlayer Mini Audio playback [5].

D. PLC

The PLC get binary signals which are based on the hand gestures. By Using seperate small parts which make the device easy to build and test.

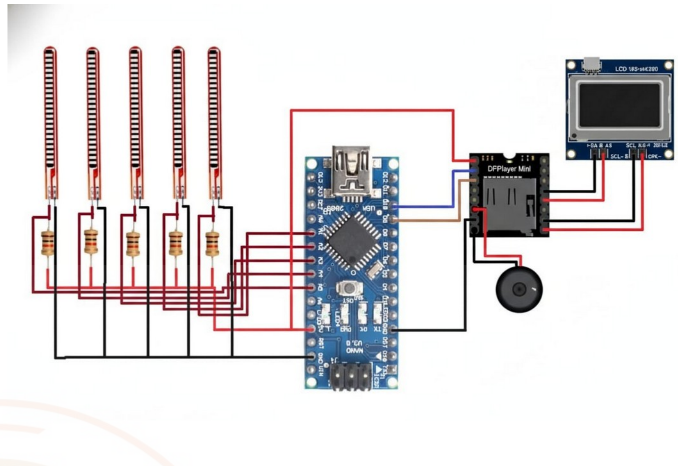

Fig. 1. Circuit Diagram

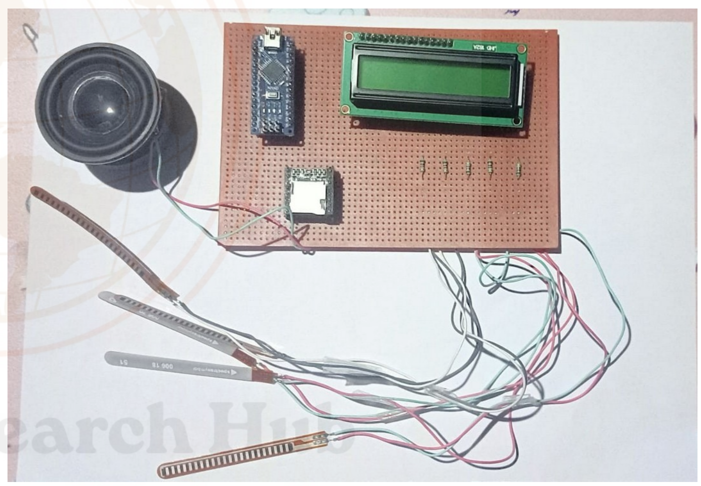

Fig. 2. Circuit Diagram

VII. SOFTWARE DEVELOPMENT

The software always checking the sensors, it reads the gestures, and turn on the output. The Arduino Nano program is written in C language and is made to work fast. The steps include reading sensor data, removing noise, checking limits, and then giving the right output.

A. Sensor Data Acquisition and Calibration

The Arduino Nano keeps reading the flex sensor values through its analog pins. When the device starts, it first check the sensor values during that period fingers are relaxed. These starting values are saved as the "normal" level. Later, the device compares every new reading with this normal level to see how much the finger is bent. The readings will be taken fast enough to catch quick finger movements but not so fast that it makes slow the device.

l Filtering and Smoothing

Because hand movements naturally generate small fluctuations,m raw ADC values require smoothing. The system makes easy the sensor readings by making average few values at a time. This will help to remove small shakes and unnecessary finger movements. The filtered signals provide stable values for comparision to the fixed thresholds.

C. Gesture Classification Algorithm

Each flex sensor voltage range is divided into threshold bands that represent finger bending levels, A combination of multiple finger states forms a unique gesture pattern. The program check the cleaned sensor values and match them to set voltage which can be ranges for each gesture. To stop wrong gesture from being detected, it waits until the sensor reading is stable in one range for a short time before accepting it as the correct gesture.

D. Output Control Logic

Once a gesture is identified, the program sends digital control signals to activate the DFPlayer Mini and LCD display modules. Audio playback is triggered by sending a command corresponding to the index of an audio file on the SD card. At the same time, the word sync to the gesture which is sent to the LCD screen. The code is written in seperate parts for sensing, then checking the gesture, and output, so each part can be changed without breaking the others.

E. PLC Interface Logic

When PLC integration is required, the microcontroller sends digital output pulses that correspond to gesture events. These signals can initiate switching, equipment control, or assistive automation process. The interface logic ensures that outputs are activated only after gesture confirmation to prevent acci- dental operation.

Fig. 3. language Signs

RESULTS AND PERFORMANCE ANALYSIS

The prototype sign language translator was tested under controlled indoor conditions to evaluate gesture detection accuracy, response time, and consistency of audio-visual output. Experiments were conducted using a set of predefined finger guestures corresponding to common vocabulary words. Each gestures was repeated multiple times to assess repeatability and stablity of sensor readings.

F. Gesture Recognition Accuracy

Gesture classification was evaluated by comparing the expected output for each gesture with actual system responses. Flex sensors voltage thresholds were calibrated individually for each finger to ensure distinct interpretation. The device consistently recognized gestures when bending angles remained within calibrated limits. Misclassification occured only when transitions between gestures was performed rapidly, indicating that stable positioning improves accuracy. Overall performance demonstrated reliable gesture translation for the tested vocabulary set.

G. Response time

The total reaction time was measured from the onset of a gesture to intiation of audio-visual output. The recorded delay included sensor sampling, filtering, threshold evaluation, and triggering of external modules. The typical response time remained below one second, providing real-time interaction from the user’s perspective. The DFPlayer Mini produced im- mediate audio playback once activated by the microcontroller, and the LCD display updated text within its standard refresh cycle.

H. Stability and Noise Handling

The Moving-average filtering improved system stability by minimizing false triggers caused by involuntary finger tremors. Sensor noise remained minimal under normal operation, and gesture outputs remained reliable as long as finger positioning remained steady for a breif confirmation period. The test results indicate that signal conditioning and filtering stretegies effectively reduce misreadings.

I. Audio and Display Output Performance

Speech clarity from the DFPlayer Mini and the DC speaker was adequete for indoor demonstration environments. Volume levels and tone remained consistent across multiple playback cycles. The LCD provided clear character visibility and accurate text representation. Both output forms demonstrated synchronized activation following confirmed gesture recognition.

J. PLC Interface Performance

When integrated with a PLC input module, digital gesture outputs were able to trigger external control logic without delay or instability. This confirms potential for extension of the tranlator into automation or assistive service applications where gesture control can supplement or replace manual switches.

APPLICATIONS

The proposed device offers practical value in range of communication and assistive contexts. Its modular hardware and portable structure enable implementation in real environments requiring hands on interaction or support for hearing or speech-impaired individuals.

- Assistive robotic devices for elderly users or individuals with mobility impairments
- Industrial robots or material-handling systems operating in hazardous environments
- Search-and-rescue robots where remote navigation is essential
- Engineering education, robotics competitions, and prototype development
- Remote inspection or surveillance robots requiring simplified control mechanisms

CONCLUSION

This work presented the design and development of a wearable sign language translator using flex sensors and embedded electronic components. The system successfully converted finger gestures into corresponding speech and visual text outputs through a compact and low-cost hardware arrangement. Flex sensors provided reliable analog signals proportional to hand movement, while the Arduino Nano performed real-time acquisition and threshold-based gesture interpretation. The DFPlayer Mini enabled immediate playback of prerecorded speech files stored on an SD card, and the LCD displayed text output simultaneously.

Performance evaluation demonstrated fast response,stable gesture recognition, and consistent audio-visual output under indoor operating conditions. The inclusion of a PLC interface expanded system usability toward automation or assistive service applications. The experimental results confirm that a practical, portable, and affordable gesture translation device can be developed using minimal hardware hardware and simple embedded software.

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