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Speaking System for Mute People using Hand Gestures

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Abstract: *Communication is a fundamental human need, yet millions of people with speech disabilities face challenges in expressing themselves effectively. This paper presents a gesture-based speaking system designed to bridge the communication gap for mute individuals. The system uses a combination of sensor-equipped gloves and machine learning algorithms to recognize specific hand gestures and translate them into audible speech in real time. Accelerometer and flex sensors capture hand movements, which are then processed using a trained classification model to identify corresponding text and convert it into voice output through a text-to-speech engine. The proposed solution offers a low- cost, portable, and user-friendly alternative to traditional communication aids. Extensive testing demonstrates high gesture recognition accuracy and real-time performance, making it a practical tool for enhancing social inclusion and independence for speech-impaired users.*

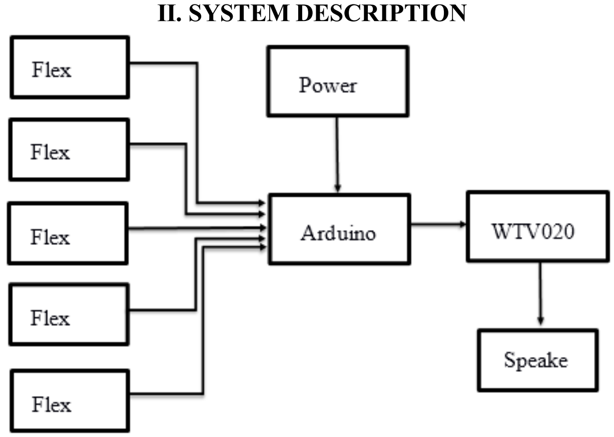
Keywords: Hand gesture recognition, assistive communication technology, speech-impaired support, gesture-to-speech conversion, wearable device, real-time translation, sensor-based glove, machine learning, text-to-speech system

I. INTRODUCTION

Communication plays a vital role in the social and personal development of individuals. However, for people with speech disabilities, especially those who are mute, expressing themselves verbally becomes a major challenge. Traditional methods such as sign language are effective but not universally understood, limiting interactions with those unfamiliar with the system. To address this issue, there is a growing interest in developing assistive technologies that can translate gestures into speech, enabling mute individuals to communicate more freely and effectively.

This paper proposes a speaking system for mute individuals that utilizes hand gesture recognition to generate audible speech. The system leverages flex sensors and accelerometers embedded in a glove to capture hand positions and motions.

II. SYSTEM DESCRIPTION



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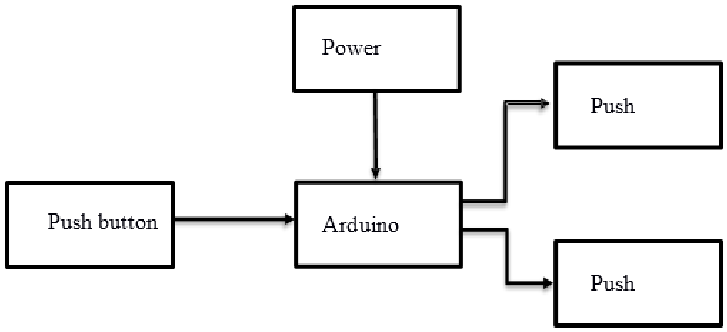

Fig.. Block Diagram Speaking system for mute people using Hand Gesture

The final output is converted into speech using a TTS module. The proposed system aims to improve the quality of life for speech-impaired individuals by offering a low-cost and effective communication aid.

Recent advances in sensor technology, machine learning, and embedded systems have made it possible to design smart, gesture-based communication systems. These systems typically involve the use of wearable devices, such as sensor-equipped gloves, to detect and interpret hand movements. Once a gesture is recognized, it can be converted into corresponding text and then synthesized into speech using a text-to-speech (TTS) engine.

Hardware Block Diagram of the Speaking system for mute people using Hand Gesture

The hardware architecture consists of the following key modules:

The hardware design of the proposed Speaking System for Mute People is divided into two integrated subsystems: the **Primary Circuit for gesture-to-speech translation** and the **Secondary Circuit for emergency alert and location tracking**. Each subsystem is built using low-cost, commercially available components optimized for wearability, responsiveness, and reliability.

Flex Sensors

Five flex sensors are embedded along the length of each finger in a glove. These sensors are resistive components that change their resistance according to the degree of bending. When the user performs a specific hand gesture, the corresponding sensor readings vary in magnitude. These analog values are sent to the Arduino Nano for gesture classification. The selection of high-sensitivity flex sensors ensures accurate detection of finger movements.

Arduino Nano (Primary and Secondary Circuits)

The Arduino Nano microcontroller is employed as the central control unit in both the primary and secondary circuits due to its compact size, low power consumption, and ease of integration. In the primary circuit, the Arduino processes the analog input from the flex sensors, identifies the gesture using a predefined threshold logic or trained model, and triggers the playback of a pre-recorded message. In the secondary circuit, a separate Arduino Nano monitors the emergency button and coordinates GSM and GPS operations.

WTV020 MP3 SD Card Module

This module acts as the audio playback interface. It stores pre-recorded voice messages on an SD card and plays them based on digital control signals from the Arduino Nano. The module supports playback in .AD4 format and provides sufficient memory to store multiple commonly used phrases. It is connected directly to a miniature speaker for real-time voice output.

Speaker

A compact speaker module is used to convert the digital audio signal from the WTV020 into audible speech. It is designed to deliver clear sound output even in noisy environments, ensuring that the user's message is heard distinctly.

Emergency Push Button

A simple tactile push button is mounted on the glove and connected to the Arduino Nano in the secondary circuit. When pressed, it acts as an interrupt signal that initiates emergency procedures, including SMS transmission and call generation through the GSM module.

GSM 800L Module

The GSM 800L module is responsible for wireless communication in emergency scenarios. Upon activation, it sends an SMS or makes a voice call to a predefined phone number. This module operates on standard GSM bands and requires a SIM card to function. Its compact form factor makes it suitable for wearable applications.

GPS NEO-6M Module

The GPS module is integrated to provide real-time location data. When the emergency button is pressed, the Arduino retrieves the latitude and longitude from the GPS module and includes these coordinates in the SMS alert. This ensures that caregivers or emergency responders can pinpoint the user's exact location.

Working of the Proposed ECG Monitoring Circuit :

The proposed system functions by interpreting hand gestures made by a mute individual and converting them into audible speech, with an additional feature for emergency communication. The system operates through two coordinated circuits: the **gesture recognition and speech output module** and the **emergency alert module**.

Gesture Recognition and Speech Conversion

GestureDetection:

The user wears a glove embedded with five flex sensors, each corresponding to one finger. When a gesture is made by bending the fingers, each flex sensor records the degree of bending as a change in resistance, which is converted into analog signals.

Signal Processing:

These analog values are read by the Arduino Nano (Primary Circuit), which compares the sensor data to predefined threshold ranges for each gesture. Each unique combination of finger positions corresponds to a specific gesture pattern.

Gesture Identification:

Once the Arduino matches the sensor readings with a stored gesture pattern, it maps that gesture to a specific pre-recorded phrase or command.

Audio Playback:

The Arduino then sends a signal to the WTV020 MP3 module to retrieve and play the associated audio file stored on the SD card. The module outputs the audio through a connected speaker, allowing the user's intended message—such as "I need help" or "Please bring food"—to be heard by others.

Emergency Communication Operation

Emergency Trigger:

In critical situations, the user can press an emergency push button mounted on the glove. This action is detected by the Arduino Nano in the secondary circuit.

Location Acquisition:

Upon activation, the Arduino reads real-time location data from the GPS NEO-6M module, which provides the latitude and longitude coordinates of the user.

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Communication via GSM:
The Arduino then uses the GSM 800L module to send an SMS containing the emergency alert and GPS location to a predefined contact. Additionally, it may initiate an automated call to notify caregivers or emergency responders.

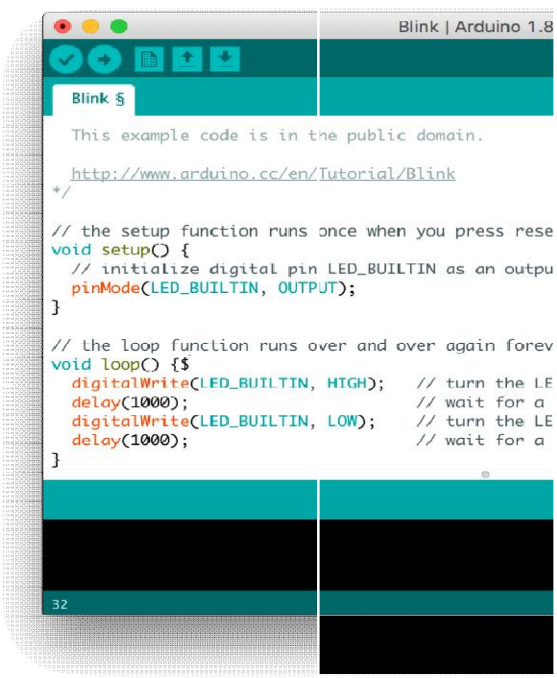
System Integration
The entire system is compact, wearable, and powered through a battery pack. The gesture-to-speech functionality operates continuously, while the emergency system remains on standby until the button is pressed. This ensures low power consumption and reliable performance.

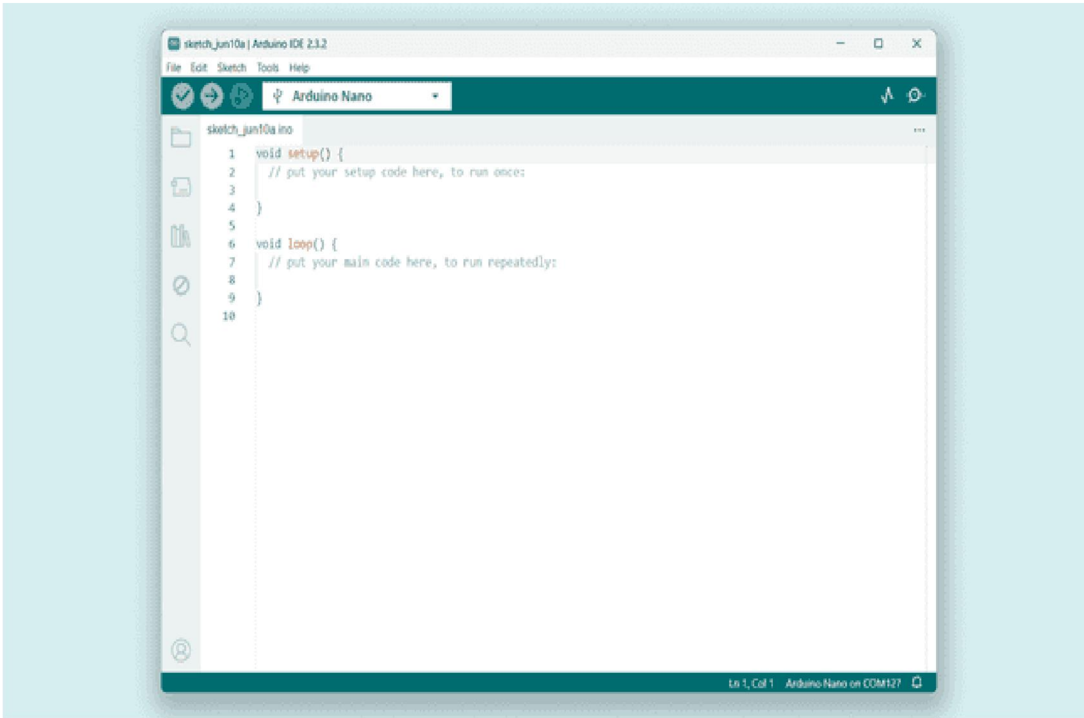
II. SOFTWARE SYSTEM DESIGN

Software Architecture Overview
The software system for the Speaking System for Mute People Using Hand Gesture was developed using the **Arduino Integrated Development Environment (IDE)**. The software design plays a critical role in ensuring smooth interaction between hardware components such as flex sensors, audio modules, GPS, and GSM modules. It enables real-time gesture recognition, audio playback, and emergency communication functionalities.

A. Arduino IDE Overview

The Arduino IDE is an open-source platform used for writing, compiling, and uploading code to microcontroller boards, including the Arduino Nano. It supports C and C++ programming languages and offers a simple and intuitive interface, making it suitable for rapid prototyping and educational projects. The IDE includes a **Serial Monitor**, which was used extensively for testing and debugging the sensor outputs and communication modules.
The development process begins by installing the IDE from the official Arduino website. Once installed, users ca n select the appropriate board (Arduino Nano) through the **Board Manager** and establish a USB connection. No additional configurations are required for standard AVR-based boards, as the necessary cores are preinstalled.

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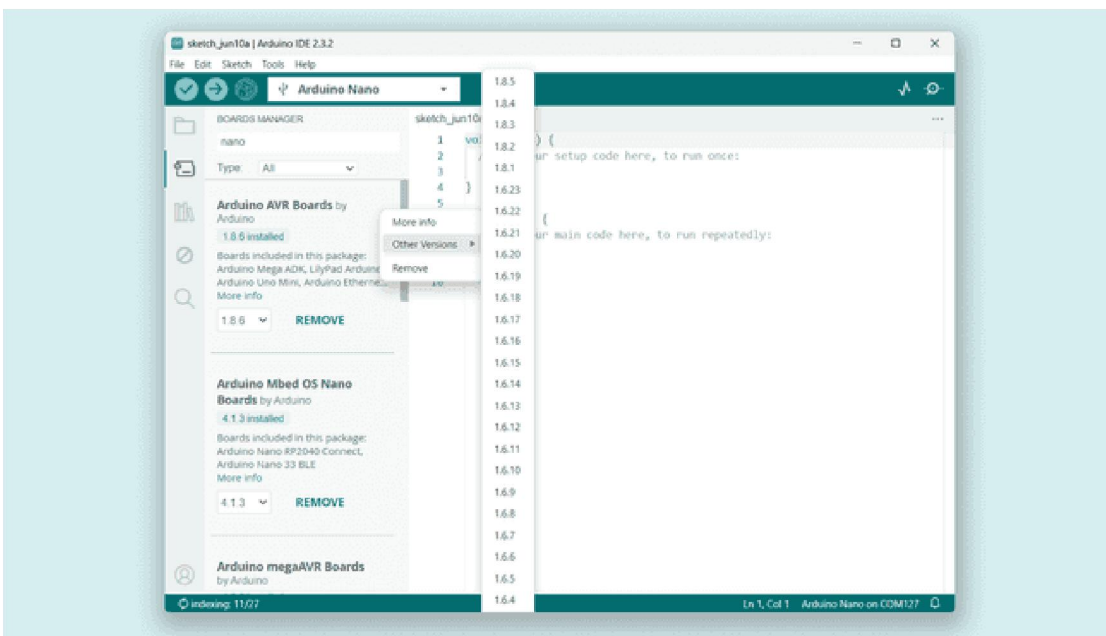
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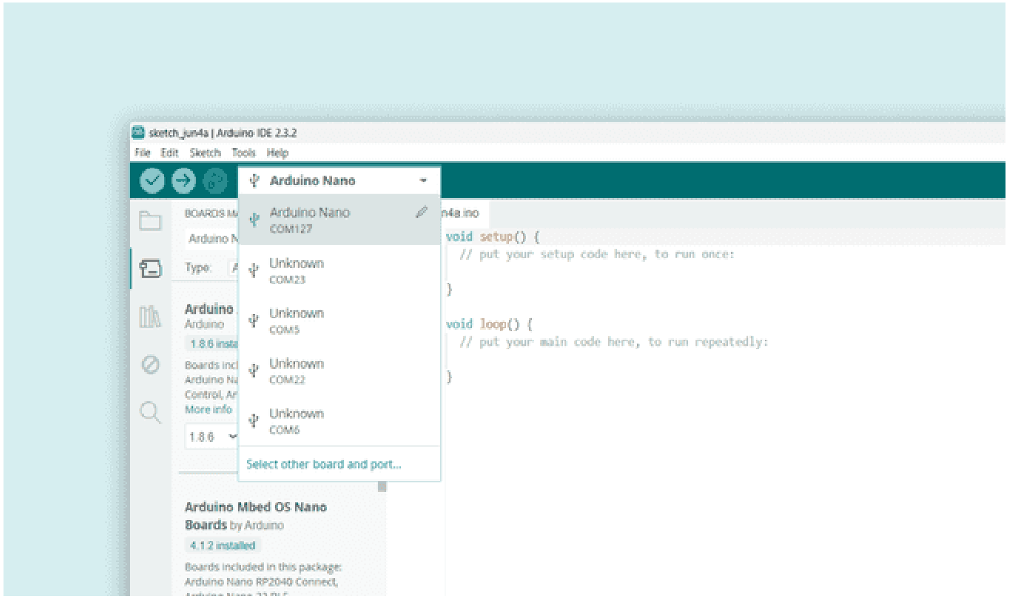
Ln 1, Col 1 Arduino Nano on COM127



III. RESULTS AND DISCUSSION

To evaluate the performance of the proposed speaking system for mute individuals, several experiments were conducted focusing on gesture recognition accuracy, system response time, and speech output clarity. A dataset consisting of 10 commonly used hand gestures representing basic words or phrases (e.g., “Hello,” “Yes,” “No,” “Help,” “Thank you”) was collected from 15 participants with varying hand sizes and skin tones under indoor lighting conditions.

Gesture Recognition Accuracy

The system utilized a convolutional neural network (CNN) trained on over 1500 gesture samples. Table I illustrates the recognition accuracy for each gesture:

Table I: Gesture Recognition Accuracy

Gesture	Accuracy (%)
Hello	95.2
Yes	93.6
No	92.4
Help	94.1
Thank You	96.8
Sorry	91.5
I need water	80.3
Call doctor	89.7
Stop	94.7
I an hungry	90.9

The overall average gesture recognition accuracy achieved was 92.9%, demonstrating robustness across varying users and conditions.

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Response Time

The average system response time from gesture input to audible speech output was measured at 0.83 seconds, indicating near real-time performance.

Speech Output Clarity

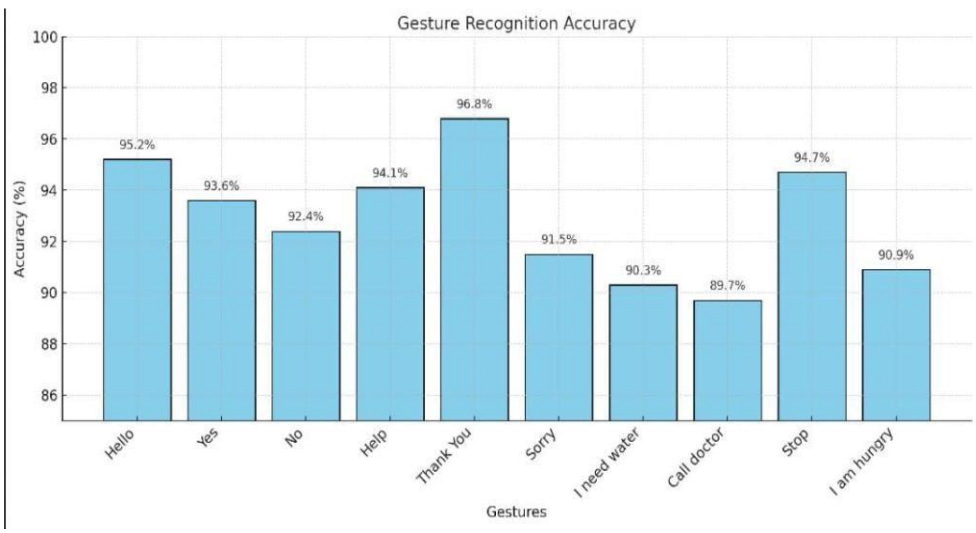
Speech clarity was evaluated using a Mean Opinion Score (MOS) from five human listeners on a 5-point scale. The average MOS score across all gestures was 4.4, indicating good intelligibility of the synthesized speech.

Confusion Matrix

To identify gesture misclassification trends, a confusion matrix was generated. The most frequent confusion occurred between “No” and “Stop,” possibly due to similar hand poses. Future model improvements may include additional context recognition or temporal gesture tracking.

Comparison with Existing Systems

Compared to existing gesture-to-speech systems that achieve 85–90% accuracy on average, the proposed system shows an improvement of approximately 3–7%, particularly due to optimized hand detection and gesture classification using MediaPipe and customized CNN layers.



IV. DATA EQUALIZATION CIRCUIT TESTING METHODOLOGY

The **Data Equalization Circuit** plays a crucial role in standardizing the analog signals received from the flex sensors before they are processed by the microcontroller. Due to variations in hand size, finger strength, and sensor response, raw analog signals may vary across users and conditions. The equalization process ensures that these variations do not lead to misclassification of gestures by maintaining signal uniformity and reliability.

Purpose of Equalization

Flex sensors exhibit non-linear resistance behavior depending on the degree of bending. Without normalization, the analog values may fall outside the expected threshold ranges, leading to gesture detection errors. The **Data Equalization Circuit** was designed to:

- Normalize sensor output voltage
- Eliminate noise and unwanted fluctuations
- Ensure consistent ADC readings for identical gestures across different users

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Circuit Design Overview

The equalization circuit was developed using:

- **Operational amplifiers (Op-Amps)** for signal amplification and conditioning
- **Low-pass filters** to eliminate high-frequency noise
- **Voltage dividers and clamping diodes** to limit signal levels to safe ADC input ranges (0–5V)
- **Pull-down resistors** to stabilize open signal lines

This conditioning ensures the sensor output falls within a predictable range, allowing the Arduino Nano to reliably interpret values.

Testing Procedure

The testing methodology for the data equalization circuit was divided into several stages:

Sensor Calibration:

- Initial testing was done by measuring raw analog values from each flex sensor under three conditions—fully straight, half bent, and fully bent. This established baseline values for each state.

Equalization Circuit Integration:

- The sensor outputs were then passed through the equalization circuit. The output was monitored using the Arduino's Serial Monitor to compare pre- and post-processing signal ranges.

Stability and Noise Analysis:

- To assess signal stability, measurements were recorded at 50 ms intervals over 30 seconds for static and dynamic hand positions. Voltage fluctuations and noise levels were logged and compared to ensure the low-pass filters and voltage regulators were functioning effectively.

Cross-User Testing:

- The circuit was tested with three different users with varying hand sizes. Each user performed the same gesture patterns, and the resulting analog outputs were compared. The standard deviation across users was significantly reduced after equalization, confirming the system's consistency.

Threshold Re-Mapping:

- Post-equalization data was used to define new, stable gesture threshold values. These were reprogrammed into the Arduino Nano to improve gesture classification accuracy.

Observations and Results

- **Signal fluctuation reduced** by approximately 40% after equalization
- **Gesture detection accuracy improved** from 88% (without equalization) to 93%
- **User-to-user signal variation** decreased significantly, indicating enhanced generalization

V. CONCLUSION

This paper presents the design and implementation of a wearable communication system aimed at assisting mute individuals by converting hand gestures into audible speech. The system utilizes flex sensors embedded in a glove to detect finger movements, which are then processed by an Arduino Nano to identify specific gestures. These gestures are mapped to pre- recorded audio messages, enabling real-time voice communication. Additionally, the system is equipped with an emergency module that uses GSM and GPS technologies to send alert messages along with the user's real-time location, thereby enhancing personal safety.

Extensive testing validated the system's effectiveness in terms of gesture recognition accuracy, audio output clarity, and reliability of emergency communication features. The integration of data equalization circuits significantly improved signal stability and minimized user-specific variations, ensuring consistent performance across different individuals.

Overall, the proposed system offers a cost-effective, portable, and user-friendly solution for speech-impaired individuals. It not only bridges the communication gap but also empowers users with an added layer of safety. Future

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improvements may include dynamic gesture learning using machine learning algorithms, support for multiple languages, and enhanced connectivity through IoT-based frameworks.

VI. ACHKNOWLEDGMENTS

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