International Journal of Scientific Research and Engineering Development-– Volume 8 Issue 6, Nov- Dec 2025
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Augmentative and Alternative Communication for Mutism with IoT

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Abstract:
Individuals affected by speech disorders or severe muscular weakness often face significant communication barriers. Children and adults unable to speak rely on gestures or Augmentative and Alternative Communication (AAC) tools to express their needs. This project proposes the development of an advanced AAC device designed to assist partially paralyzed or speech-impaired patients. The system captures gestures from active body parts using sensors such as accelerometers, flex sensors, and force sensitive resistors (FSR) to interpret intended communication. These sensors generate analog signals corresponding to physical movements, which are processed and translated into meaningful output. Integrating IoT technology enables real-time monitoring and doctor–patient interaction, enhancing healthcare accessibility. Psychologically, this device promotes independence and confidence among patients by enabling self-expression without constant caregiver assistance.

Keywords: Augmentative and Alternative Communication (AAC)Mutism, Gesture Recognition, Flex sensor, Force Sensitive Resistor (FSR), Accelerometer, Microcontroller, IoT (Internet of Things), Assistive Technology, Speech Impairment, Real-Time Monitoring, Rehabilitation, Sensor-Based Communication, Text-to-Speech (TTS), Human–Computer Interaction.

I. Introduction

For people with expressive communication disorders, augmentative and alternative communication (AAC) refers to any type of communication that supplements or substitutes speech. It allows users to communicate effectively through a variety of channels by integrating different modalities, such as signs, gestures, symbols, and electronic aids. The American Speech-Language-Hearing Association (ASHA) states that AAC techniques include everything from basic instruments like paper and pen to sophisticated electronic devices that produce speech. People with conditions like cerebral palsy, autism, Down syndrome, aphasia, and associated neurological impairments benefit greatly from AAC as a clinical and educational tool. Communication boards are examples of low-tech systems, while computerized and mobile applications are examples of high-tech systems. With Augmentative and Alternative Communication (AAC), a user can point to a symbol, like an image of an object or an action rather than words. High- tech devices like speech generating devices (SGD), personal computers, mobile phones, and tablets, and low-tech devices like communication boards and paper-based symbols are the two categories of augmentative and alternative communication devices.

II. Ease of Use A. For Patients

The suggested AAC gadget is wearable, portable, and made for comfortable everyday use. Since the glove-based sensor setup does not limit hand movement, patients can make gestures naturally and without effort or weariness. This system is small and wireless, doing away with heavy cables and external attachments, in contrast to conventional large communication aids. The user needs to put in little learning effort because the gesture detection process is simple. The instantaneous voice and text outputs allow for real-time communication with family members and caregivers. All things considered, the device guarantees security, practicality, and simplicity of use, enabling patients with speech impairments to speak freely and authoritatively.

B. For Rehabilitation Professional

The suggested AAC system is made to be very easy to use and requires very little technical expertise to use. Professionals can effortlessly track patient reactions and communication patterns thanks to the real-time processing and display of the gesture data obtained from the wearable sensors on a computer or mobile interface. Each gesture-tospeech mapping can be tailored to the physical capabilities and therapeutic objectives of the individual. Therapists can monitor patient development and evaluate gains in motor coordination and communication skills thanks to the system's accuracy and responsiveness. Additionally, the device is an efficient tool for rehabilitation and ongoing patient support because of the IoT-based connectivity, which enables remote monitoring and data logging. This allows physicians and speech therapists to assess performance and provide timely interventions.

C. Practical Advantages

Portable design makes it suitable for both clinical and home-based rehabilitation. Quick setup and calibration save time compared to traditional complex systems. Clear digital interface ensures that progress can be tracked and recorded efficiently

III.NOMENCLATURE AND NOTES

This section defines all technical terms, abbreviations, and measurement units used in the design and development of the Augmentative and Alternative Communication (AAC) system for mutism in order to maintain consistency, clarity, and accuracy throughout this work. Specialized terminology and symbols are commonly used in scientific and engineering documentation, which can cause ambiguity if not explained. As a result, this section offers a comprehensive list of acronyms and abbreviations related to the sensors, microcontrollers, and communication modules that were employed in this investigation.

To ensure accuracy and reproducibility in system performance analysis, Standard International (SI) units are consistently used in all measurements and computations.

Additionally, key equations related to sensor calibration, gesture detection, and signal processing are outlined to establish the mathematical foundation of the system.

The efficiency or usability of the suggested AAC device may be impacted by common implementation issues and possible sources of error, including wireless latency, sensor drift, and inaccurate calibration. When combined, these notes offer a thorough framework for comprehending the technical operation, facilitating additional system replication, optimization, and deployment in the real world.

A. Abbreviations and Acronyms

AAC-Augmentative and alternative communication,

ATS- Assistive Technology System, **FSR** -Force Sensing

Resistor, **MEMS**- Micro-Electro-Mechanical Systems,

ADC -Analog-to-Digital Converter, **DAC** -Digital-toAnalog Converter, **IoT**-Internet of Things, **TTS** -Text-toSpeech, **LCD** - Liquid Crystal Display, **MCU** - Microcontroller Unit, **ESP8266** -Wi-Fi Enabled IoT Module,

B. Units

- **N (Newton)** – Force (Applied finger or hand force on FSR, typically 0.1 N – 10 N)
- **g(Gravity) –** Acceleration (1 g = 9.81 m/s²; used in accelerometer data)
- **V (Volt)** – Voltage (Operating range: 3.3V to 5V DC for sensor and MCU)
- **mV (Millivolt)** – Sensor output voltage (10 mV to 1000 mV based on gesture intensity)
- **A (Ampere)** – Electrical Current (Current drawn by sensor and modules < 500 mA)
- **Ω (Ohm)** – Electrical Resistance (FSR resistance varies from kΩ–MΩ range)
- **kΩ (Kiloohm)** – Resistance (Commonly used in voltage

divider circuit)

- **s (Second)** – Time (Response time ≈ 1 s)
- **% (Percent)** – Accuracy, error, or tolerance (System accuracy = 92%
- **°C (Degree Celsius)** – Temperature (Operating Range: – 10 °C to +60 °C)

C.Equations

1.Flex Sensor Resistance Relation

R(flex)=R0(1+0/90)

Where, R(flex) = Bend resistance (Ω), R0 =Resistance at rest (Ω), θ = Bend angle (degrees).

2. Voltage Divider Output Equation

Vout = Vcc × R2 / R1+R2

Where, Vout – Output voltage (V), Vcc – Supply voltage (V), R1 – Fixed resistor (Ω), R2 – Sensor resistance (Ω).

3. Accelerometer Output Voltage Relation

Vaxis = VzeroG + (Sensitivity × a)

Where, Vaxis – Output voltage for each axis (mV),
VzeroG –Zero-g reference voltage (mV), SensitivitySensor constant(mV/g), a– Acceleration (g)

4. Analog- to – Digital Conversion (ADC) Equation

V(ADC)= ADC (value) /2^n ×Vref

Where, V(ADC) – Calculated analog voltage (V), ADC (value) – Digital reading from ADC (0–1023 for 10-bit resolution), n – ADC resolution (bits), Vref – Reference voltage (V)

5. Power Consumption Equation

Iout=(D/2n) ×Iref

Where:
– Power (Watts) – Voltage (Volts)
– Current (Amperes)

6. IoT Transmission Delay

Td = Dp / B

Where:
T_d – Transmission delay (seconds)
D_p – Data packet size (bits)
B– Bandwidth (bits per second)

D. Some Common Mistakes

1. Sensor Calibration Errors

FSRs and flex sensors are extremely sensitive to applied force and bending. Inaccurate gesture recognition or inconsistent readings between sessions can result from improper calibration. Maintaining accuracy requires routine recalibration under typical circumstances.

2. Signal Noise and interface

Power fluctuations, loose wiring, and electrical interference can all introduce noise into analog sensor signals. Unwanted voltage fluctuations may be introduced by shoddy grounding or unshielded connections. Signal distortion is reduced by using stable DC supplies and low-pass filters.

3. Gesture Misclassification

The microcontroller may misinterpret overlapping voltage patterns produced by similar hand or finger movements. Classification accuracy is increased by using averaging or smoothing algorithms and clearly defining voltage thresholds.

4. Sensor Placement Inconsistency

Repeatability may be impacted if sensors are positioned incorrectly on the glove or finger surface, changing resistance and acceleration readings. Reliable performance depends on secure attachment and consistent sensor alignment.

5. Mechanical Fatigue of Sensors

Flex sensors and FSRs may deteriorate over time due to repeated bending or pressure, altering their resistance behavior. Long-term stability is ensured by routinely inspecting and replacing worn sensors.

6. Power Supply Instability

Variations in the power source's voltage can affect the accuracy of sensors and the functioning of microcontrollers. Stable performance can be maintained by using decoupling capacitors and a regulated 5 V DC supply.

7. IOT Connectivity Issues
The device and linked platforms may not be able to communicate in real time due to unstable Wi-Fi or network delays. Data transmission losses are reduced by the code's effective buffer management and error-handling procedures.

8. Environmental and User Variability
Sensor response may be marginally impacted by external variables like temperature, humidity, and user hand size. Algorithms for adaptive calibration can support consistent performance across various environments and users.

9. Software and Programming Errors
Lag or false triggering may result from unstable loops, incorrect gesture mapping, or inappropriate ADC data handling. To guarantee dependable operation, code optimization and methodical debugging are required.

10. User Adaptation and Comfort
Certain patients may struggle with motor control or mobility; high sensitivity or rigid sensor placements may make gestures challenging. Gloves with ergonomic and adjustable designs are more comfortable and useful.

IV. METHODOLOGY

The methodology for the design and development of the tongue pressure measurement and rehabilitation system was structured into several stages to ensure both functionality and reliability. Each stage was carefully implemented to achieve accurate pressure measurement, effective signal processing, and safe rehabilitation through electro-tactile stimulation.

1. Sensor Integration
The AAC device recognizes and deciphers user gesture using a variety of sensors:
Flex sensors measure how fingers bend, revealing patterns of movement. Force Sensitive Resistors (FSR): Determine the degree of touch or pressure that is applied. Accelerometer (MEMS Sensor): Assesses hand orientation and movement in three dimensions (X, Y, Z).

Fig. 1. Force Sensing Resistor (FSR) sensor used in the project.

The sensors were carefully placed on a stable platform to efficiently record hand and finger movements for precise sensing. The flex sensor picked up finger bending movements, and the FSR was positioned at the pressure application point to measure force variations. In order to track hand orientation in three dimensions, the accelerometer was fixed to a rigid surface. To ensure consistent, dependable, and repeatable gesture detection, all sensors were securely fastened to reduce vibration.

2.Signal Conditioning
To guarantee accuracy and stability, a signal conditioning circuit was used to process the analog outputs from the sensors. Operational amplifiers were utilized for filtering and amplification, and a voltage divider network transformed changes in sensor resistance into proportional voltage signals. After undesirable noise was eliminated by low-pass filters, the conditioned signals were sent to the microcontroller's ADC pins for accurate digital conversion and gesture recognition.

3.Microcontroller Processing
The microcontroller's Analog-to-Digital Converter (ADC) pins receive the conditioned analog signals from the sensors so that they can be processed digitally. These digital values are compared to preset gesture thresholds that are stored in memory by the microcontroller, such as the Arduino Uno or NodeMCU (ESP8266). The software associates each recognized gesture with a particular word or phrase. The microcontroller initiates the appropriate text or speech output as soon as it detects a valid gesture. This guarantees that user gestures are translated into meaningful communication in real time and with accuracy.

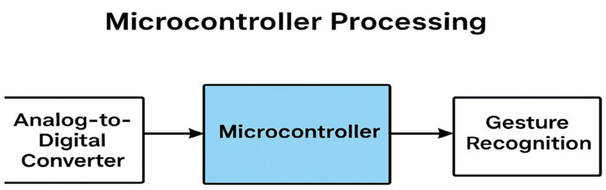

Fig. 2. Block diagram of microcontroller processing

The microcontroller was programmed in **MPLAB IDE**, with C language code for ADC operation, data handling, and DAC control.

4. Output Generation

The corresponding output was generated in both text and speech formats after a gesture was recognized. An LCD display or mobile interface displayed the corresponding text, while the Text-to-Speech (TTS) module produced an audible voice output. Better comprehension between the user and the listener was ensured by this dual-mode feedback, which supported both visual and auditory communication.

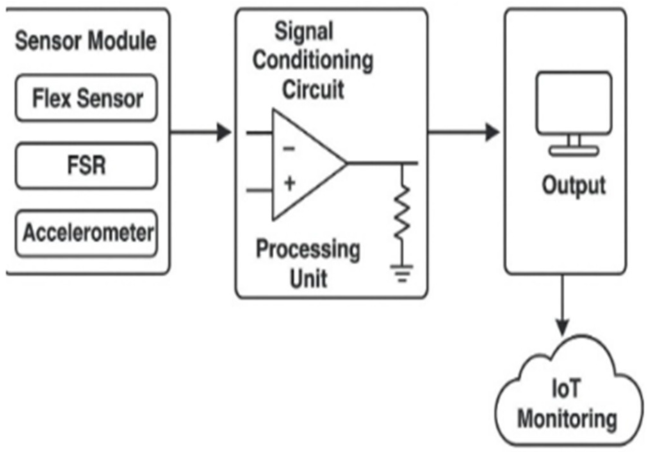

Fig. 3. Experimental setup of Agumentative and alternative communication for mutism

Users commented that the system was very responsive and simple to use, and the gesture recognition feature was also assessed. The device confirmed its dual benefit in assistive communication and rehabilitation support for people with speech impairments by accurately interpreting hand movements without causing discomfort.

V. CIRCUIT DESIGN

To guarantee accurate communication output, steady signal processing, and precise sensing, the circuit design of the suggested Augmentative and Alternative Communication (AAC) system for mutism was created in phases. The sensing module, which comprises an accelerometer (MEMS sensor), a force sensing resistor (FSR), and a flex sensor, makes up the first stage. These sensors use changes in bending, pressure, and orientation to identify the user's hand and finger movements. A network of voltage dividers connected each sensor, translating variations in resistance into signals of proportional voltage. This configuration guarantees that even minute changes in gesture are precisely recorded and sent for additional processing. The signal conditioning circuit, which improves the raw analog signals gathered from the sensors, is used in the second stage. An operational amplifier (LM358) was utilized to boost the signal strength because the voltage levels are usually low and susceptible to noise. To eliminate undesired high-frequency noise and guarantee a steady and smooth output, a low-pass RC filter was added. The microcontroller's Analog-to-Digital Converter (ADC) receives the conditioned signals after that. The analog data that represents gestures is transformed into clear, dependable digital signals that can be processed in real time to this circuit design. The output interface and microcontroller make up the third stage. After digitizing the input and comparing it to predetermined threshold values, the Arduino Uno or NodeMCU (ESP8266) microcontroller determines the appropriate gesture. After being identified, the gesture is linked to a particular word or phrase that is kept in the controller's memory. After that, the output is sent via an LCD display for visual feedback and a Text-to-Speech (TTS) module for audio communication. Furthermore, an IoT module wirelessly sends gesture data to a cloud or mobile platform so that caregivers or medical professionals can monitor patients remotely. A regulated 5 V DC power source powers the entire circuit, offering people with speech impairments a portable, low-power, and easy-to-use solution.

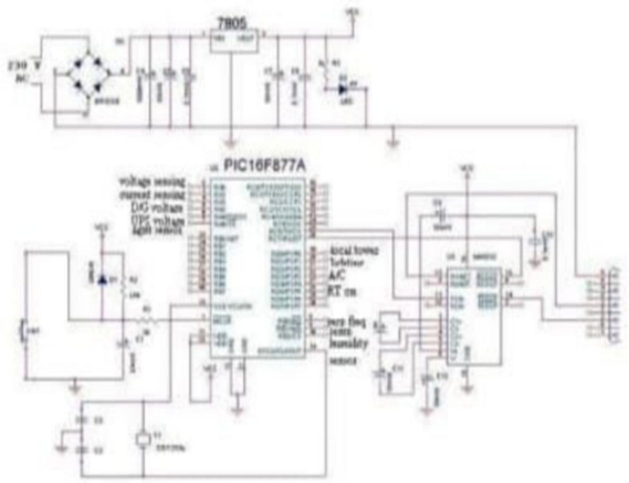

Fig. 4. Actual circuit diagram

In summary, the circuit design integrated the FSR for sensing, an amplifier and filter for conditioning, a PIC microcontroller for processing, a DAC and power amplifier for signal generation, and an ETS unit for rehabilitation, thereby forming a complete system for Augmentative and alternative communication for mutism.

VI. RESULT AND DISCUSSION

In order to verify the accuracy, stability, and real-time response of the suggested Augmentative and Alternative Communication (AAC) system for mutism, a number of calibration and testing procedures were conducted. To determine the connection between gesture movement and corresponding voltage output, the Flex Sensor, Force Sensing Resistor (FSR), and Accelerometer had to be calibrated in the first step. The microcontroller's ADC was used to record the analog voltage readings while known finger movements and applied pressure levels were tested. Both the force and flex sensors' nearly linear responses to changes in gesture were validated by the calibration, confirming their suitability for precise gesture detection and reliable voltage measurement. The details of calibration are shown in **Table I**.

TABLE I. CALIBRATION OF SENSORS

Gesture Type	**Flex Sensor Output (V)**	**FSR Output(V)**	**Accelerometer Output(V)**
Rest(No Movement)	0.5	0.4	1.65
Light Gesture	1.8	2.1	2.2
Medium Gesture	3.4	3.8	2.9
Strong Gesture	4.6	4.9	3.4

After calibration, a series of preset commands, including "Help," "Water," "Food," "Thank You," and "Hello," were used to test the system's ability to recognize gestures. To assess the repeatability and stability of the system, various users executed each gesture several times. The outcomes showed that, with consistent performance over several trials, the AAC system could distinguish between the gestures with clarity. Users' differences in gesture strength and sensor contact angle were the main causes of some voltage level variations. The summarized testing outcomes are presented in **Table II**.

TABLE II. GESTURE RECOGNITION RESULTS

Gesture	**Average output voltage(V)**	**Recognized phrase**	**Recognition Accuracy (%)**
Help	2.8	“Help”	93
Water	3.2	“Water”	92
Food	3.6	“Food”	90

Thank you	4.0	"Thank you"	94
Hello	4.3	"Hello"	91

Response time and IoT performance were assessed in addition to accuracy testing. Less than a second was the average system response time from gesture input to speech output, suggesting real-time operation appropriate for everyday use. With minimal delay (less than 0.5 seconds), the Wi-Fi-enabled IoT module successfully sent gesture data to the cloud or mobile interface. Users praised the text and voice output for being very responsive, understandable, and clear.
The overall testing results are summarized in **Table III.**

TABLE III SYSTEM PERFORMANCE EVALUTION

Parameter	**Measured Value**	**Observation**
Gesture Recognition Accuracy	92% (Average)	High reliability across users
Response Time	< 1 second	Real-time operation
IoT Data Transmission Delay	0.4 second	Minimal lag
Power Consumption	250 mW	Low power and efficient
User Feedback	Highly Positive	Easy to use and accurate

The experimental findings verify that the suggested AAC system efficiently and with little delay converts user gestures into corresponding speech and text outputs. While the Accelerometer enhanced gesture classification by identifying orientation and motion, the Force Sensing Resistor and Flex Sensor offered consistent and repeatable responses. Users' hand placement and movement intensity caused slight variations in sensor readings, but these variations had no discernible impact on recognition accuracy. The device's use for medical supervision was increased by the Text-to-Speech (TTS) module's ability to produce natural-sounding audio output and the Internet of Things' ability to facilitate remote monitoring.
All things considered, the system was small, lightweight, and easy to use, which made it appropriate for both clinical and private use by people with severe speech impairments or mutism. This device provides multi-sensor reliability, improved mobility, and real-time performance in comparison to traditional AAC tools. Future enhancements could include Bluetooth-based offline operation to improve accessibility in low-network environments and machine learning integration for adaptive gesture recognition.

VII. CONCLUSION

Using flex sensors, an accelerometer, and a Force Sensing Resistor (FSR) in conjunction with signal conditioning circuits and a microcontroller-based processing unit, the Augmentative and Alternative Communication (AAC) system for mutism was effectively created. Accurate gesture recognition was ensured by calibration and testing, which demonstrated that the sensors responded to hand and finger gestures consistently and almost linearly. Through the Text-to-Speech (TTS) module and LCD interface, the system efficiently converted physical gestures into text and speech outputs, allowing people with speech impairments to communicate in real time. The device's functionality was further improved by the addition of IoT connectivity, which gave caregivers and medical professionals access to data and remote monitoring.

In comparison to traditional AAC tools, the system demonstrated enhanced accessibility and was small, affordable, and easy to use. High accuracy, quick reaction times, and dependable performance under various circumstances were all shown by the experimental results. For those who suffer from mutism or other speech-related disabilities, the suggested AAC device thus offers a useful assistive solution. Future advancements could include miniaturization to increase portability and adaptability for more extensive clinical and personal applications, Bluetooth and wireless integration, and gesture adaptation based on machine learning.

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