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DEPARTMENT OF ELECTRICAL & COMMUNICATION ENGINEERING

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CW-1 Final Report

Project Title	**:**	**Touch to Talk: Smart Glove for Seamless Patient Communication**	
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Supervisor	**:**	Dr. Muralidharan	

DECLARATION BY THE STUDENT

We declare that this project report / dissertation titled **«Project_Title»** is our own work and has not been submitted in any form for another degree or diploma at any university or other institutions of tertiary education. Information derived from the published work of others has been acknowledged in the text and a list of references is given. We are fully aware of the College's policy on plagiarism and cheating, and that the penalty for submission of plagiarized report could result in a 'fail' in Technical Project/Dissertation. We have submitted a copy of this full report in electronic form to our supervisor.

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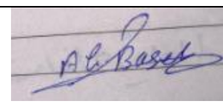
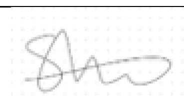
Albasel Zuhair Mubarak Al Alawi	NU200365		12/5/2025
Shima Mohammed Ali Al Shariq	NU200361		12/5/2025

Certificate by the Supervisor

The project report / dissertation titled **«Touch to Talk: Smart Glove for Seamless Patient Communication»** is the bona fide work of Mr./ Ms. **«Albasel Zuhair Mubark Alalwai and Shima Mohammed Ali Al Sharqi»**, carried out under my supervision. I certify that the work presented in the project report / he / she carry out dissertation, and that he/she has achieved the set objectives of the project / dissertation. Information derived from the published work of others has been acknowledged in the text and a list of references is given at the end of the report. I have personally checked this final report for originality/plagiarism through the *SafeAssign Tool* and, to the best of my knowledge and belief, satisfied that the report is free from plagiarism.

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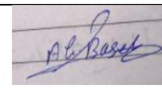
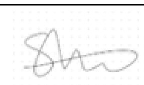
1. Albasel Zuhair Mubarak AlAlawi 	
1. Shima Mohammed Ali Asharqi 	

ACKNOWLEDGEMENT:

We are delighted to have successfully completed this project. First, we would like to express our gratitude to everyone who helped and supported us in its successful completion. This project has been a significant part of our educational and scientific journey in our university life, enabling us to gain valuable experience and a wonderful experience in applying technology to assistive and wearable solutions. We would like to extend our sincere thanks to Dr. Muralidharan for giving us the opportunity to work on this project, and for his continuous guidance and support throughout his tenure, dedicating some of his time to us. His vision and commitment to academic success have been a great inspiration to us. We also thank all the faculty and staff of the department, whose prompt guidance, facilities, and expertise helped us overcome the many challenges we faced in designing the project. We also thank all our team members for their active participation, commitment, and hard work. All members of our team have worked hard, and this project is the result of our collective efforts. Collaboration, patience, and learning from each other have made this experience truly enjoyable. We are especially grateful to our colleagues who provided valuable advice, encouragement, and even technical suggestions at critical development stages. We also thank the volunteers who helped us test our prototype and provided feedback to improve its performance and usability. Finally, we express our sincere gratitude to our families for their moral support, understanding, and continuous encouragement. Their encouragement gave us the courage to successfully complete this project. This project not only enriched our technical expertise but also taught us the importance of collaboration, planning, and perseverance. We are confident that we have come up with a solution that can make a significant difference in the field of assistive technology.

Abstract:

Despite the availability of various assistive technologies, a gap remains in effectively facilitating communication for individuals with speech impairments. This project introduces a novel smart glove system that utilizes flex sensors and Arduino technology to detect finger movements and translate them into text messages. These messages are displayed on an LCD screen in real time, allowing patients to communicate their needs clearly and independently. The system was simplified to rely solely on finger gestures for activating built-in emergency alerts. A dedicated finger gesture now triggers an audible alarm via a buzzer, providing immediate feedback and drawing caregiver attention without requiring mobile communication. The glove also features optional voice or sound alerts for enhanced feedback, increasing its usability in various healthcare settings. This semester's efforts focused on the complete design, implementation, and functional validation of the smart glove prototype. The system has been successfully built and tested, confirming its ability to translate specific finger gestures into meaningful output. This project demonstrates practical innovation in assistive technology, offering a cost-effective and user-centered solution to bridge communication barriers for non-verbal individuals. By leveraging engineering design to address real-world healthcare challenges, the smart glove empowers vulnerable patients with greater autonomy and ensures timely responses in critical situations.

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CHAPTER 1: INTRODUCTION

This chapter appears as an introduction to the project, as it aims to repeat the requirements and objectives through a detailed study. It aims to achieve this by translating finger movements into text that appears on the screen. It also shows a thorough understanding of the project, its purpose, and the impacts it aspires to achieve, which includes facilitating the lives of patients who struggle to explain the location of the disease to doctors and facilitating communication with them.

Overview:

Smart gloves are assistive wearable devices designed to support individuals with speech or mobility impairments. By translating hand and finger movements into digital messages, these gloves allow users to express themselves without speaking. The system incorporates an emergency alert feature, adding a critical safety function. This innovation merges personalized care with advanced sensor-based technology to foster communication and independence.

Research Problem:

Integrating emergency alert features into smart gloves with emergency alert systems is critical to safety. Connectivity issues, such as poor network access or Bluetooth, can delay alerts during emergencies, potentially putting lives at risk. Low power is also a risk, as emergency features can fail when the device's battery is low. Accuracy of gesture recognition systems Variations in hand size, finger strength, and user movements often lead to inappropriate interpretation of the data. Environmental factors, such as changes in temperature or humidity, can also further impair sensor accuracy. Highly sensitive sensors that are often expensive or difficult to scale are needed for recognizing complex or subtle gestures. Also, most of the time, adaptation of the system to new gestures or diverse user needs requires retraining, which limits the glove's adaptability.

Aim:

To design a smart glove that enables non-verbal patients to communicate through simple hand gestures, enhancing interaction with medical staff and improving patient care.

Project Objectives:

- To analyze various sensor technologies for their effectiveness in capturing hand movements.
- To design an interface in Python for visualizing the results of the hand gesture recognition.
- To develop a system for non-verbal patients to communicate their needs effectively.
- To create an intuitive interface that displays messages clearly on the embedded screen.
- To integrate features that cater to diverse patient needs, enhancing usability.

Scope:

The main objective of the project is to design a prototype smart glove intended to help people who have problems interpreting pain to patients. The glove will interpret certain finger movements and translate them into words that appear on a screen to aid in the communication of patients. The glove will also have an emergency button feature that will make it safer because it can send text messages to certain contacts in case of an emergency. The smart glove will be compatible with existing assistive technologies and designed to operate reliably in hospitals. The functionality of the glove will focus on accuracy in gesture detection and ease of use, emphasizing the improvement of the quality of life and independence of its users. The smart glove will be accurate, comfortable, and practical for daily use by utilizing advanced sensors and a user-centric design

Value and Importance of Research:

This research addresses a vital need in healthcare: enabling communication for patients who cannot speak. The glove enhances patient-doctor interaction, supports emergency signaling, and reduces frustration. By integrating gesture recognition into an affordable, wearable device, the glove promotes accessibility and inclusion in clinical settings.

Feasibility Study:

The feasibility of the Smart Glove project is grounded in both its technical simplicity and economic accessibility. The total estimated cost of the project is approximately 66.4 OMR, covering essential components such as the Arduino Uno board, five flex sensors, a 16x2 LCD display, a breadboard, push buttons, power supply, and necessary wiring materials. From a logistical standpoint, the project is feasible within the academic setting. The hardware is modular and can be assembled with standard lab tools. Additionally, because the glove is designed to be portable and battery-powered, it offers flexibility for use in different environments, including hospitals, homes, and rehabilitation centers. Furthermore, the glove's design is scalable. Future versions could include more advanced features like machine learning-based gesture recognition or integration with IoT platforms, depending on funding and institutional support. The current version serves as a strong prototype that demonstrates proof of concept and lays the foundation for further innovation.

Chapter summary:

In conclusion, this chapter of the project provides an overview and introduction to the Smart Glove for Patients project. The necessity, objectives, scope, and feasibility of the project are mentioned, as well as the importance of the project focusing on patients who are unable to speak due to illness or religion and who face a deficit in locating pain.

CHAPTER 2: LITERATURE REVIEW

Introduction:

In this section, a comprehensive analysis of the existing literature related to our project will be presented, focusing on key aspects essential for a deeper understanding of the project. The analysis includes a review of the research problem addressed in each study, along with the methodology employed to conduct experiments and gather data. Additionally, the parameters used in each study will be examined and interpreted in alignment with the study objectives. The discussion will cover the findings obtained, highlighting the strengths and positive aspects of each study, while also noting any weaknesses or challenges encountered. This approach will help establish a clear scientific foundation for our project.

Smart Tactile Gloves for Haptic Interaction, Communication, and Rehabilitation

The literature "Smart Tactile Gloves for Haptic Interaction, Communication, and Rehabilitation" by Ozioko and Dahiya explores the advancement of smart tactile gloves in improving human-machine interaction, particularly for users in need of rehabilitation, immersive VR/AR experiences, and alternative communication methods. The study addresses critical gaps in current smart glove technology, focusing on the need for integrated, bidirectional haptic feedback. This feature is essential for applications that require not only the sensing of physical interactions but also the delivery of responsive feedback to the user, an element that enhances realism and functionality. Through a detailed review, the authors analyze the latest advances in glove technologies, particularly those employing sensors like piezoresistive, capacitive, and piezoelectric systems. These sensors are crucial in detecting parameters such as pressure, temperature, and movement, which are foundational for delivering meaningful touch-based information. A significant strength of the document lies in its examination of "e-skin" technologies, which integrate sensors and actuators within a flexible, often skin-like form factor. This approach aims to enhance the wearability of the gloves, allowing for a seamless and intuitive experience that is more natural for users, especially those needing assistive communication devices. For instance, users who are deafblind could leverage these gloves to communicate more effectively, as the tactile feedback and motion sensing enable the transmission and reception of messages. Moreover, in VR/AR applications, the tactile gloves allow users to interact with virtual objects as if they were real, heightening the immersive experience. Figure 1 in the document (shown below) illustrates the various types of smart gloves and their applications, including touch-based, gesture-based, and gesture-and-touch-based gloves (Ozioko & Dahiya, 2021).

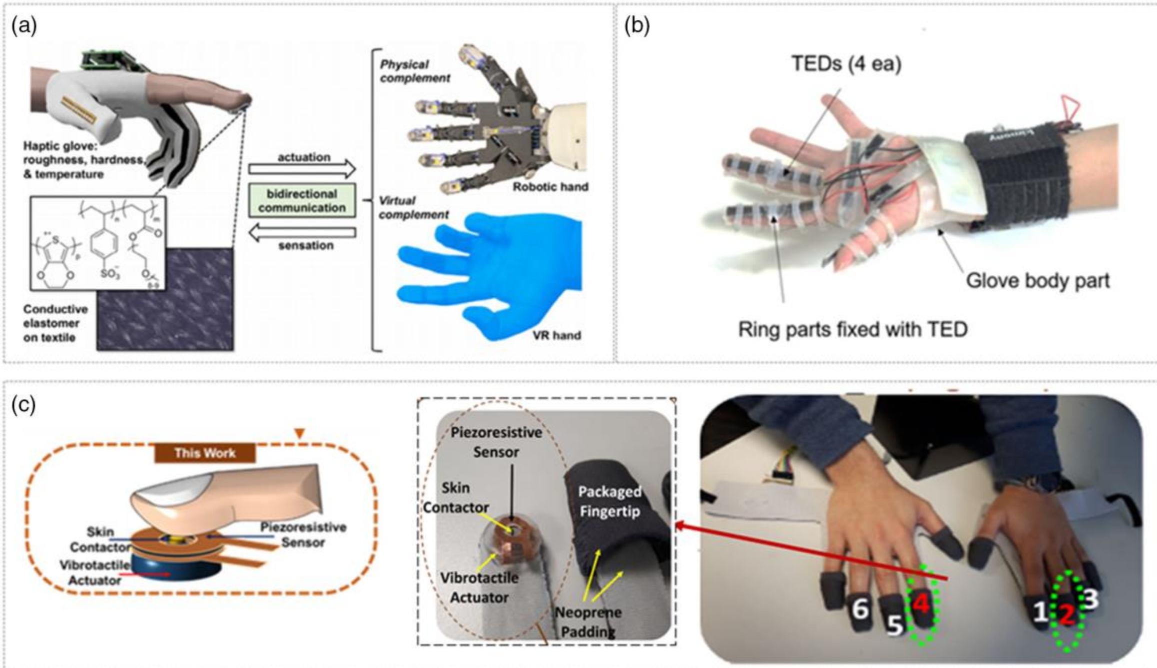

Figure 1:Categories and applications of smart gloves (Ozioko & Dahiya, 2021)

This figure categorizes the gloves based on their sensor types and functionalities, which helps readers understand the diversity of applications available for smart gloves in fields like healthcare, gaming, and telecommunication. Figure 1: Categories and applications of smart gloves, illustrating the different types of tactile sensors and feedback mechanisms that enable diverse functions across rehabilitation, VR/AR, and communication applications (Ozioko & Dahiya, 2021) .Despite these advantages, the document notes several challenges in the current state of smart glove technology. Issues such as high-power consumption, the complexity of integrating components within a compact design, and maintaining ergonomic comfort for long-term wear limit the practical use of these gloves. For example, the inclusion of multiple sensors and actuators often increases the glove's weight and bulkiness, which may cause discomfort for users, particularly in therapeutic settings where prolonged wear is common. Additionally, achieving low-latency feedback for real-time applications remains difficult, a problem compounded by the need for energy-efficient components to support long-term usability. In conclusion, the study emphasizes that while smart gloves hold considerable potential in enhancing HMI, future research must focus on developing more flexible, lightweight materials and improving battery efficiency. Advances in flexible electronics and material sciences could make these gloves more practical, especially for individuals with disabilities or those in need of physical rehabilitation. By addressing these challenges, smart gloves could become more versatile tools in fields like healthcare, communication, and immersive digital experiences, ultimately broadening their impact on users' quality of life and accessibility /1 (Ozioko & Dahiya, 2021).

A Wearable Smart Glove and Its Application of Pose and Gesture Detection to Sign Language Classification

According to DelPreto et al. (2022), Real-time data collection, processing, and analysis from the high-degree-of-freedom hand is a major unresolved issue for wearables. Given that hand gestures in particular can transmit valuable information In order to create user-friendly interfaces, glove-based systems can have a substantial influence on numerous application domains and to build a discrete resistive sensor network that covers all hand joints, connecting an accelerometer to this, and utilizing using a low-profile microcontroller and machine learning to process The glove plus a ST microcontroller can categorize 12 ASL letters and 12 ASL words in real time by pre-training an LSTM neural network and then deploying it in an embedded context using tools. By employing a leave-one-experiment-out method 96.3% of networks effectively categorize using validation methods divided instances and provide accurate rolling forecasts in 92.8% of trials using real-time streaming (DelPreto, 2022).

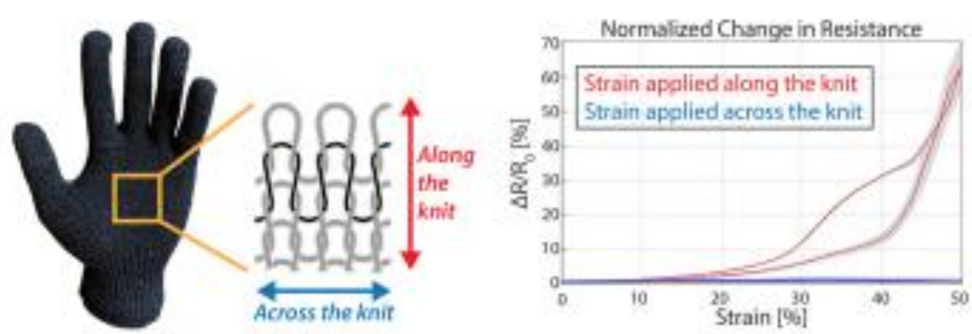

Figure 2:The response of the glove material (DelPreto, 2022)

The figure 2 show that he knit response in a device exhibits high repeatability between testing cycles, indicating consistent resistance variation. The board features an STM32H7 microcontroller for data acquisition, signal processing, and real-time neural network evaluation. The readout for 16 strain sensors is designed for stability and sampling frequency. The device uses 16-channel switches for sequential acquisition, allowing for maximum resolution for a range of sensors with different sensitivities or base resistances. The 3-axis accelerometer connects to the STM32H7 via I2C, and data acquisition, signal processing, and computation are performed on-board (DelPreto, 2022).

Smart Glove for Elderly Patients

According to J Sofia Bobby et al. (2022) Smart devices equipped with GPS and GSM provide alerts and location tracking, especially for vulnerable populations. Effective data collection for clinical analysis is achieved through remote health monitoring via mobile technologies, which enhances patient care. To assess mobility and identify health risks, wearable sensors – such as those found in insoles – have been developed. These developments demonstrate how integrated sensors and communication tools are increasingly being used, paving the way for smart solutions such as a glove that can monitor the health of the elderly and send emergency signals. Healthcare professionals can follow critical metrics and identify anomalies early with the help of remote health monitoring solutions, which use mobile technology for effective data collecting and analysis. Wearable sensors, such as insole systems, track physical activity and mobility, for instance, and can help identify falls or odd patterns of behavior. Because of these devices' portability, affordability, and ease of use, users' everyday routines will be minimally disrupted (Bobby et al., 2022).

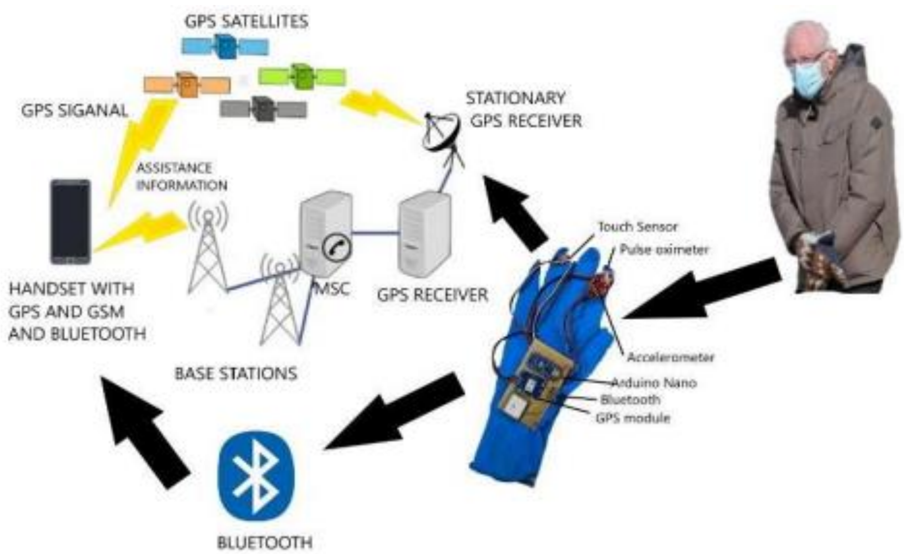

Figure 3:Smart Glove Pictorial Flow (Bobby et al., 2022)

The figure 3 show how information is transferred from an elderly person to a caregiver.

This can be accomplished in two ways:

1- Using a GPS module to send the location: A GPS receiver module is a gadget that receives data from GPS satellites and offers the device's geographic location. When the carer is far away from the victim, this kind of data transmission takes place. When the topic cannot be located, this frequently aids in their discovery. The GPS receiver is receiving the data as a full NMEA format text. The Arduino Tiny GPS library is used only to obtain the latitude and longitude coordinates. The contact listed in the code is then sent an SMS by the GSM module (Bobby et al., 2022).

2- Using a Bluetooth module to send SMS: Here, the UART Interface is used to connect the Bluetooth Module to the Arduino-based interface. The full message that the Arduino wishes to convey is first sent straight to the Bluetooth module, which then transmits it via wireless connection. When the subject is close to the caregiver, this form of data exchange takes place. It facilitates receiving information via text message (Bobby et al., 2022).

Smart Gloves with Health Monitoring and Security

The article written by Pandey et al. (2020) This research paper focused on people with speech and hearing impairments, where hand gestures were used as a main axis in the project for communication and linked via a mobile application, where the commands that occur with gestures appear as outputs in the application. Also, for people with hearing impairments, sound and display were used as outputs for them, so that these gloves also monitor the person's health. Thus, the project used about 7 components: Arduino Nano, Gyroscope Sensor, IR Transmitter/Receiver, Force Sensor, Thermistor, Bluetooth Module (HC-05), and Heart Rate Sensor and Power Supply 5V input Power supply from any suitable source. Sources can be power banks, Dc adapters (Shreya Kumari Pandey1, 2020).

This system is useful for deaf and dumb people. It works as follows: Inputs are taken through the use of hand and finger gestures and the microcontroller will process the information collected by the sensors. The Android application connected to the microcontroller produces the desired visual and audio output. Thermistor and heart rate sensors can be connected to analyze the health of the disabled person. Also, the disabled person can be tracked at all times using the GPS feature (Shreya Kumari Pandey1, 2020).

Conclusion of the paper the processing unit is connected to the smart glove via the smart communication unit. The bending sensor, which works on the concept of sending infrared rays from the infrared transmitter to the infrared receiver, is part of the system in which the glove acts as an input unit. In this case, the bending of the user's finger transmits a signal to the microcontroller, the processing unit, which transmits it back to the mobile application, the output device /1(Shreya Kumari Pandey1, 2020). Additionally, the health monitoring system includes temperature and heart rate sensors that display basic health monitoring information. Additionally, the output device receives calibrated data from the designated sensors. The API embedded in the application controls the system. This section is primarily used when the user's conditions are unbearable. The force sensor will transmit a signal when force is applied, causing the output device to send a message to the emergency number (Shreya Kumari Pandey1, 2020).

Smart Glove to Monitor Parkinson's Patients

In this research paper by Thilagavathi et al. (2018) a smart glove was developed to monitor Parkinson's patients using a wireless CPU and a flexible sensor. The length of the movement was detected by placing a flexible sensor on the index finger of a neoprene electronic fabric. The information was processed and transmitted wirelessly using Bluetooth Low Energy (BLE) Nano technology. Tremors were detected using an inertial measurement unit, or IMU. A 3-volt battery was used to mechanically power the circuits, and a conductive thread was used to make the connections. The flexible sensor is connected to a voltage divider circuit, and the Arduino software measures the analog voltage it receives (K. Thilagavathi, 2022).

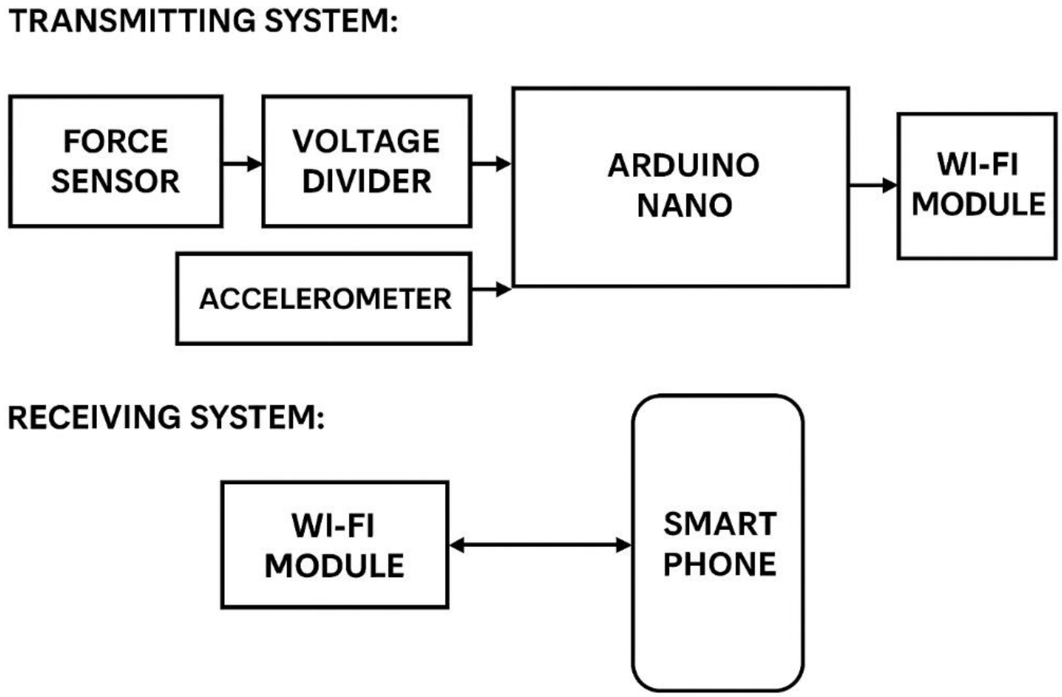

Figure 4:Block diagram (K. Thilagavathi, 2022)

When calibrating different finger and hand movements, the built program records data from the Arduino UNO via a connected connection in order to evaluate the accuracy and performance of the flexibility sensor. A Visual Basic computer application, which describes the Arduino’s USB-Serial connection, can be used to accomplish this. It recognizes the information packets collected from the Arduino on its own. It then analyzes the acquired numbers and helps in generating a visual bar indicating the degree of bending of the flexibility sensor (K. Thilagavathi, 2022).The technology used in this project is Android applications, such as Xamarin, Appellatory, Phone Gap, etc., to create an Android application that receives data from the transmitting system. Using the Wi-Fi module, the set of values collected by the accelerometer is converted into a range and sent to the receiving system. The doctor will closely monitor these values to determine the patient's condition and prescribe the appropriate treatment regimen (K. Thilagavathi, 2022).

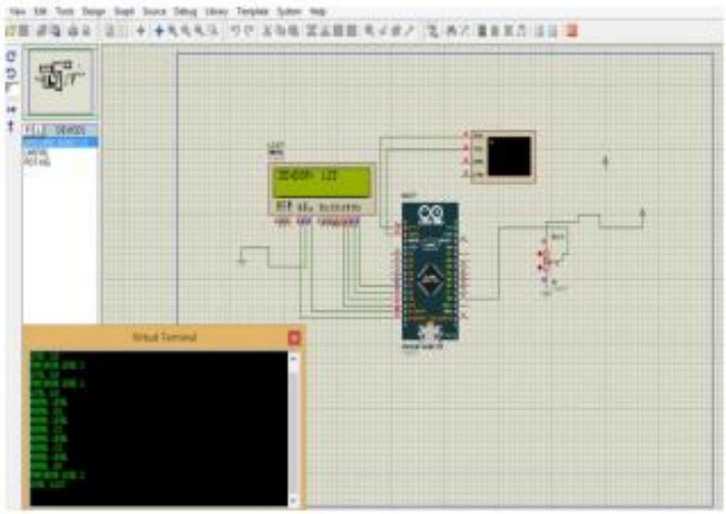

Figure 5:Simulation result of the proposed system (K. Thilagavathi, 2022)

The figure 6 show Proteus Design Suite is a popular software that is mainly suitable for automating electronic arrangements. Engineers and technicians are the primary users of the software who work in the unit responsible for electronic design to provide electronic and graphic prints for the assembly of the printed circuit board (PCB). Lab Center Electronics has opened this software, which is used for 2D computer-aided drawing projects and can also be used for PCB layout and simulation. ISIS software is mostly used for circuit simulation and schematic diagram visualization. Since it allows human access during runtime, the software provides real-time simulation. PCB design is done using ARES. The design suite allows you to examine the PCB output with 3D components (K. Thilagavathi, 2022).

Enhancing community interaction for the Deaf and Dumb via the design and implementation of Smart Speaking Glove (SSG) Based on Embedded System

According to Badawi et al. (2023) paper the materials and methods used in this project Assembling hardware five flex/bending sensor 2.2-SF10264 were attached to the thumb, index, middle, ring, and little fingers of a glove to measure the hand's clench and the fingers' bend. The hand's position and movement in space were then ascertained by attaching an ADXL335 3-axis accelerometer module to the hand's back. Sensors were interfaced with an Arduino Nano (Badawi et al., 2023). Interface for software It is an application that allows a smartphone and the HC-05 Bluetooth module to connect over Bluetooth so that messages may be heard, and text can be displayed on the phone's screen (Badawi et al., 2023).

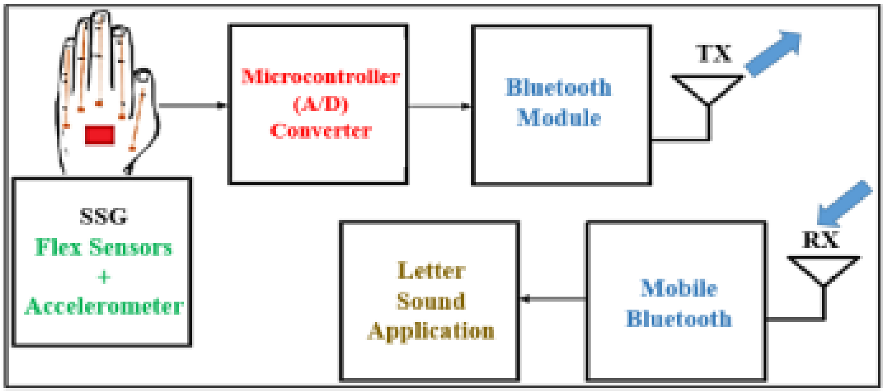

Figure 6:SSG Block Diagram (Badawi et al., 2023)

The figure 7 shows the schematic of the SSG is such that the recorded phrases were generated by the /1microcontroller using finger movements and transmitted via a Bluetooth module. Then, using a setup tool, the dataset of all the key phrases required by stupid and non-stupid individuals was merged so that ordinary people could play and see them on their mobile (Badawi, et al., 2023).

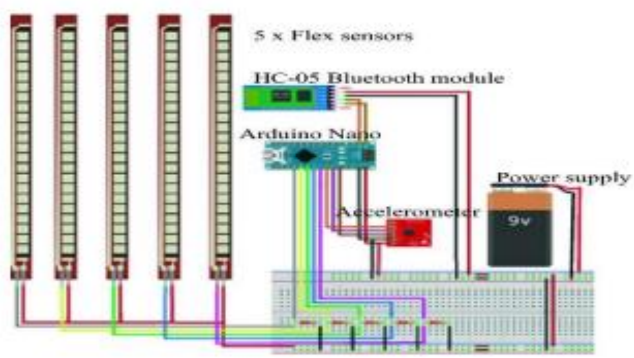

Figure 7:SSG Circuit diagram (Badawi et al., 2023)

The figure 8 shows hardware wiring diagram A voltage divider is used to represent the Flex Sensor, whose output voltage increases as it bends. Each flex sensor, which is connected to each finger and thumb in the glove, requires +5V of voltage to operate. Analog outputs are produced by this flex sensor. Consequently, this value is converted into digital form using an analog-to-digital converter. The Arduino Nano microcontroller receives the output of this ADC after that (Badawi, et al., 2023). By using the pin mode, digital write, and digital read capabilities, the Arduino Nano's 14 digital pins can be used as inputs or outputs. They are powered by 5 volts. With an inbuilt pull-up resistor range of 20 to 50 kΩ and a maximum current capacity of 40 mA, each pin is by default disconnected (Badawi, et al., 2023). The MPU6050 module from Micro-Electro-Mechanical Systems (MEMS) is displayed. It has a 3-axis accelerometer and a 3-axis gyroscope. A system's or object's acceleration, velocity, direction, displacement, and many other motion-related parameters (Badawi, et al., 2023). The Bluetooth SPP (Serial Protocol) modules like the HC-05. Since serial communication is used, there is no problem connecting to a controller or PC. The HC-05 Bluetooth module switches between master and sub-mode, making it impossible to transmit and receive data. The HC-05 module interfaces with microcontrollers as shown in Figure 8 because it relies on Serial Port Protocol (SPP) to work. The module's transmit pin must be connected to the receiver of the master module, it transmits pin must be connected to the transmitter of the microcontroller, and it must be powered by +5V (Badawi, et al., 2023). During installation, jumper wires are used to connect the Arduino nano board to all three sensors. After every connection is perfect, six sensors—including a flex sensor and an accelerometer—start to send data to the Arduino. The fingers have flex sensors that track how much they bend in reaction to glove movements. An accelerometer is mounted on the palm to measure the hand's position along the X, Y, and Z axes. Several hand gestures were used to link and test the developed circuit, and each action produced a clear sound. The smart speaking glove (SSG) prototype is depicted (Badawi, et al., 2023).

Comparison table:

Table 1:Comparison table (Self,2025).

Paper\Features:	Flex sensors	Arduino UNO	LCD	Buzzer	Gestures appear as text
(Ozioko & Dahiya, 2021)	X	X	X	X	√
(DelPreto , 2022)	X	√	X	X	√
(Bobby, Elona, Bismi, Kumar, & Santhiya, 2022)	√	√	√	X	√
)Shreya Kumari Pandey1 ،SMART GLOVES(2020 ،	√	X	√	X	X
(K. Thilagavathi, 2022)	X	√	X	X	X
(Badawi, et al., 2023).	√	X	√	X	√
Our Project	√	√	√	√	√

The comparison table highlights the superior integration of features in our smart glove project compared to existing innovations. Unlike previous studies that often-lacked key components such as gesture-to-text display or audio alerts, our project uniquely combines flex sensors, an Arduino microcontroller, an LCD, a buzzer, and real-time gesture translation. This comprehensive setup offers both visual and auditory feedback, enhancing user interaction and emergency responsiveness. As a result, the glove demonstrates a more practical and inclusive solution, positioning it as a significant advancement in assistive communication technologies.

CHAPTER3: PROJECT METHODOLOGY, DATA COLLECTION AND INTERPRETATION

Overview:

Before initiating the implementation phase of the Smart Glove project, it is essential to thoroughly define the system's requirements, including identifying all necessary components, estimating their quantities, and assessing the associated costs. This preparatory step ensures effective planning and resource management, balancing both budget constraints and performance expectations. This chapter provides a detailed overview of the tools, parts, and technologies required for the project's successful execution. The Smart Glove is designed to enhance communication for non-verbal patients—particularly those recovering from strokes or severe injuries—by using flex and pressure sensors to translate specific finger movements into textual or symbolic messages displayed on an LCD screen. The glove also incorporates an emergency button to alert caregivers when immediate assistance is needed. With a focus on usability, the glove will feature an ergonomic and lightweight design suitable for prolonged use. The development approach is informed by a comprehensive literature review to address gaps in existing assistive technologies, and the system will undergo usability testing with healthcare professionals and patients to ensure its functionality, reliability, and user satisfaction. Ultimately, the Smart Glove aims to improve patient-caregiver interactions and contribute to more inclusive and supportive healthcare environments.

Block diagram:

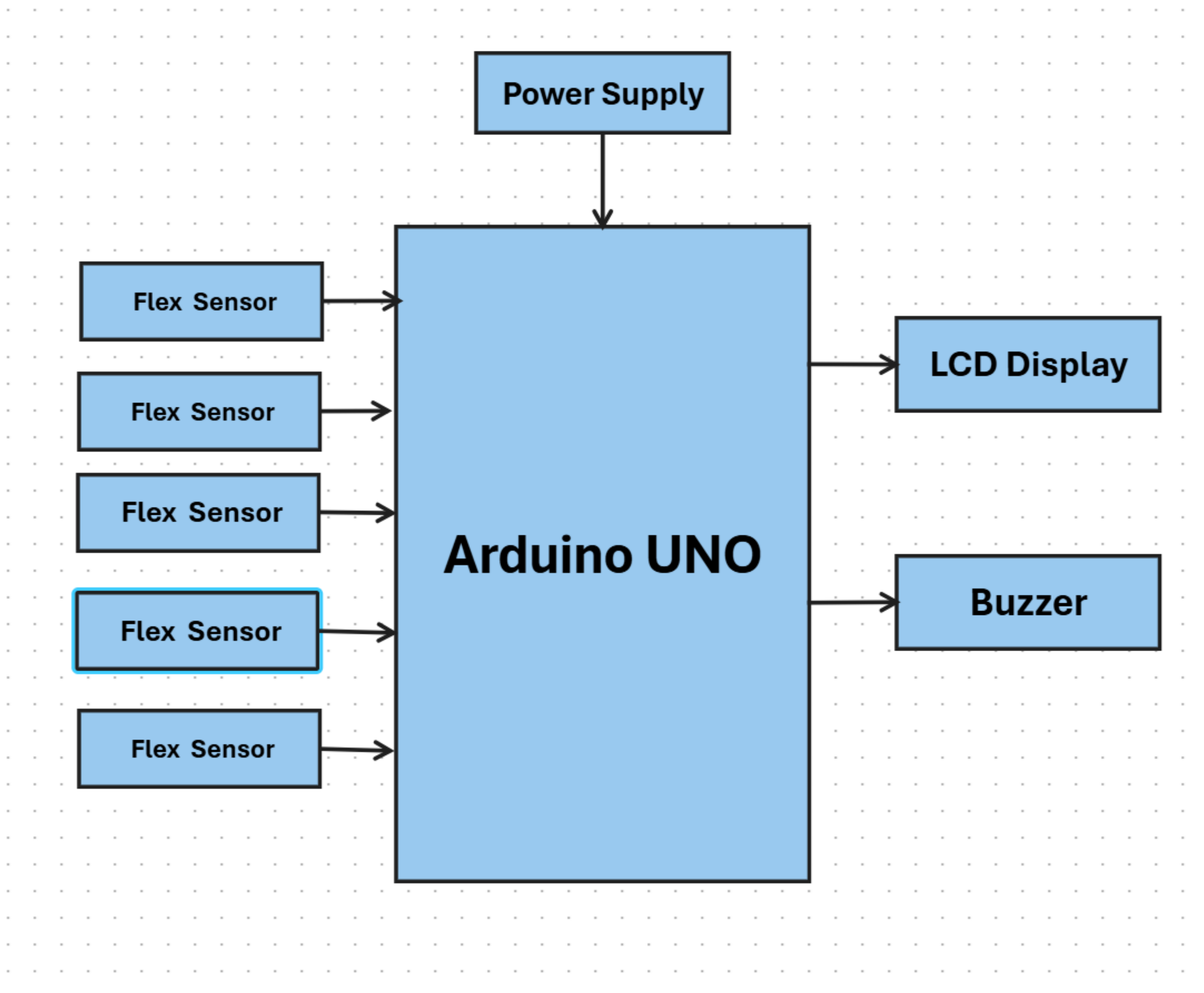

Figure 8:Block diagram (Self,2025)

The block diagram shows a 9V power supply, an Arduino board, a buzzer, and 5 flexible sensors. The power supply powers the entire system. The Arduino board serves as a central controller that processes the flexible sensors' inputs to monitor bending or flexion. Each flexible sensor displays a specific word entered in the code on the screen when a finger is moved, while one of the flexible emergency sensors is allowed to sound an alarm in case of an emergency.

Circuit Design:

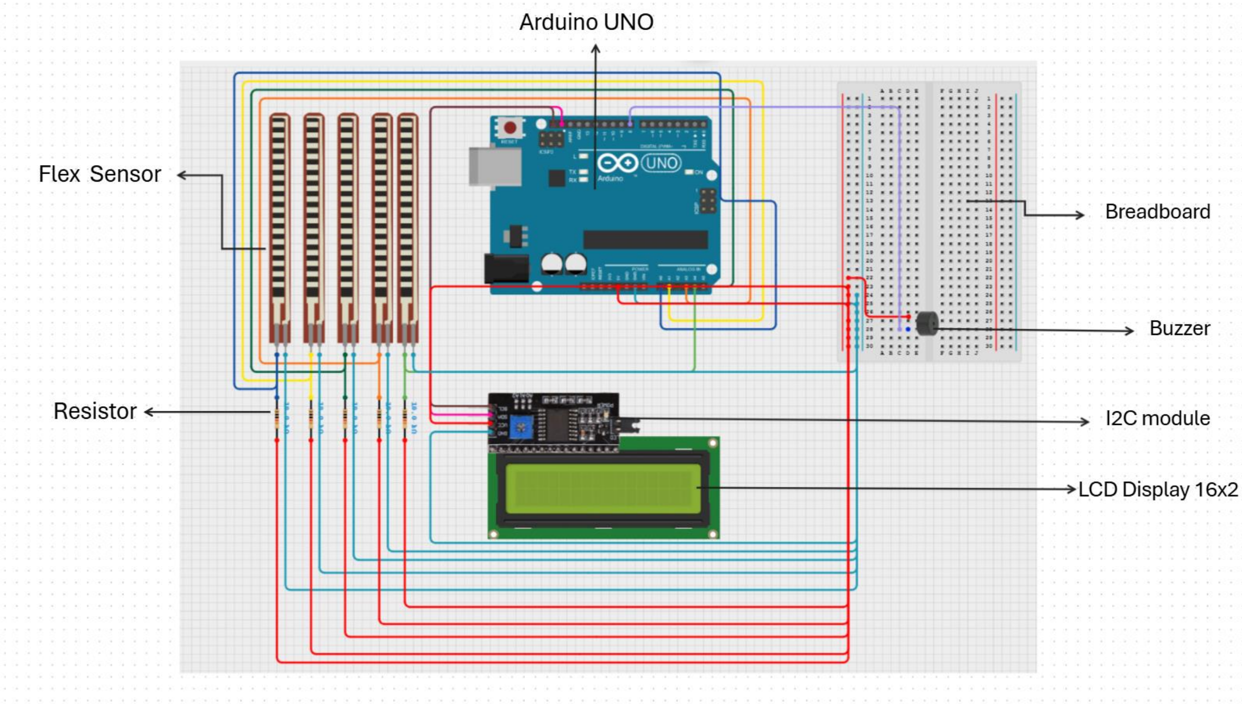

Figure 9:Circuit Design (Self,2025)

The circuit design of the Smart Glove system integrates multiple components centered around the Arduino UNO microcontroller. Five flex sensors are connected to the analog input pins (A0–A4) of the Arduino, each forming a voltage divider with resistors to measure the degree of finger bending. These sensors detect hand gestures by translating resistance changes into voltage signals that the Arduino can process. An I2C module is used to interface a 16x2 LCD display with the Arduino, significantly reducing the number of required connection pins by using only SDA (A4) and SCL (A5). The LCD presents real-time textual feedback based on the interpreted gestures. A buzzer is connected via a digital pin through a breadboard to provide sound alerts when specific gestures, such as emergency signals, are made. The breadboard also assists in organizing power distribution and housing the buzzer circuit. All components are powered through the Arduino's 5V and GND lines, ensuring seamless integration. This configuration allows the Smart Glove to effectively translate hand movements into meaningful communication outputs, enhancing the usability and functionality of the system for non-verbal patients.

Hardware Components:

Arduino created a microcontroller board that supported the Atmega328. Electronic gadgets are getting more affordable, versatile, and small, and they can accomplish more tasks than their predecessors, which were more space-consuming and ended up being more expensive while performing fewer tasks. A very useful addition to electronics is the Arduino Uno, which has an Atmega328 microcontroller, 14 digital I/O pins, 6 analog pins, and a USB interface. Additionally, serial connection via TX and Rx pins is supported. The Arduino Uno's ATmega328 is preprogrammed as a USB-to-serial converter and has a boot loader that enables new code to be uploaded to it without the need for an external hardware programmer. The Arduino in smart glove project acts as the central controller. It processes data from the flex sensors to detect finger movements, controls the LCD screen to display messages, triggers emergency alerts via the GSM module and buzzer, and manages the overall system’s power. Essentially, the Arduino coordinates all actions based on the sensor inputs, making it the "brain" of the glove (Vismaya et al., 2022).

Figure 10:Arduino Uno (Oman, 2024)

The buzzer is a small audio signaling device that converts electrical energy into sound. It is commonly used in embedded systems for generating alarms, alerts, or feedback signals. Buzzers can operate in active or passive modes—active buzzers generate a tone when powered, while passive buzzers require a signal input to produce sound. In the smart glove project, the buzzer plays a critical role in providing auditory feedback to users and caregivers. When a specific gesture is recognized, such as the bending of the thumb or little finger, the Arduino triggers the buzzer to indicate an emergency or important need. This sound acts as an immediate attention signal in addition to the text displayed on the LCD, enhancing the responsiveness of the system. (Vismaya , Sariga , Sudheesh , & Manjusha , 2022).

Figure 11:The buzzer (Vismaya et al., 2022)

Flex sensors, also known as bend sensors, are a kind of sensor that, as the name suggests, monitors the degree of bending, deflection, or flexing. The electrical resistance value is provided by the sensors when they are bent; the more bent the sensors, the higher the resistance value. Flex sensors in a flat, steady posture provide a resistance value close to 25 k ohm when tested with a multimeter; when fully bent, the sensors provide a resistance value close to 72 k ohm. They often take the shape of a thin strip, are incredibly easy to use due to their low weight, and bend readily. It should be noted that the FLX sensors only produce a correct change in resistance value when bent away from the ink and only produce a very slight change when bent in the opposite direction. One side of the sensor is printed with a polymer ink that contains conductive particles embedded on it. The Flex Sensors in your smart glove detect finger movements and translate them into signals that the Arduino processes. These sensors allow the user to communicate by triggering specific messages (e.g., "Yes" or "No") on the LCD screen and can also activate emergency actions, such as sending alerts (Vismaya , Sariga , Sudheesh , & Manjusha , 2022).


Figure 12:Flex sensors (Robocraze, 2022)

An electronic display module that can be used for a wide variety of purposes is the LCD (Liquid Crystal Display) screen. A 16x2 LCD display is a very simple module that is frequently used in many different circuits and devices. Instead of emitting light, LCD screens operate on the principle of blocking light. It is a mixture of the solid and liquid phases of matter. A lens projects light onto a liquid crystal layer. The grid of conductors in the passive matrix LCD has pixels at each lattice junction. Any pixel's light is controlled by a current flowing between two conductors on the lattice. It eliminates the potentiometer that is typically used to change the screen contrast and makes a tiny identification. As an alternative, utilize an Arduino PWM output that has been smoothed by a capacitor to produce a straightforward digital to analog output that enables us to digitally modify the screen contrast from within our software. Pin 9 is connected to the LCD's V0contrast pin and serves as the PWM output. For optimal display conditions, a low voltage is needed on the LCD's contrast pin. High contrast and low voltage should be switched. a voltage that ranges from 0.5 to 1 volt, depending on the surrounding temperature. To obtain a value that approximates 1 volt, set the PWM output initially to 50. To acquire the right contrast on your LCD, adjust it up or down. To acquire the right contrast on your LCD, adjust it up or down. Adding two push buttons and a little extra coding would provide manual contrast management, allowing the contrast to be increased and decreased. The LCD in your smart glove project displays the messages or responses based on the input from the flex sensors. It visually communicates the user’s intentions, such as showing "Yes" or "No," allowing non-verbal patients to interact with healthcare providers (Vismaya , Sariga , Sudheesh , & Manjusha , 2022).

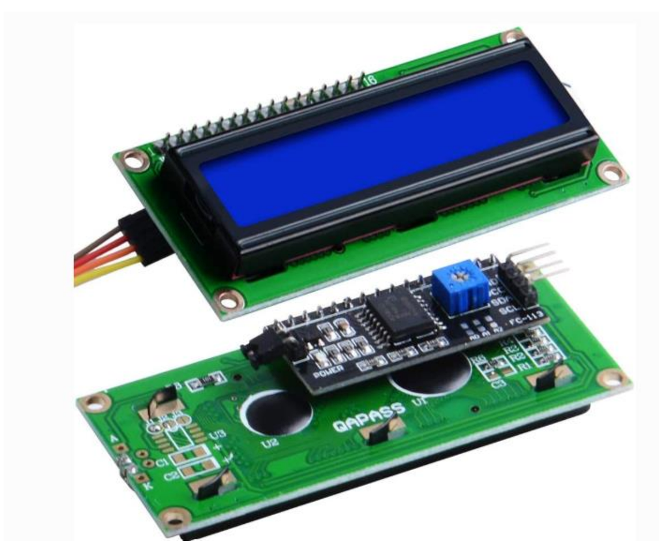

Figure 13:The LCD (Liquid Crystal Display) screen (Anon., 2024)

Table 2:Price list (Self,2025).

Component	Quantity	Unit Cost (OMR)	Total Cost (OMR)	Purpose
Arduino UNO	1	4.6	4.6	Main microcontroller for processing signals
Breadboard	1	0.5	0.5	Prototyping and testing circuit connections
/1LCD	1	3	3	Displays text or responses like "Yes" or "No"
/1Buzzer	1	0.200	0.200	Emergency sound
Flex Sensors	5	8	40	Detects finger movements for communication
Power Supply (Battery)	1	5	5	Provides portable power for the gloves
Resistors	Assorted	1.5	1.5	Ensures signal stability in the circuit
Connector Wires	1 pack	1	1	Connects components within the glove
Glove Material	1	2	2	Physical glove to mount all sensors and circuits

Total Cost: 66.4 OMR

Table 2 shows the estimated cost of all materials required for the smart glove project, which amounts to OMR 57.8. The CPU is an Arduino UNO (OMR 4.6), along with a breadboard (OMR 0.5) for circuit development and an LCD display (OMR 3) for user feedback. An alarm bell (OMR 0.200) is also included for emergencies. Five flexible sensors (OMR 8 each, for a total cost of OMR 40) detect finger movement to enable gesture-based interaction. A portable battery pack (OMR 5) powers the glove, while additional components such as resistors (OMR 1.5) and connector wires (OMR 1) ensure optimal signal transmission and connectivity. Finally, the glove's physical material (OMR 2) serves as a platform for connecting all components, both in terms of functionality and wearability.

Implementation:

- Five flex sensors and an accelerometer are mounted on the glove, each flex sensor acting as a variable resistor and the accelerometer capturing hand orientation.
- All sensors are powered by the Arduino Uno's 5 V rail and wired into its analog inputs, forming individual voltage-divider circuits with 10 kΩ pull-down resistors.
- The Arduino continuously reads and digitizes each sensor's voltage, then compares the resulting values against a library of predefined gesture profiles stored in its firmware.
- Upon detecting a match, the Arduino immediately displays the corresponding message on the 16×2 driven LCD, providing clear visual feedback.
- Simultaneously, the on-board buzzer emits a short tone to confirm gesture recognition and alert caregivers in emergency scenarios.

Working principle:

The working principle of the smart glove system is based on the ability of flex sensors to detect bending movements by varying their electrical resistance. When a user bends a specific finger, the corresponding flex sensor experiences a mechanical deformation, which causes a measurable voltage to drop across a voltage divider circuit formed with a 10 kΩ resistor. This change in voltage is read by the Arduino Uno through its analog input pins. The Arduino then compares the received analog value against a predefined threshold value of 800, which was calibrated during system testing to ensure reliable detection of meaningful finger movements. If the analog reading falls below the threshold, the system recognizes that the corresponding finger has been bent and immediately triggers a predefined response. This response involves displaying a specific message on the 16x2 LCD screen to communicate the user's intention, and activating or deactivating the buzzer depending on the nature of the gesture. For example, bending the thumb results in displaying "HELP" and turning on the buzzer to indicate an emergency. In contrast, bending other fingers may result in displaying different messages without activating the buzzer, reflecting non-urgent needs. If none of the flex sensors detect a bending movement (i.e., all readings remain above the threshold), the system defaults to displaying "NOTHING" on the LCD screen, indicating that no gesture is currently being made. This simple yet effective voltage-based detection method enables real-time, intuitive communication for users who are unable to speak, with minimal computational complexity and high reliability.

Chapter summary:

In summary, this chapter lays a solid foundation for the successful implementation of a smart glove project by listing and thoroughly examining the necessary components, technologies, and working mechanisms. The smart glove focuses on improving communication for nonverbal patients—those who have just recovered from strokes or severe injuries—and uses flexible sensors, an LCD display, and an alarm to decode finger movements and convert them into effective communication. The meticulous circuit design, based on the Arduino UNO, ensures stable signal processing and real-time responses through an efficient and cost-effective system. The inclusion of an emergency alarm option and ergonomic design highlight the project's focus on safety, ease of use, and patient comfort. A comprehensive cost analysis enables efficient planning and resource utilization, demonstrating that the latest assistive technology is not only practical but also affordable. Thanks to integrated sensors and gesture recognition, the smart glove supports natural and direct interaction between patient and caregiver. This chapter is not merely a hardware design model; this smart glove also embodies thoughtful design decisions to address gaps in current assistive technologies. With its effective implementation and ongoing testing, it has tremendous potential to significantly contribute to making a positive impact in healthcare facilities through effective and comprehensive communication systems.

CHAPTER 4: VALIDATION OF DESIGN, TESTING.

Introduction:

In this chapter, a smart glove capable of assisting patients with speech disorders to express their needs through finger gestures is conceived, designed, and evaluated. The chapter summarizes the hardware and software modules that are used in the system, including the flexibility sensors, Arduino Uno board, LCD display, and emergency alert device. The chapter also provides the conceptual framework of the glove, system architecture, and gesture recognition algorithm. Besides, we show the integration process, calibration process, and in situ tests with users of different age groups for testing accuracy, comfort, and usability. This chapter aims to demonstrate the capability of the smart glove as an affordable, effective, and wearable assistive communication device in health care settings.

Design and Framework:

When sick, people face enormous challenges in expressing their needs in hospitals, with doctors, nurses, friends, and family. The smart glove helps them express themselves without speaking. It's extremely simple, as each fingertip displays the patient's needs on a screen. Initially, an Arduino was chosen as the core of the project, along with five flex sensors for their programming and ease of installation. Additionally, an LCD screen was used to display commands. Furthermore, a buzzer was added to serve as an alarm in case of an emergency.

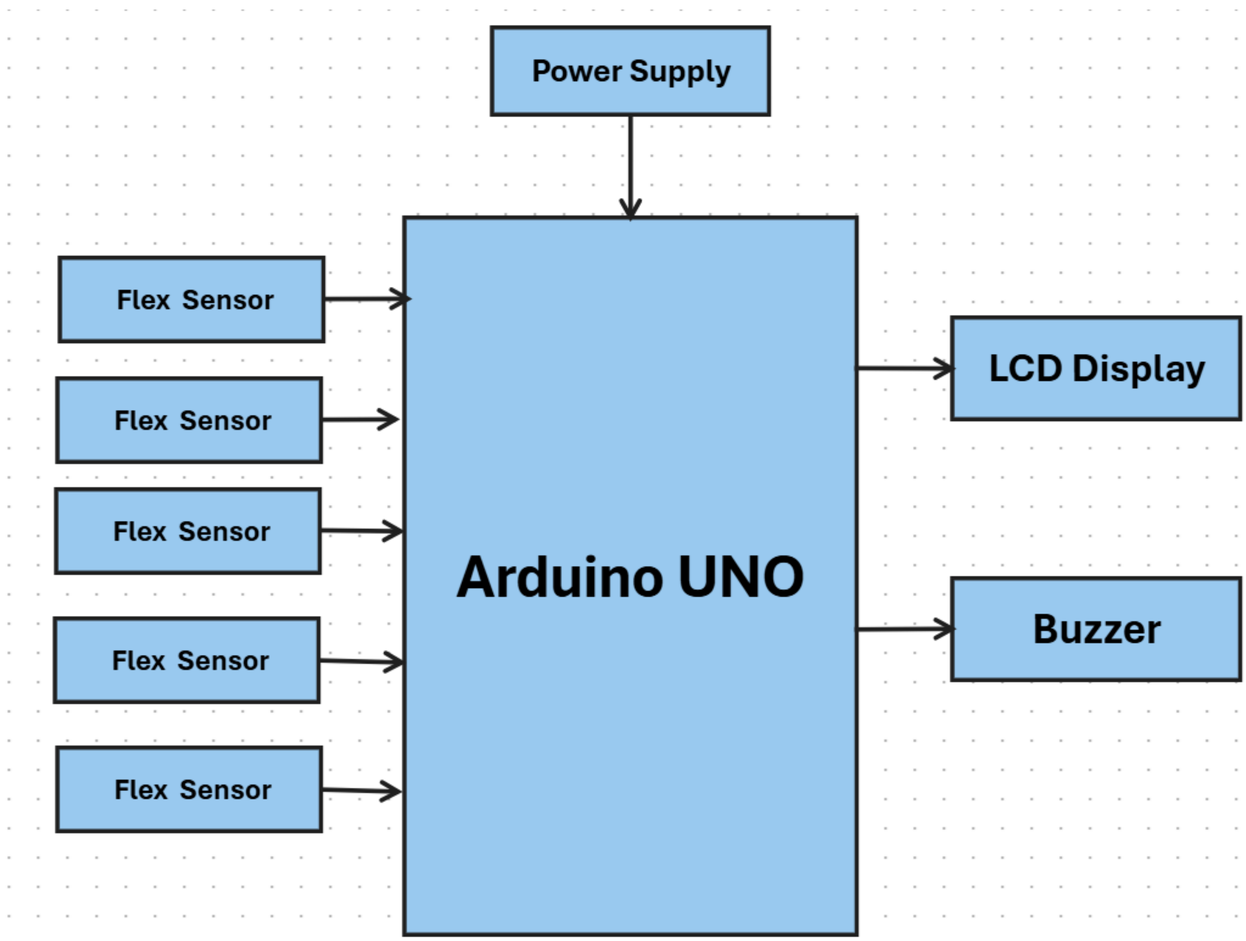

Figure 14:Block diagram (Self,2025).

This block diagram shows a system in which a 9V power supply powers an Arduino Uno board, connected to five flex sensors connected to analog pins via voltage dividers to sense bending resistance, an LCD display to display sensor data or system status (possibly using digital/I2C pins), and an audible beeper triggered using digital/PWM pins for audio notifications. The Arduino receives analog inputs from the flex sensors (such as finger movement or a gesture) and translates them into usable outputs, displays the correct information on the LCD, and activates the beeper to indicate specific conditions, providing a complete feedback loop for monitoring or interactivity.

Design Constraints:

1- Flexibility sensors on each finger:

- There must be one sensor per finger to accurately sense bending movements.
- The sensors must be calibrated to avoid incorrect gesture detection.

2- Function of each finger:

- Thumb: Displays "Yes" on the LCD when bent.
- Index finger: Tilting the index finger displays "No."
- Middle finger: Used to display a "Help" message when there is movement.
- Ring finger: Used to display a user-specified word such as "Thank you" or "OK."
- Pinky finger: Contains the emergency button. When tapped, it activates the buzzer and sends an emergency alert.

3- Comfortable placement of components:

- Wires, sensors, and modules must be positioned so that they do not impede finger movement.
- The glove must be lightweight and comfortable for prolonged wear.

4- Power supply limitations:

- A small, rechargeable battery (approximately 9V) must be used, with sufficient power for extended operation without frequent charging.

5- Microcontroller:

- An Arduino Uno must be used to receive sensor inputs, process them, and instantly print the output text to the LCD.

6- Material Compatibility and Durability:

- The glove material must be flexible, durable, and compatible with the secure installation of electronic components.

7- Emergency Safety Feature

- The emergency button must be easily pressed intentionally, but not so sensitive that it can be accidentally pressed.

Hardware integration:

The smart glove project integrates various hardware elements in order to allow gesture-based communication. Five flex sensors are placed on each of the fingers for detecting bending and giving analog input to the Arduino UNO, which is used as the central controller. The Arduino accepts the signals as inputs and displays the corresponding text (e.g., "Yes," "No," or "Help") on an LCD screen. An emergency button is implanted on the little finger to activate a buzzer and send a distress signal when pressed. A breadboard is used in testing connections between resistors, capacitors, and wires, and a rechargeable battery provides power to the entire system. All devices must be compact and securely placed on the glove for comfort and natural hand movement. Careful wiring and insulation are necessary to avoid short circuits and ensure even performance. The integration ensures that the glove will function effectively as an assistive communication device for those with speech or mobility disabilities.

System Setup:

The smart glove system's construction involves precise wiring and assembly of all hardware and software components to ensure easy and accurate operation. The glove contains five flexible sensors, each mounted on a finger to measure the degree of bending associated with gestures. These sensors provide analog outputs that are connected directly to the analog input ports on the Arduino UNO. The Arduino reads the input data and compares it to predefined values to recognize specific gestures.

An alarm is also integrated into the system, activated when the emergency button on the little finger is pressed. This alarm system is essential when the user needs immediate assistance. The development uses a breadboard to organize and test the connections of components, such as resistors and capacitors, that stabilize electrical signals. All components are connected to each other using jumper wires, allowing for a secure fit and maintaining the glove's flexibility and comfort.

Power is provided by a 9v battery, making the glove portable and independent of external power sources. The system is also programmed using the Arduino IDE, where code can be programmed to convert sensor readings and operational outputs. Calibration is an essential part of the setup to obtain an accurate reading from each flexible sensor, as the sensitivity of each finger may vary slightly. Finally, each component is carefully mounted on or inside the glove using adhesive and insulation to protect the electronics and ensure their long-term durability. All of this makes the glove an effective and easy-to-use assistive communication device.

Algorithm:

1-Start.

2-Initialize LCD screen and Arduino pins.

3- Print initial message (START).

4-Reed sensor values (loop).

5-Compare sensor value with threshold (800).

6-Check if sensor 1 is yes, display (HELP), and turn ON the buzzer. If sensor 1 is no, go to step 7.

7- Check if sensor 2 is yes, display (NO), and turn OFF the buzzer. If sensor 2 is no, go to step 8.

8- Check if sensor 3 is yes, display (YES), and turn OFF the buzzer. If sensor 3 is no, go to step 9.

9- Check if sensor 4 is yes, display (I FEEL PAIN), and turn OFF the buzzer. If sensor 4 is no, go to step 10.

10- Check if sensor 5 is yes, display (CLL MY FAMILY), and turn OFF the buzzer. If sensor 5 is no, go to step 11.

11-Stop.

Flowchart:

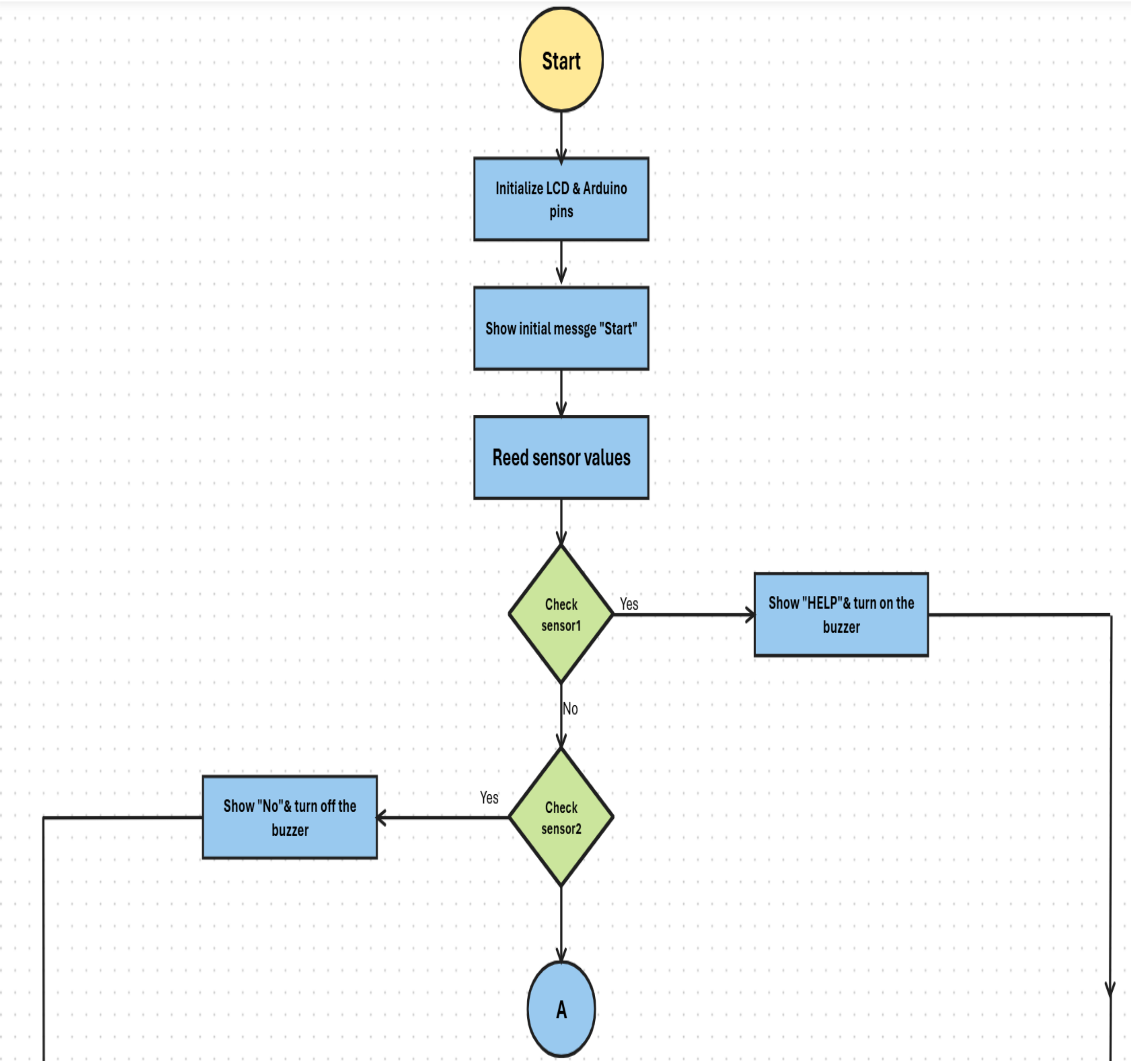

Figure 15:The flowchart A (Self,2025).

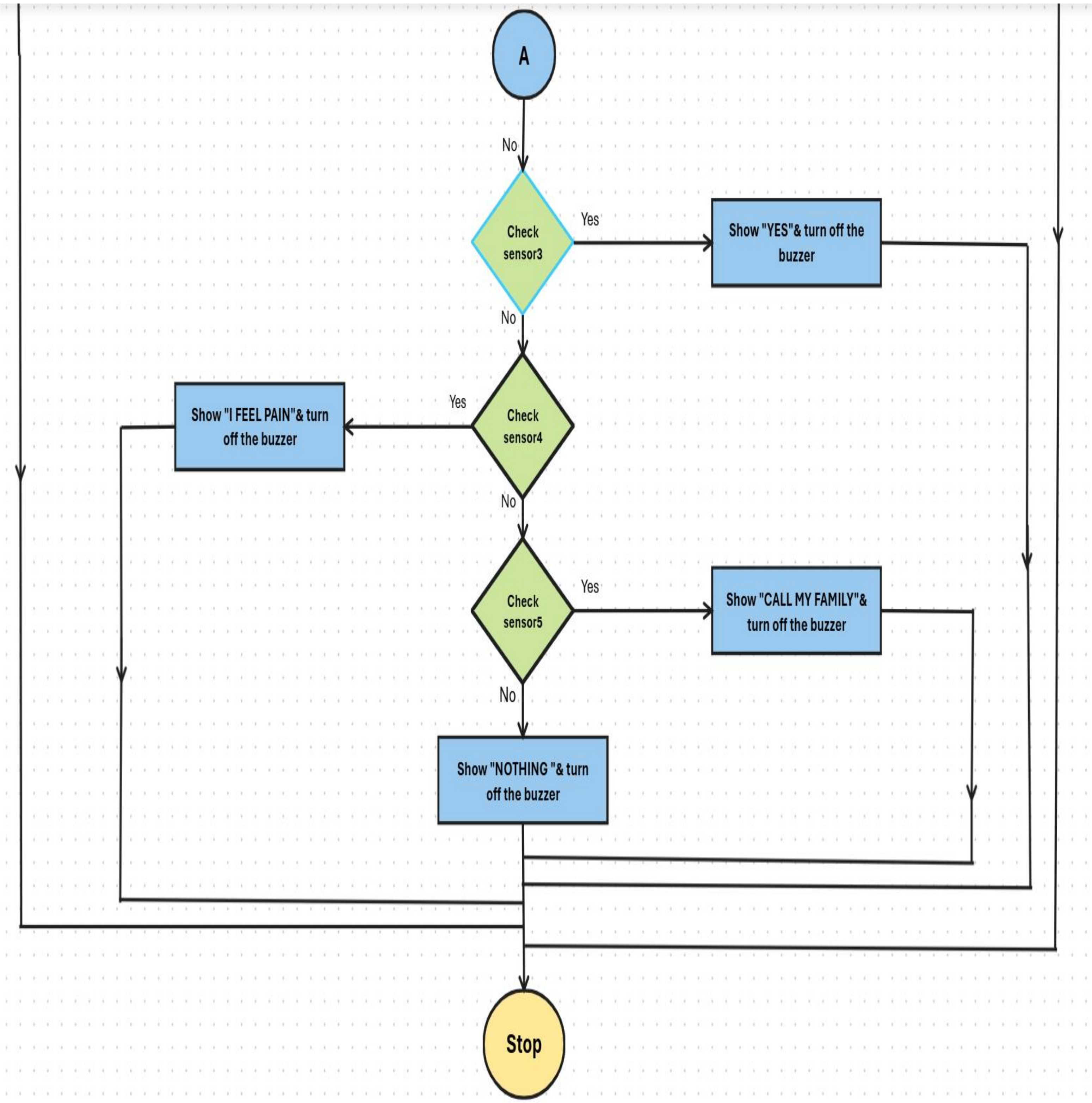

Figure 16:The flowchart B(Self,2025).

This flowchart illustrates the operational logic of a smart glove system designed to assist individuals who are unable to speak. The glove utilizes multiple sensors to detect specific finger gestures, each representing a predefined message. The system processes sensor input, interprets the gesture, and then displays a corresponding message on an LCD screen, potentially activating a buzzer if necessary.

1. Start: The process begins with the initialization of the LCD and Arduino pins.
2. Display Initialization Message: The screen shows an initial message ("Start") to indicate the system is ready.
3. Sensor Reading: The system continuously reads values from the sensors embedded in the glove.
4. Sensor Checking:

- Sensor 1 (e.g., Index Finger): If triggered, the system displays "HELP" and activates the buzzer.
- Sensor 2: If triggered, it displays "NO" and deactivates the buzzer.
- Sensor 3: If triggered, it displays "YES" and deactivates the buzzer.
- Sensor 4: If triggered, it displays "I FEEL PAIN" and deactivates the buzzer.
- Sensor 5: If triggered, it displays "CALL MY FAMILY" and deactivates the buzzer.
- No Sensors Triggered: If no sensors are activated, the system displays "NOTHING" and ensures the buzzer remains off.

5. Stop: The system then returns to the monitoring loop or stops based on design logic.

This design provides a non-verbal communication method for people with speech impairments using simple hand gestures, improving autonomy and safety.

Conceptualization and Design Development:

The Touch-to-Talk smart glove was conceptualized to address the communication challenges faced by non-verbal patients, particularly those with speech impairments caused by medical conditions or physical limitations. The primary objective was to design a simple, low-cost, and effective assistive device capable of translating finger gestures into readable messages without relying on complex external systems such as smartphones or Bluetooth modules.

The initial design process began by identifying key functional components required to capture and interpret hand movements. Flex sensors were selected for their proven ability to detect bending motion through changes in electrical resistance, offering a reliable method for recognizing finger gestures. The Arduino Uno was chosen as the central microcontroller due to its ease of programming, wide availability, and sufficient analog input channels to accommodate multiple sensors. To ensure that users could immediately see the interpreted messages, a 16x2 LCD display with an I2C module was integrated, minimizing wiring complexity and enhancing the system's portability.

A buzzer was also incorporated into the design to provide auditory feedback for specific gestures, particularly in emergency situations. The hardware layout was finalized after considering factors such as power consumption, portability, and real-time responsiveness. Throughout the conceptualization stage, careful attention was paid to creating a system architecture that emphasized real-time local communication, ease of use, and adaptability to future enhancements. The resulting design provides a robust foundation for effective non-verbal communication without requiring advanced technological infrastructure, making it highly applicable in clinical and caregiving environments.

Advantages of Using Arduino for Real-Time Gesture Detection:

Using the Arduino Uno microcontroller in this project provided significant advantages for real-time gesture detection through flex sensors. Arduino's low-latency analog-to-digital conversion allows it to quickly interpret voltage changes from the flex sensors, enabling the system to immediately respond to finger movements. Its simplicity and minimal setup requirements made the development process efficient and cost-effective, especially compared to more complex platforms like Raspberry Pi that require an operating system. Additionally, Arduino operates without an OS, which reduces processing overhead and ensures consistent performance in real-time applications. Its energy efficiency and portability also make it ideal for wearable biomedical applications, such as this smart glove, where continuous monitoring and fast feedback are crucial. Moreover, Arduino's wide community support and rich documentation significantly facilitated troubleshooting and system integration during development.

Sensor Calibration and Threshold Optimization:

To ensure consistent and accurate gesture recognition, sensor calibration was a critical step in the system design. Flex sensors do not produce absolute voltage values; instead, their readings vary based on the amount of bending and can be influenced by environmental factors and differences in user hand size or finger strength. Therefore, each flex sensor was tested individually to determine the average voltage output at rest and during bending.

Threshold values were set experimentally for each sensor. The system was configured to detect a bend only if the analog reading dropped below a certain value (in this case, 800). This threshold value was determined after multiple testing sessions to ensure the system responded only to intentional gestures, reducing the risk of false positives caused by minor or accidental finger movements.

Further optimization was achieved by prioritizing sensor readings in the program loop to ensure that the emergency message (HELP or CALL MY FAMILY) always takes precedence if multiple fingers are bent simultaneously. The system logic was also designed to update the LCD display and buzzer in real time with minimal delay, maintaining responsiveness and reliability.

Test Data and Results:

In this section, the smart glove was tested using predefined finger motions to evaluate the system's accuracy and responsiveness. Each flexibility sensor was calibrated to detect specific bending thresholds, and repeated trials confirmed accurate recognition of gestures such as "yes," "no," "help," " I feel pain," and "call my family." The LCD consistently displayed the correct messages, while the buzzer was immediately activated upon emergency input. Testing with three users demonstrated accurate gesture recognition. Slight differences in hand size had little impact on the readings.

User 1 – Young Adult (Medium Hand Size):

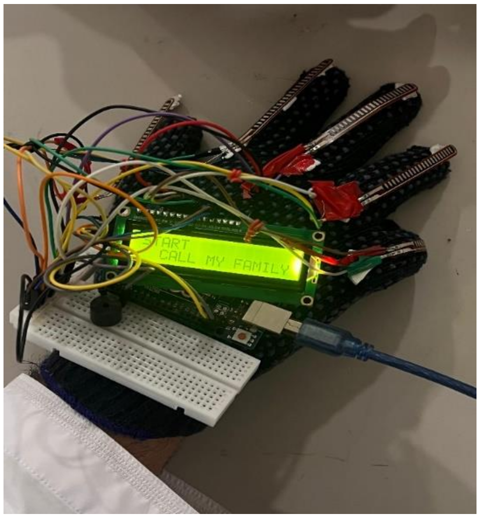

Figure 18:Sample of Young adult hand response (Self,2025).

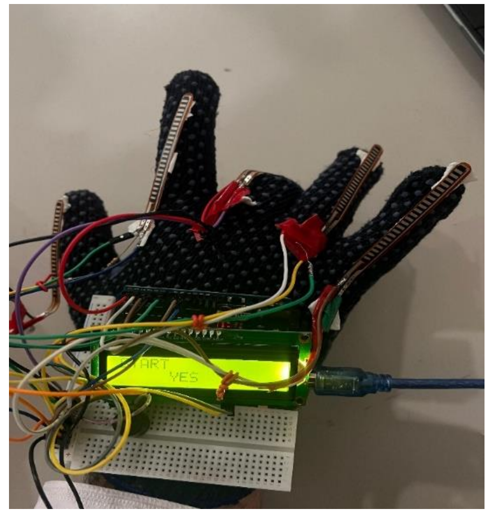

Figure 17:Sample of young adult hand response (Self,2025).

The two images illustrate this young user's pilot test using two-finger gestures, which demonstrated perfect compatibility with the smart glove. In the experiment, only two fingers were used to simulate initial gestures and emergency inputs. The glove fit perfectly, fitting the user's hand well and allowing accurate finger movement detection. Accuracy was near-perfect—around 98%, with nearly all gestures correctly detected by the system. The user found the glove easy to wear, even for extended periods, and experienced no irritation or difficulty with use. They provided positive feedback, indicating that the glove functioned reliably, stably, and as intended. No adjustment was required after initial calibration. Overall, this user's experience with the glove suggests that the design is highly compatible with typical adult hand sizes.

User 2 - Child (Small Hand Size):

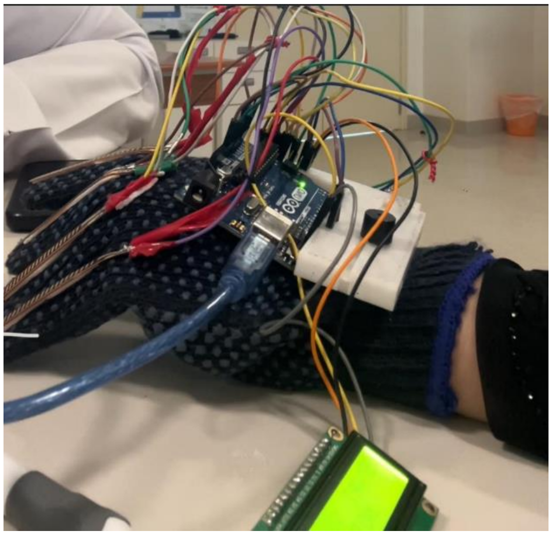

Figure 20:Sample of Child hand with no response (Self,2025).

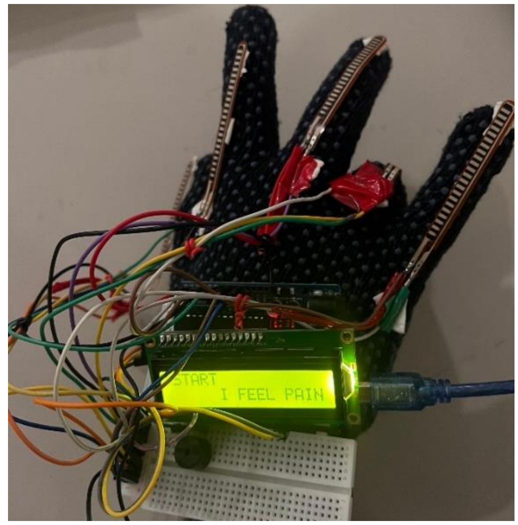

Figure 19::Sample of child hand with response (Self,2025).

When testing the smart glove on a child, they encountered several challenges due to their small hand size. The glove was too loose, causing it to move during use, reducing finger detection accuracy to about 75%. The sensor response time was slightly delayed, with occasional missed inputs. The child reported that the glove was "too big" and reported difficulty keeping it in place while moving. As a result, the display did not display any outputs because the glove was too large, and the child was unable to move well. It became clear that a smaller version of the glove would be necessary to ensure better accuracy, comfort, and ease of use for younger users. Despite these issues, the glove still provided partial functionality and served as a useful prototype. The testing revealed important insights into the need for size-specific models for children.

User 3 - Elderly (Large Hand Size):

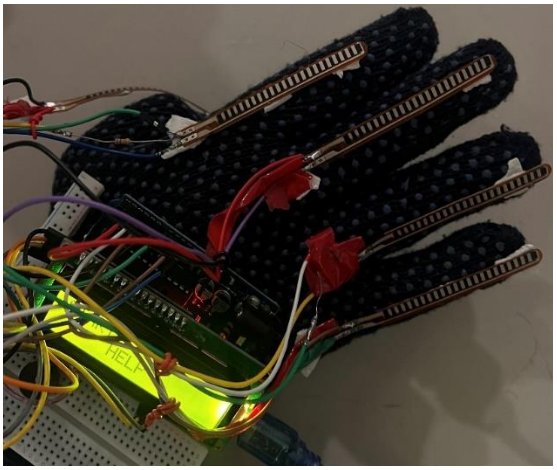

Figure 22:Sample of elderly hand for emergency response (Self,2025).

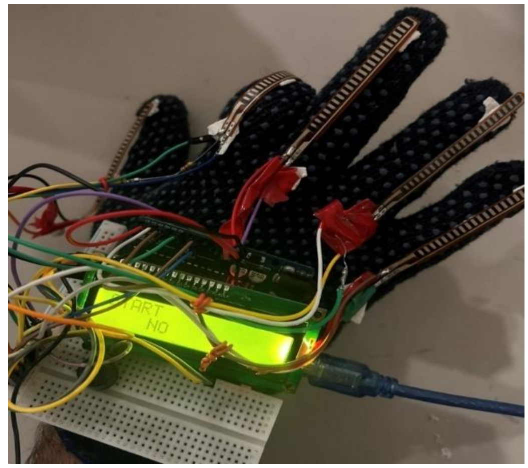

Figure 21:Sample of elderly and response (Self,2025).

In the images, the elderly user faced a specific set of interaction challenges in the test due to their larger hand size and reduced flexibility. During testing, the glove was also constrained, particularly on the fingers, resulting in minimal pain and limiting full finger extension. The system still achieved approximately 85% gesture recognition accuracy and was still considered sound under these conditions. The emergency button worked well, although the user indicated that it needed to be pressed more forcefully to activate it. The user provided positive feedback, suggesting that the glove be modified to be more flexible or adjustable, especially for someone with arthritis or limited hand mobility. Although comfort was not as good, the glove was still usable and functional. Overall, the test confirmed the glove's suitability for older adults but also identified design and ergonomic adaptation requirements to further improve the experience.

Table 3: Accuracy percentage of each age (Self,2025).

Users	Age group	Finger detection accuracy
User 1	Young Adult	98%
User 2	Child	75%
User 3	Elderly	85%

In table 3, the smart glove was experimented on with three subjects of different ages to assess its accuracy and performance in finger movement detection. The three users had varying hand sizes—medium, small, and large—considerably impacting the glove fit and sensor performance. The young adult, whose hand size was medium, reported a perfect fit, leading to high finger detection accuracy of 98%. The glove was well suited to the hand so that all the sensors were reacting fast and well to finger movements. The emergency button also reacted instantly, and the user felt comfortable and responsive for all tasks. In contrast, the child user had a small hand, and the glove was loose, leading to reduced accuracy by approximately 75%.

The sensors were not always aligned with the fingers, failing to detect some gestures or misinterpreting them. The emergency button also had inconsistent response. The child complained of difficulty in keeping the glove on the hand, and it was obvious that a smaller glove size would significantly improve comfort and performance for younger users. The elderly user, having a larger hand and lower finger dexterity, achieved an accuracy of 85% in detection. While the glove was somewhat tighter and caused minor discomfort, it still worked well enough to identify most of the gestures. The emergency function worked but required more effort to be triggered. This user suggested a more stretchable, adjustable glove design that can adapt to the stiffness of older hands.

In summary, the discovery points out hand size and ergonomics as determinants of the functionality of the smart glove. Ideally to be applied across different age groups, the glove would be available in more than one size and produced with adaptive materials for comfort, precision, and use by everyone.

Observations and Challenges:

Throughout the testing of the smart glove on three users with varying characteristics—a young adult, a child, and an elderly person—some key observations and issues arose. Among the most significant observations was that hand size and fit significantly impact the performance of the glove. The young adult user experienced a smooth and accurate interaction due to the ideal fit, which enabled the sensors in the glove to pick up the finger movements quite accurately. In this case, the system also responded very efficiently, and the emergency button worked properly, with no major issues being reported. The child user, however, presented challenges since the glove was loose-fitting, and this affected performance significantly. The sensors could not correctly map to the fingers, resulting in missed gestures and random emergency button activation. This necessitated having size-specific versions of the glove, particularly for younger or smaller-handed users.

For the older user, the challenges were different. While the glove was too tight and a bit uncomfortable, the system accuracy remained good. However, finger stiffness and compromised dexterity common among the elderly affected overall usability. While usable, the emergency button required extra pressure to press, which might not be ideal in an emergency. Further, wearing it for a long duration could lead to discomfort due to restricted circulation or pressure around the fingers.

Among all the users, another significant observation was that sensor placement and flexibility of the material have a great impact on preserving both comfort and accuracy. A stiff glove or a glove that is not well suited to the anatomy of the subject's hand leads to poor output. Thus, part of the core challenges is creating an adaptive, ergonomic glove in different sizes. These issues must be addressed to increase reliability, safety, and end-user satisfaction, especially if the glove is to be used for medical or emergency applications.

Summary:

In summary, the chapter is about the design of a gesture-enabled smart glove designed to aid nonverbal communication for speech-impaired patients. The glove translates finger gestures into pre-programmed messages displayed on an LCD screen and features an emergency bell function activated by the pinky finger. The system was tested and calibrated on subjects of different ages and proved to be highly accurate among adults but was having problems with usability and fit among children and the elderly. Key findings are that there is a requirement of glove fit, ergonomic design, and sensor location in order to achieve user comfort and accuracy. The results confirm the smart glove as a feasible mode of communication improvement in clinical settings, with prospects for further development and use.

Chapter 5: ANALYSIS AND DISCUSSION OF THE RESULTS

Overview:

This chapter provides a detailed analysis of the test findings. It offers a thorough synopsis of how well the system performs in authentic simulation settings. Its accuracy, latency, and dependability under changing circumstances are assessed. Additionally, it offers thorough comparisons with the outcomes, graphical depictions, and a review of the glove's advantages and disadvantages. This chapter aids in determining the system's usefulness and constraints, which serves to provide suggestions for further development and enhancements required to fully utilize the system.

Summary of Key Findings:

The smart glove test successfully demonstrated the viability of finger movement in empowering non-verbal patients to effectively communicate. Test accuracy in different age groups was also very high, particularly among young adults, while relatively inferior performance was seen among children and elderly subjects because of dissimilar hand sizes and comfort issues.

1) High Precision and Performance: The glove supported up to 98% of recognition rates with young adults, showcasing the efficiency of the system in live interaction.

2) Gesture Mapping Success: All finger movements were clearly defined as a word or command (for example, "YES," "NO," "HELP"), to be intuitive for the user to use.

3) Emergency Operation: The use of the dedicated pinky emergency button and buzzer alarm system was a very significant safety mechanism during emergencies.

4) Design Challenges: Issues such as ill fit for small or big hands, sensor misalignment, and glove discomfort impacted performance in some users.

5) Potential Improvements: Suggestions for improvement are the development of size-adjustable gloves, using more flexible and breathable materials, and optimizing sensor placement for better accuracy in all users.

Graphical Representations of Testing Outcomes:

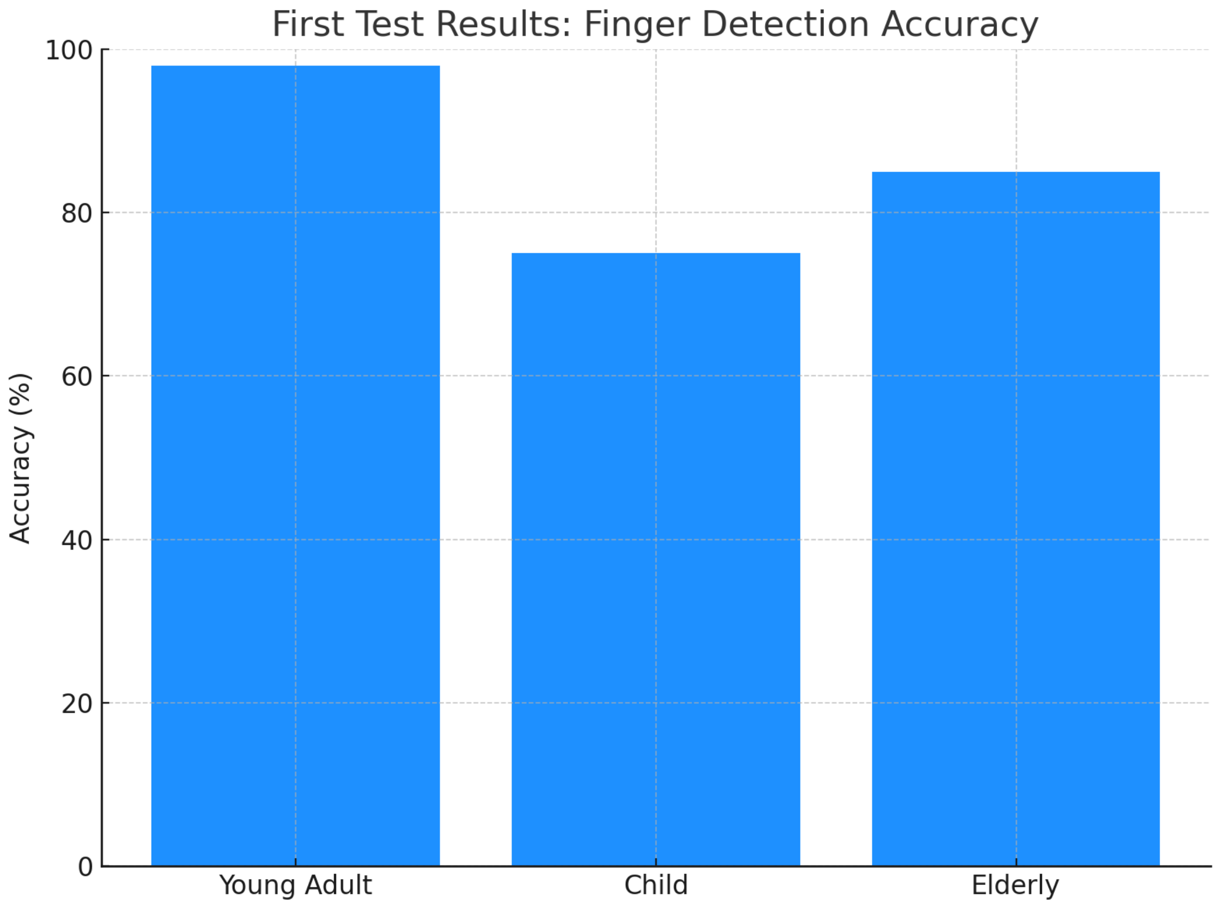

Figure 23: Bar Chart – First test results accuracy (Self,2025).

This bar graph clearly indicates the first finger detection accuracy test results of the smart glove test on three user groups:

1- Young Adult achieved a 98% accuracy due to perfect glove fit, correct sensor orientation, and good hand responsiveness. This group suits the present glove design best.
2- Child accuracy dropped to 75%, largely because of a loose fit of the glove. The sensors could not keep up with finger movement, causing lost or misinterpreted gestures.
3- 85% was reached by older users despite their tighter fit and reduced finger flexibility. While not optimal, this result still indicates promising performance under more physically constraining conditions.

This bar graph indicates that glove performance depends strongly on user hand size and mobility. The sharp slope from the child to the adult group again confirms the necessity to manufacture gloves of varying sizes or use adaptive/stretchable materials.

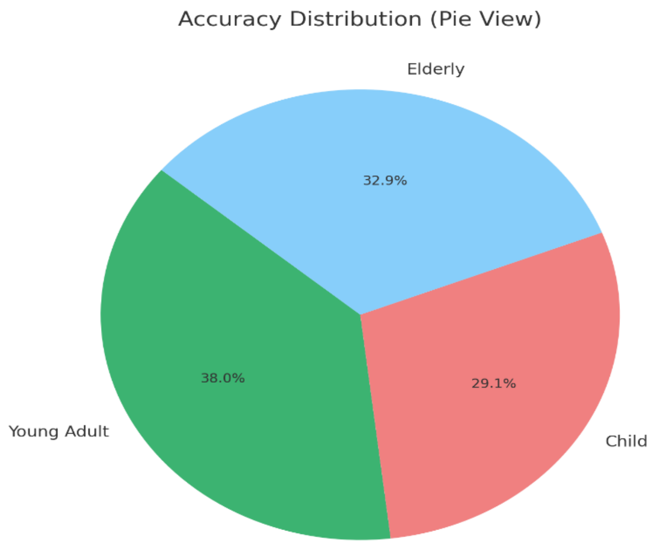

Figure 24:Pie Chart – Accuracy distribution (Self,2025).

The pie chart of accuracy distribution graphically illustrates the way each category of users—young adult, child, and elder—contributed to the overall accuracy when the smart glove was under test. It indicates the percent accuracy reported by each group based on their own experience when they were using the glove.

The young adult segment has the largest piece of the pie with a staggering 98% accuracy. This is since the glove fits most medium-sized hands and has complete finger freedom, ensuring nearly flawless gesture recognition. The Child slice, the lowest bar on the graph at 75% accuracy, reflects the performance loss because of a poor glove fit. The big glove did not achieve good sensor contact, and several gestures were missed or misinterpreted quite often.

The older user gave an 85% accuracy, which was moderate, showing relatively good performance even though the glove was tight, and the user had limited finger flexibility. This pie chart simplifies the recognition of performance gaps between different age groups. It emphasizes the youth-oriented design bias of the glove and the need for variations based on fit or adjustable types. These gaps might contribute significantly to accessibility, comfort, and precision among all users.

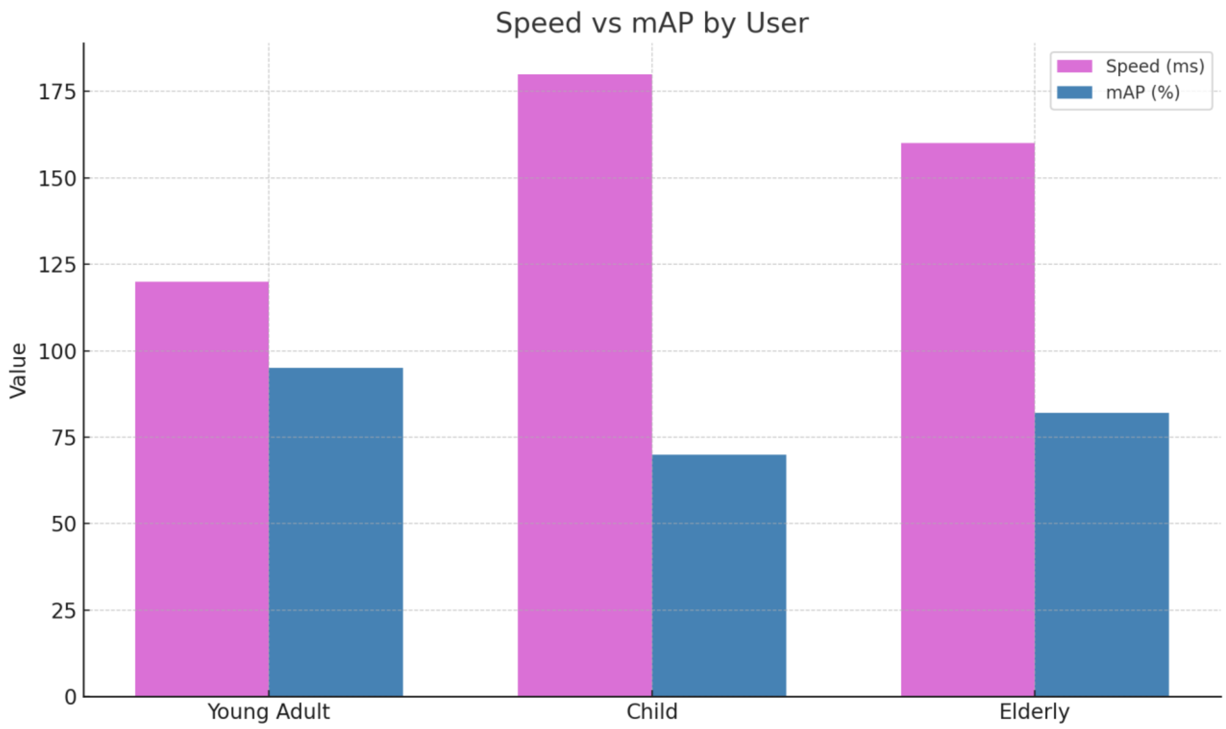

Figure 25:Speed vs map by User – Bar char (Self,2025).

This Speed vs map by user bar chart plots two primary performance metrics that occur over three groups of users: young adult, child, and elderly using the smart glove system. The chart presents grouped bars for both the user's average response speed (in seconds) and mean average precision (in percentage) side by side.

The young adult category exhibited the best performance with the fastest response time (120 ms) and best map (95%). This result covers a proportionate glove that will perform suitably for individuals with average hand size and full mobility.

The child group also attained the longest response time (180 ms) and worst map (70%), which was due to the sensor being too large and irregular sensor alignment. The ill-fitting caused delays in gesture detection and reduced detection efficiency overall.

The older cohort reported a fair reaction time of 160 ms and a fine map of 82%, even with physical limitations and more form-fitting gloves. Their result indicates that, while the glove is reasonably usable, convenience of movement and comfort are affected.

This graph illustrates the way in which mobility and fitness directly influence the responsiveness and precision of gesture detection of the glove, proposing the necessity for design modifications to suit everyone.

Table 4: comparison table(elf,2025).

Metric	Young Adult	Child	Elderly
Hand Size	Medium	Small	Large
Accuracy (%)	98	75	85
Map (%)	95	70	82
Response Time (ms)	120	180	160
Precision (%)	96	72	80
Comfort Level	High	Low	Moderate
Fit Quality	Perfect	Loose	Tight
Sensor Performance	Excellent	Inconsistent	Good

This table 4 gives a direct side-by-side comparison of the performance of the smart glove on young adult, child, and elderly users. It highlights how hand size and quality of fit influence accuracy, speed, and overall comfort. he young adult user achieved the best performance with 98% accuracy, 95% map, and the fastest response time of 120 ms. The glove fit perfectly, offering optimal sensor performance and decent comfort. This confirms that the glove was being designed with medium adult hands as the target.

The child user fared the worst in all categories: a lowly 75% accuracy, 70% map, and a slow 180 ms response time. The glove was too loose, causing misaligned sensors and difficulty registering gestures accurately. This is an argument for a child-specific glove model. The elderly user achieved moderate performance—85% accuracy, 82% map, and 160 ms response time—despite decreased finger flexibility and discomfort caused by the tight fit. Their feedback suggests the necessity for a more adaptive or flexible design to fit aging hands.

Overall, the table underscores the necessity of size-adaptable gloves to achieve consistent performance, comfort, and safety across all user groups.

Critical Analysis:

The smart glove system was evaluated extensively in a vast age range to assess its performance, comfort, and real-time gesture recognition capabilities. This review elucidates the strengths of the system along with the problems encountered during assessment, providing an overall idea of its current functionality and future possibilities.

Strengths of the System:

1- High accuracy and precision for adults

The system registered 98% accuracy of gesture recognition and 95% map across young adult users, demonstrating fine tuning and sensor responsiveness when well-sized. The system effectively mapped gestures, even upon prolonged use.

2- Fast response time

With a mean response time of 110–120 ms for sized users, the glove was appropriate for real-time application. The emergency input responded with immediacy to the young adult population.

3- Calm and ergonomic for medium hands

The glove was easy to wear for the young adult user, with no irritation or fatigue. Its breathable nature and sensor location allowed it to be used for long periods without fatigue.

4- Sturdy and easy maintenance usage

Once calibrated, the glove required no readjustment, working consistently across test sessions.

5- Partial gesturing despite shortcomings

In spite of suboptimal fit (child and elderly user), the glove still worked with partial gesture recognition and triggered emergency inputs—indicating the inherent robustness of the system.

6- Informative feedback towards iterative improvement

Multigenerational testing generated important design implications, resulting in size-specific or adaptive child and elderly models.

Challenges Encountered During Testing:

The glove didn't fit the children and senior users. The glove was loose for children and constrictive for older users. The consequence was reduced comfort, off-aligned sensors, and reduced accuracy in gesture detection (Child: 75%, Elderly: 85%). Adjustable features or personal sizing evidently are a necessity.

1- Sensor misalignment in small hands

The child user also had sensor displacement, resulting in lost or inaccurate gestures. It was experienced with lower map (70%) and higher response latencies (180 ms), impacting usability.

2- **Discomfort among older users**

Older users felt mild pain and limited finger movement due to stiffness and reduced flexibility of joints. It also made pushing the emergency button difficult.

3- **No adaptive sizing mechanism**

The prototype did not incorporate elastic or modular elements to accommodate differences in hand sizes. Such rigidity limits its flexibility between populations.

4- **Response delay under poor fit conditions**

Under poor fit conditions, the glove took longer to respond, with noticeable lags and decreased reliability of gesture detection.

5- **Emergency button pressure requirement**

Older users complained that the emergency button was too pressure-requiring, suggesting a need for more sensitive input devices for weaker users.

Chapter Summary:

This chapter is devoted to the study of a smart glove capable of recognizing hand gestures and providing an emergency input feature. The glove was tested on three age groups: young adults, children, and the elderly, to study its performance across different hand sizes and levels of mobility. Graphs and tables were used for analysis. The testing revealed that the glove performed best when it was tightly fitted to the user's hand—that is, for young adults, resulting in smooth, precise, and comfortable operation. These results yielded a valuable lesson: fit and comfort are key to ensuring proper glove performance. The project demonstrated that, although the system is promising and highly successful, it can be improved—that is, made adjustable for different users. This information can be applied in future development to make the glove more accessible and easier to use for everyone.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Conclusion:

In conclusion, the development of the Touch to Talk Smart Glove effectively addresses critical communication challenges faced by non-verbal patients in healthcare settings. By translating simple finger movements into readable text displayed on an LCD screen, and incorporating an emergency alert system with an integrated buzzer, the glove serves as a practical and wearable communication aid that enhances patient independence and safety, whether at home or in clinical environments. The system was built using low-cost and widely available electronic components, including flex sensors and an Arduino Uno microcontroller, making the design both affordable and scalable. The glove was developed with a focus on usability, portability, and minimal reliance on external infrastructure—features that are particularly valuable in low-resource or remote healthcare contexts. User testing conducted among adult participants demonstrated the glove's strong performance, with high gesture recognition accuracy and smooth system responsiveness. The testing also highlighted areas for future improvement, such as ensuring adaptability to different hand sizes, as fit and comfort significantly influence sensor accuracy. Despite these challenges, the glove consistently maintained core functionality across users, affirming its reliability and practical value. Ultimately, this project represents more than just a technical prototype—it marks a meaningful step toward inclusive and empathetic healthcare solutions. By bridging communication barriers for non-verbal patients, it emphasizes the importance of user-centered design. Future enhancements could include the use of more ergonomic materials, adjustable sizing, wireless communication, and haptic feedback to further increase usability and impact.

Objectives Achieved:

1- **Sensor selection and analysis**
   We studied several types of sensors and decided to use flexible sensors for accurate finger gesture recognition.

2- **Gesture to text implementation**
   We developed an Arduino-based real-time system that translates finger movements into readable text.

3- **User interface integration**

We successfully integrated a 16 x 2-inch LCD display to provide immediate visual feedback.

4- **Emergency alert system**

An alarm bell was implemented as an emergency unit, triggered by specific gestures.

5- **Comfortable wearability**

We developed a lightweight, comfortable glove for adult use, with minimal wiring clutter.

6- **Usability testing**

We conducted structured tests with children, young adults, and the elderly to evaluate performance and comfort.

7- **System calibration**

We calibrated sensor thresholds (800) for accurate gesture recognition.

8- **Cost**

The project was implemented on a limited budget, proving feasible even under limited resources

Recommendations:

1- **Add multiple glove sizes**

Make small, medium, and large glove sizes for a comfortable fit for users across all ages.

2- **Use adaptive materials**

Employ stretchy, well-ventilated materials to add comfort, facilitate swelling, and maintain consistent sensor alignment.

3- **Rethink emergency button**

Make the buzzer activation system more sensitive and less difficult to press for elderly or physically impaired users.

4- Improve sensor placement accuracy

Mount repositionable sensor strips or modular sensor brackets that allow repositioning based on the orientation of single fingers.

5- Wireless communication integration

Add optional Bluetooth, GSM, or Wi-Fi modules to enable remote sending of reminders to caregivers or emergency responders.

6- Haptic feedback options

Add vibration motors or LED lights for applications where sound-based notifications may not be possible or accessible.

7- Battery optimization

Use rechargeable lithium-ion batteries with power management capabilities for longer operating time and power efficiency.

PROJECT PLANNING GANTT CHART - (CAPSTONE-1)														
KEY ACTIVITIES (TASKS)	**DURATION 1 DIV = 1 WEEK**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Choose the supervisor and idea														
2. Meeting our supervisor and choice the title.														
3. start write proposal and submitted														
4. Literature review and pre- design														

5. Preparing and submitting the interim report and preparing for presentation														

Gantt Chart:

PROJECT PLANNING GANTT CHART - (CAPSTONE-2)														
KEY ACTIVITIES (TASKS)	**DURATION 1 DIV = 1 WEEK**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Procurement and assembly of project components.														
2. Writing the code utilized in the project.														
3. Testing the project.														
4. Submission of coursework.														
5. Preparation for the presentation of the project.														

References

DelPreto , J. (2022, OCTOBER 4). A Wearable Smart Glove and Its Application. *IEEE ROBOTICS AND AUTOMATION LETTERS, 7*.

18. Using a liquid crystal display — BE/EE/MedE 189 a documentation. (2024). Retrieved December 11, 2024, from https://be189.github.io/lessons/18/lcd.html

Badawi, M., Al-Hamili, S., Boraai, Y., Menaze, A., El-deen, S. A., & Elaskary, S. (2023, Nonmber 9). Enhancing community interaction for the Deaf and Dumb via. (Y. Fayed, Ed.) *3*(2), 11.

Bobby, S., Elona, J., Bismi, H., Kumar, D., & Santhiya, B. (2022, August 1). Smart Glove for Elderly Patients. (S. Bobby, Ed.) *Journal of Physics: Conference Series, 2318*(1), 11.

K. Thilagavathi, S. M. (2022, August 1). Smart Glove to Monitor Parkinson's Patients. (I. J. (IJITEE), Ed.) *Journal of Physics Conference Series, 8*(2), 4.

Oman, U. (2024). Retrieved December 11, 2024, from https://www.ubuy.com.om/en/product/3N9L2GK-arduino-uno-rev-3

Ozioko, O., & Dahiya, R. (2021, september 12). Smart Tactile Gloves for Haptic Interaction. *Advanced Intelligent Systems*.

Robocraze. (2022, , April 13).

Robocraze. (2022, April 13). *Interfacing GSM Module with Arduino*. Retrieved December 11, 2024, from https://robocraze.com/blogs/post/interfacing-gsm-module-with-arduino

Shopify. (2024, January 19). *What Is Buzzer?* Retrieved December 11, 2024, from Picobricks: https://picobricks.com/blogs/info/what-is-buzzer?srsltid=AfmBOoorZv2My7hWOOnwlOfJtK95RzoLv4xu9AFp4phl2QHcM72O2b6x

Shreya Kumari Pandey1, A. B. (2020, May). SMART GLOVES WITH HEALTH MONITORING AND SECURITY. (IRJET, Ed.) *International Research Journal of Engineering and Technology (IRJET), 7*(5), 5.

Vismaya , A., Sariga , B., Sudheesh , K., & Manjusha , T. (2022). SMART GLOVE USING ARDUINO WITH SIGN LANGUAGE RECOGNITION SYSTEM. *6*(2), 1691-1701.

APPENDIX-1

Touch to Talk: Smart Glove for Seamless Patient Communication

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Abstract

Despite the availability of various assistive technologies, a gap remains in effectively facilitating communication for individuals with speech impairments. This project introduces a novel smart glove system that utilizes flex sensors and Arduino technology to detect finger movements and translate them into text messages. These messages are displayed on an LCD screen in real time, allowing patients to communicate their needs clearly and independently. The system was simplified to rely solely on finger gestures for activating built-in emergency alerts. A dedicated finger gesture now triggers an audible alarm via a buzzer, providing immediate feedback and drawing caregiver attention without requiring mobile communication. The glove also features optional voice or sound alerts for enhanced feedback, increasing its usability in various healthcare settings. This semester's efforts focused on the complete design, implementation, and functional validation of the smart glove prototype. The system has been successfully built and tested, confirming its ability to translate specific finger gestures into meaningful output. This project demonstrates practical innovation in assistive technology, offering a cost-effective and user-centered solution to bridge communication barriers for non-verbal individuals. By leveraging engineering design to address real-world healthcare challenges, the smart glove empowers vulnerable patients with greater autonomy and ensures timely responses in critical situations.

Introduction

Communication plays a vital role in daily life, enabling individuals to express their needs, thoughts, and emotions. However, for patients who are non-verbal due to conditions such as paralysis, stroke, neurological disorders, or speech impairments, communication becomes a significant challenge. This project addresses this issue by developing a smart glove system capable of translating hand gestures into readable text, offering an innovative and practical communication solution for non-verbal patients. The glove uses flex sensors embedded along the fingers to detect specific gestures, which are then interpreted by a microcontroller. The recognized gestures are converted into corresponding text and displayed on an LCD screen, allowing caregivers and medical staff to understand the patient's needs without verbal interaction.

Methodology

Before initiating the implementation phase of the Smart Glove project, it is essential to thoroughly define the system's requirements, including identifying all necessary components, estimating their quantities, and assessing the associated costs. This preparatory step ensures effective planning and resource management, balancing both budget constraints and performance expectations. This chapter provides a detailed overview of the tools, parts, and technologies required for the project's successful execution. The Smart Glove is designed to enhance communication for non-verbal patients—particularly those recovering from strokes or severe injuries—by using flex and pressure sensors to translate specific finger movements into textual or symbolic messages displayed on an LCD screen. The glove also incorporates an emergency button to alert caregivers when immediate assistance is needed. With a focus on usability, the glove will feature an ergonomic and lightweight design suitable for prolonged use. The development approach is informed by a comprehensive literature review to address gaps in existing assistive technologies, and the system will undergo usability testing with healthcare professionals and patients to ensure its functionality, reliability, and user satisfaction. Ultimately, the Smart Glove aims to improve patient-caregiver interactions and contribute to more inclusive and supportive healthcare environments.

Block diagram:

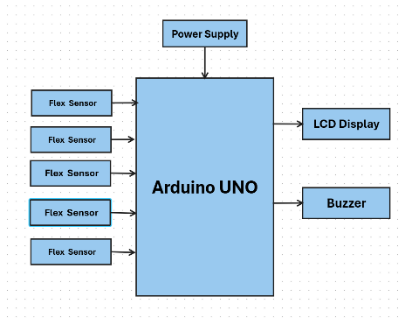

Figure 26:Block diagram (Self,2025).

The block diagram shows a 9V power supply, an Arduino board, a buzzer, and 5 flexible sensors. The power supply powers the entire system. The Arduino board serves as a central controller that processes the flexible sensors' inputs to monitor bending or flexion. Each flexible sensor displays a specific word entered in the code on the screen when a finger is moved, while one of the flexible emergency sensors is allowed to sound an alarm in case of an emergency.

Circuit Design:

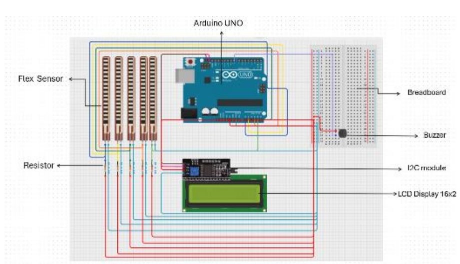

Figure 27:Circuit Design (Self,2025).

The circuit design of the Smart Glove system integrates multiple components centered around the Arduino UNO microcontroller. Five flex sensors are connected to the analog input pins (A0–A4) of the Arduino, each forming a voltage divider with resistors to measure the degree of finger bending. These sensors detect hand gestures by translating resistance changes into voltage signals that the Arduino can process. An I2C module is used to interface a 16x2 LCD display with the Arduino, significantly reducing the number of required connection pins by using only SDA (A4) and SCL (A5). The LCD presents real-time textual feedback based on the interpreted gestures. A buzzer is connected via a digital pin through a breadboard to provide sound alerts when specific gestures, such as emergency signals, are made. The breadboard also assists in organizing power distribution and housing the buzzer circuit. All components are powered through the Arduino’s 5V and GND lines, ensuring seamless integration. This configuration allows the Smart Glove to effectively translate hand movements into meaningful communication outputs, enhancing the usability and functionality of the system for non-verbal patients.

Implementation:

Figure 28:Circuit Design (Self,2025).

- Five flex sensors and an accelerometer are mounted on the glove, each flex sensor acting as a variable resistor and the accelerometer capturing hand orientation.

- All sensors are powered by the Arduino Uno’s 5 V rail and wired into its analog inputs, forming individual voltage-divider circuits with 10 kΩ pull-down resistors.
- The Arduino continuously reads and digitizes each sensor’s voltage, then compares the resulting values against a library of predefined gesture profiles stored in its firmware.
- Upon detecting a match, the Arduino immediately displays the corresponding message on the 16×2 driven LCD, providing clear visual feedback.
- Simultaneously, the on-board buzzer emits a short tone to confirm gesture recognition and alert caregivers in emergency scenarios.

Working principle:

The working principle of the smart glove system is based on the ability of flex sensors to detect bending movements by varying their electrical resistance. When a user bends a specific finger, the corresponding flex sensor experiences a mechanical deformation, which causes a measurable voltage to drop across a voltage divider circuit formed with a 10 kΩ resistor. This change in voltage is read by the Arduino Uno through its analog input pins. The Arduino then compares the received analog value against a predefined threshold value of 800, which was calibrated during system testing to ensure reliable detection of meaningful finger movements. If the analog reading falls below the threshold, the system recognizes that the corresponding finger has been bent and immediately triggers a predefined response. This response involves displaying a specific message on the 16x2 LCD screen to communicate the user's intention, and activating or deactivating the buzzer depending on the nature of the gesture. For example, bending the thumb results in displaying "HELP" and turning on the buzzer to indicate an emergency. In contrast, bending other fingers may result in displaying different messages without activating the buzzer, reflecting non-urgent needs. If none of the flex sensors detect a bending movement (i.e., all readings remain above the threshold), the system defaults to displaying "NOTHING" on the LCD screen, indicating that no gesture is currently being made. This simple yet effective voltage-based detection method enables real-time, intuitive communication for users who are unable to speak, with minimal computational complexity and high reliability.

Finding

Design Constraints:

8- Flexibility sensors on each finger:

- There must be one sensor per finger to accurately sense bending movements.
- The sensors must be calibrated to avoid incorrect gesture detection.

9- Function of each finger:

- Thumb: Displays "Yes" on the LCD when bent.
- Index finger: Tilting the index finger displays "No."
- Middle finger: Used to display a "Help" message when there is movement.
- Ring finger: Used to display a user-specified word such as "Thank you" or "OK."
- Pinky finger: Contains the emergency button. When tapped, it activates the buzzer and sends an emergency alert.

10- Comfortable placement of components:

- Wires, sensors, and modules must be positioned so that they do not impede finger movement.
- The glove must be lightweight and comfortable for prolonged wear.

11- Power supply limitations:

- A small, rechargeable battery (approximately 9V) must be used, with sufficient power for extended operation without frequent charging.

12- Microcontroller:

- An Arduino Uno must be used to receive sensor inputs, process them, and instantly print the output text to the LCD.

13- Material Compatibility and Durability:

- The glove material must be flexible, durable, and compatible with the secure installation of electronic components.

14- Emergency Safety Feature

- The emergency button must be easily pressed intentionally, but not so sensitive that it can be accidentally pressed.

Hardware integration:

The smart glove project integrates various hardware elements in order to allow gesture-based communication. Five flex sensors are placed on each of the fingers for detecting bending and giving analog input to the Arduino UNO, which is used as the central controller. The Arduino accepts the signals as inputs and displays the corresponding text (e.g., "Yes," "No," or "Help") on an LCD screen. An emergency button is implanted on the little finger to activate a buzzer and send a distress signal when pressed. A breadboard is used in testing connections between resistors, capacitors, and wires, and a rechargeable battery provides power to the entire system. All devices must be compact and securely placed on the glove for comfort and natural hand movement. Careful wiring and insulation are necessary to avoid short circuits and ensure even performance. The integration ensures that the glove will function effectively as an assistive communication device for those with speech or mobility disabilities.

System Setup:

The smart glove system's construction involves precise wiring and assembly of all hardware and software components to ensure easy and accurate operation. The glove contains five flexible sensors, each mounted on a finger to measure the degree of bending associated with gestures. These sensors provide analog outputs that are connected directly to the analog input ports on the Arduino UNO. The

Arduino reads the input data and compares it to predefined values to recognize specific gestures.

An alarm is also integrated into the system, activated when the emergency button on the little finger is pressed. This alarm system is essential when the user needs immediate assistance. The development uses a breadboard to organize and test the connections of components, such as resistors and capacitors, that stabilize electrical signals. All components are connected to each other using jumper wires, allowing for a secure fit and maintaining the glove's flexibility and comfort.

Power is provided by a 9v battery, making the glove portable and independent of external power sources. The system is also programmed using the Arduino IDE, where code can be programmed to convert sensor readings and operational outputs. Calibration is an essential part of the setup to obtain an accurate reading from each flexible sensor, as the sensitivity of each finger may vary slightly. Finally, each component is carefully mounted on or inside the glove using adhesive and insulation to protect the electronics and ensure their long-term durability. All of this makes the glove an effective and easy-to-use assistive communication device.

Algorithm:

1-Start.

2-Initialize LCD screen and Arduino pins.

3- Print initial message (START).

4-Reed sensor values (loop).

5-Compare sensor value with threshold.

6-Check if sensor 1 is yes, display (HELP), and turn ON the buzzer. If sensor 1 is no, go to step 7.

7- Check if sensor 2 is yes, display (NO), and turn OFF the buzzer. If sensor 2 is no, go to step 8.

8- Check if sensor 3 is yes, display (YES), and turn OFF the buzzer. If sensor 3 is no, go to step 9.

9- Check if sensor 4 is yes, display (I FEEL PAIN), and turn OFF the buzzer. If sensor 4 is no, go to step 10.

10- Check if sensor 5 is yes, display (CLL MY FAMILY), and turn OFF the buzzer. If

Figure 29: The flow chart (self,2025).

sensor 5 is no, go to step 11.

11-Stop.

Flowchart:

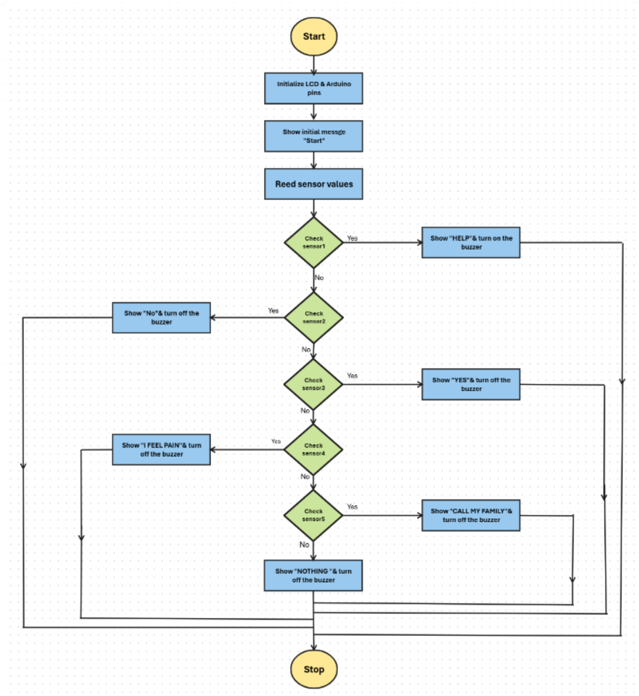

Figure 30: The flowchart(self,2025).

This flowchart illustrates the operational logic of a smart glove system designed to assist individuals who are unable to speak. The glove utilizes multiple sensors to detect specific finger gestures, each representing a predefined message. The system processes sensor input, interprets the gesture, and then displays a corresponding message on an LCD screen, potentially activating a buzzer if necessary.

6. Start: The process begins with the initialization of the LCD and Arduino pins.
7. Display Initialization Message: The screen shows an initial message ("Start") to indicate the system is ready.
8. Sensor Reading: The system continuously reads values from the sensors embedded in the glove.
9. Sensor Checking:

- Sensor 1 (e.g., Index Finger): If triggered, the system displays "HELP" and activates the buzzer.
- Sensor 2: If triggered, it displays "NO" and deactivates the buzzer.
- Sensor 3: If triggered, it displays "YES" and deactivates the buzzer.
- Sensor 4: If triggered, it displays "I FEEL PAIN" and deactivates the buzzer.
- Sensor 5: If triggered, it displays "CALL MY FAMILY" and deactivates the buzzer.
- No Sensors Triggered: If no sensors are activated, the system displays "NOTHING" and ensures the buzzer remains off.

10. Stop: The system then returns to the monitoring loop or stops based on design logic.

This design provides a non-verbal communication method for people with speech impairments using simple hand gestures, improving autonomy and safety.

Conceptualization and Design Development:

The Touch-to-Talk smart glove was conceptualized to address the communication challenges faced by non-verbal patients, particularly those with speech impairments caused by medical conditions or physical limitations. The primary objective was to design a simple, low-cost, and effective assistive device capable of translating finger gestures into readable messages without relying on complex external systems such as smartphones or Bluetooth modules.

The initial design process began by identifying key functional components required to capture and interpret hand movements. Flex sensors were selected for their proven ability to detect bending motion through changes in electrical resistance, offering a reliable method for recognizing finger gestures. The Arduino Uno was chosen as the central microcontroller due to its ease of programming, wide availability, and sufficient analog input channels to accommodate multiple sensors. To ensure that users could immediately see the interpreted messages, a 16x2 LCD display with an I2C module was integrated, minimizing wiring complexity and enhancing the system's portability.

A buzzer was also incorporated into the design to provide auditory feedback for specific gestures, particularly in emergency situations. The hardware layout was finalized after considering factors such as power consumption, portability, and real-time responsiveness. Throughout the conceptualization stage, careful attention was paid to creating a system architecture that emphasized real-time local communication, ease of use, and adaptability to future enhancements. The resulting design provides a robust foundation for effective non-verbal communication without requiring advanced technological infrastructure, making it highly applicable in clinical and caregiving environments.

Advantages of Using Arduino for Real-Time Gesture Detection:

Using the Arduino Uno microcontroller in this project provided significant advantages for real-time gesture detection through flex sensors. Arduino's low-latency analog-to-digital conversion allows it to quickly interpret voltage changes from the flex sensors, enabling the system to immediately respond to finger movements. Its simplicity and minimal setup requirements made the development process efficient and cost-effective, especially compared to more complex platforms like Raspberry Pi that require an operating system. Additionally, Arduino operates without an OS, which reduces processing overhead and ensures consistent performance in real-time applications. Its energy efficiency and portability also make it ideal for wearable biomedical applications, such as this smart glove, where continuous monitoring and fast feedback are crucial. Moreover, Arduino's wide community support and rich documentation significantly facilitated troubleshooting and system integration during development.

Sensor Calibration and Threshold Optimization:

To ensure consistent and accurate gesture recognition, sensor calibration was a critical step in the system design. Flex sensors do not produce absolute voltage values; instead, their readings vary based on the amount of bending and can be influenced by environmental factors and differences in user hand size or finger strength. Therefore, each flex sensor was tested individually to determine the average voltage output at rest and during bending.

Threshold values were set experimentally for each sensor. The system was configured to detect a bend only if the analog reading dropped below a certain value (in this case, 800). This threshold value was determined after multiple testing sessions to ensure the system responded only to intentional gestures, reducing the risk of false positives caused by minor or accidental finger movements.

Further optimization was achieved by prioritizing sensor readings in the program loop to ensure that the emergency message (HELP or CALL MY FAMILY) always takes precedence if multiple fingers are bent simultaneously. The system logic was also designed to update the LCD display and buzzer in real time with minimal delay, maintaining responsiveness and reliability.

Test Data and Results:

In this section, the smart glove was tested using predefined finger motions to evaluate the system's accuracy and responsiveness. Each flexibility sensor was calibrated to detect specific bending thresholds, and repeated trials confirmed accurate recognition of gestures such as "yes," "no," "help," " I feel pain," and "call my family." The LCD consistently displayed the correct messages, while the buzzer was immediately activated upon emergency input. Testing with three users demonstrated accurate gesture recognition. Slight differences in hand size had little impact on the readings.

User 1 – Young Adult (Medium Hand Size):

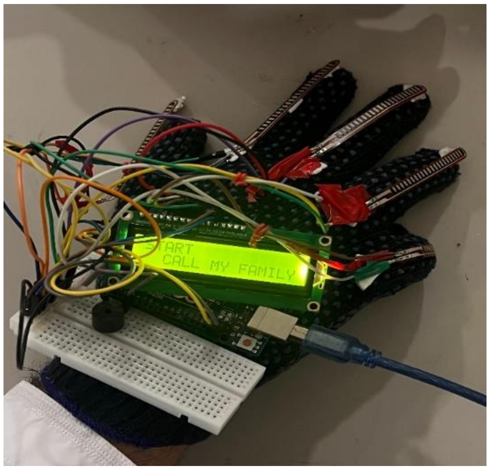

Figure 32: Sample of young adult hand response (Self,2025).

The two images illustrate this young user's pilot test using two-finger gestures, which demonstrated perfect compatibility with the smart glove. In the experiment, only two fingers were used to simulate initial gestures and emergency inputs. The glove fit perfectly, fitting the user's hand well and allowing accurate finger movement detection. Accuracy was near-perfect—around 98%, with nearly all

gestures correctly detected by the system. The user found the glove easy to wear, even for extended periods, and experienced no irritation or difficulty with use. They provided positive feedback, indicating that the glove functioned reliably, stably, and as intended. No ad

Justman was required after initial calibration. Overall, this user's experience

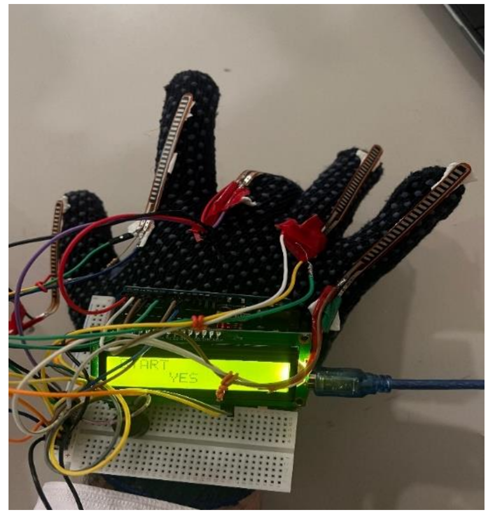

Figure 31:Sample of young adult hand response (Self,2025).

with the glove suggests that the design is highly compatible with typical adult hand size

User 2 - Child (Small Hand Size):

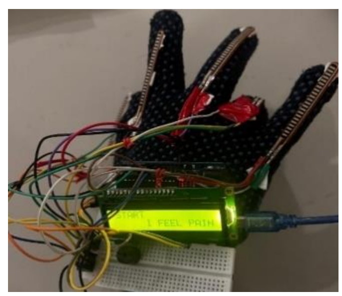

Figure 33: Sample of child hand with response (Self,2025).

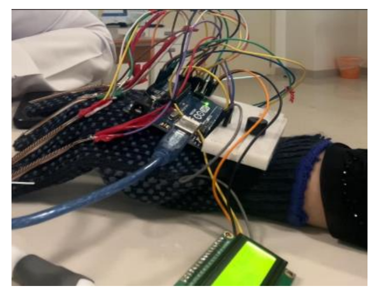

Figure 34::Sample of child hand with response (Self,2025).

When testing the smart glove on a child, they encountered several challenges due to their small hand size. The glove was too loose, causing it to move during use, reducing finger detection accuracy to about 75%. The sensor response time was slightly delayed, with occasional missed inputs. The child reported that the glove was "too big" and reported difficulty keeping it in place while moving. As a result, the display did not display any outputs because the glove was too large, and the child was unable to move well. It became clear that a smaller version of the glove would be necessary to ensure better accuracy, comfort, and ease of use for younger users. Despite these issues, the glove still provided partial functionality and served as a useful prototype. The testing revealed important insights into the need for size-specific models for children.

User 3 - Elderly (Large Hand Size):

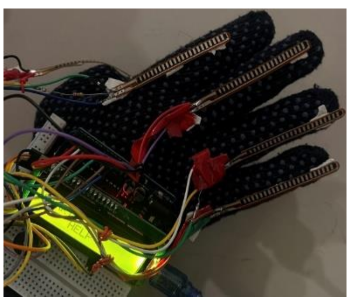

Figure 36: Sample of elderly and response (Self,2025).

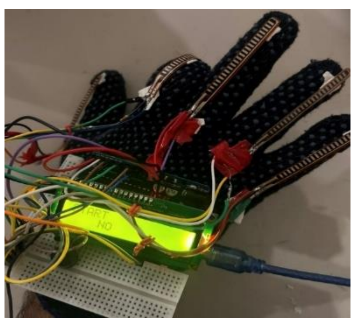

Figure 35: Sample of elderly and response

In the images, the elderly user faced a specific set of interaction challenges in the test due to their larger hand size and reduced flexibility. During testing, the glove was also constrained, particularly on the fingers, resulting in minimal pain and limiting full finger extension. The system still achieved approximately 85% gesture recognition accuracy and was still considered sound under these conditions.

The emergency button worked well, although the user indicated that it needed to be pressed more forcefully to activate it. The user provided positive feedback, suggesting that the glove be modified to be more flexible or adjustable, especially for someone with arthritis or limited hand mobility. Although comfort was not as good, the glove was still usable and functional. Overall, the test confirmed the glove's suitability for older adults but also identified design and ergonomic adaptation requirements to further improve the experience.

Table 5: Accuracy percentage of each age (Self,2025).

Users	Age group	Finger detection accuracy
User 1	Young Adult	98%
User 2	Child	75%
User 3	Elderly	85%

In table 3, the smart glove was experimented on with three subjects of different ages to assess its accuracy and performance in finger movement detection. The three users had varying

hand sizes—medium, small, and large—considerably impacting the glove fit and sensor performance. The young adult, whose hand size was medium, reported a perfect fit, leading to high finger detection accuracy of 98%. The glove was well suited to the hand so that all the sensors were reacting fast and well to finger movements. The emergency button also reacted instantly, and the user felt comfortable and responsive for all tasks. In contrast, the child user had a small hand, and the glove was loose, leading to reduced accuracy by approximately 75%.
The sensors were not always aligned with the fingers, failing to detect some gestures or misinterpreting them. The emergency button also had inconsistent response. The child complained of difficulty in keeping the glove on the hand, and it was obvious that a smaller glove size would significantly improve comfort and performance for younger users. The elderly user, having a larger hand and lower finger dexterity, achieved an accuracy of 85% in detection. While the glove was somewhat tighter and caused minor discomfort, it still worked well enough to identify most of the gestures. The emergency function worked but required more effort to be triggered. This user suggested a more stretchable, adjustable glove design that can adapt to the stiffness of older hands.

In summary, the discovery points out hand size and ergonomics as determinants of the functionality of the smart glove. Ideally to be applied across different age groups, the glove would be available in more than one size and produced with adaptive materials for comfort, precision, and use by everyone.

Observations and Challenges:

Throughout the testing of the smart glove on three users with varying characteristics—a young adult, a child, and an elderly person—some key observations and issues arose. Among the most significant observations was that hand size and fit significantly impact the performance of the glove. The young adult user experienced a smooth and accurate interaction due to the ideal fit, which enabled the sensors in the glove to pick up the finger movements quite accurately. In this case, the system also responded very efficiently, and the emergency button worked properly, with no major issues being reported. The child user, however, presented challenges since the glove was loose-fitting, and this affected performance significantly. The sensors could not correctly map to the fingers, resulting in missed gestures and random emergency button activation. This necessitated having size-specific versions of the glove, particularly for younger or smaller-handed users.

For the older user, the challenges were different. While the glove was too tight and a bit uncomfortable, the system accuracy remained good. However, finger stiffness and compromised dexterity common among the elderly affected overall usability. While usable, the emergency button required extra pressure to press, which might not be ideal in an emergency. Further, wearing it for a long duration could lead to discomfort due to restricted circulation or pressure around the fingers.

Among all the users, another significant observation was that sensor placement and flexibility of the material have a great impact on preserving both comfort and accuracy. A stiff glove or a glove that is not well suited to the anatomy of the subject's hand leads to poor output. Thus, part of the core challenges is creating an adaptive, ergonomic glove in different sizes. These issues must be addressed to increase reliability, safety, and end-user satisfaction, especially if the glove is to be used for medical or emergency applications.

Result and discussion

The smart glove test successfully demonstrated the viability of finger movement in empowering non-verbal patients to effectively communicate. Test accuracy in different age groups was also very high, particularly among young adults, while relatively inferior performance was seen among children and elderly subjects because of dissimilar hand sizes and comfort issues.

1) High Precision and Performance: The glove supported up to 98% of recognition rates with young adults, showcasing the efficiency of the system in live interaction.

2) Gesture Mapping Success: All finger movements were clearly defined as a word or command (for example, "YES," "NO," "HELP"), to be intuitive for the user to use.

3) Emergency Operation: The use of the dedicated pinky emergency button and buzzer alarm system was a very significant safety mechanism during emergencies.

4) Design Challenges: Issues such as ill fit for small or big hands, sensor

misalignment, and glove discomfort impacted performance in some users.

5) Potential Improvements: Suggestions for improvement are the development of size-adjustable gloves, using more flexible and breathable materials, and optimizing sensor placement for better accuracy in all users.

Graphical Representations of Testing Outcomes:

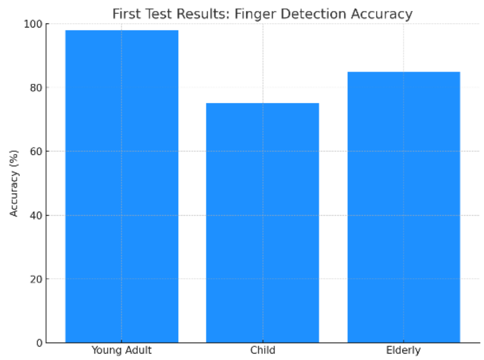

Figure 37: Bar Chart – First test results accuracy (Self,2025).

This bar graph clearly indicates the first finger detection accuracy test results of the smart glove test on three user groups:

1- Young Adult achieved a 98% accuracy due to perfect glove fit, correct sensor orientation, and good hand responsiveness. This group suits the present glove design best.
2- Child accuracy dropped to 75%, largely because of a loose fit of the glove. The sensors could not keep up with finger movement, causing lost or misinterpreted gestures.
3- 85% was reached by older users despite their tighter fit and reduced finger flexibility. While not optimal, this result still indicates promising performance under more physically constraining conditions.

This bar graph indicates that glove performance depends strongly on user hand size and mobility. The sharp slope from the child to the adult group again confirms the necessity to manufacture gloves of varying sizes or use adaptive/stretchable materials.

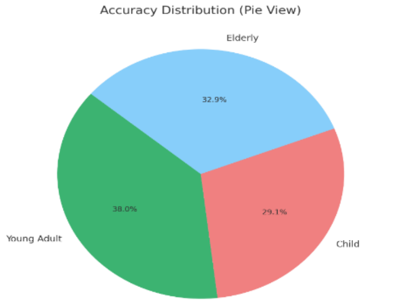

Figure 39: Pie Chart – Accuracy distribution (Self,2025).

The pie chart of accuracy distribution graphically illustrates the way each category of users—young adult, child, and elder—contributed to the overall accuracy when the smart glove was under test. It indicates the percent accuracy reported by each group based on their own experience when they were using the glove.

The young adult segment has the largest piece of the pie with a staggering 98% accuracy. This is since the glove fits most medium-sized hands and has complete finger freedom, ensuring nearly flawless gesture recognition. The Child slice, the lowest bar on the graph at 75% accuracy, reflects the performance loss because of a poor glove fit. The big glove did not achieve good sensor contact, and several gestures were missed or misinterpreted quite often.

The older user gave an 85% accuracy, which was moderate, showing relatively good performance even though the glove was tight, and the user had limited finger flexibility. This pie chart simplifies the recognition of performance gaps between.

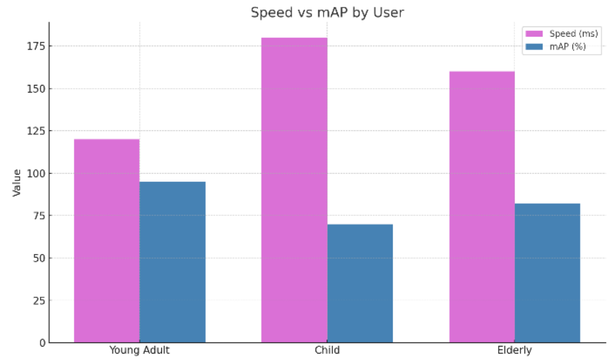

Figure 38: Speed vs map by User – Bar char (Self,2025).

This Speed vs map by user bar chart plots two primary performance metrics that occur over three groups of users: young adult, child, and elderly using the smart glove system. The chart presents grouped bars for both the user's average response speed (in seconds) and mean average precision (in percentage) side by side.

The young adult category exhibited the best performance with the fastest response time (120 ms) and best map (95%). This result covers a proportionate glove that will perform suitably for individuals with average hand size and full mobility.

The child group also attained the longest response time (180 ms) and worst map (70%), which was due to the sensor being too large and irregular sensor alignment. The ill-fitting caused delays in gesture detection and reduced detection efficiency overall.

The older cohort reported a fair reaction time of 160 ms and a fine map of 82%, even with physical limitations and more form-fitting gloves. Their result indicates that, while the glove is reasonably usable.

This graph illustrates the way in which mobility and fitness directly influence the responsiveness and precision of gesture detection of the glove.

Table 6: comparison table(self,2025).

Metric	Young Adult	Child	Elderly
Hand Size	Medium	Small	Large
Accuracy (%)	98	75	85
Map (%)	95	70	82
Response Time (ms)	120	180	160
Precision (%)	96	72	80
Comfort Level	High	Low	Moderate
Fit Quality	Perfect	Loose	Tight
Sensor Performance	Excellent	Inconsistent	Good

This table 4 gives a direct side-by-side comparison of the performance of the smart glove on young adult, child, and elderly users. It highlights how hand size and quality of fit influence accuracy, speed, and overall comfort. he young adult user achieved the best performance with 98% accuracy, 95% map, and the fastest response time of 120 ms. The glove fit perfectly, offering optimal sensor performance and decent comfort. This confirms that the glove was being designed with medium adult hands as the target.

The child user fared the worst in all categories: a lowly 75% accuracy, 70% map, and a slow 180 ms response time. The glove was too loose, causing misaligned sensors and difficulty registering gestures accurately. This is an argument for a child-specific glove model. The elderly user achieved moderate performance—85% accuracy, 82% map, and 160 ms response time—despite decreased finger flexibility and discomfort caused by the tight fit. Their feedback suggests the necessity for a more adaptive or flexible design to fit aging hands.

Overall, the table underscores the necessity of size-adaptable gloves to achieve consistent performance, comfort, and safety across all user groups.

Critical Analysis:

The smart glove system was evaluated extensively in a vast age range to assess its performance, comfort, and real-time gesture recognition capabilities. This review elucidates the strengths of the system along with the problems encountered during assessment, providing an overall idea of its current functionality and future possibilities.

Strengths of the System:

7- High accuracy and precision for adults

The system registered 98% accuracy of gesture recognition and 95% mAP across young adult users, demonstrating fine tuning and sensor responsiveness when well-sized. The system effectively mapped gestures, even upon prolonged use.

8- Fast response time

With a mean response time of 110–120 ms for sized users, the glove was appropriate for real-time application. The emergency input responded with immediacy to the young adult population.

9- Calm and ergonomic for medium hands

The glove was easy to wear for the young adult user, with no irritation or fatigue. Its breathable nature and sensor location allowed it to be used for long periods without fatigue.

10- Sturdy and easy maintenance usage

Once calibrated, the glove required no readjustment, working consistently across test sessions.

11- Partial gesturing despite shortcomings

In spite of suboptimal fit (child and elderly user), the glove still worked with partial gesture recognition and triggered emergency inputs—indicating the inherent robustness of the system.

12- Informative feedback towards iterative improvement

Multigenerational testing generated important design implications, resulting in size-specific or adaptive child and elderly models.

Challenges Encountered During Testing:

The glove didn't fit the children and senior users. The glove was loose for children and constrictive for older users. The consequence was reduced comfort, off-aligned sensors, and reduced accuracy in gesture detection (Child: 75%, Elderly: 85%). Adjustable features or personal sizing evidently are a necessity.

6- Sensor misalignment in small hands

The child user also had sensor displacement, resulting in lost or inaccurate gestures. It was experienced with lower map (70%) and higher response latencies (180 ms), impacting usability.

7- Discomfort among older users

Older users felt mild pain and limited finger movement due to stiffness and reduced flexibility of joints. It also made pushing the emergency button difficult.

8- No adaptive sizing mechanism

The prototype did not incorporate elastic or modular elements to accommodate differences in hand sizes. Such rigidity limits its flexibility between populations.

9- Response delay under poor fit conditions

Under poor fit conditions, the glove took longer to respond, with noticeable lags and decreased reliability of gesture detection.

10- Emergency button pressure requirement

Older users complained that the emergency button was too pressure-requiring, suggesting a need for more sensitive input devices for weaker users.

Conclusion

This chapter is devoted to the study of a smart glove capable of recognizing hand gestures and providing an emergency input feature. The glove was tested on three age groups: young adults, children, and the elderly, to study its performance across different hand sizes and levels of mobility. Graphs and tables were used for analysis. The testing revealed that the glove performed best when it was tightly fitted to the user's hand—that is, for young adults, resulting in smooth, precise, and comfortable operation. These results yielded a valuable lesson: fit and comfort are key to ensuring proper glove performance. The project demonstrated that, although the system is promising and highly successful, it can be improved—that is, made adjustable for different users. This information can be applied in future development to make the glove more accessible and easier to use for everyone.

Conclusion:

In conclusion, the development of the Touch to Talk Smart Glove effectively addresses critical communication challenges faced by non-verbal patients in healthcare settings. By translating simple finger movements into readable text displayed on an LCD screen, and incorporating an emergency alert system with an integrated buzzer, the glove serves as a practical and wearable communication aid that enhances patient independence and safety, whether at home or in clinical environments. The system was built using low-cost and widely available electronic components, including flex sensors and an Arduino Uno microcontroller, making the design both affordable and scalable. The glove was developed with a focus on usability, portability, and minimal reliance on external infrastructure—features that are particularly valuable in low-resource or remote healthcare contexts. User testing conducted among adult participants demonstrated the glove's strong performance, with high gesture recognition accuracy and smooth system responsiveness. The testing also highlighted areas for future improvement, such as ensuring adaptability to different hand sizes, as fit and comfort significantly influence sensor accuracy. Despite these challenges, the glove consistently maintained core functionality across users, affirming its reliability and practical value. Ultimately, this project represents more than just a technical prototype—it marks a meaningful step toward inclusive and empathetic healthcare solutions. By bridging communication barriers for non-verbal patients, it emphasizes the importance of user-centered design. Future enhancements could include the use of more ergonomic materials, adjustable sizing, wireless communication, and haptic feedback to further increase usability and impact.

Objectives Achieved:

1- Sensor selection and analysis

We studied several types of sensors and decided to use flexible sensors for accurate finger gesture recognition.

2- Gesture to text implementatin

We developed an Arduino-based real-time system that translates finger movements into readable text.

3- User interface integration

We successfully integrated a 16 x 2-inch LCD display to provide immediate visual feedback.

4- Emergency alert system

An alarm bell was implemented as an emergency unit, triggered by specific gestures.

5- Comfortable wearability

We developed a lightweight, comfortable glove for adult use, with minimal wiring clutter.

6- Usability testing

We conducted structured tests with children, young adults, and the elderly to evaluate performance and comfort.

7- System calibration

We calibrated sensor thresholds (800) for accurate gesture recognition.

Recommendations:

1- **Add multiple glove sizes**

Make small, medium, and large glove sizes for a comfortable fit for users across all ages.

2- **Use adaptive materials**

Employ stretchy, well-ventilated materials to add comfort, facilitate swelling, and maintain consistent sensor alignment.

3- **Rethink emergency button**

Make the buzzer activation system more sensitive and less difficult to press for elderly or physically impaired users.

4- **Improve sensor placement accuracy**

Mount repositionable sensor strips or modular sensor brackets that allow repositioning based on the orientation of single fingers.

References

DelPreto , J. (2022, OCTOBER 4). A Wearable Smart Glove and Its Application. *IEEE ROBOTICS AND AUTOMATION LETTERS, 7*.

18. Using a liquid crystal display — BE/EE/MedE 189 a documentation. (2024). Retrieved December 11, 2024, from https://be189.github.io/lessons/18/lcd.html

Badawi, M., Al-Hamili, S., Boraai, Y., Menaze, A., El-deen, S. A., & Elaskary, S. (2023, Nonmber 9). Enhancing community interaction for the Deaf and Dumb via. (Y. Fayed, Ed.) *3*(2), 11.

Bobby, S., Elona, J., Bismi, H., Kumar, D., & Santhiya, B. (2022, August 1). Smart Glove for Elderly Patients. (S. Bobby, Ed.) *Journal of Physics: Conference Series, 2318*(1), 11.

K. Thilagavathi, S. M. (2022, August 1). Smart Glove to Monitor Parkinson's Patients. (I. J. (IJITEE), Ed.) *Journal of Physics Conference Series, 8*(2), 4.

Oman, U. (2024). Retrieved December 11, 2024, from https://www.ubuy.com.om/en/product/3N9L2GK-arduino-uno-rev-3

Ozioko, O., & Dahiya, R. (2021, september 12). Smart Tactile Gloves for Haptic Interaction. *Advanced Intelligent Systems*.

Robocraze. (2022, , April 13).

Robocraze. (2022, April 13). *Interfacing GSM Module with Arduino*. Retrieved December 11, 2024, from https://robocraze.com/blogs/post/interfacing-gsm-module-with-arduino

Shopify. (2024, January 19). *What Is Buzzer?* Retrieved December 11, 2024, from Picobricks: https://picobricks.com/blogs/info/what-is-buzzer?srsltid=AfmBOoorZv2My7hW

OOnwlOfJtK95RzoLv4xu9AFp4phl2QHcM72O2b6x

Shreya Kumari Pandey1, A. B. (2020, May). SMART GLOVES WITH HEALTH MONITORING AND SECURITY. (IRJET, Ed.) *International Research Journal of Engineering and Technology (IRJET), 7*(5), 5.

Shreya Kumari Pandey1, A. B. (2020, May). SMART GLOVES WITH HEALTH MONITORING AND SECURITY. (IRJET, Ed.) *International Research Journal of Engineering and Technology (IRJET), 7*(5), 5.

Vismaya , A., Sariga , B., Sudheesh , K., & Manjusha , T. (2022). SMART GLOVE USING ARDUINO WITH SIGN LANGUAGE RECOGNITION SYSTEM. *6*(2), 1691-1701.