Calcutta Institute of Engineering and Management

Department of Computer Science and Engineering

(Affiliated to Maulana Abul Kalam Azad University of Technology, West Bengal)

Kolkata, West Bengal 700040

SonoMimic - Transmuting Sign Language to Verbal Communication

Submitted by

Name	Roll Number
Shahbaz Hussain	16500120010
Souptik Sarkar	16500120020
Bipasha Paul	16500120022
Shilajit Acharjee	16500120028

Under the guidance of

Asst. Prof. Amrita Bhattacharya

[Session: 2020-2024]

CALCUTTA INSTITUTE OF ENGINEERING AND MANAGEMENT

24/1A Chandi Ghosh Road, Tollygunge, Kolkata-700040

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

BONAFIDE CERTIFICATE

This is to ensure and certify that this project report, "**SonoMimic – Empowering Silent Expression**", is a bonafide work of Shahbaz Hussain, Souptik Sarkar, Bipasha Paul and Shilajit Acharjee, who carried out the project under my supervision.

Asst. Prof. Amrita Bhattacharya
(PROJECT MENTOR)
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
CALCUTTA INSTITUTE OF ENGINEERING AND MANAGEMENT

Countersigned By :

Head of the Department
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
CALCUTTA INSTITUTE OF ENGINEERING AND MANAGEMENT

Principal
CALCUTTA INSTITUTE OF ENGINEERING AND MANAGEMENT

Acknowledgements

The realization of SonoMimic has been a collaborative journey, and we extend our sincere gratitude to all those who have played pivotal roles in its development and success. We express our heartfelt gratitude to Mrs. Amrita Bhattacharya ma'am, our esteemed project mentor, for her unwavering support, invaluable guidance, and mentorship throughout the development of SonoMimic. Her wealth of knowledge, insightful input, and dedication significantly contributed to the success and refinement of our project.

We extend our sincere appreciation to the Principal of Calcutta Institute of Engineering and Management, for fostering an environment that encourages innovation and research. The support and encouragement provided by him have been instrumental in our journey, empowering us to explore and implement innovative solutions in the field of human-computer interaction.

Our sincere thanks also go to all the faculty members. Their encouragement, constructive feedback, and academic mentorship have played a pivotal role in shaping our understanding, refining our approach, and overcoming challenges encountered during the development of SonoMimic.

I express gratitude to my fellow teammates for their collaboration, exchange of ideas, and constructive critiques, which enriched our project and provided diverse perspectives.

Lastly, we thank our families and friends for their unwavering encouragement, understanding, and support throughout the project's duration. Their belief in our abilities and constant encouragement have been a source of inspiration and motivation.

This project, SonoMimic, stands as a testament to the collaborative spirit and dedication of all those who have contributed to its realization. We are grateful for the opportunities, guidance, and support that have shaped our academic journey, and we look forward to continued exploration and innovation in the dynamic landscape of technology and research.

Project by :

Shahbaz Hussain - 16500120010

Souptik Sarkar - 16500120020

Bipasha Paul - 16500120022

Shilajit Acharjee – 16500120028

Calcutta Institute of Engineering and Management

24/1A Chandi Ghosh Road, Tollygunge, Kolkata-700040

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE OF APPROVAL

The project at instance is hereby approved as a creditable study of a B.Tech. subject carried out and presented in a manner satisfactory to warrant its acceptance as prerequisites to the degree for which it has been submitted. It is understood that by this approval the undersigned does not necessarily endorse to approve any statement made, opinion expressed or conclusion drawn therein, but approves this thesis for the purpose for which it is submitted.

Signature of the project mentor

Declaration

We, **Shahbaz Hussain, Souptik Sarkar, Bipasha Paul and Shilajit Acharjee** students of B.Tech., CSE 4th year declare that we have submitted this report in partial fulfilment of the requirements of Bachelor of Technology in Computer Science and Engineering of Maulana Abul Kalam Azad University of Technology, West Bengal.

We solemnly declare that the project report on **"SonoMimic - Empowering Silent Expression"** is based on our work carried out during the course of our study under the supervision of **Asst. Prof. Amrita Bhattacharya** madame.

We assert the statements made and conclusions drawn are an outcome of our research work. We further certify that,

1. The work contained in the report is original and has been done by me under the general supervision of my supervisor.
2. The work has not been submitted to any other Institution for any other degree/diploma/certificate in this university or any other University in India or abroad.
3. We have followed the guidelines provided by the university in writing the report.
4. Whenever we have used materials (data, theoretical analysis, and text) from other sources, we have given due credit to them in the text of the report and given their details in the references.

Project by :

Shahbaz Hussain - 16500120010

Souptik Sarkar - 16500120020

Bipasha Paul - 16500120022

Shilajit Acharjee – 16500120028

TABLE OF CONTENTS

Abstract

SonoMimic is a novel communication aid designed to address the challenges faced by speech-impaired individuals, particularly in scenarios where sign language may not be easily understood. The system employs an Arduino Nano microcontroller, flex sensors embedded in gloves, and a DF Mini Player for audio output. The flex sensors detect hand gestures, translating them into numeric outputs, each associated with a predefined line of communication. These lines are converted into audible speech through the DF Mini Player, allowing seamless communication without the need for sign language interpretation.

The Arduino Nano, chosen for its compact size and compatibility, processes the analog outputs from the flex sensors. Calibration ensures accurate mapping of sensor data to specific hand gestures, enhancing the system's usability across diverse users. The DF Mini Player, with its microSD card support and simple serial communication, facilitates audio file playback and volume control, providing a versatile and user-friendly interface.

The project aims to reduce the communication gap for speech-impaired individuals, especially in regions with a significant population facing speech challenges. The simplicity of the hardware-based approach enhances accuracy and reliability, while the flexibility of the system allows for potential expansions, such as user customization and adaptive gesture recognition. SonoMimic represents a practical and inclusive solution, providing a virtual voice for those who face challenges in traditional verbal and sign language communication.

Introduction

SonoMimic is an innovative project that draws inspiration from a diverse range of research papers, each contributing unique insights to its development. This smart wearable hand device combines the principles of gesture recognition, flex sensor technology, and predefined pattern recognition methodologies. The system employs flex sensors to capture intricate hand movements, which are then processed using Arduino microcontrollers. predefined pattern recognition methodologies enhance gesture recognition accuracy, ensuring seamless communication for users. The incorporation of an audio output system, including the DF Mini Playback Music System and speakers, provides an additional dimension to communication. The project's user-centric design, cost-effectiveness, and wearability make it practical for individuals to communicate through sign language. SonoMimic's advancements include multi-sensor integration and natural language processing showcasing a comprehensive approach to sign language interpretation. It aims to bridge communication gaps offering an inclusive and user-friendly solution.

The gloves in SonoMimic operate through a network of flex sensors seamlessly embedded within their structure. These flex sensors are strategically positioned to detect and measure the intricate movements of the wearer's fingers and hands. As the user engages in sign language or other gestural expressions, the flex sensors capture the subtle nuances and variations in hand gestures. The obtained data is then processed by the system. This meticulous analysis enables the accurate recognition of specific gestures, translating them into meaningful commands or communications. The precision and responsiveness of the gloves in capturing and interpreting nuanced hand movements contribute to the effectiveness of SonoMimic as an intuitive and versatile communication system.

Following the interpretation of hand gestures into numerical data by SonoMimic's flex sensor-equipped gloves, the system employs a sophisticated algorithmic process to convert these numerical representations into actionable commands. These commands are then mapped to specific audio outputs, creating a seamless bridge between the user's gestural expressions and audible communication. SonoMimic integrates an advanced audio output system, featuring components such as the DF Mini Player and a speaker. This integration allows the system to deliver clear and intelligible audio representations corresponding to the interpreted gestures. The use of audio output enhances accessibility and ensures effective communication, particularly in scenarios where visual feedback may be limited or impractical.

SonoMimic draws inspiration from diverse sources, synthesizing ideas from research papers that delve into flex sensors, image-based recognition, machine learning algorithms, and wearable devices. The integration of flex sensors, as demonstrated in numerous studies [3, 6, 8], forms the backbone of SonoMimic's tactile precision, capturing the nuances of hand and finger movements with unparalleled accuracy [3, 8]. This design choice aligns with the low-cost yet highly effective nature of non-vision-based methods explored in the literature [4, 9], presenting a breakthrough in overcoming challenges posed by background interference and varying environmental conditions.

Our project leaps forward by adopting a hardware-based approach, steering away from conventional image-based systems. By leveraging flex sensors, Arduino microcontrollers and specialized audio output modules [5, 7, 9], SonoMimic transcends traditional boundaries. The incorporation of an array of flex sensors manifests in a versatile and context-aware system [9, 11]. This amalgamation ensures a holistic interpretation of gestures, encompassing not only hand movements but also providing a desired audio output, thus enriching the scope of interaction.

In SonoMimic, gloves play a crucial role as integral components embedded with an array of flex sensors, representing a pivotal element in facilitating seamless communication. The project strategically advances the concept inspired by the incorporation of flex sensors into gloves [12], enhancing the original idea by introducing additional flex sensors. This refinement significantly improves precision in gesture recognition while simultaneously diversifying the available set of commands, thereby amplifying the communicative versatility of the system.

This project aspires to break the barriers in communication for individuals with diverse needs, including those with speech disabilities and physical limitations. By employing predefined gesture mappings, audio outputs, and customizable patterns [2, 10], SonoMimic transforms hand gestures into a universal language, bridging the gap for users across the spectrum of abilities.

Related Work

Significant strides have been made in the field of human-computer interaction, particularly in the domain of gesture recognition for communication and control systems. This section provides an elaborate overview and analysis of the related papers, each contributing valuable insights and ideas that have shaped the development of the SonoMimic project.

In Mexican Sign Language Recognition Using Movement Sensors **[1]**, R. Galicia, O. Carranza, E. D. Jiménez, and G. E. Rivera delve into the recognition of Mexican Sign Language (MSL) using movement sensors. The incorporation of Kinect sensors for capturing depth images and analyzing hand skeleton movements lays the foundation for recognizing signs accurately. This paper inspires SonoMimic's focus on recognizing sign language through sensor-based technologies, providing a precedent for leveraging movement sensors for accurate gesture interpretation.

Ashish S. Nikam & Aarti G. Ambekar in Sign Language Recognition Using Image-Based Hand Gesture Recognition Techniques **[2]** Focused on image-based hand gesture recognition for sign language, this research paper employs techniques such as HSV color space for skin color segmentation. The proposed methodology involves webcam data acquisition, image preprocessing, and analysis for successful finger gesture detection. SonoMimic borrows the concept of predefined datasets and finger-bending measurements, ensuring precise gesture recognition by integrating flex sensors into the glove design.

In the paper Flex Sensor Based Robotic Arm Controller Using Micro Controller **[3]**, Abidhusain Syed, Zamrrud Taj H. Agasbal, Thimmannagouday Melligeri, Bheemesh Gudur introduce a flex sensor-based robotic arm controller using a microcontroller, emphasizing the precise measurement of human limb movements. The use of flex sensors and Arduino Nano significantly influences SonoMimic's hardware-based approach. The integration of flex sensors for measuring finger movements ensures accurate and real-time gesture recognition, enhancing the system's responsiveness.

Ruslan T, Yerden K and Md. Hazrat Ali in their paper Development of Arduino Glove-Based Autonomous Car **[6]** introduced an Arduino glove for human-computer interaction, particularly designed to control an RC car. The usage of flex sensors and Arduino Nano, along with the predefined mapping of gestures, influences SonoMimic's design. The incorporation of audio output through a DF Mini Player enhances the communication capabilities of the system.

Patient Assistance using Flex Sensor **[8]** by Kollu Jaya Lakshmi, Akshada Muneshwar, A Venkata Ratnam & Prakash Kodali addresses the assistance needs of individuals with paralysis, utilizing flex sensors and Arduino micro-controllers. SonoMimic draws inspiration from the flex sensor application, emphasizing its role in gesture recognition for communication. The expanded gesture database and the integration of augmented reality (AR) technologies align with the project's user-centric design.

Pavan Telluri, Saradeep Manam, Sathwic Somarouthu, Jayashree M Oli & Chinthala Ramesh in their paper about Low-cost flex powered gesture detection system and its applications **[10]** addressed the need for low-cost gesture detection, this paper proposes a flex-powered system with applications in virtual keyboards and medical emergencies. SonoMimic borrows the concept of flex sensors for gesture recognition, incorporating additional sensors for enhanced precision. The mapping of gestures to corresponding audio commands ensures customization and accessibility.

In Smart Wearable Hand Device for Sign Language Interpretation System With Sensors Fusion **[11]**, Boon Giin Lee & Su Min Lee focused on a wearable hand device for sign language interpretation, integrating various sensors. SonoMimic aligns with the multi-sensor integration concept, incorporating depth sensors and accelerometers. Machine learning algorithms and natural language processing enhance the interpretation accuracy, providing a comprehensive solution for sign language communication.

Hand Gesture Recognition using Flex Sensor and Machine Learning Algorithms **[12]** by Akash Kumar Panda, Rommel Chakravarty & Soumen Moulik proposes a hand gesture recognition system using flex sensors and machine learning algorithms. SonoMimic borrows the concept of flex sensor application for gesture recognition and integrates machine learning algorithms for improved accuracy. The user-centric design and enhanced gesture database contribute to a more versatile and user-friendly communication experience.

In summary, these research papers collectively form the knowledge foundation for the SonoMimic project, shaping its design, hardware integration, and overall approach to gesture recognition for communication systems. Each paper contributes unique perspectives and methodologies, influencing the evolution of SonoMimic into a comprehensive and innovative solution.

Proposed Work

SonoMimic redefines human-computer interaction through an innovative gesture recognition system. The project aims to create a seamless communication experience by interpreting hand gestures using an array of sensors embedded in a glove. Our proposed work seeks to elevate the precision and versatility of gesture recognition. The core of SonoMimic lies in the integration of flex sensors, which capture intricate hand movements, ensuring real-time and accurate interpretation. Building upon the borrowed ideas, our approach involves the incorporation of additional sensors, enriching the system's understanding and functionality. The system's hardware-based design guarantees immediate responsiveness, and an extensive gesture database ensures the recognition of a diverse range of gestures, making it adaptable to various user needs.

➤ Fabrication Methodology

Materials Needed:

1. Gloves: Obtain or custom build a flexible and comfortable glove.
2. Flex Sensors: Acquire five flex sensors for each finger.
3. Adhesive or Stitching Material: Use adhesive or stitching to attach the flex sensors to the gloves.
4. Arduino Nano: Microcontroller for processing flex sensor data.
5. Wires: Connect flex sensors to the Arduino.

Subsequent Steps:

1. Glove Selection:

Choose or custom-create a pair of gloves that are comfortable to wear and allow for finger movements.

2. Flex Sensor Placement:

Decide on the location for each flex sensor on the gloves, considering the placement on each finger.
Ensure that the placement allows for the natural bending of the fingers.

3. Attachment:

Attach a flex sensor to each finger using adhesive or stitching.
For adhesive, apply it to the back of the flex sensor and press it onto the glove surface firmly.
For stitching, sew the flex sensor securely to the glove.

4. Wiring:

Route the wiring from the flex sensors along the glove to a central location where the Arduino Nano and other components will be placed.
Ensure that the wiring does not hinder finger movements.

5. Integration with Arduino:

Connect the flex sensors to the Arduino Nano using wires.
Use the analog pins (A0-A4) on the Arduino Nano to receive input from the flex sensors.

6. Arduino Program:

Upload a program to the Arduino Nano using the Arduino IDE.
The program reads analog values from the flex sensors, interprets finger movements, and triggers corresponding actions.

7. Integration:

Secure the wiring along the glove using small pockets or channels to keep it organized.
Test the flexibility of the gloves to ensure that the flex sensors can bend freely.

8. Finalization:

Double-check the attachment of flex sensors to ensure they are secure.
Trim any excess wiring and secure it neatly along the glove.

9. Comfort and Fit:

Ensure that the gloves remain comfortable to wear after attaching the flex sensors.
Test the gloves on a user to ensure they do not restrict hand movements.

10. Testing:

Connect the gloves to the Arduino Nano and test the flex sensors' functionality.
Verify that the sensors respond appropriately to finger movements.

11. User Instructions:

Provide clear instructions on how to wear the gloves.
Explain the purpose of each finger's flex sensor and how it corresponds to communication.

➤ Operational Framework

1. Working of Flex Sensor:

- **Structure:**
  A flex sensor is a resistive device with a flexible material embedded with conductive material.
  It typically consists of a thin film or plastic with conductive elements.

- **Working Principle:**
  The resistance of the flex sensor changes based on the degree of bending or flexing.
  As the sensor bends, the distance between the conductive elements changes, altering the overall resistance.
  The relationship between the degree of bending and resistance change is usually linear.

- **Output:**
  The flex sensor has two leads, and its resistance changes between these leads.
  The output is a variable resistor that varies in proportion to the angle of bending.

2. Gloves Reading the Bend:

- **Flex Sensor Placement:**
  Flex sensors are attached to each finger of the gloves.
  The placement allows the sensors to bend naturally with finger movements.

- **Attachment:**
  Flex sensors are securely attached using adhesive or stitching.
  This ensures that the sensors move synchronously with finger bending.

- **Wiring:**
  Wiring runs from each flex sensor along the glove to a central point.
  The wiring carries analog signals representing the degree of bending for each finger.

- **Integration:**
  The gloves are designed to maintain flexibility while accommodating the attached flex sensors.
  The integration ensures that the sensors can accurately capture finger movements.

3. Working of Arduino:

- **Microcontroller:**
  The Arduino Nano serves as the central microcontroller for processing input from flex sensors.
  It reads analog signals from the flex sensors connected to its analog pins.

- **Analog Readings:**
  The Arduino continuously reads analog values from each flex sensor.
  These readings represent the varying resistance of the flex sensors as the fingers bend.

- **Decision Making:**
  Based on the analog readings, the Arduino makes decisions about the gestures detected.
  Threshold values determine specific hand gestures, activating corresponding actions.

4. Audio Output & postprocessing:

- **DF Mini Player:**
  The DF Mini Player is connected to the Arduino for audio playback.
  It supports audio files stored on a microSD card and has a built-in amplifier.

- **Gesture-Associated Audio:**
  Each detected hand gesture is associated with a specific audio file.
  The Arduino sends commands to the DF Mini Player to play the corresponding audio file.

- **Volume Control:**
  The volume of the audio output is controlled by the Arduino.
  The DF Mini Player has a built-in amplifier, allowing direct connection to speakers or headphones.

- **Real-time Feedback:**
  The audio output provides real-time feedback, converting recognized gestures into audible speech.
  This aids in communication for speech-impaired individuals.

5. Overall Process:

- **Gesture Recognition:**
  Flex sensors on the gloves capture finger movements.
  The Arduino interprets analogue signals and recognizes specific hand gestures.

- **Audio Feedback:**
  The DF Mini Player plays pre-recorded audio associated with each gesture. This provides a virtual voice for communication.

- **Real-time Communication:**
  The integrated system allows speech-impaired individuals to communicate in real time through hand gestures.

Utilizing flex sensors embedded in each finger of the gloves, user hand gestures are captured. The Arduino Nano meticulously processes the bending angles of each flex sensor, enabling the precise recognition of specific gestures. Subsequently, these recognized gestures trigger corresponding actions, seamlessly facilitating communication. The DF Mini Player, integrated into the system, translates these gestures into audible speech, adding an audio dimension to the communication experience.

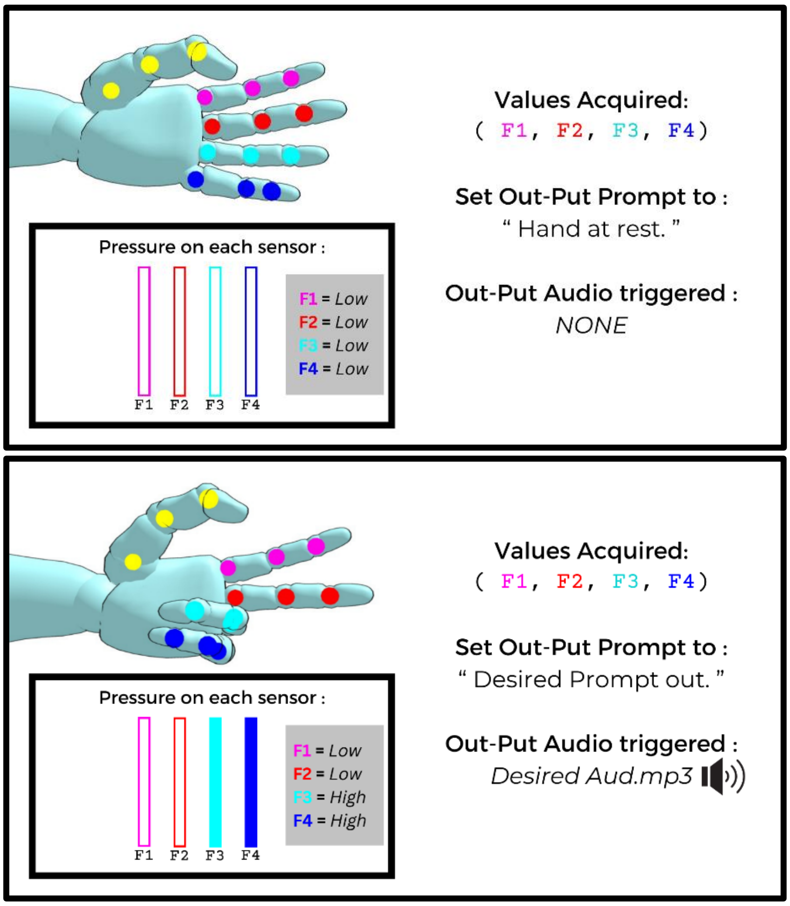

Fig.: Pictorial representation of the operation of the proposed system along with the inputs and outputs for cases of (a) rest and (b) flexed.

Objective

SonoMimic endeavours to revolutionize non-verbal communication, particularly focusing on individuals facing challenges in conventional speech and communicational methods. The primary objective of this innovative project is to design and implement an advanced gesture recognition system that transcends traditional barriers, offering a novel means of interaction through hand gestures.

1) Facilitating Inclusive Communication:

The core objective is to create a communication platform that is inclusive and accessible to a diverse user base, encompassing individuals with speech disabilities, hearing impairments, or language barriers. By harnessing the power of gesture recognition, SonoMimic aims to empower users to express themselves naturally and effectively.

2) Integration of Sensor Technology:

Leveraging sensor technology, especially flex sensors embedded within gloves is at the heart of SonoMimic. The project seeks to seamlessly integrate these sensors to capture nuanced hand movements, providing a tangible and intuitive interface for users to convey their thoughts and expressions.

3) Precision and Versatility:

The project aspires to enhance precision in gesture recognition by introducing a sophisticated network of sensors. This not only refines the accuracy of interpreting gestures but also expands the range of recognizable commands, ensuring a versatile and responsive communication system.

4) Real-time Gesture Processing:

SonoMimic is designed to process gestures in real time, allowing for immediate and seamless communication. The project prioritizes reducing latency in interpreting gestures to enhance user experience, making it practical for diverse applications.

5) Audio Conversion for Accessibility:

An integral aspect of the project is the conversion of interpreted gestures into audio output. SonoMimic aims to employ audio feedback as a supplementary communication channel, ensuring accessibility in various environments and for users with varying communication needs.

6) Customization and User-Friendly Design:

The project strives to provide a user-friendly experience by allowing customization of gestures and corresponding outputs. This user-centric approach ensures that SonoMimic can cater to individual preferences and diverse communication styles, making it adaptable to a wide range of users.

7) Exploring Potential Applications:

Beyond its fundamental communication role, SonoMimic aims to explore potential applications in diverse fields. This includes but is not limited to healthcare, education, and human-computer interaction. The objective is to unleash the full potential of gesture-based communication in various practical scenarios.

Thus, the overarching objective is not only to create a functional prototype but to pave the way for continuous improvement and future research. SonoMimic is positioned as a foundation for further exploration into advanced gesture recognition techniques, potential collaborations, and its integration into assistive technologies.

Preliminary Insight

- **Arduino Nano –** The Arduino Nano is an open-source breadboard-friendly microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2008. It offers the same connectivity and specs as the Arduino Uno board in a smaller form factor.

- **Flex Sensor –** A flex sensor is a resistive device that changes its electrical resistance based on the degree of bending or flexing. It typically consists of a thin, flexible substrate with conductive material. As the sensor bends, the distance between the conductive materials changes, altering the resistance. This change in resistance is proportional to the degree of flexion. Flex sensors are commonly used in electronic applications, including wearable technology, to detect and measure the extent of bending in various applications such as robotic limbs or gesture-sensing gloves.

- **Motion Tracking –** Motion tracking is a technology that captures and monitors the movement of objects or individuals in real time. It relies on sensors, cameras, or other tracking devices to collect positional data. This information is then processed to create a virtual representation of the object's or person's motion. Commonly used in various fields motion tracking enables accurate and dynamic mapping of movements.

- **Articulation Point –** An articulation point is a specific location in a structure where movement or bending occurs, often referring to joints in mechanical or virtual systems. In the context of motion tracking or virtual skeletons, it represents key points of flexibility in a simulated body, such as the finger joint. Articulation points are crucial for realistic animation and accurate representation of movements. These points serve as pivotal connections, allowing for dynamic and natural motion in response to external stimuli. Articulation points play a fundamental role in capturing and reproducing motions.

Tools & Technology

1. Arduino Nano –

The Arduino Nano (Fig. 1) is a crucial component in the SonoMimic project, serving as the central microcontroller for flex sensor integration. Here are its key roles:

Fig. 1: Arduino nano microconrtoller

- **Microcontroller for Flex Sensor Integration:**
  Processes analog output from flex sensors.
  Reads analog signals from connected flex sensors (A0-A8).

- **Size and Space Efficiency:**
  Compact and breadboard-friendly for glove integration.

- **Voltage Compatibility:**
  The operating voltage of 5v aligns with flex sensor requirements.
  Built-in voltage regulator allows versatile power sources.

- **USB Connectivity for Programming:**
  Enables easy code development and modification.
  Particularly useful during testing and prototyping.

- **Analog and Digital I/O Pins:**
  Provides multiple analog and digital I/O pins.
  Crucial for handling complex input patterns from flex sensors.

- **Compatibility with Flex Sensors:**
  Acts as a bridge between hand gestures and associated audio output.

- **Integration with DF Mini Player:**
  Manages connection between DF Mini Player and flex sensors for audio playback.

2. Flex Sensor –

The flex sensor (Fig. 2) plays a crucial role in capturing hand gestures and translating them into recognizable signals for communication. Here are its key roles:

Fig. 2: Flex sensor

- **Gesture Recognition:**
  The flex sensor is integrated into gloves to detect finger movements and bending of the hand.

❖ **Interface with Microcontroller:**
Easily interfaces with the Arduino Nano microcontroller, allowing for straightforward integration into the SonoMimic system.
The analog signals from the flex sensor are read by the Arduino Nano, enabling the translation of hand gestures into numerical data.

❖ **Customization for Speech Output:**
Each specific numeric output from the flex sensor is associated with a predefined line or phrase for communication.
This customization allows users to associate their hand gestures with specific messages, providing a personalized and versatile communication tool.

❖ **Real-time Response:**
The flex sensor's ability to change resistance in real time allows for dynamic and responsive gesture recognition.
As users bend their fingers, the flex sensor provides immediate feedback to the Arduino Nano, triggering the corresponding audio output.

3. DF Mini Player –

The DF Mini Player (Fig. 3) is a compact module designed for audio file playback from a microSD card, supporting MP3, WAV, and WMA formats. Key features include a microSD card slot, built-in amplifier, 3.5mm audio jack, and UART compatibility with Arduino and other microcontrollers.

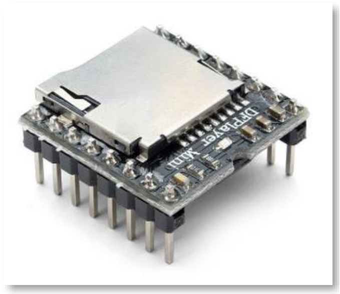

Fig. 3: DF player mini

❖ **Audio Output for Gestures:**
DF Mini Player integrates with Arduino Nano to convert recognized hand gestures into audible speech.

❖ **Communication Aid:**
Plays back phrases associated with specific hand gestures, providing a voice for speech-impaired individuals.

❖ **Compact and Wearable:**
Contributes to the portability and wearability of the project, enhancing user accessibility.

❖ **Easy Integration:**
Designed for seamless integration into Arduino projects with minimal wiring requirements.

4. Speaker –

In this project, an 8 Ohm / 0.25-watt speaker (Fig. 4) is utilized. This speaker, known for its clarity and precise sound reproduction, plays a pivotal role in delivering audible output corresponding to recognized hand gestures. Its use ensures a clear and effective communication experience for speech-impaired individuals interacting with the system.

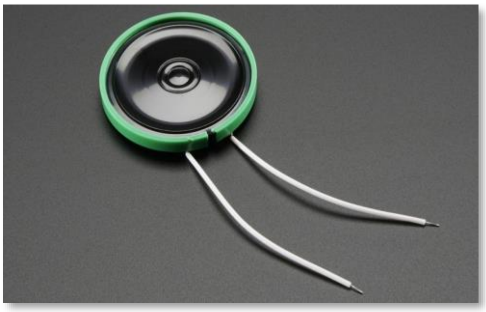

Fig. 4: Speaker

5. Zero PCB –

In this project, a zero PCB (Fig. 5) is employed for building prototypes and conducting tests. This versatile PCB serves as a sturdy foundation for soldering and securing all components. On the back side of the zero PCB, all the project components are securely soldered, ensuring a reliable and organized structure for seamless integration and functionality.

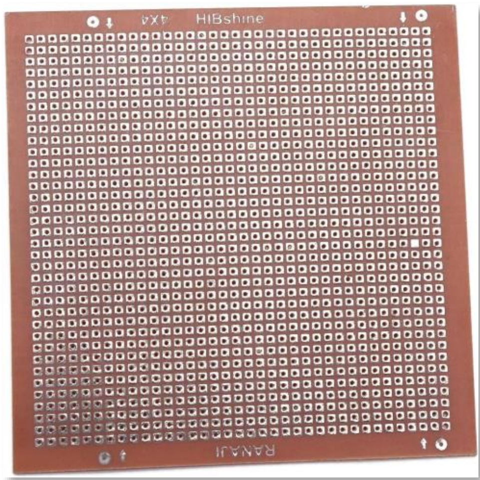

Fig. 5: Zero printed circuit board

Thus, the approximated rough table of utilised components is as follows:

	Components	Quantity
1	10k Resistor	4
2	0 PCB	1 – 2
3	2.2-inch Flex sensor	4
4	DF mini player	1
5	Arduino Nano	1
6	Loud Speaker	1
7	Jumper, Ribbon & Connecting wires	As per req.
8	9V Battery	As per req.
9	Battery connector	1
10	Heat Shrink tube	As per Req.
12	SD Memory Card	1

The components hence acquired are utilized to make the desired circuit utilizing the circuit diagram provided below:

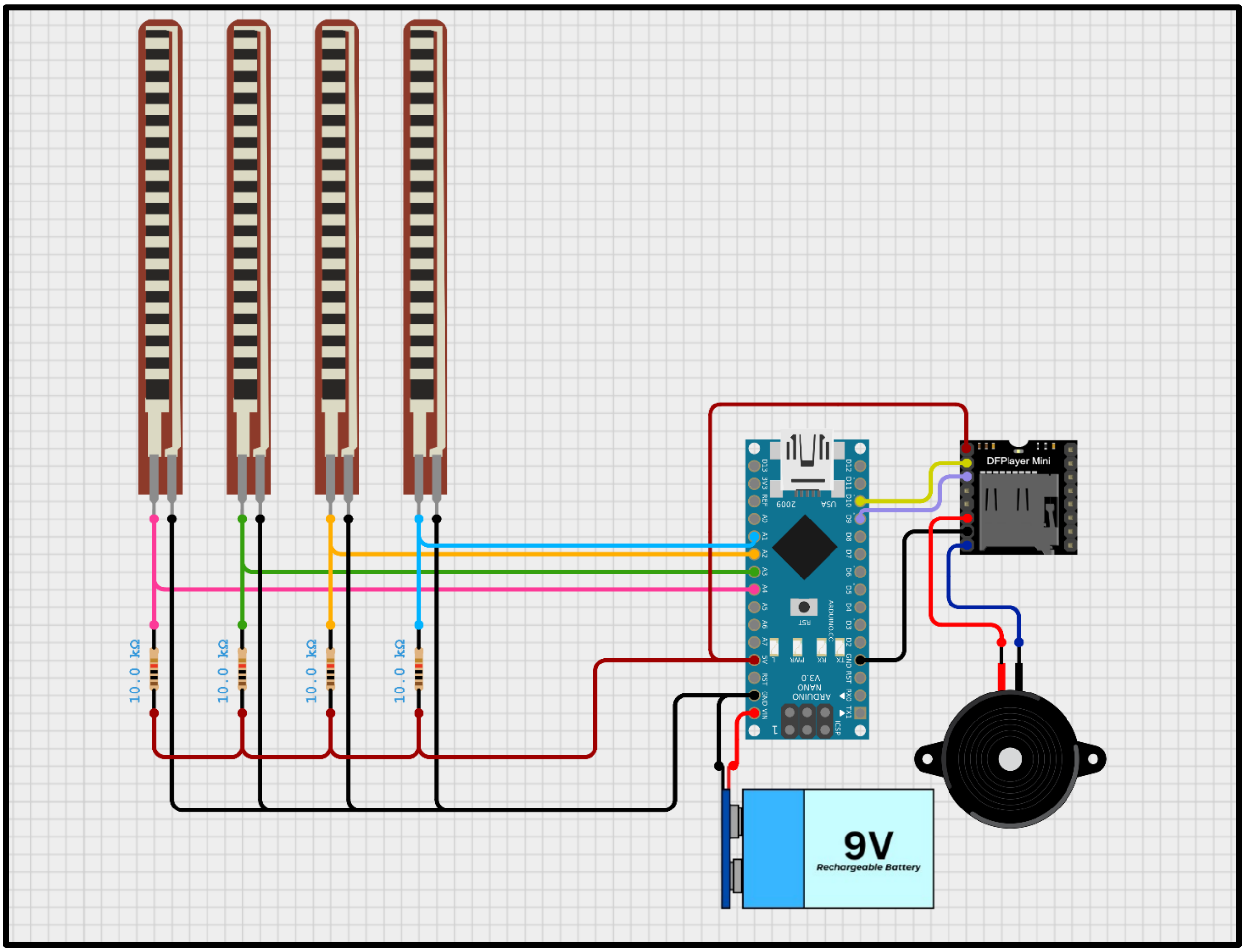

Fig. 6: Circuit diagram

Circuit Details:

1. Connect the +5V pin of the Arduino to the +5V pin of the Flex Sensor and DF Mini Player.
2. Connect the GND (ground) pin of the Arduino to the GND pins of the Flex Sensor and DF Mini Player.
3. Connect the analogue output pin (A0) of the Flex Sensor to the A0 pin of the Arduino.
4. Connect the digital pins D9 and D10 of the Arduino to the TX and RX pins of the DF Mini Player, respectively.
5. Connect the +5V and GND pins of the DF Mini Player to the +5V and GND pins of the Arduino.
6. Connect digital pins D2, D3, and D4 of the Arduino to the Blue, Green, and Red LEDs, respectively.
7. Connect the Speaker/Headphones to the audio output jack of the DF Mini Player.

The SonoMimic Circuit & Components :

- <u>SonoMimic Glove</u> :

The glove is crafted using cardboard and silicon springs, serving as the exoskeletal structure that encases the flex sensors.

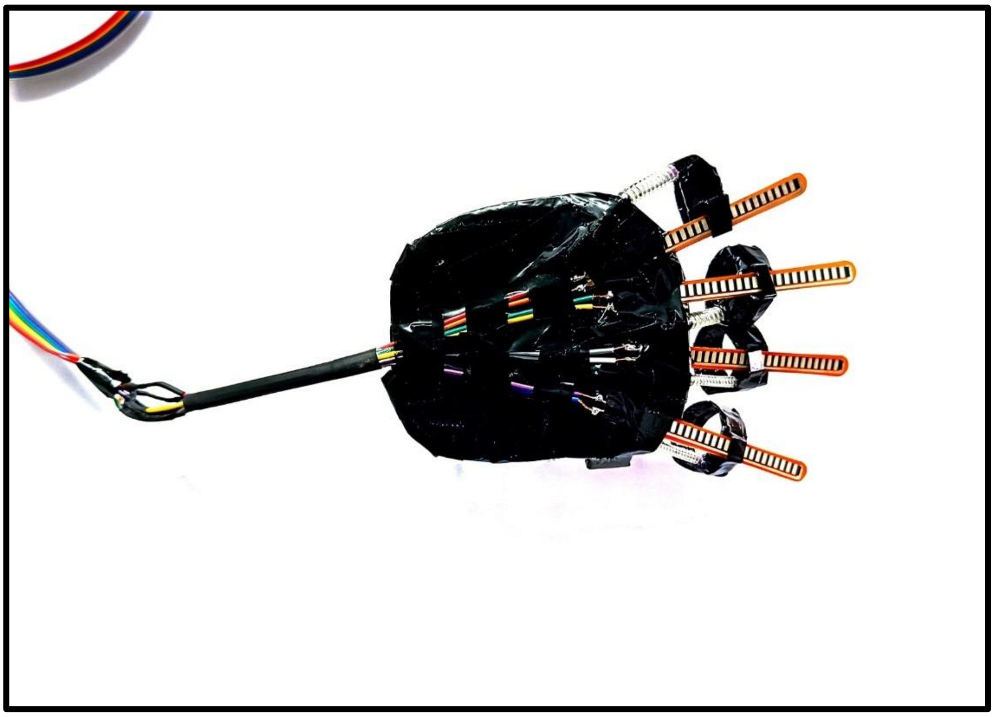

Fig. 7: Glove

- <u>SonoMimic Circuit Box</u> :

The assorted supplementary components, along with the primary circuit, are enclosed within a compact cardboard box, prioritizing portability and minimizing spatial requirements. This initial iteration of the project represents a foundational model, allowing room for future iterations to incorporate even more streamlined designs for enhanced portability.

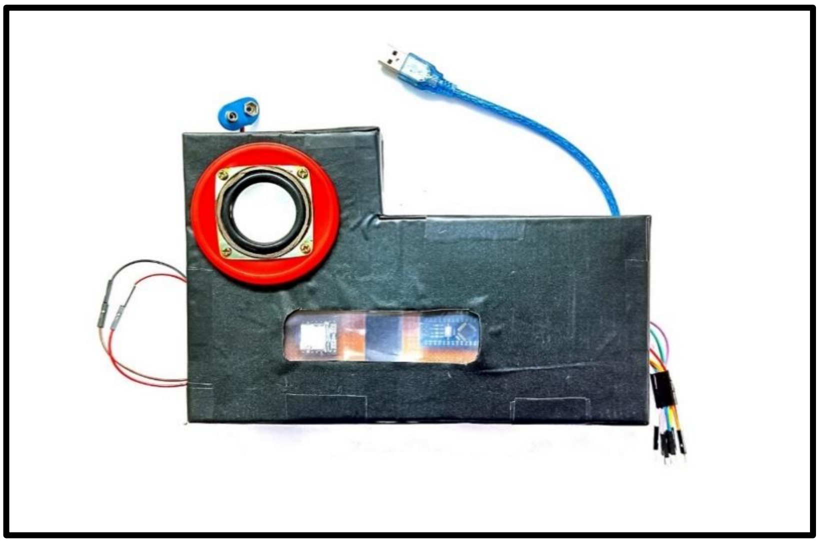

Fig. 8: Circuit box

- <u>Complete Circuit</u> :

Therefore, the constructed main circuit comprises the two aforementioned segments that can be seamlessly connected or disconnected using M-F jumper wires, allowing for easily detachable connections.

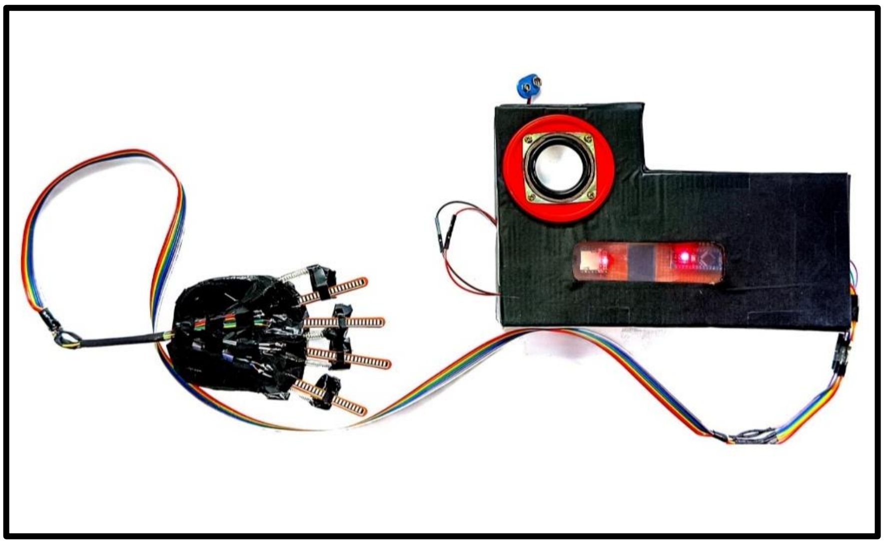

Fig. 9: Complete circuit

Algorithm:

1. **Initialization:**
   Include necessary libraries for communication with DF Mini Player.
   Define required pins and create an unsigned integer variable for Flex Sensor input.

2. **Setup:**
   Set pin modes for inputs and initialize serial communication.
   Initialize DF Player, check for errors and set volume.

3. **Loop:**
   Continuously read analogue input from Flex Sensor.
   Print the sensor value to the serial monitor for debugging.
   Based on the sensor value:
   a. If > Threshold Value, print "Command x" and play audio file x.
   b. Else If between Value 1 and Value 2, print "Command y" and play audio file y.
   c. Else when none of the above, prompt " rest state ".

4. **Delay:**
   Introduce a desired delay to avoid rapid iterations.
   This algorithm outlines the main steps in the code, from initialization to continuous sensor reading and audio responses based on the flex sensor's input value.

Methodology & Results

The main component of the SonoMimic hand gesture recognition gloves lies in the functioning of the flex sensors and relies on the analogue values thus provided by it. These values are then utilized to match with the priorly existing input pattern and hence trigger the various desired commands.

Flex sensors are devices that change their electrical resistance in response to bending or flexing. They are typically made of a flexible substrate with conductive material (usually carbon) applied in a way that allows the resistance to change when the sensor is bent. These sensors are commonly used in applications like robotics, medical devices, and virtual reality to measure the degree of bend or flex in various objects. The basic working principle of flex sensors is that their electrical resistance increases or decreases depending on the amount of bending or flexing they experience. This change in resistance is often due to the alteration in the spacing between the conductive particles within the sensor material as it deforms.

Flex sensors are always utilized along with a resistance of certain measured values to obtain the readings. Flex sensors are essentially variable resistors, and to measure the change in resistance accurately, they are often used in a voltage divider circuit. The voltage divider circuit typically includes the flex sensor along with another resistor, known as a series resistor or pull-up resistor. This resistor is added to create a voltage drop across the flex sensor, and the voltage at the junction between the flex sensor and the resistor is measured.

Flex sensors, when incorporated into a circuit with 10k resistors, yield an analog difference of approximately 4 to 5 between an unflexed and fully flexed state. Recognizing that this initial difference is relatively modest, it is enhanced by a factor of 7 through multiplication. This amplification results in a broader and more diverse range of analogue values, effectively capturing the nuances between the flexed and unflexed states with increased variance.

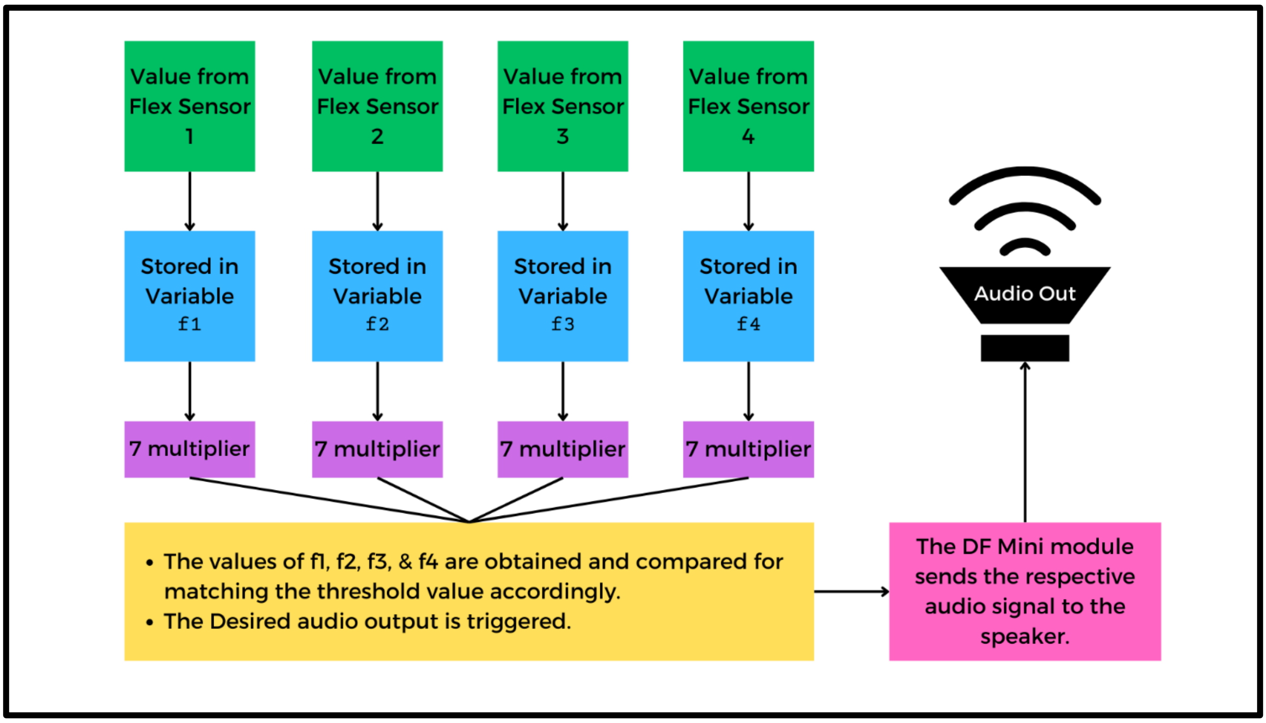

Fig. 10: Process flow block diagram

After the assembly of the gloves designed for use, the initial step involves executing the GetVal.ino in the Arduino IDE. This action facilitates the acquisition of individual flex sensor values corresponding to various states and degrees of flexion utilizing the Arduino serial monitor. These values are subsequently documented for future reference and utilization.

GetVal.ino

```
const int f1 = A1;
const int f2 = A2;
const int f3 = A3;
const int f4 = A4;

void setup() {
  Serial.begin(9600);
}

void loop() {
  int V1,V2,V3,V4;
  V1 = 7 * analogRead(f1);
  V2 = 7 * analogRead(f2);
  V3 = 7 * analogRead(f3);
  V4 = 7 * analogRead(f4);

  Serial.print("Index: ");
  Serial.println(V1);

  Serial.print("Middle: ");
  Serial.println(V2);
```

```
  Serial.print("Ring: ");
  Serial.println(V3);

  Serial.print("Tiny: ");
  Serial.println(V4);

  Serial.println("------------------------------------------------------------");

  delay(2000);
}
```

➤ Corresponding Observations and Outputs :

‣ Hand Gesture 1 (G0) :

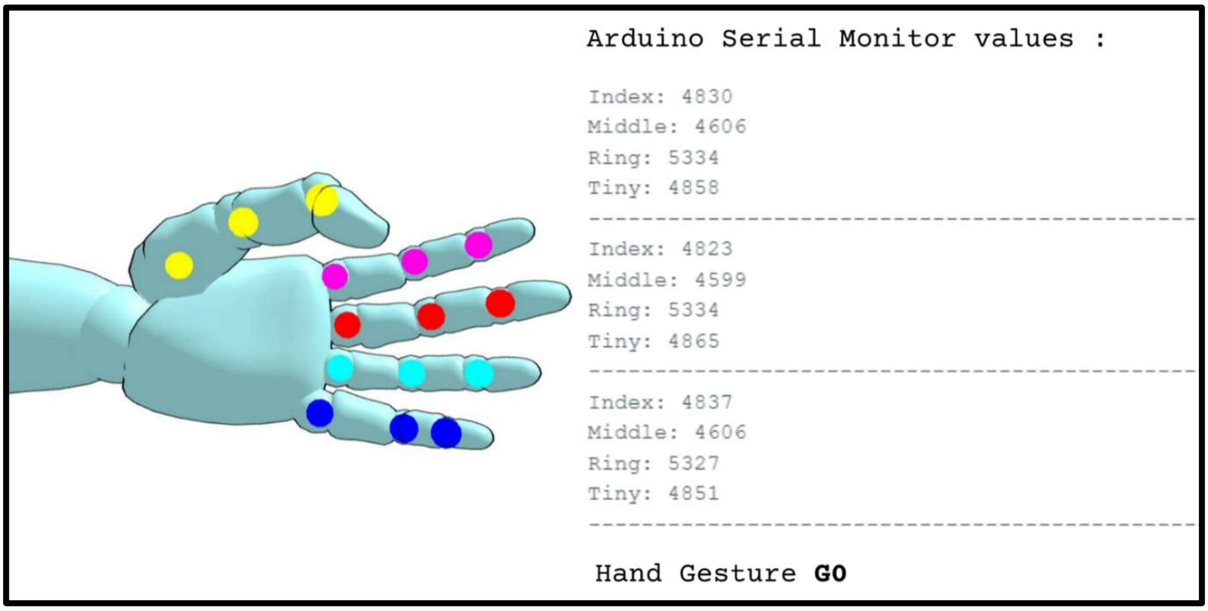

Fig.: Hand gesture 1

‣ Hand Gesture 2 (G1) :

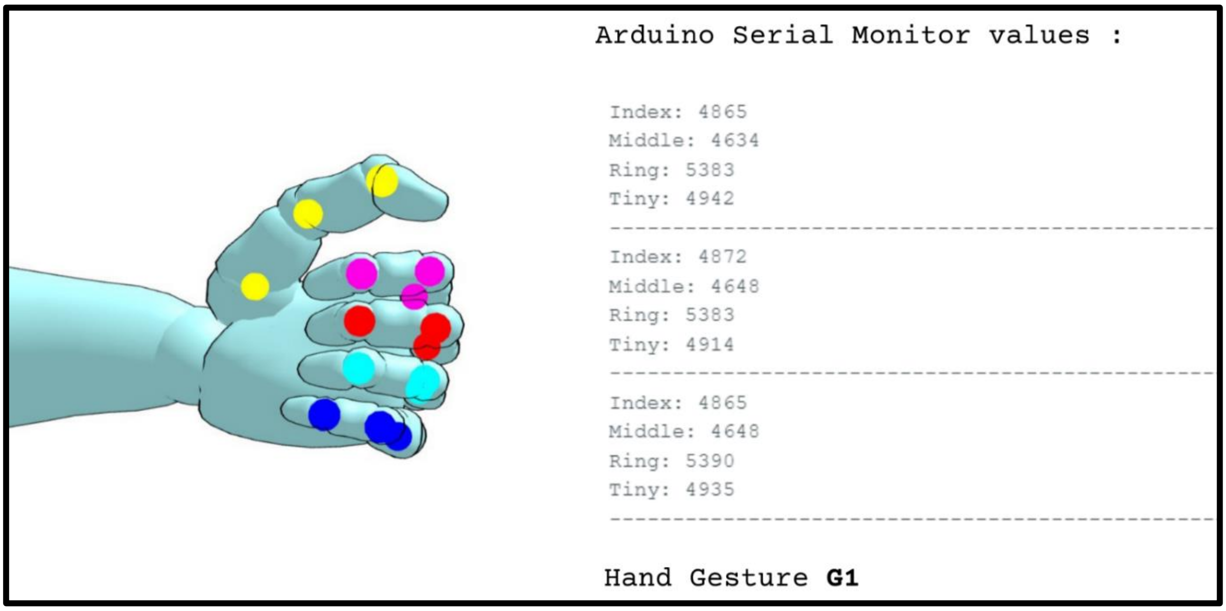

Fig.: Hand gesture 2

▸ Hand Gesture 3 (G2) :

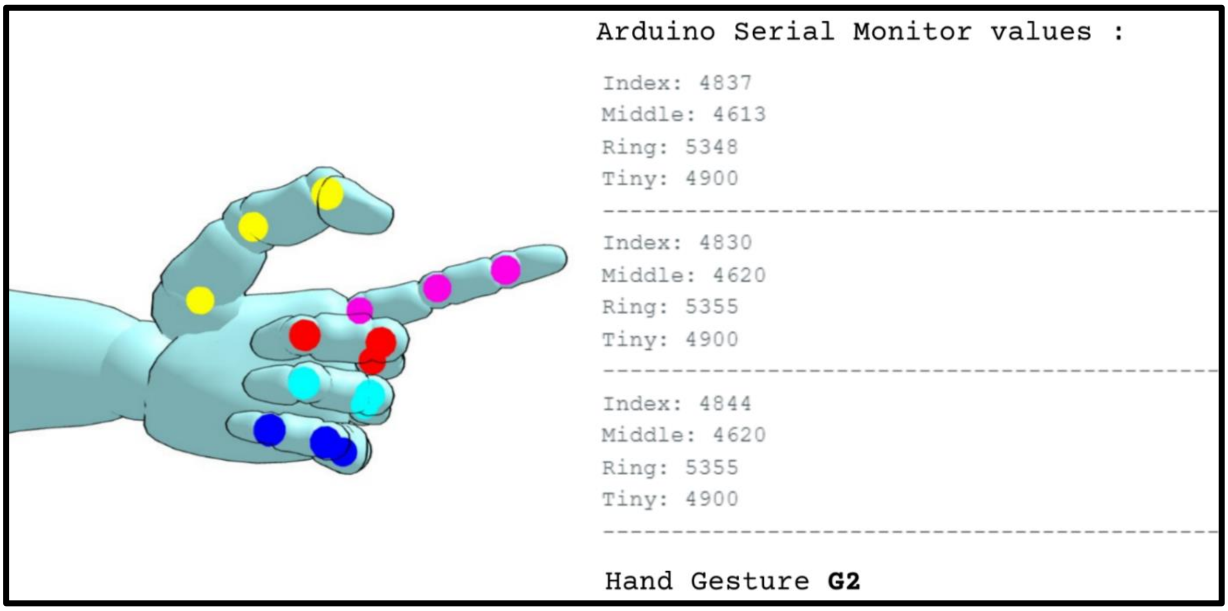

Fig.: Hand gesture 3

▸ Hand Gesture 4 (G3) :

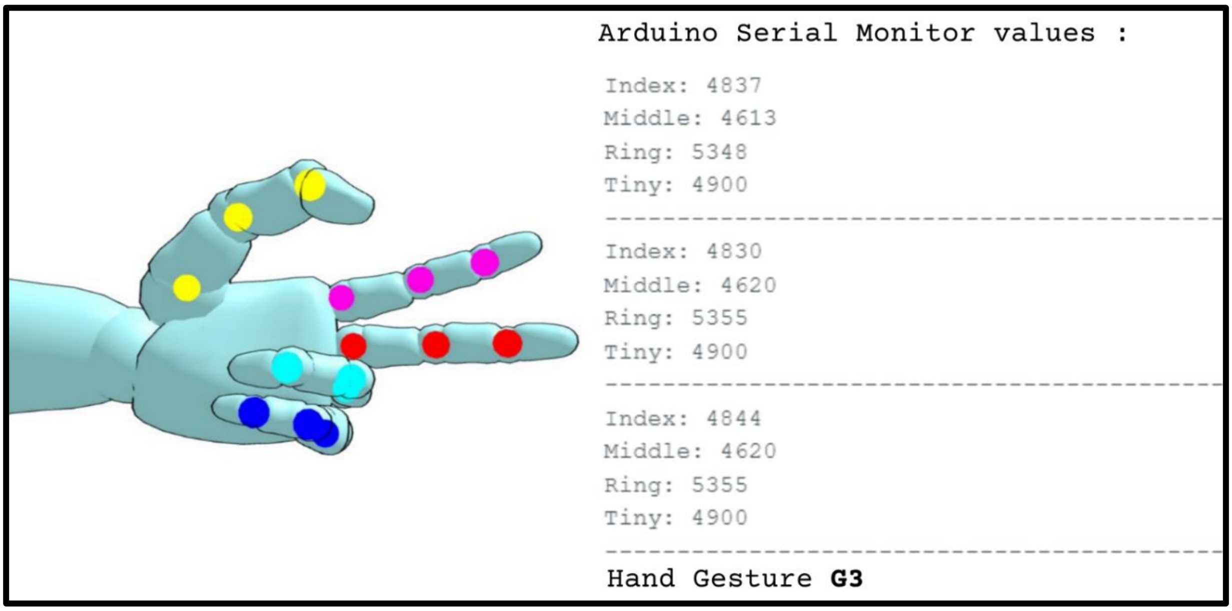

Fig.: Hand gesture 4

‣ Hand Gesture 5 (G4) :

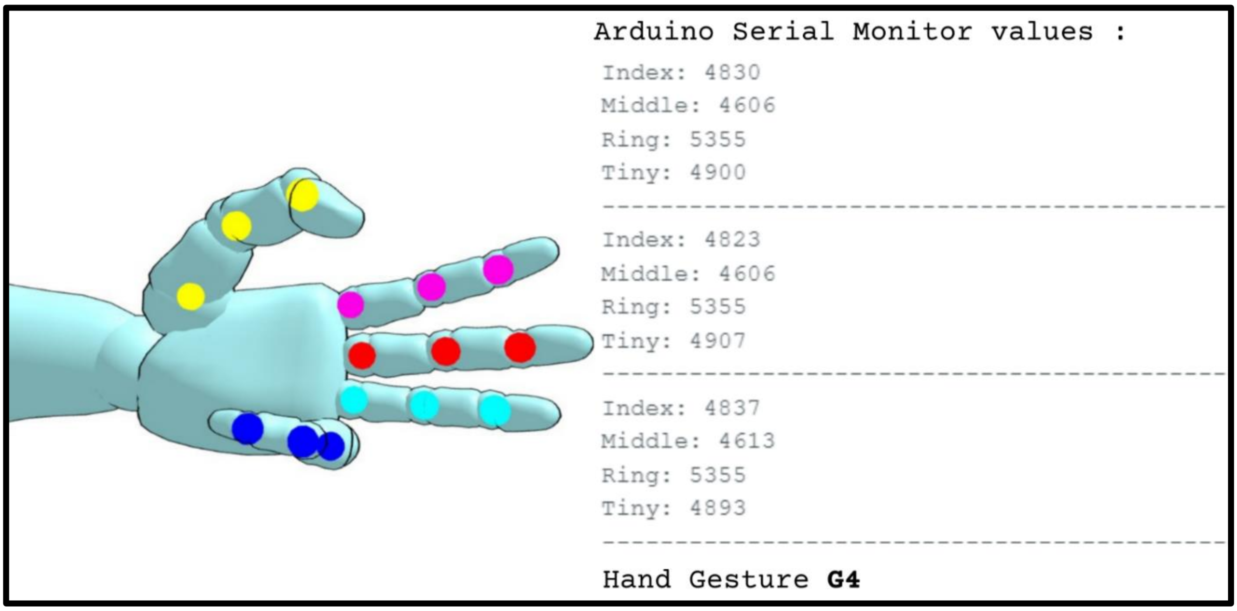

Fig.: Hand gesture 5

‣ Hand Gesture 6 (G5) :

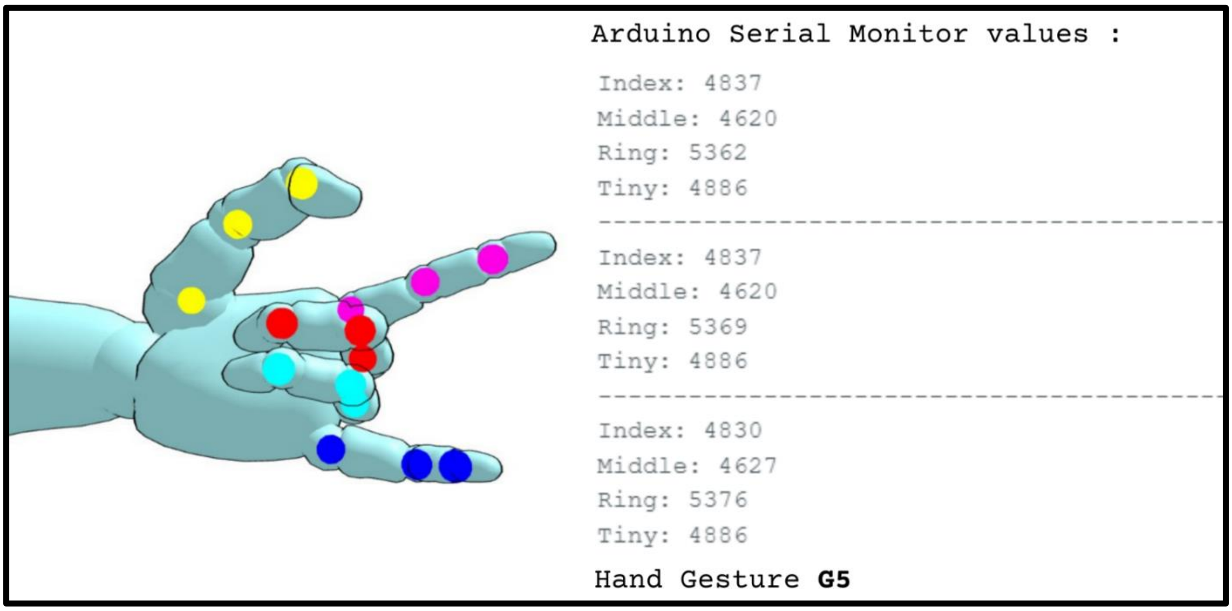

Fig.: Hand gesture 6

‣ Hand Gesture 7 (G6) :

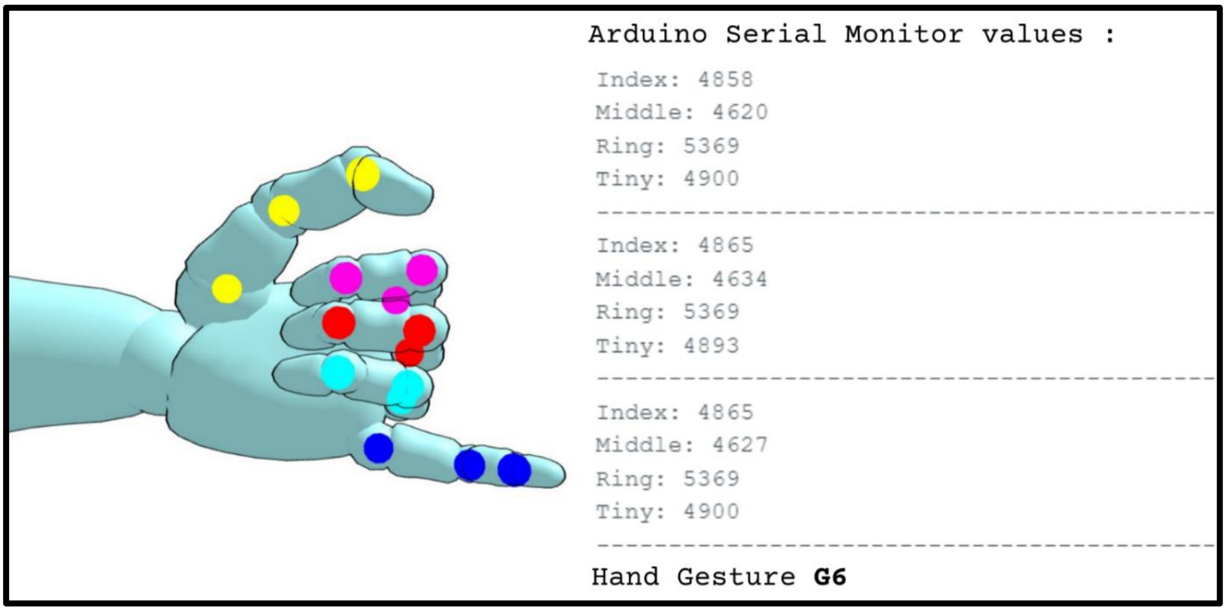

Fig.: Hand gesture 7

The sequence of obtained values undergoes analysis, wherein an approximation process focuses on identifying more repetitive values. Specifically, the maximum values recorded for each sensor in its fully flexed state are chosen as references. These maximum values serve as benchmarks for determining the analogue thresholds indicative of full flexion. This meticulous approach is adopted to mitigate the risk of random or false triggers, ensuring that a genuine and deliberate bending action is required to activate the specified condition, given that it aligns with the maximum achievable value.

Therefore, the tabulated values, derived from the observations in the preceding program, are outlined as follows:

Finger	Rest(un-flexed)	Bent(flexed)
Index finger(f1)	<4870	>=4870
Middle finger(f2)	<4625	>=4625
Ring finger(f3)	<5369	>=5369
Tiny finger(f4)	<4914	>=4914

Using the acquired values, a conclusive code is to be developed to seamlessly integrate with the DF Mini. This code aims to generate the desired audio output precisely when needed or triggered by specific hand gestures. Given below is the code FinalCode.ino thus prepared:

```
#include "SoftwareSerial.h"
#include "DFRobotDFPlayerMini.h"
DFRobotDFPlayerMini myDFPlayer;
void printDetail(uint8_t type, int value);
unsigned int f1,f2,f3,f4;
SoftwareSerial mySoftwareSerial(9,10);

void setup()
{
  Serial.begin(9600);
  mySoftwareSerial.begin(9600);
  Serial.println();
  Serial.println(F("Initializing DFPlayer..."));

  if (!myDFPlayer.begin(mySoftwareSerial)) {
    Serial.println(F("Unable to begin:"));
    Serial.println(F("1.Please recheck the connection!"));
    Serial.println(F("2.Please insert the SD card!"));
    while (true);
  }
  Serial.println(F("DFPlayer Mini online."));
  myDFPlayer.volume(30);
}

void loop()
{
  f1 = 7 * analogRead(1);
  f2 = 7 * analogRead(2);
  f3 = 7 * analogRead(3);
  f4 = 7 * analogRead(4);

  if ((f1>6000) || (f2>6000) || (f3>6000) || (f4>6000)){
    Serial.println("Flex sensor not connected");
    delay(2000);
  }
  else if ((f1>=4870) && (f2>=4625) && (f3>=5369) && (f4>=4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: ^^^^, \nHelp me please!
\n_______________________________________");
    myDFPlayer.play(1);
    delay(2000);
  }
  else if ((f1<4870) && (f2>=4625) && (f3>=5369) && (f4>=4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.print("\nHand Sign: ^^^|, \nI am hungry...
\n_______________________________________");
    myDFPlayer.play(2);
    delay(2000);
  }
  else if ((f1<4870) && (f2<4625) && (f3>=5369) && (f4>=4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: ^^||, \nI need Water...
\n_______________________________________");
```

```
    myDFPlayer.play(3);
    delay(2000);
  }
    else if ((f1<4870) && (f2<4625) && (f3<5369) && (f4>=4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: ^|||, \nPlease give me medicine.
\n_____________________________________");
    myDFPlayer.play(4);
    delay(2000);
  }
      else if ((f1<4870) && (f2>=4625) && (f3>=5369) && (f4<4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: |^^|, \nYES
\n_____________________________________");
    myDFPlayer.play(5);
    delay(2000);
  }
        else if ((f1>=4870) && (f2>=4625) && (f3>=5369) && (f4<4914)){
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: |^^^, \nNO
\n_____________________________________");
    myDFPlayer.play(6);
    delay(2000);
  }
  else{
    Serial.print("\nIndex: " + String(f1) + "\nMiddle: " + String(f2) +
"\nRing: " + String(f3) + "\nTiny: " + String(f4));
    Serial.println("\nHand Sign: ||||, \nHand at rest
\n_____________________________________");
    delay(500);
  }
  delay(50);
}
```

The provided Arduino code utilizes the SoftwareSerial and DFRobotDFPlayerMini libraries to create a system for gesture-controlled audio output. The setup initializes serial communication, software serial, and the DFPlayer Mini module. In the loop, analogue readings from four flex sensors are multiplied by 7 for scaling. The code checks for sensor connections, and if any sensor value exceeds 6000, it indicates a disconnected flex sensor. Recognizing specific hand gestures, the system triggers corresponding audio playback through the DFPlayer Mini. Delays are strategically added to manage timing and prevent unintended triggers. The multiplier of 7 scales analogue readings for effective gesture recognition. This compact design demonstrates a versatile and responsive hand gesture-controlled audio system.

Acquired Observations :

Constrained by current technological limitations and limited access to advanced methodologies, we have developed the initial and rudimentary version of our device, capable of recognizing multiple hand gestures. Due to constraints such as a shortage of a comprehensive database and a limited pool of trained personnel, the current code is restricted to a modest number of predefined inputs and their corresponding outputs. However, we hold optimism for future development, anticipating advancements with expanded capabilities and functionalities as resources and expertise become more accessible. The following are the observations acquired :

- GO – Hand at rest.

Arduino Serial Monitor values :

```
Index: 4844
Middle: 4613
Ring: 5348
Tiny: 4886
Hand Sign: ||||,
Hand at rest
```

Hand Gesture : **GO**
Prompt : **Hand at rest**
Audio output : **None**

Fig.: Hand gesture 1

▹ G1 – Help me please.

Fig.: Hand gesture 2

▹ G2 – I am hungry.

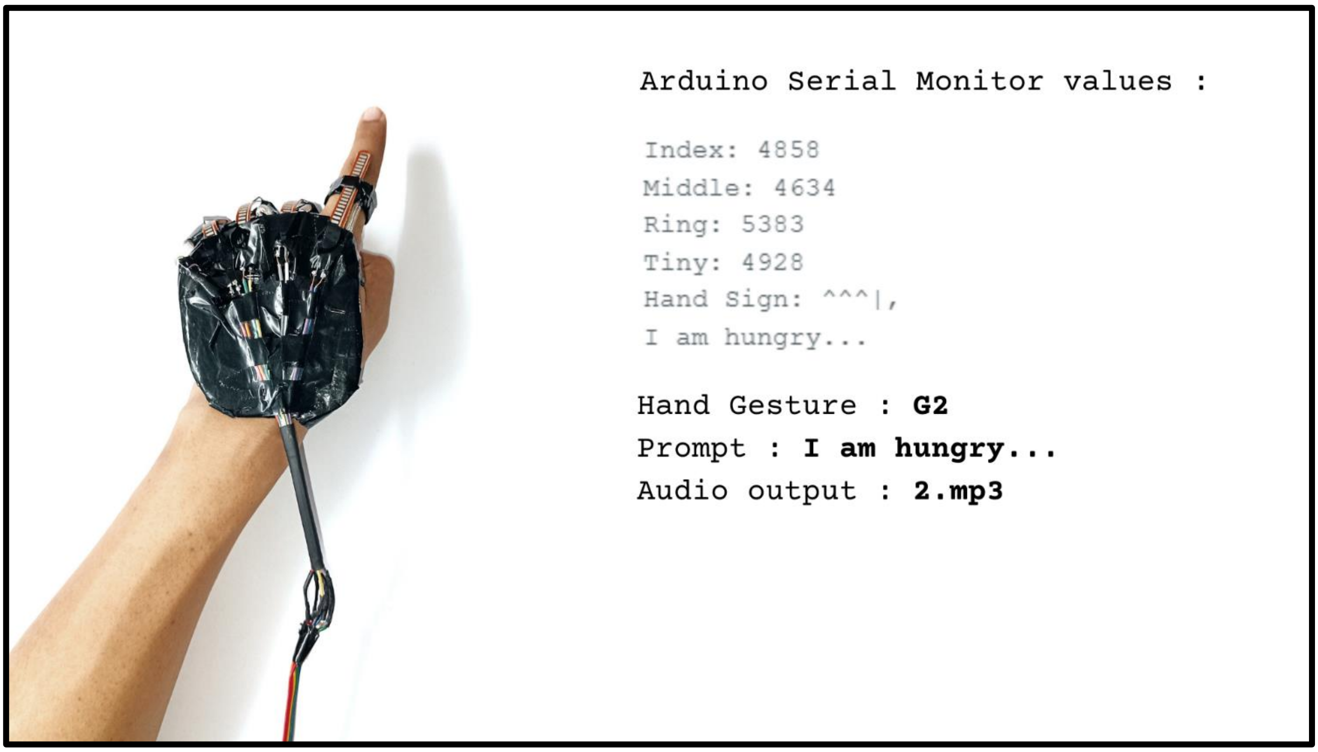

Fig.: Hand gesture 3

- G3 – I need water.

Fig.: Hand gesture 4

- G4 – Please give me medicine.

Fig.: Hand gesture 5

▹ G5 – Yes.

Fig.: Hand gesture 6

▹ G6 – No.

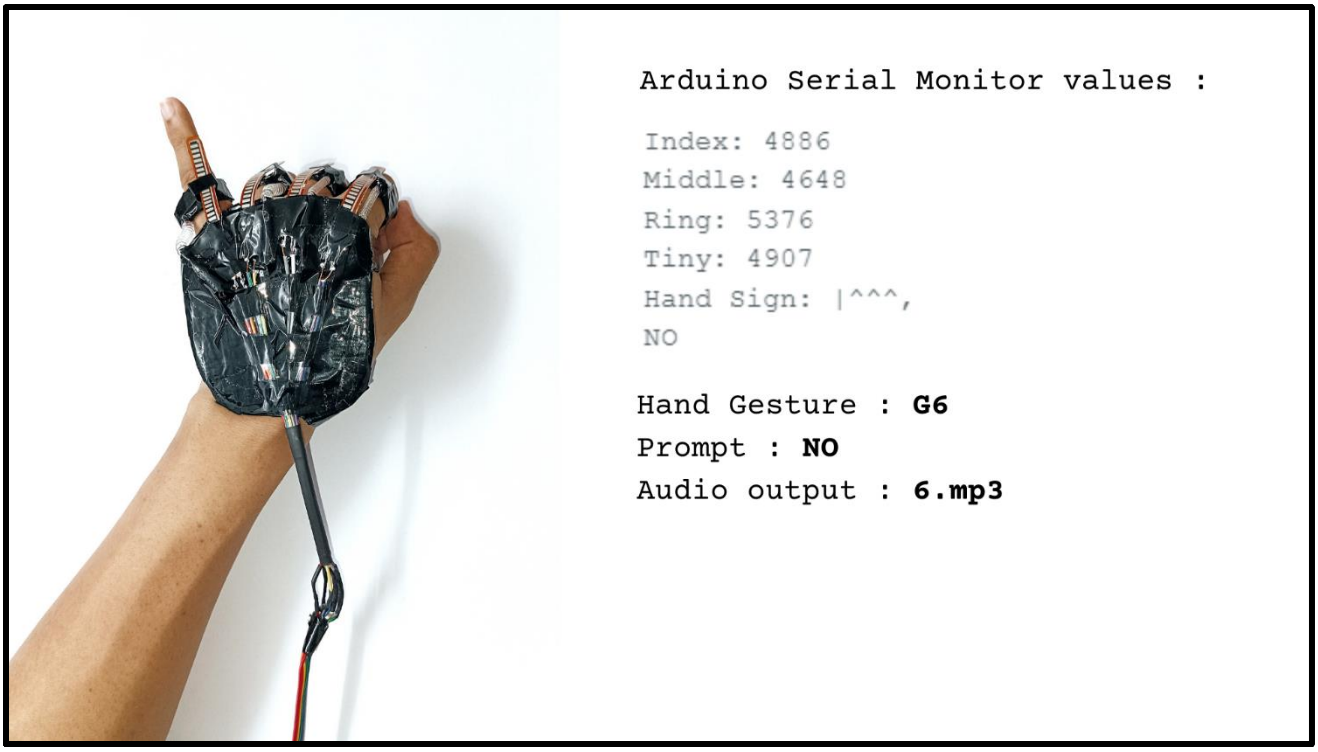

Fig.: Hand gesture 7

Conclusion & Future Scope

In conclusion, SonoMimic represents a significant advancement in gesture-based communication systems, leveraging flex sensors integrated into gloves and Arduino Nano processing for precise gesture recognition. The incorporation of the DF Mini Player contributes to the system's versatility, transforming recognized gestures into audible speech. This innovative approach transcends conventional hearing impairment applications, offering a broad spectrum of interaction possibilities.

The future scope for SonoMimic is promising and encompasses several avenues for improvement and expansion. Firstly, the addition of more sensors to capture the complete movement of wrists and arms would enhance the system's ability to interpret complex gestures, providing a richer user experience. Extending the system to accommodate gestures from both hands would further broaden the range of available options, fostering more nuanced and expressive communication. Additionally, enriching the pattern database could enable precise recognition of established sign languages such as ASL (American Sign Language) and ISL (Indian Sign Language), catering to a more diverse user base. Introducing a dynamic user interface (UI) that allows for the customization and allocation of commands in real-time would enhance user adaptability and make the system more user-friendly. Finally, exploring machine learning techniques for continuous improvement in gesture recognition accuracy and incorporating feedback from users could contribute to the ongoing evolution of SonoMimic, ensuring its relevance and effectiveness in diverse communication scenarios.

References

(1) Mexican Sign Language Recognition Using Movement Sensors
Authors: R. Galicia; O. Carranza; E. D. Jiménez; G. E. Rivera
DOI: 10.1109/ISIE.2015.7281531

(2) Sign Language Recognition Using Image Based Hand Gesture Recognition Techniques
Authors: Ashish S. Nikam; Aarti G. Ambekar
DOI: 10.1109/GET.2016.7916786

(3) Flex Sensor Based Robotic Arm Controller Using Micro Controller
Authors: Abidhusain Syed; Zamrrud Taj H. Agasbal; Thimmannagouday Melligeri; Bheemesh Gudur
DOI: 10.4236/jsea.2012.55042

(4) Machine Learning Model for Sign Language Interpretation Using Webcam Images
Authors: Kanchan Dabre; Surekha Dholay
DOI: 10.1109/CSCITA.2014.6839279

(5) Motion Capture based Human Motion Recognition and Imitation by Direct Marker Control
Authors: Christian Ott; Dongheui Lee; Yoshihiko Nakamura
DOI: 10.1109/ICHR.2008.4755984

(6) Development of Arduino Glove-Based Autonomous Car
Authors: T. Ruslan; K. Yerden; Md. Hazrat Ali
DOI: 10.1109/ICSTCC.2017.8107036

(7) A Wireless-controlled 3D printed Robotic Hand Motion System with Flex Force Sensors
Authors: Fazil Salman; Cui Yuanhui; Zafar Imran; Liu Fenghua; Wang Lijian; Wu Weiping
DOI: 10.1016/j.sna.2020.112004

(8) Patient Assistance using Flex Sensor
Authors: Kollu Jaya Lakshmi; Akshada Muneshwar; A Venkata Ratnam; Prakash Kodali
DOI: 10.1109/ICCSP48568.2020.9182277

(9) Arduino Robotic Hand: Survey Paper
Authors: Vaibhav Oza; Pranav Mehta
DOI: 10.1109/ICSCET.2018.8537312

(10) Low cost flex powered gesture detection system and its applications
Authors: Pavan Telluri; Saradeep Manam; Sathwic Somarouthu; Jayashree M Oli; Chinthala Ramesh
DOI: 10.1109/ICIRCA48905.2020.9182833

(11) Smart Wearable Hand Device for Sign Language Interpretation System With Sensors Fusion
Authors: Boon Giin Lee; Su Min Lee
DOI: 10.1109/JSEN.2017.2779466

(12) Hand Gesture Recognition using Flex Sensor and Machine Learning Algorithms
Authors: Akash Kumar Panda; Rommel Chakravarty; Soumen Moulik
DOI: 10.1109/IECBES48179.2021.9398789