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VIBRATED GLOVE

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A WEARABLE FEEDBACK SYSTEM FOR TREMOR MANAGEMENT IN PARKINSON'S DISEASE & RELATED NEUROLOGICAL DISORDERS

Using Mechatronics and Assistive Robotics

Declaration of No Plagiarism

I hereby declare that this submitted report work is a result of my own efforts and I have not plagiarized any other person's work. I have provided all references of information that I have used and quoted in my work.

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Abstract

This project is focused on creating gloves that vibrate to help individuals, with Parkinsons disease enhance their motor skills and well-being. By delivering vibratory feedback to parts of the hand and fingers these gloves are designed to lessen tremors improve hand coordination and boost overall motor abilities.

Acknowledgements

I want to thank everyone who helped make this project successful. The project is focused on creating wearable vibratory gloves to help Tremor's patients improve their motor function and quality of life.

Above all, I want to express my sincere gratitude to the Clinical instructor. Asmaa Sabry Nagy Elwany **from the Department of Mental Health and Psychiatric Nursing at 6th October University. She provided the idea and medical insights, Your device has been made possible by your passion, dedication and creative ideas. This project into a valuable instrument for enhancing lives.**

I am grateful to my university mentors and advisors, Dr. Ramadan Fawzy Mohamed Babers and Dr. Ibrahim Elhasoni, **for their ongoing support, technical assistance, and constructive comments throughout this process. Your knowledge and contributions have been important in overcoming hurdles and ensuring the success of this project.**

This project is the outcome of working together, dedication and ideas from different sources. I trust it will have a positive impact on people with Parkinson's disease, essential tremor, or similar neurological conditions..

Table of Contents

ABSTRACT 2

ACKNOWLEDGEMENTS 2

CHAPTER 1: PROBLEM STATEMENT 6

1.1 Overview 6
1.2 The Problem 6
1.3 Suggested Solutions 7
1.4 Objectives and Goals of the Project 8
1.4.1 Objectives 8
1.4.2 Goals 9
1.5 Scope and Limitations 10
1.5.1 Scope 10
1.5.2 Limitations 11

CHAPTER 2: LITERATURE REVIEW / RELATED WORK 12

2.1 Current Assistive Technologies 12
2.1.1 Wearable Devices 12
2.1.2 Neurostimulation Devices 12
2.1.3 Tools 12
2.1 Technologies for Tremor Detection and Mitigation 13
2.2.1 Sensor Technologies 13
2.2.2 Actuation Mechanisms 13
2.2.3 Artificial Intelligence and Machine Learning. 13
2.3 Relevant Research Studies. 14
2.3.1 Gyro Glove. 14
2.3.2 Intelligent Glove. 15
2.3.3 EMG-Based Systems 16
2.4 Gaps in Existing Solutions 17
2.5 Research and Innovation 18
2.5.1 Research Basis 18
2.5.2 Innovative Features 19

CHAPTER 3: SYSTEM ANALYSIS / DIAGRAMS 20

3.1 Overview of the Proposed System 20
3.2 Functional Requirements 20
3.2.1 User-Specific Requirements 21
3.2.2 Technical Requirements 21
3.3 Components of the System 22
3.3.1 Hardware Components: 22
3.3.2 Software Components: 23
3.4 System Workflow 24
3.5 System Architecture 25
3.6 Initial System design 26
3.6.1 Use case diagram 26
3.6.2 Activity diagram 27

3.6.3 Class Diagram ... 28
3.7 GANTT CHART ... 29
CONCLUSION OF PART A ... 30
CHAPTER 4: DESIGN, IMPLEMENTATION AND TESTING ... 31
4.1 OVERVIEW ... 31
4.2 HARDWARE AND SOFTWARE DEVELOPMENT APPROACH ... 31
4.2.1 USED APPROACH: ... 31
4.2.2 Justification of the Used Approach: ... 32
4.2.3 Phases of the Chosen Model Approach: ... 32
4.3 IMPLEMENTATION: ... 34
4.3.1 User Interface: ... 34
4.3.2 Arduino IDE Code ... 42
4.3.3 Application Blocks ... 48
4.3.4 Hardware Prototyping ... 56
4.3.5 Database ... 61
4.4 ISSUES AND PROBLEMS FACED IN THE PROJECT ... 62
4.4.1 Hardware-Related Issues: ... 62
4.4.2 Software-Related Issues: ... 63
4.4.3 Integration Challenges: ... 63
4.5 TESTING ... 64
4.5.1 White Box Testing ... 64
4.5.2 Black Box Testing ... 65
4.5.3 Unit Testing ... 65
4.5.4 System Testing ... 66
4.5.5 Validation and Verification ... 66
4.5.6 Clinical Testing ... 67
SUMMARY OF CHAPTER 4 ... 69
CHAPTER 5: RESULTS AND DISCUSSION ... 70
5.1 CRITICAL DISCUSSION ... 70
5.2 SKILLS ACQUIRED FROM THE PROJECT ... 71
5.3 DEVELOPMENT GOALS AND RESULTS ... 71
5.4 FUTURE WORK ... 73
5.4.1 Innovation in Therapy and Clinical Integration Using AI ... 73
5.4.2 Hardware and Software Design Enhancements ... 76
5.4.3 Real-World Deployment and Manufacturing ... 76
5.4.4 Patent and Intellectual Property Protection ... 79
5.4.5 Competitions and Exposure ... 79
5.5 ETHICAL, LEGAL, AND SOCIAL CONSIDERATIONS ... 80
SUMMARY OF CHAPTER 5 ... 81
CHAPTER 6: CONCLUSION ... 82
REFERENCES ... 85
APPENDICES ... 87

Figures and Tables

Figure 1 Hand Tremor 6
Figure 2 Gyro Glove 14
Figure 3 Intelligent Glove. 15
Figure 4 EMG-based control 16
Figure 5 Hardware Components 22
Figure 6 MIT App Inventor 23
Figure 7 System Architecture 25
Figure 8 Use Case Diagram 26
Figure 9 Activity Diagram 27
Figure 10 Class Diagram 28
Figure 11 development life cycle 31
Figure 12 Application UI page1 36
Figure 13 Application UI page 2 38
Figure 14 Application UI page 3 41
Figure 15 Color template UI 42
Figure 16 App Block Screen 1 48
Figure 17 App Block Screen 2 49
Figure 18 App Bluetooth Block Connection 50
Figure 19 App Bluetooth Block DisConnection 51
Figure 20 App Block Return Data 51
Figure 21 App Block Data Receiving 52
Figure 22 App Block Motor Activation 53
Figure 23 App Block Change Frequency 54
Figure 24 App Block Motor Pulse Control 55
Figure 25 All Blocks Screen 3 55
Figure 26 ESP32 Board 57
Figure 27 IMU Sensor 57
Figure 28 Mini Micro Vibration Motor 58
Figure 29 TP4056 Charging Module 58
Figure 30 Lithium Battery and Holder 58
Figure 31 Breadboard 59
Figure 32 Glove Design 59
Figure 33 Connecting Jumper Wires 59
Figure 34 Design of Hardware Connection 60
Figure 35 Project Future Vision diagram 81

Letters

Paper 1 Manufacturing Model Letter 87

Chapter 1: Problem Statement

1.1 Overview

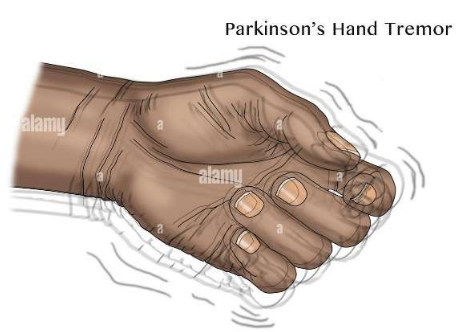
The progressive neurological condition known as Parkinson's disease impairs mobility and causes symptoms like stiffness, tremors, and poor balance. Hand tremor is one of the most prevalent and disruptive symptoms, affecting daily functions like eating, writing, and dressing.

This research aims to create a vibrated glove system that can help Parkinson's patients manage their hand tremors. The glove uses vibratory stimulation to counteract tremor signals, giving alleviation and enhancing the quality of life for sufferers. The system combines hardware (sensors, vibration motors, and microcontrollers) and intelligent software to provide real-time detection, analysis, and therapeutic responses.

1.2 The Problem

Parkinson's Hand Tremor: Hand tremors are one of the most visible and debilitating motor signs of Parkinson's disease, a degenerative neurological condition caused by the brain's loss of dopamine-producing neurons. Tremors have a significant impact on patients' quality of life, making it difficult to carry out daily activities and social contacts.

Figure 1 Hand Tremor



1.3 Suggested Solutions

It is essential to control the symptoms of Parkinson's disease in order to improve the quality of life for both patients and their caregivers. Despite the lack of a cure, proper symptom management for Parkinson's can greatly lessen the physical, emotional, and social challenges linked to the condition.
Managing Parkinson's symptoms is vital for improving patient autonomy, safety, and overall well-being. Improving the ability to move and stay secure. reducing fall risks managing balance problems and episodes of freezing decreases the likelihood of falls and related injuries.

Role of Assistive Devices in Managing Symptoms: Assistive devices, such as vibrated gloves, are particularly important for managing symptoms that are difficult to control with medication alone**.**

Vibrated gloves can:

- Stabilize tremors through controlled vibrations, enabling patients to perform tasks with greater precision.
- Improve sensory feedback, which may help patients overcome challenges like freezing episodes.
- Offer a non-invasive, user-friendly solution to symptom management.

1.4 Objectives and Goals of the Project

The goal of this project is to create and produce vibrating gloves as a unique tool to aid in reducing the motor symptoms of Parkinson's disease, specifically tremors, and improve the life quality of patients. The project seeks to close the gap between current treatment options and the unmet needs of patients by tackling the specific challenges experienced by those with Parkinson's

1.4.1 Objectives

- **Symptom Management:** reduces tremors through controlled vibratory stimulation. improve the ability to perform daily activities.

- **User-Centered Design:** gloves are lightweight, ergonomic, and comfortable for prolonged use. Incorporate adjustable settings varying needs.

- **Affordability and Accessibility:** Design a device that is easy to use, even for individuals with limited technical knowledge or dexterity.

- **Complementing Existing Treatments:** Provide an alternative for patients who may not respond well to medication or are unsuitable for surgical interventions.

- **Customization and Adaptability:** Design the gloves to accommodate different hand sizes and conditions. Allow for adjustments in vibration intensity and frequency to meet individual preferences and medical requirements.

1.4.2 Goals

- **Improved Quality of Life**: Empower Parkinson's patients to regain confidence and independence in daily life.
- **Enhanced Mobility and Dexterity**: Stabilize hand movements to facilitate smoother motor function.
- **Wider Adoption of Assistive Technology**: Promote the use of assistive devices in managing Parkinson's symptoms through the development of a practical and effective solution.
- **Scalability and Future Development**: advanced features like sensors for real-time feedback, data monitoring, and integration with mobile applications for patient tracking.

1.5 Scope and Limitations

The creation of vibrated gloves for Parkinson's patients aims to offer a convenient, non-intrusive, and efficient remedy for easing motor symptoms, specifically tremors. While the project seeks to tackle particular difficulties, it also acknowledges certain constraints that come with the technology and its use.

1.5.1 Scope

- **Intended Audience**: Patients with Parkinson's disease looking for non-invasive options or additions to standard treatments.

- **Primary Features:** The gloves will utilize regulated vibratory stimulation to lessen tremors. Personalized vibration intensity and frequency can be adjusted.

- **Characteristics of the design:** Comfortable gloves that are easy to wear for long periods of time. Suitability for different hand sizes and adjustability options for user comfort.

- **Incorporation with Current Therapies:** The device will enhance current medical treatments, like medications or physical therapy, instead of replacing them.

- **Efficiency in terms of cost:** The project focuses on ensuring affordability for patients of various economic backgrounds to guarantee accessibility.

- **Possible Future Uses:** The basic design could incorporate sensors, data collection, and mobile apps for monitoring and analysis in real-time.

1.5.2 Limitations

- **Effectiveness for All Symptoms:** The gloves are tailored to target tremors and may not have a significant effect on other Parkinson's symptoms.

- **Differences in individuals:** The impact of vibratory stimulation may differ based on symptom severity and how each patient responds.

- **Intended Use:** These gloves are suitable for individuals with mild to moderate tremors, but may not be as beneficial for those with severe symptoms.

- **Battery Life and Power Dependency:** The gloves, being an electronic device, will need to be charged regularly.

- **Durability and Maintenance:** Regular use can cause damage, necessitating upkeep or replacement. Periodic calibration may be necessary for the technology to remain effective.

Chapter 2: Literature Review / Related Work

2.1 Current Assistive Technologies

Designed to help ease symptoms, enhance the quality of life and promote independence for patients. These advancements help with both motor and non-motor symptoms and frequently work alongside conventional therapies such as medication and physical therapy.

2.1.1 Wearable Devices

- **Vibration Therapy Devices:** Wearables that apply controlled vibrations to specific body parts to reduce tremors or stiffness.

2.1.2 Neurostimulation Devices

- **Deep Brain Stimulation (DBS):** Surgically implanted devices that deliver electrical impulses to the brain to regulate abnormal signals.
- **External Neurostimulation Devices:** Non-invasive devices that deliver stimulation to improve motor control.

2.1.3 Tools

- **Writing Aids:** Weighted pens or tools that stabilize hand movements, enabling patients to write with greater accuracy.

2.1 Technologies for Tremor Detection and Mitigation

2.2.1 Sensor Technologies

- **Accelerometers and gyroscopes:** These sensors measure motion, vibration, and angular velocity, providing data for analyzing tremor frequency and amplitude.

- **Electromyography (EMG):** This technology detects electrical activity in muscles and distinguishes between voluntary and involuntary movements.

2.2.2 Actuation Mechanisms

- **Vibration Dampening Systems:** Tunable mass dampers (TMD) are used to prevent tremor-induced oscillations.

- **Active Force Feedback:** Actuators create opposing forces to stabilize hand movements, which are frequently controlled by real-time algorithms.

2.2.3 Artificial Intelligence and Machine Learning.

- **AI algorithms:** are increasingly being used in wearable devices to tailor tremor relieving behaviors to particular users.

- **Machine learning:** models based on motion data can distinguish between deliberate and unintended movements, ensuring that the gadget offe rs exact support.

2.3 Relevant Research Studies.

2.3.1 Gyro Glove.

Xie et al. (2020) found that gyroscopic devices are successful in stabilizing hand tremors, with a 70% reduction in tremor amplitude during tests. However, these devices frequently lack user comfort and portability.

- **Smart Glove Gyroscopic Wearable Technologies:** is a wearable glove that uses gyroscopic technology to calm hand tremors. It gives users more control over their hands by counteracting the tremor motions.

- **Key Features:** Hand tremors are reduced by using gyroscopes, passive design which doesn't require outside power to perform its essential functions, wearable and lightweight.

- **Relevance:** Like vibration-based gloves, this glove aims to improve hand control in Parkinson's sufferers by using gyroscopes to stabilize movements.

Figure 2 Gyro Glove

2.3.2 Intelligent Glove.

- **Intelligent glove:** for suppression of resting tremor in Parkinson’s disease.
- **Description:** The goal of this research is to create an intelligent glove that will help Parkinson's patients with their resting tremors. The technology applies counteractive vibrations or forces to decrease tremors, which are monitored by sensors.
- **Key Features:**
    1. Real-Time Tremor Detection .
    2. Dynamic Vibration Feedback .
    3. Adaptive Algorithms .
    4. User-Friendly Style.
    5. Integration with mobile app.
- **Relevance to Your Project:**

1. The primary goals of this glove are similar employing wearable vibration technology for tremor detection and suppression.
2. It highlights the need of real-time processing and adaptive algorithms, which may be a key component in improving the efficacy of your gloves.
3. The integration of the mobile app fits in nicely with the emphasis on user involvement and customization in your project.

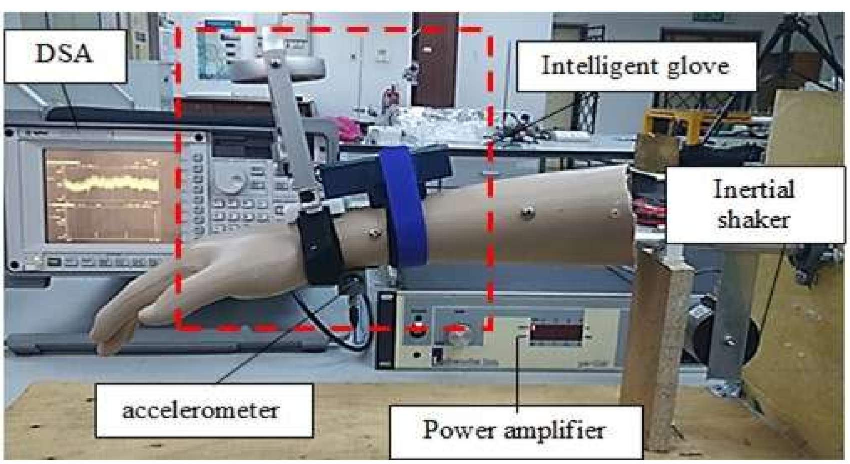


Figure 3 Intelligent Glove.

2.3.3 EMG-Based Systems

- **Objective:** Investigated EMG-based control systems in wearable devices, finding great accuracy in detecting tremors but necessitating extensive calibration methods unsuitable for everyday users.
- **Key Features:**

1. Even at low amplitudes, EMG-based systems showed excellent accuracy in detecting tremor patterns.

2. These systems' potential as dependable control mechanisms could be increased by their ability to discriminate between deliberate movements and uncontrollable tremors.

3. By offering real-time feedback, the method made it possible to use actuators or vibration mechanisms to dynamically inhibit tremors.

- **Relevance to Vibrated Gloves Project:**

1. EMG sensors could increase the accuracy of your system's tremor detection by making sure that only real tremor signals cause vibration feedback.

2. Accuracy and usability could be balanced in a hybrid system that combines EMG and MPU6050 sensors.

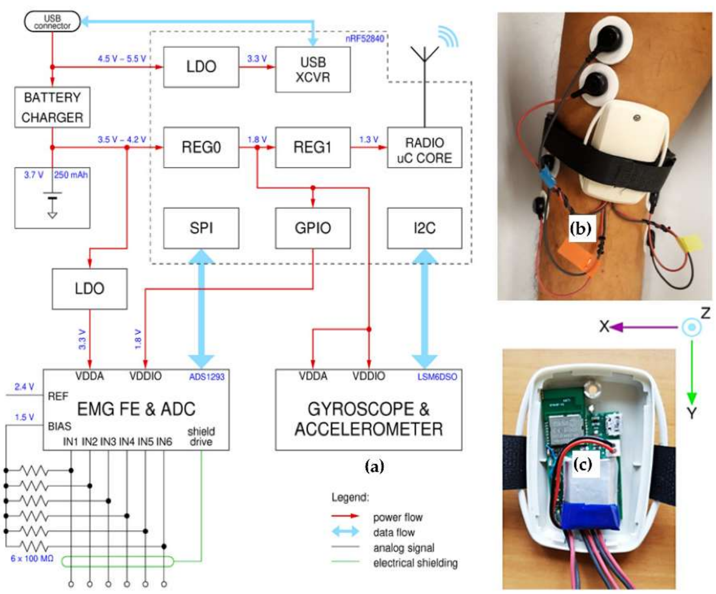


Figure 4 EMG-based control

2.4 Gaps in Existing Solutions

Here's a comparison table between Existing Solution:

Table 1 Existing Solution

Feature	GyroGlove	Intelligent Gloves	EMG-Based Systems	My Project (Vibration Gloves)
Technology	Gyroscopes	Accelerometer & Vibration	EMG Sensors	Accelerometer, Gyroscope, Vibration & Ai
Tremor Detection	Indirect	Direct	Direct	Direct
Feedback	Gyroscopic resistance	Adaptive vibrations	Actuator-based forces	Adaptive vibrations
Ease of Use	High	High	Low	High
Calibration	Minimal	Minimal	Extensive	Minimal
Accuracy	Moderate	High	Very High	High
Cost	Moderate to High	Moderate	High	Moderate
Power Efficiency	High	High	Moderate	High
Integration	No	Yes (Mobile App)	Rarely implemented	Yes (Mobile App)
Key Limitation	Limited adaptability	Vibration efficacy reliance	Complex and bulky	Dependent on vibration algorithms

- **Vibration Gloves:** offers a balance of usability, real-time adaptability, and accuracy, while remaining cost-effective and easy to calibrate compared to EMG systems.
- **GyroGlove**: Ideal for passive tremor stabilization without requiring much user interaction or power but lacks real-time adaptability.
- **Intelligent Gloves**: Offers a balance of usability, adaptability, and effectiveness, making it a practical solution for real-world use.
- **EMG-Based Systems**: Extremely precise but impractical for non-technical users due to calibration needs and Complex hardware.

2.5 Research and Innovation

To fill gaps in existing tremor treatment options, The Vibrated Gloves Project presents a novel way to treating Parkinson's hand tremors with strategically applied vibration treatment. This section emphasizes the scientific foundations and novel characteristics that set the project apart from previous solutions.

2.5.1 Research Basis

According to research, regulated vibrations can interfere with tremor patterns, reducing amplitude and frequency. The Vibrated Gloves Project is based on the following key findings:

- **Vibration Therapy Studies**: Research indicates that particular vibration frequencies might desynchronize brain activity, resulting in tremors, providing a non-invasive mitigating technique.

- **Wearable Device Advancements:** Wearable device research shows that putting vibration motors into gloves has the potential to deliver localized therapy.

- **Sensor Guided Feedback:** Combining sensors and vibration technology allows for targeted intervention, ensuring that therapy is tailored to the user's real-time needs.

2.5.2 Innovative Features

1. Specific Vibration Treatment

- Hand instability is decreased via embedded vibration motors that produce micro-vibrations that are precisely calibrated to break the tremor cycle.
- Frequency and intensity can be changed to suit specific demands.

2. Real-Time Identification of Tremors

- Tremors are detected by sensors (gyroscopes and accelerometers), which dynamically initiate vibration therapy.
- In order to gradually optimize vibration settings, AI algorithms examine tremor patterns.

3. Comfortable User-Friendly Design

- Comfort throughout prolonged use is ensured by lightweight, breathable fabrics.
- Both wearability and attractiveness are enhanced by a modern, ergonomic design.

4. **Economical Option**

- The use of widely accessible parts (such as simple sensors and vibration motors) guarantees affordability for a larger audience.

Chapter 3: System Analysis / Diagrams

3.1 Overview of the Proposed System

This section provides a detailed explanation of the system's purpose, components, and workflow. The proposed vibrated gloves aim to assist Parkinson's patients in managing motor symptoms using robotics, mechatronics and artificial intelligence programming in manufacturing through integrates hardware (sensors, motors, microcontroller, and battery) and software (mobile app) to offer a seamless, user-friendly experience.

- **Key features:**
  1. include motion sensor-based real-time tremor detection.
  2. Vibration frequency and intensity can be changed.
  3. Lightweight and portable for everyday use.
  4. user-friendly and non-invasive.

3.2 Functional Requirements

Providing efficient tremor control while preserving user comfort and accessibility is the goal of the vibrated gloves for Parkinson's sufferers. A thorough breakdown of the functional requirements, divided into user-specific, technical, and performance criteria specific to this project, can be found below.

3.2.1 User-Specific Requirements

1. **Comfort and Usability:** lightweight, ergonomic, and breathable for extended use, the design should accept different hand sizes using adjustable straps or flexible materials.
2. **Ease of Use:** Users should be able to change vibration intensity and frequency with simple controls, such as buttons, dials, or a mobile app, The device should be easy to set up and operate, requiring no technical knowledge.
3. **Non-Invasiveness:** Gloves should not require any invasive treatments or external medical intervention.
4. **Aesthetics:** The gloves should have a subtle and appealing appearance to encourage regular use and avoid stigma.

3.2.2 Technical Requirements

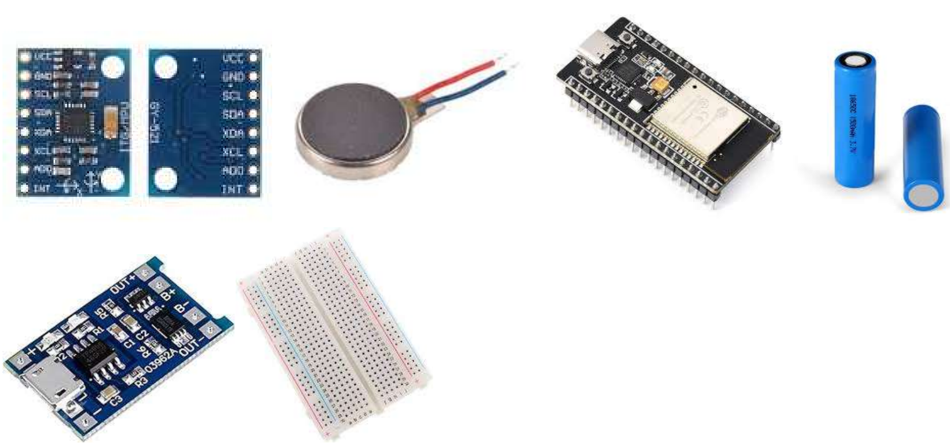
1. **Tremor Detection System:** The gloves should have an Inertial Measurement Unit (IMU) with accelerometers and gyroscopes that can detect tremor frequencies from 3-12 Hz, which is typical for Parkinson's-related tremors.
2. **Real-Time Data Processing:** The system has to process tremor data in real-time to change vibration output dynamically, low-latency algorithm analyzes data with a response time of less than 100 ms to provide timely stimulation.
3. **Customizable Vibration Control:** allow users to alter vibration parameters, such as Intensity (low to high) based on tremor severity, Frequency 10-100 Hz, according on user sensitivity and effectiveness.
4. **Power Supply:** rechargeable battery with a minimum usage time of 6-8 hours on one charge, battery level indicator should alert consumers when recharging is required.
5. **Wireless Connectivity** : Include Bluetooth or Wi-Fi capabilities for pairing with a smartphone app.
6. **Safety Features:** include a safety cut-off mechanism to prevent overheating of the vibration motors, all materials used hypoallergenic and safe for sensitive skin.

3.3 Components of the System

3.3.1 Hardware Components:

- **ESP32 Module:** Serves as the central processing unit for tremor detection algorithms, motor control and facilitates wireless communication between the gloves and a mobile application via Bluetooth or Wi-Fi.
- **MPU6050 IMU Sensor:** Detects hand and finger movements, measuring both acceleration and angular velocity. Used for real-time tremor detection by analyzing motion patterns.
- **Micro Mini Vibration Motors:** Provide targeted vibratory stimulation to specific areas of the hand and fingers. Intensity and patterns are adjustable based on tremor severity and user preferences.
- **Rechargeable Lithium Battery With TP4056 Lithium Charger Module:** Powers the system, ensuring portability, extended operation and the module to Manages safe and efficient charging of the battery.
- **Breadboard (for prototyping):** Serves as a platform for testing and connecting hardware components.
- **Wires and Resistors ….. other tools**

Figure 5 Hardware Components



3.3.2 Software Components:

Mobile Application: A custom mobile application was developed using **MIT App Inventor**. The app provides an intuitive interface for users to monitor tremor activity and adjust vibration settings via Bluetooth. It allows real-time customization of vibration intensity, duration, and patterns. The application communicates with the glove using Bluetooth serial commands and displays live feedback such as tremor intensity and battery status.

Figure 6 MIT App Inventor

It is a simulation of real mobile application using in future evaluation for controlling the wearable device. Incorporates real-time tremor analysis, control panels for altering vibration intensity and frequency. It is created with the user in mind.

3.4 System Workflow

Step-by-Step Operations:

1. **Initialization:**
   - When powered on, the system initializes all hardware components, including the MPU6050 sensor, vibration motors and ESP32 module.
   - The mobile app connects to the gloves via Bluetooth or Wi-Fi.

2. **Tremor Detection:**
   - The MPU6050 continuously monitors hand and finger movements, collecting acceleration and angular velocity data.
   - The Arduino Nano processes this data to detect tremor patterns based on predefined thresholds and algorithms.

3. **Vibration Activation:**
   - Upon detecting tremors, the Arduino Nano activates the vibration motors.
   - The intensity and duration of vibrations are dynamically adjusted based on the severity of the detected tremors.

4. **Data Transmission:**
   - Detected tremor data are sent to the mobile app via the ESP32 module.
   - The app displays real-time tremor data for user monitoring.

5. **User Interaction:**
   - **With the mobile app to:** Adjust vibration settings (intensity, duration, patterns), View tremor activity logs and system status, Receive alerts for low battery or other system notifications.

6. **Power Management:**
   - The TP4056 module ensures safe charging and prevents overcharging or overheating.

3.5 System Architecture

Overall Purpose:

The system combines hardware, processes and software to provide targeted vibratory stimulation to patients, aiming to improve motor function and quality of life. The modular design also allows future enhancements, such as additional sensors or advanced data analytics.

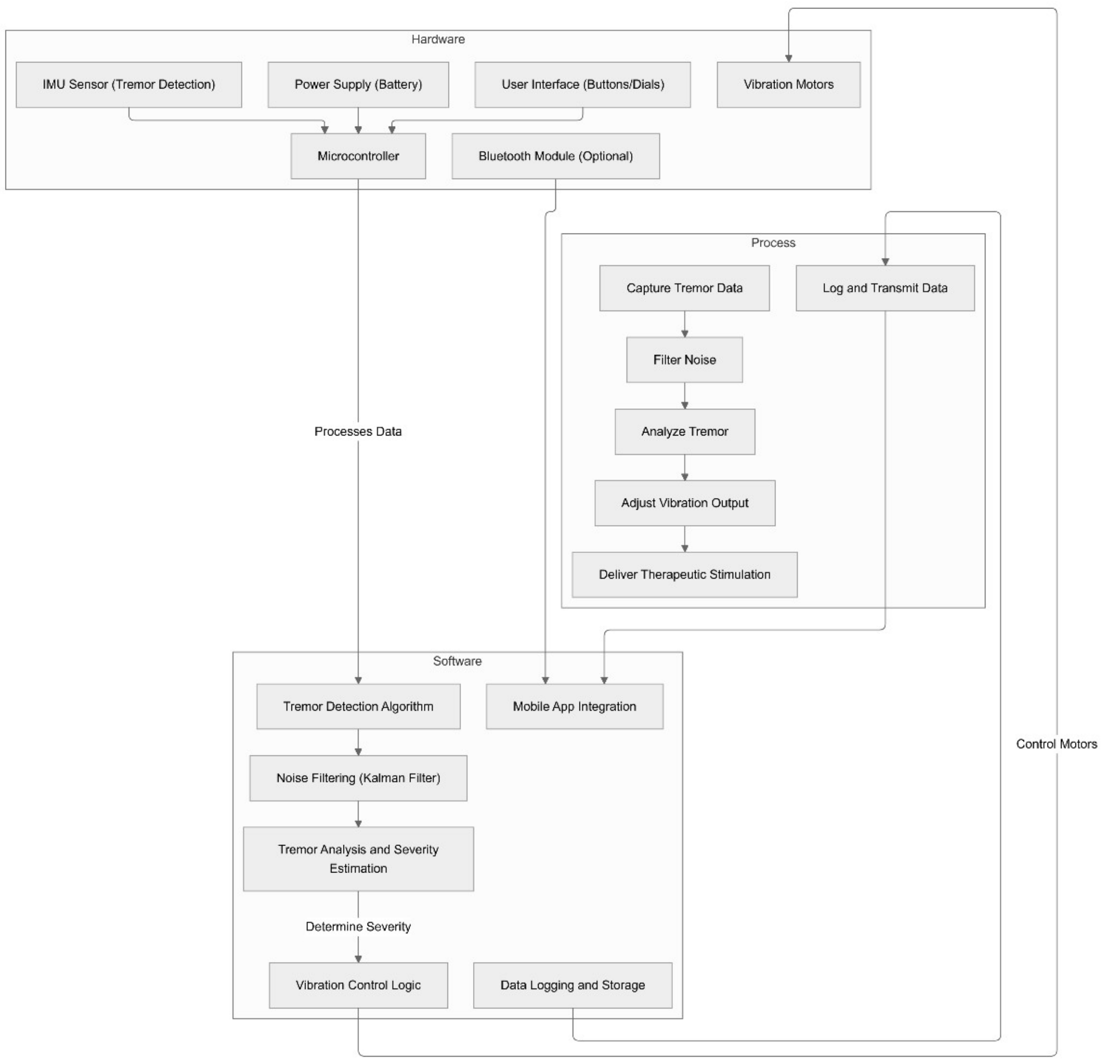


Figure 7 System Architecture

3.6 Initial System design

3.6.1 Use case diagram

The Use Case Diagram represents the system's interaction with external entities (actors) such as the user (Parkinson's patient or caregiver) and the mobile application. It outlines the primary use cases the system supports.

Actors:

- **User:** Wears the gloves, adjusts settings, and monitors performance.
- **Mobile App:** Interfaces with the gloves for customization and feedback.

Use Cases:

1. Detect tremors using the MPU6050 sensor.
2. Activate vibration motors for stimulation.
3. Adjust vibration settings via the app.
4. Monitor tremor data on the app.
5. Provide low-battery alerts

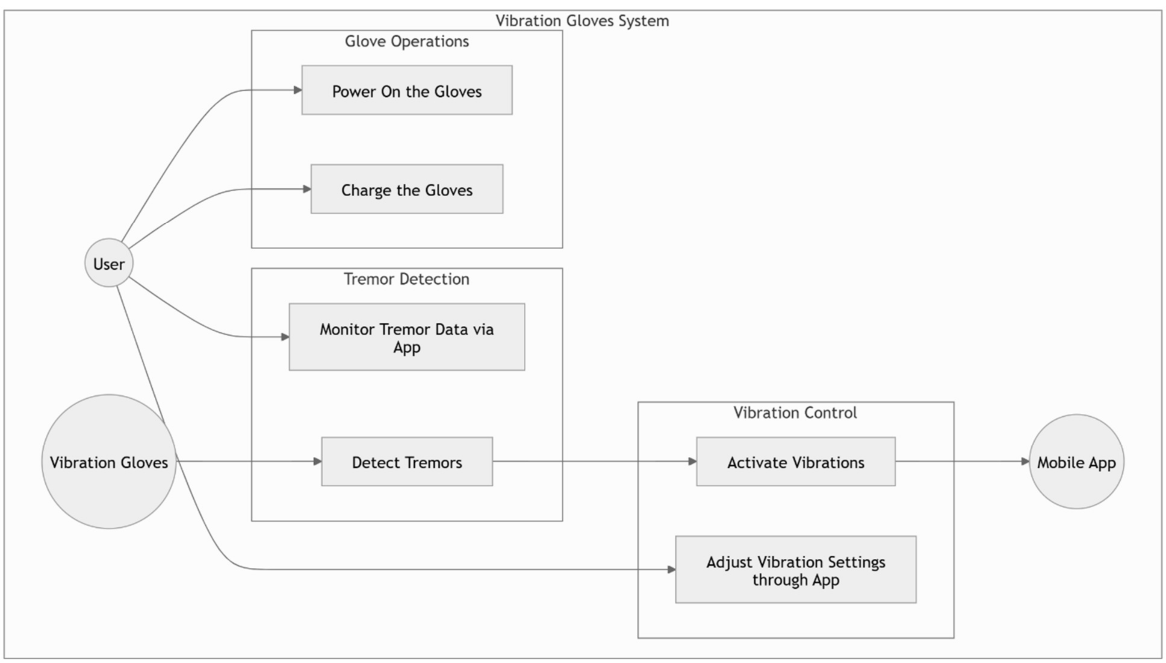


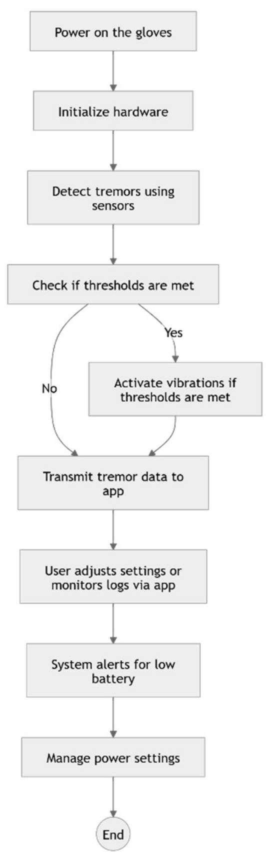
Figure 8 Use Case Diagram

3.6.2 Activity diagram

The Activity Diagram outlines the workflow of the system, illustrating the sequence of operations and decision points.

1. **Start:** User powers on the system.
2. **Initialize Sensors:** The MPU6050 and motors are initialized.
3. **Tremor Detection:** The MPU6050 monitors hand movements.
   - **If tremors are detected:** Activate motors.
   - **If no tremors are detected:** System continues monitoring.
4. **Data Transmission:** Send tremor data to the mobile app.
5. **User Interaction:** The user adjusts settings via the app.
6. **Battery Monitoring:** Notify the user if the battery is low.
7. **End:** System shuts down or recharges.

Figure 9 Activity Diagram



3.6.3 Class Diagram

The Class Diagram defines the static structure of the system, including its key components and their relationships.

Classes:

1. **Glove System:**
   - **Attributes:** status, power Level, vibration Pattern.
   - **Methods:** initialize(), detectTremors(), activateMotors(), sendData().
2. **MPU6050 Sensor:**
   - **Attributes:** acceleration, gyroscopeData.
   - **Methods:** readData(), processTremorData().
3. **Vibration Motor:**
   - **Attributes:** intensity, location.
   - **Methods:** start Motor(), stop Motor(), adjustIntensity().
4. **Mobile App:**
   - **Attributes:** userSettings, tremorLogs.
   - **Methods:** adjustSettings(), displayData(), alertUser().
5. **Power Module:**
   - **Attributes:** batteryLevel, chargingStatus.
   - **Methods:** monitorBattery(), alertLowPower().

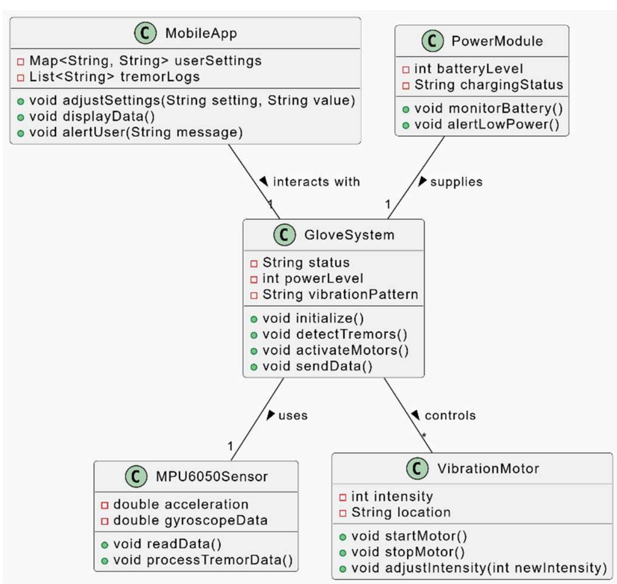


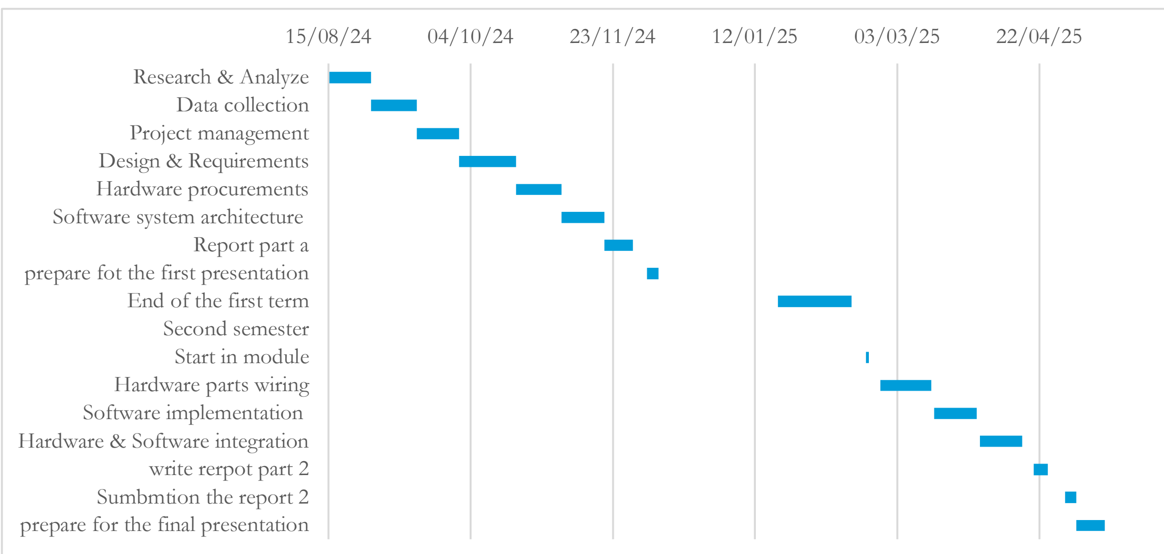
Figure 10 Class Diagram

3.7 Gantt Chart

A Gantt chart is essential to track project progress.

Task	Start Date	End Date	Duration/Day
Research & Analyze	15/08/24	30/08/24	15
Data collection	30/08/24	15/09/24	16
Project management	15/09/24	30/09/24	15
Design & Requirements	30/09/24	20/10/24	20
Hardware procurements	20/10/24	05/11/24	16
Software system architecture	05/11/24	20/11/24	15
Report part a	20/11/24	30/11/24	10
prepare for the first presentation	05/12/24	09/12/24	4
End of the first term	20/01/25	15/02/25	26
Second semester	15/02/25	15/02/25	0
Start in module	20/02/25	21/02/25	1
Hardware parts wiring	25/02/25	15/03/25	18
Software implementation	16/03/25	31/03/25	15
Hardware & Software integration	01/04/25	16/04/25	15
Write report part 2	20/04/25	25/04/25	5
Submit the report 2	01/05/25	05/05/25	4
Prepare for the final presentation	05/05/25	15/05/25	10

Table 2 Gantt chart



Conclusion Of Part A

Part A of the report provides an overview of Parkinson's disease, highlighting the difficulties patients have in daily tasks owing to tremors and impaired motor skills. This was followed by an examination of existing treatments and assistive technology, which indicated considerable gaps in tremor management using non-invasive and user-friendly ways. The literature review emphasized the relevance of vibratory stimulation in reducing tremors, which created the ground work for this novel technique and describes the design and development of a novel wearable device vibrated gloves.

Chapter 4: Design, Implementation and testing

4.1 Overview

This chapter describes the overall design, implementation, and testing phases of a wearable vibrating glove system designed to treat hand tremors utilizing robotics and mechatronics. The concept incorporates motion sensors, vibration feedback, and wireless control via controller mobile application.

4.2 Hardware and Software Development Approach

4.2.1 Used Approach:

The development followed **iterative methodology**, progressing through 6 critical phases that supported both technical development and user-centered validation:

- ✓ **Research** to understand tremor dynamics and explore existing solutions.
- ✓ **Planning** to define requirements, select components, and estimate risks.
- ✓ **Design** to build a modular architecture integrating sensor processing, Bluetooth communication, and feedback.
- ✓ **Prototyping** to implement and test features on real hardware.
- ✓ **Testing** to evaluate sensor precision, system responsiveness, and usability.
- ✓ **Maintenance** to ensure long-term reliability, allow updates, and support further enhancements based on feedback.

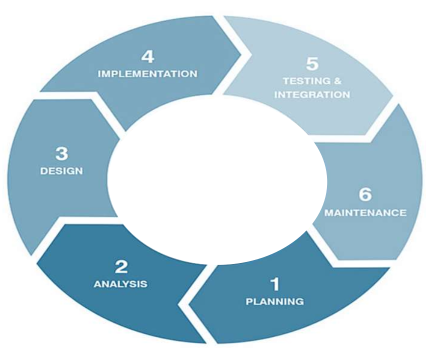


Figure 11 development life cycle

4.2.2 Justification of the Used Approach:

This approach was chosen because of its capacity to:

- Handle both hardware and software integration, which is very important in embedded systems.
- Provide early and continuous testing to reduce errors.
- Allow for incremental improvements, which is especially important when working with patients or real-world data.
- Provide a clear approach for post-deployment support and updates, as outlined in the maintenance phase.

The approach strikes a balance between structure and adaptability, which is critical in projects that involve wearable health technology and real-time feedback systems.

4.2.3 Phases of the Chosen Model Approach:

1. Research Phase

- **Hardware:** Investigated suitable sensors (MPU6050), microcontrollers (ESP32), vibration actuators, and power systems for wearable applications.
- **Software:** Studied tremor patterns in Parkinson's disease and explored existing solutions for motion analysis and feedback. Identified optimal filtering and control algorithms for tremor detection.

2. Planning Phase

- **Hardware:** Defined system requirements such as sensor sensitivity, motor output, battery capacity, and PCB layout. Selected reliable components with minimal noise and power consumption.
- **Software:** Outlined app functionalities (Bluetooth communication, parameter customization, data display), selected **MIT App Inventor** as the development tool, and mapped out command structures and data receiving.

3. Design Phase

- **Hardware:** Designed a modular glove layout integrating the ESP32 board, MPU6050 sensor, vibration motors, battery, and charging module (TP4056). Pin mapping and wiring were carefully planned for compactness and safety.
- **Software:** Developed a modular software architecture including:
  - Sensor reading and tremor intensity computation
  - Motor control logic
  - Bluetooth command parsing
  - Battery monitoring and warnings
  - App UI for settings control and real-time monitoring

4. Prototyping Phase

- **Hardware:** Built a physical prototype glove, soldered connections, and integrated all components into a wearable form. Ensured secure attachment and comfort for the user.

- **Software:** Coded the firmware using Arduino IDE. Developed the mobile app using MIT App Inventor, allowing users to connect via Bluetooth, adjust vibration settings, and view tremor and battery data.

5. Testing Phase

- **Hardware:** Verified accuracy of motion sensing and motor functionality. Tested battery charging/discharging cycles, Bluetooth range, and glove durability under motion.

- **Software:** Evaluated app responsiveness, command reliability, and sensor data visualization. Performed stress tests to handle invalid commands and low-battery scenarios.

6. Maintenance Phase

- **Hardware:** Designed the system to allow component replacement or upgrades (e.g., higher capacity battery or enhanced IMU). Proposed design improvements for future iterations.

- **Software:** Structured code for future updates (vibration pattern presets)App enhancements planned based on user feedback, including UI improvements

4.3 Implementation:

The implementation phase involved the practical development and integration of both the software and hardware components of the vibrating glove system. The system is composed of an embedded microcontroller (ESP32), motion sensors (MPU6050), vibration feedback actuators, and a mobile control application built using MIT App Inventor. This section covers the user interface, embedded and mobile application code, and data handling aspects of the system.

4.3.1 User Interface:

The mobile application for the vibrating glove system was developed using **MIT App Inventor**, a visual programming tool designed for rapid development of Android apps using a block-based interface. The UI was intentionally designed to be simple, user-friendly, and suitable for patients with Parkinson's or other tremor-related conditions.

The application is composed of **three sequential pages (screens)**, each fulfilling a specific role in the interaction flow from user onboarding to device connection and control.

Page 1:

Welcome Screen Titled with “Vibrated Gloves App”

Purpose:
To introduce the app and guide users smoothly into the system.

Design Features:

- **App Title:**
  A label at the top center of the screen shows the app’s name:
  "Vibrated Glove"
  Styled with a bold font and large size for readability.

- **Logo of Application and small brief for app**

- **"Get Started" Button:**
  Placed at the center of the screen.
  When clicked, it navigates the user to the second page

This page sets the tone of professionalism and simplicity while keeping the navigation intuitive.

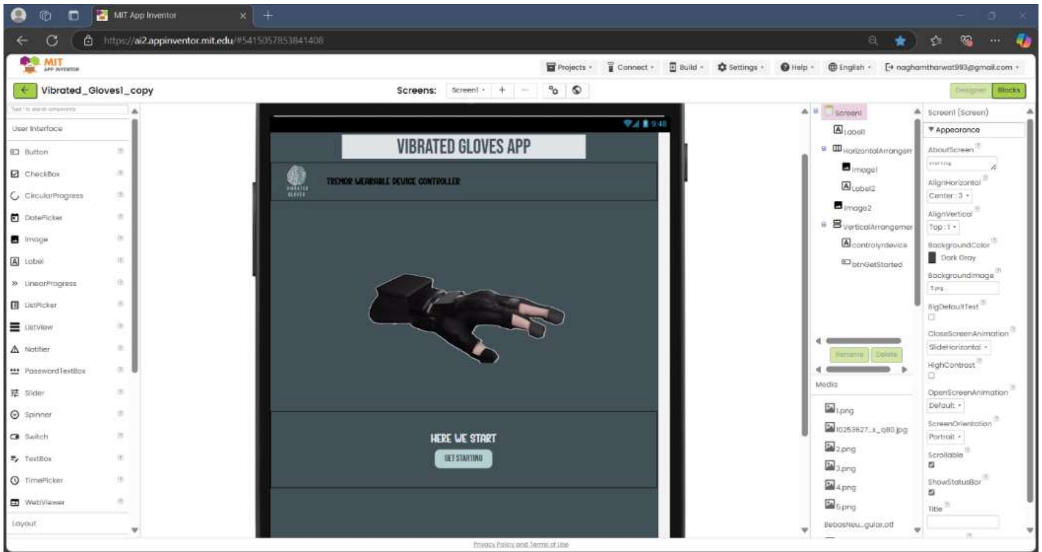


Figure 12 Application UI page1

Page 2: Patient Information Form

Purpose:
To capture basic patient information before starting the session.

Design Features:

- **Input Fields:**
  - **Patient Name:**
    A TextBox for entering the patient's full name.
  - **Age:**
    A TextBox for numeric input representing age.
  - **Tremor Type:**
    A Dropdown List (ListPicker) or TextBox for selecting or entering the tremor type (Parkinson's , Essential Tremor , Dystonic or Other)
- **"Next" Button:**
  - On click, the app stores the entered information (can use TinyDB if needed) and navigates to the third screen

This screen helps personalize the session and could be extended in the future to include medical history or doctor notes.

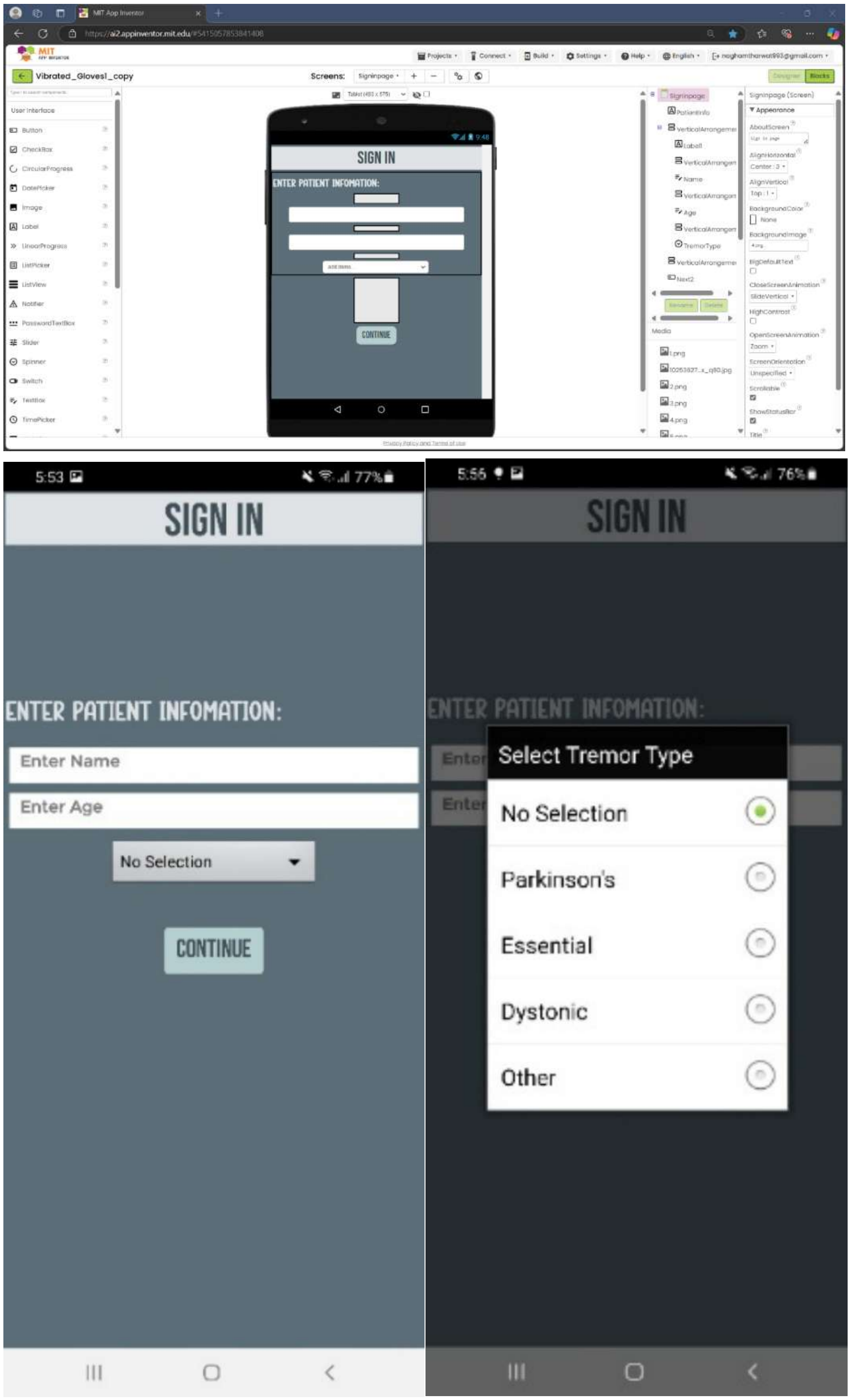


Figure 13 Application UI page 2

Page 3: Device Control and Monitoring Dashboard

Purpose:
To connect to the vibrating glove via Bluetooth, send control commands, and receive tremor/battery feedback in real-time.

Design Features:

1. **Return patient information stored :**
    - Patient Name
    - Age
    - Tremor Type

2. **Bluetooth Device Scanner:**

- **Bluetooth List Picker:**
    - Scans and lists available Bluetooth devices.
    - When the user selects Vibrated Glove, a connection attempt is made.
    - Displays a status message: **"Connected to Vibrated Glove"** or **"Connection Failed"**
- With Disconnected button at end

3. **Tremor Monitoring:**

- **Live Tremor Intensity Display:**
    - A Label shows values like:
      Tremor: Stable or Medium or High

- **Battery Monitoring Display:**
  - Battery percentage is parsed from the ESP32 Bluetooth feedback.
  - A Label displays emoji icons based on level:
    - 🔋 (Full)
    - 🪫 (Critical)

4. Control Panel:

- **Motor Control Buttons:**
  - With Labeled Turn on/off
  - Button **"ON"** → sends MOTORS_ON
  - Button **"OFF"** → sends MOTORS_OFF
- **Set Frequency:**
  - A Button labeled **" Frequency Levels "**
  - LOW or Medium or HIGH
  - That was sends command via Bluetooth: SET_FREQ “ ”
- **Set Pulses:**
  - A Button labeled **"Pulses Duration"**
  - Short Pulses or Long Pulses
  - Sends command via Bluetooth: SET_PULSES “ ”

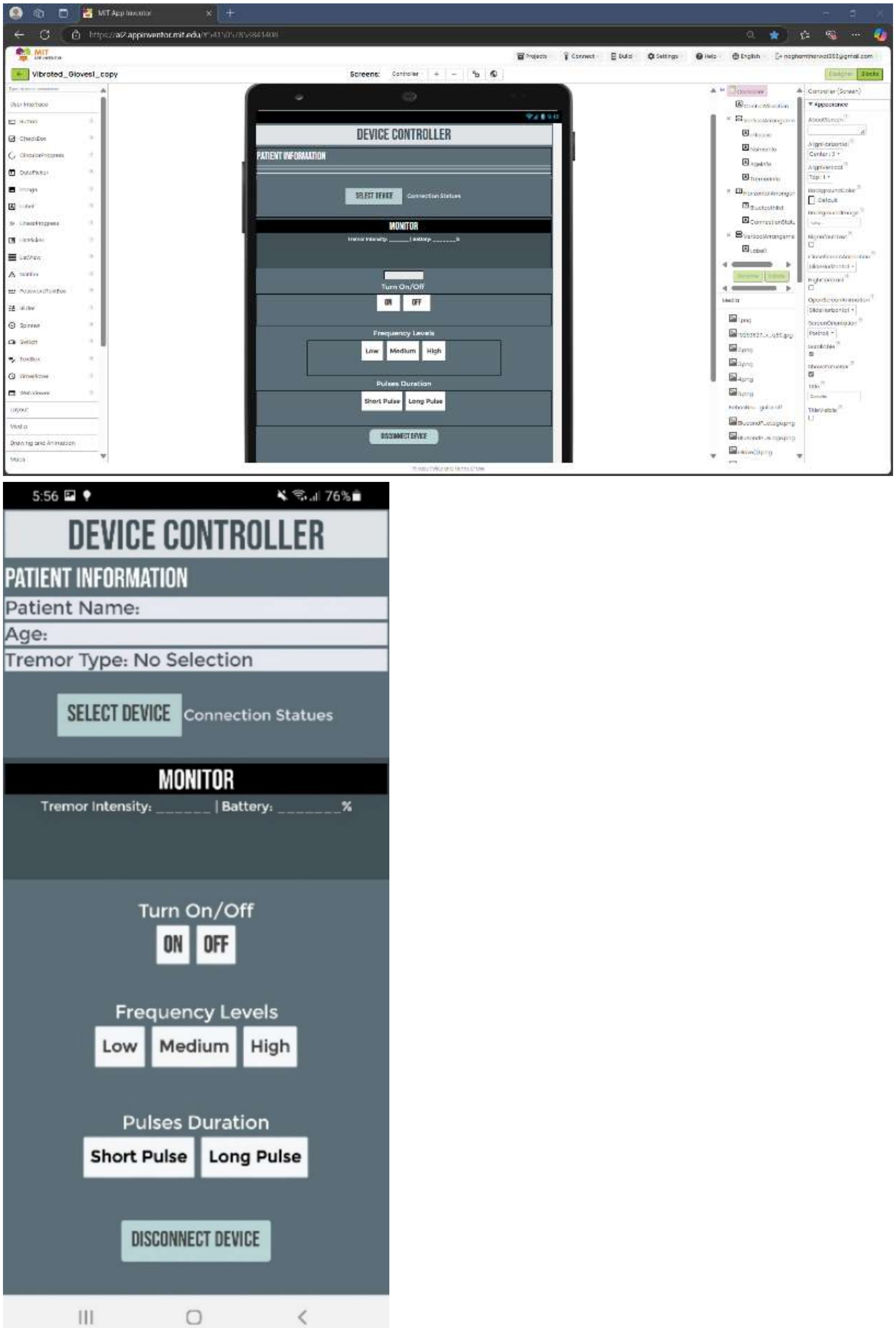


Figure 14 Application UI page 3

Visual Layout:

- Clean grid layout for organized control sections.
- Fonts are bold and large for accessibility.
- Color-coded status indicators (green for connected, red for connected failed)

Color template used :

Figure 15 Color template UI

User Flow Summary:

1. **Start on Page 1** → Tap **Get Started**
2. **Page 2** → Enter patient details → Tap **Next**
3. **Page 3** →
    - Connect to glove
    - Monitor tremor intensity and battery status
    - Adjust vibration settings

4.3.2 Arduino IDE Code

The firmware of the Vibrated Glove system is written in **C++** using the **Arduino framework** and is deployed to an **ESP32 Dev module microcontroller**. The software integrates 3 main functionalities:

1. **Tremor detection using the MPU6050 IMU sensor**
2. **Bluetooth communication via ESP32 and MIT App Inventor**
3. **Vibration motor control based on tremor intensity**

The code is structured into logical modules to ensure clarity and maintainability.

- **Import required libraries & Set required Variables**

```
#include <Wire.h>
#include <MPU6050.h>
#include <BluetoothSerial.h>

MPU6050 mpu;
BluetoothSerial SerialBT;

#define NUM_MOTORS 5
int motorPins[NUM_MOTORS] = {12, 14, 26, 27, 32};
int vibrationFrequency = 1;         // PWM frequency
int pulseCount = 3;                 // Number of pulses per activation
int pulseDuration = 200;            // Duration of each pulse in milliseconds
float tremorThreshold = 15000.0;    // Adjust based on your needs
bool motorsEnabled = true;          // Motor activation flag

// Pulsing state variables
bool isPulsing = false;
unsigned long pulseStartTime;
int pulsesRemaining = 0;
```

- **Initialization (Setup)**

```
void setup() {
 Serial.begin(115200);
 SerialBT.begin("VibratedGlove");
 Wire.begin();
 mpu.initialize();

 if (!mpu.testConnection()) {
  Serial.println("MPU6050 connection failed!");
  while (1);}

 for (int i = 0; i < NUM_MOTORS; i++) {
  pinMode(motorPins[i], OUTPUT); }
 Serial.println("Device Initialized.");
}
```

- Initializes the **serial monitor** and **Bluetooth Serial** with the device name "VibratedGlove".
- Starts the **I2C bus** for communication with the MPU6050 sensor.
- Tests the MPU6050 connection; halts execution if not detected.
- Configures the **motor pins as outputs**.

- **Main Loop: Continuous System Operation**

```
void loop() {
 static unsigned long lastUpdateTime = 0;
 unsigned long currentTime = millis();

 // Read IMU data
 int16_t ax, ay, az, gx, gy, gz;
 mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

 // Calculate tremor intensity
 float intensity = calculateTremorIntensity(gx, gy, gz, ax, ay, az);

 // Tremor detection and motor control
 if (intensity > tremorThreshold && motorsEnabled && !isPulsing) {
  startPulsing();
 }

 // Handle motor pulsing
 handlePulsing();

 // Send data every 100ms
 if (currentTime - lastUpdateTime > 1000) {
  lastUpdateTime = currentTime;
  sendData(intensity);
  plotData(intensity, gx, gy, gz, ax, ay, az);
 }

 // Handle Bluetooth commands
 if (SerialBT.available()) {
  String command = SerialBT.readStringUntil('\n');
  handleCommand(command);
 }
}
```

The loop continuously:

- Reads **acceleration and gyroscope data** from the MPU6050.
- Calculates **tremor intensity** using a combined weighted metric.
- Starts a **pulsing routine** if the intensity exceeds the threshold.
- Handles **Bluetooth communication** by listening for commands and responding accordingly.

- **Tremor Detection Logic**

```
float calculateTremorIntensity(int16_t gx, int16_t gy, int16_t gz,
                               int16_t ax, int16_t ay, int16_t az) {
 // Calculate combined tremor intensity (gyroscope-based)
  float gyroMag = sqrt(pow(gx, 2) + pow(gy, 2) + pow(gz, 2));
  float accelMag = sqrt(pow(ax, 2) + pow(ay, 2) + pow(az, 2));
  return gyroMag * 0.7 + accelMag * 0.3; // Weighted combination
}
```

- Uses a **weighted average** of gyroscope and accelerometer magnitudes to calculate the overall tremor intensity.
- The formula emphasizes **gyroscopic data (70%)** due to its reliability in detecting high-frequency tremors.

- **Vibration Motor Control**

```
void startPulsing() {
  isPulsing = true;
  pulsesRemaining = pulseCount;
  pulseStartTime = millis();
  activateMotors(); }
void handlePulsing() {
  if (!isPulsing) return;
  if (millis() - pulseStartTime >= pulseDuration) {
    deactivateMotors();
    pulsesRemaining--;
    if (pulsesRemaining > 0) {
      pulseStartTime = millis();
      activateMotors();
    } else {
      isPulsing = false;}}}

void activateMotors() {
  for (int i = 0; i < NUM_MOTORS; i++) {
    analogWrite(motorPins[i], vibrationFrequency); } }

void deactivateMotors() {
  for (int i = 0; i < NUM_MOTORS; i++) {
    analogWrite(motorPins[i], 0); } }
```

Start Pulses

- Called when tremor intensity exceeds the threshold.
- Begins a motor pulsing cycle with a defined number of pulses and duration.

Pulse Handler

- Uses a timer-based approach to turn motors ON and OFF at fixed intervals.
- Ensures motors do not run continuously—delivers precise feedback.

Activate & Deactivate Motors

- Uses PWM (Pulse Width Modulation) via analogWrite to control vibration strength.
- All five motors are activated simultaneously with the current frequency setting.

- **Data Transmission and Plotting**

```
void sendData(float intensity) {
  String data = "Patient Tremor Intensity:" + String(intensity);
  SerialBT.println(data);
}

void plotData(float intensity, int16_t gx, int16_t gy, int16_t gz,
              int16_t ax, int16_t ay, int16_t az) {
  Serial.print("Patient Tremor Intensity:");
  Serial.print(intensity);
  Serial.print(",GyroX:");
  Serial.print(gx);
  Serial.print(",GyroY:");
  Serial.print(gy);
  Serial.print(",GyroZ:");
  Serial.print(gz);
  Serial.print(",AccelX:");
  Serial.print(ax);
  Serial.print(",AccelY:");
  Serial.print(ay);
  Serial.print(",AccelZ:");
  Serial.println(az);
}
```

- Transmits real-time tremor data over Bluetooth to the MIT App Inventor UI.
- Outputs detailed data to the serial monitor for development and debugging purposes.

- **Command Handling (Bluetooth Control)**

```
void handleCommand(String command) {
 command.trim();
 if (command.startsWith("SET_FREQ")) {
  vibrationFrequency = command.substring(9).toInt();
  SerialBT.println("Frequency Set: " + String(vibrationFrequency) + "Hz");
 }
 else if (command.startsWith("SET_PULSES")) {
  int space1 = command.indexOf(' ');
  int space2 = command.indexOf(' ', space1 + 1);
  if (space1 != -1 && space2 != -1) {
   pulseCount = command.substring(space1 + 1, space2).toInt();
   pulseDuration = command.substring(space2 + 1).toInt();
   SerialBT.println("Pulses Set: " + String(pulseCount) +
            "x" + String(pulseDuration) + "ms");
  }
 }
 else if (command == "MOTORS_ON") {
  motorsEnabled = true;
  SerialBT.println("Motors Enabled");
 }
 else if (command == "MOTORS_OFF") {
  motorsEnabled = false;
  SerialBT.println("Motors Disabled");
 }
 else {
  SerialBT.println("Invalid Command");
 }
}
```

- Parses commands sent from the mobile app.
- **SET_FREQ " "** adjusts vibration intensity.
- **SET_PULSES " "** sets the number and duration of pulses.
- **MOTORS_ON/OFF** enables or disables motor activity.
- Ensures dynamic, real-time control by the user.

4.3.3 Application Blocks

The application has 3 screens:

1. **Screen1** – Welcome Page
2. **Screen2** – Patient Sign-In
3. **Screen3** – Bluetooth Control & Monitoring

- **Screen1: Welcome Screen**

Blocks:

when GetStartedButton.Click
→ Opens the next screen:
open another screen screenName: "Screen2"

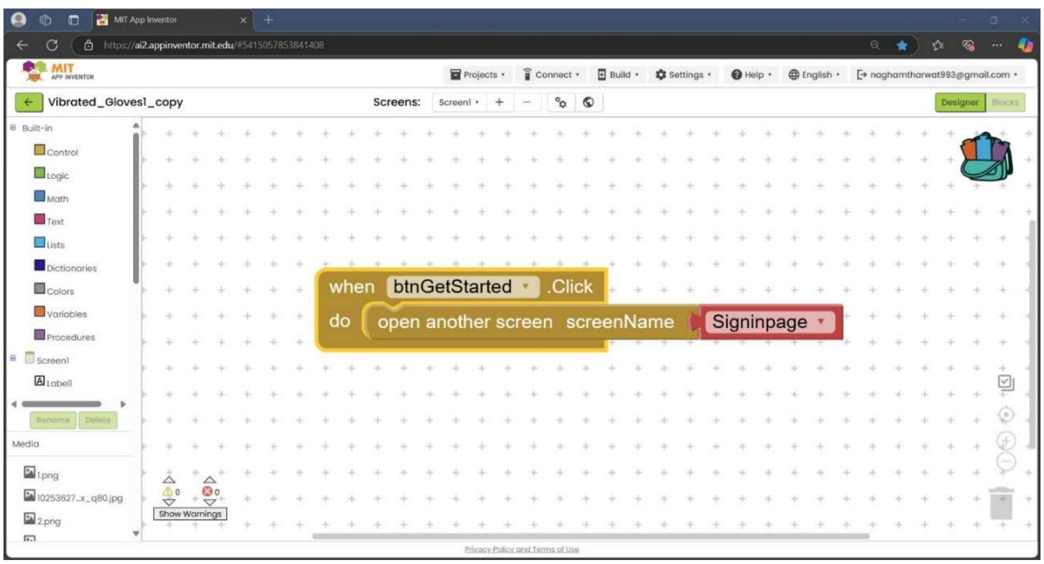


Figure 16 App Block Screen 1

- ## Screen2: Patient Info Entry

Blocks:

when NextButton.Click
→ Validates user input (optional)
→ Stores info using TinyDB.StoreValue for use in Screen3
→ Navigates to the Controller Screen:
open another screen screenName: "Screen3"

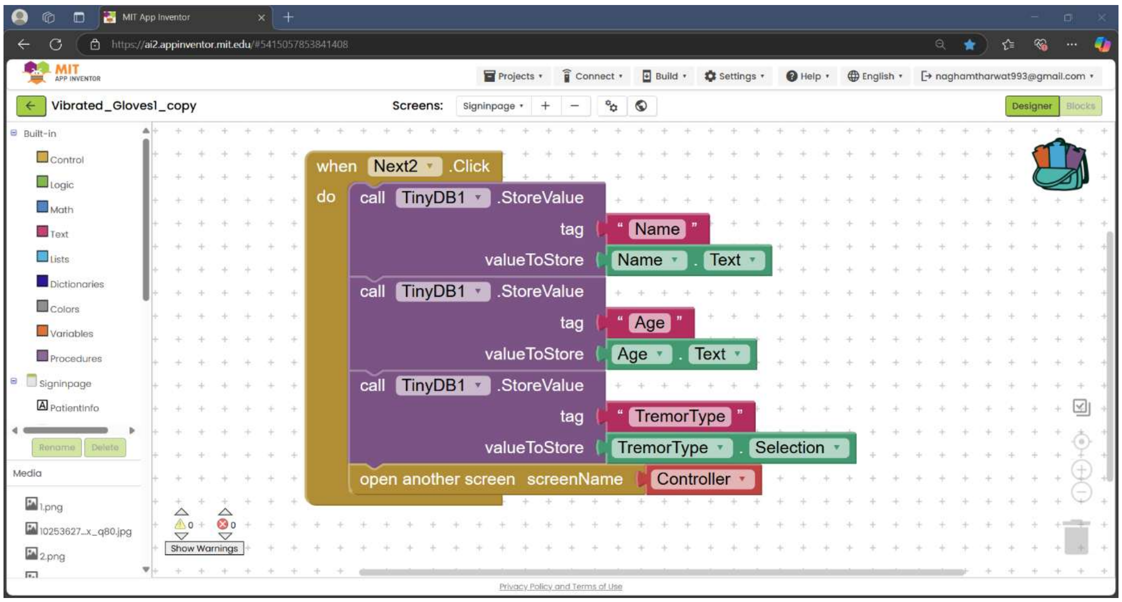


Figure 17 App Block Screen 2

- **Screen3: Bluetooth Control & Monitoring**

1. Bluetooth Device Selection & Connection:

when BluetoothList1.BeforePicking

- Populates the list of available Bluetooth devices.
- Uses BluetoothClient1.AddressesAndNames to display devices to choose from.

when BluetoothList1.AfterPicking

- Connects to the selected device via:

  call BluetoothClient1.Connect address BluetoothList1.Selection
- If the connection is successful :
  - Changes ConnectionStatus.Text to "Connected"
  - Updates the color to green for visual confirmation.

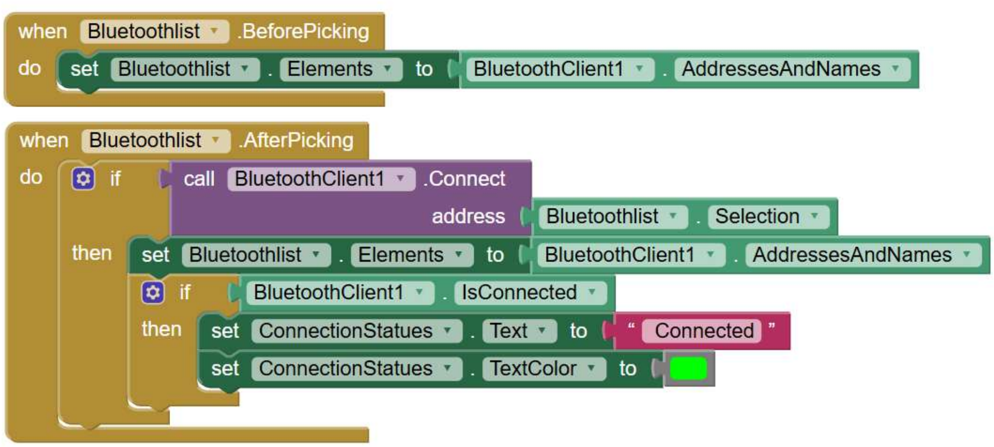


Figure 18 App Bluetooth Block Connection

2. Disconnect Function

Disconnect.Click

- Triggers BluetoothClient1.Disconnect
- Changes ConnectionStatus1.Text to "Connection Failed"
- Updates text color to red as a warning or error state.

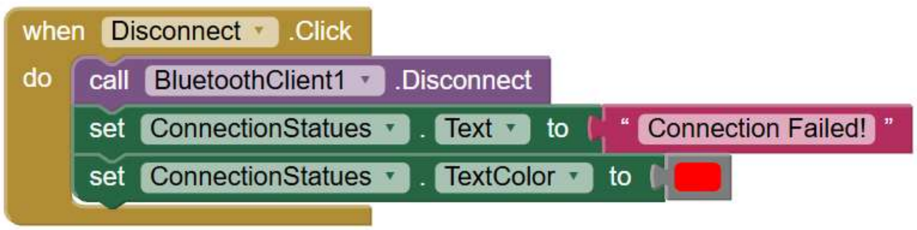


Figure 19 App Bluetooth Block DisConnection

3. Initialize Patient Data:

when Controller1.Initialize

- Loads stored patient data using TinyDB1:
  - Retrieves and sets:
    Name, Age, and TremorType
- Displays data on labels like NameInfo, AgeInfo, and TremorInfo.

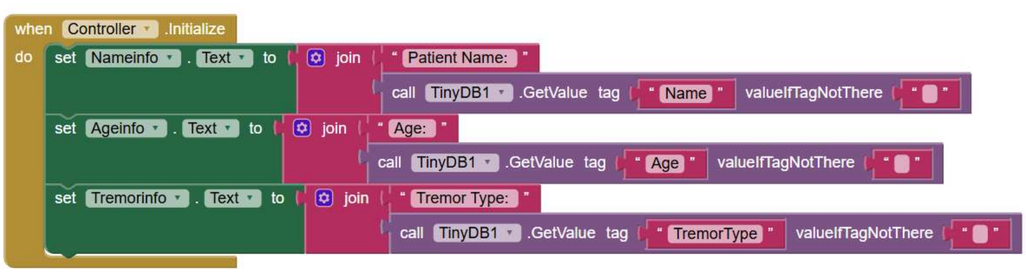


Figure 20 App Block Return Data

4. Data Receiving via Timer

Clock1.Timer

- Runs continuously (based on the Clock interval you set).
- Checks if the Bluetooth connection is active.
- If bytes are available, it:
  - Reads incoming text using BluetoothClient1.ReceiveText
  - Stores it in global receiveData
  - If the text contains " | " as Bluetooth received text , updates the label TremorBattery with the value.

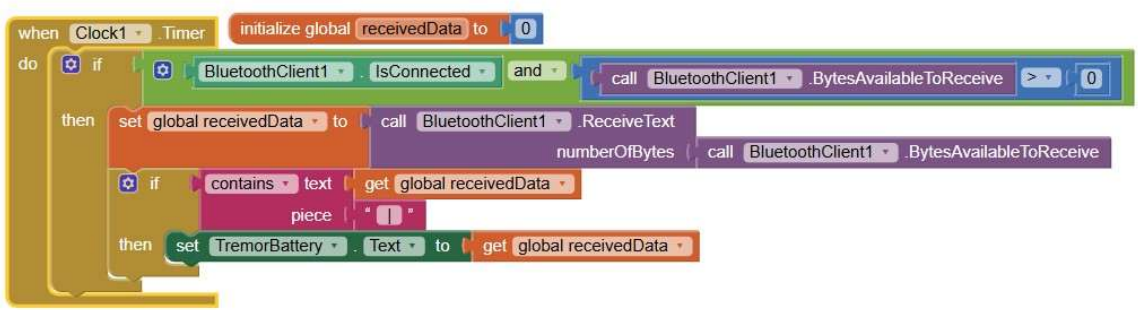


Figure 21 App Block Data Receiving

5. Motor Activation

ON.Click

- Sends command: "MOTORS_ON" to activate motors.

OFF.Click

- Sends command: "MOTORS_OFF" to deactivate motors.

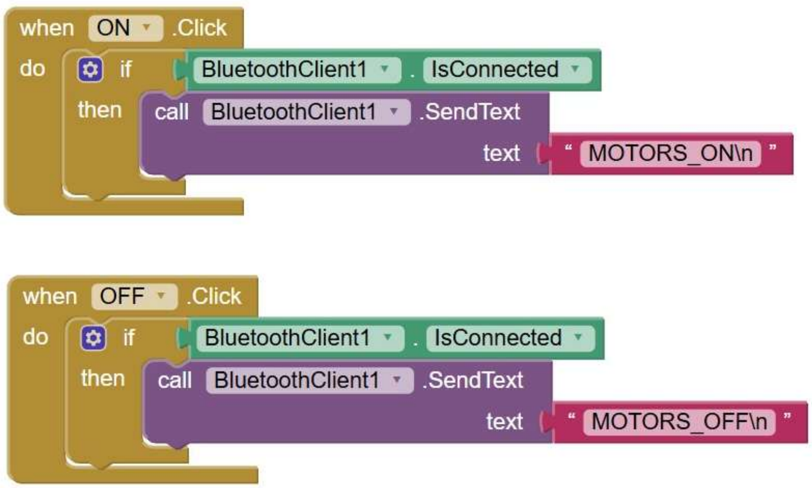


Figure 22 App Block Motor Activation

6. Change Vibration Frequency

“ This Frequency numbers for prototyping only because of weakness of vibration motor used ”

Low.Click

- Sends: "SET_FREQ 200"

Medium.Click

- Sends: "SET_FREQ 500"

High.Click

- Sends: "SET_FREQ 1000"

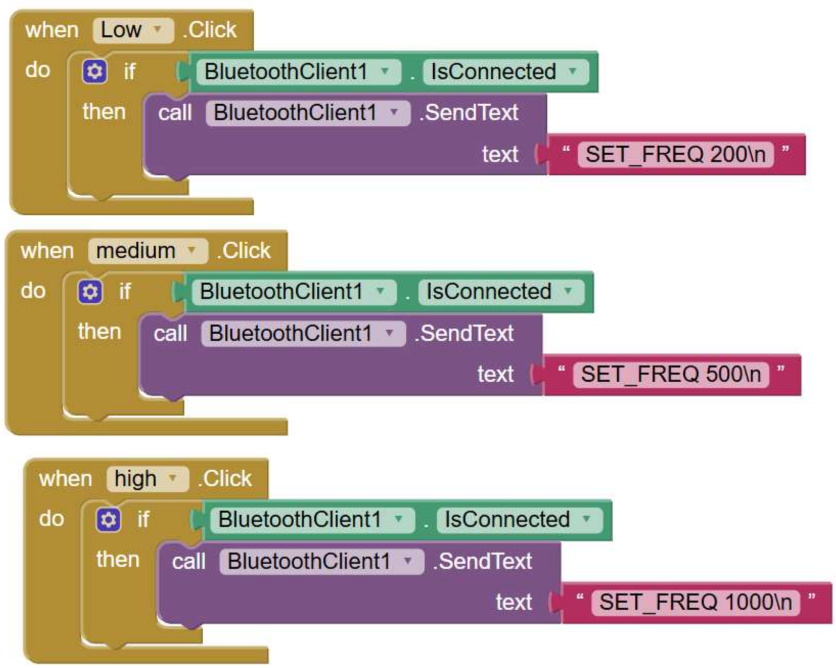


Figure 23 App Block Change Frequency

7. Motor Pulse Control

PulseShort.Click

- Sends: "SET_PULSES 3 200" (3 pulses of 200ms duration) if connected.

PulseLong.Click

- Sends: "SET_PULSES 5 300" (5 pulses of 300ms) if connected.

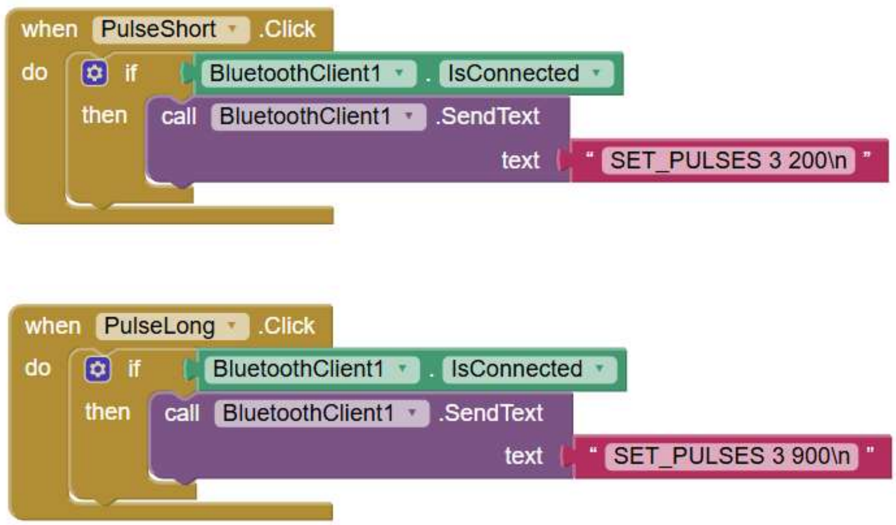


Figure 24 App Block Motor Pulse Control

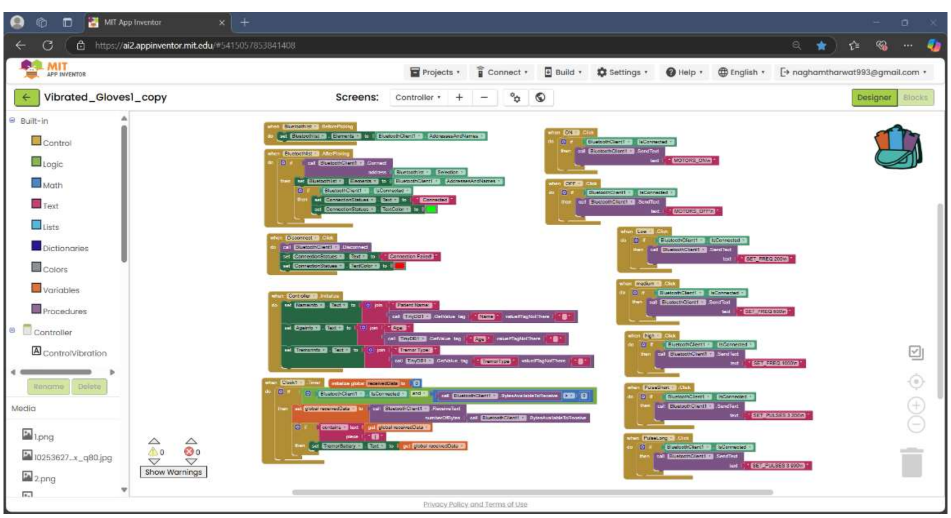


Figure 25 All Blocks Screen 3

4.3.4 Hardware Prototyping

- **Components and Descriptions**

Component	Description
ESP-WROOM-32 (ESP32) 30 pins	The core microcontroller unit used to process sensor data, manage Bluetooth communication, and control vibration motors. It features a dual-core processor with built-in Wi-Fi and Bluetooth, making it ideal for real-time wearable applications.
MPU6050 (IMU Sensor)	A motion-tracking sensor that integrates a 3-axis gyroscope and a 3-axis accelerometer. It captures tremor-related motion in all spatial directions and sends the data to the ESP32 for processing.
Vibration Motors (x5)	Small coin or cylindrical vibration motors attached to specific parts of the glove to provide feedback. These motors are triggered based on the tremor intensity detected.
TP4056 Charging Module	A lithium-ion battery charger circuit used to charge the glove's battery via USB. It includes overcharge, over-discharge, and short-circuit protection for safety.
Lithium-ion Battery (3.7V)	Powers the system including the ESP32, sensor, and motors. Selected for its lightweight, rechargeability, and sufficient capacity to support the wearable device.
PCB or Breadboard	A platform for connecting all components in a compact and organized manner during prototyping. PCB will be used for final integration after successful testing on a breadboard.
Glove (Wearable Structure)	A comfortable, fabric-based wearable in which the electronics are embedded. The glove provides the structural form for placing sensors and motors close to the hand.
Wires and Connectors	Used to establish reliable electrical connections between components. Includes jumper wires, soldered joints, and flexible connectors suited for wearable designs.

Table 3 Hardware Componant Description

1. ESP-WROOM-32 (ESP32) 30 pins:

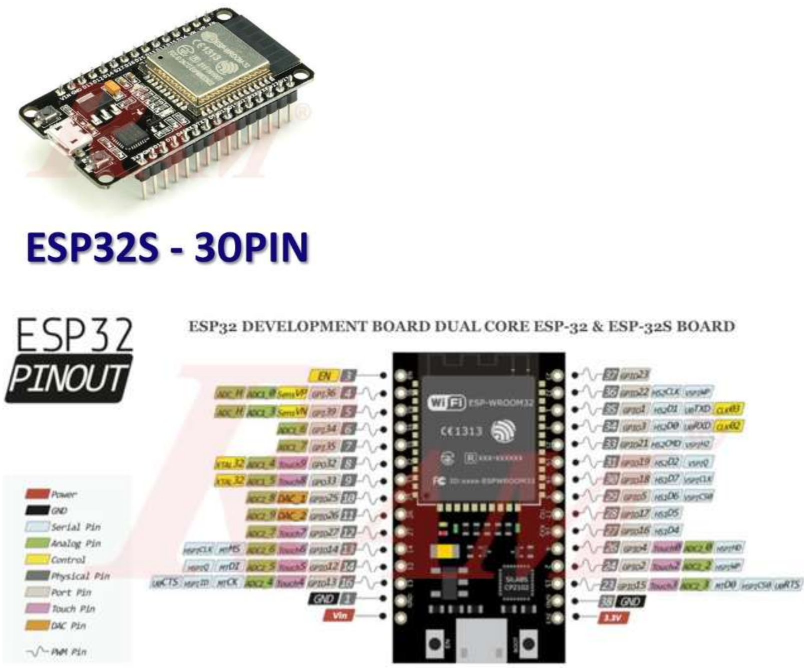


Figure 26 ESP32 Board

2. MPU6050 (IMU Sensor):

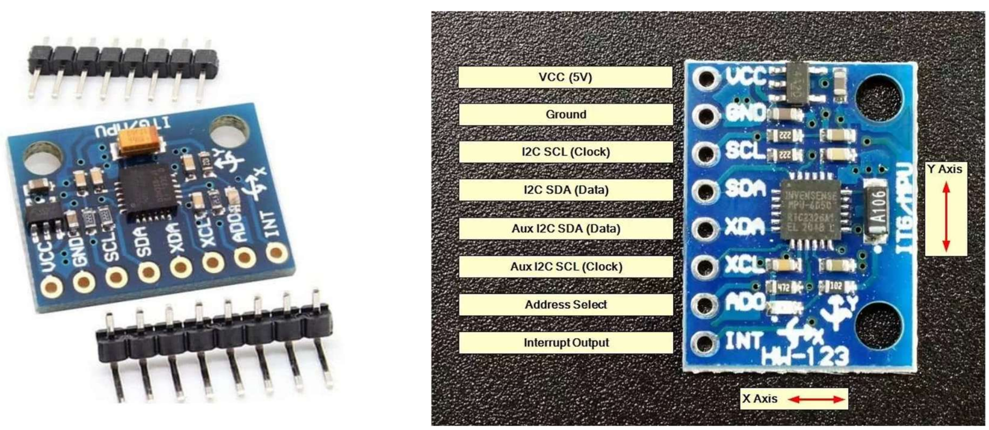


Figure 27 IMU Sensor

3. Vibration Motors:

Figure 28 Mini Micro Vibration Motor

4. TP4056 Charging Module:

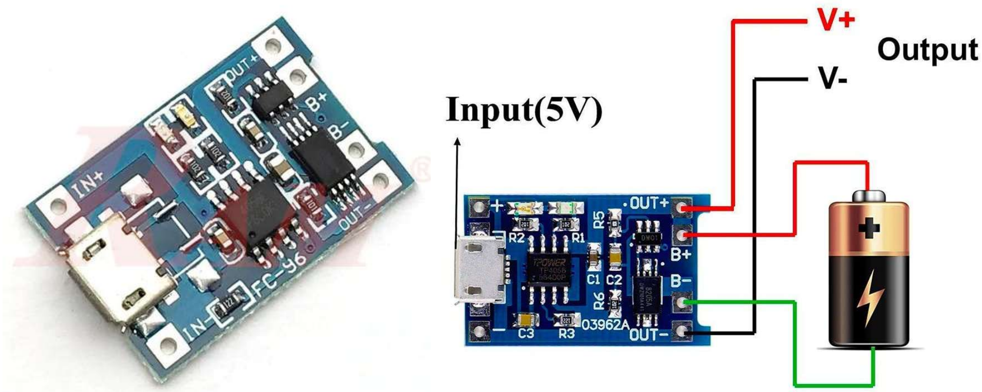


Figure 29 TP4056 Charging Module

5. 2 Lithium-ion Battery (3.7V):

Figure 30 Lithium Battery and Holder

6. Breadboard with 400 Tie-Point:

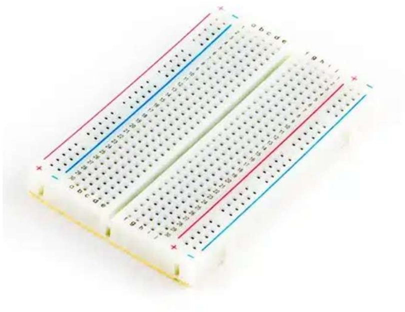


Figure 31 Breadboard

7. Glove (Wearable Structure):

Figure 32 Glove Design

8. Wires and Connectors:

Figure 33 Connecting Jumper Wires

• Labeled Hardware Connections

Component	ESP32 Pin
MPU6050 (IMU)	SDA → GPIO 21 in bread board(11 to 22) SCL → GPIO 22 in bread board(14 to 21)
Vibration Motors (x5)	GPIO 12, 14, 26, 27, 32 GND to (-)
TP4056 Charger	BAT+ → Battery + BAT- → Battery - OUT+ → ESP32 3.7V IN OUT- → GND
Lithium Battery (3.7V)	Connected via TP4056
Power Switch (optional)	Inline with battery VCC

Table 4 Hardware Connections

• Design Connection Hardware Parts:

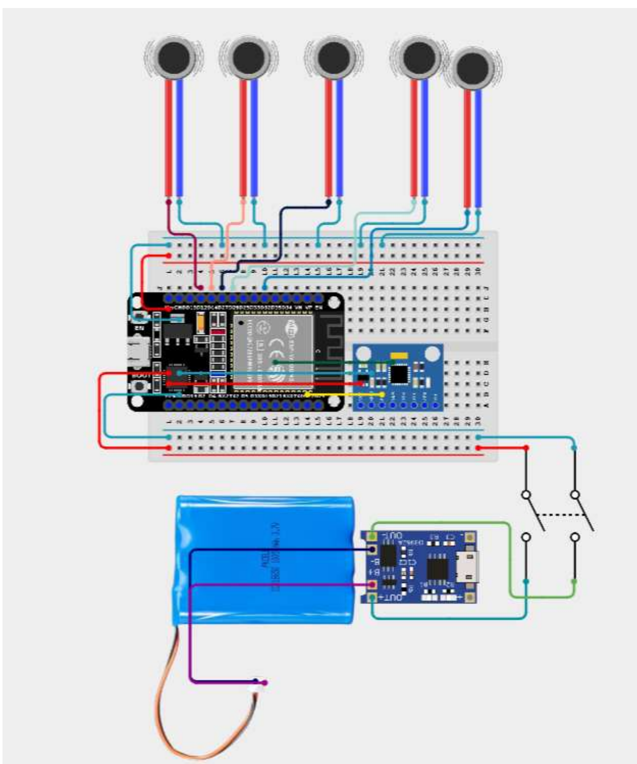


Figure 34 Design of Hardware Connection

4.3.5 Database

1. Current System:

At this stage, the system is **operational without a database**. All communication between the mobile app and glove is **real-time** and **session-based**. Once the app is closed, no data is saved.

2. Future Database Integration (Proposed Enhancements):

To support long-term monitoring and clinical analysis, future versions of the system may include:

- **Local Storage (Tiny DB in MIT App Inventor):**
  - Save tremor intensity values locally with timestamps.
  - Allow the patient to view trends or logs of previous sessions.
- **Cloud Storage (Firebase or Google Sheets Integration):**
  - Synchronize tremor data for cloud-based review.
  - Allow doctors or caregivers to monitor progress remotely.
  - Store user profiles, motor settings, and session logs.
- **Database Use Cases:**
  - Generate tremor trend charts.
  - Predict tremor severity changes using machine learning models.
  - Enable personalized therapy recommendations.

4.4 Issues and Problems Faced in the Project

During the development of the vibrating glove system, several challenges and technical issues were encountered. These were categorized into **hardware issues**, **software issues**, **integration challenges**, and **user experience difficulties**:

4.4.1 Hardware-Related Issues:

1. **MPU6050 Sensor Instability:**

   The MPU6050 occasionally failed to initialize or returned incorrect data due to poor soldering connections or noisy communication. This problem was addressed by reinforcing connections and adding I2C pull-up resistors to SDA and SCL lines.

2. **Power Supply and Brownout Resets:**

   When all five vibration motors were activated simultaneously, the current demand surged, causing voltage drops and leading to ESP32 resets. The issue was solved by upgrading to a higher-capacity lithium-ion battery and optimizing the pulsing pattern to avoid simultaneous activation of all motors.

3. **Overheating of Motors:**

   Prolonged use at high vibration frequencies caused certain motors to heat up, risking damage. This was mitigated by adding pulse duration limits and allowing cool-down intervals in the pulsing logic.

4. **Loose Pin Connections:**

   On a breadboard, connections were frequently loose, especially under movement. Finalizing a soldered PCB helped ensure stable, long-term hardware functionality.

4.4.2 Software-Related Issues:

1. **Bluetooth Connectivity Drop:**
   The ESP32 sometimes disconnected from the app without warning, especially during long usage periods. To handle this, a connection monitoring system was added, and the app was updated to attempt auto-reconnect or notify the user.
2. **Command Parsing Bugs:**
   When Bluetooth commands were not formatted properly, the ESP32 sometimes misinterpreted them or crashed. Improved string validation and condition checks were introduced in the handleCommand() function to prevent this.
3. **Incorrect Sensor Data Interpretation:**
   Early in development, tremor intensity was miscalculated due to improper scaling of raw IMU values. Adjustments to the formula and applying a weighted average (70% gyro, 30% accelerometer) resolved the issue and improved sensitivity.

4.4.3 Integration Challenges:

1. **Synchronization between App and Device:**
   Timing conflicts occurred when both sensor data was being sent and new Bluetooth commands were being received simultaneously. Non-blocking programming using millis() helped synchronize operations and reduce data loss.

2. **Battery Level Monitoring:**
   Accurately reading and displaying battery level from ESP32 to the app was challenging due to analog voltage fluctuations. A voltage divider and analog averaging technique improved reading accuracy, with added UI alerts in case of low battery.

3. **Data Overload in Serial Monitor:**
   Debugging with high-frequency serial output led to buffer overflows and sluggish performance. Limiting serial output frequency and simplifying logs made debugging more manageable.

4.5 Testing

To ensure the accuracy, reliability, and robustness of the vibrating glove system, a comprehensive testing strategy was adopted. This included various forms of testing covering both software and hardware aspects throughout different stages of development.

4.5.1 White Box Testing

White box testing focused on the internal logic of the code:

- **Function Testing:**

  Each function such as calculateTremorIntensity(), handleCommand(), activateMotors(), and startPulsing() was individually tested using known inputs and expected outputs to verify correct behavior.

- **Flow Control Validation:**

  Conditions such as tremor thresholds and motor activation flags were tested through manual inputs and sensor simulation to ensure the logic was correctly followed.

- **Edge Cases:**

  Handled edge cases such as:

  - Sending an empty Bluetooth command.
  - Inputting extremely high or low frequency/pulse values.
  - Receiving corrupted sensor data.

- **Code Optimization and Efficiency:**

  Loops, delays, and memory usage were reviewed to prevent memory leaks and unnecessary delays, ensuring smooth system response.

4.5.2 Black Box Testing

Black box testing involved verifying the system from an external perspective without knowledge of the internal code:

- **App Navigation:**
  Ensured all pages (Start, Patient Info, Bluetooth Control) navigated correctly and inputs worked as expected.
- **Bluetooth Communication:**
  Tested communication between the MIT App Inventor app and ESP32. Commands such as “SET_FREQ”, “SET_PULSES” and “MOTORS_ON” were sent and verified.
- **Tremor Response:**
  Verified the motors vibrate only when tremor intensity exceeds the threshold, regardless of how the backend logic works.
- **User Interaction Simulation:**
  Simulated real users by testing various actions such as fast tapping, invalid inputs, and Bluetooth toggling.

4.5.3 Unit Testing

Unit testing involved testing the smallest components in isolation:

- **Motor Driver Test:** Each motor pin was tested individually to ensure output control.
- **IMU Sensor Module:** Raw values were printed and checked for anomalies in motion.
- **Bluetooth Command Handler:** Sent sample strings from a terminal app to check that only correct and valid commands are accepted.
- **Battery Voltage Sensing:** The analog pin readings were tested using known voltage values from a multimeter to confirm accuracy.

4.5.4 System Testing

System testing validated the complete integration of hardware and software components:

- **Real-World Simulation:**
  The glove was worn during simulated tremor conditions (hand shaking at different intensities) to test live tremor detection and motor response.
- **Simultaneous Operation:**
  Verified that Bluetooth commands could be received and acted upon while the tremor monitoring was actively sending intensity data.
- **Stress Testing:**
  Long-duration tests (1-2 hours) were performed to check for overheating, memory overflow, or Bluetooth dropouts.
- **Power Management:**
  Full battery cycles were tested to monitor battery drain during active and idle modes.

4.5.5 Validation and Verification

Verification (Are we building the product right?):

Confirmed that each module (IMU sensor, Bluetooth, motor driver, app interface) was implemented as per technical specifications.

Validation (Are we building the right product?):

Ensured the final system met the goals of monitoring tremors and providing responsive feedback improving usability for Parkinson's patients and other Tremor disease patients.

Traceability Matrix:

Each requirement was traced back to a tested feature to ensure no functionality was left untested.

4.5.6 Clinical Testing

To evaluate the effectiveness and practicality of the vibrating glove in a real-world medical context, **preliminary clinical testing** was conducted with patients exhibiting Parkinsonian tremors under controlled, supervised conditions. The goal was to assess usability, comfort, and performance in an actual healthcare scenario.

Objectives of Clinical Testing:

- Evaluate real-time tremor detection accuracy.
- Assess patient comfort while wearing the glove.
- Measure the glove effectiveness in providing feedback during tremor episodes.
- Gather feedback from both patients and healthcare professionals.

Participants:

- **Test Subjects:** A small group of volunteer Parkinson's patients (3–5 individuals) with varying tremor intensities.
- **Supervision:** Tests were conducted under the supervision of a medical professional to ensure safety and observation of physiological responses.

Procedure:

1. Preparation:

- Patients were briefed on the purpose and operation of the glove.
- Patient data (name, age, tremor type) was entered into the app.

2. Device Wearing:

- Patients wore the glove for 15–30 minutes while seated and performing basic tasks (resting, reaching, light movements).

3. **Monitoring:**
   - The tremor intensity was recorded live and displayed on the mobile application.
   - Motor vibrations were activated automatically when tremor levels exceeded the predefined threshold.
4. **Feedback Collection:**
   - Patients were asked about comfort, sensation, and usability.
   - Medical professionals observed physical response, behavior, and ease of use.

Results:

- **Tremor Detection:**
  The glove accurately responded to moderate to high tremor intensities with minimal latency.
- **Motor Feedback:**
  Vibrations were noticeable but not irritating. Patients described the sensation as "gentle yet informative."
- **Comfort and Wearability:**
  The glove was lightweight and comfortable for short-term use. Some suggestions were made to improve fit for different hand sizes.
- **Data Usefulness:**
  Healthcare professionals found the tremor intensity data helpful in visually tracking fluctuations during patient activity.

Challenges Faced:

- Bluetooth interference in hospital environments with many active devices.
- Glove fit needed adjustment for patients with larger hands or restricted mobility.
- Varying levels of patient digital literacy affected their ability to use the mobile interface independently.

Summary Of Chapter 4

Chapter 4 provides a comprehensive overview of the practical development and evaluation of the vibrating glove system. The chapter begins with detailed implementation processes covering both software and hardware components. The **mobile application** designed using MIT App Inventor.

The **microcontroller code**, implemented The code is modular, covering sensor initialization, tremor analysis, Bluetooth communication, and customizable vibration feedback.

The **hardware prototyping** section details the components used.

A range of **testing methodologies** were applied to validate the system, including:

- **White-box testing** to examine code functionality.
- **Black-box testing** to verify system output from user input.
- **Unit and system testing** to ensure that individual modules and the overall system performed correctly.
- **Acceptance testing** to evaluate usability from a user perspective.
- **Verification and validation** to confirm that the system met technical and functional requirements.

Additionally, **clinical testing** with real patients demonstrated the system's effectiveness in tremor detection, ease of use, and comfort, providing valuable feedback for future improvements.

Lastly, the chapter outlines **issues and challenges** encountered, such as Bluetooth connectivity instability, component limitations, and glove fit adjustments, offering insights into the iterative nature of hardware, software integration and testing in healthcare oriented wearable technology.

Chapter 5: Results and Discussion

5.1 Critical Discussion

The Vibrated Glove project successfully demonstrated the integration of hardware and software components to create a wearable solution for monitoring and managing hand tremors in Parkinson's patients. The Bluetooth-based communication between the mobile application and the glove worked efficiently in most environments, allowing real-time control and feedback. However, challenges such as signal interference and occasional latency during motor activation were noted.

The tremor detection algorithm, based on combined accelerometer and gyroscope data, performed reliably under testing. Yet, the threshold calibration required multiple iterations to minimize false positives in tremor detection. Power consumption and battery life were also closely analyzed, leading to optimized motor pulsing and data transmission routines.

Additionally, user feedback from initial clinical testing was instrumental in identifying areas for improvement, particularly in user interface clarity and glove comfort. These insights will guide future iterations of the project.

5.2 Skills Acquired from the Project

Throughout the project, several valuable technical and soft skills were developed, including:

- **Embedded Systems Programming** (Arduino Board, C++ with sensors and motors)
- **Mobile Application Development** using MIT App Inventor
- **Bluetooth Communication Protocols**
- **Sensor Data Processing** (working with the MPU6050 IMU sensor)
- **Project Management**
- **Clinical Feedback Analysis**
- **Troubleshooting & Debugging** complex hardware/software interactions
- **Report Writing & Documentation**

These skills have equipped Me with practical knowledge relevant to real world IoT and biomedical device development.

5.3 Development Goals and Results

The development of this project was driven by the vision to create an **innovative medical technology** that could offer practical assistance to individuals suffering from hand tremors, particularly those affected by Parkinson's disease and **Neurostimulation** . The project extended beyond technical implementation, aiming to address real healthcare challenges by blending biomedical insight, user-centric design, and technological innovation.

From the **medical technology standpoint**, the glove was not just a gadget, but a tool intended to complement clinical care. It offered non-invasive support that could be easily used by patients without requiring constant medical supervision. The integration of vibration motors responding to tremor events was explored as a form of physical therapy, potentially improving hand stability and patient confidence.

The **development goals** included:

- **Clinical relevance**: Ensuring the system could detect tremors with sufficient sensitivity and accuracy to be meaningful in a medical context.
- **Patient-centered usability**: Creating an interface and wearable form factor that patients could use independently, with minimal training or technical knowledge.
- **Adaptability and personalization**: Allowing vibration settings (frequency, pulse count, and duration) to be adjusted for different tremor types and patient needs.
- **Mobility and accessibility**: Utilizing Bluetooth technology and a lightweight glove design to maximize user comfort and independence in daily life.
- **Scalability for future research**: Laying the foundation for extended clinical trials, data logging, and potential integration with machine learning models for predictive analysis.

The development process succeeded not only in achieving its technical objectives but also in producing a **medical assistive device** that bridges the gap between healthcare needs and engineering solutions. It sets the stage for future enhancements, clinical research, and the potential commercialization of an affordable, patient-friendly solution to manage hand tremors.

5.4 Future Work

The project lays the groundwork for an innovative medical assistive device, and several future directions have been identified to further improve, scale, and commercialize the technology. These directions cover technological enhancement, clinical validation, business development, and intellectual property protection.

5.4.1 Innovation in Therapy and Clinical Integration Using AI

Future advancements in the vibrating glove system will prioritize deep integration of Artificial Intelligence (AI) to significantly elevate the device's therapeutic effectiveness, clinical relevance, and user personalization. By harnessing AI, the system will move beyond simple tremor detection to offering dynamic, predictive, and patient-tailored therapies. Several innovative AI-driven solutions will be pursued:

1. **Intelligent Tremor Classification and Diagnosis Assistance:**
   Using advanced machine learning models (such as convolutional neural networks and recurrent neural networks), the system will classify tremors into types (resting, action, postural, kinetic) with high precision, not only improving therapy personalization but also assisting clinicians in differential diagnosis between Parkinson's disease, Essential Tremor, and other neurological disorders.

- **Solution:** Build a labeled IMU dataset across multiple tremor conditions and apply supervised learning to achieve clinical-grade classification accuracy.

- **Innovation:** The device could eventually suggest diagnostic insights to clinicians, supporting faster and more accurate diagnosis.

2. **Adaptive Vibration Control via Reinforcement Learning:**

Traditional control algorithms are limited by pre-programmed settings. Reinforcement learning (RL) agents can be trained to adaptively optimize vibration motor patterns (amplitude, frequency, timing) in response to real-time changes in tremor severity.

- **Solution:** Implement an on-device RL agent that continuously learns the most effective vibration strategies to suppress or counteract specific tremor patterns.
- **Innovation:** Each user would have a dynamically evolving therapy optimized uniquely for their tremor behavior, greatly enhancing therapy effectiveness.

3. **Predictive Analytics for Proactive Intervention**

Rather than reacting to tremor events after they occur, predictive models can analyze historical sensor data to anticipate tremor onset seconds or minutes in advance. This enables pre-emptive vibration therapies that may reduce the severity or delay the onset.

- **Solution:** Apply time-series forecasting models such as LSTM (Long Short-Term Memory networks) to IMU data.
- **Innovation:** Early detection and preventive action could redefine tremor management from reactive to proactive care.

4. **Continuous Rehabilitation Monitoring and Automated Progress Reports**

AI systems can track subtle improvements or deteriorations in tremor characteristics over time, offering clinicians rich rehabilitation insights without requiring manual measurements.

- **Solution:** Develop trend analysis algorithms and visualize rehabilitation progress with smart dashboards in the mobile app.
- **Innovation:** This shifts therapy from episodic clinical evaluations to continuous at home monitoring, making treatments more responsive and evidence-based.

5. **Edge AI and TinyML for Real-Time Decision-Making**

   Deploying lightweight AI models (TinyML) directly onto the ESP32 microcontroller enables real-time, offline decision-making without the need for constant cloud connectivity.

- **Solution:** Train and compress deep learning models (e.g., via TensorFlow Lite for Microcontrollers) to run on low-power devices.
- **Innovation:** Offers ultra-fast reaction times, ensures data privacy, reduces battery consumption, and enhances user independence.

6. **Personalized Therapy Plans Using Federated Learning**

   Patient data privacy is a major concern. Using federated learning, models could be improved across a population of users without sharing raw personal data.

- **Solution:** Local models train on-device and only share model updates (not raw data) with a central server.
- **Innovation:** Continually improving system intelligence while safeguarding patient privacy and meeting healthcare data regulations (HIPAA, GDPR).

7. **Emotional and Psychological State Detection (Future Vision)**

   Tremor severity can often be influenced by emotional stress. Future AI models could also analyze heart rate, speech patterns, or facial expressions to infer emotional states and dynamically adjust therapy accordingly.

- **Solution:** Multimodal sensing (IMU + heart rate sensors + optional microphones) feeding into emotion-aware models.
- **Innovation:** Create holistic care that not only addresses physical symptoms but also considers emotional well-being.

5.4.2 Hardware and Software Design Enhancements

To improve usability and reliability, the next phase will focus on:

- **Ergonomic Redesign:** Creating a more comfortable, wearable glove using breathable, lightweight materials with integrated electronics.
- **Miniaturization of Electronics:** Reducing board and battery size to make the device less intrusive for patients.
- **Power Optimization:** Enhancing battery life through optimized motor control.
- **Cross-platform Mobile Application:** Upgrading the MIT App Inventor prototype to a professional Flutter-based mobile app with better UI/UX, richer features, and potential iOS support.
- **Cloud Integration :** Allowing patient data synchronization with cloud platforms for clinician monitoring.

5.4.3 Real-World Deployment and Manufacturing

Transitioning the wearable tremor-control glove from prototype to a real-world, manufacturable medical device requires careful planning, refinement, and adherence to industry standards. The following steps outline the vision for real-world deployment:

1. **Design for Manufacturability (DFM)**
2. **Component Selection and Standardization.**
3. **Industrial Design and Ergonomics.**
4. **Testing and Certification.**
5. **Manufacturing Partnerships**
6. **Scalability and Cost Management**
7. **Distribution and Support Infrastructure**

1. **Design for Manufacturability (DFM):**
   The existing prototype needs to be re-engineered with a focus on mass production. This involves optimizing PCB layouts, minimizing component count, selecting readily available industrial-grade sensors and motors, and designing a glove that can be manufactured using cost-effective and scalable processes like injection molding or industrial textile fabrication.

2. **Component Selection and Standardization:**
   Prototype components were chosen primarily for flexibility and rapid prototyping. For deployment, components will be selected based on reliability, lifespan, regulatory compliance (medical grade certifications), and global availability to ensure consistent product quality and supply chain stability.

3. **Industrial Design and Ergonomics:**
   The glove's form factor must be refined for comfort, wearability, and aesthetics. Collaborations with biomedical engineers and product designers will ensure that the device fits various hand sizes, uses breathable materials, and maintains a lightweight profile suitable for long-term daily use by patients.

4. **Testing and Certification:**
   Before deployment, the product must undergo rigorous medical device testing, including:
   - Electromagnetic Compatibility (EMC) tests,
   - Biocompatibility and skin-safety evaluations,
   - Battery and electrical safety certifications,
   - Clinical validation through controlled trials. The device will be prepared for certifications such as CE marking in Europe and FDA approval in the United States.

5. **Manufacturing Partnerships:**

   Strategic partnerships with manufacturers specializing in medical devices or wearable electronics will be pursued. These partners will provide access to automated assembly lines, quality assurance systems, and packaging expertise necessary for high-volume production.

6. **Scalability and Cost Management:**

   A key focus will be maintaining a balance between production costs and device affordability, ensuring the product remains accessible to a wide range of patients while maintaining profitability and high standards.

7. **Distribution and Support Infrastructure:**

   Real-world deployment will also include the establishment of :

- Distribution networks (online platforms, hospitals, clinics, assistive technology vendors)
- Warranty and customer support systems
- Software update pipelines to ensure continued product improvement post deployment.

➢ **Successful real-world deployment and manufacturing require a multidisciplinary approach involving engineering, regulatory compliance, business development, and user-centered design. This roadmap sets the foundation for turning the project from a functional prototype into a reliable and impactful medical technology available to patients worldwide**.

5.4.4 Patent and Intellectual Property Protection

A crucial next step involves:

- **Formalizing the Patent:** Finalize and expand the existing patent filing to protect the full scope of the invention, including hardware, software, therapeutic methods, and AI integration.
- **Licensing Strategy:** Explore licensing opportunities to medical companies or startups interested in wearable health technologies.

5.4.5 Competitions and Exposure

To gain recognition, funding, and partnerships:

- **Participation in Tech and Medical Competitions:** Apply to global competitions such as the **Hult Prize Final Rounds**, in medical innovation challenges to showcase the project and attract attention.
- **Innovation Showcases:** Present the device at health-tech expos, university research fairs, and startup accelerators.
- **Research Publication:** Publish scientific papers or posters in conferences related to biomedical engineering, wearable health devices, or assistive AI.

5.5 Ethical, Legal, and Social Considerations

The project's design was approached with careful consideration of the ethical implications. The device is non-invasive, respects user privacy, and aims to improve quality of life. Data captured by the glove could potentially reveal sensitive health information; therefore, future versions must integrate proper data security protocols and comply with standards like GDPR.

On the legal front, the glove is currently protected by a patent, and further steps will be taken to meet the requirements for medical device certification . Socially, the project addresses a significant gap in affordable and accessible assistive technologies, aiming to empower patients and reduce caregiver burden. Inclusivity and accessibility were kept in mind throughout the design process.

Summary of Chapter 5

This future roadmap aims to evolve the project from an innovative prototype to a **clinically relevant, AI-powered medical product** that can make a measurable impact in the lives of patients. By combining AI, user-centric design, clinical validation, and business strategy, the Vibrated Glove can become a breakthrough solution in neurological care.

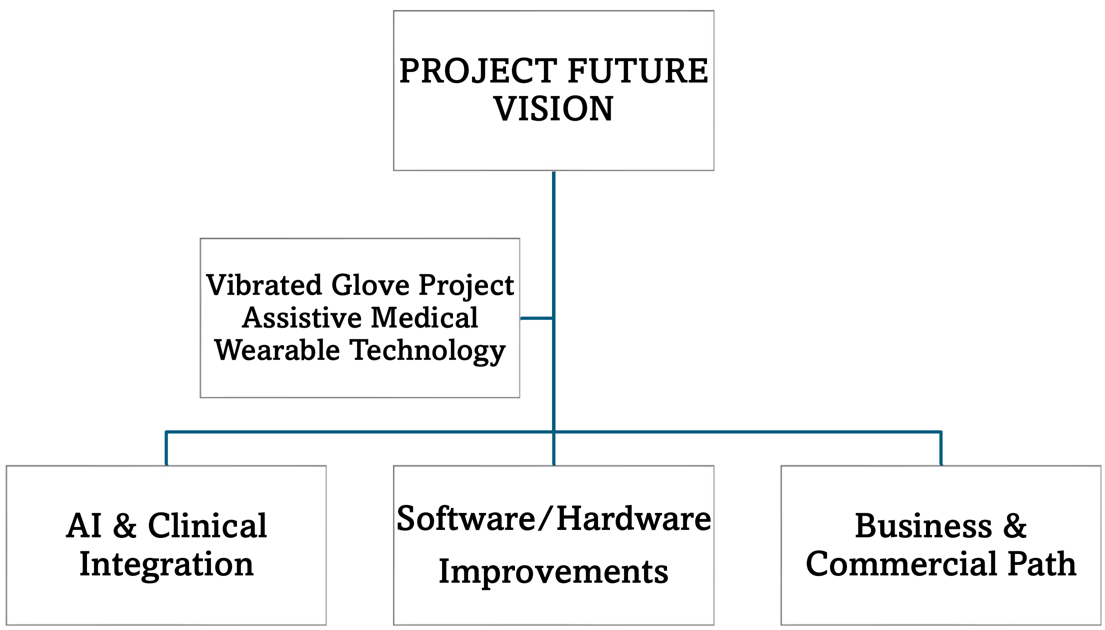


Figure 35 Project Future Vision diagram

Chapter 6: Conclusion

This project set out to design and prototyping device **vibrated glove system** aimed at assisting individuals with **Parkinson's disease, Essential Tremor**, and other neurological conditions that manifest in hand tremors. By integrating mechatronics, robotics, and real-time sensor feedback, the glove leverages both hardware and software innovations to detect tremor activity and respond with targeted feedback.

The development process encompassed a multidisciplinary approach involving **IMU-based tremor detection**, **Bluetooth communication**, **actuator control**, and a **user-friendly mobile interface**. The system architecture was carefully designed to be modular and scalable, allowing future enhancement of features such as AI-driven tremor classification and adaptive feedback loops.

Throughout the prototyping stage, the key functionalities of the vibrating glove were successfully validated through extensive testing and refinement, demonstrating the following achievements:

- **Accurate Tremor Detection:** Reliable capture and analysis of hand tremor data using the MPU6050 sensor, with effective separation of tremor signals from normal movements.
- **Effective Motor Response:** Responsive and adaptive vibration feedback to help counteract tremor episodes based on real-time sensor inputs.
- **Seamless Bluetooth Communication:** Stable and low-latency Bluetooth connectivity, enabling real-time monitoring, control, and adjustment through the mobile application.
- **Easy User Interaction:** Smooth handling of user commands (such as vibration settings and motor control) received from the mobile app, confirming system responsiveness and ease of use.

Testing procedures included both **white-box and black-box methodologies**, as well as **unit, system, and acceptance testing**, to ensure the reliability and performance of the device.

Preliminary **clinical Testing** scenarios demonstrated promising usability and user comfort, although large-scale medical trials are still required for full validation.

The project also tackled several real-world engineering challenges such as **sensor calibration**, **motor synchronization**, **Bluetooth instability**, and **battery limitations**. Addressing these led to better design decisions and reinforced the importance of iterative hardware/software co-development in wearable medical devices.

From a broader perspective, this project contributed significantly to personal and academic development. Technical skills in embedded systems, mobile app development, and signal processing were enhanced, along with soft skills in project planning, documentation, and team collaboration.

The findings clearly illustrate the **viability of wearable assistive devices** in improving the quality of life for individuals with motor disorders. The glove's potential extends beyond academic prototyping; with further refinements in ergonomics, AI integration, and industrial design, it may become a **commercially viable therapeutic aid**.

In future directions include implementing **machine learning algorithms** for dynamic tremor pattern recognition, improving device aesthetics and comfort, conducting comprehensive **clinical trials**, and pursuing **patent protection and product certification**. Moreover, we plan to expand outreach by participating in competitions, publishing findings, and initiating **manufacturing partnerships** to transition from prototype to market ready product. integration of AI transforms the vibrating glove from a passive assistive device into an intelligent, adaptive therapeutic companion. It enables personalized care, predictive intervention, clinical decision support, and a revolutionized patient experience paving the way for a new standard of non-invasive therapy for neurological tremors.

Finally, this project represents a significant advancement at the intersection of assistive robotics, wearable technology, and healthcare innovation. It reaffirms the transformative potential of engineering solutions to not only assist individuals with neurological conditions such as Parkinson's disease but also to restore a sense of independence, dignity, and improved quality of life. Through the integration of precise sensor-based measurement, intelligent feedback mechanisms, and real-time wireless communication, the vibrating glove prototype paves the way for future developments in personalized therapeutic devices. This work highlights how thoughtful application of technology can bridge the gap between clinical needs and real-world functionality, setting a strong foundation for future research, clinical validation, and widespread adoption in the medical field.

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Appendices

This section includes supplementary materials that support and validate the research, design, and implementation of the "Vibrated Glove" project. These appendices provide additional documentation, approvals, and evidence of ethical compliance.

Appendix A: Letter of Approval

This is a request for a contract for manufacturing the model with the innovator, including the percentages of returns for each of the researcher, the entity and the TICO office located at 6th of October University in cooperation with the Academy of Scientific Research and Technology, taking into account all intellectual property rights, but it is still under review and no return has been till now.

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Paper 1 Manufacturing Model Letter

Appendix B: Patent Documentation

We have submitted all the required papers and are waiting for acceptance to give the device an application number for the patent or utility model.

VIBRATED GLOVE

THE END