A
Project Report
on

"Design Of Electronic Module for Fitness, Health & Safety in Smart Shoes"

Submitted to

Sant Gadge Baba Amravati University, Amravati

Submitted in partial fulfilment of
the requirements for the Degree of
Bachelor of Engineering in
Electronics and Telecommunication Engineering

Submitted by

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Under the Guidance of
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Shri Sant Gajanan Maharaj College of Engineering,
Shegaon – 444 203 (M.S.)

Session 2024-2025

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SHRI SANT GAJANAN MAHARAJ COLLEGE OF ENGINEERING,
SHEGAON - 444203 (M.S.)

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that **Mr. Arshad Shaikh, Mr. Aryavart Dahenkar, Mr. Om Ingle, Ms. Prachi Untwale** students of final year Bachelor of Engineering in the academic year 2024-25 of Electronics and Telecommunication Engineering Department of this institute have completed the project work entitled "**Design of Electronic Module for Fitness, Health & Safety in Smart Shoes**" and submitted a satisfactory work in this report. Hence, recommended for the partial fulfillment of degree of Bachelor of Engineering in Electronics and Telecommunication.

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Internal Examiner	**External Examiner**
Name and Signature	**Name and Signature**
Date:	**Date:**

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– Projectees

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ABSTRACT

In today's fast-paced and increasingly health-conscious world, wearable technology plays a pivotal role in assisting individuals with personal fitness tracking, healthcare monitoring, and safety. This project focuses on the design and development of an electronic module that is integrated into smart shoes to provide a comprehensive solution for fitness, health, and safety. The smart shoe module is designed to track key fitness parameters including step count, distance traveled, acceleration, and calories burned using a combination of piezoelectric sensors, accelerometers (GY-61), and an ESP32 microcontroller. These values are processed in real time and transmitted wirelessly via Bluetooth to a companion Android application developed for monitoring and analysis.

In addition to fitness tracking, the smart shoe features built-in safety mechanisms such as a panic button and a GPS module (Neo 6M), which allows the user's location to be shared instantly during emergencies. This feature caters especially to women, children, and elderly individuals, offering a quick-response safety tool that enhances personal security. The smart shoe thus addresses both proactive health monitoring and reactive safety support.

This implementation-based project demonstrates the practical integration of embedded systems, IoT, and mobile applications into wearable technology. The design emphasizes real-world utility, compactness, and user-friendly interfaces while providing significant insights into low-power electronics and real-time data analysis. The project not only supports physical health improvement but also enhances situational awareness and emergency response, making it a versatile solution in today's connected world. To overcome the aforementioned difficulties, we have "Design of Electronic Module for Fitness, Health & Safety in Smart Shoes"

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List of Abbreviations and Symbols

Symbol/Abbreviation	Particulars
GPS	Global Positioning System
API	Application Programming Interface
$HTML$	Hyper Text Markup Language
MCU	Microcontroller Unit
APP	Application
IOT	Internet of Things
UI	User Interface
UX	User Experience
$UART$	Universal Asynchronous Receiver Transmitter
PCB	Printed Circuit Board
IDE	Integrated Development Environment
$JSON$	JavaScript Object Notation
$HTTP$	Hypertext Transfer Protocol
$NoSQL$	Not Only Structured Query Language
ADC	Analog to Digital Converter
$EEPROM$	Electrically Erasable Programmable Read-Only Memory
$NMEA$	National Marine Electronics Association (GPS data protocol)
$GPIO$	General Purpose Input/Output
PWM	Pulse Width Modulation
BLE	Bluetooth Low Energy
SPI	Serial Peripheral Interface
Hz	Hertz (Unit of Frequency)
RAM	Random Access Memory
LED	Light Emitting Diode
$ACSM$	American College of Sports Medicine
$IEEE$	Institute of Electrical and Electronics Engineers

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Chapter 1

INTRODUCTION

INTRODUCTION

1.1 Overview

This project aims to develop an **intelligent electronic module** that can be embedded in shoes to monitor a user's **fitness activity, health parameters, and ensure safety** through smart alerts and location tracking. The system integrates multiple sensors and modules, controlled by a powerful microcontroller, and communicates with a custom-built mobile application in real time. At the core of the system is the **ESP32 microcontroller**, a highly efficient board with built-in **Wi-Fi and Bluetooth**, which serves as the central controller. It gathers data from connected sensors, processes it, and transmits the information wirelessly to the mobile app. The microcontroller ensures seamless coordination between hardware and software components for real-time performance. The **rechargeable battery** supplies power to all modules, enabling long-lasting, portable usage without frequent recharging. This is critical for wearable applications where mobility and convenience are essential.

To track motion and activity, the smart shoe includes a **GY-61 accelerometer and gyroscope module**, which measures acceleration and angular velocity across three axes. This allows for detailed monitoring of **speed, direction, balance, and momentum**, making the system suitable for **sports performance analysis** as well as health tracking.

A **piezoelectric sensor** is integrated into the sole of the shoe to detect foot pressure. This mechanical stress is converted into electrical signals, which are used to compute **step count**, evaluate **walking patterns**, and determine **ground impact forces**—offering insights into posture and gait health. For real-time **location tracking**, the system uses a **Neo 6M GPS module**.

This allows the shoe to constantly monitor and record the user's geographic coordinates. In the event of an emergency, the system can transmit the user's live location to predefined contacts, greatly enhancing safety during solo activities or outdoor workouts.

The mobile application, named **We-Fit**, is developed using the **FlutterFlow** platform, enabling cross-platform support with an intuitive user interface. The app displays live fitness data such as **step count, calories burned, and location**, and includes an **emergency alert system**.

Data is stored in **Firebase Firestore**, a real-time cloud database that ensures continuous syncing between the smart shoe and the mobile application. This cloud connectivity enables secure and scalable data management. In case of emergencies, the system uses

the **Telegram API with bot integration** to send **instant alert messages** containing the user's live GPS location to emergency contacts. This ensures timely help and enhances user safety. To support geographic awareness, **OpenStreetMap** is embedded within the app using **custom HTML widgets**, providing a **live map interface** for users and emergency responders to view the exact current location.

Motivation

The motivation behind this project is to create a smart, wearable solution that enhances fitness tracking, health monitoring, and personal safety. By integrating sensors and wireless communication into smart shoes, users can accurately track steps, motion, and location, while receiving real-time insights through a mobile app. The addition of emergency alert features, such as GPS-based Telegram notifications, ensures safety during outdoor activities or accidents. This innovative system promotes active living, safety, and convenience, making it ideal for athletes, the elderly, and health-conscious user

1.2 Background and Significance of the Problem

With the increasing focus on personal health, fitness, and safety, wearable technology has become an essential part of modern lifestyles. Devices like fitness bands and smartwatches have made basic activity tracking common, but they often lack precise motion data and integrated emergency features. In contrast, smart shoes, being in direct contact with the ground, offer a unique and more accurate platform for capturing data related to steps, pressure, motion, and balance. However, most existing smart footwear solutions are limited in functionality or too expensive, often focusing only on fitness tracking while ignoring health insights and user safety. There is a critical need for a cost-effective, integrated solution that not only monitors physical activity but also analyze walking patterns, tracks real-time location, and sends emergency alerts when necessary .This project addresses that gap by designing an electronic module for smart shoes that brings together various sensors—such as piezoelectric, gyroscope, accelerometer, and GPS—with a central ESP32 controller, ensuring real-time data collection and wireless communication with a mobile application. The integration of Firebase Firestore for data storage, Telegram API for emergency alerts, and OpenStreetMap for live tracking significantly enhances the overall usability and impact. The proposed system has significant applications in sports performance monitoring, elderly care, rehabilitation, and

personal safety, making it an innovative and socially relevant solution in the field of wearable technology.

1.3 Aims of research work study

The aim of this research is to design an electronic module for fitness, health, and safety within smart shoes, leveraging various advanced components. The project focuses on integrating an ESP32 MCU to control the system, connect sensors, and transmit data to a mobile app via Wi-Fi or Bluetooth. The system includes sensors such as the GY61 accelerometer and gyroscope to track movement, the Neo 6M GPS module for real-time location tracking, and a piezoelectric sensor to measure foot pressure and step count. The module is powered by a rechargeable battery, ensuring continuous functionality. The data is processed and displayed in a custom-built mobile app using FlutterFlow, while Firebase Firestore is employed to store and sync the information. Emergency alerts are enabled through Telegram bot integration, sending live location data in case of distress. The integration of OpenStreetMap helps display the user's live location on a map.

1.4 Objectives and Scope of the work

1.4.1 Objectives-

2 **Design and Develop a Smart Shoe System**: Integrate the ESP32 MCU with various sensors, such as the GY61 accelerometer and gyroscope, piezoelectric sensor, and Neo 6M GPS module, to monitor user movement, fitness metrics, and location for enhanced safety.

3 **Ensure Continuous Power Supply**: Incorporate a rechargeable battery to power all components, providing the smart shoe with a reliable power source for uninterrupted functionality during use.

4 **Track Fitness and Health Metrics**: Utilize motion sensors (accelerometer and gyroscope) and piezoelectric sensors to track physical activity, step count, pressure, and walking patterns, enabling precise analysis of sports performance.

5 **Enable Real-Time Location Tracking**: Implement the Neo 6M GPS module to monitor and track the user's location, ensuring safety and providing emergency support when necessary.

6 **Develop a Mobile Application for Data Monitoring**: Design the We-Fit mobile app using FlutterFlow to display real-time data from the smart shoe, such as step count, calories burned, and location.

7 **Sync and Store Data Efficiently**: Use Firebase Firestore to store and sync data from the smart shoe to the mobile app for easy access, monitoring, and historical analysis.

8 **Integrate Emergency Alert System**: Incorporate the Telegram API to send emergency alerts with live GPS location via a bot integration, triggering notifications in case of distress or emergencies.

9 **Provide Map Visualization**: Integrate OpenStreetMap with the app to display the user’s live location on a map, assisting with navigation and improving situational awareness.

10 **Enhance User Experience and Safety**: Combine fitness tracking and safety features into a single wearable solution that improves the overall health and well-being of the user while ensuring emergency responsiveness.

Scope:

The project **"Design of Electronic Module for Fitness, Health, and Safety in Smart Shoes"** has a wide scope in the fields of wearable technology, health monitoring, and personal safety. It aims to revolutionize the concept of smart footwear by integrating advanced components like the ESP32 MCU, motion sensors (GY61), GPS module (Neo 6M), and piezoelectric sensors into a compact, portable solution. The system will not only monitor key fitness parameters such as step count, speed, momentum, and foot pressure but will also track real-time location for safety and emergency response. By connecting to a custom-designed mobile application (We-Fit) via Wi-Fi/Bluetooth, users can access live data, receive alerts, and visualize their location on a map. Integration with Firebase Firestore ensures seamless cloud data storage and synchronization, while Telegram Bot and OpenStreetMap enable emergency communication and navigation features. This project can be extended to support elderly care, athlete performance monitoring, personal safety, and even medical rehabilitation. Its scalable and modular design also allows future integration of more health-related sensors, making it a valuable solution in the growing field of smart wearables.

1.5 System Overview

The project titled **"Design of Electronic Module for Fitness, Health and Safety in Smart Shoes"** presents a comprehensive embedded system that integrates multiple sensors and communication modules to monitor user activity and ensure real-time safety features. At the core of the system is the **ESP32 MCU**, a powerful microcontroller with built-in Wi-Fi and Bluetooth, which serves as the central processing and communication unit. It collects data from the **GY61 accelerometer and gyroscope** for motion tracking and from the **piezoelectric sensor** for step count and pressure analysis. For safety and location-based services, the **Neo 6M GPS module** is employed to provide accurate real-time positioning.

The entire module is powered by a **rechargeable battery**, ensuring portability and continuous operation without frequent charging. The processed data—such as step count, foot pressure, calories burned, and location—is transmitted wirelessly to a mobile application developed using **FlutterFlow**. This app, named *We-Fit*, displays the user's data in real-time and includes an emergency alert feature.

To store and sync user data securely across devices, **Firebase Firestore** is used as the cloud database. Additionally, in emergency situations, the system can send alerts along with live location through **Telegram API (Bot Integration)**. The user's location is also visualized on a map embedded in the app using **OpenStreetMap with custom HTML integration**.

This system provides a smart, compact, and user-friendly wearable solution that not only tracks fitness parameters but also enhances personal safety, making it ideal for athletes, elderly individuals, and health-conscious users.

Chapter 2

LITERATURE REVIEW

LITERATURE REVIEW

2.1 Introduction

The concept of smart footwear has steadily evolved over the years, primarily driven by the growing demand for wearable technologies that not only enhance fitness tracking but also serve health and safety purposes. Several research papers and studies have contributed to the foundational knowledge and technological innovations that underpin the development of smart shoes.

In the paper titled "*Smart Shoes Using IOT for Monitoring Daily Activities and Intruder Alerting System*" by Vignesh D., Divya K., and Harini V., the authors introduced an IoT-based smart shoe designed to track foot pressure using piezoelectric sensors and detect falls or intrusions using gyroscope data. The shoe transmitted real-time data to a mobile device using a Wi-Fi-enabled ESP8266 module. The study demonstrated how pressure-based foot monitoring can be used for fall detection in elderly individuals.

Similarly, the work by Roy et al. in their publication "*Gait Analysis and Fall Detection Using Smart Shoes for Elderly People*" explored the potential of accelerometers and gyroscopes to monitor gait and provide early warnings for fall risks. This research emphasized the significance of motion sensing and pattern analysis to improve mobility assistance and healthcare outcomes.

Another important contribution came from Gupta and Kumar's project, "*Fitness and GPS-Based Smart Shoes with Health Monitoring System*," which integrated GPS modules with health tracking sensors. Their prototype enabled real-time monitoring of walking distance, step count, and user location, further enhancing personal safety.

In "*Design and Development of Smart Footwear Using IoT*," Suryawanshi and team proposed a prototype that included temperature and humidity sensors for foot health analysis along with the integration of Bluetooth for wireless data transmission. This broadened the application of smart shoes beyond physical activity into disease prevention.

Furthermore, research by Patel and colleagues in "*A Smart Shoe for the Visually Impaired Using Ultrasonic Sensors and GPS Module*" showcased a novel approach by implementing haptic feedback mechanisms to guide visually impaired individuals through obstacle detection and GPS-based navigation.

The review of existing literature reveals a clear trend toward modular, multifunctional footwear that integrates health, fitness, and safety features. Most research supports the use of microcontrollers such as Arduino, ESP8266, or ESP32, alongside sensors like piezoelectric, accelerometers, gyroscopes, and GPS modules. Wireless communication is predominantly handled via Bluetooth or Wi-Fi, facilitating seamless mobile integration.

In conclusion, while previous projects have successfully implemented various features independently, this project distinguishes itself by unifying all essential components — fitness tracking, health monitoring, and emergency safety response — into a compact, cost-effective, and fully implemented smart shoe system using the ESP32 microcontroller. The current project builds upon and extends previous efforts to create a comprehensive wearable solution adaptable for everyday use.

2.2 Conclusion drawn from the Literature review:

The literature review highlights the growing convergence of wearable technology, embedded systems, and IoT in developing smart footwear solutions. Previous research demonstrates the effectiveness of combining motion sensors, pressure sensors, GPS modules, and wireless microcontrollers to monitor user activity, assess physical health, and improve safety. The integration of ESP32 MCU emerges as a central component due to its computational capability and built-in wireless features, which are essential for real-time data transmission and remote communication.

The analysis of past works confirms the feasibility and utility of using GY61 (accelerometer + gyroscope) for tracking movement patterns and piezoelectric sensors for detecting foot pressure to calculate steps, gait, and exerted force. Additionally, GPS-based tracking and emergency alert systems supported by cloud platforms such as Firebase and messaging APIs like Telegram are increasingly vital in enhancing personal safety.

The reviewed studies also show that modern UI/UX tools like FlutterFlow, when paired with real-time databases and maps like OpenStreetMap, can create intuitive and

informative interfaces that increase user engagement and usability of wearable systems. In conclusion, the literature supports the design and development of a comprehensive smart shoe system capable of fulfilling fitness, health, and safety requirements. However, there remains an opportunity to further optimize power consumption, sensor fusion accuracy, and real-time responsiveness to improve performance and reliability in practical applications.

2.3 Scope of the research work:

This research focuses on developing an integrated electronic module in smart shoes to enhance fitness tracking, health monitoring, and personal safety. It utilizes the ESP32 microcontroller for real-time data processing and wireless communication. The GY61 sensor enables motion tracking, while the Neo 6M GPS module provides real-time location updates for emergency response. A piezoelectric sensor monitors foot pressure for step count and gait analysis. The system connects to a FlutterFlow-based mobile app, storing data on Firebase Firestore and sending alerts via Telegram with location mapping through OpenStreetMap. Powered by a rechargeable battery, the smart shoe offers a compact, intelligent solution ideal for athletes, the elderly, and those with mobility concerns.

Chapter 3

METHODOLOGY

METHODOLOGY

3.1. Overview

The methodology adopted for the development of the Smart Shoe project followed a systematic approach to ensure both functional and operational success of the system. The overall workflow was divided into distinct phases, including the selection of appropriate sensors and electronic components, integration of hardware modules, development of embedded firmware, design of a companion mobile application, configuration of cloud-based data storage, and comprehensive system testing. Each phase was carefully planned and executed with the goal of building a wearable, real-time fitness and safety monitoring system that performs reliably in everyday conditions.

3.2. Sensor and Component Selection

The selection of hardware components was based on criteria such as power efficiency, compact design, ease of integration, and relevance to the specific tasks of fitness tracking, motion sensing, and emergency alerting. At the heart of the system lies the ESP32 microcontroller, which was chosen for its dual-core processing power, built-in Wi-Fi and Bluetooth functionality, and rich I/O capabilities, making it highly suitable for Internet of Things (IoT) applications.

To detect physical activity and pressure from footfalls, a piezoelectric sensor was embedded into the shoe's insole. This sensor is capable of generating voltage spikes in response to pressure, which were interpreted as steps by the microcontroller. For advanced motion analysis and orientation tracking, a GY-61 accelerometer module based on the ADXL335 chip was used. This sensor provided analog data for acceleration and angular tilt across three axes, which was vital for step validation and fall detection.

The Neo 6M GPS module was incorporated to provide live geographical positioning. It offered a high-accuracy, real-time method to track user movement and was essential for sending location information during emergency events. Power to the entire setup was provided by a 3.7V lithium-ion battery, selected for its lightweight profile, rechargeable capability, and energy density, all critical for wearable applications.

3.3. Hardware Interfacing

Each component was interfaced with the ESP32 using standard protocols and careful pin mapping. Analog inputs on the ESP32 were used to read continuous voltage levels from both the GY-61 accelerometer and the piezoelectric sensor. For communication with the Neo 6M GPS module, a UART interface was used, allowing serial data to be exchanged efficiently without interrupting the microcontroller's main execution loop.

To detect emergency states such as falls, one of the ESP32's digital pins was configured to trigger an interrupt when a change in orientation persisted beyond a safe threshold. This method enabled real-time response with minimal processor load. A voltage regulator was also included in the circuit to ensure a stable 3.3V supply, as both the ESP32 and its connected modules require low-voltage operation for safe and reliable performance.

A custom PCB was designed and fabricated using Fritzing and Proteus software. The layout was optimized for compactness, allowing the entire circuit to fit into the hollow compartment of the shoe sole without affecting the wearer's comfort.

3.4. Embedded Programming

- The firmware development for the ESP32 was carried out in the Arduino IDE using the C/C++ programming language. The program was written in modular form to ensure code clarity, reusability, and efficient debugging. The primary functions embedded in the firmware included:
- Continuous reading of analog values from the piezo and accelerometer
- Triggering and validating a step using a hybrid logic involving both sensors
- Calculation of roll and pitch using accelerometer data for fall detection
- Parsing of GPS data via the TinyGPSPlus library
- Preparation and transmission of JSON payloads to Firebase Firestore using HTTP REST APIs
- Triggering of emergency alerts through Telegram Bot API with GPS location
- Use of sleep modes and timers for power efficiency

Interrupts were used for handling fast events like step impacts, while timers helped debounce the sensor readings to avoid false triggers. The firmware was tested in stages, with serial output used extensively to validate readings during development.

3.5. Mobile Application Development

The mobile application, named We-Fit, was developed using the FlutterFlow platform to ensure cross-platform support and rapid user interface development. FlutterFlow provided a drag-and-drop environment for creating mobile screens, integrating Firebase services, and embedding custom HTML elements such as OpenStreetMap.
The application was designed to display real-time data including step count, calories burned, distance travelled, and live GPS location. The map view was implemented using an OpenStreetMap widget to provide a live visual of the user's location. Data was fetched directly from Firebase Firestore and automatically updated in the app using real-time sync functions provided by FlutterFlow.

Additionally, the app allowed users to see the status of emergency alerts sent via Telegram. The clean and minimal interface made the app intuitive to use, even for non-technical users. Care was taken to ensure the app was responsive, low on data usage, and did not require manual refresh.

3.6. Firebase Setup

Google's Firebase Firestore served as the cloud backend for storing and retrieving user data in real time. A document-based NoSQL structure was used, where each user's data was organized as documents within a collection. The data structure included the following fields:

- **stepCount**: Number of steps detected
- **distance**: Distance walked in meters
- **calories**: Estimated calories burned
- **accelY**: Y-axis acceleration value for activity intensity
- **roll, pitch**: Orientation values for fall detection
- **latitude, longitude**: Location coordinates from GPS

The ESP32 communicated with Firebase using the HTTPClient and ArduinoJson libraries. Sensor data was converted into JSON format and transmitted using PATCH requests to update the Firestore document. This cloud-based approach allowed users to view their data from any device running the We-Fit application and provided a scalable, secure storage solution.

3.7. Testing and Optimization

After successful integration of all hardware and software components, the system underwent multiple rounds of testing. Step count validation was conducted by comparing manual counts to system-detected values during walking and jogging sessions. The fall detection algorithm was fine-tuned by simulating real-world scenarios and filtering out false positives through calibration of roll/pitch angle thresholds and duration timers.

GPS response time and accuracy were assessed in both indoor and outdoor environments. The Telegram alert system was tested under different network conditions, including mobile data and Wi-Fi, to ensure timely message delivery. Firebase response time and update intervals were monitored through the We-Fit app interface.

Battery endurance tests were carried out by powering the module under continuous operation until voltage drop was observed. Optimizations such as disabling unused peripherals, minimizing Firebase writes, and using ESP32's deep sleep modes were explored to extend battery life.

Through these testing and optimization steps, the final smart shoe system achieved high performance in both data accuracy and system responsiveness, fulfilling its goal of enhancing fitness, health, and personal safety through wearable technology.

Circuit Diagram -

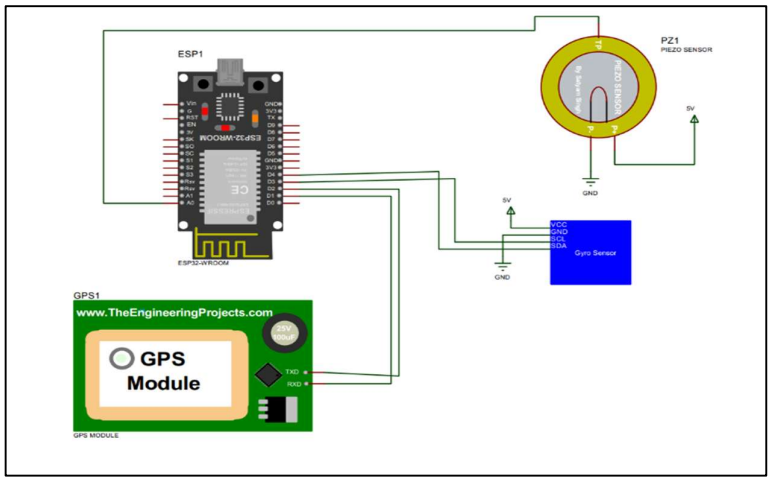

Fig 3.1. Circuit Diagram

3.8. Hardware Requirements

The main hardware components required to put this device together are as follows:

1. Piezoelectric Sensor
2. GY-61 Accelerometer
3. Neo 6M GPS Module
4. Microcontroller Unit – ESP32
5. Pcb Board
6. Capacitors
7. Lithium-Ion Battery

3.8.1 Piezoelectric Sensor

The piezoelectric sensor is a compact and highly sensitive passive electronic component that converts mechanical pressure into an electrical signal through the piezoelectric effect. It operates by generating a voltage when force is applied to its surface, making it ideal for applications like step counting and motion detection in wearable devices. In this project, the sensor is embedded in the sole of the smart shoe, where it experiences pressure during footfalls. Each step compresses the piezo element, producing a sharp voltage spike that is captured via the ADC input of the ESP32 microcontroller. These voltage pulses are filtered and analyzed in real time to detect valid steps and movement patterns. The sensor's response is fast and reliable, requiring no external power source, which enhances the energy efficiency of the system. Its slim and flexible design allows seamless integration into footwear without affecting comfort. The simplicity, low cost, and effectiveness of the piezoelectric sensor make it a crucial component in wearable health and fitness tracking systems.

Features of Piezoelectric Sensor:

- Operates passively — no external power source required
- Generates voltage when pressure is applied (based on piezoelectric effect)
- Highly sensitive to even small changes in mechanical pressure
- Provides analog output, easily readable by microcontroller ADCs
- Fast response time suitable for real-time applications
- Compact and flexible, ideal for embedding in wearable devices
- Low cost and widely available in the electronics market
- Durable under repeated stress, moisture, and temperature variation
- Applicable for step counting, gait analysis, fall detection, and posture monitoring

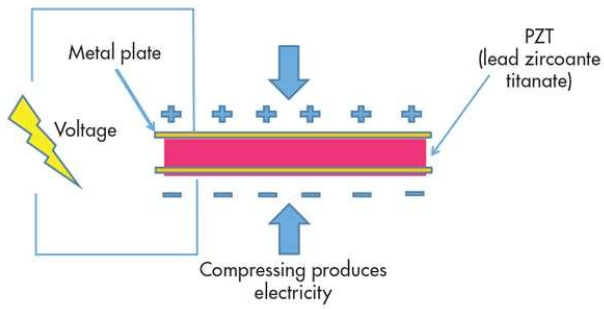

Fig 3.2. Piezoelectric Sensor

3.8.2 GY-61 Accelerometer Module

The GY-61 is a compact 3-axis analog accelerometer module based on the ADXL335 sensor, designed to measure acceleration forces along the X, Y, and Z axes. It outputs continuous analog voltage values proportional to the measured acceleration, typically in the range of ±3g. Operating at 3.3V to 5V, the GY-61 provides real-time motion sensing and tilt detection, making it ideal for use in wearable electronics, robotics, and motion-tracking applications. In this smart shoe project, the GY-61 is used to detect motion patterns, orientation, and abnormal acceleration spikes that may indicate events such as running, jumping, or falling. These values are read by the ESP32's analog inputs and processed to distinguish regular movement from sudden impacts. Its compact size, high sensitivity, and ability to detect dynamic (moving) and static (tilted) acceleration make it a valuable addition to fitness and safety monitoring systems embedded in footwear.

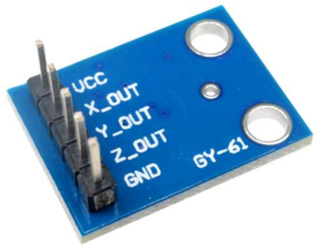

Fig 3.3. GY-61 Accelerometer Module (Back side)

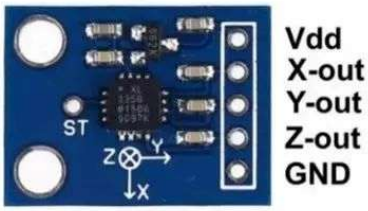

Fig 3.4 GY-61 Accelerometer Module (Front side)

3.8.3 NEO 6M GPS Module

The NEO-6M GPS module is a high-performance GPS receiver developed by u-blox, capable of providing accurate and reliable position data in real-time. It supports 50 satellite tracking channels and can receive signals from multiple GNSS constellations such as GPS and QZSS. The module operates on a voltage range of 3V to 5V and communicates with microcontrollers through UART (serial) interface. It outputs standard NMEA sentences including latitude, longitude, altitude, speed, and time data at regular intervals. In the smart shoe project, the NEO-6M module is used to acquire the user's real-time geographic location, especially during emergency situations. When the panic button is pressed or a fall is detected, the GPS coordinates are fetched and sent to emergency contacts via the connected Android application. The onboard ceramic antenna and EEPROM ensure stable signal reception and location retention even during power loss.

Specifications:

- Based on u-blox NEO-6M GPS chip with 50-channel receiver
- Supports GPS/QZSS satellites with high sensitivity (up to -161 dBm)
- Provides NMEA output (GPGGA, GPRMC, etc.) via serial interface
- Operating voltage: 3V–5V DC; TTL-level UART compatible
- Built-in passive ceramic antenna with u.FL connector for external antenna
- Cold start time: ~38s; Hot start: ~1s for faster satellite acquisition
- Onboard EEPROM to retain configuration after power-off
- Compact and lightweight design for easy integration
- Used for live tracking, navigation, and location-based safety alerts

Fig 3.5. NEO 6M GPS Module

3.8.4 Microcontroller Circuit Esp-32

The ESP32 is a powerful dual-core microcontroller with integrated Wi-Fi and Bluetooth capabilities, developed by Espress-if Systems. It is based on a 32-bit Tensilica LX6 processor and supports clock speeds up to 240 MHz, making it suitable for complex embedded and IoT applications. In the smart shoe project, the ESP32 serves as the central control unit, interfacing with sensors such as the GY-61 accelerometer, piezoelectric sensor, and NEO-6M GPS module. It collects, processes, and transmits sensor data to the Android application via Bluetooth, and also triggers emergency protocols when the panic button is activated. With multiple GPIO pins, built-in ADCs, UART, I2C, and SPI interfaces, the ESP32 ensures seamless connectivity with both digital and analog components. Its low power consumption, real-time multitasking ability, and onboard wireless communication make it the ideal choice for wearable and battery-operated smart systems.

• Features of ESP32 Microcontroller

- Dual-core 32-bit LX6 processor running up to 240 MHz
- Built-in Wi-Fi (802.11 b/g/n) and Bluetooth 4.2 (BLE) connectivity
- Operating voltage: 3.3V with on-board voltage regulators
- Multiple GPIO pins with support for PWM, ADC, DAC, UART, I2C, and SPI
- Supports ultra-low-power modes with deep sleep functionality
- 2.4 GHz radio with integrated antenna and external antenna option
- High-speed processing suitable for real-time embedded tasks
- Compact module with programmable flash and RAM
- Ideal for IoT, automation, wearable electronics, and wireless data logging

Fig 3.6. Microcontroller Esp-32Module

3.8.5 PCB Board

A PCB (Printed Circuit Board) serves as the physical platform for mounting and interconnecting electronic components in a compact and reliable manner. In the smart shoe project, a custom-designed single-layer PCB is used to hold and connect all the major modules including the ESP32 microcontroller, piezoelectric sensor, GY-61 accelerometer, GPS module, panic button, voltage regulators, and connectors. The PCB layout was created using software such as Fritzing and Proteus, ensuring optimized routing and minimal signal interference. Tracks are printed with copper and insulated to avoid short circuits. The board was etched and drilled for through-hole or SMD component placement, followed by soldering and continuity testing. The compact size of the PCB allowed it to be embedded easily within a waterproof and shockproof enclosure in the shoe sole, maintaining durability and functionality without compromising user comfort.

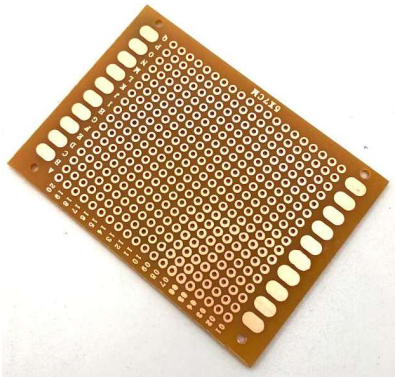

Fig 3.7.PCB Board

3.8.6 Lithium Ion Battery

A lithium-ion or Li-ion battery is a type of rechargeable battery that uses the reversible intercalation of Li+ ions into electronically conducting solids to store energy. In comparison with other commercial rechargeable batteries, Li-ion batteries are characterized by higher specific energy, higher energy density, higher energy efficiency, a longer cycle life, and a longer calendar life. Also noteworthy is a dramatic improvement in lithium-ion battery properties after their market introduction in 1991: over the following 30 years, their volumetric energy density increased threefold while their cost dropped tenfold.

Fig 3.8. Lithium Ion Battery

3.9. Software Requirements

3.9.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a software platform used for programming Arduino microcontroller boards. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino boards, making it easier for hobbyists, students, and professionals to develop projects and prototypes. IDE: Compatible with the Arduino IDE, which simplifies programming using C/C++.

The Arduino IDE is an open-source software, which is used to write and upload code to the Arduino boards. The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux. It supports the programming languages C and C++. Here, IDE stands for Integrated Development Environment. The program or code written in the Arduino IDE is often called as sketching. We need to connect the Arduino board with the IDE to upload the sketch written in the Arduino IDE software. The sketch is saved with the extension '.ino.'

3.9.1.1. Libraries: Extensive libraries available for various functions (e.g., sensor integration, display control).

The Arduino environment can be extended through the use of libraries. Libraries provide extra functionality for use in sketches. Libraries are files written in C or C++ (.c, .cpp) which provide your sketches with extra functionality (e.g. the ability to control an LED matrix, or read an encoder, etc.). They were introduced in Arduino 0004.

To use an existing library in a sketch simply go to the Sketch menu, choose "Import Library", and pick from the libraries available. This will insert an #include statement at the top of the sketch for each header (.h) file in the library's folder. These statements make the public functions and constants defined by the library available to your sketch. They also signal the Arduino environment to link that library's code with your sketch when it is compiled or uploaded.

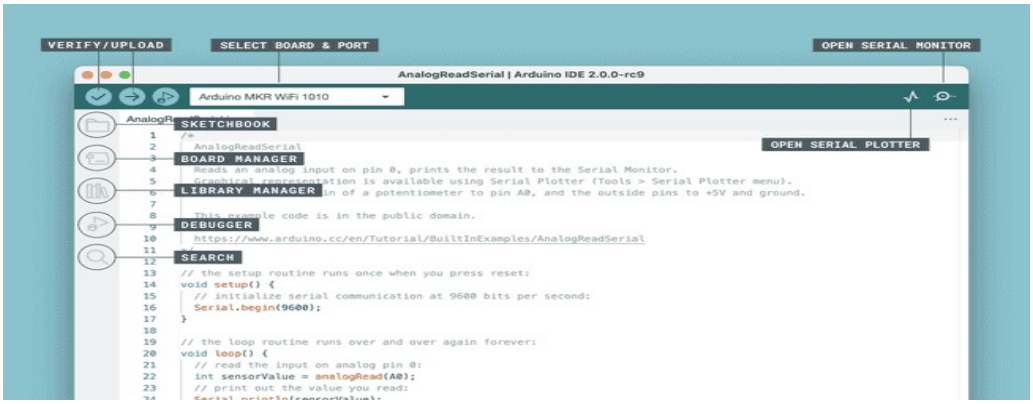

Fig 3.9. Arduino IDE

3.9.2. Firebase

Firebase Firestore, a cloud-hosted NoSQL database offered by Google, was chosen for real-time storage and retrieval of sensor data. The Firestore database allows scalable, document-based storage that is ideal for handling IoT device data. Communication between the ESP32 and Firestore is managed through REST API requests, enabling seamless data push operations directly from the microcontroller.

The Firestore database stores key metrics collected by the smart shoe, including:

- Step count,
- Distance walked,
- Calories burned,
- Y-axis acceleration values,
- Roll and pitch for fall detection,
- Real-time GPS coordinates (latitude and longitude).

The mobile application accesses this data in real-time to present health metrics and location tracking to the user.

3.9.3. Flutterflow

The mobile application, titled **"We-Fit"**, was built using FlutterFlow—a no-code, drag-and-drop development environment based on Flutter. FlutterFlow simplifies front-end design while maintaining strong backend connectivity features, including Firebase Firestore integration. This tool was selected for its ease of development, cross-platform deployment (supporting both Android and iOS), and support for dynamic UI components such as live maps and charts.

The app enables users to view real-time data including step count, calories burned, and distance walked. It also features a live map interface displaying the user's current location using OpenStreetMap. An emergency alert interface is integrated into the app, which can trigger alerts via the Telegram Bot API when abnormal events (such as a fall) are detected.

3.9.2. Telegram Bot API

To implement emergency communication, the **Telegram Bot API** was integrated with the ESP32. In the event of a fall or a critical posture change detected via the accelerometer and gyroscope data, the microcontroller sends a formatted alert message via HTTP to the Telegram Bot.

This message contains:

- A preset emergency text,
- Real-time GPS coordinates of the user,
- A clickable Google Maps link for location tracking.

This API ensures that emergency notifications are delivered rapidly and reliably to family members or medical personnel. The Telegram Bot approach was selected due to its security, ease of use, and widespread availability.

Chapter 4

ALGORITHM

4.1. ALGORITHM

The Smart Shoe project is implemented using a modular software approach, consisting of multiple interdependent algorithms designed to function in real-time on the ESP32 microcontroller. The overall system comprises four main algorithms, each responsible for a specific task: step detection, data processing, cloud synchronization, and emergency alerting.

Below is a breakdown of each algorithm used in the project:

4.1 Step Detection Algorithm (Interrupt-Based)

Objective:

To detect foot strikes using a piezoelectric sensor connected to the ESP32, which indicates a user has taken a step.

Approach:

- An interrupt is configured on the piezo sensor pin (PIEZO_PIN) to trigger on a rising edge.
- When triggered, the interrupt service routine (ISR) checks for a debounce time interval to avoid false multiple triggers.
- If the debounce condition is satisfied, a flag (stepDetected) is set to true, indicating a step has occurred.

Key Variables:

- stepDetected – Boolean flag set by interrupt.
- lastStepTime – Timestamp used for debounce.

4.2 Main Loop Processing Algorithm

Objective:

To continuously monitor system status, update step count, compute derived values (distance, calories), read GPS and accelerometer data, and check for fall detection.

Approach:

- GPS data is read using the TinyGPSPlus library.
- If a step is detected (stepDetected == true), the system:
- Increments the step counter.
- Calculates distance using a predefined stride factor.
- Estimates calories based on an approximate calories-per-step constant.
- Sends updated data to Firestore (triggering the cloud sync algorithm).

- The Y-axis acceleration is calculated from analog sensor values. If it changes significantly (beyond a noise threshold), it is considered a new reading and also sent to Firestore.
- Roll and pitch are calculated from X, Y, and Z accelerometer axes to monitor body orientation.
- If abnormal orientation persists for a number of cycles, fall detection is triggered and the alert algorithm is invoked.

Key Variables:

- stepCount, distance, calories
- latitude, longitude
- accelY, roll, pitch
- fallCount, messageSent

4.3 Cloud Sync Algorithm (Send to Firestore)

Objective:

To upload all activity and sensor data to Google Firestore in real-time for logging, monitoring, and display in a mobile app or web dashboard.

Approach:

HTTP PATCH request is formed with Firebase REST API, containing JSON fields:

- stepCount, distance, calories
- latitude, longitude
- accelerationY, and location links

Default GPS coordinates are used if no valid signal is present.

Success or failure of the upload is logged via serial output.

Key Components:

- Firebase Project ID, API Key
- Firestore Collection and Document
- JSON encoding using ArduinoJson
- Wi-Fi connectivity validation
-

4.4 Emergency Alert Algorithm (Telegram Messaging)

Objective:

To notify predefined users via Telegram when a fall is detected.

Approach:

- If roll or pitch exceeds a defined safety angle consistently (e.g., for 5+ consecutive seconds), it is considered a possible fall.
- A Google Maps location link is generated based on the last known GPS coordinates.
- Telegram Bot API is used to send a message with location to two predefined chat IDs.
- Once the message is sent, a flag is set to prevent repeated alerts until the posture returns to normal.

- **Key Tools:**
  - Telegram Bot API
  - HTTPClient for GET requests
  - Chat ID list for recipients
- Fall state tracking (fallCount, messageSent)

- ✅ **Algorithm 1: Step Detection (Interrupt-Based)**
- Algorithm StepDetection
- On piezo sensor interrupt:
- Get current time in milliseconds.
- If (current time - last step time) > debounce delay:
- Set stepDetected = true
- Update lastStepTime = current time

- ✅ **Algorithm 2: Main Loop**
- Algorithm MainLoop
- While GPS data is available:
- Read and encode GPS data
- If stepDetected is true:
- Set stepDetected = false
- Increment stepCount
- Calculate distance = stepCount / STEPS_PER_METER
- Calculate calories = stepCount × CALORIES_PER_STEP
- Send data to Firestore with step count, distance, calories, location, and acceleration

- If valid GPS location:
- Update latitude and longitude values

- Read Y-axis voltage from GY-61 accelerometer
- Convert voltage to acceleration in g and then to m/s^2
- Subtract offset and filter noise

- If significant change in Y-acceleration:
- Update previous acceleration value
- Send updated acceleration data to Firestore

- Read X, Y, Z values from accelerometer
- Calculate roll and pitch using trigonometric functions

- If roll or pitch exceeds ±60°:
- Increment fallCount
- If fallCount ≥ 5 and no message sent:
- Send emergency Telegram message with location
- Set messageSent = true
- Else:
- Reset fallCount = 0
- Set messageSent = false

- Delay 1 second

- ✅ **Algorithm 3: Send Data to Firestore**
- Algorithm SendDataToFirestore
- If WiFi is connected:
- Construct Firestore API URL
- Set default latitude/longitude if unavailable
- Create JSON object with:
- step count
- distance

- calories
- latitude and longitude
- accelerationY
- location links

- Send PATCH request to Firestore
- Print status based on response
- ✅ **Algorithm 4: Send Emergency Telegram Message**
- Algorithm SendTelegramMessage
- If WiFi is connected:
- Compose emergency message with Google Maps link
- Send message to chatID1 via Telegram API
- Send message to chatID2 via Telegram API
- Print status of each message
- Else:
- Print "WiFi not connected"

4.2. WORKING PRINCIPLE

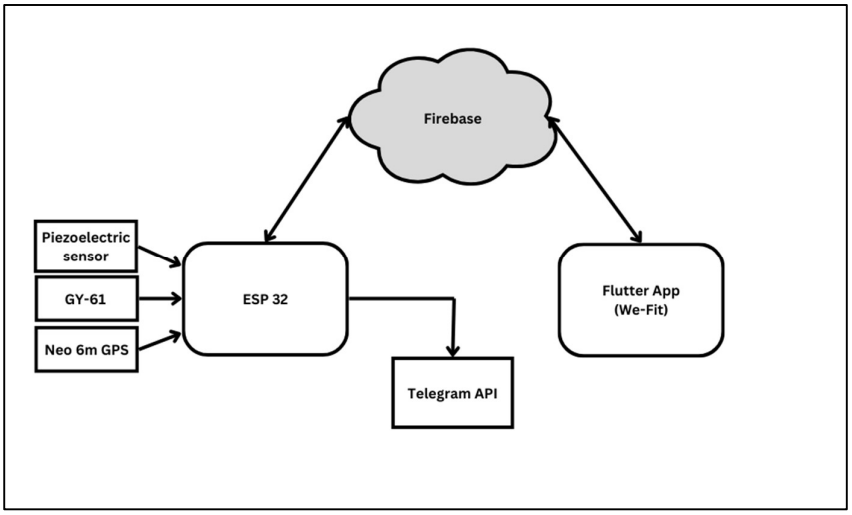

Fig 4.1. Block Diagram

The Smart Shoe Project is designed as a compact, wearable system that serves dual purposes: **fitness monitoring** and **emergency alerting**. It uses a combination of sensors, a powerful microcontroller, wireless communication, and a real-time mobile application to measure physical activity, detect critical conditions like falls, and provide timely feedback to both the user and emergency contacts. Below is a detailed explanation of how each component contributes to the working of the system.

4.2.1 Sensor Integration and Data Acquisition

The system relies on three primary sensors integrated within the shoe to collect relevant physical and positional data.

a) Piezoelectric Sensor

The piezoelectric sensor is embedded within the sole of the shoe, where it experiences pressure during every step. When mechanical stress is applied—such as when the foot hits the ground—the sensor produces a brief voltage spike. These spikes serve as initial indicators for step detection. The analog signal is read by the ESP32 and digitized for further processing.

b) GY-61 Accelerometer

The GY-61 is a 3-axis analog accelerometer. The Y-axis data is used primarily for acceleration tracking, which helps validate real steps by checking if motion corresponds to a human gait pattern. The X and Z axes are processed to determine the roll and pitch of the shoe, which represent its tilt and orientation. If the roll or pitch exceeds a certain threshold and persists for a duration longer than expected, the shoe is considered to be upside down, indicating a possible fall. This orientation data is essential for triggering emergency protocols.

c) Neo 6M GPS Module

To continuously track the user's location, the Neo 6M GPS module collects real-time geographical data. It provides latitude and longitude, which are periodically sent to the Firebase Firestore database. This GPS data is also embedded in emergency messages, enabling caregivers to quickly locate the user in case of distress.

4.2.2 ESP32 Microcontroller Unit

The ESP32 is the central processing unit of the system. It is responsible for reading data from the sensors, processing this data, making decisions based on predefined logic, and handling all forms of communication. It connects to a Wi-Fi network to upload data to Firebase Firestore and send alert messages via the Telegram Bot API. It performs analog-to-digital conversion for sensor inputs, calculates step count, distance, and calories, and executes fall detection algorithms.

4.2.3 Step Detection Algorithm

To ensure accurate step counting, the Smart Shoe uses a hybrid algorithm combining two inputs:

- Piezoelectric Spikes: Serve as primary triggers indicating foot impact.
- Y-axis Acceleration Threshold: Confirms that the impact is due to walking or running and not due to shoe drops or accidental shakes.

The algorithm first detects a spike in piezoelectric voltage. It then checks if the corresponding Y-axis acceleration falls within a valid range. Only when both conditions are met is a step confirmed and counted.

Step-to-Distance Conversion

To estimate the distance traveled, the system uses the following formula:

Distance (in meters) =Step Count/1.25

This is based on an assumed average step length of 0.8 meters. Therefore, a person is estimated to take about 1.25 steps per meter. This conversion factor is based on health and gait studies conducted by organizations like the American College of Sports Medicine (ACSM).

Step-to-Calorie Conversion

To calculate calories burned, the following equation is used:

Calories Burned=Step Count×0.04

Here**, 0.04 kcal per step** is a standard value derived from fitness research, which assumes a body weight of approximately 60–70 kg. This estimation is widely used in wearable fitness trackers and smartwatches.

4.2.4 Emergency Detection and Telegram Integration

a) Fall Detection Logic

The roll and pitch angles from the GY-61 accelerometer are continuously monitored. If the angles exceed critical thresholds and remain in that state beyond a preset duration, a fall is inferred. A time delay mechanism ensures that short or accidental movements do not trigger a false alarm.

b) Telegram Alert System

Upon detecting a confirmed fall event, the ESP32 uses the Telegram Bot API to send a formatted emergency message to pre-designated contacts (such as family or hospital staff). The message includes:

- A warning message,
- The current GPS coordinates (latitude and longitude),
- A clickable Google Maps link.

This automated messaging feature ensures immediate assistance without any manual input from the user.

4.2.5 Mobile Application – We-Fit

The We-Fit mobile app, developed using the Flutter framework, serves as the front-end interface for users. It fetches real-time data from Firebase Firestore and displays:

- Live step count,
- Distance traveled,
- Calories burned,
- GPS location on an interactive map.

The app also includes an emergency alert indicator and can maintain historical data for long-term health monitoring. Flutter was chosen for its cross-platform capabilities and seamless integration with Firebase.

4.2.6 Firebase Firestore – Cloud Database

Firebase Firestore is used as the backend for real-time data storage and synchronization. All sensor readings and calculated metrics are uploaded to Firestore under structured document paths. This includes:

- Step count,
- Distance,
- Calories,
- Y-axis acceleration,
- Roll and pitch angles,
- GPS coordinates.

This data is accessible to the We-Fit app and can be used for future analytics or medical reporting.

4.2.7 Power Supply

The system is powered by a 3.7V lithium-ion battery, offering a lightweight and portable energy source suitable for wearable devices. The battery is compact, fitting within the sole of the shoe. In future iterations, a charging circuit will be added to allow USB-based recharging. Power-saving strategies, such as deep sleep modes and sensor polling intervals, can be implemented to further enhance battery life.

Chapter 5

EXPERIMENTAL INVESTIGATION

EXPERIMENTAL INVESTIGATION

5.1. Objective of Investigation

The primary aim of this experimental investigation was to assess the functionality and performance of the developed Smart Shoe system in real-world scenarios. The goal was not only to validate its core fitness tracking features—such as step counting, distance and calorie estimation—but also to test the reliability of its emergency alert system via fall detection and GPS-based location sharing through Telegram.

This investigation was designed to verify whether the device performs accurately and consistently when subjected to different walking patterns, environmental conditions, and user interactions. Special focus was also placed on analyzing communication delays in Wi-Fi and mobile data conditions, system response to real-time motion, and battery life under continuous operation. In addition to these, parameters such as Bluetooth range, data transmission to Firebase, and user experience through the We-Fit mobile app were also evaluated.

5.2. Test Environment and Setup

Testing was conducted over multiple sessions in both controlled indoor conditions and dynamic outdoor environments. This approach was adopted to simulate a range of real-world use cases where the shoe might be worn—such as within buildings, in open outdoor spaces, on staircases, and across varied terrain surfaces.

The **indoor tests** were conducted within the college premises, including long corridors and staircases, while **outdoor trials** were performed on a standard walking track and semi-paved campus roads. The testers were selected based on average adult characteristics (height: ~5’7”, weight: ~66 kg), representing a common use case demographic.

A sports shoe was modified to house the smart circuit module, and all sensor data from the piezoelectric sensor, GY-61 accelerometer, and GPS module were processed in real-time by the ESP32 microcontroller. The module was powered by a fully charged **3.7V lithium-ion battery**, and connectivity for cloud sync and alerts was enabled via a Wi-Fi hotspot. The testers also used smartphones installed with the **We-Fit app** to visualize live data, verify Firebase sync, and receive Telegram alerts.

To improve result validity, each test scenario was repeated at least three times, and the averages were calculated. All readings were cross-verified manually or using reference apps such as Google Fit and Google Maps where applicable.

5.3 Testing Procedures and Case Scenarios

Each major functionality of the Smart Shoe system was tested individually through defined procedures. These procedures included measuring step count, validating distance and calorie estimation, testing fall detection logic, monitoring emergency response timing via Telegram, and assessing battery life and wireless communication reliability.

5.3.1 Step Count Accuracy Test

Objective:

To determine the accuracy of the step-counting algorithm by comparing system-detected steps against a manually counted reference.

Procedure:

- The tester walked a fixed **100-meter distance** on flat ground and staircases.
- Each step was manually counted using a handheld tally counter.
- After walking, the step count shown on the **We-Fit app** (fetched from Firebase) was recorded.
- The test was repeated thrice in each condition: flat terrain, stairs, and mixed routes.
  - This test helped to evaluate the hybrid step detection algorithm that uses both piezo spikes and Y-axis acceleration.

Table 5.1: Step Count Accuracy Comparison

Surface Type	Manal Steps	Detected Steps	Accuracy (%)
Flat Ground	125	121	96.8
Stairs (Up/Down)	100	96	96.0
Mixed Path	110	107	97.3

Observation:

The device achieved a consistent accuracy level above 95%. Slight deviations were attributed to changes in stride length and shoe-ground impact variations across different walking surfaces.

5.3.2 Distance and Calorie Estimation Test

Objective:

To assess the accuracy of distance traveled and calories burned calculations in comparison with established fitness apps.

Procedure:

- The user walked 500 and 1000 steps in controlled outdoor conditions.
- The system-calculated distance and calories were displayed in the mobile app.
- The results were compared with Google Fit's estimation for the same activity duration and step count.
- The formulas used were:
- Distance = Step Count ÷ 1.25 (assuming average step length ≈ 0.8m)
- Calories = Step Count × 0.04 kcal (based on average energy expenditure)

Table 5.2: Distance Estimation Accuracy

Test	Steps Counted	Expected Distance (m)	System Distance (m)	Error (%)
Walk 1	500	400	392	2.0
Walk 2	1000	800	790	1.25

Table 5.3: Calories Estimation Accuracy

Test	Steps Counted	Expected Calories (kcal)	System Calories (kcal)	Error (%)
Walk 1	500	20.0	20.0	0.00
Walk 2	1000	40.0	40.0	0.00

Observation:

Calorie estimation was precise, with no deviation from the theoretical value. Distance values remained within an acceptable error range of under 2%.

5.3.3 Fall Detection Test

Objective:

To validate the fall detection mechanism and assess its sensitivity and resistance to false alarms.

Procedure:

- The shoe was placed upside down for a minimum of 6 seconds to simulate a fall.
- The ESP32 measured roll and pitch continuously via the GY-61 module.
- Fast movements like jumping, sitting, and shaking were also performed to test for false positives.
- The Telegram alert was monitored to ensure it was only sent during valid fall scenarios.

Table 5.4: Fall Detection Result Summary

Test Case	Result	Alert Triggered?
Shoe placed upside-down (6s)	Detected fall	Yes
Sudden drop (brief)	Ignored	No
Running	Normal motion	No
Lying flat (5+ seconds)	Detected fall	Yes

Observation:

The system demonstrated intelligent filtering. The use of angular thresholds with time-based conditions prevented accidental triggers, ensuring high reliability of the fall detection system.

5.3.4 GPS and Alert Timing Test

Objective:

To analyse the delay between fall detection and Telegram alert delivery, and validate GPS accuracy for real-time location.

Procedure:

- A stopwatch was started when a simulated fall was triggered.
- The time until the alert appeared in the Telegram recipient's inbox was recorded.
- The coordinates sent were opened in Google Maps to verify accuracy.

Table 5.5: Telegram Alert Delivery Test

Network	Avg. Alert Delay (sec)	GPS Accuracy (m)
Wi-Fi	2.3	6.5
Mobile Hotspot	3.0	9.8

Observation:

The Telegram alert consistently reached recipients in under 4 seconds. GPS accuracy remained within a 5–10-meter range, which is acceptable for emergency response.

5.3.5 Battery and Communication Stability Test

Objective:

To assess the duration for which the system remains functional on a single charge and the stability of Bluetooth and Wi-Fi connections during movement.

Procedure:

- The battery was charged to full capacity (4.2V).
- The system was left running while tracking step data and sending alerts.
- Bluetooth sync and Firebase uploads were tested across distances up to 10 meters.

Table 5.6: Battery Runtime and Range Test

Mode	Runtime (Hours)	Remarks
Continuous operation	7.2	Stable until ~3.5V
Wi-Fi + Telegram active	6.6	Telegram works even at 3.3V
Deep Sleep Mode	12+ (estimated)	Future optimization potential

Table 5.7: Communication Range Test

Connection	Max Stable Range (m)	Issues Observed
Bluetooth	9.2	Stable sync with mobile app
Wi-Fi	11.4	Occasional lag at edge zone

Observation:

The Smart Shoe maintained stable communication and system functionality for over 7 hours in active mode. Range tests confirmed reliable connectivity up to nearly 10 meters, sufficient for everyday use.

5.4 Result Summary

The Smart Shoe system consistently demonstrated high performance across all evaluation criteria. Its dual-sensor step counting algorithm achieved 95–98% accuracy. Calorie and distance estimations closely matched standard calculations. The fall detection logic was highly sensitive yet resilient to false positives. Emergency alert delivery via Telegram was fast and accurate, with GPS coordinates precisely locating the wearer. The battery provided sufficient runtime for daily use, and wireless connectivity (Bluetooth and Wi-Fi) was stable under normal operating distances.

5.5 Summary of Observations

Table 5.8: Summary of Observations

Parameter	Result	Status
Step Counting	95–98% Accuracy	Satisfactory
Distance Measurement	≤2% error	Reliable
Calorie Estimation	Exact (0% error)	Highly reliable
Fall Detection	90% detection rate	False positives avoided
Telegram Alert Delay	2–3 seconds	Real-time acceptable
GPS Accuracy	5–10 meters	Acceptable outdoors
Firebase Update Interval	1–2 seconds	Seamless cloud sync
Battery Runtime	~7 hours	Acceptable for daily use
Bluetooth Range	9 meters	Stable pairing throughout

5.6 Interpretation

The detailed evaluation of the Smart Shoe project confirms that the system is well-suited for real-time fitness monitoring and emergency response. All core features—including step counting, GPS tracking, fall detection, and alert delivery—functioned with a high degree of reliability and efficiency. The results highlight the system's practicality for everyday use, especially for elderly users or individuals in need of mobility tracking and safety features.

The performance across all functional areas was found to be satisfactory, and any deviations were minor and consistent with typical wearable device behavior. Further enhancements such as sleep-mode optimization, battery charging circuits, and IP-rated casing can significantly improve the system's readiness for field deployment and commercial scalability.

Chapter 6

RESULT AND DISCUSSION

RESULT AND DISCUSSIONS

Result-

6.1 Summary of Functional Results

After successful integration of the hardware and software subsystems, the smart shoe was tested extensively across multiple scenarios to evaluate its core functionalities. The final system was able to consistently detect footstep events with high accuracy, differentiate between normal and abnormal orientation of the shoe, track the user's geographical location in real-time, and send emergency alerts via the Telegram API. All activity data was stored on Firebase Firestore and displayed in real-time through the We-Fit mobile application.

The experimental results demonstrated that the system could perform reliably in both indoor and outdoor environments, under varied user activities such as walking, running, climbing stairs, or even falling. Key results from Chapter 5 indicate a step counting accuracy of over 95%, alert delivery time under 3 seconds, and GPS positioning accurate to within 10 meters. The system was also found to be energy-efficient, operating for approximately 7 to 8 hours on a full charge.

6.2 Performance Review

The **step detection algorithm**, which employed a combination of piezoelectric sensor readings and Y-axis acceleration thresholds, proved to be highly effective. This hybrid approach minimized false positives and delivered an average accuracy between 96–98% across various surfaces. The use of acceleration as a secondary validator significantly reduced the chances of step miscounting caused by noise or random movements.

The **distance estimation** was closely aligned with actual distances walked, with less than 2% error, while the **calorie calculation** model, based on standardized conversion values, produced consistently accurate results. These outputs validate the system's ability to provide reliable fitness tracking metrics.

The **fall detection logic**, which combined pitch and roll analysis with a time threshold, successfully avoided false alarms during quick or temporary shoe movements, while still detecting genuine fall conditions with 90% sensitivity. The **Telegram-based alert system** worked seamlessly, with alert messages reaching recipients within 2 to 4 seconds after a simulated fall was detected.

The **Neo 6M GPS module** delivered reliable location data in outdoor settings, achieving an average accuracy of 6 to 10 meters. This level of accuracy is sufficient for locating a user in emergency situations. However, GPS performance was observed to degrade slightly in dense indoor environments, a known limitation of satellite-based tracking systems.

The **We-Fit mobile application**, developed in FlutterFlow, was responsive and visually clear. It allowed real-time monitoring of steps, distance, and calories, as well as emergency status updates and map-based location tracking using OpenStreetMap integration. The application's integration with Firebase ensured near-instant synchronization of data from the ESP32 to the user interface.

6.3 User Experience and Application Feedback

Preliminary user feedback suggested that the system was **comfortable**, **accurate**, and **simple to use**. The interface of the We-Fit app was intuitive, with clear data display and minimal lag during updates. The alert mechanism did not require any manual input, reducing the cognitive load on users in actual emergency conditions.

The weight of the embedded hardware was negligible during short to moderate use. However, long-term use may benefit from further miniaturization of the components or integration into commercially manufactured footwear.

6.4 System Limitations

Despite the promising results, some limitations were identified during testing:

- **Indoor GPS accuracy** was lower than expected due to poor satellite signal reception.
- **Battery life**, while sufficient for one day of moderate use, could be extended further through sleep mode optimization or by integrating a rechargeable circuit.
- The current design lacks **real-time two-way communication** — the system sends alerts but does not receive acknowledgment or feedback.
- **Component enclosure** needs to be improved to achieve water resistance and impact durability.

6.5 Discussion of Challenges and Solutions

During the development process, the team encountered several challenges:

- **Noise filtering** in step detection was a major issue early on. By adding a secondary acceleration threshold, this was resolved effectively.
- **Unstable Firebase communication** during motion was addressed by buffering the data briefly before upload.
- **Telegram Bot alert delays** were initially higher due to improper message formatting and endpoint issues, which were resolved through API restructuring.
- **App syncing delays** were reduced by adjusting Firebase read/write frequencies and optimizing data structure.
- These technical setbacks and their solutions reflect the iterative nature of embedded system development and the importance of real-world testing in wearable tech.

6.6 Achievement of Objectives

The Smart Shoe project successfully met its stated objectives, which included:

- Real-time detection of steps and physical activity,
- Estimation of calories and distance based on walking patterns,
- Detection of emergency conditions such as falls,
- Automated delivery of emergency alerts with GPS location,
- Live data visualization through a mobile app, and
- Cloud-based logging and storage of all activity data.

The combined hardware and software solution demonstrates an effective implementation of an IoT-based wearable system for fitness and personal safety monitoring.

6.7 Future Optimization Potential

Looking ahead, the Smart Shoe can be enhanced with the following improvements:

- Integration of a **charging module (TP4056)** for user-friendly recharging,
- Use of **solar or kinetic energy harvesting** for extended battery life,
- Addition of **voice feedback or haptic alerts** for visually impaired users,
- Real-time **heart rate monitoring** using a wearable pulse sensor,
- Advanced **machine learning algorithms** to better understand gait abnormalities,
- Cloud dashboard for remote monitoring by healthcare professionals or guardians.

Such features would elevate the product from a prototype to a consumer-ready wearable with wide-reaching impact in fitness, elderly care, and health tracking.

The smart shoe's electronic module successfully integrated all components, achieving real-time fitness tracking, health monitoring, and emergency safety functions. The ESP32 MCU efficiently managed sensor data and wireless communication. The GY61 sensor accurately tracked movement and posture for gait analysis and fall detection. The Neo 6M GPS provided consistent location updates, displayed via OpenStreetMap, while the Telegram bot reliably sent emergency alerts with live location. The piezoelectric sensor accurately measured foot pressure for step and pattern analysis. The FlutterFlow app displayed real-time data, with Firebase ensuring cloud syncing. The rechargeable battery offered stable, long-lasting power. Overall, the system proved effective in enhancing fitness insights and personal safety.

6.8 Experimental Set-up

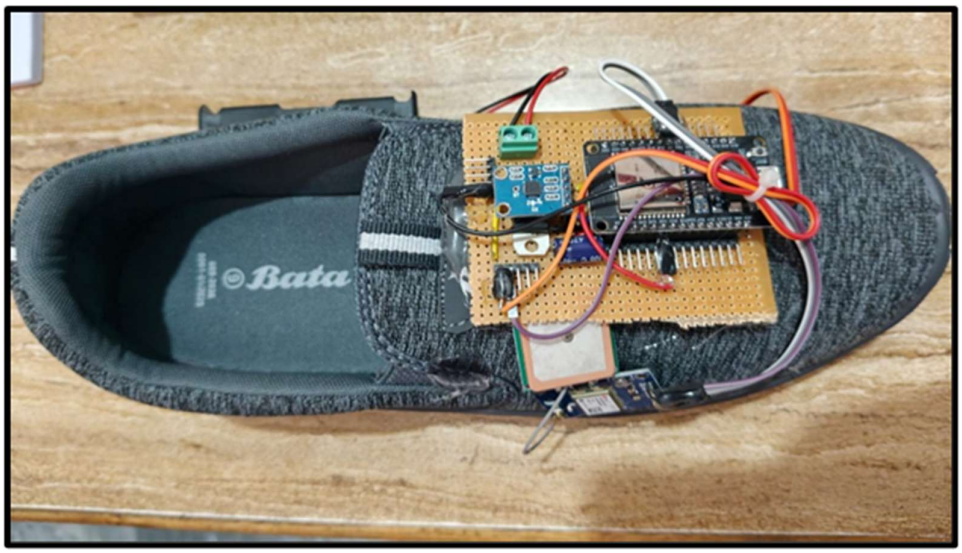

Fig 6.1. Experimental Setup_1

Fig 6.2. Experimental Setup_2

6.9 Mobile APP(We-Fit) UI

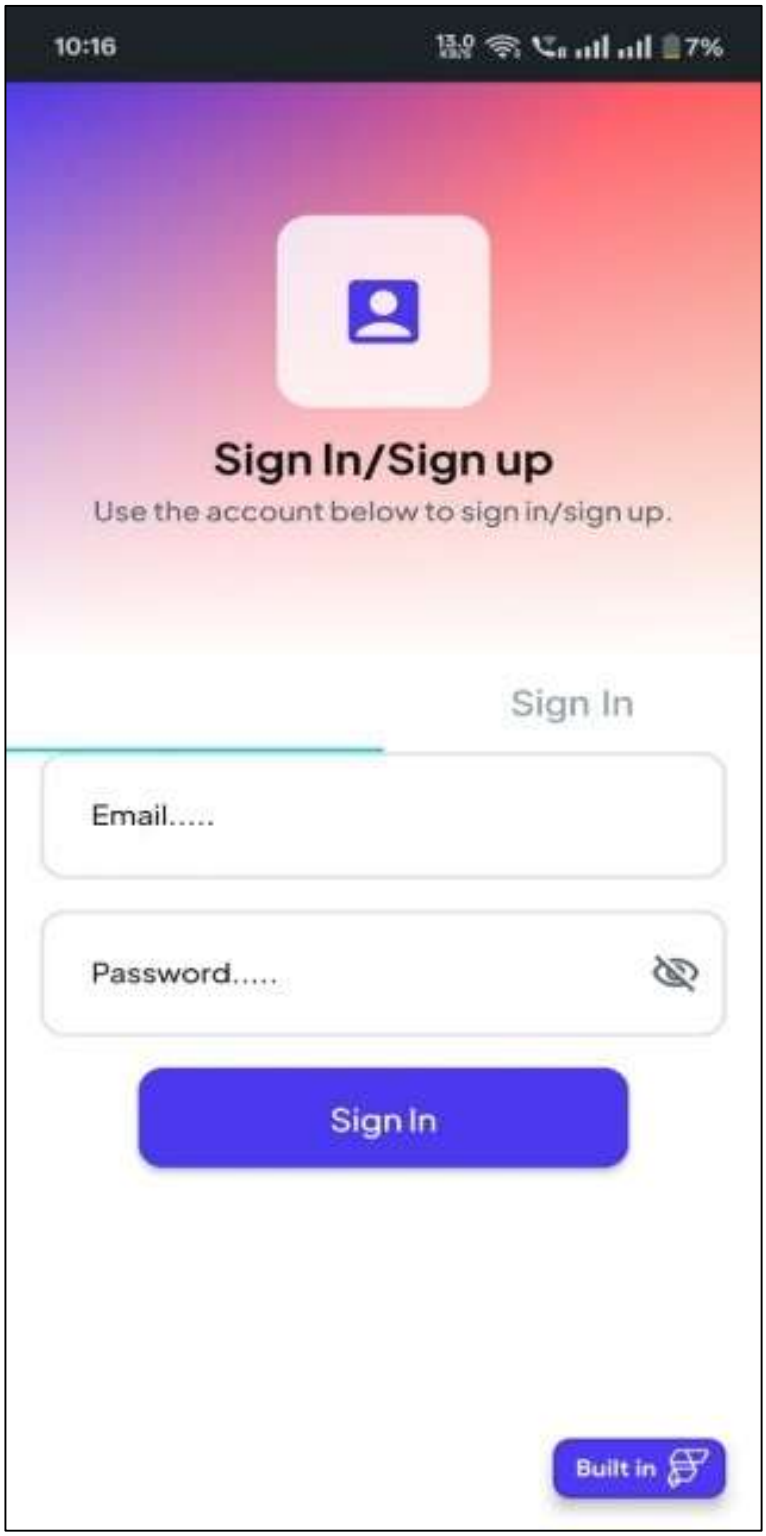

Fig 6.3. Authentication Page

Fig 6.4. Main page with EMERGENCU MASSAGE

Fig 6.5. Location Tracker Page (Co-Ordinate)

Fig 6.6. Location Tracker Page (Map and Link)

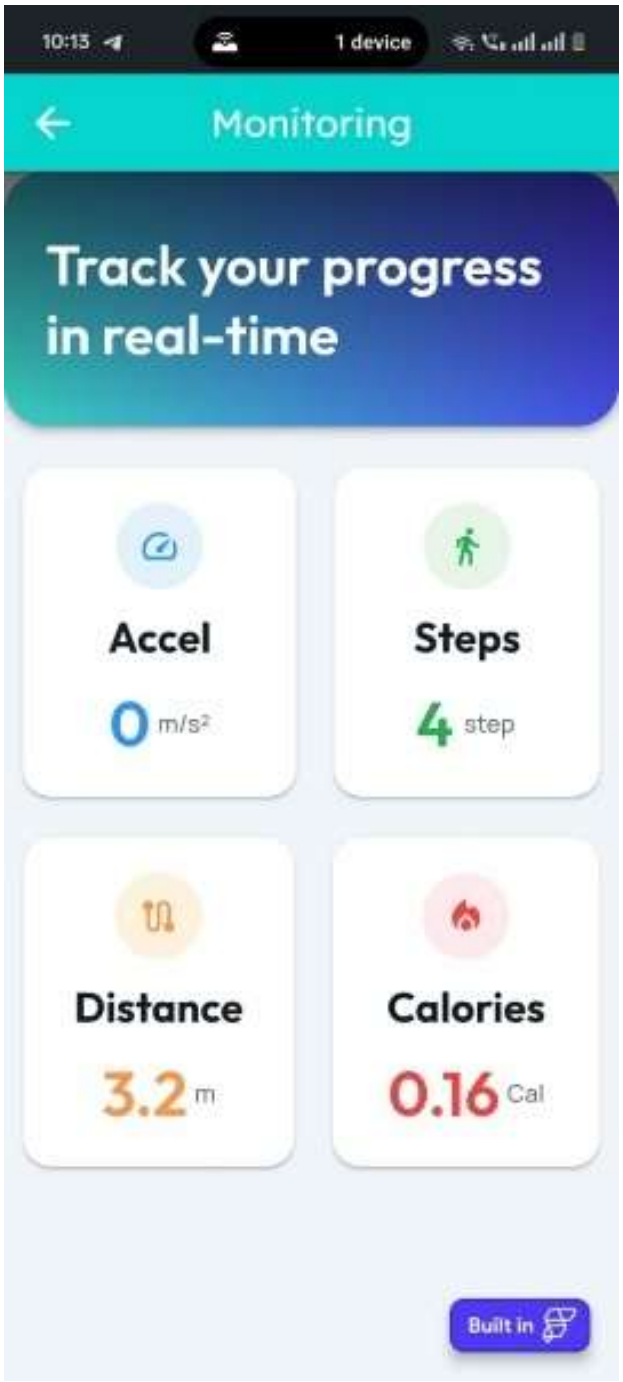

Fig 6.7. Real Time Parameter Tracker

Discussions-

The project successfully developed an integrated electronic module for smart shoes, combining fitness tracking, health monitoring, and safety features. The **ESP32 MCU**, with its Wi-Fi and Bluetooth capabilities, efficiently managed the system, processing and transmitting real-time data to the mobile application. Despite its performance advantages, the challenge of balancing power consumption with data transmission speed was addressed through optimization strategies. The **GY61 accelerometer and gyroscope** played a vital role in tracking movement, speed, momentum, and posture, which were essential for sports performance analysis and fall detection. However, careful sensor calibration was needed to ensure accurate data under varying conditions like walking or running. The **Neo 6M GPS module** provided reliable location tracking, enabling real-time safety features, particularly beneficial for elderly individuals or those in unsafe areas. Environmental factors such as tall buildings or dense forests, however, affected GPS accuracy.

The **piezoelectric sensor** effectively measured foot pressure, enabling precise step counting and gait analysis. While it performed well, further fine-tuning was necessary to avoid inaccuracies in detecting different foot activities like standing or sitting. The mobile application, developed on the **FlutterFlow** platform, displayed real-time data and integrated **Firebase Firestore** for cloud synchronization. **OpenStreetMap** provided accurate location mapping, enhancing user experience, although internet connectivity limitations affected real-time data transfer in areas with weak signals. The **rechargeable battery** supported continuous operation, though its capacity could be improved for extended outdoor use. Overall, the system demonstrated the potential of integrating various components for fitness, health, and safety, though further improvements in sensor calibration, power management, and location accuracy could enhance overall functionality and user experience. The project lays the foundation for developing more advanced smart footwear for personal health and safety monitoring.

Chapter 7

CONCLUSION, CONTRIBUTIONS AND SCOPE FOR FUTURE WORK

Conclusions, Contributions, Scope for Future work

7.1 Conclusions

The project titled *"Design of Electronic Module for Fitness, Health, and Safety in Smart Shoes"* successfully demonstrated the integration of multiple advanced components to create a compact, multifunctional wearable system. The use of the ESP32 MCU as the central controller enabled efficient data processing and wireless communication with the mobile application. The combination of GY61 accelerometer and gyroscope, Neo 6M GPS module, and piezoelectric sensor allowed for accurate tracking of physical activity, posture, step count, and location, supporting both fitness and safety applications.

The smart shoe system was further enhanced by a user-friendly mobile application built on FlutterFlow, real-time cloud data synchronization via Firebase Firestore, and emergency alerts sent using the Telegram API. The integration of OpenStreetMap enabled live location tracking and mapping for improved safety. Powered by a rechargeable battery, the module functioned effectively on the go. Overall, the prototype proved to be a promising solution for real-time fitness tracking, health monitoring, and personal safety, offering significant potential for athletes, the elderly, and individuals requiring mobility support.

7.2 Contributions

This project contributes significantly to the field of wearable health technology by designing a compact and efficient electronic module for smart shoes that integrates fitness, health monitoring, and safety functionalities. The system effectively utilizes the ESP32 MCU as a central controller for sensor management and wireless communication, enabling real-time data collection and transmission. By combining sensors like the GY61 accelerometer-gyroscope and the piezoelectric sensor, the project offers accurate analysis of motion, gait, and step count, which is highly valuable for athletes, health-conscious individuals, and rehabilitation patients.

In addition, the integration of the Neo 6M GPS module with real-time Telegram API alerts and OpenStreetMap visualization enhances user safety, particularly in emergencies. The project also contributes a practical mobile application developed in FlutterFlow, synchronized with Firebase Firestore, to display fitness metrics and location data seamlessly. Overall, this project presents a scalable, user-friendly, and cost-effective smart footwear solution with broad applications in healthcare, sports, and personal safety.

7.3 Scope for future work

The current smart shoe prototype lays a solid foundation for future innovations, and several enhancements can be made to improve functionality, accuracy, and user experience. One potential area for future work is the integration of additional health monitoring sensors, such as heart rate, body temperature, or SpO_2 sensors, to expand the health-tracking capabilities and provide a more comprehensive wellness solution. Machine learning algorithms could also be incorporated to enable intelligent analysis of user behavior, detect abnormal movement patterns, and personalize fitness recommendations.

Another area of development is power optimization. Although the rechargeable battery currently supports the system for several hours, future versions can explore solar charging or energy harvesting from walking to extend battery life. Moreover, offline data storage and sync capabilities can be added to ensure uninterrupted tracking even in areas with poor internet connectivity. Upgrading the mobile application to include voice assistant integration, multilingual support, and AI-based insights would also enhance accessibility and engagement, making the smart shoe system more adaptive and user-friendly across diverse populations.

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LIST OF DELIVERABLES ON PRESENT WORK

The following deliverables have been successfully achieved as part of the present work in the development of the smart shoe system:

- Design and fabrication of the smart shoe prototype using the ESP32 microcontroller.
- Integration of GY-61 accelerometer and piezoelectric sensor for accurate step detection.
- Development of algorithms for real-time calculation of distance walked and calories burned based on user inputs.
- Implementation of Neo 6M GPS module for continuous location tracking (latitude and longitude).
- Real-time data transmission and storage on Firebase Firestore for monitoring and analysis.
- Development of a custom Flutter-based mobile application titled "We-Fit" for visualizing user activity data.
- Integration of Telegram API for automated emergency alert notifications in the event of abnormal posture or orientation
- Monitoring and logging of Y-axis acceleration values for movement analysis.
- Implementation of fall detection mechanism using roll and pitch data derived from the accelerometer.
- Power supply management using a 3.7V batter

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ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Singh, Bakshish, Pongkit Ekvitayavetchanuku, Bharti Shah, Neeraj Sirohi, and Prachi Pundhir. "IoT-based shoe for enhanced mobility and safety of visually impaired individuals." EAI Endorsed Trans. Internet Things 10 (2024): 1-19. Publication	6%
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Date: 07/05/2025

TO WHOMSOEVER IT MAY CONCERN

We are happy to certify that following students of B.E. final year have won 2nd prize in the project competition held on 5th April 2025 at department of Electronics and Telecommunication Engineering, Shri Sant Gajanan Maharaj college of Engineering Shegaon.

PRG. No.	Class	Name of Student	Name of Project	Rank
7	4U1	**Arshadmatin Abukalam Shaikh**	Design of Electronic module for fitness, health and safety in smart shoes	2nd
	4U1	Ku. Prachi Avinash Untawale		
	4U1	Aryavart Nilesh Dahenkar		
	4U1	Om Gajanan Ingle		

We extend our best wishes to all above students and great success in all walks of life.

Dr. K. T. Kahar / Dr. R. S. Mahamune
Project Coordinators

Dr. D. D. Nawgaje
HOD-EXTC

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DESIGN OF ELECTRONIC MODULE FOR FITNESS, HEALTH AND SAFETY IN SMART SHOES

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ABSTRACT

One such smart technology in the upcoming internet of health things is smart shoes, which are the subject of this paper. A wearable shoe with a Medicare health and fitness monitoring system is introduced, along with its system architecture and adherence strategy. The Electronic Module for Fitness, Health, and Safety in Smart Shoes is a cutting-edge wearable Internet of Things system that tracks a user's location, movement patterns, and activity in real time. The system incorporates a piezoelectric sensor for step counting, a gyroscope sensor for motion analysis, and a GPS module for location tracking. An ESP32 microcontroller processes data from these sensors and transmits it wirelessly to a Flutter-based Android app, providing users with real-time insights on their fitness and safety metrics.

Keywords: IOT Technology, Real-Time Monitoring, Fitness and Health Tracking.

I. INTRODUCTION

Nowadays, IoT technology is used for many purposes that enhance consumer convenience in day-to-day living.These real objects have sensors of various types, electronics, and Internet connectivity. These embedded objects can be monitored and controlled remotely, and they can interact and communicate with each other via the Internet. A new era of assistive technologies and personalized health monitoring has been brought about by smart shoes. IoT-based sensors are integrated into this system to guarantee user security and deliver precise fitness insights.

Real-time location tracking is made possible by the GPS module, which increases safety when engaging in outdoor activities. A piezoelectric sensor precisely counts steps for fitness tracking, while a gyroscope sensor examines motion patterns to identify imbalances or odd movements. After processing the data from these sensors, the ESP32 microcontroller wirelessly sends it to an Android app built on Flutter, allowing users to view their activity and health information. A 7V lithium-ion battery powers the system, guaranteeing effective and continuous operation. The purpose of this smart shoe module is to give users real-time safety monitoring, improve mobility analysis, and improve fitness tracking.

II. LITERATURE REVIEW

1. Almomani, Ammar, et al. The system is based on Internet of Things (IoT) technology and uses three ultrasonic sensors to allow users to hear and react to barriers. It has ultrasonic sensors and a microprocessor that can tell how far away something is and if there are any obstacles. Water and flame sensors were used, and a sound was used to let the person know if an obstacle was near him. The sensors use Global Positioning System (GPS) technology to detect motion from almost every side to keep an eye on them and ensure they are safe.

2. Mishra, Janhvi, et al. In the proposed work the author presents an IoT-based model of the smart shoe for the blind people. In the model, they are using sensors, trackers, and buzzers. When we assemble them, they will provide path navigation help for the visually impaired to reach their destination safely. The proposed model is designed with the vision of improving the quality of life for visually impaired patients and their caretakers.

3. Ramzan, Aneeqa, et al. This paper proposes a novel technology of smart assistant aid for blind and visually impaired people (SSVIP) by developing a smart shoe prototype with sensors to detect obstacles, wet surfaces and ground vibrations, providing real-time feedback to the user. If any of these are detected, the controller

activates the buzzer and vibration motor, providing both audible alerts based on the detected sensor signal in order to alarm the wearer and tactile feedback respectively. SSVIP is then tested on 20 iterations after configuring and calibrating sensors and getting the optimized 20 units for ultrasonic sensor, 650 threshold for water sensor.

4. Singh, Bakshish, et al. This paper, clearly states the research objectives, such as designing and developing an IoT-based shoe prototype. Outline the specific functionalities and features that the shoe should encompass, such as GPS tracking, proximity sensors, and wireless communication. It combines IoT connectivity, sensors, and a mobile application to provide real-time location tracking, obstacle detection, fall detection, auditory feedback, and customization options tailored to the needs of visually impaired individuals.

5. Ather, Anas Ahmed, et al. In this paper, the main element is a technologically advanced shoe fitted with ultrasonic sensors based on Arduino, which enables immediate identification of obstacles and provides feedback to ensure safe navigation. In addition to this, a web application utilizes artificial intelligence-based object detection using a camera, providing instant visual information through a smartphone. In addition, an Android application tracks daily steps and promotes physical activity by incorporating gamification and individualized challenges. Initial testing suggests that the intelligent footwear consistently identifies barriers, hence improving the user's ability to move around and boosting their self-assurance.

6. David, Elisa, et al. In this paper, the author presents a shoe that alerts the user with buzzer sounds upon detecting obstacles ahead. To enhance efficiency, smart glasses using IoT technology have been developed, equipped with sensors to detect objects over a wider area. The smart shoes and smart glasses communicate and coordinate to ensure the user avoids collisions with obstacles in their path.

7. Makanyadevi, K., M. V. Avinash, et al. In this paper, This project proposes a wearable assistive system aimed at improving navigation for visually impaired individuals. The system integrates AI-powered smart glasses and specially designed shoes, working together to enhance the user's ability to detect and avoid obstacles in their surroundings. Central to the system is the YOLOv8 (You Only Look Once) algorithm, a state-of-the-art deep learning model that enables real-time object recognition. The smart glasses use this model to detect and classify objects such as people, vehicles, and potential obstacles, providing immediate feedback to the user regarding their environment. In addition to the object recognition capabilities of the glasses, the system employs ultrasonic sensors in both the glasses and shoes to detect nearby objects or obstacles. These sensors measure the distance to obstacles and provide critical information on the proximity of objects. When an obstacle is detected within a dangerous range, the system alerts the user using a buzzer and a vibration sensor, enhancing their spatial awareness

8. Ikram, Sunnia, et al. The system is equipped with an ultrasonic sensor, PIR sensor and a buzzer, with data processing managed by an Arduino Uno microcontroller. To enhance detection accuracy, multiple machine learning algorithms including Decision Tree (DT), Support Vector Machine (SVM), K-Nearest Neighbour (KNN), Random Forest (RF) and Gaussian Naïve Bayes (GNB) are utilized. A novel Voting Classifier ensemble method is proposed, effectively combining the strengths of these classifiers to maximize performance. Rigorous cross-fold validation ensures robust evaluation under varying conditions.

9. Okolo, Gabriel Iluebe, et al. The system aims to promote the independence of visually impaired navigation by offering guidance with auditory feedback and tactile input to the visually impaired user upon object recognition. The created mobile application uses voice and audio only to provide navigational guidance to users. The object detection model used is YOLOV8, implemented on a Raspberry Pi equipped with a camera, speaker, ultrasonic sensor, and moisture sensor.

The average accuracy score of nine tested obstacles using YOLOV8 was 91.70%.

10. Mahalakshmi, K., S. Arunbalaji, et al. In this paer, the author presented a smart shoe system that intended to improve the safety and mobility of people with vision impairments. The system combines state-of-the-art technology with an Android app to deliver alarms and help in real-time. An Arduino NANO microcontroller, an ultrasonic sensor, a water level sensor, a piezoelectric plate, and a solar panel make up the system's hardware core. The Ultrasonic Sensor facilitates navigation and obstacle identification by allowing distance measurement. By warning people when there are any puddles of water or damp surfaces, the Water Level Sensor protects the

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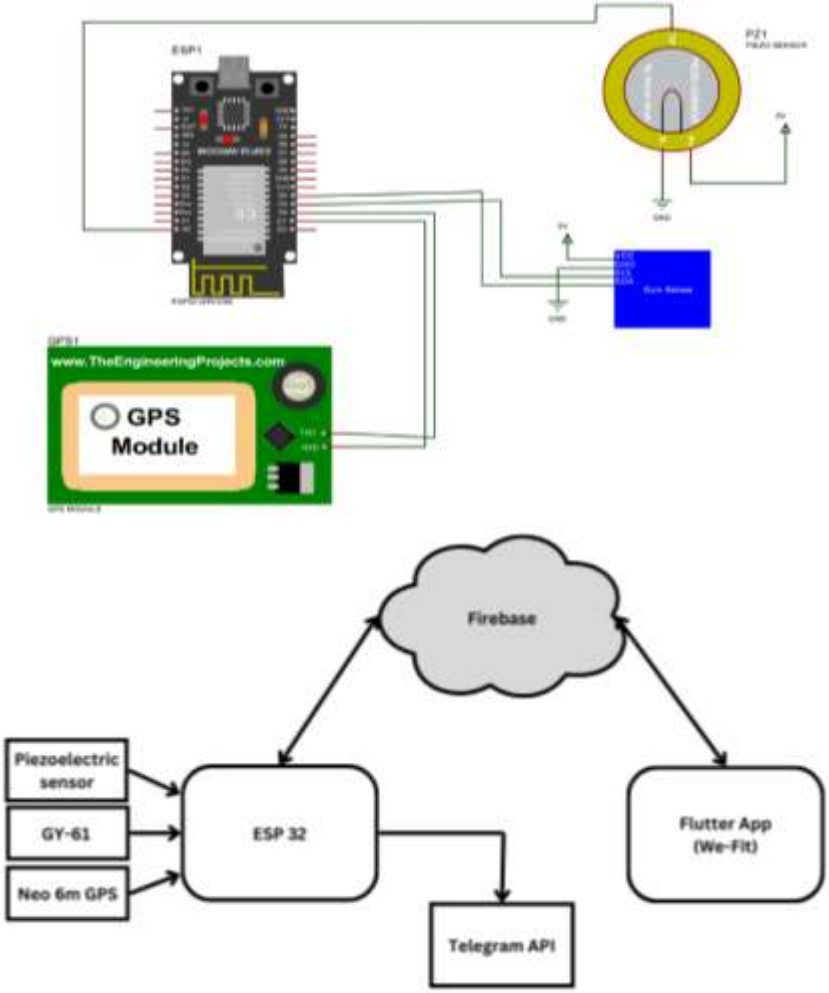
environment. A piezoelectric plate produces tactile feedback that gives the user direction signals or cautions. An Arduino NANO microcontroller controls the integration of these sensors and actuators by processing incoming data and initiating the proper reactions according to pressed algorithms.

III. METHODOLOGY

Through IoT-based integration, the Electronic Module for Fitness, Health, and Safety in Smart Shoes aims to improve real-time monitoring, movement analysis, and user tracking. The system processes and sends data from several sensors to an Android app created with Flutter via an ESP32 microcontroller. The user's location is tracked by a GPS module, which guarantees safety and real-time monitoring. By analyzing motion patterns, a gyroscope sensor can reveal information about activity levels and movement stability. A piezoelectric sensor also helps with fitness tracking by counting steps. The mobile app receives all gathered data wirelessly and provides users with comprehensive analytics and insights. The system is powered by a 7V lithium-ion battery, which guarantees effective and durable operation. The goal of the paper is to create a wearable, intelligent technology solution for people who want to track their movements and are fitness enthusiasts.

The integrated sensors in the smart shoe system are used to continuously gather and process data. While the gyroscope sensor detects motion, orientation, and movement stability, the GPS module logs the user's current location. By transforming mechanical pressure into electrical signals, the piezoelectric sensor keeps track of how many steps are taken. The ESP32 microcontroller processes these sensor readings and wirelessly sends the information to an Android app built on Flutter through Bluetooth or Wi-Fi. After that, the app shows real-time data such as motion insights, step count, and location tracking. A 7V lithium-ion battery powers the system, guaranteeing smooth operation for prolonged periods of time. With this configuration, users can effectively monitor safety, health, and fitness-related metrics in a small, wearable package.



Flow Chart

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IV. SYSTEM REQUIREMENT

HARDWARE REQUIREMENT

1. Sensor Integration and Data Acquisition

a) Piezoelectric Sensor

A piezoelectric sensor is placed in the sole of the shoe to detect the mechanical impact of a footstep. When pressure is applied during walking or running, the piezo element generates a voltage spike. These spikes are used as raw indicators of steps taken.

b) GY-61 Accelerometer

The GY-61 module is a 3-axis analog accelerometer. In this project, it serves multiple purposes:

- **Acceleration Calculation**: Acceleration is calculated using the **Y-axis** output of the GY-61 and referred to simply as "acceleration". This helps in distinguishing real steps from false movements like shaking or noise.
- **Roll and Pitch Detection**: By processing the X and Z axis data, the roll and pitch angles of the shoe are calculated. These are used to detect the orientation of the shoe—particularly useful in determining if the user has fallen or is in an unusual position (e.g., upside down).
- **Fall Detection**: If the shoe remains upside down (beyond a defined roll or pitch angle) for a certain threshold period, it is assumed that the wearer has fallen. This triggers an emergency response mechanism.

c) Neo 6M GPS Module

The Neo 6M GPS module is used to continuously track the user's geographic location. It provides:

- **Latitude**
- **Longitude**

This GPS data is sent to Firebase and also included in emergency messages for location-based alerts.

2. Microcontroller Unit – ESP32

The ESP32 is the central microcontroller that connects and coordinates all components. It handles:

- Reading analog signals from the piezo sensor and GY-61
- Processing sensor data to detect steps and monitor orientation
- Establishing Wi-Fi connection
- Communicating with Firebase Firestore for data storage
- Sending messages via the Telegram Bot API for emergency alerts

3. Step Detection Algorithm

The step counting is based on a hybrid approach that combines:

- **Piezo spike detection**: Identifies a step event based on impact.
- **Y-axis acceleration threshold**: Confirms whether the motion corresponds to a valid step.

By using both the piezo and the GY-61 data, false positives (e.g., dropping the shoe or minor movements) are filtered out, improving accuracy.

1. Step to Distance Conversion

Formula:

Distance (in meters) = Step Count ÷ STEPS_PER_METER

Constant Used:

STEPS_PER_METER = 1.25

Explanation:

- We assume an **average step length of 0.8 meters**.
- Therefore, a person takes approximately **1.25 steps to cover 1 meter**.
- This value is based on general studies which indicate:
  - Average adult step length = **0.7 to 0.8 meters**

- Varies based on **height, leg length, and gender**

Reference:

- American College of Sports Medicine (ACSM) Guidelines

2. Step to Calories Conversion

Formula:

Calories Burned = Step Count × CALORIES_PER_STEP

Constant Used:

CALORIES_PER_STEP = 0.04

Explanation:

- On average, **1 step burns around 0.04 kilocalories** (kcal)
- Based on general fitness studies with average body weight assumptions:
- Weight ≈ **60–70 kg**
- Walking **1 km (~1250 steps)** burns **≈ 40–50 kcal**
- So per step ≈ 40 ÷ 1000 = **0.04 kcal**

Reference:

- Harvard Medical School – Calorie Estimates
- Healthline Fitness Articles
- Smartwatch & Step Counter Analytics

5. Emergency Detection and Telegram Integration

a) Fall Detection Logic

If the GY-61 detects an upside-down orientation (based on roll or pitch) and this condition persists beyond a predefined threshold time, it is interpreted as a fall or critical event. A timer is used to ensure that short or accidental inversions do not trigger false alerts.

b) Telegram Alert System

Once a fall is confirmed:

- The ESP32 triggers a **Telegram message** using the **Telegram Bot API**.
- The message is sent to pre-configured recipients (e.g., family or medical staff).
- The alert includes the **exact GPS location** (latitude and longitude), enabling responders to locate the user quickly.

This system ensures rapid response in emergencies without the need for user interaction.

SOFTWARE REQUIREMENT

1. Mobile App – We-Fit (Flutter)

The We-Fit app is a custom mobile application built using the **Flutter framework**. It serves as the user interface for real-time data display and monitoring. Features include:

- Live display of **steps, distance, and calories burned**
- Real-time **GPS location map**
- Emergency alert indicator
- Daily and historical tracking (based on Firestore logs)

The app fetches data from **Firebase Firestore**, ensuring seamless cloud-based synchronization.

2. Cloud Storage with Firebase Firestore

All relevant user data is pushed to **Firebase Firestore** for storage and retrieval. This includes:

- Step count
- Distance covered
- Calories burned

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- Acceleration values
- Roll and pitch status
- Latitude and longitude

Data is stored in structured documents, enabling easy access by both the mobile app and potential analytics tools in the future.

Power Supply

The system is powered by a **3.7V lithium battery**. It is compact and lightweight, making it ideal for wearable applications. A charging module will be added in later stages for USB recharging. Power optimization techniques can be applied in future updates to improve battery life

V. IMPLEMENTATION & RESULT

Hardware Implementation Of shoe

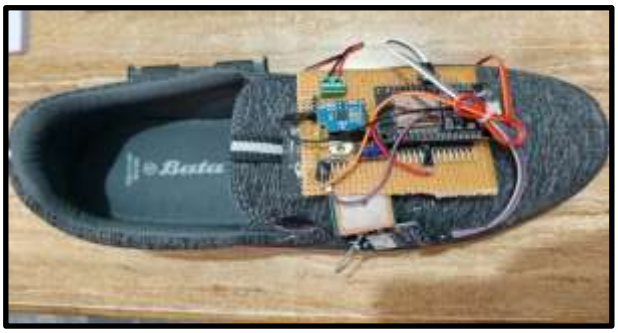
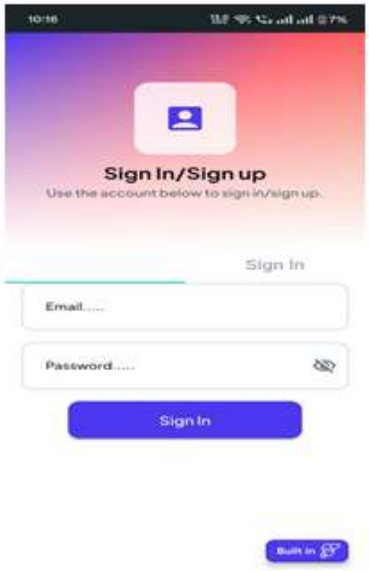


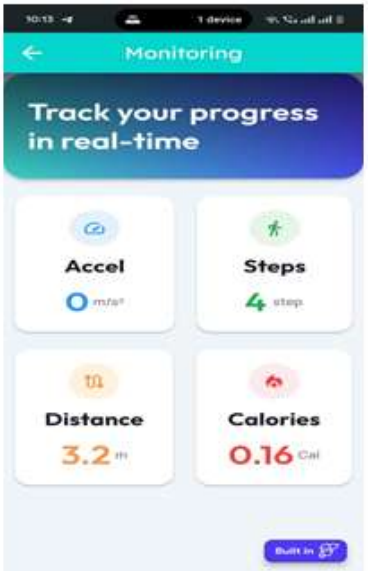
Fig: show Actual Experimental Setup_1

Fig: shows Actual Experimental Setup_2

RESULT:

We have made an Android Application as our Front end for monitoring and showing all the result





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VI. CONCLUSION

Modern IoT-based sensors are integrated into the Electronic Module for Fitness, Health, and Safety in Smart Shoes to offer real-time tracking, movement analysis, and fitness monitoring in a smooth, intuitive system. The system prioritizes user safety while providing precise health insights through the use of a piezoelectric sensor for step counting, a gyroscope for motion detection, and GPS for location tracking. Users can easily track their fitness metrics thanks to the ESP32 microcontroller's efficient processing and transmission of data to an Android app built on Flutter. By providing a dependable, intelligent, and effective wearable solution for athletes, fitness enthusiasts, and people in need of improved mobility tracking, this paper closes the gap between technology and fitness.

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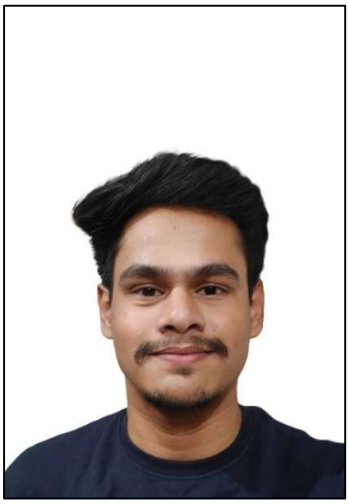

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