

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%.

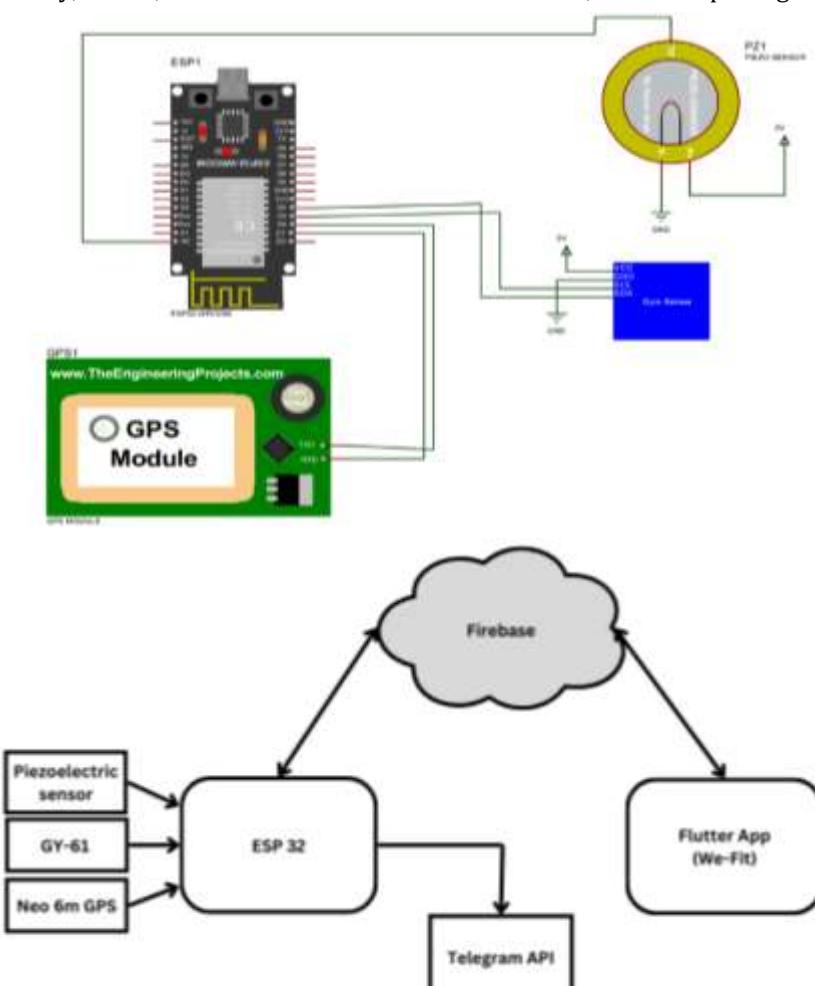
10. Mahalakshmi, K., S. Arunbalaji, et al. In this paer, the author presented a smart shoe system that intended to improve the safety and mobility of people with vision impairments. The system combines state-of-the-art technology with an Android app to deliver alarms and help in real-time. An Arduino 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

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

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**

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

Reference:

- American College of Sports Medicine (ACSM) Guidelines

2. Step to Calories Conversion**Formula:**

$$\text{Calories Burned} = \text{Step Count} \times \text{CALORIES_PER_STEP}$$

Constant Used:

$$\text{CALORIES_PER_STEP} = 0.04$$

Explanation:

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

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

- 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

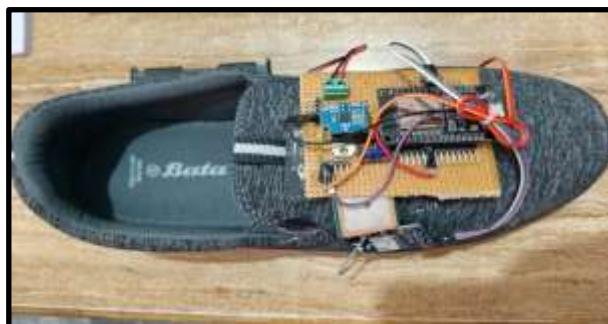


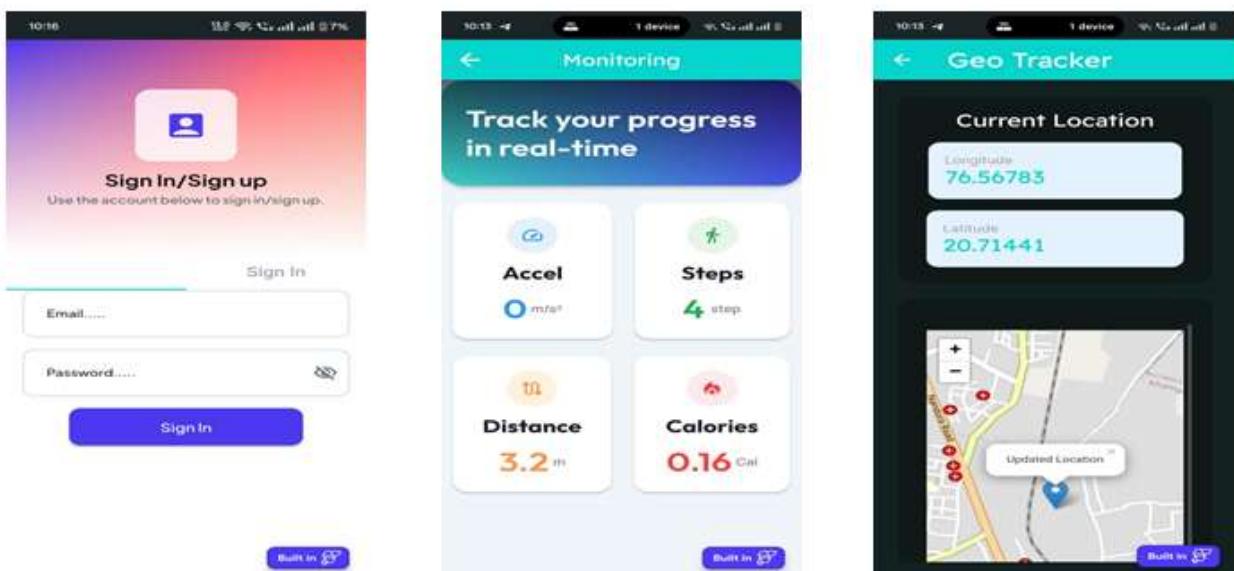
Fig: show Actual Experimental Setup_1

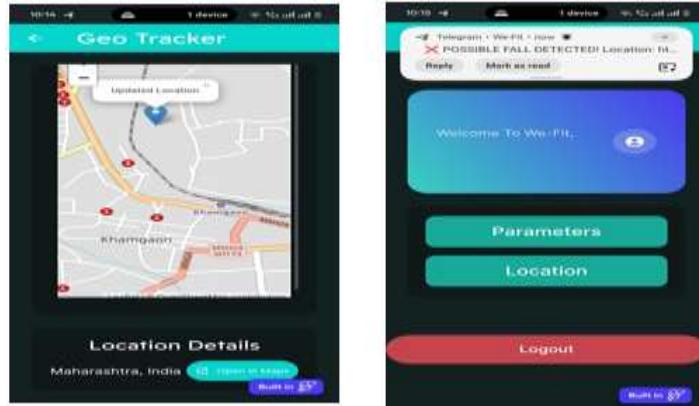


Fig: shows Actual Experimental Setup_2

RESULT:

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





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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