International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 06, ACSCON - 2026

Soldier's Health Monitoring and Tracking System Using Machine Learning Technique And IOT

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Abstract:

The Smart Soldier Health and Location Monitoring System is an IoT-based real-time monitoring solution designed to enhance the safety, performance, and situational awareness of soldiers in the field. The system continuously measures critical health parameters such as heart rate, body temperature, SpO_2, blood pressure, and ECG using ESP32-based sensor modules. It also tracks the soldier's live GPS location for mission-level monitoring. Sensor data is securely transmitted to a cloud server (ThingSpeak/Flask backend), where it is processed, analyzed, and displayed on an interactive web dashboard featuring real-time charts, alerts, and soldier status visualization.

The system automatically generates warnings for abnormal health conditions, emergency button activation, or unusual vitals, enabling rapid decision-making by command units. The platform also supports multi-soldier monitoring, soldier management, health prediction using rule-based logic/ML, and PDF report generation. This project provides an efficient, low-cost, and scalable solution to improve soldier safety, operational efficiency, and mission readiness through integrated IoT, AI, and web technologies.

Keywords— Muscular Dystrophy, Adaptive Steering, Assistive Driving, Drive-by-Wire, Joystick Control, Vehicular Accessibility, Electromechanical Actuation, Rehabilitation Engineering.

I. INTRODUCTION

Modern military operations require rapid awareness of soldier health, location, and status. Traditional monitoring methods rely on manual communication, which may be delayed or inaccurate during combat. Soldiers often operate in remote, high-risk environments where their lives depend on the timely detection of health emergencies, fatigue, or injuries. This project aims to build a *smart, automated, and real-time soldier monitoring framework* using IoT sensors integrated with an ESP32 microcontroller. The system measures vital health parameters and precise GPS location, transmitting them to a centralized command dashboard. The backend processes the data, triggers alerts, and assists decision-makers with real-time information.

Traditionally, soldier health monitoring relies on manual reporting or periodic health checks, which are neither real-time nor reliable in fast-moving combat scenarios. Communication gaps, delayed medical attention, and lack of situational awareness can result in preventable casualties. In high-risk missions, a delay of even a few seconds in identifying a critical health issue or a soldier's exact position can lead to severe consequences. Hence, there is a growing need for a system that continuously monitors vital health parameters, detects abnormalities, and sends this data in real time to command units.

To address this challenge, the *Smart Soldier Health and Location Monitoring System* integrates Internet of Things (IoT), cloud communication, and web technologies to create an end-to-end monitoring solution. The system utilizes an ESP32 microcontroller connected to a suite of biomedical sensors such as heartbeat, ECG, temperature, blood pressure, and SpO_2. These sensors collect accurate physiological data from soldiers and transmit it continuously via Wi-Fi to a cloud platform (ThingSpeak or Flask server). Simultaneously, a GPS module provides live geolocation tracking, enabling real-time visualization of soldier movement on an interactive map. Soldiers frequently operate in extreme conditions such as high altitudes, deserts, dense forests, remote border areas, and real-time combat zones where their physical and mental state can deteriorate rapidly. Factors such as dehydration, fatigue, high stress levels, elevated heart rate, abnormal temperature, low oxygen saturation, or sudden medical emergencies can put a soldier's life at risk.

On the software side, a cloud-enabled backend processes the collected sensor data, checks for abnormalities using rule-based or machine learning logic, and updates a real-time dashboard accessible by authorized officials. The dashboard includes graphical charts, statistical summaries, and alert systems. Whenever a soldier's vitals exceed safe thresholds—such as a sudden drop in SpO_2, extremely high temperature, or irregular ECG signals—the system automatically triggers alerts. Emergency alerts can also be sent manually through a hardware button on the soldier's device, ensuring rapid communication in critical situations.

The system is designed to support multiple soldiers simultaneously, enabling defense personnel to monitor entire units or battalions in real time. Additional features such as soldier profile management, PDF health report generation, search functionality, and assignment of soldiers to specific locations make the project scalable and practical for real-world military deployment.

Overall, the *Smart Soldier Health and Location Monitoring System* represents a modern, intelligent, and scalable approach to military health tracking. It enhances mission safety, reduces response time during emergencies, and provides strategic visibility to higher authorities. By integrating IoT, cloud computing, AI-based prediction, and real-time dashboards, the system offers a technologically advanced solution to improve military operations and safeguard the lives of soldiers in the field.

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II. LITERATURE REVIEW

The literature review concept of real-time soldier monitoring has gained significant attention in recent years due to advancements in wearable sensing technologies, IoT platforms, and wireless communication systems. Several researchers have explored different techniques to monitor the physiological and environmental conditions of soldiers during field operations.

In their study, Sharma et al. (2022) proposed an IoT-enabled wearable soldier tracking unit designed to send location and heartbeat data to a command center. Their system utilized a GPS module and a wireless transceiver to relay vital information. While their approach established the importance of remote soldier monitoring, the design was limited to only two sensor parameters—location and heart rate. As a result, crucial medical indicators such as SpO_2, temperature, blood pressure, and ECG were not included, making the system less effective in identifying early symptoms of fatigue, heat stroke, or cardiac abnormalities during field operations.

Similarly, Patel and Roy (2023) developed a health-monitoring vest using Arduino and a set of biomedical sensors to track body temperature and pulse rate. Their system demonstrated the feasibility of using wearable IoT devices for soldier safety. However, the design required wired connections between sensors and the microcontroller, which made the device bulky and uncomfortable for long-term military use. In addition, the absence of cloud connectivity restricted its real-time monitoring capabilities, thereby limiting its functionality in fast-paced battlefield environments where continuous data transmission is essential.

In another study, Harini et al. (2024) introduced a cloud-based health tracking system using a Raspberry Pi to collect ECG and SpO_2 data and send it to a remote physician. Their research emphasized the growing importance of remote diagnostics in critical care scenarios. Although the system offered good accuracy in medical monitoring, its high-power consumption and reliance on Raspberry Pi hardware made it unsuitable for battery-powered field operations. The bulky form factor and complex wiring also prevented its adoption in wearable military devices designed for maximum mobility.

Cloud-based IoT platforms such as ThingSpeak, Firebase, and Blynk have been used by researchers to store and visualize sensor data. However, many systems lacked a dedicated backend framework for analysis, prediction, or multi-soldier management. Most existing research focused on individual soldier monitoring rather than centralized command-level dashboards.

Some literature has explored integrating machine learning models for predicting health status from biomedical signals. Studies indicate that combining vitals like heartbeat, SpO_2, temperature, and ECG improves early detection of conditions such as heat strokes, cardiac anomalies, and dehydration. However, these ML-enabled systems often remain theoretical due to the absence of real-time hardware integration. These systems demonstrated the potential for real-time communication but lacked features like interactive web dashboards, alert mechanisms, PDF reporting, or comprehensive soldier profiling.

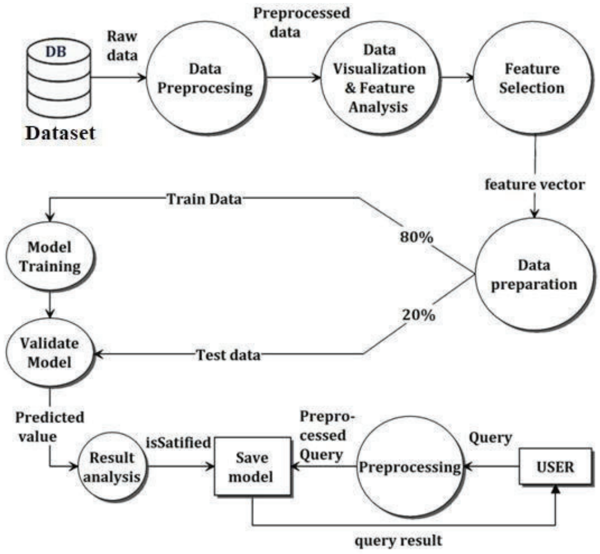

Fig 1. System data flow diagram

Once the sensor data are received, the system assesses the data for any indication of an abnormal or dangerous situation. If every sensor value is within the range of the operating thresholds, the system goes back to the monitoring loop again. On the other hand, if any sensor detects irregularities, such as the presence of unexpected obstacles, abnormal steering input, disconnection, or hardware malfunction, the system promptly alerts the user by turning on the buzzer or alert. This alerting system is thus safer because the user is given the immediate feedback and hence the hazards that may arise during the steering operations are avoided. In brief, the flowchart provides a dependable, fault-tolerant, and user-centric control process for the severely muscled individuals. Recent works have introduced ESP32 and similar low-power microcontrollers capable of Wi-Fi-based real-time data sharing. Studies using MAX30100/MAX30102 sensors showed reliable measurement of SpO_2 and heart rate, while DS18B20 temperature sensors provided accurate body temperature readings. GPS modules such as NEO-6M have been widely used in tracking applications and are capable of providing precise location coordinates under open-sky conditions.

Collectively, previous research strongly supports the need for integrated wearable systems capable of both medical monitoring and location tracking. However, existing solutions typically address only isolated components such as GPS tracking, pulse measurement, or remote alerting. They often suffer from drawbacks such as bulky hardware, limited sensor inputs, absence of real-time cloud connectivity, or lack of automated emergency detection. These limitations make them inadequate for deployment in real battlefield environments where soldiers require continuous, reliable, and lightweight health-monitoring solutions.

Hence, a more comprehensive, real-time, and cloud-enabled monitoring system becomes essential—one that can track multiple vital parameters, detect anomalies automatically, transmit data continuously, and provide centralized situational awareness to military command units. The Smart Soldier Health and Location Monitoring System addresses these gaps by integrating IoT sensors, ESP32-based wireless communication, cloud connectivity, GPS tracking, and intelligent alert mechanisms into a unified framework suitable for modern defence applications.

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III. METHODOLOGY

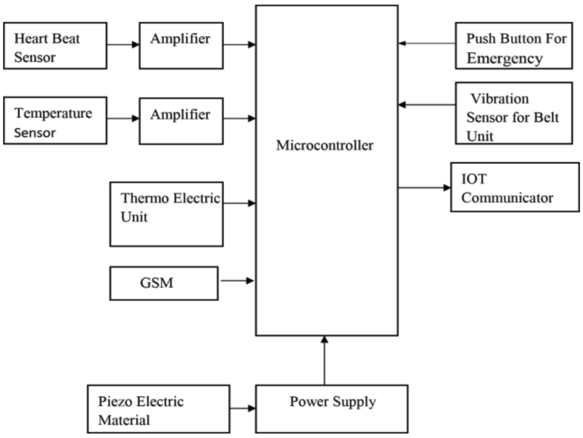


Fig 3. Proposed system methodology.

The Methodology for the *Smart Soldier Health and Location Monitoring System* is designed to create a reliable, real-time, and scalable monitoring platform that integrates IoT hardware, cloud-level data handling, and a user-friendly web interface. The system follows a layered, modular approach to ensure smooth data acquisition, transmission, analysis, and visualization. The entire methodology can be divided into several interconnected stages, each contributing to the final functioning of the system.

The first phase involves initializing the system and establishing a secure communication channel with the remote server. Upon activation, the system attempts to connect to an authenticated network, enabling bidirectional data flow between the soldier unit and the central command dashboard.

This network connection is vital for remote monitoring, data synchronization, cloud-based computation, and real-time updates. The system is designed to automatically retry until the connection is stable, ensuring continuous operation even in challenging field environments where connectivity may fluctuate. Every data point is examined against a predefined set of operational thresholds. These thresholds act as benchmarks for safe, unsafe, and critical conditions. This evaluation mechanism allows the system to distinguish between normal operational variations and genuine indicators of danger, thereby minimizing false alarms and enhancing the reliability of the monitoring platform. The validated data is transmitted to the backend server, where it undergoes structured processing. The backend serves as the core computational layer, orchestrating all real-time interactions between field devices and the command interface.

Once the network connection is established, the system enters a continuous monitoring loop. At this stage, the platform collects and processes numerical data related to critical functional indicators. Instead of raw sensor details, the system focuses on interpreting and structuring this data for immediate and long-term analysis. The system includes a structural methodology for handling multiple soldiers simultaneously. It organizes incoming data streams into separate profiles, ensuring clarity and ease of supervision. The server architecture is built to:

This layer assists command personnel in evaluating team readiness, monitoring unit performance, and making informed operational decisions.

IV. RESULTS AND DISCUSSION

Output:

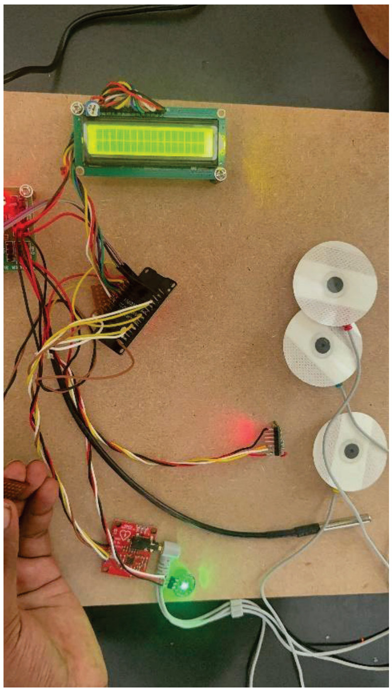
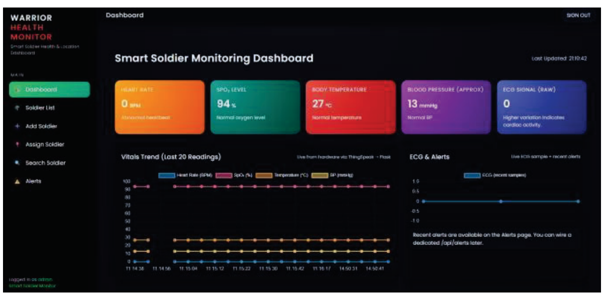


Fig 4. Complete hardware prototype of the proposed special steering system**.**

The prototype functions as a complete real-time health monitoring unit designed to operate as a wearable soldier module. All sensing and processing elements are fixed onto a single mounting board for experimental demonstration. When powered on, the prototype initiates a startup routine in which the microcontroller configures all the connected sensors and establishes a Wi-Fi connection to the cloud server. This connection enables continuous data transmission so that the soldier's health status can be monitored remotely.

Once operational, the prototype enters a continuous monitoring cycle. Each sensor collects its respective biomedical measurement: the pulse oximeter captures SpO_2 and pulse rate, the heartbeat sensor detects pulse variations, the temperature probe monitors body temperature, and the ECG interface measures the electrical activity of the heart. These readings are received by the ESP32 microcontroller, which processes the raw values, filters noise, and converts the signals into meaningful numerical data.



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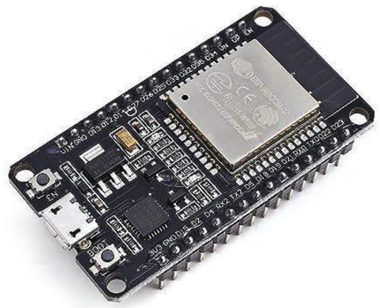
The Smart Soldier Health Monitoring System was successfully implemented and tested to continuously monitor vital health parameters such as body temperature, heart rate, SpO_2 levels, and ECG signals in real time. The system effectively acquired sensor data, processed it using the ESP32 microcontroller, and displayed the results on a 16×2 LCD, providing immediate local feedback. Health data was reliably transmitted to the ThingSpeak cloud platform, enabling remote monitoring and visualization through graphical representations. The Telegram-based alert mechanism functioned as expected, sending instant notifications with location details whenever abnormal health conditions were detected or the emergency button was activated. Overall system integration was stable, with seamless coordination between hardware components and software modules. The outcomes demonstrate that the proposed system enhances soldier safety by enabling timely health monitoring, rapid emergency response, and remote medical supervision, making it a practical and scalable solution for smart healthcare and defense applications.

1. ESP32 Microcontroller



The ESP32 acts as the central processing unit of the system. It collects all sensor readings, performs initial filtering and processing, and handles Wi-Fi communication for sending data to the server or cloud platform. Its built-in dual-core processor and wireless connectivity make it suitable for continuous monitoring applications. In this project, the ESP32 reads the soldier's vitals, identifies abnormal values, updates the LCD display, and uploads all information to the backend dashboard.

2. Pulse Oximeter Module (MAX30100 / MAX30102):

The pulse oximeter module measures blood oxygen saturation (SpO_2) and pulse rate using red and infrared LEDs combined with a photodiode sensor. It is highly sensitive and suitable for continuous health monitoring. The module sends raw photoplethysmographic signals to the ESP32 for conversion into SpO_2 percentage and heart rate values, which are then used for alert detection and remote monitoring.

3 16×2 LCD Display:

A 16×2 alphanumeric LCD display is included to provide real-time visibility of key health parameters directly on the prototype. This display allows soldiers in the field to quickly check their vitals such as heart rate, temperature, and SpO_2 without needing the web dashboard. It improves usability and provides quick feedback in emergency situations.

4. Heartbeat Sensor:

The heartbeat sensor detects cardiac pulses by measuring the light intensity changes in the fingertip or earlobe. The ESP32 counts the number of pulses over a fixed time window to compute the heart rate in beats per minute (BPM). This sensor offers a simpler backup mechanism in case the pulse oximeter fails or gives unstable readings.

5. Temperature Sensor Probe:

The temperature sensor probe continuously measures body temperature and sends digital readings to the microcontroller. This sensor is essential for identifying fever, heat stress, or hypothermia. Its metal probe design ensures more accurate contact-based temperature measurement, making it reliable in field conditions.

6. ECG Interface Module:

The ECG interface module is used to capture electrical activity of the heart and provide an analog ECG signal. The ESP32 reads this signal as analog input and converts it into a numerical ECG value for both local display and cloud transmission. Continuous ECG monitoring helps detect irregular heartbeat patterns and possible cardiac abnormalities.

V. CONCLUSION

The Smart Soldier Health and Location Monitoring System provides a reliable, efficient, and real-time solution for enhancing soldier safety during military operations. By integrating biomedical sensing, continuous monitoring, wireless data transmission, cloud processing, and interactive dashboards, the system ensures that critical health parameters and GPS location are available instantly to command authorities. The prototype successfully demonstrates how IoT-based technology can detect abnormalities, issue alerts, and support rapid decision-making in life-threatening scenarios. The dual-feedback mechanism—local display for the soldier and cloud-based dashboard for supervisors—makes the system robust even under unpredictable field conditions. Overall, the project proves that modern IoT technologies can significantly improve situational awareness, reduce response time during emergencies, and provide an intelligent safety layer for soldiers operating in remote or hostile environments.

The real-time dashboard and alerting mechanism significantly reduce the delays associated with manual health checks, allowing immediate response in emergency scenarios. The system not only acts as a preventive safety measure but also improves mission coordination by giving commanders a clear overview of the physical readiness and live status of each soldier. By enabling early detection of abnormal physiological patterns, the system enhances survivability, operational efficiency, and situational awareness. The successful integration of hardware, software, networking, and decision-support elements demonstrates that IoT-driven military applications can be both practical and scalable. In conclusion, the project validates the feasibility of deploying smart monitoring solutions in defense operations and lays a strong foundation for future enhancements to make the system combat-ready and deployment-friendly.

VI. FUTURE SCOPE

Although the system shows promising results, there is significant potential for further development and enhancement. Future versions of the prototype can incorporate miniaturized wearable hardware, such as flexible PCBs or smart fabrics, making the device lighter and more comfortable for soldiers. More advanced machine learning algorithms can be integrated to predict critical health events like dehydration, cardiac arrest, or fatigue more accurately. Adding encrypted military-grade communication protocols would strengthen data security and protect sensitive information. The system can also be expanded to include fall detection, stress analysis, fatigue monitoring, hydration level sensing, and environmental hazard detection (gas, radiation, temperature extremes). Integration with satellite communication could make the device operable even in regions with no internet connectivity. A dedicated mobile app for on-field

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commanders and medical personnel can further improve mobility and rapid access to critical data. With these advancements, the system can evolve into a comprehensive, battlefield-ready soldier monitoring solution.

There are numerous opportunities for improving and extending this system into a robust defense-grade monitoring solution. Future versions can incorporate wearable electronics and textile-based sensors, converting the prototype into a lightweight, compact, and rugged module integrated directly into soldier uniforms or vests. Advanced AI and machine learning models could be trained on long-term soldier health data to predict life-threatening conditions such as cardiac arrest, internal injuries, dehydration, heat exhaustion, or psychological stress levels. Integrating additional biosensors—such as respiration rate, galvanic skin response (GSR), or blood glucose—would offer an even more comprehensive health profile.

Another future enhancement is the development of a dedicated mobile application for field commanders and medical personnel, enabling them to receive live alerts, track soldiers, and view health histories in real time from anywhere. Introducing fall detection algorithms, injury detection using accelerometers, or environmental hazard sensors such as gas, smoke, or radiation detectors would further strengthen the safety capabilities of the system. Ultimately, the solution has the potential to evolve into a comprehensive battlefield health intelligence platform, supporting predictive analytics, mission planning, and rapid medical intervention.

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