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Real-Time Physiological Monitoring and Automated Alert System for Enhanced Soldier Safety and Survivability

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Abstract— This research introduces the "Wounded Soldier Auto-Alert System," a prototype designed to significantly increase the survival rates of military personnel in combat zones. In high-stakes environments, the delay between an injury and medical intervention is often the difference between life and death. Our system addresses this by integrating a pulse sensor to continuously monitor critical physiological parameters—specifically vital signs, specifically pulse and internal heat. Using a Wi-Fi-enabled communication hub, this streams the readings instantly to a central processing unit. The system's primary innovation is its ability to autonomously detect anomalies; if a soldier's vital signs indicate distress, the system immediately dispatches an alert to command, complete with the soldier's pre-registered location. This moves military health monitoring from passive data collection to a proactive, life-saving tool, streamlining emergency response coordination.

1. INTRODUCTION

Modern warfare exposes soldiers to dynamic and hazardous environments where physical trauma, heat exhaustion, and hypothermia are constant risks. Historically, the military has relied on manual protocols to track the health of deployed units—often involving radio check-ins or visual confirmation. However, in the chaos of the field, these methods are prone to human error and significant delays. If a soldier is incapacitated and unable to call for help, their critical condition may go unnoticed until it is too late.

To address this specific oversight, this paper proposes the "Wounded Soldier Auto-Alert System." This technology is engineered to provide an objective, real-time view of a soldier's physiological status. By leveraging wearable sensor technology, we can track heart pulse speed and thermal levels, which are the two most reliable indicators of immediate health crises like shock or trauma.

The core objective of this research is to automate the "call for help." Unlike conventional systems that merely keep a historical record for future review, our system is designed to act. It continuously analyzes incoming data streams; the moment a vital sign breaches a safe threshold, the system triggers a high-priority alert to the central command. By coupling this health data with location tracking, we aim to provide commanders with immediate situational awareness, allowing for faster decision-making and rapid deployment of medical extraction teams.

Problem Statement

The demanding and often hazardous environments encountered by military personnel present significant challenges to their safety and well-being, primarily due to the critical gap in immediate and reliable detection of injuries or health crises among soldiers in the field. Current protocols, which largely rely on manual reporting and periodic check-ins, are inherently prone to delays, proving detrimental as timely medical intervention is crucial for mitigating severe injury and enhancing survivability. The distinct lack of a real-time, automated system for monitoring vital key physical indicators—specifically pulse speed and thermal regulation—means that critical conditions may go unnoticed for extended periods, directly impacting how rapidly the medical team can intervene and hindering swift, informed decisions by commanders and medical teams. Therefore, there is an urgent need for an automated, real-time soldier health monitoring and alert system that can promptly detect these physiological anomalies and instantly communicate critical alerts, along with the soldier's pre-registered location, to a central command, thereby overcoming existing limitations and significantly improving response times and survival rates.

1.1. Objectives

- ❖ **Develop a Real-time Health Monitoring System:** Implement a system to keep a constant, real-time eye on

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cardiac activity and skin temperature using a pulse sensor.

❖ **Ensure Seamless Wi-Fi Data Transmission:** Establish robust Wi-Fi connectivity for reliable data transfer from sensors to a central unit.

❖ **Automate Critical Alert Generation:** Create a mechanism for automatically issuing alerts to command upon detecting abnormal vital signs.

❖ **Design an Intuitive Monitoring Interface:** Develop a user-friendly dashboard for real-time display of soldier health status and location.

❖ **Improve Emergency Response Times:** Expedite medical assistance by providing immediate, actionable health alerts.

2. LITERATURE SURVEY

The push to digitize the battlefield has led to extensive research into wearable technology. We reviewed existing literature to understand the current landscape and identify where our system could offer improvements.

Early concepts, such as Burns' "Combat-wireless health monitoring system" (2009), established the feasibility of remote sensing module networks in defense scenarios. This foundational work highlighted the immense value of immediate data access but also noted the difficulties of maintaining connectivity in rough terrain.

As sensor technology evolved, the focus shifted to accuracy and wearability. Kodam et al. (2020) provided a critical review of smart wearable devices, emphasizing that while many sensors exist, few can withstand the rigors of the battlefield while remaining comfortable for the soldier. Their work suggests that simplicity and durability are as important as electronic precision.

Regarding data transmission, Sharma et al. (2015) explored the incorporation of Commercial Off-The-Shelf (COTS) components. They argued that standard wireless protocols are often more practical and easier to deploy than proprietary military networks. We adopted this philosophy by utilizing standard Wi-Fi protocols, ensuring our system is cost-effective and compatible with existing infrastructure.

Finally, recent work by Patel et al. (2024) demonstrated why it is so essential to link health data with geographical tracking. We are taking these existing foundations a step further by focusing specifically on the automation of the alert. While previous systems often require a human to look at a screen to spot a problem, our system is designed to notify the human only when action is required, reducing cognitive load on command staff.

3. PROPOSED METHODOLOGY

The "Wounded Soldier Auto-Alert System" is designed as a cohesive loop of data acquisition, transmission, and analysis. The architecture minimizes human intervention, ensuring that the system acts as a silent guardian until a crisis occurs.

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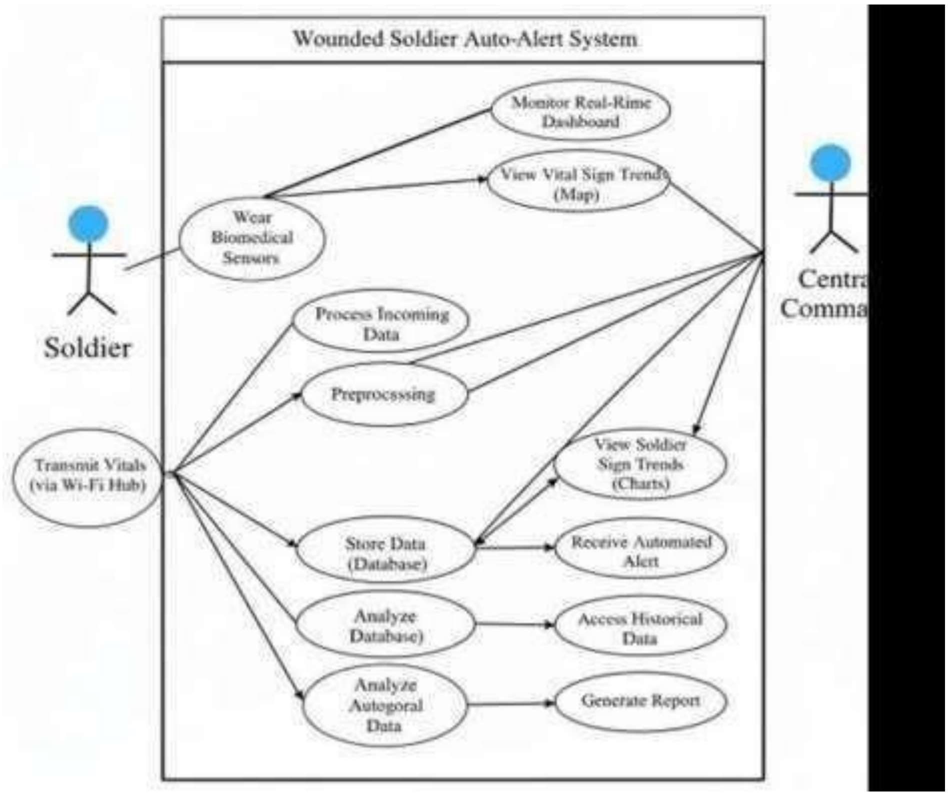

Figure 1: Use Case Diagram for the Wounded Soldier Auto-Alert System, illustrating interactions between soldiers and central command.

The core of the system focuses on continuously monitoring soldiers' vital signs during field operations. A wearable pulse sensor tracks two key health indicators—heart rate and body temperature—offering quick insight into issues such as injury, dehydration, heat exhaustion, or extreme cold. Basic processing is performed on the device itself to clean and organize the data before it is sent further.

To reliably deliver this information to command units, the system uses a Wi-Fi communication module that securely transmits the processed readings to a central server or dashboard. The software then evaluates the data in real time and compares it against normal physiological limits. If an abnormal value is detected, the system immediately generates an alert along with the soldier's registered location. This fast, automated reporting ensures commanders can respond quickly, coordinate medical support, and make informed tactical decisions when time is critical.

Figure 2: Data Processing Workflow for Physiological Data in the Wounded Soldier Auto-Alert System, highlighting steps from extraction to normalization.

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3.1. Sensor Module

The frontline of the system is the Sensor Module worn by the soldier. We utilize a specialized pulse sensor capable of non-invasive monitoring. It simultaneously captures Heart Rate (BPM) and Body Temperature (°C). The sensor translates these analog readings from analog to digital locally. We prioritized this sensor combination because it offers the fastest indication of physical trauma (spiking or dropping heart rate) and environmental stress (hyperthermia/hypothermia).

3.2. Wi-Fi Communication Module

To move data from the field to the command center, we employ a Wi-Fi Communication Module. This module connects the wearable sensor to the network. We chose Wi-Fi because of its ability to handle heavy data loads and reliability. In a real-world deployment, this guarantees that every critical health metric packet is delivered with minimal latency, providing a "live" snapshot of the soldier's status.

3.3. Monitoring & Alert Module

The brain of our architecture is the Monitoring Module. It doesn't just display numbers; it evaluates them. We have programmed the system with "safe ranges" for human vitals.

Normal Operation: Data is logged, and the status is marked "Green."

Anomaly Detection: If the heart rate exceeds a high threshold (stress/panic) or drops below a low threshold (unconsciousness/bradycardia), or if the temperature deviates significantly, the system flags the event.

Trigger: This flag immediately generates a notification sent to the dashboard, bypassing the necessity for manual checks.

3.4. The Command Dashboard Module

The Command Dashboard Module gives commanders and medical teams a clear, real-time view of each soldier's condition. It displays key information—such as cardiac activity, skin temperature, and location—through simple visual indicators and status labels like "Normal" or "Critical." If an alert is issued, the affected soldier is immediately highlighted on the dashboard, making urgent cases easy to spot. The interface is intentionally designed to be quick to understand, helping decision-makers respond efficiently during high-pressure situations.

4. IMPLEMENTATION

To verify the concept, we built a functional prototype using a robust, open-source technology stack. This approach ensures the system is scalable and easy to modify.

4.1. Platform & Language

Backend (Python & Flask): We chose Python for the server-side logic due to its speed in data processing. The Flask framework handles the incoming data streams from the sensors and manages the API requests.

Tech Stack Decisions

For the database, we decided to use SQLite. Since we are tracking individual soldier profiles and health logs rather than handling millions of global transactions, setting up a massive enterprise database would have been overkill. SQLite provides the lightweight, serverless efficiency needed to keep things fast.

On the front end, we prioritized usability for commanders who might be using tablets in the field. We built the interface using Bootstrap 5 so the layout adjusts automatically to any screen size. We also integrated Chart.js to handle data visualization; it turns the raw heart-rate numbers into live graphs, making it much faster to spot dangerous trends than reading text. To handle location tracking, we implemented Leaflet.js, which allows us to plot the soldiers' coordinates directly onto an interactive map.

How the System Works

The process kicks off the moment a soldier's device connects to the network.

Ingestion: The Python backend picks up an incoming JSON packet containing the Soldier ID, current heart rate,

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temperature, and timestamp.

The Check: Immediately upon arrival, the backend runs this data against our safety thresholds to check for abnormalities.

Visualization: The dashboard reflects this in real-time. Under normal conditions, it simply logs the data. However, if the analysis detects a critical value—like a sudden heat spike—the dashboard forces a "Red Status" alert and instantly highlights that specific soldier's location on the map so they can get help.

5. RESULT

Bringing the architecture to life yielded a fully functional dashboard capable of real-time surveillance. The interface was built with a focus on simplicity, so users can operate it immediately without a steep learning curve.

Figure 4: Real-Time Soldier Vitals Dashboard Overview. This illustrates the high-level summary of active soldiers and their classified health statuses within the monitoring network.

5.1. Dashboard Overview

The main view provides a "Health Matrix" of the entire unit. Soldiers are categorized by status: Normal, Warning, or Critical. This allows a commander to assess the unit's combat readiness in a single glance.

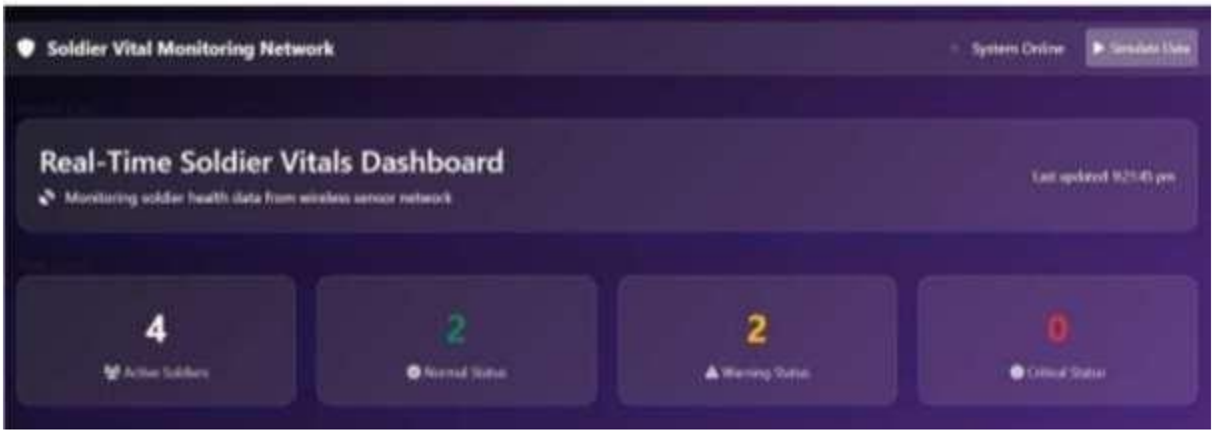

Figure 5: Active Alerts Panel Displaying Critical Soldier Notifications. This shows specific alerts for individual soldiers, indicating their ID, abnormal heart rate and/or temperature readings, and the timestamp of the last update.

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5.1. Active Alert System

When we simulated a soldier entering a distress state (e.g., heart rate > 120 BPM or Temp > 39°C), the system successfully triggered an instantaneous alert. An "Active Alerts" panel appeared on the screen, flashing the Soldier's ID and the specific vital sign that was failing. This proves the system's ability to prioritize critical information over routine data.

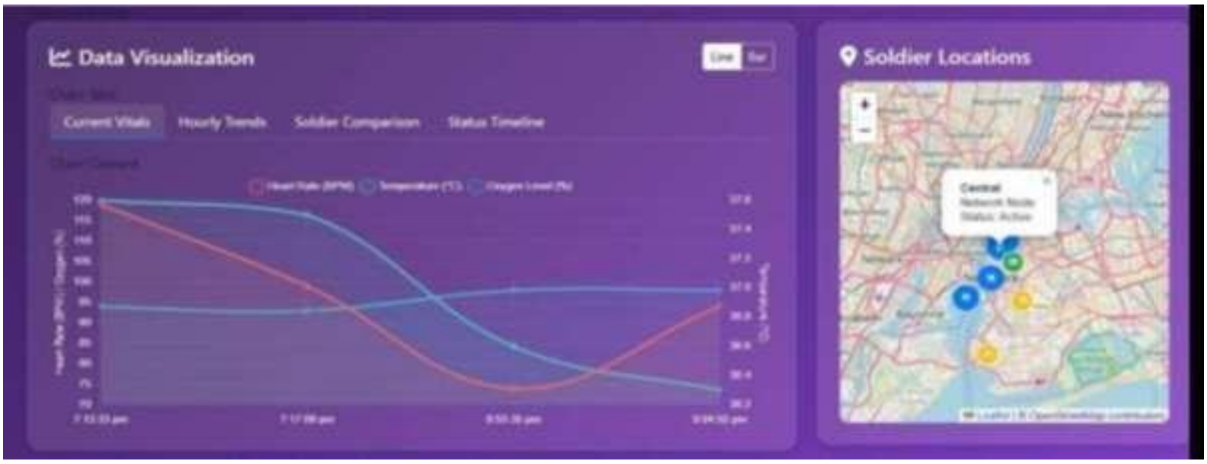

Figure 6: Detailed Latest Soldier Data Table. This table offers a comprehensive breakdown of each soldier's current status, ID, heart rate, temperature, pre-registered location, and the time of the last data update.

Figure 7: Data Visualization and Soldier Location Map Interface. This panel illustrates the graphical representation of patterns in their physical condition across the duration of the mission (heart rate and temperature) alongside a map showing the pre-registered locations of all monitored soldiers.

6. CONCLUSION

The "Wounded Soldier Auto-Alert System" represents a significant step forward in military safety technology. By successfully integrating wearable sensors with automated web-based monitoring, we have demonstrated that we can realistically remove the "fog of war" regarding soldier health.

The workflow shifts beyond traditional, reactive methods. It does not wait for a wounded soldier to call for help; it calls for help on their behalf. The combination of real-time anomaly detection, instant alerts, and location visualization empowers commanders to make faster, data-driven decisions. While currently a prototype, this architecture lays the groundwork for a future where every soldier is digitally tethered to safety, drastically improving survivability in the most hostile environments.

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