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IOT-Enhanced Soldier Health System with Predictive Analytics and Real-Time Emergency Notifications and Qgis- Based Geospatial Monitoring System

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Abstract:
Soldiers' health and safety are of utmost importance in the defense industry, particularly in combat or isolated areas where prompt medical assistance may not always be accessible. In order to continually watch and forecast soldiers' health, this article describes the design and development of an Internet of Things (IoT)-based Soldier Health Monitoring System that combines cutting-edge sensors, machine learning, and real-time communication technologies. This system combines IoT with AI-powered health forecasts to provide rapid decision-making, continuous monitoring, and prompt emergency responses. The work is an essential tool for military health management since it greatly improves soldiers' operational safety and well-being when they are in the field. The interface includes standard QGIS tools and menus for map navigation, layer control, and attribute management. In the defense section of a health monitoring project, a shortest path algorithm optimizes data transmission routes between sensors and the monitoring system, ensuring minimal latency and secure communication. It also helps allocate resources efficiently, improving the overall system's performance and reliability. In the defense section of a health monitoring project, the K-Nearest Neighbors (KNN) algorithm can be used to classify or predict the health status of a patient based on similar data points from neighboring patients.

Keyword: Accident Detection, Accident Prevention, GPS, GSM, Raspberry Pi, IOT, QGIS.

1. INTRODUCTION

Wearable health monitoring of soldiers is very technologically sophisticated in that it assures the protection of troops in real time. Wearable technologies offer a suitable degree of monitoring in combat and other operations that occur in distant locations. Wearable devices are made up of sensors that monitor heart rate, body temperature, blood pressure, and oxygen saturation. The data collected is then transmitted electronically to a command center or central monitoring station where medical personnel can immediately assess the servicemen's health status. In cases of emergency or anomalous readings, immediate medical intervention can be given. By enabling early detection of illnesses or injuries, this technology not only maximizes soldiers' survival potential but also enables proper mission planning and management by keeping track of the physical condition of the troops. It is critical in modern warfare, when the physical state and readiness of every soldier directly impact the success of the mission. The need for reliable, real-time monitoring systems in modern healthcare. Additionally, the convergence of wearable technology and mobile apps enables ongoing patient interaction, allowing people to become active players in their own healthcare. This active participation not only improves outcomes, but also maximizes healthcare.

It is increasingly important, especially for elderly persons, individuals with chronic diseases, and those in urgent need of medical care. Remote access, unhampered emergency communication, and real-time notifications are often lacking in conventional healthcare setups. Through the integration of real-time health tracking and Telegram instant messaging, the Emergency Health Monitoring and Alert System addresses these challenges and provides family members and caregivers with rapid alerts in the event of an emergency. The MAX30100 sensor that is continuously monitoring key parameters such as pulse rate and SpO2 is employed in the system design. Users can signal distress manually by pushing a push button during emergency situations. The key component of the system is the ESP32 microcontroller, which communicates with GPS and GSM modules and reads and processes sensor data. This functionality is commonly accessed through the "Shortest Path (Point to Point)" algorithm in the Processing Toolbox or by using the Road Graph plugin. By inputting a line vector layer that represents the network and specifying the start and end points, can compute the optimal route based on distance, travel time, or any other defined cost attribute. The result is a new line layer that highlights the shortest route along with details such as total distance or estimated travel time. This tool is particularly useful in applications like urban planning, emergency response, transportation logistics, and infrastructure development, where identifying the quickest or most efficient route is critical. It ensures accurate route analysis by relying on properly connected and attribute-rich network. The remaining work is further organized as follows, Section briefly stated the previous work, section 2 mentioned the Existing Work. Section 3 gives the details of Proposed Work; Section 4 introduces the Flow Sequence. In section 5, results discussed, finally section concludes the work.

2. EXISTING WORK

There are several existing systems proposed to build a soldier health monitoring system [1]. The study suggests that the accuracy of such a system could benefit that using cloud computing and area learning with the internet of things (IoT) is providing a mechanism to calibrate real-time systems when the scenario does not have enough visual features or has changing characteristics regarding geometry or climate, which compromise the accuracy. After studying various approaches, a hardware-based approach is proposed in which the body temperature and soldier's current location tracking are detected by applying sensors and utilizing cloud computing for sending information. It was proposed in the paper by Hock Beng Lim [2] nonstop communication is possible. Soldiers can communicate anywhere, which can help the soldier to communicate with their other soldiers whenever in need. Peripherals used are smaller in size and also have low weight so that can be carried around safely and securely by soldiers. The methodology proposed in [3,4] the proposed framework can be mounted on the warrior's body to track their well-being status and current area utilizing GPS. The proposed framework involves small wearable physiological equipment, sensors, and transmission modules. Prof. Amruta V. Patil proposed a system [3] mounted on a soldier's body that can be used to track his health. This information will be transmitted to the control room through IoT. Only hardware approach and no use of software systems. The sensor is a belt shaped wearable device consisting of an accelerometer (tri-axial) and gyroscope [4]. These sensors are used to classify the posture and dynamics of the user. The primary goal of the work is to create effective algorithms to use these sensors to detect falls and tell them apart to been developed for monitoring human physiological parameters [5,6]. The Body Sensor Network (BSN) consists of many biomedical and psychological sensors such as blood pressure sensors, Electrocardiogram (ECG) sensors, and electrodermal activity (EDA) sensors which can be placed on the human body for health monitoring in real time. In paper author had suggest a strategy for creating a BSN-based system for tracking troops' health in real-time [7]. The authors presented an idea for the safety of soldiers by using sensors to monitor the health status of soldiers as well as ammunition on them. GPS module has been used for location tracking and RF module has been used for high speed, short-range data transmission, for wireless communications between soldier-to soldiers [8,9]. Existing soldier health monitoring systems primarily rely on basic sensor setups and hardware approaches with limited software integration and minimal real-time analytics. Many lack predictive capabilities, offer no image verification, and depend on traditional communication methods, which delay response times [10]. Furthermore, earlier works often do not utilize spatial analysis tools for path optimization or rescue planning. To address these gaps, the proposed work introduces a comprehensive IOT enabled health monitoring system that integrates real-time data acquisition, machine learning for heart disease prediction, and instant alert mechanisms via Telegram and GSM. Additionally, it incorporates QGIS for shortest path to assist rescuers in reaching the soldier swiftly during emergencies [11]. By combining health sensors, GPS tracking, ESP32CAM imaging, cloud storage via Firebase, and mobile application access, the system ensures enhanced situational awareness, faster emergency response, and proactive health management in defense applications.

3. PROPOSED WORK

In contemporary combat operations, the safety and health of soldiers are decisive factors that impact mission success and overall battlefield performance. Soldiers tend to work in difficult and isolated environments, where access to healthcare facilities and timely health checks may be restricted. This requires a need for an intelligent, automated system to constantly monitor essential health parameters, forecast potential health hazards, and immediately notify concern authorities in the event of emergencies. This work meets these challenges by designing a Soldier Health Monitoring System that incorporates Internet of Things (IoT) devices, machine learning, and real time communication technologies to enable effortless health monitoring and emergency notification. The system is capable of monitoring important health parameters like body temperature, heart rate, and oxygen saturation levels using the DS18B20 and MAX30100 sensors.

These sensors, a GPS module for locating and a panic button for emergencies, give all-round real-time information regarding the status of the soldier. The minimum distance utilized here is between Soldier Location and Control centerOne of the key innovations in this system is the use of machine learning [12], specifically the K- Nearest Neighbour's (KNN)algorithm, historical health data. The K Nearest Neighbour's (KNN) algorithm was used in this project because of its simplicity, efficiency, and capability for real-time prediction tasks of health. KNN is a non-parametric, instance-based learning algorithm, which classifies instances based on the majority class among its closest neighbours. This makes it especially useful for health monitoring, when similar physiological readings can suggest similar health conditions. Since the system collects real-time data such as heart rate and oxygen levels, KNN can quickly analyse this data against a pre-trained dataset to predict potential heart disease with minimal computational resources. This predictive capability allows for early detection of potential health issues, enabling proactive medical attention before conditions worsen. Additionally, the system employs ESP32CAM to capture images and send them. Telegram for visual confirmation, ensuring that concerned authorities can assess the soldier's physical state remotely [13]. The communication infrastructure is supported by a GSM module, which sends SMS alerts in emergencies, and Google Firebase, which stores health data in real time. A custom-built mobile application, developed using MIT App Inventor, allows for easy access to the stored data and provides a user- friendly interface for health monitoring. This introduction highlights the significance of combining IoT and AI technologies to provide soldiers with enhanced health security, offering timely medical intervention and real-time communication that can make the difference between life and death in critical situations. Continuous health monitoring is essential for soldiers because they often operate in extreme and unpredictable environments where immediate medical assistance may not be available. In such high stress and physically demanding situations, real-time tracking of vital parameters like heart rate, body temperature, and oxygen saturation can help detect early signs of fatigue, dehydration, or serious medical conditions such as cardiac arrest [14,15]. By continuously monitoring a soldier's health, commanders and medical teams can respond promptly to emergencies, reducing the risk of severe injuries or fatalities. The following section shows the steps involved in building the soldier health monitoring system

The Fig 1. block diagram illustrates a health and safety system based on the ESP32 microcontroller. It integrates multiple sensors and modules to collect and transmit real-time data.

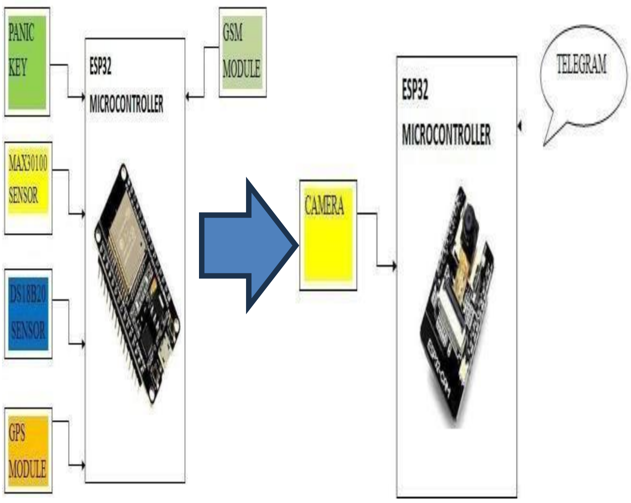

Figure 1. block diagram of health monitoring system

The MAX30100 sensor is employed to sense heart rate and blood oxygen saturation, whereas the DS18B20 sensor tracks body temperature.[4] A GPS module offers location tracking, and a GSM module transmits the recorded data to a remote server or emergency contact. Moreover, a panic key enables the user to send an alert manually in case of an emergency. ESP32 is the central processing unit, which manages communication between the modules and sensors. This setup is typically deployed in wearable health monitoring systems and emergency alerting devices**.**

1) Continuous Health Monitoring:

MAX30100 sensor to continuously track the

user's pulse rate and oxygen saturation (SpO2).

These health indicators are critical to identifying potential health concerns and are transmitted in real-time through Telegram for immediate response from caregiver. The high sensitivity of MAX30100, its compact size, and

microcontroller compatibility with ESP32 make it an ideal candidate for field deployment in military situations, ensuring a soldier's vital signs are independently monitored continuously and precisely in missions.

2) Push Button:

In the event of an emergency, users can press the emergency switch, that initiates the system to send an alert message via Telegram. The alert holds the user's health information (e.g., SpO2, pulse) and GPS location so that caregivers can evaluate the circumstance immediately and react appropriately.

3)Telegram Bot Integration:

The system is linked to a Telegram bot, which sends health information and emergency notifications to pre-defined contacts (e.g.

caregivers, family members, or medical professionals). The Telegram bot offers an easy and efficient method of delivering important health information in real-time.

Real-Time Notifications: The Telegram bot delivers immediate notifications to the defined contacts whenever there are updates on the user's health, such as any irregular readings or when the emergency button is activated.

4)GPS Module and GSM Module

The GPS module gives live location information, which is important when an emergency occurs. When the emergency button is pressed by the user or a health anomaly is sensed, the ESP32 transmits the user's current location and health information through Telegram.

GSM Module:

Apart from Telegram, the system can also transmit SMS notifications through the GSM module, so that multiple communication avenues are made available to reach the caregivers during an emergency.

The system employs an external power supply board to make it feasible to use reliably over long periods, even in areas where access to traditional, power sources is restricted.

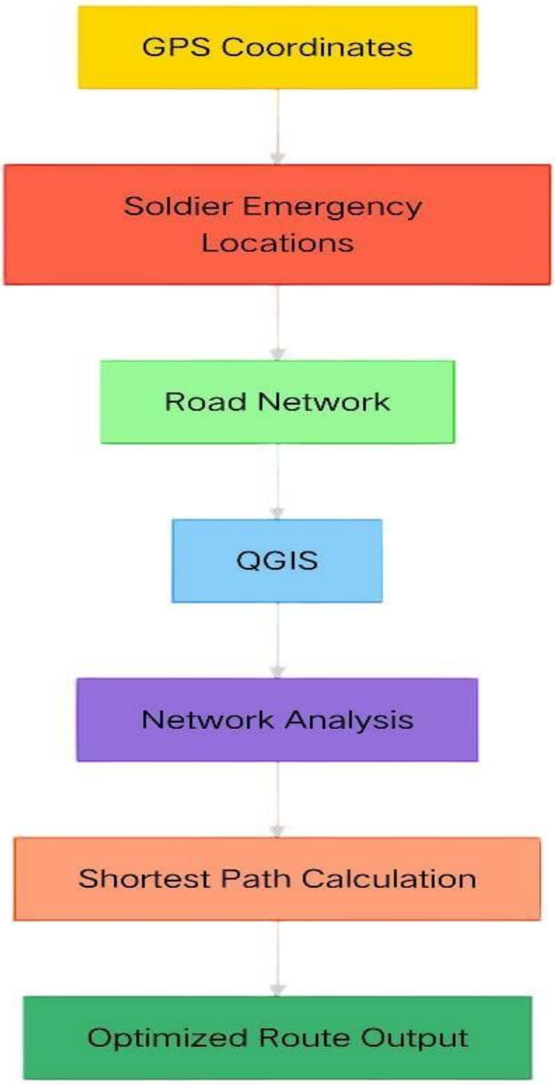

Fig 2 flow sequence of Shortest path using QGIS

The block diagram centers on technologies such as wearable sensors, cloud-based platforms, and smart analytics can improve soldier readiness, avert health crises, and enhance battlefield medical care. The system employs a mix of sensors, GPS technology, and wireless communications to gather and transmit a soldier's vital signs, location, and environmental conditions [1].

This data can be utilized by military commanders to make effective decisions regarding troop deployment, medical treatment, and battle strategies.

The fig 2 illustrates a way to discover optimized routes for soldiers during emergencies. It begins with gathering GPS coordinates of the soldiers.

4. FLOW SEQUENCE

The figure 3 depicts the system development followed a structured workflow starting from system design, hardware setup, and data acquisition, progressing through machine learning implementation, cloud integration, and mobile application development. Final stages included alert mechanism setup, testing and validation using QGIS, field testing, and deployment to ensure a robust and scalable solution.

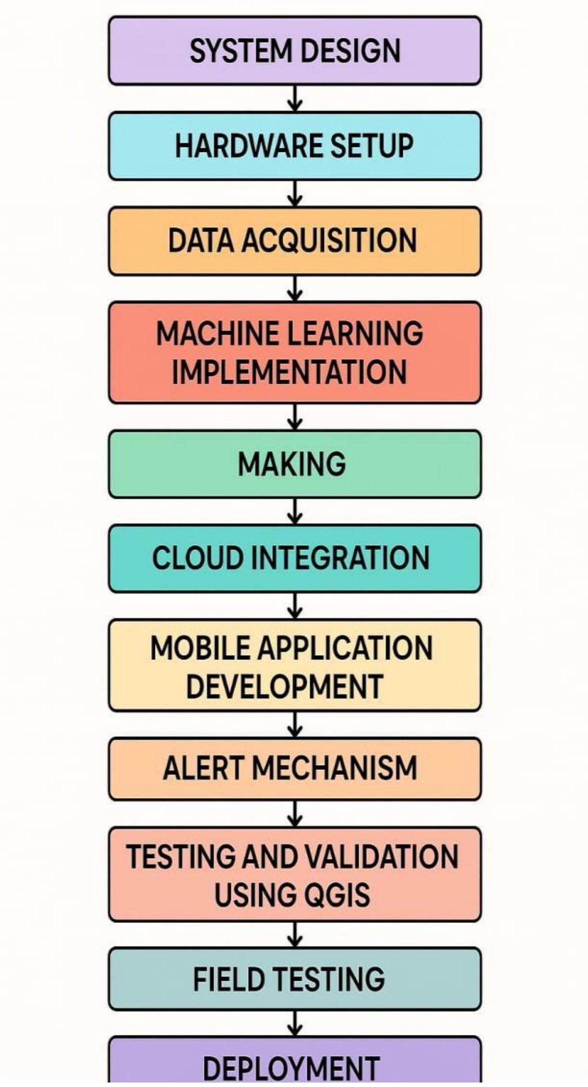

Fig 3. Flow Sequence of the Soldier health monitoring system

1.System Design:

Requirement Analysis: Identify the key health parameters to monitor (body temperature, heart rate, oxygen levels) and the emergency features needed (location tracking, panic key).
Component Selection: Select appropriate sensors (DS18B20 for temperature, MAX30100 for heart rate and SpO2), microcontrollers (ESP32 and ESP32-CAM), communication modules (GSM, GPS), and other hardware components for seamless integration.

2.Hardware Setup:

Sensor Integration: Connect DS18B20 and MAX30100 sensors to the ESP32 microcontroller to collect real-time health data.
GPS and Panic Key Setup: Integrate a GPS module to obtain location data and a panic key for emergencies. Communication Modules: Set up the GSM module for sending SMS alerts in critical situations.
ESP32-CAM: Integrate the ESP32-CAM to capture and transmit real-time images via Telegram.

3.Data Acquisition:

Program the ESP32 microcontroller to collect data from the sensors at regular intervals. Capture real-time health statistics (temperature, heart rate, SpO2) and transfer them to a central server with Google Firebase for remote storage and access.

4. Implementation of Machine Learning:

Data Preprocessing: Organize historical health records for training the K-Nearest Neighbour's (KNN) algorithm. This involves having data and data sets with heart rate, oxygen levels, and other related health parameters. The K-Nearest Neighbour's (KNN) algorithm is of very important value in the discipline of

machine learning because of its simplicity, flexibility, and effectiveness in solving many real-life problems. One of its strengths is that it is a non-parametric approach, which implies that it does not make any assumptions about the data distribution, making it useful for both linear and non-linear data. on the ESP32 to forecast heart disease. In defense operations, a Soldier Health Monitoring System makes real-time monitoring possible of such vital signs as heart rate, body temperature, oxygen levels, and fatigue. This provides instantaneous medical response in combat, enhances mission planning by determining troop readiness, and improves soldier survivability through continuous remote health monitoring even in extreme conditions.

5.Making:

The system analyses the incoming data using KNN and triggers alerts if such as KNN or a sensor-based monitoring setup because it represents a critical and prevalent health condition that benefits greatly from early detection and a high risk of heart disease is predicted. Heart disease is mentioned in the context of the system or algorithm continuous monitoring . With millions affected worldwide, timely identification of abnormal heart conditions like arrhythmia, low oxygen saturation, or abnormal pulse rates can save life of the soldier.

The integration of sensors like MAX30100 (which measures heart rate and SpO2) and intelligent algorithms like KNN enables real-time monitoring and accurate prediction of heart-related anomalies. By focusing on heart disease, such systems demonstrate their practical relevance and lifesaving potential in the healthcare domain and In the defense section of a health monitoring project, a shortest path algorithm optimizes data transmission routes between sensors and the monitoring system, ensuring minimal latency and secure communication. It also helps allocate resources efficiently, improving the overall system's performance and reliability.

6.Cloud Integration:

Google Firebase: Implement Firebase for real-time data storage. This allows health data to be accessed and monitored remotely through a mobile app.

7.Mobile Application Development:

Use MIT App Inventor to design and develop a user- friendly mobile application for monitoring the soldier’s health data, receiving alerts, and viewing their current location. Ensure the app pulls data from Firebase and displays it in real time, allowing for remote monitoring.

8.Alert Mechanism:

SMS Alerts: Program the GSM module to send automatic SMS alerts to predefined emergency contacts, including health data and GPS coordinates, whenever a health emergency or panic button activation occurs .Telegram Alerts: Configure ESP32-CAM to capture and send photos of the soldier via Telegram for visual verification during emergencies.

9.Testing and Validation using QGIS:

Test the entire system in a controlled environment to ensure the sensors provide accurate readings. Validate the KNN algorithm’s performance by simulating various health conditions to check the reliability of heart disease predictions. Test communication systems (SMS, Firebase, and Telegram) to ensure timely and accurate alerting.

In a soldier medical monitoring system, QGIS can play an important role by using its shortest path process to provide instant medical care. By displaying the terrain of the battlefield, soldier locations, hospitals, and potential hazards, QGIS can analyze and identify the best evacuation routes when a soldier is hurt. Through the use of the "Shortest Path (point to point)" tool of network analysis, the system can compute the shortest or safest path from the soldier's present location to the closest medical facility. This real-time routing assists in reducing evacuation time, factoring in aspects such as the difficulty of terrain and possible threats, thus greatly enhancing the likelihood of prompt medical attention, and saving lives in critical situations.

10. Field Testing:

Perform field trials for testing the performance of the system in actual conditions. Verify that the sensors, GPS tracking, and the communication systems perform effectively across different environmental conditions.

11.Deployment:

Deploy the system for real-time monitoring of soldier health. Gather user feedback and optimize the system further as appropriate.

This approach guarantees the construction of a robust, reliable, and scalable soldier health monitoring system incorporating IoT, machine learning, and communication technologies for real-time time health monitoring and emergency response.

This deployment methodology ensures the creation of a robust, reliable, and scalable soldier health monitoring system that seamlessly integrates Internet of Things (IoT) devices, machine learning algorithms, and advanced communication technologies.

12.Mathematical Equation:

The Equation gives prediction and decision- making process involve comparing the soldier's current health parameters with predefined thresholds, ensuring immediate alerts

through a Telegram bot if abnormal conditions are detected. This enables quick medical attention and improves the overall safety of soldiers deployed in remote and challenging environments.

The Mathematical Equation is below:

$$d(\mathbf{x}, \mathbf{x}_i) = \sqrt{\sum_{j=1}^{n} (x_j - x_{ij})^2}$$

$$\sum_{k=1}^{K} \mathbb{I}(C_k = c)$$

5. RESULT

The results show accurate real-time tracking of health parameters, as seen in the images below. The figure 4 shows the complete hardware setup of soldier health monitoring system with components like GPS, GSM, Telegram Bot, and Finger Print Sensor. And usage of emergency button.

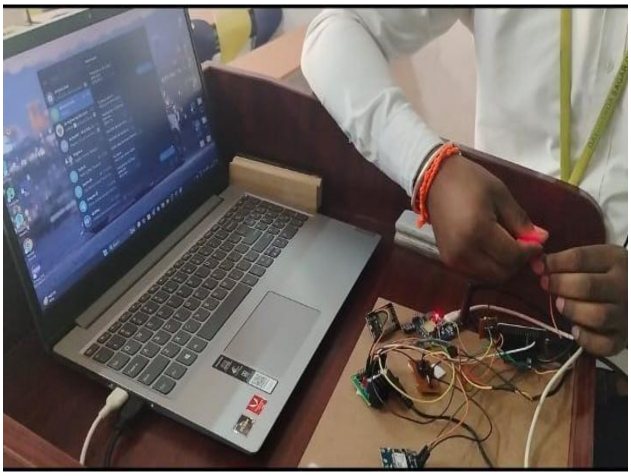

Fig 4 The Hardware Setup of the System

The Fig 5. Shows the Output of Health data of Soldier in telegram bot along with the /request and /photo commands and the medical parameters including Name, Temperature in Deg C and BPM, SPO2,

The Fig 5. displays a Telegram chat interface with a bot named "Soldier health," which is part of a real-time health monitoring system, likely designed for remote tracking of individuals such as soldiers. The user, identified as Manjunath B H, interacts with the bot using commands like /request to retrieve sensor data and /photo to capture a live image from an integrated camera module. In response, the bot provides key health parameters including body temperature (29.44°C), heart rate (53.23 BPM), and blood oxygen level (SpO2: 95.00%).

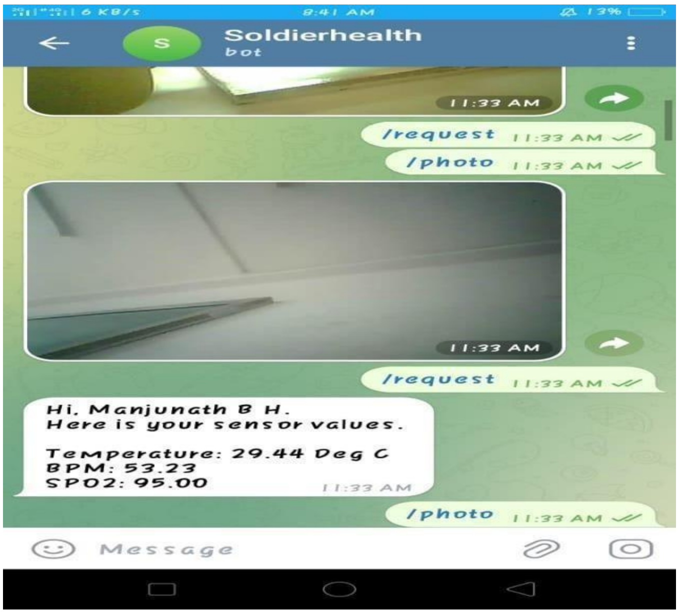

Fig 5. Screenshot of the Telegram bot chat

"Heart rate and SpO2 readings": the bot keeps track of and provides the users oxygen saturation and heart rate. For instance, warnings with SpO2 levels between 95% display numbers such as 128bpm (externally high), 105bpm, and 167bpm

"Location Link": To assist rescuers in finding the person as soon as possible, each alert includes a goggle map link to the user location

"Emergency alert": when the readings are aberrant, the message style include an emergency indicator, indicating that the patient need immediates

Name	Temperature in Deg C	BPM	SPO2
Manjunath BH	29.44	53.26	95.00
Jeevan S	31.00	51.12	96.12
Benaka k	26.55	52.34	98.22
Manjunath BN	27.88	51.22	97.8

The Table 1. Shows the medical parameters like Temperature, Spo2, BPM, along with the names of the Person

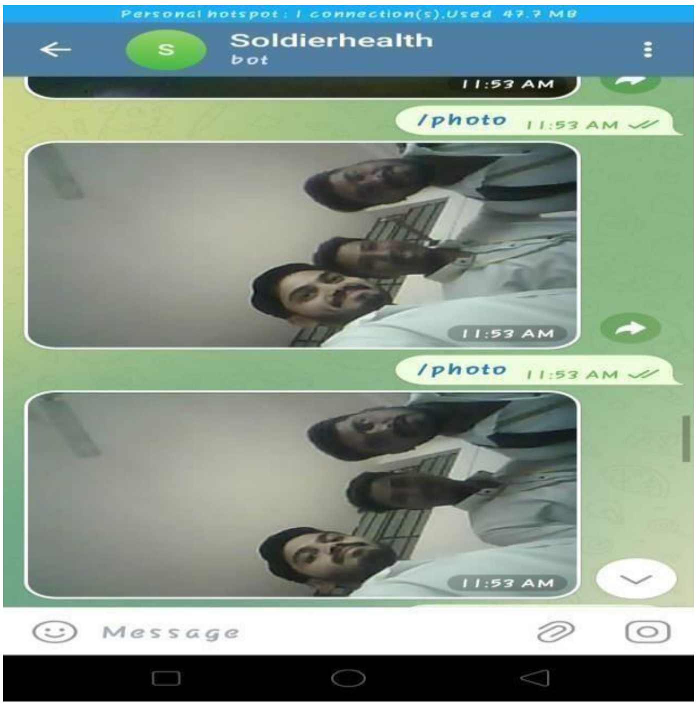

Fig 6 Screenshot of live image through telegram

Fig 6 shows the live image of the soldier through telegram to the command center so that they can send rescue team to help the soldier during emergencies.

Here we usually use shortest path to identify the route which usually helps the rescue team to reach the soldier in quick time basically shortest path uses the longitude and the latitude of the location received from the transmitter and corelates it with the respect to the command room location and uses KNN algorithm to identify the best route to reach the soldier which intern help the command room to identify the soldier and medicate him.

The **shortest path algorithm** plays a crucial role in enhancing safety, efficiency, and decision-making for soldiers, especially during operations in unknown or hostile territories.

By determining the most efficient route between two points on a map, this algorithm helps minimize travel time, conserve energy, and reduce exposure to threats In critical missions, it can guide soldiers to reach a destination— such as a target location, medical facility, or evacuation point—faster and more safely. When integrated with GPS and GIS technologies, the shortest path algorithm can adapt to changing conditions such as blocked roads, enemy zones, or environmental hazards, offering alternative routes in real time. This is particularly useful in rescue missions, patrolling, or supply delivery where timely movement is essential. Additionally, in coordination with surveillance systems or IoT devices, it can dynamically update the safest and most efficient path based on real-time data, thereby ensuring efficient data analysis and providing necessary location.

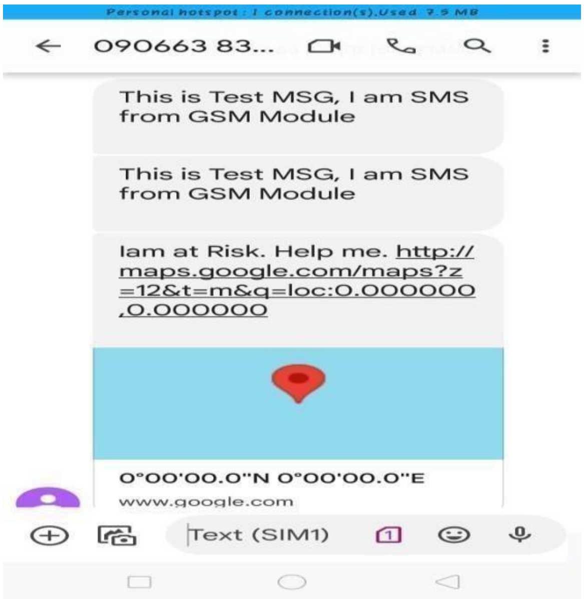

Fig 7 Screenshot of Message sent by GSM Module

The Fig 7 shows the Screenshot of Google maps link and latitude and longitude sent by GSM Module so that the command center can gets the coordinates to locate the soldier in emergency

The Fig 8 shows the QGIS software where the shortest path can be defined by control center to find the soldier at the earliest so that they can send the rescue team to save the life of the Soldier.

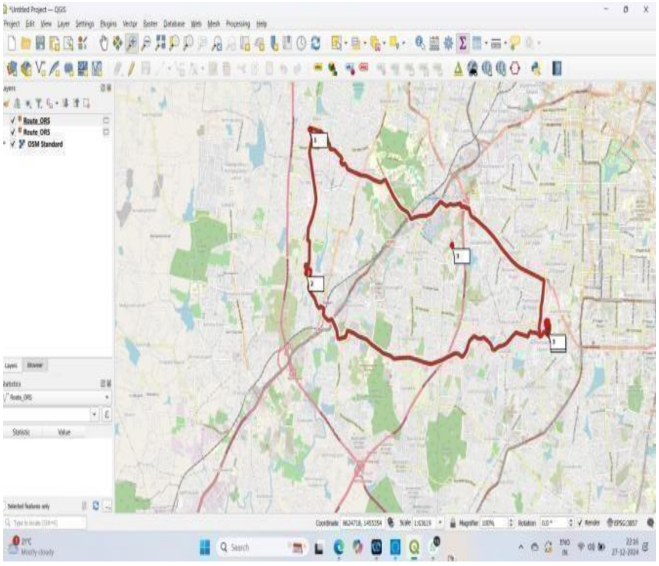

Fig 8. Shortest path using QGIS

6. CONCLUSION

The proposed IoT-Enhanced Soldier Health System, integrated with predictive analytics, real-time emergency alerts, and QGIS-based geospatial tracking, presents a transformative leap in military healthcare and operational safety.

Designed for deployment in critical defense scenarios, the system empowers command units with live monitoring of soldiers' vital parameters such as heart rate, SpO2, and body temperature, thereby enabling early detection of health anomalies and rapid emergency intervention.

With the integration of GPS and QGIS to conduct shortest path analysis, the system improves rescue and evacuation effectiveness in combat or far-located operations, allowing timely medical assistance even in geographically challenging terrain.

The use of machine learning in health prediction, using the K- Nearest Neighbors (KNN) algorithm, introduces an intelligent layer to predict health risks, minimizing the risk of mission failure due to undetected medical problems.

And the work not only demonstrate the revolutionizing potential of IoT in improving health tracking and emergency response but also lays a strong foundation for improvement in the future, for instance, the inclusion of more sensors, the use of AI to provide predictive information,

Data encryption to enhance data safety. Summing up, the scheme not only demonstrate technical feasibility but also supports the greater vision of utilizing IoT and real-time analytics to advance health monitoring and emergency response

ability. Its cutting-edge design fills gaps in conventional healthcare systems, providing a flexible, effective, and life-saving instrument for an array of situations.

Finally, this system is a holistic, expandable, and lifesaving solution for critical healthcare requirements in adverseenvironment.

Its modular, flexible design not only adapts to existing healthcare needs, vowing even more accuracy and anticipatory care.

Despite persistence of challenges like power optimization andconnectivity reliability, the cost-effectiveness, scalability, and user-centric nature of the system render.

It a solution with potential in varied contexts ranging from remote patient monitoring to disaster response situations.

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