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SMART MONITORING OF HUMAN PRESENCE IN AVALANCHE PRONE AREAS USING AI & IOT

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Abstract-- This project proposes an AI and IoT-based smart monitoring system for improving human safety in avalanche-prone areas. The system uses temperature and pulse sensors to continuously monitor vital signs and an ESP32 microcontroller to process the data. GPS and GSM modules provide real-time location tracking and instant emergency alerts to rescue teams. A camera module enables remote visual monitoring, while an emergency button allows manual alert activation. AI algorithms such as Isolation Forest and LSTM are used to detect abnormal conditions and predict avalanche risk levels. This system helps in real-time monitoring, early danger detection, and faster rescue response, improving survival chances in critical situations.

Index Terms-- Artificial Intelligence (AI), Internet of Things (IoT), Avalanche Monitoring System, Smart Safety Jacket, Vital Sign Monitoring, Isolation Forest, LSTM, GPS Tracking, GSM Communication, Geofencing, Emergency Alert System, ESP32 Microcontroller, Remote Monitoring, Disaster Management.

1. Introduction

Avalanches are among the most dangerous natural disasters occurring in mountainous regions, posing serious risks to mountaineers, military personnel, trekkers, and rescue teams. Victims may be buried under snow, leading to critical conditions such as hypothermia, suffocation, and cardiac arrest.Therefore, continuous monitoring of vital signs and precise location tracking are essential for effective rescue operations. With the advancement of Artificial Intelligence (AI) and

Internet of Things (IoT) technologies, smart wearable monitoring systems have become an effective solution for real-time safety management. This project presents an AI and IoT-based smart monitoring system that uses wearable sensors, GPS, GSM, and camera modules to monitor health conditions, track location, detect abnormalities using AI algorithms, and enable immediate emergency response in avalanche-prone areas.

2. RELATED WORKS

1. **Denissova et al. (2025)** – Developed a real-time **AI and IoT-based avalanche monitoring system** using weather sensors and laser rangefinders to analyze snow conditions and predict environmental hazards in mountainous regions.
2. **Mundargi (2025)** – Proposed an **IoT-enabled outdoor safety monitoring system** for remote tracking, wireless communication, and emergency alert transmission in disaster-prone areas.
3. **Shinde et al. (2025)** – Presented a **wearable sensor-based health monitoring system** integrated with IoT for continuous tracking of vital signs such as heart rate and body temperature in emergency situations.
4. **IoT Smart Band Study (2023)** – Introduced a **wearable IoT device with GPS tracking** to monitor the health status and location of missing persons or disaster victims for faster rescue operations.
5. **LoRa-Based Mountaineering Safety System (2025)** – Proposed an **AI-assisted IoT communication framework** using long-range wireless technology for emergency support and risk monitoring in mountainous environments.
6. **AI-Based Anomaly Detection System (2025)** – Recent studies have applied **Isolation Forest and LSTM algorithms** with IoT sensor data to detect abnormal health conditions and predict risk levels in disaster-prone areas.

3.PROPOSED SYSTEMS:

The proposed AI and IoT-based Smart Monitoring System is developed to enhance human safety in avalanche-prone areas through real-time health monitoring, risk prediction, location tracking, and emergency communication. The system is implemented using a wearable safety jacket integrated with temperature and pulse sensors to continuously monitor vital signs such as body temperature and heart rate. The ESP32 microcontroller acts as the central processing unit, collecting and processing sensor data efficiently. The continuous physiological monitoring techniques discussed in [1] and [2] form the basis for the wearable sensing framework used in this system. To improve intelligence and prediction accuracy, Artificial Intelligence algorithms are incorporated into the system. The Isolation Forest algorithm, inspired by the anomaly detection methods in [3], is used to detect sudden abnormal conditions such as rapid temperature drop, irregular pulse rate, or prolonged inactivity. Furthermore, the LSTM algorithm, as highlighted in [4], is employed for time-series analysis of sensor data to predict avalanche risk levels as *Safe, Warning,* or *High Risk*. A GPS module is integrated for real-time location tracking and geofencing, based on the location monitoring approaches described in [5], to detect entry into dangerous avalanche zones. The GSM module, following the communication strategies discussed in [6], sends immediate alert messages along with GPS coordinates to rescue teams during emergencies. In addition, a camera module enables remote visual monitoring, while an LCD display shows the wearer's vital parameters and status in real time. All sensor and location data are transmitted to a cloud-based IoT platform for continuous monitoring and remote supervision, as supported by the IoT frameworks in [7]. Thus, by integrating AI-based anomaly detection and

prediction with IoT-enabled monitoring and communication, the proposed system ensures faster emergency response and improved survival chances in avalanche-prone regions.

3.1 Sensing Layer Construction

The sensing layer is designed to capture real-time physiological and environmental information concerning the wearer's safety. This layer comprises a series of sensors that are embedded in the safety jacket.

3.1.1 Temperature Sensor

The temperature sensor (LM35/DS18B20) is designed to capture the body temperature of the wearer. In low temperatures, an abrupt change in body temperature may signal a possible hypothermia condition. The sensor is designed to continuously capture the temperature reading and transmit the information to the processing unit for analysis.

3.1.2 Pulse Sensor

The pulse sensor (MAX30100) is incorporated to capture the heart rate of the wearer in real time. The sensor captures irregular changes in the heart rate that signal stress, shock, or unconsciousness. Under normal circumstances, the heart rate is expected to be within the pre-defined safe limits. An abrupt irregularity in the heart rate signals an alert to the processing layer.

3.2 Processing Layer Construction

The processing layer is the central part of the system. An ESP32 microcontroller is used as the central processing unit to process sensor information and implement decision-making algorithms.

The microcontroller continuously compares the values with predefined threshold limits. If the body temperature drops below a safe level, the pulse rate becomes abnormal, or the user enters a restricted area, the system identifies it as an emergency condition.

The processing unit also controls data transmission to the cloud platform and activates the alert mechanisms when necessary.

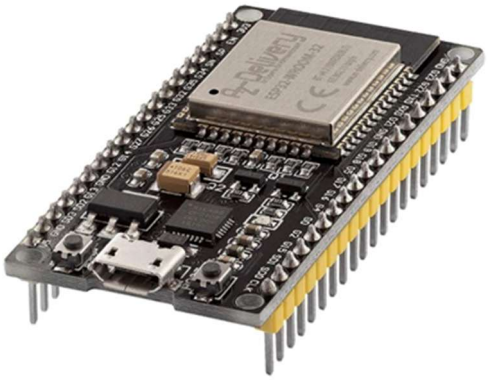

Figure3.2.1 ESP32 MICROCONTROLLER

3.3 Communication Layer Development

The communication layer facilitates real-time data transfer between the wearable device and the external monitoring systems.

3.3.1 GSM Communication module

The design incorporates a GSM module (SIM800L/SIM900) to transmit emergency messages with GPS location and health status information to rescue teams. The ESP32 module's Wi-Fi feature is utilized to upload data to a cloud database for remote monitoring.

The communication layer is designed to provide reliable connectivity even in the most distant mountainous areas.

3.3.2 GPS Communication Module

The GPS module (Neo-6M) is designed to provide real-time geographic location information of the wearer. It receives signals from satellites and determines accurate latitude and longitude location information.

The GPS module is connected to the ESP32 microcontroller using UART communication. The location information is continuously updated

and processed by the microcontroller. In emergency situations, the location information is transmitted using the GSM module and uploaded to the cloud using Wi-Fi.

The GPS module is an essential component of the wearable device, which enables accurate tracking, geofencing, and rapid rescue services in avalanche zones.

3.3.3 Camera Module

The camera module (ESP32-CAM) is incorporated to enable real-time visual surveillance during emergency events. It is also incorporated into the wearable jacket to capture the surrounding environment.

The camera is in standby mode under normal circumstances to conserve energy. However, once abnormal health values are sensed or the emergency button is activated, the camera is switched on. The captured images are then wirelessly sent to the cloud for remote surveillance.

The camera module enhances emergency response and helps rescue teams make quicker and more accurate decisions in avalanche regions.

3.4 Alert Modules

The alert modules are responsible for sending emergency alerts when abnormal situations are identified. This module provides an immediate means of communication and local notification for better safety and rapid response.

3.4.1 LCD Module

The LCD module is employed for displaying real-time data like body temperature, pulse rate, and system status. It is connected with the ESP32 microcontroller and continuously displays sensor data.

During emergency situations, the LCD displays warning messages such as abnormal pulse or alert sent status. This module offers immediate visual feedback to the wearer and functions with low power consumption.

3.4.2 Buzzer Alert

A buzzer is incorporated for sending a local audible signal during emergency situations. When an abnormal situation is identified, the buzzer is triggered to notify nearby people and identify system malfunction.

3.5 Power Supply and Hardware

The system is designed to function with a rechargeable battery that powers the ESP32, sensors, GSM, GPS, LCD, and camera modules with a regulated 5V supply**.**

All hardware devices such as temperature sensors, pulse sensors, GPS, GSM, LCD, buzzer, and camera are connected to the ESP32 microcontroller. The system is designed to be compactly integrated into the wearable jacket to provide lightweight and durable performance in avalanche zones.

4.SYSTEM MODEL

The proposed AI and IoT-based system model is designed to provide continuous monitoring and intelligent emergency detection in avalanche-prone areas. The sensing module continuously monitors the wearer's body temperature and pulse rate using embedded wearable sensors, while the GPS module tracks the real-time location of the user. All collected data is transmitted to the ESP32 microcontroller, which acts as the central processing unit of the IoT system. The processing module integrates Artificial Intelligence algorithms to analyze sensor data in real time. The Isolation Forest algorithm is used to detect abnormal conditions such as sudden drops in body temperature, irregular pulse rate, or prolonged inactivity, while the LSTM model predicts future avalanche risk levels based on time-series sensor and location data. If any abnormal condition is identified or the wearer enters a high-risk avalanche zone through geofencing, the system automatically declares an emergency. Once the emergency is detected, the communication module is activated, where the GSM module sends warning messages along with GPS

coordinates to the rescue team, and the Wi-Fi/IoT cloud platform transmits the data for remote monitoring and AI-based supervision. Simultaneously, the alert module activates the buzzer and LCD display to provide immediate local warnings. In critical situations, the camera module captures and transmits real-time visual information through Wi-Fi for remote assessment. Thus, the system ensures continuous monitoring, AI-based early danger detection, automatic alert generation, and faster rescue response, thereby improving safety and survival chances in avalanche-prone regions.

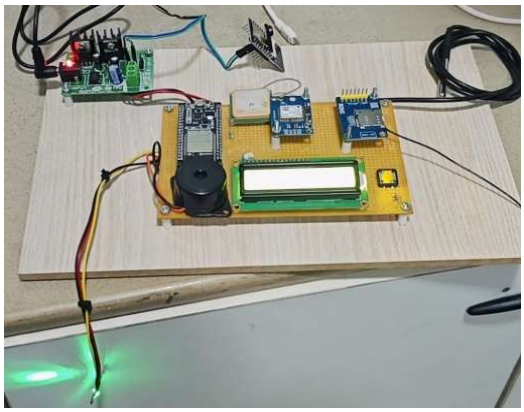

Figure 4.1.1 Working model

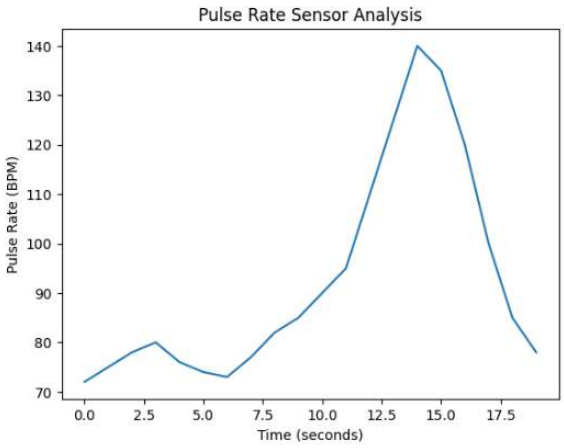

Figure 4.1.2 pulse rate sensor analysis

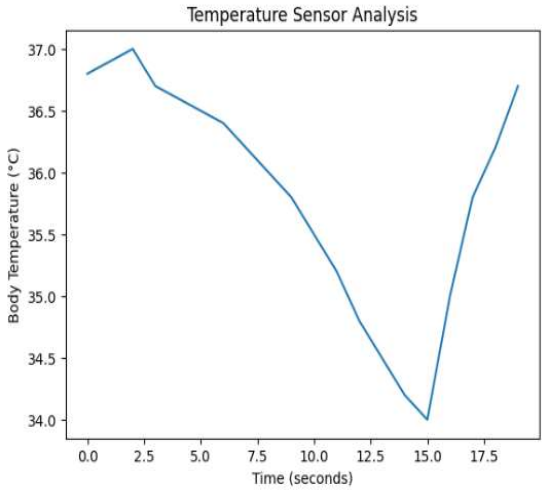

Figure 4.1.3 temperature rate sensor analysis

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helped us stay motivated throughout the project duration.

6.FUTURE WORK

In future, the proposed AI and IoT-based system can be improved by adding snow depth, motion, and vibration sensors for early avalanche prediction. Advanced AI models can be used to improve risk prediction accuracy and reduce false alerts. The system can also include satellite/LoRa communication, solar-powered energy management, and a mobile app or cloud dashboard for real-time multi-user monitoring and faster rescue coordination.

7.CONCLUSION

The proposed AI and IoT-based smart monitoring system is an effective solution for improving human safety in avalanche-prone areas. By integrating wearable vital sign sensors, GPS tracking, GSM emergency alerts, camera monitoring, and AI algorithms such as Isolation Forest and LSTM, the system enables real-time monitoring, early danger detection, and quick rescue response. This intelligent and scalable system improves reliability, reduces rescue time, and increases survival chances in high-risk mountainous regions.

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