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IOT-Based Advanced Monitoring System for Outdoor Safety

Prof. Ms. Zarinabegam[1], Ishan Kale[2], Parth Deshmukh[3], Arnav Khilare[4]
[1]*Kasimali Mundargi, Vishwakarma Institute of Technology Pune, India*
[2, 3, 4]*Department of AI&DS, Vishwakarma Institute of Technology Pune, India*

Abstract: ***Mountain climbing is an exhilarating but risky adventure due to extreme environmental conditions and the remoteness of locations. Accidents can result in delayed or unsuccessful rescue operations due to a lack of real-time information on the climber's location and health status. This paper introduces an IoT-enabled monitoring system designed to mitigate such risks. By integrating heartbeat and temperature sensors with GPS, GSM, and an Atmega microcontroller, the system enables continuous real-time monitoring of vital signs and location. The system is capable of generating alerts when vital parameters exceed predefined thresholds, sending SMS notifications with GPS coordinates to designated contacts or rescue teams. Even in cases of network unavailability, the last recorded location aids rescue operations. The project highlights the use of IoT for real-time data visualization and emergency management, offering a lifesaving solution for climbers in remote and high-altitude environments. This system significantly enhances safety and responsiveness during outdoor expeditions.***

Keywords: ***IoT, Mountain Climbing Safety, Real-Time Monitoring, Search and Rescue, Vital Signs Tracking, GPS, GSM Module.***

I. INTRODUCTION

Mountain climbing is a captivating activity that combines physical endurance, mental resilience, and a profound connection with nature; however, it comes with significant dangers, particularly in high-altitude and remote regions. These risks, which include falls, extreme weather conditions, and medical emergencies such as hypothermia or altitude sickness, are exacerbated by the remoteness and lack of reliable communication infrastructure. In such environments, rescue operations face critical challenges, starting with delays in reporting accidents, which can go unnoticed for hours or even days. These delays significantly diminish the chances of a successful rescue and can even prove fatal in emergencies. Additionally, the remote and rugged terrain, often marked by dense forests, steep cliffs, and unmarked landscapes, makes locating an injured or stranded climber particularly difficult. Beyond these logistical hurdles, rescuers often lack access to real-time health data about the climber, leaving them uncertain about whether the individual is alive, critically injured, or in a less dire situation. This absence of health and location data hampers prioritization, leading to inefficiencies in rescue operations and reduced survival rates. To address these pressing challenges, a solution is needed that bridges the gap between climbers in distress and search-and-rescue teams, enabling timely and effective interventions. This project proposes the development of an Internet of Things (IoT)enabled system specifically designed to enhance the safety and survival chances of mountain climbers. The primary objective of this system is to provide real-time monitoring and communication of climbers' vital health metrics and precise location coordinates. By continuously tracking critical parameters such as heart rate and body temperature, the system aims to identify health crises early and notify emergency contacts or rescue services immediately if predefined safety thresholds are breached, such as when the heart rate becomes abnormally high or low. Furthermore, the system includes GPS functionality to ensure rescuers have access to the climber's exact location, minimizing delays in locating and assisting the individual. In scenarios where network coverage is lost, the system retains the climber's last recorded location, allowing search efforts to remain focused on a specific area and thereby increasing the likelihood of a successful rescue.

The system achieves these capabilities by leveraging advanced IoT technologies, integrating heartbeat and temperature sensors, GSM modules for communication, and GPS tracking. This combination enables live monitoring and instant notifications while also empowering rescue teams to deploy resources efficiently and prioritize critical cases. In practice, the system continuously monitors vital signs and transmits this data to a connected platform, ensuring constant visibility of the climber's condition. Should the parameters exceed safe limits, the system not only triggers alerts on the IoT platform but also sends SMS notifications to preconfigured contacts. These messages include essential details such as the climber's health status and GPS location, with the latter provided as a clickable link to guide rescuers directly to the individual. Additionally, the system is equipped to operate in environments with limited connectivity, making it suitable for the extreme conditions often encountered during mountain climbing.

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The scope of this project extends beyond its application for mountain climbers, making it relevant for a wide range of high-risk outdoor activities. For instance, it could be employed in wilderness trekking, remote scientific explorations, and adventure sports, where similar challenges of safety and communication persist. Key features of the system include continuous real-time vitals monitoring, emergency alerts, precise location tracking, and offline functionality for retaining last-known coordinates. These capabilities collectively provide a robust safety net for individuals venturing into hazardous environments, offering peace of mind to both adventurers and their loved ones. By enhancing the efficiency and effectiveness of rescue operations, this system not only mitigates the inherent risks of outdoor activities but also significantly improves the chances of survival in emergencies. In doing so, it represents a vital innovation in the field of adventure safety, catering to the growing needs of a community that seeks to explore the limits of human potential while prioritizing safety and preparedness.

II. LITERATURE SURVEY

"A Novel Drone-based Search and Rescue System using Bluetooth Low Energy Technology" (2023) by Anas M. Hashmi introduces a UAV drone system designed to locate lost individuals using Bluetooth Low Energy (BLE) technology. The system's innovative approach enhances search and rescue efficiency by detecting BLE signals from devices carried by missing persons. However, the research identifies challenges such as computationally expensive simulations and accuracy limitations, particularly in turbulent flow conditions. These factors may hinder the system's effectiveness in complex rescue environments. Despite these limitations, the approach promises improvements in drone-assisted rescue operations [1].

"Indoor Real-Time Location System for Efficient Location
Tracking Using IoT" (2023) by Arya Jayaprakash, Renuka M, and Sheik Mohammed explores the use of IoT in realtime location tracking for indoor environments. The system offers efficient solutions for indoor navigation and monitoring. However, the authors highlight concerns regarding privacy risks and challenges in maintaining connectivity and infrastructure, particularly in large, complex indoor settings. Despite these challenges, the research shows promise for improving location tracking in buildings, though future work may need to address privacy and scalability issues [2].

"The Use of Unmanned Aerial Vehicles and Drones in Search and Rescue Operations – A Survey" (Date not specified) by Sean Grogan, Michel Gamache, and Robert Pellerin surveys the role of UAVs and drones in search and rescue operations, identifying technological gaps and optimization strategies for SAR tasks. The paper emphasizes the potential of UAVs to improve search efficiency, though it notes limited practical implementations and ongoing challenges in sensor integration, especially in urban SAR environments. The survey provides valuable insights into the current state of UAV technology in SAR, highlighting both its potential and existing hurdles [3].

"Trekking Navigation System using Opportunistic
Communication" (2013) by Yasuhiko Kitamura, Shunsuke Nosaka, Hirofumi Kishino, and Yui Okuda presents a navigation system for climbers in remote areas with limited communication infrastructure. By leveraging opportunistic communication, the system improves location estimation in areas with poor connectivity. However, the study acknowledges its reduced effectiveness in regions with fewer climbers and the high battery consumption due to frequent communication attempts. Despite these challenges, the system offers a promising solution for enhancing navigation in remote trekking environments [4].

"An IoT Based Health Monitoring System" (April 2023) by
Harsiddh Bhagchand Khosa, Avinash T Rajput, Abhishek N Aher, and Darshan C Bhatt explores the integration of IoT technology in healthcare monitoring. The system focuses on continuous monitoring of health parameters to provide realtime data for medical assessment. However, the authors note its limitations in providing immediate interventions or conducting in-depth critical analysis, restricting the system's application to basic health monitoring tasks. Despite these limitations, the approach offers a valuable solution for ongoing health tracking [5].

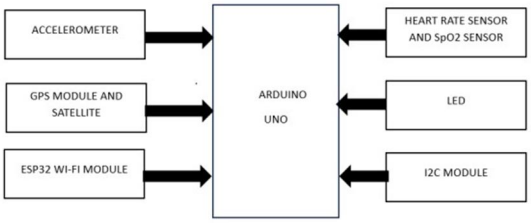
"IoT-based Healthcare Monitoring and Tracking System for
Soldiers using ESP32" (2020) by P. Sujitha, V. Srinivasan, R. Sushmitha, and K. Sugapriya develops an IoT-based healthcare monitoring system for soldiers using ESP32 modules. This system allows for real-time tracking of health data, enhancing situational awareness in military contexts. However, challenges include limited geographic coverage, connectivity issues in remote areas, and

the need for a continuous power supply. Despite these challenges, the system offers a useful tool for healthcare monitoring in military operations, requiring further refinement for broader deployment [6].

III. METHODOLOGY

The Mountain Climber Health Monitoring and GPS Tracking System is designed to provide real-time monitoring of climbers' health parameters and location. The system integrates multiple hardware components such as sensors, communication modules, and a microcontroller to collect, process, and transmit data effectively. Key sensors include a heart rate and SpO2 sensor for monitoring vital signs, an accelerometer to calculate acceleration along the Z-axis, and a GPS module to determine the climber's location in terms of latitude and longitude. A push button serves as an emergency alert mechanism, enabling the climber to send distress signals if needed.

The microcontroller (ESP32) acts as the central processing unit, interfacing with the sensors and communication modules. Data from the sensors are processed and displayed on an LCD in real time, while the GPS coordinates are periodically updated. The ESP32 transmits this data to an AWS IoT platform using its Wi-Fi capabilities. The AWS cloud platform hosts a dashboard that visualizes key metrics, including heart rate, SpO2 levels, location, and acceleration. In emergency situations, the GSM module sends an SMS alert containing the climber's vital signs and GPS coordinates to predefined contacts. To ensure robust system performance, the hardware components are carefully integrated, with data communication facilitated through I2C and GPIO interfaces. The software is developed using embedded C/C++ for firmware programming and cloud integration scripts for AWS. The system undergoes extensive testing, including unit testing of individual components and integration testing of the entire system, to ensure reliability in real-world scenarios. Finally, the system is encased in a rugged, waterproof enclosure to withstand harsh environmental conditions during mountain expeditions. This comprehensive methodology ensures the effective monitoring of climbers' health, real-time tracking of their location, and immediate emergency assistance, enhancing safety during challenging mountain climbs.



IV. RESULT AND DISCUSSION

The IoT-enabled safety system for mountain climbers successfully achieves its intended functionalities of realtime monitoring, emergency alerts, and precise location tracking. The system integrates heartbeat and temperature sensors, GPS tracking, and GSM communication modules to ensure seamless operation in remote and rugged terrains.

Below are the observed outcomes:

1) Real-Time Monitoring

The system continuously monitors vital parameters, including heart rate and body temperature. The data is displayed in real-time on an LCD screen (refer to fig1) and transmitted to a cloud-based platform. This allows for constant supervision of climbers' health conditions.

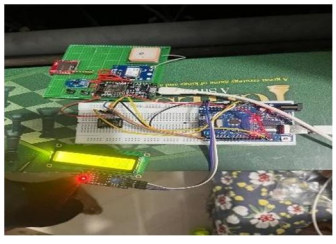


Fig no.1 (circuit setup with LCD)

2) Emergency Alerts

In case of health parameters breaching predefined thresholds, the system successfully sends SMS notifications to preconfigured emergency contacts. These alerts contain essential details, such as the climber's heart rate, temperature, and GPS location, ensuring rapid response.

3) Location Tracking

The GPS module provides accurate real-time location data of the climber. Even in areas with limited network connectivity, the system stores the last-known location, enabling rescuers to focus search efforts effectively.

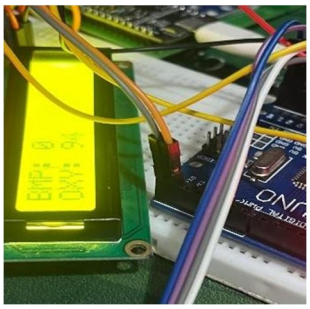


Fig no.2 (closer view of the LCD display)

4) Web Dashboard Integration

The data transmitted is visualized on a web-based dashboard, which shows the climber's vitals and their live location on a map. This dashboard serves as a centralized hub for monitoring and decisionmaking (refer to fig3).

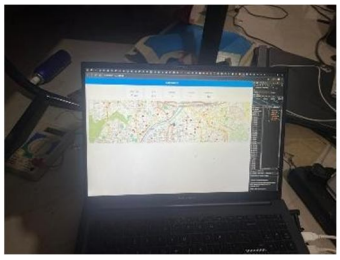


Fig no.3 (web dashboard screenshot)

The implemented system demonstrates significant potential in improving the safety and survival of mountain climbers.
Key points of discussion are as follows:

1) Efficiency in Emergency Response: The system's ability to monitor health parameters and transmit real-time alerts greatly reduces the time taken to detect and respond to emergencies. By providing exact GPS coordinates, it ensures rescuers can reach the affected climber promptly.

2) Reliability in Remote Conditions: With offline functionality for retaining the lastknown location, the system proves reliable in areas with limited or no network coverage, a common scenario in high-altitude regions.

3) Versatility: While designed for mountain climbers, the system's applicability extends to other high-risk activities, such as trekking, scientific expeditions, and adventure sports, making it a versatile safety solution.

4) Limitations: The system relies on GSM connectivity for transmitting SMS alerts, which could be a challenge in extremely remote locations. Future iterations could integrate satellite communication for enhanced coverage. o Power consumption is another concern; optimizing the energy efficiency of the system would be critical for prolonged use.

V. RESEARCH GAP

While significant advancements have been made in integrating Internet of Things (IoT) technology into various domains, including healthcare and search-and-rescue operations, there remains a notable gap in applying IoT systems specifically to the safety and well-being of mountain climbers in remote, high-altitude environments. Previous research has focused on improving real-time location tracking, emergency response systems, and health monitoring for general outdoor activities or soldiers in the field.

However, these studies often overlook the unique challenges faced by mountaineers, such as extreme environmental conditions, lack of stable communication infrastructure, and the need for real-time health monitoring coupled with precise geolocation tracking. Existing systems in rescue operations often rely on dronebased solutions (e.g., UAVs using BLE technology), but these are limited by their accuracy, environmental conditions, and computational requirements, particularly in turbulent mountain environments. Similarly, while health monitoring systems using IoT are explored in medical or military contexts, these solutions often fail to address the specific constraints of mountain climbing, such as battery consumption, unreliable networks, and the need for realtime location data to optimize rescue operations. Furthermore, many location-based tracking systems designed for low-connectivity areas use opportunistic communication techniques but suffer from issues like high battery consumption and inefficiency in sparsely populated regions, which are common in mountain terrain. Many health-monitoring IoT systems, though useful for basic vitals tracking, do not offer real-time alerts or integration with a rescue operation network, nor do they consider the unique topographical and logistical challenges faced during mountain rescues.

Thus, there is a clear gap in developing an IoT-based system specifically tailored for mountain climbing that integrates continuous health monitoring (e.g., heart rate, body temperature), location tracking (via GPS), and emergency communication (via GSM) in a way that mitigates the impact of unreliable connectivity and ensures efficient and timely search-and-rescue operations. This project seeks to fill this gap by providing a comprehensive solution that combines real-time monitoring with offline functionality, offering a robust safety net for climbers and an effective tool for rescuers, which has yet to be addressed comprehensively in the existing body of research.

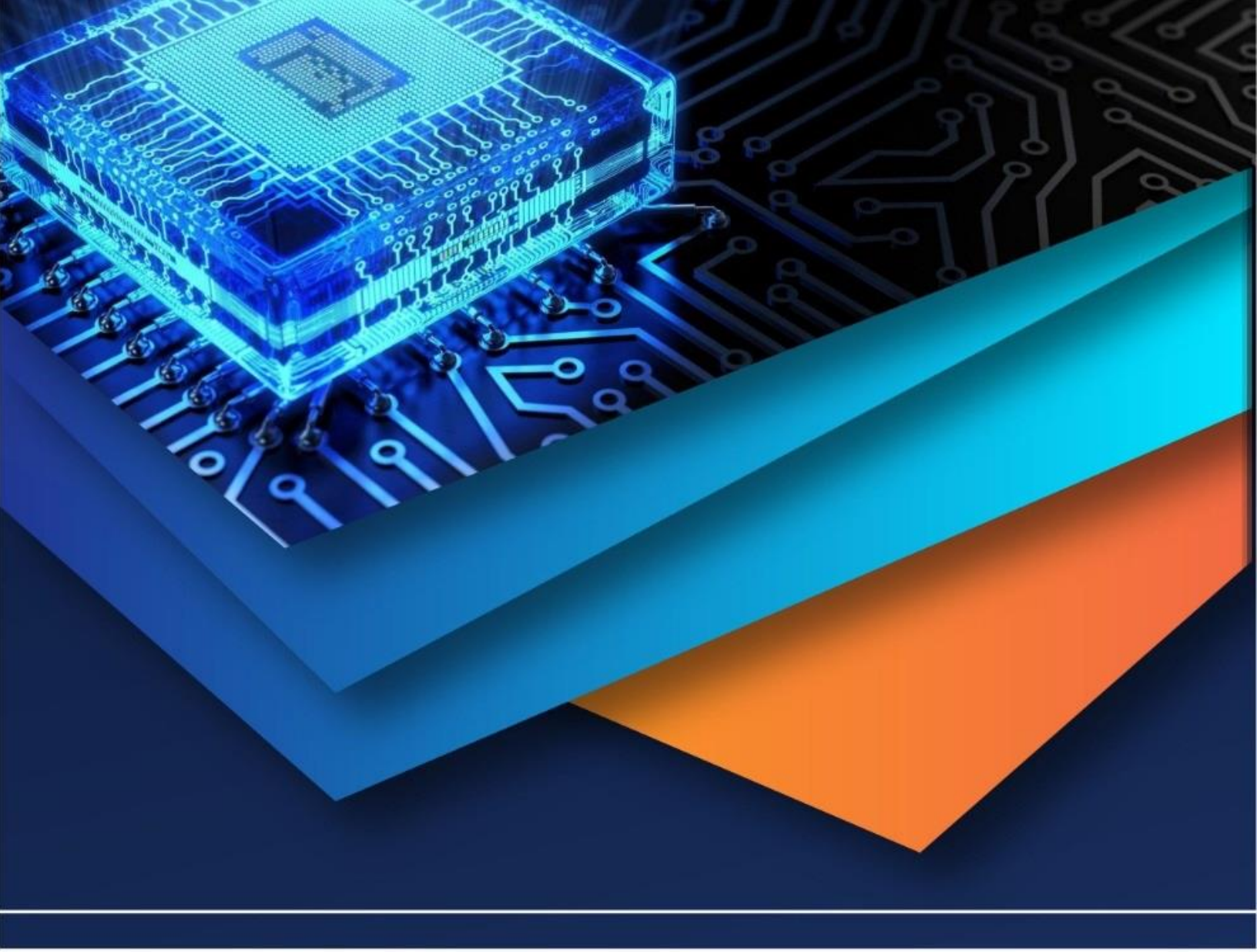
VI. CONCLUSION

This project proposes an innovative IoT-enabled monitoring system designed to enhance the safety of mountain climbers by providing real-time tracking of their health and location in remote, high-altitude environments. By integrating sensors to monitor vital signs such as heart rate and body temperature, along with GPS for precise location tracking and GSM for emergency communication, the system offers a robust solution to mitigate the inherent risks of mountain climbing. The ability to send real-time alerts when health parameters exceed predefined thresholds, coupled with lastrecorded location data in the absence of network connectivity, significantly improves the chances of a timely and successful rescue operation. The IoT system addresses critical challenges in rescue operations, such as delayed responses due to the lack of real-time information, and the difficulty of locating climbers in rugged and remote terrains. The continuous monitoring of vital signs ensures that health crises, such as hypothermia or altitude sickness, can be detected early, while location tracking provides rescuers with the climber's exact coordinates, even in cases of network failure. This system not only enhances climber safety but also optimizes the effectiveness of search-andrescue efforts, potentially saving lives. The implications of this project extend beyond mountain climbing to other highrisk outdoor activities such as trekking, wilderness exploration, and adventure sports. By offering real-time monitoring, emergency alerts, and precise location tracking, the system ensures a higher level of preparedness and response in dangerous environments, contributing to overall safety and survival. In conclusion, this IoT-based solution represents a significant step forward in the integration of technology into adventure safety, providing an essential tool for both adventurers and rescue teams in managing risks associated with outdoor expeditions.

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