AMERICAN JOURNAL OF MANAGEMENT AND IOT MEDICAL COMPUTING
Peer Reviewed, Referred & Indexed Journal
E-ISSN: 3069-0110
Vol.5, No.2(2026)
www.ajmimc.com

IoT-Based Emergency Rescue System for Real-Time Accident Detection and Location Tracking

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Abstract

The increasing occurrence of accidents and emergency situations has highlighted the critical need for rapid response systems, with over 1.3 million road accident deaths reported annually and delayed emergency response contributing significantly to preventable fatalities, while IoT-based emergency systems are projected to grow at over 17% annually. Additionally, in disasters and industrial hazards, the lack of immediate location tracking and communication often leads to delayed rescue operations and increased loss of life. Traditional emergency response systems rely heavily on manual reporting, which can be delayed or impossible if the victim is incapacitated, and they often lack precise location tracking and automated alert capabilities. Furthermore, conventional systems do not provide continuous monitoring or integration with modern communication networks, reducing their effectiveness in critical situations. To address these challenges, the proposed IoT Emergency Rescue System utilizes the ESP32 microcontroller to develop an intelligent and automated emergency detection solution. The system integrates a vibration sensor to detect sudden shocks or accidents and an ultrasonic sensor to identify nearby obstacles or environmental changes. A GPS module determines the exact location of the incident, while a GSM module transmits real-time alerts and location details to predefined contacts or emergency services. The system also provides local alerts through a buzzer and displays status information on an LCD. Additionally, IoT integration enables remote monitoring and data visualization through cloud platforms. This smart system enhances emergency response efficiency, reduces rescue delays, and provides a reliable and scalable solution for saving lives in critical situations.

Keywords: Accident Detection, Emergency Response System, GSM Communication, Internet of Things, Real-Time Monitoring, Smart Safety System, Ultrasonic Sensor, Vibration Sensor

1. Introduction

The increasing occurrence of accidents and emergency situations has made rapid response systems a critical necessity worldwide [1]. It is estimated that over 1.3 million people lose their lives annually due to road accidents, with many fatalities resulting from delayed emergency assistance [2]. In disaster scenarios and industrial hazards, the absence of immediate communication and accurate location tracking further increases the risk of loss of life. Additionally, IoT-based emergency response systems are projected to grow at over 17% annually, reflecting the growing adoption of intelligent technologies for safety and rescue operations [3].

In environments such as road accident sites, disaster management zones [4], industrial areas, and remote locations, there is a crucial need for systems capable of real-time monitoring, instant alert generation [5], and precise location tracking to ensure timely and effective rescue efforts.

Traditional emergency response systems primarily depend on manual reporting through phone calls or third-party intervention. These methods are often unreliable [6], especially when victims are unconscious, injured, or unable to communicate [7]. Delays in reporting incidents can significantly impact rescue operations and survival rates. Furthermore, conventional systems lack automated detection mechanisms and do not provide continuous monitoring of critical conditions. The absence of integrated GPS tracking and real-time communication reduces the ability of emergency services to respond quickly and accurately [8]. These limitations make traditional systems inadequate for handling modern emergency scenarios efficiently.

In real-time situations, these limitations lead to several critical challenges that can severely affect rescue outcomes. Accidents or sudden impacts may go undetected without automated sensing systems, delaying emergency response. The lack of precise location information can slow down rescue teams, especially in remote or unfamiliar areas. Additionally, the absence of continuous monitoring and instant alert mechanisms prevents timely intervention during critical moments. In industrial or disaster environments, environmental changes and hazards may not be communicated effectively, increasing risks to affected individuals. These challenges highlight the need for an intelligent, IoT-based emergency rescue system capable of automatic incident detection, real-time communication, and accurate location tracking, ensuring faster response, improved coordination, and ultimately saving lives.

2. Literature Survey

Biswal et al. [9] proposed an Internet of Things (IoT)-based smart alert system for drowsy driver detection that utilized sensor data and behavioral analysis to identify fatigue conditions. Zhen et al. [10] proposed an early collision detection mechanism for massive random access in satellite-based IoT systems using communication analysis techniques.

Uma et al. [11] proposed an accident prevention and safety assistance system using IoT and machine learning techniques to monitor driving behavior and predict potential hazards. Bhakat et al. [12] proposed a vehicle accident detection and alert system using IoT and Artificial Intelligence (AI) that identified accidents through sensor data and triggered emergency notifications.

Balfaqih et al. [13] proposed an accident detection and classification system using IoT and machine learning for smart city applications. Pathik et al. [14] proposed an AI-enabled accident detection and alert system using IoT and deep learning for smart cities that enhanced detection accuracy and response efficiency.

Geetha et al. [15] proposed a vehicular accident detection and alert generation system using IoT that monitored vehicle conditions and transmitted emergency alerts upon detecting abnormal events. Zavantis et al. [16] proposed an automatic accident detection system using IoT and compared its performance with traditional traffic center-based detection systems.

Alkhaiwani et al. [17] proposed an IoT-based accident detection framework that securely reported accidents along with driver information using secure communication protocols. Dange et al. [18] proposed an IoT-based vehicle accident detection system integrated with an application interface for emergency assistance.

Patel et al. [19] proposed a cloud-enabled automatic accident detection system using IoT that integrated sensors, cloud computing, and communication technologies for prompt emergency response. Li et al. [20] proposed a freeway incident detection method using wireless positioning techniques to identify accidents and abnormal events on highways.

3. Proposed System

Figure 1 illustrates the architecture of an ESP32-based smart emergency detection and alert system designed to identify accidents and provide immediate notifications. The system is built around the ESP32, which acts as the central processing unit. It integrates multiple sensors such as a vibration sensor for accident detection, an ultrasonic sensor for obstacle detection, and a GPS module for real-time location tracking. A regulated power supply ensures stable operation of all components. The ESP32 processes the sensor data and activates output devices including an LCD display, buzzer, GSM module for alert messaging, and IoT connectivity for remote monitoring. This system ensures rapid emergency detection, real-time alerts, and efficient rescue response.

Step 1: Power Supply Initialization: The regulated power supply converts input voltage into stable DC voltage required for the ESP32 and all connected components, ensuring reliable system operation.

Step 2: Vibration-Based Accident Detection: The vibration sensor detects sudden shocks or impacts that may occur during accidents. When abnormal vibration is sensed, it sends a signal to the ESP32 indicating a possible emergency.

Step 3: Obstacle Detection using Ultrasonic Sensor: The ultrasonic sensor measures the distance between the system and nearby objects. It helps in detecting obstacles and monitoring surroundings to prevent collisions.

Step 4: Location Tracking using GPS: The GPS module determines the exact geographical location of the system using satellite signals. This information is crucial for identifying the location of an accident or emergency.

Step 5: Data Processing by ESP32: The ESP32 processes inputs from all sensors and determines whether an emergency condition has occurred based on predefined thresholds.

Step 6: LCD Display Output: The LCD displays system status, sensor readings, and emergency alerts, allowing users to understand the system condition in real time.

Step 7: Buzzer Alert System: When an emergency is detected, the buzzer is activated to provide an audible alert, notifying nearby individuals of the situation.

Step 8: GSM-Based Emergency Notification: The GSM module sends alert messages along with GPS location details to predefined contacts or rescue authorities, enabling quick response.

Step 9: IoT-Based Remote Monitoring: The ESP32 uploads system data to a cloud platform via IoT, allowing remote monitoring, tracking of emergency events, and data analysis through web or mobile applications.

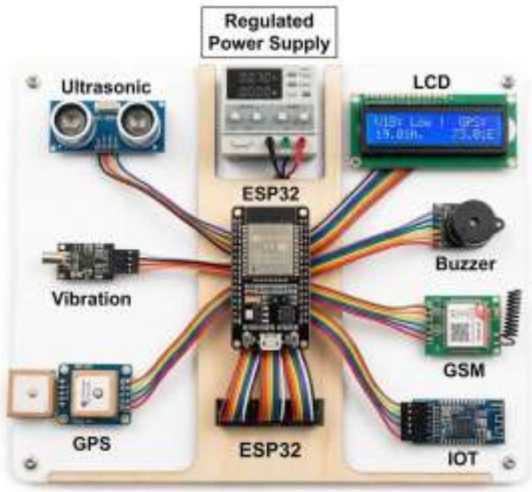

Figure 1. ESP32-Based Smart Emergency Detection and Alert System.

3.1 Working Procedure

The working of the IoT Emergency Rescue System as shown in Figure 2 begins when the system is powered on. The ESP32 microcontroller initializes all connected components such as the vibration sensor, ultrasonic sensor, GPS module, GSM module, LCD display, and buzzer.

The vibration sensor continuously monitors the system for sudden shocks or abnormal vibrations that may indicate an accident or emergency. At the same time, the ultrasonic sensor monitors nearby obstacles or surrounding objects. If the vibration sensor detects a strong impact, the ESP32 recognizes it as an emergency.

Once an emergency condition is detected, the ESP32 retrieves the exact geographical coordinates from the GPS module. These coordinates represent the location of the accident or emergency event.

The system then activates the buzzer, which provides an audible alert to notify nearby people. The LCD display simultaneously shows emergency information and system status messages.

Next, the ESP32 sends an emergency alert message using the GSM module, which includes the GPS location of the accident. This message is sent to predefined contacts or emergency authorities so that rescue teams can reach the location quickly.

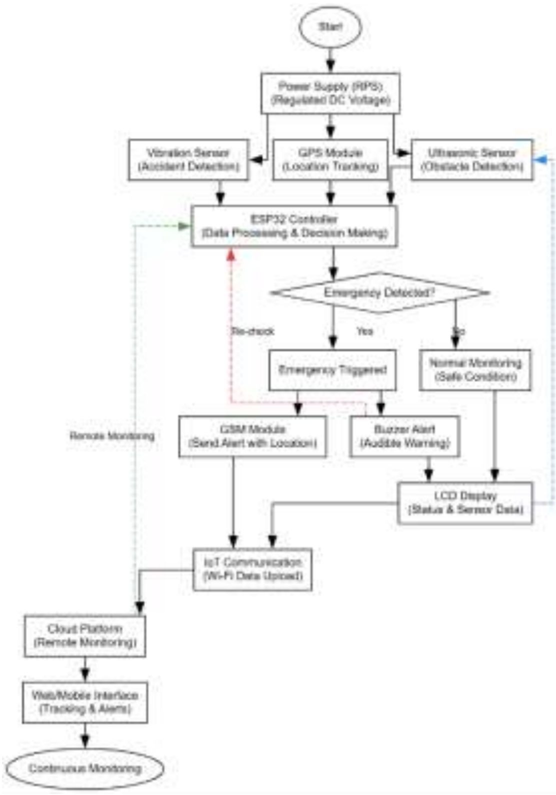

Figure 2. Proposed Flowchart.

Additionally, the system uploads the collected data to an IoT platform, allowing remote monitoring of the emergency in real time. Through continuous monitoring, location tracking, and automatic communication, the proposed system significantly reduces the time required for emergency response and improves rescue efficiency.

Figure 3 illustrates the circuit diagram of an ESP32-based IoT emergency rescue system designed for real-time monitoring and rapid response during critical situations.

The system is powered by a regulated power supply unit consisting of a step-down transformer, bridge rectifier, filter capacitors, and a 7805-voltage regulator to provide a stable +5V output. The ESP32 microcontroller acts as the central control unit, interfacing with a GSM module for sending emergency alerts, a GPS module for real-time location tracking, and a vibration sensor to detect accidents or unusual movements. An ultrasonic sensor is included for obstacle detection or proximity sensing, enhancing situational awareness. The system also integrates an IoT module for remote monitoring and data transmission to cloud platforms, while a 16×2 LCD displays real-time system status and alerts. A buzzer provides immediate audible warnings during emergencies. This integrated system ensures quick detection, communication, and response, making it highly suitable for rescue operations, accident detection, and personal safety applications.

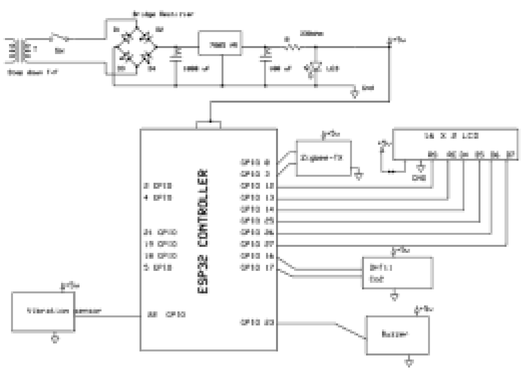

Figure 3. Circuit Diagram of ESP32-Based IoT Emergency Rescue System.

4. Results and Discussion

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Figure 4 shows the complete hardware setup of the IoT Emergency Rescue System. The system integrates an ESP32 microcontroller, GPS module, ultrasonic sensor, vibration sensor, buzzer, and LCD display to detect accidents and transmit emergency alerts with location information.

Figure 5 shows the LCD display output of the Emergency Rescue System. The display indicates that the system is active and ready to detect emergency situations such as accidents or obstacle detection.

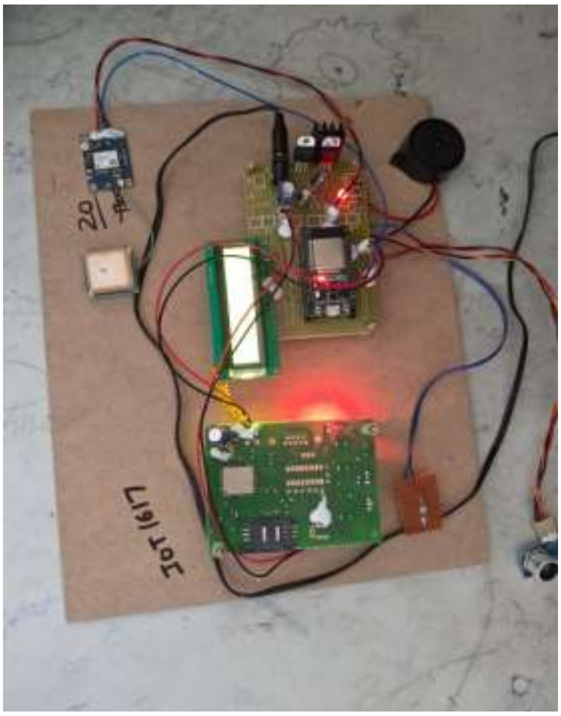

Figure 4. Hardware Implementation of IoT Emergency Rescue System

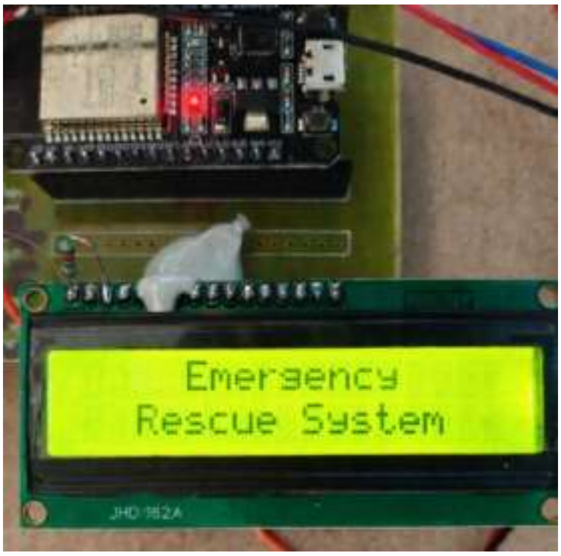

Figure 5. LCD Display Showing Emergency Rescue System Status.

Figure 6. IoT Server Monitoring Dashboard

Figure 6 shows the IoT web server interface used for monitoring emergency events remotely. The dashboard displays sensor data including ultrasonic readings, vibration status, location information, and timestamps for real-time rescue monitoring.

5. Conclusion

The proposed IoT Emergency Rescue System presents an effective and intelligent solution for addressing critical delays in emergency response by integrating real-time detection, location tracking, and automated communication. By utilizing the ESP32 microcontroller along with vibration and ultrasonic sensors, the system can promptly detect accidents and abnormal situations without relying on manual intervention. The integration of GPS ensures accurate location identification, while GSM-based alerts enable immediate notification to emergency contacts or rescue services, significantly reducing response time. Local alerts through a buzzer and LCD display further enhance situational awareness. Additionally, IoT connectivity allows remote monitoring and data analysis, supporting better coordination and decision-making during emergencies. This system overcomes the limitations of traditional methods by providing continuous monitoring, instant alerts, and reliable communication. Finally, it enhances rescue efficiency, minimizes fatalities, and contributes to the development of smart, responsive, and life-saving emergency management systems.

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