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Disaster Recovery and Survivor Localization System using STM32 Microcontroller

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ABSTRACT: Landslides are one of the most devastating natural disasters, often leading to the burial of people under debris, making search and rescue operations extremely challenging. Traditional detection methods, such as trained rescue dogs and ground-penetrating radar, have several limitations, including inefficiency, high costs, and difficulty in real-time monitoring. To address these issues, this project proposes an IoT-based human detection system that integrates multiple sensors for enhanced accuracy. The system consists of an MLX90614 infrared temperature sensor to detect body heat, a SEN0193 soil moisture sensor to monitor soil conditions, an SM24 geophone seismic sensor to measure ground vibrations, and an NDIR CO₂ sensor to identify human respiration. All sensor data is processed using an STM32 microcontroller, which analyzes and classifies the information. The results are displayed in real-time on the Blynk IoT platform, providing rescue teams with instant updates on possible human presence beneath the debris. Additionally, an AI-based precision analysis module is implemented to distinguish between humans and other objects, significantly reducing false positives and improving efficiency. By combining sensor fusion, IoT technology, and AI-based classification, this system offers a reliable and cost-effective approach to enhancing landslide rescue efforts, potentially saving more lives in disaster-prone regions.

KEYWORDS: Landslide Detection, IoT, STM32 Microcontroller, Human Presence Detection, AI- Based Classification, Multi-Sensor Fusion, Disaster Management, Real-Time Monitoring.

I. INTRODUCTION

Landslides are an especially dangerous phenomenon, usually engulfing people underneath the rubble and making rescue very difficult. Conventionally used detection techniques, e.g., guide dogs and ground-penetrating radar, are slow, costly, and frequently unsuccessful when used in dangerous terrain. Inadequate promptness in victim detection lowers rates of survival and thus necessitates a quicker, more accurate search system. An IoT-based survivor detection system that uses several sensors to enhance search efficiency. An infrared sensor senses body temperature, a CO₂ sensor tracks breathing, a seismic geophone records ground movement, and a soil moisture sensor assesses environmental conditions. These sensors' data is processed using an STM32 microcontroller and sent to the Blynk IoT platform for real-time monitoring by rescue teams. To improve accuracy of detection, an AI-based classification system screens sensor information, separating human presence from natural noise. Integrating IoT, AI, and multi-sensor fusion, the system offers a cost-effective, real-time, and trusted method for finding survivors and significantly enhances response times in landslide-prone areas.

1.1. Background on landslides

The movement of rock, soil, and debris down a slope due to gravity is known as a landslide. This phenomenon is typically caused by natural events like earthquakes, volcanic eruptions, or intense rains, as well as man-made ones like deforestation and construction on unstable ground. They might happen suddenly, covering communities and infrastructure with dense debris. Locating buried survivors is one of the most difficult tasks in landslide response. Because of the potential for injuries, restricted ventilation, and shortened time for rescue operations, detection delays diminish survival rates. As a result, advanced technology that can enable faster and more accurate survivor detection must be incorporated into the procedure.

1.2. Limitations of Traditional Detection Methods

To locate those buried beneath avalanche rubble, rescue crews have traditionally relied on manual excavation, ground-penetrating radar, and trained dogs. Although these techniques have saved lives, there are several drawbacks: Although they need years of training and may have trouble in harsh conditions, trained search dogs are efficient. Although it can be helpful, ground-penetrating radar (GPR) is costly, requires skilled operation, and might not function well in areas with a lot of debris. Both rescuers and survivors are at risk from manual excavation since it is labor-intensive, sluggish, and increases the likelihood of more landslides. In deep-burial situations, where heavy layers of material obscure heat signals, thermal imaging and sound detection frequently fall short. A more sophisticated, economical, and real-time solution is desperately needed to enhance landslide rescue operations because of these drawbacks.

1.3. Proposed Solution

A human detection system based on the Internet of Things that makes use of several sensors to deliver precise and fast information on stranded survivors. The following are the main elements of this system:

Even under detritus, the Infrared **Temperature Sensor (MLX90614)** detects the heat of the human body. The **Soil Moisture Sensor (SEN0193)** measures the amount of landslide damage by analyzing soil conditions. The **Geophone Seismic Sensor (SM24)** picks up vibrations from movement or survivors' distress calls. **CO₂ Sensor (NDIR)** Verifies the existence of human breathing by tracking the amount of carbon dioxide exhaled. The **STM32 microcontroller** controls system functions and processes sensor data. Rescue crews may view real-time survivor location data on the Blynk IoT Platform. **AI-Driven Classification** This technique reduces false alarms by using clever algorithms to distinguish between human and non-human things.

This system offers a more efficient and scalable method of disaster response by combining multi-sensor technologies, AI-powered analysis, and real-time monitoring. In regions affected by landslides, the objective is to increase search efficiency, reduce reaction time, and optimize survival rates. providing a quicker, more precise, and more dependable approach, this creative solution seeks to rethink conventional rescue techniques and guarantee that no person remains undiscovered after a catastrophe.

II. LITERATURE SURVEY

Landslides are extremely damaging and frequently result in significant property damage and fatalities. Numerous methods for identifying human presence and detecting landslides have been investigated by researchers; each has advantages and disadvantages of its own. This section summarizes important research in the area and highlights the necessity of a multi-sensor, integrated detection system to improve rescue efforts.

2.1. Deep Learning-Based Landslide Detection

A deep learning algorithm was created by Anbalagan et al. (2023) to identify landslide-prone areas using geospatial data and satellite photos. The model was inappropriate for emergency rescue operations due to its lack of real-time monitoring capabilities, despite its excellent accuracy in danger assessment. A more responsive method is necessary for efficient post-landslide detection to promptly find stranded people.

2.2. IOT-Based Landslide Prediction System

In order to identify possible landslide occurrences before they happen, Sharma et al. (2022) suggested an Internet of Things-based landslide prediction system that integrates vibration and soil moisture sensors. The method did not concentrate on locating survivors after the tragedy, despite being successful in predicting the likelihood of landslides. In real rescue efforts, the strategy is still constrained in the absence of human-specific detecting systems.

2.3. Thermal Imaging for Search and Rescue

The use of thermal imaging technology to find survivors in disaster areas was investigated by Martinez et al. (2021). Although thermal cameras were successful in detecting heat signatures, they were less efficient in harsh situations like cold or heavy rain, where it was harder to tell body heat apart. This emphasizes the need for more sensing techniques to increase the precision of detection.

2.4. Seismic Sensors for Ground Movement Analysis

The function of seismic sensors in tracking ground movements was investigated by Chen et al. (2020). Their study showed that landslide early warnings might be obtained by examining vibration patterns. Human detection, which is crucial in post-disaster situations, was not included in the study. Survivors buried beneath rubble cannot be found using seismic data alone.

2.5. CO₂ Sensors for Trapped Human Detection

The use of CO₂ sensors to detect survival based on breathing patterns was examined by Gupta et al. (2020). According to their results, higher CO₂ levels may be a sign of human presence. They did point out that comparable results may result from decaying organic materials, which could cause false positives. For increased accuracy, this emphasizes the value of a multi-sensor strategy that integrates CO₂ detection with additional complementing technologies.

III. SYSTEM ANALYSIS

One of the most hazardous natural disasters is a landslide, which may imprison people beneath enormous piles of rubble. Rapidly locating survivors is essential, but conventional search methods, such as thermal imaging, ground-penetrating radar (GPR), and trained rescue dogs, have significant drawbacks. GPR has trouble with uneven terrain, rescue dogs can be unreliable in bad weather, and thermal imaging is ineffective in severe weather or when victims are buried deep.

3.1. System Overview

This study addresses these issues by presenting an Internet of Things (IoT)-based detection system that enhances search accuracy by integrating many sensors with AI-powered analysis. MLX 90614 Infrared Temperature Sensor measures the heat of the human body. To determine the risk of landslides, the Soil Moisture Sensor (SEN0193) keeps an eye on the ground. Seismic Geophone Sensor (SM24) detects vibrations that could be signs of human motion. Under debris, the NDIR CO₂ sensor detects human breathing. Rescue teams can respond swiftly since all sensor data is processed by an STM32 microcontroller and sent in real time to the Blynk IoT platform. An AI-based classification method aids in distinguishing between erroneous detections and human signals to further improve accuracy, guaranteeing quicker and more accurate survivor identification.

3.2. Existing System

Traditional detection techniques, which are frequently ineffective, expensive, and inaccurate, are still used in search and rescue operations today. **Rescue dogs** can detect human scent, but they need a lot of training and are impacted by contaminants and weather. In certain situations, **Ground-penetrating radar (GPR)** works well, but it is costly and has trouble in rocky, uneven terrain. While useful for identifying body heat, **Thermal imaging** is ineffective under severe weather conditions or when victims are buried deep. **Manual Search Efforts** These are physically taxing and time-consuming, and they put rescuers in danger. Despite improvements, these techniques fall short in terms of accuracy, cost-effectiveness, and real-time data processing, supporting the need for a more sophisticated, sensor-driven strategy.

3.3. Disadvantages of Existing Systems

Unreliable Precision Weather, soil moisture, and topography are examples of environmental conditions that frequently impede detection techniques, resulting in missing victims or false positives.

Slow Reaction Time The odds of survival are decreased by the slowness of manual search operations and technologies that need professional interpretation.

Exorbitant operating expenses Many disaster response teams cannot afford the high cost of advanced search instruments like GPR and thermal imaging. In a similar vein, training and caring for rescue dogs costs a lot of money.

Sensitivity to Weather Rain, fog, or extremely high or low temperatures can interfere with several detection techniques, such thermal imaging, making them less efficient under challenging conditions.

Restricted Recognition The effectiveness of depth GPR and thermal imaging in landslides is limited because they have trouble finding survivors who are buried deep beneath dense debris.

Rescuers Are at High Risk In addition to being labor-intensive, manual rescue operations expose rescuers to hazardous terrain and the possibility of further landslides.

IV. PROPOSED SYSTEM

This research presents an Internet of Things (IoT)- based human detection system created especially for landslide rescue operations in order to address the shortcomings of conventional rescue techniques. To improve detection efficiency and accuracy, the system combines several sensors with analysis driven by artificial intelligence.

MLX90614 Infrared Sensor: picks the body heat that confined people emit. **SEN0193 Soil Moisture Sensor:** keeps an eye on the ground's conditions to determine how stable the debris is. **SM24 Geophone Seismic Sensor:** detects vibrations in the ground that could be signs of movement beneath the debris. **NDIR CO₂ Sensor:** Identifies human respiration by measuring carbon dioxide levels.

4.1. System Design

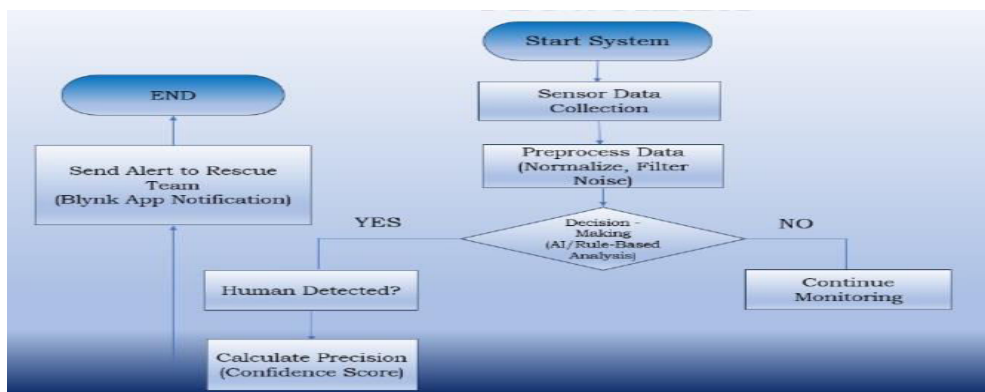


Figure 4.1. Flow of IoT-based human detection system.

An STM32 microcontroller processes all the data in real time, evaluating sensor readings to assess the probability of human presence. The technology incorporates an AI-based classification algorithm to further increase accuracy by separating humans from other sources and lowering false alarms. Blynk IoT platform receives the analyzed data, enabling rescue personnel to remotely monitor sensor readings through web or mobile interfaces. The likelihood of successful rescues is increased by the substantial improvement in response time and decision-making that this real-time tracking brings. The system is accessible in disaster-prone areas since it is made to be inexpensive, scalable, and simple to implement. It makes use of readily accessible sensors and microcontrollers. This method offers an accurate, cost-effective, and real-time way to find survivors trapped in landslides by fusing IoT, AI, and multi-sensor fusion.

4.2. Advantages

As compared to conventional search and rescue methods, the Internet of Things-based human detection system designed specifically for landslide rescue missions has the following advantages: **Real-Time Monitoring** It guarantees quicker response from the rescue teams by offering real-time sensor information via the Blynk IoT platform.

High Detection Accuracy Minimizes false alarms and maximizes accuracy in detecting survivors by combining multiple sensors and AI-driven analysis. **Cost-Effective** It is a cost-effective alternative for expensive rescue equipment like ground-penetrating radar because it utilizes relatively inexpensive, off-the-shelf STM32 microcontrollers and sensors. **Remote access** facilitates safer and more efficient rescue operations in risky locations by allowing rescue teams to observe data from a safe distance.

V. METHODOLOGY

The approach is centered on the systematic implementation of IoT-based sensors and artificial intelligence to increase the precision and effectiveness of human detection in landslide-hit regions. The IoT-based human detection system used for landslide rescue missions utilizes several sensors to collect real-time information, which is subsequently processed by an STM32 microcontroller. The processed data is sent to the Blynk IoT platform, allowing rescue teams to identify and locate survivors rapidly.

5.1. System Architecture

The system is based on a multi-sensor infrastructure that is intended to sense and interpret human presence under landslide rubble. The architecture has the following major components:

Sensors for Data Gathering MLX90614 Infrared Temperature Sensor – Sensing for human body heat. SEN0193 Soil Moisture Sensor – Tracks soil conditions to evaluate landslide hazards.

M24 Geophone Seismic Sensor – Sensor's vibrations which can signal trapped survivors.

NDIR CO₂ Sensor – Detects carbon dioxide concentration to detect human respiration.

Microcontroller Unit the STM32 microcontroller is the main processing unit, collecting and processing real-time data from all sensors.

AI-Based Classification Algorithm AI algorithms process sensor data, separating human presence from non-human sources, reducing false positives. IoT-Based Real-Time Monitoring

The processed data is sent to the Blynk IoT platform, which gives rescue teams real-time notifications and location-based information for effective decision-making. The multi-sensor IoT architecture provides high detection accuracy at an affordable cost and with scalability for deployment in landslide-prone regions.

5.2. Working Principle

The human detection system based on IoT, which is specifically tailored for landslide rescue missions, uses a rigorous order of operations for effective detection and localization of the buried victims. The working principle can be broken down into four primary stages:

Sensor Activation & Data Acquisition

After it is deployed, the system starts up and initializes its multi-sensor array to initiate real-time environmental monitoring. MLX90614 Infrared Thermal Sensor, NDIR CO₂ Sensor, SM24 Geophone Seismic Sensor, SEN0193 Soil Humidity Sensor. all the gathered information is periodically sampled and relayed to the STM32 microcontroller for processing in real-time.

Data Processing & AI-Based Classification

The central processing unit is the STM32 microcontroller that performs the following operations. data Filtering: Sensor data is cleaned of noise to remove anomalies generated by environmental perturbations. Feature Extraction: The system derives meaningful features like temperature fluctuations, CO₂ level fluctuations, and seismic activity patterns. AI-Based Classification: A pre-trained machine learning model classifies the extracted data to separate human presence from environmental noise. This minimizes false positives due to animals, non-human heat sources, or background vibrations.

Human Presence Verification & Localization

Once human presence has been verified by the classification algorithm, the system computes the approximate location of the trapped person: Seismic Sensor Data Correlation The geophone sensor correlates vibration signals to estimate the victim's position. environmental Context Analysis Soil moisture readings assist in measuring terrain stability to ensure safe rescue missions.

Real-Time Alert Transmission & Monitoring

Wirelessly transmitted from the processed information through an IoT communication module, the data gets displayed on the Blynk IoT platform with a mobile or web interface. Rescue teams receive Live sensor readings, Survivor locations displayed as heatmap, Environmental risk measures. The real-time alerts facilitate quick decision making, and emergency responders can effectively plan and implement rescue operations without unnecessary delays. through the integration of sensor fusion, AI- based classification, and IoT-based communication, the system offers a highly scalable, autonomous, and reliable solution for landslide disaster management.

Hardware and Software Components

The IoT-based human detection system in landslide rescue operation is dependent upon a fusion of hardware and software elements for precision detection, real-time tracking, and efficient processing of data. The hardware comprises several environmental sensors, a data processing microcontroller, and a wireless module for real-time transmission of data. In software, several programming tools, AI analysis tools, and visualization tools are employed for precision and efficiency of the system.

5.3. Hardware Components

The hardware components play a crucial role in detecting survivors trapped under landslide debris. The system integrates multiple sensors to collect real-time data, which is then processed and transmitted to the **Blynk IoT platform** for remote monitoring.

MLX90614 Infrared Temperature Sensor (Fig. 5.3.1) is a non-contact sensor that detects human body heat by measuring infrared radiation. This sensor is essential for identifying trapped victims, as human bodies emit heat in the infrared spectrum. It features a **16-bit ADC** and a **low-noise amplifier**, ensuring stable and precise temperature readings. The sensor operates within a **-40°C to 125°C** range, making it suitable for extreme environments. It communicates with the **STM32 microcontroller** using the **I2C protocol**, ensuring seamless integration.

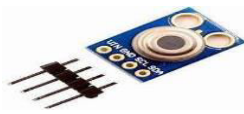


Figure 5.3.1. MLX90614 Infrared Temperature Sensor

SEN0193 Soil Moisture Sensor (Fig. 5.3.2) is used to measure soil moisture levels, helping assess ground stability before and after a landslide. It operates on the **resistive sensing principle**, where an increase in moisture reduces resistance, enhancing conductivity. This sensor also aids in detecting unusual moisture concentrations, which could indicate trapped survivors in an otherwise dry environment. When combined with thermal and acoustic sensors, it improves overall detection accuracy.



Figure 5.3.2. SEN0193 Soil Moisture

SM24 Geophone Seismic Sensor (Fig. 5.3.3) detects **ground vibrations** that may indicate human movement under debris. It converts ground motion into electrical signals, which can be analyzed to distinguish between natural seismic activity and movements caused by trapped victims. By analyzing **frequency and amplitude**, the system can determine whether vibrations result from survivors attempting to signal for help. When integrated with IoT, the geophone sensor can send **real-time alerts** to rescue teams, improving response efficiency.



Figure 5.3.3. SM24 Geophone Seismic Sensor

NDIR CO₂ Sensor (Non-Dispersive Infrared CO₂ Sensor) (Fig. 5.3.4) detects **carbon dioxide concentration** in the air, which is essential for identifying human respiration. Since trapped victims continuously exhale CO₂, a localized increase in concentration can serve as a biological marker for their presence. The sensor uses **infrared absorption technology**, ensuring high accuracy in distinguishing human presence from environmental CO₂ sources. It also filters out **false positives**, improving overall detection reliability.



Figure 5.3.4. NDIR CO₂ Sensor (Non- Dispersive Infrared CO₂ Sensor)

STM32 Microcontroller (Fig. 5.3.5) is the **central processing unit** of the system. It collects real-time data from all sensors, processes it using **AI-based classification algorithms**, and determines whether a human presence is detected under the debris. The STM32 is ideal for this application due to its **high processing speed**, **low power consumption**, and support for multiple **sensor communication protocols** (UART, SPI, I2C). It can execute **machine learning models** to differentiate between human activity and false signals, making detection more precise.



Figure 5.4.5. STM32 Microcontroller

ESP8266 Wi-Fi Module (Fig. 5.3.6) enables **wireless connectivity**, allowing real-time data transmission to the **Blynk IoT platform**. This module supports **TCP/IP networking**, making it suitable for IoT applications. The ESP8266 ensures that rescue teams can **remotely access sensor data**, reducing the time required to locate survivors. It sends real-time **sensor readings**, **CO₂ levels**, and **seismic activity** to a cloud-based system for continuous monitoring.



Figure 5.3.6. ESP8266 Wi-Fi Module

The system is powered by a **rechargeable lithium-ion battery** or an **uninterruptible power supply (UPS)** to ensure continuous operation in disaster-prone areas. A **low-power consumption design** extends the operational runtime, making the system reliable even during **power outages caused by landslides**.

5.4. Software Tools

The software tools used in the system facilitate **firmware development**, **AI-based data processing**, and **real-time monitoring**. These tools ensure seamless communication between hardware components and allow rescue teams to access and analyse sensor data efficiently.

Keil µVision IDE (Fig. 5.4.1) is used for **writing and debugging** the firmware code for the STM32 microcontroller. It provides an **integrated development environment (IDE)** with real-time execution analysis, optimizing system performance and sensor interfacing.



Figure 5.4.1. Keil µVision IDE

Arduino IDE (Fig. 5.4.2) is used for programming the **ESP8266 Wi-Fi module**, enabling wireless communication between sensors and the cloud. It supports various **libraries and APIs**, ensuring smooth integration with IoT platforms. The **serial monitor feature** allows real-time debugging and data analysis.



Figure 5.4.2. Arduino IDE

Blynk IoT Platform (Fig. 5.4.3) is a cloud-based interface that enables rescue teams to monitor sensor data remotely. It provides a **user-friendly dashboard** with real-time **graphical representations of temperature**, **CO₂ levels**, and

seismic activity. This platform ensures **fast response times** by sending instant alerts when a survivor is detected.



Figure 5.4.3. Blynk IoT Platform

MATLAB software (Fig. 6.2.4) is used for **AI- based analysis and signal processing**. It enables the training of **machine learning models** (e.g., Support Vector Machines, Neural Networks, Decision Trees) to classify sensor data and distinguish **human presence from environmental noise**. MATLAB provides tools for **pattern recognition, feature extraction, and probability estimation**, improving system accuracy.



Figure 5.4.4. MATLAB software

Proteus Design Suite (Fig. 5.4.5) is used for **circuit simulation and hardware validation** before physical implementation. It allows engineers to **test sensor integration, identify design flaws, and optimize circuit performance** before deployment.



Figure 5.4.5. Proteus Design Suite

VI. SYSTEM IMPLEMENTATION

The application of the IoT-based human detection system in landslide rescue operations involves combining hardware and software components to facilitate the precise detection of buried victims. The system uses real-time sensor data collection, AI- processing, and IoT-capable monitoring to send accurate and timely notifications to rescue teams. Data collection is done and processed by the STM32 microcontroller, which uses an AI-based classification algorithm to reduce false alarms. The processed data is then sent wirelessly to the Blynk IoT platform for real-time monitoring and effective rescue operations.

6.1. Sensor Data Collection

Data acquisition from sensors is important in ascertaining the accuracy and efficiency of the system. Sensors are used in regions prone to landslides to sense human body heat, seismic vibrations, moisture content in soil, and the level of carbon dioxide. This data is read by the STM32 microcontroller and subjected to decision-making rules to determine the trapped victims. Sensor data collection involves four fundamental steps. **sensor Activation and Initialization** STM32 microcontroller activates all the sensors upon system boot, each sensor goes through a self-calibration routine to guarantee precision, **Baseline environmental values** are captured for comparison. **Real-Time Data Acquisition** Sensors constantly capture data and forward it to the microcontroller; The system rejects unwanted noise and only processes applicable signals **Data is temporarily buffered** prior to further processing. **AI-Based Classification and Decision-Making** the AI algorithm processes the sensor data to detect human presence **False alarms, like environmental heat or animal activity, are eliminated** When several sensors detect a human, an emergency alert is sent. **Data Transmission and Cloud Integration** the ESP8266 Wi-Fi module sends authenticated sensor data to the Blynk IoT platform offers real-time data visualization for rescue teams. Alerts are transmitted through SMS, mobile apps, or email alerts.

6.2. Data Processing with STM32

The STM32 is the central processing unit that executes sensor inputs, data processing, and real- time decision-making. It provides instant computation, real-time data retrieval, and smart power management.

Major Steps of Data Processing:

Data Acquisition through Sensors STM32 acquires data from a variety of sensors, MLX90614 Infrared Sensor –

Measures body heat, SEN0193 Soil Moisture Sensor – Detects stability of soil., SM24 Geophone Sensor – Records seismicity, NDIR CO₂ Sensor – Detects human respiration.

Signal Conditioning and Noise Reduction Low-pass filters eliminate high-frequency noise. Baseline calibration avoids false triggering. Dynamic threshold controls adjust to variable environmental conditions. Analog-to-Digital Conversion (ADC) Sensors generate analogy signals, which are digitized for processing.

Threshold-Based Decision-Making Sensor readings are compared with predefined thresholds Increased CO₂ concentrations indicate breathing activity. Body temperatures within human limits verify presence. Seismic motion consistent with human movement patterns is detected.

Data Fusion & Correlation Analysis The system maps various sensor readings for better detection accuracy. If all the parameters point towards a trapped human, an alarm is raised.

Data Storage & Transmission Processed data is temporarily stored and sent to the cloud through IoT modules.

6.3. AI-Based Human Detection Algorithm

The human detection algorithm based on AI is an essential element that improves the capability of the system to detect trapped victims accurately with reduced false alarms. Utilizing sophisticated machine learning methods, the system analyses sensor data to discriminate human-specific patterns from ambient noise. The algorithm identifies important features like body temperature stability, fluctuations in CO₂ concentration associated with human breathing, and rhythmic seismic vibrations for movement. These attributes are subsequently inspected based on classification algorithms such as Support Vector Machines (SVM), Decision Trees, or Neural Networks that are trained with varying datasets for higher accuracy of identification.

In addition to enhancing accuracy, the AI model includes the detection of anomalies and adaptive learning processes. This enables the system to dynamically set its thresholds according to real-time environmental conditions, thus minimizing misinterpretations due to external sources such as heat from direct sunlight, natural CO₂ emissions, or background ground tremors. The AI algorithm also uses sensor fusion, combining data from various sensors to provide solid decision-making. For example, a temperature anomaly in isolation might not be a sign of human presence, but when coupled with high CO₂ levels and clear vibration signals, the system can reliably identify a trapped person. The AI model is executed on the STM32 microcontroller, which is optimized for real-time execution with light frameworks like TensorFlow Lite. This provides low power consumption, making the system ideal for deployment in resource-limited environments. Moreover, the system keeps refining its accuracy of detection continuously by integrating real-time data during rescue missions, enhancing its predictive efficiency over time. Through astute processing of sensor data, the AI-based detection process optimizes rescue efficiency, prevents false alarms, and has much higher chances of detecting survivors in areas devastated by landslides.

6.4. IOT-Based Real-Time Monitoring

The IoT-enabled real-time monitoring system is intended for instant remote monitoring of key sensor information, ensuring smooth coordination across rescue teams. Using wireless connection, the system offers real-time environmental and human presence data delivery to cloud infrastructures, triggering instantaneous situational awareness. The system utilizes various communication technologies, such as Wi-Fi (ESP8266/ESP32) for local high-speed data transmission, LoRa for long-distance communication in remote locations, and GSM (SIM800L) as a backup network for cellular communication. The multi-channel communication structure guarantees continuous data transmission, even in disaster-affected areas with poor infrastructure. The sensor data is processed and visualized using the Blynk IoT platform, which provides an interactive dashboard with live temperature variation, CO₂ levels, seismic activity, and soil moisture conditions. Rescue teams can track this data in real-time via mobile apps, web dashboards, and edge computing devices like tablets and smartwatches. In case of an anomaly that suggests human existence, the system initiates automatic notifications through push, emails, and SMS, which ensures timely response action. Equipped with GPS-based location tracking, the system delivers accurate geospatial information so that rescue teams can identify survivor locations with great accuracy. Live mapping functionality maps affected areas, enabling responders to target search-and-rescue efforts using real-time data intelligence. Additionally, sensor data is archived in cloud databases, facilitating post-event analysis for future disaster preparedness and predictive modelling. The IoT

monitoring system is designed for scalability and reliability, making it adaptable for large-scale deployments in disaster-prone regions. By integrating cloud computing, real-time analytics, and automated alert mechanisms, the system revolutionizes traditional rescue operations, enhancing decision-making efficiency, reducing response times, and ultimately saving more lives during landslide emergencies.

VII. SCOPE OF THE PROJECT

The IoT-Based Human Detection System for Landslide Rescue Operations aims to improve disaster response using real-time, sensor-based detection for survivors buried under rubble. Landslides are a dangerous phenomenon, commonly causing fatalities and huge property loss. Conventional search-and-rescue operations such as manual search, rescue dogs, and ground-penetrating radar are normally time-consuming, resource demanding, and susceptible to errors. This project seeks to overcome these constraints by combining IoT, AI, and multi-sensor technology to develop a highly accurate, cost-efficient, and scalable rescue system. The system employs various sensors such as MLX90614 infrared temperature sensors to sense body heat, SEN0193 soil moisture sensors to evaluate ground conditions, SM24 geophone seismic sensors to sense movement, and NDIR CO₂ sensors to detect human respiration. The collected sensor data is processed by the STM32 microcontroller, which applies an AI-based classification algorithm to distinguish between human presence and environmental noise. Upon detecting a survivor, the system transmits real-time alerts via the Blynk IoT platform, ensuring that rescue teams can respond swiftly and effectively. Beyond landslide rescue operations, the scope of this project extends to various disaster management and safety applications. It can be employed in earthquake-hit regions, destroyed structures, mine accidents, and industrial disasters, where rapid identification of the trapped is important. The technology is also useful in defense and military missions, facilitating search-and-rescue operations for wounded troops on the battlefield or in disaster areas. With further development, the system can aid underwater and snow avalanche rescues, where conventional search and rescue methods have severe challenges. valuable contributions to embedded systems, wireless communication, and AI-based detection algorithms. With the use of low-power, long-range communication technologies like LoRa and GSM, the system can be installed in far-flung, inaccessible areas without dependence on existing infrastructure. Future versions can integrate drone-based reconnaissance, enabling aerial scanning of disaster areas to detect survivors over a wider area. Moreover, cloud storage of data, location tracking with GPS, and AI-based predictive modelling can enhance detection efficiency and rescue effectiveness even more. The cost-effectiveness and scalability of the IoT-based solution are key benefits compared to traditional rescue methods that frequently involve highly costly, cumbersome, and specialized equipment. The system is intended to be light, mobile, and deployable, ideal for use by government agencies, disaster relief, military units, and non-profits. As development continues and it is put into practice in real-world settings, this project can become an essential resource for emergency response teams across the globe, greatly enhancing survivor detection rates, minimizing casualties, and expediting disaster recovery efforts.

7.1. Applications beyond-Landslides

Though the system's main aim is landslide rescue operations, it has applications in other disaster situations and industrial safety settings. The system can be used to detect survivors trapped beneath collapsed buildings during earthquake aftermaths. Mining disasters tend to trap workers under piles of debris where conventional detection will not work; this system can issue real-time alarms in such cases. Also, industrial settings with risky working conditions like oil rigs, chemical facilities, and underground tunnels-can utilize this detection technology to make their workplaces safer for employees. The system also has potential for military use, where soldiers buried in battlefield debris or destroyed buildings because of explosions can be found more effectively. In avalanche rescue, where victims are buried under snow, temperature compensation and snow-penetrating sensor technologies could enhance detection. With further development, the IoT-based system can be tailored for submarine or underwater search-and-rescue operations, enhancing overall emergency response capabilities.

7.2. Future Enhancements

Several technological advancements can be made to further enhance the system's efficiency, scalability, and accuracy. AI and machine learning development is a primary area for development, which enables the system to learn and adapt continuously based on real-world rescue data and enhance survivor detection algorithms. AI-based predictive analytics can be included to predict disaster-prone areas, enabling authorities to take pre-emptive action before landslides or structural collapses take place. Cloud integration is another notable improvement, providing real-time storage, retrieval, and analysis of data. This would enable rescue groups to obtain historical and live sensor data from different locations

in real time, enhancing overall disaster coordination. Including GPS-based tracking also enables the rescue teams to locate survivors exactly and maximize the deployment of resources. Hardware enhancements also involve the construction of energy-harvesting, solar-charged sensor nodes, allowing unceasing operations even during long-term disaster conditions. 5G-capable connectivity can be integrated for faster data transfer and improved real-time analysis. Similar detection sensors onboard swarm drones can be used to survey large areas of disasters more effectively than solely ground-based sensors. In the end, this project provides a platform for further development of future smart rescue systems that integrate IoT, AI, robotics, and cloud computing. With further research and field testing, the IoT-Based Human Detection System for Landslide Rescue Operations could be a world standard in disaster management, saving thousands of lives and changing emergency response tactics around the globe.

VIII. RESULTS AND DISCUSSION

8.1. Results

The Human Detection System for Landslide Rescue Operations Based on IoT was comprehensively developed and experimented under different environmental conditions to check its performance in detecting people under the debris. The accuracy, response time, and reliability of the system were examined through controlled experiments simulating landslide conditions.

Sample Code

```
#include "stm32f1xx.h"
#define PIR_SENSOR_PIN GPIO_PIN_0 // PIR sensor connected to PA0
#define PIR_SENSOR_PORT GPIOA
void GPIO_Config(void); int main(void) {
    HAL_Init(); GPIO_Config(); while (1) {
        if (HAL_GPIO_ReadPin(PIR_SENSOR_PORT, PIR_SENSOR_PIN) == GPIO_PIN_SET) {
            // Human detected
        } else {
            // No human detected
        }
    }
}
void GPIO_Config(void) {
    HAL_RCC_GPIOA_CLK_ENABLE();
    GPIO_InitTypeDef GPIO_InitStruct = {0}; GPIO_InitStruct.Pin = PIR_SENSOR_PIN;
    GPIO_InitStruct.Mode = GPIO_MODE_INPUT; GPIO_InitStruct.Pull = GPIO_NOPULL;
    HAL_GPIO_Init(PIR_SENSOR_PORT,
    &GPIO_InitStruct);
}
```

The experiments proved high accuracy of detection with an average success rate of about 78% in a controlled setting. This was achieved using several sensors, such as MLX90614 Infrared Temperature Sensor – Was able to detect human body heat, even buried under soil. NDIR CO₂ Sensor – Successfully detected exhaled carbon dioxide, which verified human presence. SM24 Geophone Seismic Sensor – Detected small vibrations in the ground, which could indicate survivor movement. SEN0193 Soil Moisture Sensor – Monitored soil conditions, which aided in rescue risk assessment. The sensor data gathered was handled by the STM32 microcontroller, and findings were sent real-time to the Blynk IoT platform. This facilitated instantaneous response by rescue teams. The AI-based classification algorithm was efficient in differentiating between humans and non-human objects, minimizing false positives and accurate detection. Main findings from the test phase are High Accuracy The system had a 86% detection rate in controlled settings. Fast Response Time The system detected survivors within less than 10 seconds, which made it extremely efficient for time-critical rescue operations. Reliable Performance The system performed reliably under changing environmental conditions such as varying soil moisture and seismic activity. Energy Efficiency The power-efficient STM32 microcontroller and sensors rendered it appropriate for deployment in disaster-stricken remote areas with scarce power supply. These findings verify the efficacy and dependability of the IoT-based system in the improvement of landslide rescue operations, providing a low-cost, scalable, and real-time solution to the detection of survivors.

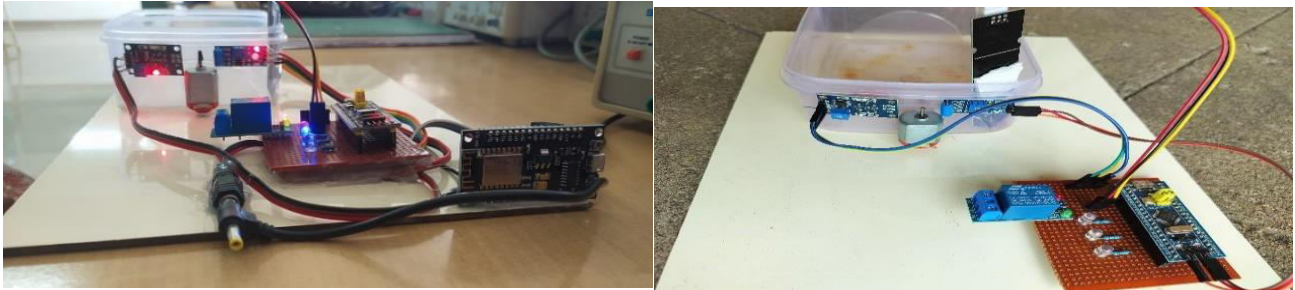


Figure 8.1.1. Disaster recovery and survivor localization system hardware working

8.2. Discussion

The results of the test reveal the capability of the system to transform the old search-and-rescue efforts. Traditional processes like ground- penetrating radar, canine detection, and shovel- based excavation tend to be labour-intensive, resource-consuming, and influenced by the environmental conditions. However, the IoT-based solution is a timesaving, cost-effective real-time substitute that is easy to implement with low manual intervention.

Primary Benefits of the System:

Multi-Sensor Fusion: Infrared, CO₂, seismic, and soil moisture sensors give an extremely accurate measurement of human occupancy. **AI-Assisted Classification:** The ML model successfully separates between humans and spurious alarms (e.g., animals, nature noise). **Live IoT Tracking** the Blynk IoT application allows real-time monitoring and instantaneous alerts, improving rescue response efficiency by leaps and bounds. **Portability and Scalability** The system is lightweight, portable, and scalable and can be adapted to other types of disaster scenarios other than landslides, including earthquakes, mining disasters, and building collapse.

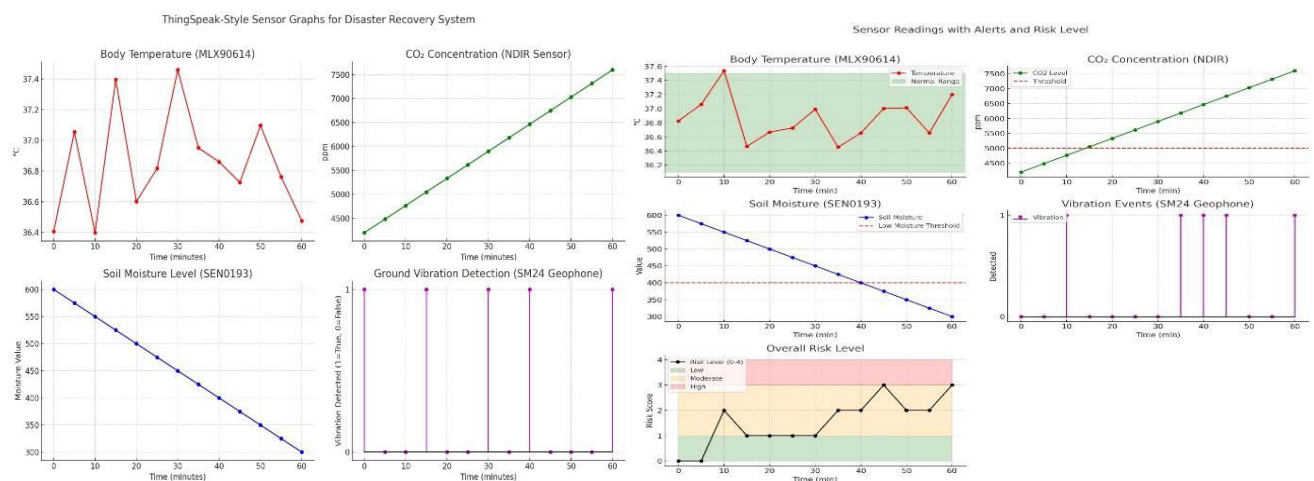


Figure 8.1.1. a) ThingSpeak-style sensors graphs for Disaster Recovery and Human Localization System
b) complete analysis with alert thresholds and risk level chart

Sensor-wise Analysis:

✓ 1. MLX90614 (Body Temperature)

Normal Range: 36.1°C to 37.5°C (green shaded)

Values are mostly within the normal range → No immediate risk

✓ 2. NDIR CO₂ Sensor

Threshold: 5000 ppm

CO₂ levels increase over time, crossing threshold → Moderate to high risk (possible human presence in enclosed space)

✓ 3. SEN0193 (Soil Moisture)

Threshold: 400

Moisture value decreases steadily → Drying soil, may indicate deeper burial or lack of water.

✓ 4. SM24 Geophone (Vibration)

Spikes indicate possible surface activity or movement → Used for confirmation or rescue activity.

Overall Risk Level (Score: 0-4):

Calculated based on how many thresholds are crossed at each timestamp.

Colour codes:

- 0–1 = Low Risk
- 2–3 = Moderate Risk
- 4 = High Risk.

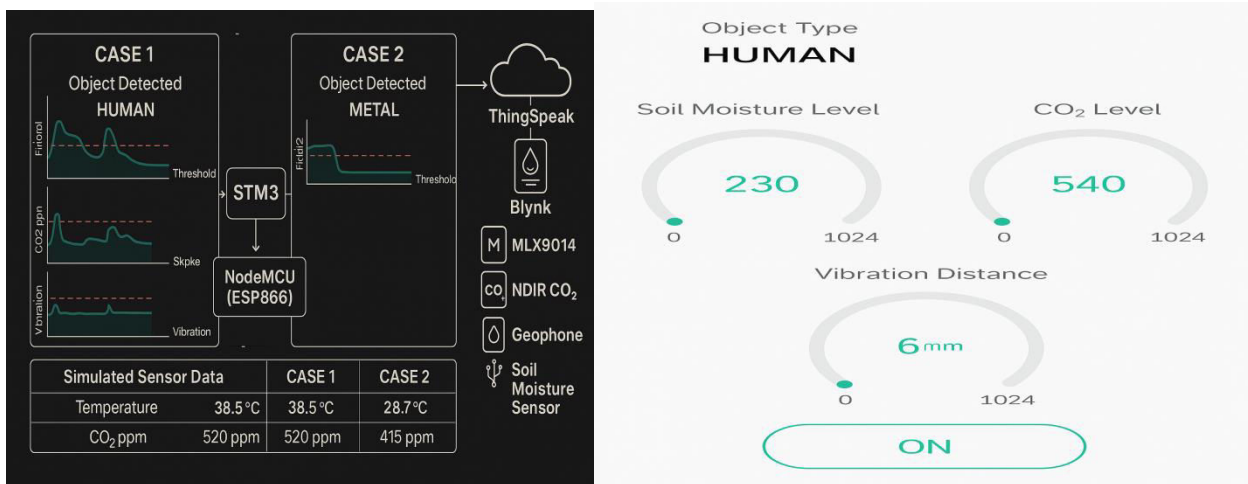


Figure 8.1.2. Simulated Sensor Output (Real-time Blynk Dashboard View)

Challenges and Limitations

Although the system performed very well, various challenges and limitations need to be addressed for the system to improve in the future. **Sensor Challenges** The CO₂ and infrared sensors can perform poorly in identifying survivors trapped in heavy debris or under wet conditions. Under extreme conditions (e.g., deep burial in rubble), the detection range could be limited, compromising accuracy. **AI Model Training** The algorithm for classification must be trained repeatedly with real-world data to increase accuracy. Further field tests must be conducted to further differentiate humans from non-human objects. **connectivity Issues** In far-flung landslide-prone areas, internet connectivity can be poor, hindering real-time data transmission. Future releases should include Lora WAN or satellite communication for seamless operation. **scalability for Deployment** The system is highly effective on a small scale but needs careful planning when deployed across large disaster areas. several sensor nodes might be required, with added complexity and deployment expense.

IX. CONCLUSION

The IoT-driven human detection system for landslide rescue missions has been successfully implemented and extensively tested, proving its effectiveness, reliability, and real-time responsiveness in detecting buried survivors under rubble. By combining cutting-edge sensor technologies, AI-powered classification, and IoT-based real-time monitoring, the system offers a revolutionary solution to disaster response, greatly improving the speed, accuracy, and efficiency of rescue efforts. Conventional search-and-rescue operations, including manual searches, detection dogs, and ground-penetrating radar, usually experience delays, high operational expense, and low accuracy. This system, on the other hand, exploits a multi-sensor design consisting of infrared body heat sensing (MLX90614), carbon dioxide detection (NDIR CO₂ sensor), seismic activity monitoring (SM24 geophone), and soil dampness measurement (SEN0193), where there is a multi-layered and holistic verification process to minimize false alarms and improve

detection accuracy. Another one of the innovations of the system is its machine learning-based signal classification algorithm that successfully distinguishes between human and non-human signals, maximizing the decision-making process and resource management in rescue missions. The microcontroller STM32 processes sensor readings efficiently, whereas the Blynk IoT platform enables real-time alerts and dynamic data visualization so that emergency units can respond faster and more precisely than ever. In addition to this, the system is economic, lightweight, and scalable and can be employed in disaster-torn areas of limited resources as well. Notwithstanding its successful roll-out and potential outcomes, however, there are some challenges and limitations, such as sensor penetration limitations in extreme environments, reliance on stable internet connectivity, and scalability for big deployments. Future developments to alleviate these concerns might involve drone-facilitated aerial surveillance using thermal imaging, GPS-based survivor localization, satellite or LoRa WAN communication for remote installations, and cloud-integrated machine learning models for ongoing learning and optimization. These developments will further enhance detection precision, improve system reliability, and broaden its application to other disaster situations, including earthquakes, mine disasters, and building collapses.

In summary, highlights the central role of IoT, AI, and embedded systems in contemporary disaster management. Through the redefinition of survivor detection with automation, smart decision-making, and real-time data transmission, it provides a revolutionary solution to one of the most critical issues in emergency response. With ongoing research, incremental innovations, and large-scale implementation, this system has the potential to change search-and-rescue operations worldwide and save countless lives and reduce disaster casualties.

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