DOPPLER-MICROWAVE-RADAR BASED VITAL SIGN DETECTION FOR HUMAN PRESENCE IDENTIFICATION

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ABSTRACT

Natural disasters like earthquakes, landslides, and building collapses pose significant challenges for search-and-rescue operations. In such catastrophic events, survivors are often trapped under rubble and debris, and traditional rescue methods, which primarily rely on manual labor and human intervention, tend to be slow, labor-intensive, and potentially dangerous. These methods can take hours or even days to locate survivors, drastically reducing the chances of survival, especially when every minute counts. To address these challenges, this project introduces an innovative rover that leverages cutting-edge technology to revolutionize the way we approach disaster response. The rover is designed with multiple sensing capabilities, including microwave sensors, thermal imaging, ground-penetrating radar (GPR), and IoT (Internet of Things) integration, enabling it to detect and locate trapped individuals efficiently in real time. By utilizing a combination of advanced sensors and communication technologies, the rover can map out the disaster site, detect heat signatures, penetrate the ground to locate buried individuals, and transmit crucial data to a centralized control system for analysis.

Keywords: Landslide, rover, microwave sensors, GPR

1. INTRODUCTION

Natural disasters such as landslides, earthquakes, and building collapses often result in individuals being trapped under debris, making search-and-rescue operations extremely challenging. The efficiency of these operations relies on the ability to detect survivors quickly and accurately. Traditional rescue methods depend largely on manual search operations, which can be slow, labor-intensive, and ineffective in large-scale disasters. The inability to locate survivors in time often results in loss of lives due to delayed assistance. In recent years, technology has played a vital role in improving disaster response strategies. Robotics, artificial intelligence, and advanced sensing techniques such as infrared imaging and ground-penetrating radar (GPR) have significantly enhanced the effectiveness of search-and-rescue operations. However, limitations such as high implementation costs, inadequate penetration depth, and inefficiency in remote monitoring continue to hinder their full potential. To address these challenges, this project proposes the development of an IoT- integrated robotic rover equipped with microwave sensors, thermal imaging, and GPR for effective human detection in disaster scenarios.

1.1 Problem Statement

Search-and-rescue operations face multiple challenges that impact their efficiency and success rates. One of the major concerns is the inefficiency of manual rescue methods, which are often slow and prone to human errors. Traditional detection techniques such as visual inspection and sound- based methods fail to locate victims trapped deep under debris, further delaying timely rescue efforts. Additionally, there is a lack of real-time monitoring and automated data transmission, which limits coordination among rescue teams and delays decision-making. To overcome these obstacles, the proposed system introduces a robotic rover equipped with advanced sensing capabilities. By integrating IoT and real- time data transmission, the rover enhances rescue efficiency by providing instant location data of survivors. This technology reduces human dependency in hazardous environments while increasing the accuracy of detection, ultimately improving survival rates.

1.2. Objective

The primary objective of this project is to develop an autonomous robotic rover capable of detecting human presence in disaster-stricken areas by integrating advanced sensing technologies, real-time monitoring, and automated data transmission to ensure effective and efficient search- and-rescue operations. The system incorporates an advanced detection mechanism that utilizes microwave sensors, thermal imaging, and ground-penetrating radar to enhance accuracy in identifying survivors beneath debris. To improve situational awareness and response time, the rover is equipped with IoT-based remote monitoring, enabling real- time data transmission to rescue teams. Additionally, the robotic system is designed for autonomous navigation, allowing it to maneuver through challenging terrains without human intervention, ensuring effective operation in disaster zones. By deploying this system, the project aims to enhance safety measures by reducing human risk in hazardous environments while efficiently performing search-and-rescue tasks. human intervention, ensuring effective operation in disaster zones.

1.3 Scope of the Project

This project has a broad range of applications across various fields. In disaster response scenarios, the system can be deployed in landslide-affected regions, earthquake-hit areas, and collapsed structures to aid in efficient survivor detection. In military and security applications, the technology proves valuable for detecting individuals trapped in hazardous conditions or warzones. Additionally, in industrial and mining safety, the rover can be utilized in underground mining operations to locate workers trapped due to cave-ins or gas leaks. Looking ahead, the system offers significant potential for scalability and future enhancements, including AI-based algorithms for improved detection accuracy, advanced sensor integration, and drone-assisted operations for expanded coverage. This project has a broad range of applications in different fields

2. METHODOLOGY

2.1 BLOCK DIAGRAM

The proposed system is designed to detect alive humans trapped under rubble during disasters using IoT and robotic technologies. The system employs various sensors and modules connected via an ESP32-CAM microcontroller for efficient data processing and remote monitoring. The system architecture integrates multiple hardware and communication modules designed to collaborate effectively for efficient rescue operations. At the core of the system lies the ATmega328 microcontroller, which controls data flow between sensors, the ESP32-CAM, and the motor driver module. The ATmega328 is programmed to coordinate the system's key functions, including data acquisition, signal processing, and remote control. Its central role ensures seamless integration of all components, resulting in precise navigation and detection. The ESP32-CAM module captures real-time video footage of the environment, which is transmitted directly to the Blynk IoT Dashboard. This video feed enables rescue operators to remotely observe the surroundings, assess risks, and guide the rover's movements. The camera's integration with the microcontroller ensures visual data can be processed alongside sensor readings, improving the accuracy of survivor detection and minimizing false alerts.

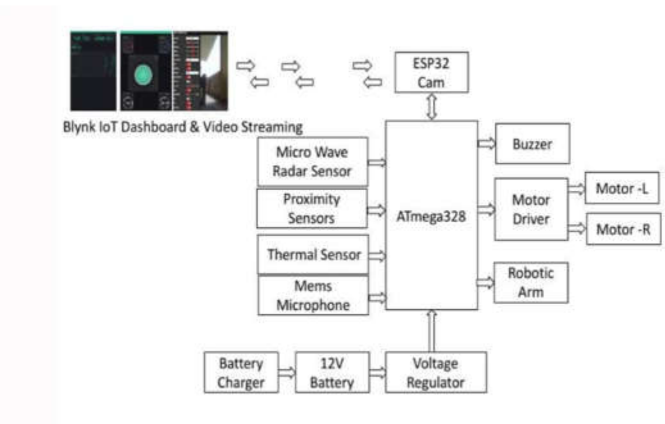

Fig.1. Block Diagram

The Microwave Radar Sensor is a crucial component for detecting survivors. It operates by emitting electromagnetic waves that can penetrate layers of rubble or debris. When these waves reflect off moving objects, particularly those caused by breathing or heartbeat patterns, the system interprets these signals as potential survivors. This sensor is highly effective for locating individuals in confined or hard- to-reach spaces, providing vital information in search operations. To enhance detection reliability, the system employs a Thermal Sensor, which identifies heat signatures emitted by the human body. This sensor excels in low- visibility conditions such as darkness, smoke, or dust-filled environments. The thermal data complements radar readings by confirming the presence of a warm body, improving accuracy in complex search scenarios.

Additional features like the MEMS Microphone capture faint noises such as tapping, knocking, or cries for help. This enhances the system's ability to detect survivors who may be unable to move but can make sound signals. The rover's navigation is safeguarded by Proximity Sensors, which detect obstacles and guide the rover through narrow or hazardous pathways. Finally, the Motor Driver Module powers the rover's wheels and controls the robotic arm for debris clearance, ensuring both mobility and precision. The Blynk IoT Dashboard serves as the user interface, displaying live sensor data, video feed, and alerts, while also enabling remote control of the rover and its robotic arm to facilitate efficient search and rescue missions.

2.1.1 Mechanical Structure and Chassis Design

The rover's chassis is built from durable metal or reinforced plastic, ensuring stability and impact resistance. Shock-absorbing mechanisms minimize vibrations for stable sensor readings. A Four-Wheel Drive System with motor- driven wheels and rugged tires enhances traction on rough terrain, while a Suspension Mechanism improves maneuverability over debris. Its Compact Form Factor allows navigation through confined spaces, optimizing rescue operations.

2.1.2 Robotic Arm Design

The robotic arm, essential for debris removal and object manipulation, features Three Degrees of Freedom (DoF) for flexible movement. A precision-controlled Gripper Mechanism enables secure handling of objects. Built from lightweight metal with multiple Servo Motors, the arm ensures durability and precise operation for delicate rescue tasks.

2.1.3. Sensor Integration Positioning

Strategically placed sensors enhance detection accuracy:

- **ESP32-CAM**: Mounted at the front for live video streaming via the Blynk IoT Dashboard.
- **Microwave Radar Sensor**: Positioned at an angle for detecting breathing and heartbeats under debris.
- **Thermal Sensor**: Detects human heat signatures in low-visibility conditions.
- **MEMS Microphone:** Isolated to capture faint rescue signals with noise filtering.
- **Proximity Sensors**: Placed at multiple points to prevent collisions and guide navigation.

2.1.4. Control and Power Supply System

Powered by an ATmega328 microcontroller and ESP8266 Wi-Fi module, the system enables real-time remote control via the Blynk Dashboard. A Motor Driver Module ensures smooth navigation, while Joystick Control allows precise movement and arm adjustments. An Alert System notifies operators upon survivor detection. A rechargeable battery pack with a voltage regulator ensures stable power for extended operations, balancing efficiency with performance.

2.1.5. Overall Design Efficiency

The combination of rugged construction, flexible robotic arm, and precise sensor integration makes this alive human detection system highly effective in disaster scenarios. Its user-friendly control interface and adaptable movement capabilities ensure that rescue teams can efficiently locate and assist survivors in challenging environments.

The alive human detection system effectively integrates advanced sensor technologies, precise motor control, and robust mechanical design to support search and rescue teams during disaster recovery operations. By combining reliable detection capabilities, efficient navigation features, and remote-controlled precision, the system significantly enhances the chances of locating and rescuing survivors trapped under debris or in low- visibility environments. Its modular design also allows future upgrades and sensor expansions to adapt to evolving rescue challenges.

2.2 FLOW CHART

The flowchart below outlines the complete operational sequence of the developed robotic system designed for detecting human presence using microwave sensing and temperature monitoring. Initially, the system starts by initializing all input devices and sensors, followed by reading the serial data. It then checks for joystick input to determine manual control. If no input is detected, the system verifies the connection status to ensure reliable communication.
When joystick input is present, the motors are activated, and the robot proceeds to detect microwave signals and measure ambient temperature. If the temperature exceeds 90°F, it triggers the human detection module using the radar sensor. At this stage, **Figure 2** illustrates how the system makes real-time decisions based on the environmental data and initiates further actions depending on the conditions.

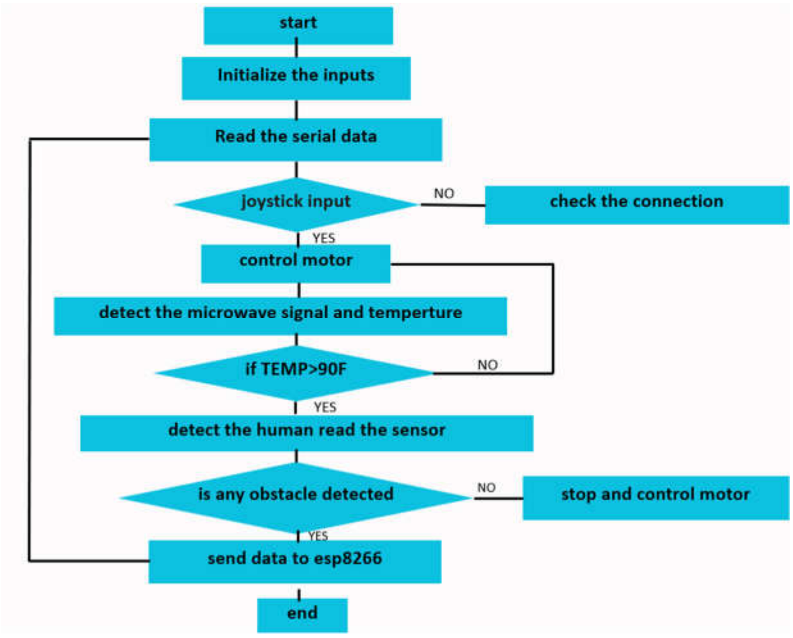

Fig.2. Flow Chart

Once a human is detected, the system checks for nearby obstacles to ensure safe navigation. If an obstacle is present, the data is transmitted to the ESP8266 module for wireless communication. If no obstacle is found, the system halts motor movement to avoid collision and prepares for the next detection cycle. This loop continues to ensure the robot can safely and efficiently operate in real-time rescue scenarios.

A. Hardware Implementation

The Alive Human Detection System is an advanced embedded system designed to locate individuals trapped under debris in disaster-prone areas like landslides and earthquakes. It integrates multiple sensors, microcontrollers, and communication modules for precise detection. Powered by a 12V adapter, it uses an AMS1117 3.3V voltage regulator to provide stable power to low-voltage components like the ESP32-CAM and sensors. The Arduino Nano acts as the central processor, handling sensor data, decision-making, and motor control to detect movement and trigger alerts when necessary. To ensure accurate detection, the system incorporates three key sensors. The SR-04 ultrasonic sensor measures distances to detect obstacles and potential gaps where humans may be trapped. The microwave sensor detects motion through obstacles, enabling identification of subtle movements under debris. The MLX90614 thermal sensor identifies human body heat, distinguishing between living beings and surrounding environmental conditions to reduce false positives. The system also features mobility and alert mechanisms to enhance efficiency. A geared motor, controlled by a motor driver, enables autonomous navigation across rough terrain, expanding the search area. When a human is detected, a buzzer sounds an alert, and the ESP32- CAM captures images or video for visual confirmation, aiding in rescue efforts. The real-time data transmission further improves response efficiency. By combining multiple sensing technologies, mobility, and automated alerts, this system significantly enhances search and rescue operations while also being applicable in military, security, and hazardous environment monitoring.

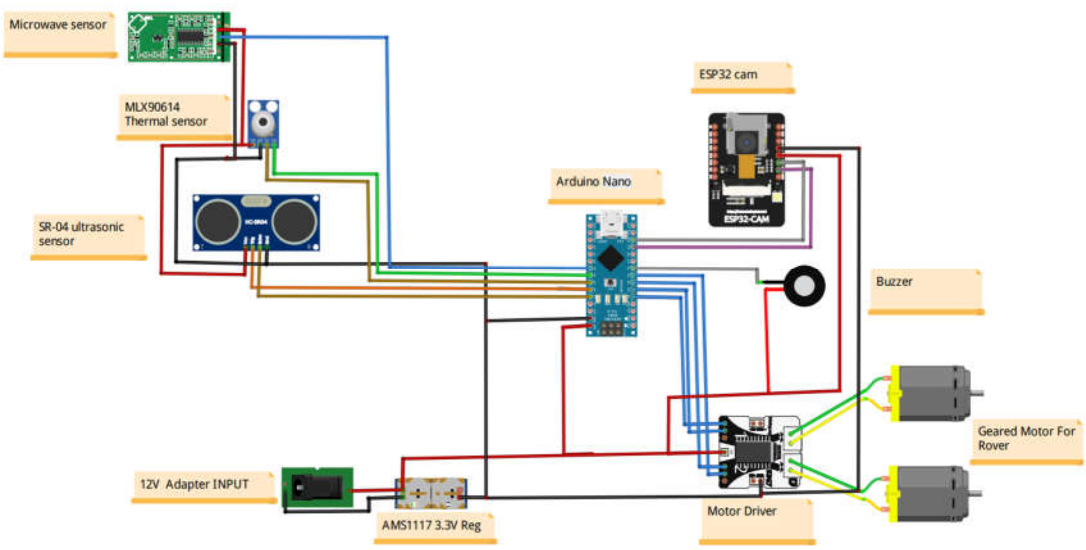

Fig.3. Circuit Diagram

- *IoT Interface*

The "Alive Human Detection Under Rubble" project integrates a multi-sensor detection system to identify living individuals beneath debris, utilizing microwave radar, proximity sensors, thermal sensors, and a MEMS microphone. These sensors work together to gather critical data, which is displayed on a Blynk IoT dashboard for real- time monitoring. The dashboard features visual gauges, such as a binary indicator (1 for detection, 0 for no detection) for quick decision-making, and a numerical value that likely represents parameters like distance or signal strength, helping the operator assess the proximity of potential survivors. The use of multiple sensors ensures higher accuracy by detecting movement, heat signatures, and faint sounds, even in environments where debris may obstruct direct signals.

Fig.4. IoT Interface

The robot's control system is designed for smooth navigation and precise manipulation, with the Blynk interface providing intuitive controls. Operators can move the robot through challenging environments using directional buttons (Forward, Backward, Left, Right) and control the robotic arm’s vertical movement with Up and Down buttons. A gripper slider allows for precise control over the robot’s gripping mechanism, enabling it to grasp, lift, or move objects. This combination of sensor data, movement control, and arm functionality enhances the robot’s ability to navigate complex terrain, investigate voids, and assist rescue teams by clearing debris or lifting objects, improving the overall efficiency of search and rescue operations.

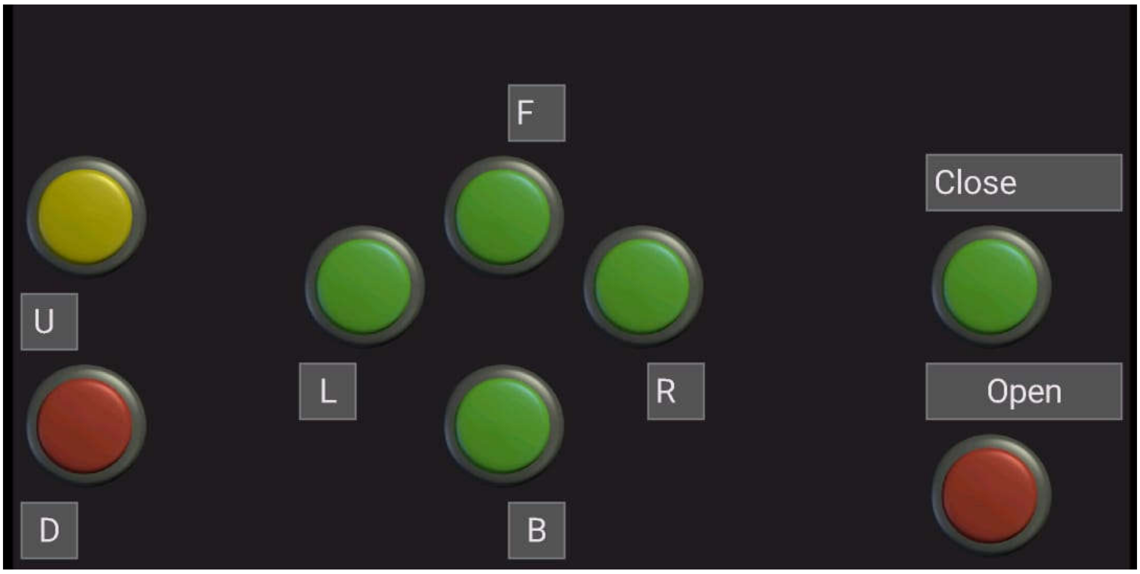

Fig.5. Control of Rover and Arm

B. System Operation and Functionality

The Alive Human Detection System efficiently operates in disaster environments by integrating sensor data, remote control, and real-time monitoring via the Blynk IoT Dashboard. The ATmega328 microcontroller initializes sensors, processes data, and communicates with components, while the ESP8266 module establishes a Wi-Fi connection for remote operation.

- *Real-Time Monitoring & Control*
  The Blynk Dashboard provides an intuitive interface with gauges, buttons, and alerts for system control. The ESP32- CAM streams live video, aiding navigation and hazard assessment. Operators can remotely control the rover and robotic arm using directional buttons and a gripper control slider, enabling debris handling and rescue operations.

- *Sensor Integration*
  - Microwave Radar Sensor detects breathing and heartbeats under debris, triggering alerts upon human detection.
  - Thermal Sensor identifies body heat, enhancing detection in low-visibility conditions.
  - MEMS Microphone captures faint rescue signals, filtering background noise.
  - Proximity Sensors prevent collisions and assist in safe navigation.

- *Mobility & Data Transmission*

The motor driver module ensures stable movement in four directions, while the robotic arm's U/D controls adjust its position for precise handling. The Blynk Dashboard displays real-time data, including sensor readings, video feeds, and alert notifications, ensuring rescue teams receive critical information instantly. This system enhances search and rescue efforts by providing reliable detection, remote navigation, and real-time decision-making, significantly improving survival chances in disaster scenarios.

3. RESULTS AND DISCUSSION

The Advanced Microwave Radar Rover for Disaster Response was successfully designed and implemented to enhance search-and-rescue operations in disaster-stricken areas. The system integrated microwave radar, thermal sensors, ground-penetrating radar (GPR), and IoT connectivity to improve the detection and location of trapped survivors. The microwave radar sensor demonstrated high accuracy in detecting human presence by identifying breathing and heartbeat patterns, while the thermal sensor effectively captured heat signatures even in low-visibility conditions such as smoke or darkness. The ESP32-CAM module enabled real-time video transmission to the Blynk IoT Dashboard, providing rescue teams with a continuous live feed and real-time sensor data, enhancing situational awareness.

The mobility of the rover was tested on different terrains to evaluate its ability to navigate through disaster environments. The rover efficiently moved through uneven surfaces and debris using its optimized wheel configuration and motor control system. The obstacle avoidance mechanism, powered by ultrasonic sensors, allowed it to detect and maneuver around obstacles autonomously, ensuring smooth navigation in critical areas. One of the key advantages of the system was its real-time data processing and IoT integration, which allowed emergency responders to receive immediate alerts and track the location of survivors remotely. The Blynk IoT platform played a crucial role in displaying essential data, such as radar-detected movement, temperature readings, and real-time video, enabling quick decision-making.

The successful implementation of this technology suggests that such automated systems can significantly improve disaster response efforts by reducing human risk and increasing the efficiency of search and rescue missions. The results indicate that the Advanced Microwave Radar Rover has the potential to be a valuable asset in disaster management. The integration of multiple sensing technologies and IoT-based remote monitoring enhances its capability to locate survivors quickly, making it a reliable and efficient tool for emergency response teams. Future improvements, such as increasing sensor range, improving battery efficiency, and refining AI-based survivor detection algorithms, could further enhance its effectiveness and applicability in large-scale disaster scenarios.

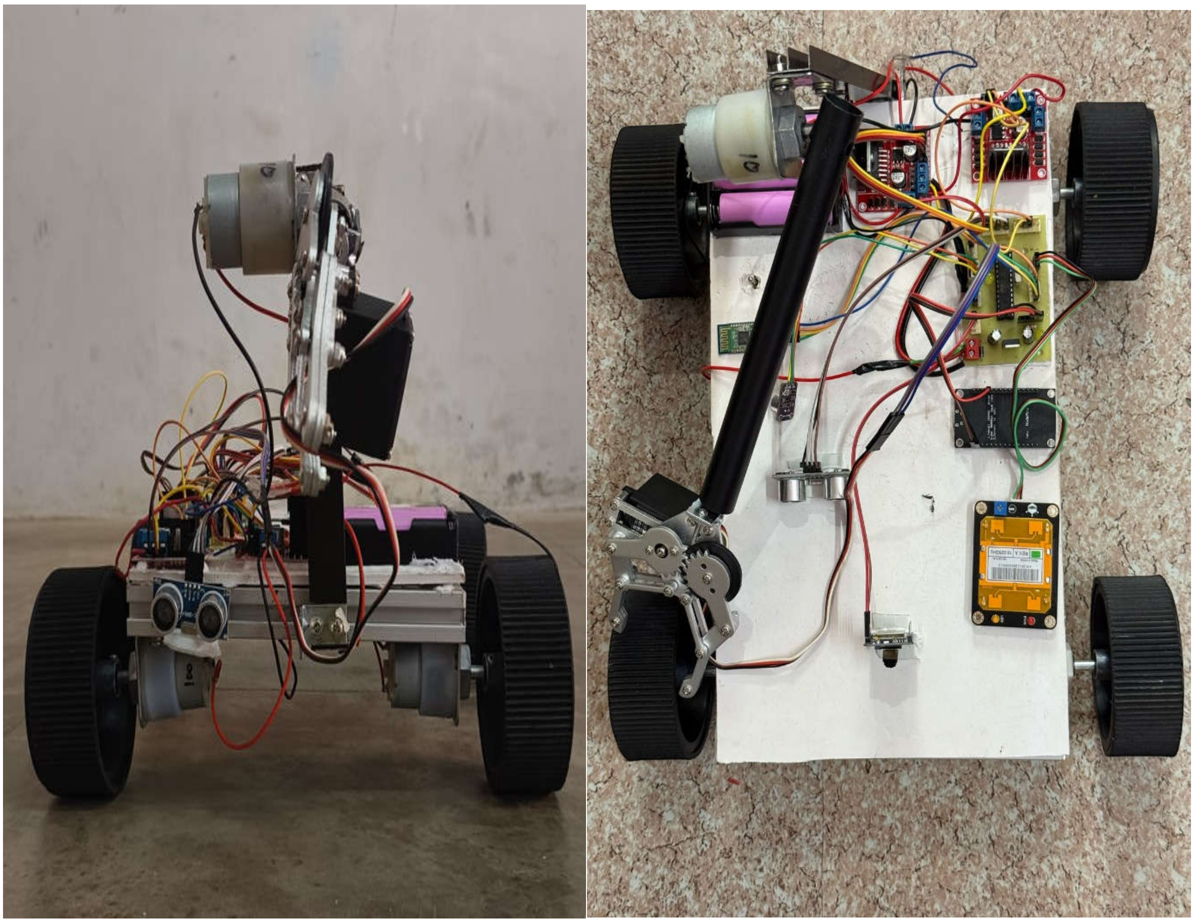

Fig.6. Hardware Setup

4. CONCLUSION

The "Alive Human Detection" system combines hardware and software innovations to enhance search and rescue operations. By integrating components like the ESP32-CAM, Microwave Radar, Thermal Sensor, and MEMS Microphone, the system provides multiple detection layers for locating survivors. The Blynk IoT Dashboard ensures real-time monitoring and remote control, improving decision-making. Its robust design and efficient power management enable reliable operation in tough environments, detecting breathing, heat, and faint sounds while minimizing false alarms. The system's potential for further improvements, such as waterproofing for flood areas, advanced thermal cameras, and better sensor calibration, will enhance detection accuracy and expand its applications in future rescue operations.

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