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App Based Robot Monitoring for Anomalies Detection with Live Streaming Using Arduino Uno

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Abstract: This paper presents a real-time, app-based robot monitoring system capable of detecting operational anomalies and providing live video streaming for enhanced supervision. The proposed system integrates sensors and a camera module on the robot, which continuously transmit performance metrics and visual data to a custom-built mobile application via Wi- Fi or the internet. The robot integrates a metal detector and gas/smoke sensing array with a 1080p camera to detect suspicious metallic objects and hazardous atmospheres while streaming live video to a secure mobile application. Experiments in controlled environments demonstrate reliable detection of simulated anomalies, low-latency streaming over typical wireless links, and effective alerting via the app.

The paper outlines hardware selection, software architecture, anomaly detection logic, and considerations for secure remote operation. This work aims to provide a practical, user-centric tool for first responders, security teams, and field operators who require fast, remote reconnaissance of hazardous environments. This paper aims to improve robotic safety, prevent system failures, and enhance remote operability in war fields and rescue missions. With its mobile technology, and real-time analytics, the system offers a scalable and user-friendly approach to next-generation robotic monitoring.

Keywords: Robot Monitoring, Anomaly Detection, Live Streaming, IoT, War-Field Surveillance

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I. INTRODUCTION

In the modern era of automation and intelligent systems, robotics plays a crucial role in ensuring safety, surveillance, and efficient decision-making in critical environments. This paper is designed to address the growing need for remote monitoring and real-time situational awareness, particularly in high-risk areas such as war fields. In present times, military operations increasingly rely on unmanned robots equipped with sensors and cameras to monitor enemy zones, detect suspicious movements, and identify potential threats without exposing soldiers to danger. Through a mobile application interface, operators can control the robot, stream live video, and receive real-time alerts when anomalies or irregular activities are detected using artificial intelligence and sensor data analysis.

The robot integrates a metal detector and gas/smoke sensing array with a 1080 pixels camera to detect suspicious metallic objects and hazardous atmospheres while streaming live video to a secure mobile application. Experiments in controlled environments demonstrate reliable detection of simulated anomalies, low-latency streaming over typical wireless links, and effective alerting via the app. The project outlines hardware selection, software architecture, anomaly detection logic, and considerations for secure remote operation. This work aims to provide a practical, user-centric tool for first responders, security teams, and field operators who require fast, remote reconnaissance of hazardous environments. In recent years, rapid advancements in robotics, wireless communication, and embedded systems have led to the development of intelligent mobile robots capable of performing complex monitoring and surveillance tasks. The increasing demand for safety, security, and automation in industrial, defence, and hazardous environments has accelerated the need for reliable robotic monitoring systems. Human involvement in such environments often exposes individuals to significant risks, including toxic gases, explosive materials, and unpredictable operational conditions. As a result, mobile robots have emerged as an effective alternative to human presence in dangerous and inaccessible locations.

Traditional surveillance and monitoring systems are largely static in nature, relying on fixed cameras and manual observation, which limits coverage and real-time responsiveness. These systems often fail to detect anomalies efficiently, especially in dynamic environments where conditions continuously change. To overcome these limitations, mobile robotic platforms equipped with sensors and real-time communication capabilities have gained significant attention. Such robots can actively move within the environment, collect multi-sensor data, and provide live visual feedback to remote operators. The integration of Internet of Things (IoT) technologies with mobile robotics has further enhanced the capability of monitoring systems. IoT-enabled robots can transmit sensor data, video streams, and alert notifications over wireless networks, enabling remote supervision and control through mobile or web-based applications. This connectivity allows operators to monitor real-time conditions, analyze abnormal events, and make informed decisions without being physically present at the site. The addition of anomaly detection mechanisms further improves system reliability by automatically identifying unusual or unsafe conditions based on predefined criteria or learned patterns.

Anomaly detection plays a crucial role in intelligent surveillance systems, as it enables early identification of abnormal environmental conditions or suspicious activities. By continuously analysing sensor readings and visual inputs, robotic systems can detect deviations from normal behaviour and generate timely alerts. This capability is particularly valuable in applications such as industrial inspection, security patrols, disaster response, and hazardous material monitoring, where early detection can prevent accidents and minimize damage.

Motivated by these challenges and technological advancements, this project focuses on the design and development of a mobile robot–based real-time monitoring and anomaly detection system. The proposed system integrates an Arduino-based control unit, multiple environmental sensors, a Wi-Fi communication module, and a live video streaming camera to provide effective surveillance and remote-control functionality. The robot can be operated through a mobile application, allowing users to navigate the robot, observe the surroundings, and receive alert notifications in real time. The primary objective of this work is to develop a cost-effective, flexible, and user-friendly robotic monitoring solution that can operate efficiently in real-world environments. By combining embedded hardware with wireless communication and software control, the proposed system aims to enhance safety, reduce human risk, and improve the effectiveness of monitoring and surveillance operations. The successful implementation and demonstration of the system validate its feasibility and potential for future enhancements such as autonomous navigation and intelligent decision-making.

- **Mobile-Based Remote Control and Command**

Through the mobile app, military personnel can remotely control various functions of the robot, including navigation, camera angles, and sensor operations. This functionality allows for dynamic responses in real-time, especially in environments that are too dangerous for direct human intervention. The mobile interface is designed to be intuitive, ensuring ease of use even in high-pressure combat scenarios.

Through the mobile app, users can view live feeds from the robot's cameras, monitor sensor data, and receive instant notifications of any detected anomalies such as suspicious movements, hazardous materials, enemy presence, or equipment malfunctions. Anomaly detection is powered by advanced machine learning algorithms and sensor fusion techniques, allowing the system to identify potential threats and irregularities with high accuracy. This real-time intelligence supports faster and more informed decision-making while minimizing the exposure of human soldiers to dangerous environments. By combining mobility, autonomy, and intelligent monitoring in a user-friendly mobile interface, this technology significantly enhances tactical operations, reconnaissance missions, and overall battlefield strategy.

- **Live Video Streaming for Enhanced Situational Awareness**

One of the core functionalities of this system is real-time video streaming from the robot's onboard camera to a mobile application. This enables soldiers and commanders to visually monitor the battlefield remotely, gaining critical insights into enemy movements, terrain conditions, and mission progress. The live feed can be accessed from anywhere, making it ideal for field operations where time-sensitive intelligence is vital.

In modern warfare, the integration of robotics and advanced monitoring technologies has become essential for enhancing both operational efficiency and personnel safety. An app-based robot monitoring system with anomaly detection and live streaming is a cutting-edge solution specifically designed for deployment in war fields and combat zones. This system allows military personnel to remotely observe and control robots operating in high-risk or inaccessible areas via a secure mobile application. The robot is equipped with real-time video streaming capabilities, enabling continuous surveillance and situational awareness on the battlefield.

In high-risk environments such as war fields, disaster zones, and hazardous industrial sites, robotic systems play a crucial role in performing tasks that are too dangerous for humans. However, effective use of these robots depends on continuous monitoring and fast, informed decision-making. This project introduces an app-based robot monitoring system designed to enhance operational safety and efficiency by integrating live video streaming and real-time anomaly detection. The system enables remote operators to observe live feeds from the robot's onboard cameras through a mobile or web application, offering clear, real-time visuals of the robot's surroundings. Simultaneously, it collects sensor data such as battery level and obstacle detection and uses intelligent algorithms to detect abnormal behaviours or system faults. If any anomaly is detected, the system immediately sends alerts and notifications to the operator, ensuring quick response and minimizing potential risks.

The app also provides manual control options, allowing users to override autonomous operations in critical situations. With its combination of mobility, real-time data access, and intelligent monitoring, this system offers a powerful solution for enhancing the reliability and effectiveness of robotic operations in challenging and unpredictable environments.

1.1 Problem Statement

In modern war fields, soldiers often face life-threatening dangers when they have to manually inspect suspicious areas for hidden bombs, landmines, or toxic gases caused by explosions. Such tasks are not only time-consuming but also put human lives at great risk. Traditional surveillance equipment used in these environments mainly provides live video feeds without any intelligent features to automatically detect potential threats like metallic objects or dangerous gases. This limitation causes delays in threat recognition and response, which can lead to catastrophic consequences. Improving safety and speed in such high-risk operations requires an advanced system that combines real-time data collection, intelligent anomaly detection, and easy remote monitoring.

This paper addresses these challenges by developing an app-based robot specifically designed for war field applications, equipped with integrated metal detectors and gas sensors alongside a high-definition Wi-Fi camera. The robot streams live video and sensor data to a mobile application, enabling operators to remotely monitor the environment without physical exposure to danger. The system's automatic anomaly detection alerts users instantly when it senses unusual metal objects or hazardous gases, helping troops and commanders make faster, more informed decisions. By combining robotics, IoT technology, and mobile connectivity, this solution enhances battlefield safety, reduces human risk, and improves operational efficiency in hostile environments.

1.2 Objectives

- Design and develop a mobile application that interfaces with a robot to monitor real-time performance data.
- Implement a live streaming module (e.g., using Wi-Fi Camera) to provide visual feedback to the user via the mobile app.
- Enable real-time alerts and notifications on the app when abnormal behaviour or system faults are detected.

2. Literature Survey

The literature survey covers several existing systems that combine robotics, IoT, mobile apps, and anomaly detection, but each is designed for a different domain such as steam turbine monitoring, indoor Wi-Fi surveillance, healthcare robots, environmental mapping, firefighting, or network-based anomaly detection. These works show that mobile apps, wireless communication, and sensors can be successfully used for real-time monitoring and fault or anomaly detection in their respective areas. However, none of them directly address the specific needs of war-field operations, where detecting hidden metallic bombs, landmines, and hazardous gases is critical for soldier safety.

Across these projects, common limitations appear: they are domain-specific (power plants, hospitals, environmental study, etc.), often focus on a single type of parameter (like temperature, humidity, or patient vitals), and usually do not combine multiple threat-oriented sensors with live streaming in a single robot. Surveillance bots mainly provide audio/video and obstacle detection, while anomaly detection frameworks are mostly software-level and not tied to a real war-field robot. As a result, they cannot directly provide a complete, deployable solution for battlefield reconnaissance where integrated metal, gas/smoke detection, and visual monitoring are required.

Your proposed project fills this gap by designing an app-based robot specifically aimed at war fields, integrating a metal detector, gas/smoke sensor, and Wi-Fi camera into one platform controlled and monitored via a mobile application. The system offers live video streaming, real-time sensor readings, and automatic alerts when anomalies such as suspicious metallic objects or dangerous gases are detected, allowing soldiers to observe and assess risky areas from a safe distance. This combination of domain focus (war-field safety), integrated threat-oriented sensing, and user-friendly app-based monitoring makes your project more directly useful for military reconnaissance than the previously surveyed systems.

Chen et al. [1] developed a mobile application–based monitoring and health management system for steam turbines, where real-time operational data was collected, analyzed, and displayed through a mobile interface. Their system focused on condition monitoring, fault diagnosis, and improving maintenance efficiency using mobile technology. Singh et al. [2] designed a Wi-Fi enabled surveillance robot that provides real-time audio and video streaming to an Android mobile device. The robot was remotely controlled through a mobile application, demonstrating effective live monitoring for security and surveillance applications.

Adey et al. [3] proposed a region-based anomaly detection approach that performs real-time training and analysis to identify abnormal activities. Their system divided video frames into regions and analyzed behavioral patterns to detect anomalies efficiently with reduced computational complexity. Hossain et al. [4] designed and implemented an IoT-based medical assistant robot capable of assisting patients and healthcare professionals. The robot monitored patient conditions and communicated data through IoT platforms, improving automation and efficiency in medical environments.

Hossain et al. [5] In this work, the authors presented an enhanced version of an IoT-based medical assistant robot that focused on real-time data collection and remote monitoring. The system demonstrated reliable communication between sensors, the robot, and cloud-based applications. Nayanasitachowdary and Padmaja (2021) [6] The authors developed a GPS-based environmental monitoring robotic system using IoT technology. The robot collected environmental parameters along with location information, enabling accurate real-time monitoring and tracking of environmental conditions.

Hossain et al. [7] proposed an IoT-based firefighting and affected-area monitoring robot designed to operate in hazardous fire environments. The robot detected fire-related parameters and transmitted real-time data to remote monitoring systems, supporting disaster management operations. Guo et al. [8] developed an active environmental monitoring and anomaly search system using Markov Decision Processes and active sensing techniques. Their work focused on optimizing sensing actions to efficiently detect anomalies in complex environments such as space habitats.

Yahyaoui et al. [9] introduced READ-IoT, a reliable framework for real-time event and anomaly detection in IoT networks. The framework improved detection accuracy and reliability by efficiently processing distributed sensor data in IoT environments. Choi et al. [10] provided a comprehensive review and analysis of deep learning techniques used for anomaly detection in time-series data. The paper discussed various models, challenges, and guidelines to help researchers select suitable methods for real-world applications.

Zaheer et al. [11] introduced an anomaly detection framework using mobile surveillance robots that actively move within an environment to collect visual data. The system combined computer vision techniques with human-in-the-loop collaboration, where detected suspicious activities were verified by human operators. This approach reduced false alarms and improved detection reliability in complex surveillance scenarios such as public spaces. Nassif et al. [12] conducted an extensive systematic review of machine learning-based anomaly detection methods across multiple application domains. The study categorized techniques into statistical, classical machine learning, and deep learning approaches, and discussed their performance, scalability, and limitations. The authors also highlighted key challenges such as data imbalance, model interpretability, and real-time deployment constraints.

Zhang et al. [13] proposed a real-time mobile network traffic anomaly detection system focused on monitoring user behaviour patterns. The system analyzed traffic features such as usage frequency, session duration, and access behaviour to identify abnormal network activities. Their method enhanced mobile network security by detecting intrusions and suspicious behaviour in real time. Deák et al. [14] developed smartphone-controlled industrial robots to evaluate user interaction efficiency and control accuracy. Their system integrated mobile interfaces for robot operation and conducted performance evaluations based on task completion time, error rate, and user satisfaction. The study demonstrated that mobile-based control significantly improves flexibility and usability in industrial environments.

Kumari and Saini [15] proposed an adaptive anomaly detection framework for time-series audio-visual data, particularly useful in surveillance applications. The framework dynamically adjusted detection thresholds and feature extraction parameters based on environmental changes. This adaptability improved detection accuracy in varying lighting and noise conditions. Ranjan et al. [16] designed a multipurpose combat mobile robot equipped with localization sensors to enable accurate navigation in complex terrains. The robot utilized sensor fusion techniques for positioning and movement control. Their system was aimed at military and defence operations, emphasizing robustness and real-time situational awareness.

Chen et al. [17] resented an AIoT-based autonomous mobile robot for garbage collection that integrates artificial intelligence with IoT connectivity. The robot employed intelligent decision-making algorithms to identify garbage and plan cleaning paths autonomously. The system demonstrated improved efficiency in waste management and reduced the need for human intervention. Ghosh et al. [18] developed a web-application-based user interface to remotely control and monitor an automated mobile robot. The system allowed users to issue commands, monitor sensor data, and observe robot behaviour in real time through a web browser. This approach improved accessibility and reduced dependency on dedicated control hardware.

Ghosh et al. (2024) [19] In an extension of their previous work, the authors enhanced web-based robot control by focusing on system responsiveness and network reliability. The system demonstrated stable robot operation over the internet with minimal latency, making it suitable for real-time remote surveillance and monitoring tasks. Islam et al. [20] proposed an advanced IoT-based robotic system integrated with GPS, GSM, image processing, and live video streaming capabilities. The robot was designed to detect landmines and monitor hazardous areas while providing real-time alerts to operators. Their system significantly improved safety and situational awareness in high-risk environments.

Fährmann et al. [21] provided a comprehensive survey of anomaly detection techniques applied in smart environments. The study reviewed sensor-driven, data-centric, and AI-based models, discussing their suitability for smart cities, healthcare, and industrial monitoring. The authors also identified research gaps related to scalability, privacy, and real-time performance. He et al. [22] introduced an online anomaly detection system for live social video streaming platforms. The system analyzed video streams in real time using scalable data processing techniques to detect abnormal activities. Their work addressed challenges related to high data volume and low-latency processing in live streaming environments.

Ajalkar et al. [23] proposed a generative AI-based solution for enhancing the quality of live surveillance videos while simultaneously identifying anomalies. The system used advanced deep learning models to upscale video resolution and improve visibility, leading to more accurate anomaly detection in real-world surveillance applications. L. M et al. (2025) [24] The authors designed an IoT-based night patrol robot that integrates voice technology for interactive surveillance operations. The robot enabled voice commands, night-time monitoring, and real-time alert generation, making it suitable for security patrols in low-visibility conditions. Mohana et al. [25] developed a web-controlled surveillance robot using computer vision techniques to detect suspicious activities. The system processed live video data to identify anomalies and allowed users to monitor and control the robot remotely through a web interface. This approach enhanced flexibility and real-time decision-making in surveillance applications.

3. Methodology of Implementation

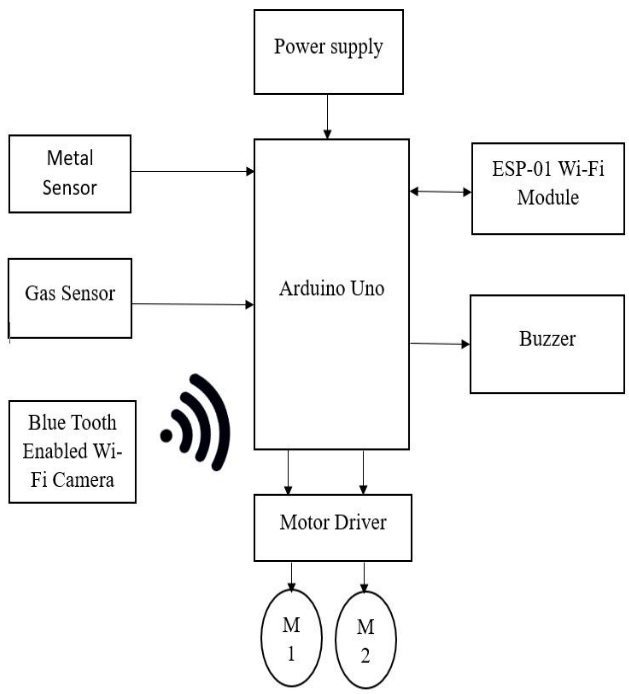

Figure-1: Block diagram of a system

The above Figure-1 shows the block diagram of app-based robot monitoring for anomalies detection with live streaming. The proposed system is an app-based robot designed for war-field monitoring and anomaly detection. The complete setup is built around the Arduino Uno microcontroller, which acts as the brain of the robot and coordinates all input and output operations. A regulated power supply feeds the Arduino board and, through it, all the connected modules such as sensors, the ESP-01 Wi-Fi module, the motor driver, and the buzzer. This ensures that every component receives a stable voltage so that the robot can operate reliably in outdoor war-field conditions.

On the sensing side, two main sensors are interfaced with the Arduino a metal sensor and a smoke sensor. The metal sensor is used to detect the presence of metallic objects such as bombs. Whenever a metallic object comes within the sensing range, the sensor outputs a signal to the Arduino. Similarly, the smoke sensor continuously monitors the surrounding air for the presence of smoke produced by explosions or chemical leaks. Any abnormal rise in gas concentration is converted into an electrical signal and sent to the Arduino. The microcontroller reads these sensor values, compares them with predefined threshold levels, and decides whether an anomaly is present in the war field.

For visual monitoring, the robot is equipped with a Bluetooth-enabled Wi-Fi camera. This camera is mounted on the robot chassis and captures live video of the environment in front of the robot. The video stream is sent wirelessly over Wi-Fi to the mobile application used by the operator. In this way, soldiers or commanders can see the real-time situation on their smartphone screen without going physically into the risky area. While the camera handles the visuals, a separate ESP-01 Wi-Fi module connected to the Arduino manages data communication such as sensor readings and control commands between the robot and the mobile app. Through this wireless link, the app can send movement commands to the robot and receive feedback about detected anomalies.

The motor driver module is used as an interface between the low-power control signals of the Arduino and the higher-current DC motors (M1 and M2) that drive the wheels of the robot. Based on commands received from the mobile app such as forward, backward, left, and right the Arduino generates appropriate control signals to the motor driver. The motor driver then energizes the motors accordingly, allowing the robot to move through the war field and scan different regions. This arrangement ensures smooth and reliable navigation while keeping the high motor currents isolated from the microcontroller.

For local indication of danger, a buzzer is connected to one of the Arduino's output pins. When either the metal sensor or smoke sensor crosses its set threshold, the Arduino not only sends an alert to the mobile application but also activates the buzzer. The audible buzzer helps personnel nearby to immediately recognize that a bomb, or smoke has been detected. The motor driver block acts as an interface between the microcontroller and the DC motors. Since the microcontroller cannot directly supply the high current required by the motors, the motor driver amplifies the control signals and enables bidirectional motor control. This block allows precise control over the robot's movement, including forward, backward, left, and right navigation. The DC motor block, mechanically connected to the wheels, converts electrical energy into mechanical motion, enabling the robot to move smoothly across the operating area.

Overall, the working of the system can be summarized as follows the power supply energizes the Arduino and all modules; the robot navigates the war field using its motors controlled by the motor driver; the metal and gas sensors continuously scan for explosives and smoke; their outputs are processed by the Arduino, which triggers the buzzer and sends anomaly data through the ESP-01 Wi-Fi module when danger is detected; and the Bluetooth-enabled Wi-Fi camera streams live video to the mobile app, giving the operator both visual and sensor-based information. By combining these functions, the robot enables safe, real-time reconnaissance of war zones while minimizing direct human exposure to life-threatening conditions. the block diagram clearly represents the systematic flow of power, data, and control signals between different system components. The modular architecture improves system reliability, scalability, and maintainability, making the proposed system suitable for real-time surveillance, monitoring, and anomaly detection applications in hazardous and remote environments.

3.1 Methodology

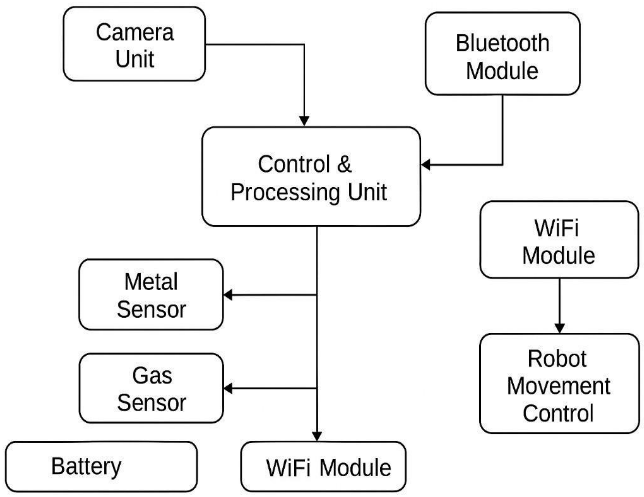

Figure-2: Methodology of a system

The above Figure-2 shows the methodology of App based robot monitoring for anomalies detection with live streaming describes how the war- field robot senses anomalies, communicates data, and allows the user to monitor and control it through mobile applications. It links hardware components like sensors, camera, and motors with software elements such as Arduino code, Bluetooth control app, and cloud- based live streaming to form one integrated monitoring system.

The methodology of the proposed app-based robot monitoring and anomaly detection system explains the systematic flow of data, control signals, and decision-making among various hardware and software components. The system is designed to perform real-time monitoring, remote control, and anomaly detection using a mobile robotic platform integrated with sensing, communication, and processing units. At the core of the methodology is the Control and Processing Unit, which acts as the central decision-making block of the system. This unit continuously receives input data from multiple sensing modules and communication interfaces. All incoming signals are processed using embedded logic to determine appropriate actions such as robot movement, alert generation, and data transmission.

The Camera Unit is interfaced with the control and processing unit to capture real-time visual information from the robot's surroundings. The captured video frames provide live surveillance data, which is transmitted through the Wi-Fi module to the remote user interface. This enables continuous visual monitoring of the operational area and assists in identifying abnormal situations. The Metal Sensor and Gas Sensor form the environmental sensing unit of the system. These sensors continuously monitor the surroundings for the presence of metallic objects and harmful gases. The sensor outputs are fed to the control and processing unit, where the values are analyzed and compared with predefined threshold levels. If the sensed values exceed safe limits, the system identifies the situation as an anomaly and generates alert signals.

The Bluetooth Module is used to receive control commands from the mobile application. Commands such as forward, backward, left, and right movement are transmitted wirelessly to the control and processing unit. This allows the user to manually control the robot's navigation in real time from a safe remote location.

The Wi-Fi Module plays a dual role in the system. First, it enables real-time data communication between the robot and the mobile application, including sensor data and alert notifications. Second, it supports live video streaming from the camera unit, allowing the user to visually monitor the robot's environment. The Wi-Fi module ensures fast and reliable wireless connectivity, which is critical for real-time monitoring applications. The Robot Movement Control block represents the motor driver and DC motor arrangement. Based on the control signals generated by the processing unit, the motor driver controls the speed and direction of the motors. This block converts logical commands into mechanical motion, enabling smooth and accurate robot navigation. The Battery Unit supplies power to all system components, including sensors, microcontroller, communication modules, camera, and motors. Proper power distribution ensures uninterrupted operation during extended monitoring and surveillance tasks.

Overall, the methodology diagram clearly represents the sequential and parallel operations of sensing, processing, communication, and actuation. The integration of Bluetooth-based control, Wi-Fi-based monitoring, and sensor-based anomaly detection enables the system to function efficiently in real-time environments. This structured methodology ensures reliable surveillance, effective anomaly detection, and safe remote operation, making the proposed system suitable for industrial, security, and hazardous area applications.

- **Robot sensing and control**

The core of the methodology is the Arduino Uno, which continuously reads data from the metal sensor and gas sensor to detect bombs, smoke in the War field. These sensor signals are processed in real time, and whenever values cross predefined thresholds, the controller classifies them as anomalies and triggers actions such as buzzer alerts, motor stop, or warning messages to the user.

- **Wireless communication and live streaming**

For local control, the Bluetooth module connects the Arduino to the Arduino Bluetooth mobile app, through which the operator sends movement commands and receives basic status information. For long- range access, the Wi- Fi module and Wi- Fi camera send sensor readings and live 1080p video to the True Cloud platform or similar cloud service, so the user can remotely watch the robot's surroundings and analyze anomalies from any location.

- **Navigation and actuation**

Movement of the robot is achieved by a motor driver interfaced with the Arduino, which drives the DC motors according to commands from the apps and feedback from sensors. When the robot approaches a suspicious object or hazardous gas region, the control logic can automatically slow down, stop, or redirect the robot to maintain safety while still keeping the camera pointed for visual inspection.

- **Alerting and data handling**

Whenever an anomaly such as a metallic threat or gas leak is detected, the system activates the buzzer on the robot and simultaneously sends alert information to the mobile app along with current video and sensor values. The cloud platform can also log these events with timestamps and locations, enabling later review of recordings and anomaly history for post- mission analysis or evidence.

- **Power and deployment considerations**

A dedicated battery- based power supply feeds the Arduino, sensors, communication modules, and motors, ensuring the robot can operate for a reasonable duration in real war- field. The overall methodology is designed so that all operations—sensing, communication, movement, and alerting—run autonomously under Arduino control, while the human operator supervises the mission through intuitive mobile and cloud interfaces without entering hazardous zones

4. Hardware and Software Used

The proposed app-based robot monitoring system is developed using an integrated combination of hardware and software components to ensure reliable operation in war-field and hazardous environments. The hardware architecture is centred around a microcontroller, which serves as the main processing and control unit of the system. It continuously collects data from various sensors, processes the inputs, and generates control signals for robot movement and communication. A Wi-Fi module is used to establish wireless connectivity between the robot and the mobile application, enabling real-time transmission of sensor data and control commands. For visual monitoring, a Wi-Fi camera is mounted on the robot to capture high-resolution live video, which is streamed directly to the mobile application, allowing remote surveillance without human presence in the dangerous area. Metal detection sensors are integrated to identify the presence of metallic objects such as landmines or hidden explosives, while gas sensors are used to detect toxic gases or smoke, indicating hazardous environmental conditions. A motor driver module interfaces between the microcontroller and the DC motors, allowing precise control of speed and direction for smooth robot navigation. The entire hardware system is powered using a rechargeable battery unit, ensuring portability and uninterrupted operation.

On the software side, the system is programmed using the Arduino Integrated Development Environment (IDE), where embedded C language is used to implement sensor interfacing, motor control logic, data acquisition, and wireless communication. Threshold-based algorithms are developed to analyze sensor readings and identify abnormal conditions. When sensor values exceed predefined limits, the system classifies the situation as an anomaly and immediately triggers alert messages. A mobile application serves as the user interface for the operator, providing features such as robot navigation controls, real-time video viewing, and instant alert notifications. Wireless communication protocols support continuous data exchange between the robot and the mobile device, ensuring low-latency monitoring and fast response. Together, the hardware and software components form a robust and efficient system that enhances situational awareness, minimizes human risk, and improves safety in hazardous and war-field environments.

The proposed robot monitoring and anomaly detection system is implemented using an integrated set of hardware and software components designed to ensure reliable operation, real-time monitoring, and effective remote control. The core hardware component of the system is the Arduino-based microcontroller, which functions as the central processing and control unit. It is responsible for acquiring sensor data, executing control algorithms, handling communication protocols, and generating control signals for motor operation. The microcontroller continuously processes inputs from various sensors and responds according to predefined logic and threshold conditions.

The robotic platform is driven by DC motors connected to the wheels, enabling smooth and controlled movement across different surfaces. A motor driver module is used as an interface between the microcontroller and the motors, as the controller alone cannot supply sufficient current to drive the motors directly. The motor driver facilitates bidirectional motor control, allowing precise navigation of the robot in forward, backward, left, and right directions based on user commands received through the mobile application.

For environmental sensing and anomaly detection, the system incorporates multiple sensors such as a metal detector and a gas sensor. The metal detector is used to identify the presence of metallic objects, which is particularly useful in security, industrial, and hazardous area monitoring applications. The gas sensor detects harmful or combustible gases in the environment and provides early warnings of unsafe conditions. Sensor outputs are continuously monitored by the microcontroller and compared with predefined threshold values to detect abnormal situations.

Wireless communication is enabled through a Wi-Fi module, which establishes a real-time connection between the robot and the remote user interface. This communication link allows the transmission of control commands from the mobile application to the robot, as well as the feedback of sensor readings and alert notifications from the robot to the user. A Wi-Fi camera module mounted on the robot captures live video of the surrounding environment and streams it in real time to the user interface, enabling visual surveillance and situational awareness.

The entire system is powered by a rechargeable battery pack that supplies regulated voltage to all hardware components. A proper power management arrangement ensures stable operation of the microcontroller, sensors, communication modules, and motors, even during continuous operation.

On the software side, the Arduino Integrated Development Environment (IDE) is used to develop and upload embedded C programs to the microcontroller. The embedded software handles sensor data acquisition, motor control logic, anomaly detection algorithms, and wireless communication tasks. A mobile application serves as the user interface, allowing the user to remotely control the robot's movement, monitor live video streams, and receive alert notifications when abnormal conditions are detected. The integration of hardware and software components enables efficient real-time monitoring, remote operation, and anomaly detection, making the system suitable for surveillance and hazardous environment applications.

5. Result

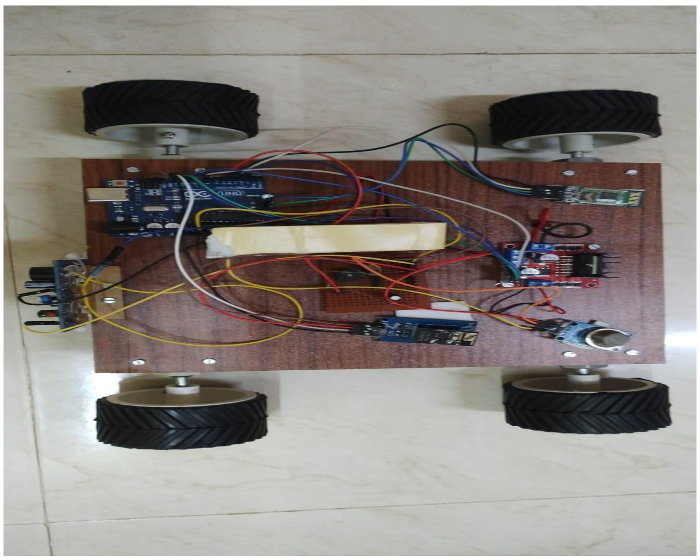

Figure-3: Hardware proposed system

The implemented system successfully achieved app-based robot monitoring for anomalies in a simulated war-field environment. The Arduino-controlled platform integrated the metal sensor, gas sensor, motor driver, buzzer, ESP-01 Wi-Fi module, and T18205-A Wi-Fi camera, all powered from a regulated 5 V supply. During testing, the robot could be navigated remotely using the Bluetooth control app while simultaneously streaming live video via the True Cloud application, demonstrating seamless parallel operation of motion control, sensing, and video transmission.

Metal-detection trials were conducted by placing different metallic objects such as nuts, bolts, and small containers at varying depths and distances from the detector coil. The metal sensor reliably detected objects within the designed sensing range, and the Arduino generated corresponding alerts by activating the buzzer and flagging the anomaly in the monitoring interface. Non-metallic objects did not trigger false alerts, indicating satisfactory selectivity of the sensor and proper calibration of the threshold level in the code.

Gas-sensing experiments involved exposing the gas sensor to smoke and controlled gas sources while the robot was stationary and in motion. The analog readings from the gas sensor showed a clear change when smoke or gas was present, and once the measured value crossed the preset limit, the system raised an alarm and logged the condition. The response time from exposure to audible alert was short enough for practical use in early detection of hazardous atmospheres in war-field scenarios.

The T18205-A camera, combined with the True Cloud app, provided stable live video streaming under indoor and low-light conditions, enabling operators to visually verify the environment around the robot. Pan-tilt control from the app made it possible to scan wider areas without moving the base robot, and motion-detection features of the camera offered additional situational awareness beyond the Arduino sensors. Overall latency of the live feed remained acceptable for reconnaissance tasks, and recorded clips and snapshots could be stored for later analysis.

From these results, it can be concluded that the proposed system effectively reduces human exposure to dangerous zones by combining sensor-based anomaly detection with real-time video monitoring and mobile control. However, the experiments also highlighted areas for improvement, such as extending wireless range, hardening the robot chassis for rough outdoor terrain, optimizing power consumption for longer missions, and integrating more advanced anomaly-detection algorithms on the sensor data or video stream. With these enhancements, the prototype can evolve into a more robust field-deployable solution for military and disaster-management applications.

Metal Sensor

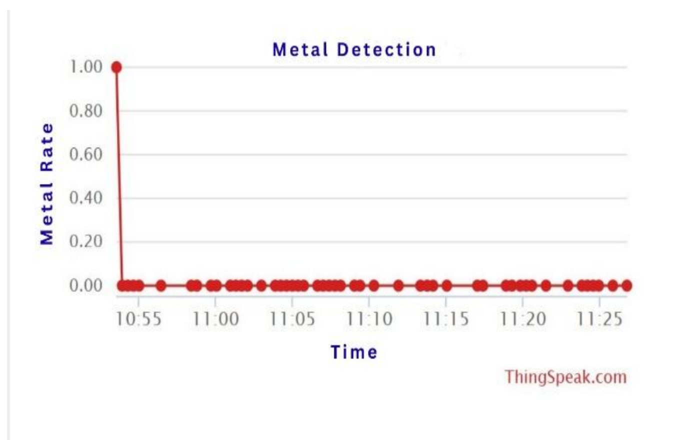

Figure-4: Metal sensor readings

The above Figure-4 shows the Graph of a Metal sensor. The metal sensor block is used to detect metallic objects such as bombs in the war-field. This Analog or Digital signal is sent to the Arduino Uno, which checks whether the reading crosses a predefined threshold. If metal is detected, the Arduino can treat it as a potential explosive, turn on the buzzer for a local alarm, and send an alert to the mobile app so that soldiers know a suspicious metallic object is present at that location. . When the robot detected any metal the graph value should be at 1 and when metal is not detected any metal or bombs the graph value should be at 0. This function is shown in the figure.

Smoke sensor

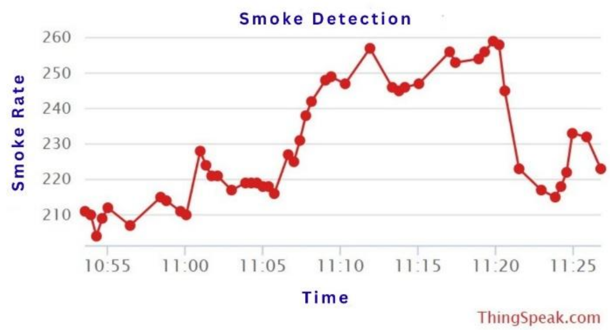

Figure-5: gas sensor readings

The above Figure-5 shows the graph of a gas sensor. The gas sensor block is responsible for detecting harmful gases or smoke present in the war field. It continuously samples the air around the robot and converts the gas concentration into an Analog voltage signal. This signal is fed to one of the Analog input pins of the Arduino Uno, where it is compared with a predefined threshold value. If the gas level exceeds the safe limit, the Arduino treats it as a gas anomaly and can immediately activate the buzzer and send an alert to the mobile application through the Wi-Fi link. In this way, the gas sensor helps identify hazardous atmospheres such as explosion smoke or toxic leaks before soldiers enter the area.

Arduino Bluetooth

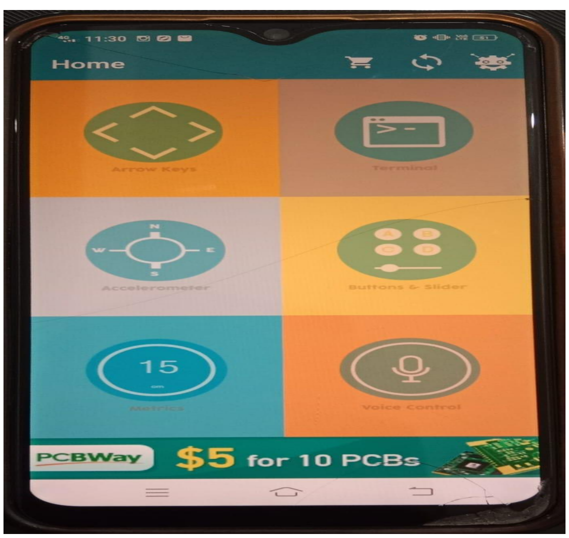

Figure-6: Arduino Bluetooth Controller

The Arduino Bluetooth Controller app is used to manually drive the war- field robot from an Android smartphone. After powering the robot and switching on the onboard Bluetooth module, the user opens the Arduino Bluetooth app, where the splash screen appears followed by the main home screen showing different control modes such as Arrow Keys, Terminal, Accelerometer, Buttons & Slider, and Voice Control. The phone is first paired with the robot's Bluetooth module from within the app; once the connection is established, any command selected in the app is transmitted as serial data over Bluetooth to the Arduino Uno mounted on the robot.

For normal navigation in the war- field test area, the operator typically selects the Arrow Keys or Buttons interface on the home screen. Each on- screen button (forward, backward, left, right, stop) is pre- mapped to a specific character or number in the Arduino code; when the user taps a button, the app sends that code via Bluetooth, the Arduino receives it on its serial pins, and then sets the appropriate motor- driver pins high or low to run motors M1 and M2 in the required direction. While the robot is moving under this Bluetooth control, the metal sensor, gas sensor, buzzer, ESP- 01 Wi- Fi module, and T18205- A camera continue to operate, so the operator can simultaneously drive the robot, listen for alarms, and view the live video stream on the True Cloud app, achieving safe remote inspection of the war- field environment.

The Arduino microcontroller serves as the central control and processing unit of the proposed robotic system, coordinating all sensing, communication, and actuation tasks. It is programmed using embedded C through the Arduino Integrated Development Environment (IDE), enabling efficient control of peripheral devices and real-time decision making. The Arduino continuously monitors incoming data from environmental sensors and communication modules while generating control signals for robot movement and alert mechanisms.

The Bluetooth module is interfaced with the Arduino to provide short-range wireless communication between the robot and the mobile application. This module enables the user to send real-time control commands such as forward, backward, left, right, and stop directly from a smartphone. The Bluetooth communication ensures low-latency and reliable command transmission, making it suitable for precise manual control of the robot during operation.

The Arduino communicates with the Bluetooth module using serial communication (UART protocol). Commands received via Bluetooth are interpreted by the Arduino, which processes them using predefined logic. Based on the received command, the Arduino generates appropriate control signals and forwards them to the motor driver unit to control the robot's movement. This interaction allows smooth and responsive navigation of the robot in real time. In addition to movement control, the Arduino manages the integration of Bluetooth communication with other system functions such as sensor monitoring and anomaly detection. While receiving control commands, the Arduino simultaneously reads sensor data and checks for abnormal conditions. This parallel processing capability ensures that safety monitoring is not interrupted during manual robot operation.

The use of an Arduino–Bluetooth combination provides several advantages, including simplicity of implementation, low power consumption, and wide compatibility with Android devices. The modular nature of this setup allows easy replacement or upgrading of the Bluetooth module without affecting the core system design. Overall, the Arduino and Bluetooth module play a critical role in enabling user-friendly, real-time, and wireless control of the robotic platform.

Working Model

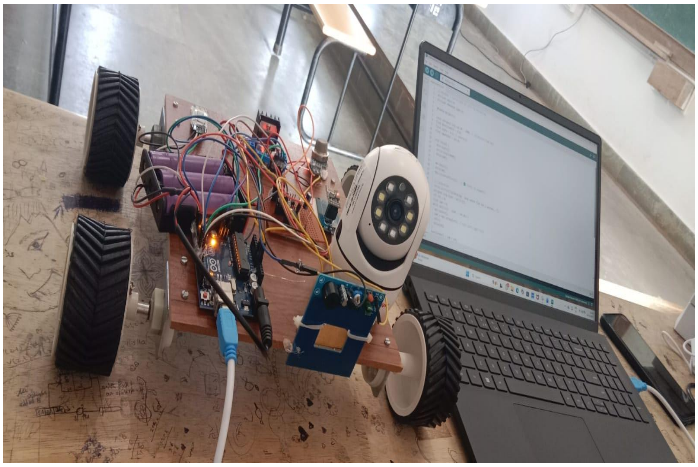

Figure-7: Working Model

The related diagram of the proposed system represents the overall architecture and functional relationship between the hardware and software components used in the app-based robot monitoring system. The system is built around a mobile robotic platform controlled by a microcontroller unit, which acts as the central processing block. The microcontroller continuously receives input signals from multiple sensors mounted on the robot, processes the data, and generates appropriate control outputs.

The power supply block consists of a rechargeable battery pack that provides regulated power to the microcontroller, sensors, motor driver, and camera module. The motor driver block interfaces between the microcontroller and the DC motors, enabling bidirectional control of the robot's movement such as forward, backward, left, and right navigation. The DC motors are mechanically connected to the wheels, allowing the robot to move smoothly on different surfaces.

For environmental monitoring, metal detection and gas sensing blocks are integrated with the microcontroller. These sensors continuously monitor the surroundings for the presence of metallic objects and harmful gases. The sensor data is sent to the microcontroller, where it is analyzed using predefined threshold values. If abnormal conditions are detected, the system identifies them as anomalies.

The Wi-Fi communication block plays a crucial role in enabling wireless connectivity between the robot and the mobile application. Control commands sent from the mobile application are received through the Wi-Fi module and forwarded to the microcontroller. At the same time, sensor data and alert signals are transmitted back to the mobile device for real-time monitoring. A Wi-Fi camera module mounted on the robot captures live video and streams it directly to the mobile application, providing continuous visual surveillance of the operational area.

On the software side, the mobile application acts as the user interface block, allowing the operator to control robot movement, view live video feed, and receive instant alert notifications when anomalies are detected. The Arduino IDE is used to develop embedded software that coordinates sensor data acquisition, motor control, wireless communication, and anomaly detection logic. Thus, the related diagram clearly illustrates the interaction between the power supply, sensing unit, processing unit, communication unit, actuation unit, and user interface, forming a complete real-time robot monitoring and anomaly detection system.

True Cloud

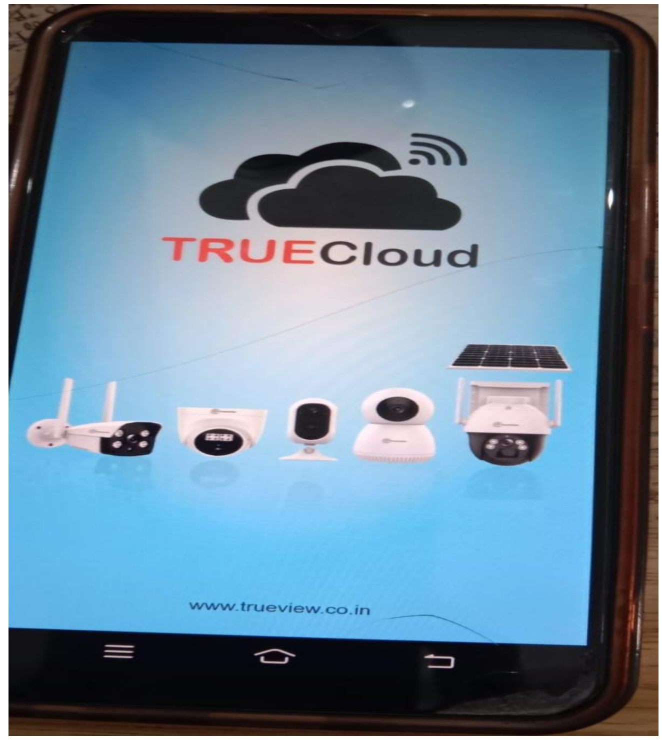

Figure-7: True Cloud

The T18205-A is a 2 MP Wi-Fi robot camera from True Cloud that provides all-time colour video with pan–tilt control, making it well suited for live monitoring from your war-field robot. It uses a 1/4.6-inch CMOS image sensor with 2-megapixel resolution and a 4 mm lens, giving clear footage of the surroundings while the robot moves. The camera includes both IR LEDs and white LEDs along with a smart dual-light mode, so it can automatically switch between normal colour view and enhanced night vision, ensuring that your app receives usable video even in low-light or smoky conditions in the field.

True Cloud is the official mobile and PC application used to access True Cloud cameras over the internet. After installing True Cloud from the Play Store or App Store, the user creates an account and adds the T18205-A camera by scanning its QR code or entering the camera ID, as described in the True Cloud user manuals. During initial setup, the app sends the Wi-Fi SSID and password to the camera, allowing it to join the local wireless network; once connected, the camera registers itself with True Cloud service so it can be reached remotely without complex router configuration.

In operation, the camera continuously captures video and compresses it using H.264, then streams the main video stream (1280×1080 at 15 fps) and a sub-stream (640×360 at 15 fps) to the True Cloud servers. When the operator opens the True Cloud app, the app authenticates to the cloud service and requests the live feed for the selected camera; the cloud then relays the video to the phone in real time, giving the user a live view of the robot's surroundings from anywhere with internet access. This is what enables safe remote monitoring of war- field areas while the robot is moving through dangerous zones.

True Cloud also exposes control features such as pan- tilt (PTZ) movement, digital zoom, and switching between smart night- vision modes. Inside the app, the user can swipe or use on- screen PTZ controls to rotate the T18205- A horizontally up to about 355° and vertically up to about 110°, which is executed by the camera's internal motors. This allows the operator to scan a wider region without physically rotating the robot, complementing the robot's own motion and making area coverage more efficient during reconnaissance.

In addition to live streaming, the T18205- A and True Cloud support local micro- SD recording and optional cloud storage, motion and human detection, motion- tracking, two- way audio, and snapshot/clip backup from within the app. In your project, these functions enhance the anomaly- detection system by allowing the operator to record evidence of detected threats, receive motion- based push notifications, and even talk through the robot using the built- in speaker and microphone if needed. Together, the T18205- A camera and True Cloud software form the visual and communication backbone of the app- based robot monitoring system, tightly integrated with the Arduino- controlled metal and gas sensors for comprehensive war- field surveillance.

True Cloud is utilized as a cloud-based platform to store, manage, and visualize the data generated by the robotic monitoring system. Sensor readings, system status information, and alert notifications are transmitted from the Arduino controller to the True Cloud server through the Wi-Fi module in real time. This cloud integration enables remote access to collected data from any location using an internet-connected device. By leveraging True Cloud, the system ensures secure data storage, reliable data synchronization, and improved scalability. The cloud platform also supports historical data analysis, allowing users to review past sensor values and system performance, which is useful for identifying recurring anomalies and enhancing decision-making. Overall, the integration of True Cloud enhances the monitoring capability of the system by providing centralized data management and continuous availability of system information.

Working Model of Proposed System

Figure-8: Working Model of Proposed System

The Figure-8 shows the real-time experimental demonstration of the proposed mobile robot monitoring and anomaly detection system developed as part of the final-year project. The robotic platform is placed on a flat indoor surface and is being observed during operation by the project team members. This demonstration validates the practical implementation of the designed hardware and software architecture under real-world conditions.

The robot consists of a four-wheel mobile chassis powered by DC motors, ensuring stable movement and maneuverability. An Arduino-based microcontroller mounted on the robot serves as the central control unit, interfacing with various sensors, communication modules, and actuation components. A Wi-Fi camera module is fixed at the front of the robot, enabling live video streaming of the surrounding environment. This visual feedback allows users to remotely monitor the robot's movement and detect any unusual activities or obstacles in real time.

During the demonstration, the robot responds to control commands sent through a mobile application using Wi-Fi communication. The microcontroller processes these commands and controls the motor driver to execute directional movements such as forward, backward, left, and right. Simultaneously, environmental sensors mounted on the robot continuously monitor parameters such as the presence of metallic objects or harmful gases. When abnormal conditions are detected, the system generates alert signals that are transmitted wirelessly to the user interface.

The image also reflects the successful integration of hardware components such as the power supply unit, sensor modules, motor driver, and communication interface on a compact platform. The demonstration confirms the reliability of wireless connectivity, smooth motor operation, and effective sensor response. Observing the robot in motion allows verification of system stability, responsiveness, and real-time monitoring capability.

Overall, this experimental setup and live demonstration validate the feasibility of the proposed system for surveillance and monitoring applications. The results indicate that the robot can effectively operate in real environments, provide live video streaming, detect anomalies, and be remotely controlled through a user-friendly interface, making it suitable for security, industrial, and hazardous area monitoring applications.

6. Conclusion

This paper successfully demonstrates a practical solution for enhancing safety in war- field environments. By integrating an Arduino- based control unit with a metal sensor, gas sensor, buzzer, motor driver, ESP- 01 Wi- Fi module, Bluetooth control, and the T18205- A Wi- Fi camera, the system can remotely detect hidden metallic objects and hazardous gases while simultaneously providing live video to the operator's mobile phone. Experimental results in controlled conditions showed reliable sensing performance, timely alert generation, and stable wireless communication, proving that the robot can effectively reduce direct human exposure to dangerous zones.

The combination of real-time anomaly detection and IP-based video streaming, along with user-friendly mobile apps for robot control and camera viewing, makes this prototype a strong base for future military and disaster-response applications. Although improvements are still possible in areas such as terrain handling, wireless range, and advanced AI-based analytics, the implemented system meets its primary objectives of remote surveillance, early threat identification, and safe reconnaissance.

This project successfully designed and implemented a mobile robot–based real-time monitoring and anomaly detection system that integrates sensing, wireless communication, and remote-control functionalities. The proposed system effectively demonstrates the use of an Arduino-based control unit in coordinating sensor data acquisition, motor control, and Wi-Fi communication, enabling reliable operation in real-world environments. The integration of environmental sensors and a live video streaming module allows continuous surveillance and timely detection of abnormal conditions, enhancing situational awareness and operational safety.

The experimental results and live demonstration confirm that the robot can be remotely controlled through a user-friendly mobile application while simultaneously transmitting real-time sensor data and video feedback. The system shows stable movement, accurate response to control commands, and effective anomaly detection using predefined threshold mechanisms. The wireless communication framework ensures low-latency data transmission, making the system suitable for applications requiring immediate monitoring and response.

Furthermore, the modular design of the hardware and software architecture provides flexibility for future enhancements. Advanced anomaly detection techniques such as machine learning, cloud-based data analytics, and autonomous navigation algorithms can be incorporated to improve system intelligence and scalability. Overall, the proposed system offers a cost-effective, reliable, and efficient solution for surveillance and monitoring in hazardous, industrial, and security-sensitive environments, thereby reducing human risk and improving operational efficiency.

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