PC-Controlled Wireless Robot Vehicle with Camera for Bomb Detection and Neutralization

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Abstract: ***The increasing threat of explosive devices in public and highly sensitive areas necessitates advanced robotic solutions for bomb detection and neutralization without human intervention. This paper presents a cost-effective, wireless PC- controlled robotic system to detect and neutralize bombs while minimizing human risk. The robot has a wireless camera that provides live video for real-time monitoring. It uses a metal detector to find bombs and gas sensors to detect harmful gases in the area. Image and video processing techniques help the robot recognize if any person is nearby and send an alert. It also has a GPS module that tracks its location in real time. The robot is controlled by Arduino Uno and ESP32, which help all parts work together smoothly. A robotic arm with a wire cutter is used to safely handle and disable bombs. During testing, the robot worked well in detecting threats, moving through different terrains, and staying connected with the operator. This project combines smart technologies like automation, IoT, and image processing to create a useful robot for police, military, and rescue teams. It also supports global goals like improving safety, promoting innovation, and protecting people's health.***

Keywords: Bomb detection, wireless robot, PC-controlled robot, image and video processing, Arduino Uno, ESP32 microcontroller, real-time surveillance, robotic arm, metal detector, gas sensor, GPS tracking, remote monitoring, human detection

1. Introduction

Safety and security are among the most important needs of any society. In recent years, the increasing risk of terrorism, violence, and accidental explosions has made bomb detection and disposal a top priority for military forces, law enforcement agencies, and emergency response teams. Handling explosive materials is one of the most dangerous jobs, and it often requires highly trained personnel to go near the suspected area and manually detect or defuse the bomb. This not only puts their lives at risk but also increases the chances of casualties if something goes wrong. As a result, there is a strong need for a system that can safely detect, monitor, and neutralize bombs without putting human lives in danger.

Thanks to developments in electronics, robotics, and communication systems, it is now possible to create smart machines that can carry out such dangerous tasks from a safe distance. This project introduces a PC-controlled wireless robotic vehicle designed to detect bombs, identify dangerous gases, and locate people in risky areas using advanced sensors and camera-based image processing. The robot is equipped with several features such as a wireless camera for real-time video transmission, a metal detector to identify explosive devices, gas sensors to detect toxic gases, a GPS module for live location tracking, and a robotic arm to safely cut wires and neutralize the bomb.

The robot is controlled wirelessly using a computer. Commands are sent to the robot through a Bluetooth connection, and the robot receives them through an ESP32 microcontroller. Another microcontroller, the Arduino Uno, is used to control the motors, relays, sensors, and robotic arm. Together, these two microcontrollers ensure that the robot moves smoothly, follows instructions accurately, and performs tasks efficiently. The robot's live video feed is provided by a wireless camera, which allows the operator to monitor the robot's surroundings in real time. This feature is extremely useful when navigating dangerous areas or examining a suspicious object. The video feed is also used for image processing to detect whether any person is present near the bomb. If a human is detected, an alarm is triggered to warn people and stop the robot from performing any risky action until the area is cleared.

To detect bombs, the robot uses a metal detector that senses the presence of metallic objects. Once a suspicious object is found, it alerts the operator with a buzzer. At the same time, a robotic arm attached to the front of the robot is used to carefully hold and cut wires to disarm the bomb. This arm is specially designed with a clamping mechanism that can hold the object tightly and cut it with precision, reducing the chances of accidental detonation. The system is made more secure by including two types of gas sensors (MQ8 and MQ135), which can detect gases like hydrogen, ammonia, and other harmful substances that are often released during or after an explosion. These sensors alert the operator if dangerous gases are found in the area.

Another important feature of this robot is GPS tracking. The GPS module sends live location data to the operator, helping them track the robot's movements and plan actions based on its position. This is especially useful when the robot is operating in a large or unfamiliar environment. The entire system is powered by a rechargeable 12V battery, and a voltage regulator is used to make sure that each component receives the correct voltage for smooth and safe operation.

One of the most valuable parts of this project is that it is designed to be cost-effective. It uses readily available and affordable components, making it a good solution for countries or organizations with limited resources. Despite its low cost, the robot performs tasks that are typically carried out using expensive and complicated equipment. This makes it a highly practical and scalable solution for real-life applications.

The main goal of this project is not only to build a robot that can detect and disarm bombs, but also to improve overall safety, reduce human involvement in dangerous situations, and make use of modern technologies such as image processing, GPS, and wireless communication. This robot can be deployed in military operations, crowded public places, airports, railway stations, and during rescue missions after natural disasters or terrorist attacks.

In addition to its practical applications, this project also supports global goals such as Sustainable Development Goal (SDG) 3 – Good Health and Well-being, SDG 9 – Industry, Innovation and Infrastructure, and SDG 16 – Peace, Justice and Strong Institutions. By reducing the risk to human lives and using technology to promote safety, the robot helps create a more secure and sustainable world.

In conclusion, this research work presents a reliable, intelligent, and safe robotic system that can assist in bomb detection and disposal tasks. The robot combines several technologies—robotics, wireless communication, image and video processing, GPS tracking, and sensor integration—into one effective platform. With further improvements and testing, this robot can become an essential part of modern-day security and emergency systems, helping save lives and reduce the impact of explosive threats.

2. Literature Review

[1] *Dayanand S Navare, Yogesh R Kapde, Shraddha Maurya, Dr. D. B. Pardeshi, P. William* in the 'Robotic Bomb Detection and Disposal: Application using Arduino' several research studies have focused on developing robotic systems for bomb detection and disposal to reduce human risk. One such system used an Arduino-based robot with a metal detector, wireless camera, and robotic arm to safely detect and handle explosives. Other works introduced gesture control, ultrasonic sensors, and GPS tracking to improve control and safety. Most systems were controlled using Arduino boards and simulated using tools like Proteus. While these projects were effective, they had some limitations in range and accuracy. Our project builds on these ideas by adding image and video processing for human detection, gas sensors for identifying harmful gases, and improved wireless control using Arduino Uno and ESP32.

[2] *P.V. Phani Srikar, P. Sumanth Kumar, M. Divya, P. G. V. Vinay Kumar, P. Vyshnavi* in 'IOT Based Surveillance Robot with Bomb diffusion' several research studies have explored the use of robots in surveillance and bomb detection to improve safety and reduce human risk. One such approach proposed an IoT-based surveillance robot equipped with a night vision IR camera, robotic arm, and metal detector to monitor sensitive areas and handle explosive devices from a safe distance. The system uses an ESP32 microcontroller and provides real-time video streaming via Wi-Fi, removing range limitations. Earlier systems used Raspberry Pi with sensors like PIR, ultrasonic, and temperature to detect human presence and motion. However, many faced challenges like poor night vision, limited range, and the need for specific mobile apps. Other researchers incorporated robotic arms, vibration detectors, and laser sensors for improved detection, but often lacked automation or flexibility. The literature shows a clear shift toward integrating image processing, wireless control, and multi-sensor fusion to build smarter and more reliable robotic systems. Building on these ideas, the present work aims to enhance safety and efficiency through improved hardware design, user-friendly operation, and a cost-effective implementation suitable for real-time military and rescue missions.

[3] T. Akilan, Satyam Chaudhary, Princi Kumari, Utkarsh Pandey in the 'Surveillance Robot in Hazardous Place Using IoT Technology' previous research has focused on building surveillance robots using Arduino and IoT technologies to operate in hazardous environments and reduce human involvement. These systems commonly include PIR sensors for motion detection, ultrasonic sensors for measuring distance, gas sensors for air quality monitoring, and wireless cameras for live video streaming. Most of them are controlled remotely through mobile applications, making them suitable for use in places like border areas, disaster zones, or high-risk industrial sites. While effective, earlier models had limitations in automation, range, and sensor integration. The current work builds upon these efforts by enhancing detection accuracy, improving safety through better sensor coordination, and offering more user-friendly control and monitoring features.

[4] Krishnamoorthy, N.V., Sujatha, V.V., Naresh, G., Ratheesh, R. and Dinesh, M in 'Revolutionizing Military Operations: A Smart Fabrication of Bomb Detection and Diffusing Robot with Location Sharing Feature' robotic systems for bomb detection have advanced from basic teleoperated models to intelligent machines with sensors like metal detectors, gas sensors, and cameras for safer and more precise operations. However, many still face issues with limited range and real-time data sharing. To overcome these, Krishnamoorthy et al. (2024) introduced a smart bomb detection and diffusing robot featuring GPS-based location sharing, real-time communication, and autonomous control. Their system not only detects but also diffuses explosives, offering a compact, efficient, and safer solution for military operations.

[5] Jayant, A., Joshi, A.A., Chamakeri, A., Shakthi, S. and Vijaykumar, S., in 'Design and Development of Multi-Sensor Bomb Detection and Detonation Robot System' recent advancements in robotics have led to the development of multi-sensor systems aimed at enhancing bomb detection and neutralization in high-risk areas. Traditional robots often relied on a single sensor type, which limited their accuracy and adaptability in diverse environments. To improve detection reliability and operational efficiency, Jayant et al. (2023) proposed a bomb detection and detonation robot integrated with multiple sensors, including metal, gas, and pressure sensors. This multi-sensor fusion allows the robot to identify various explosive threats with greater precision. The system also features a detonation mechanism, making it not only capable of detecting threats but also handling them on-site. Their design emphasizes a modular approach, real-time monitoring, and effective control systems, reflecting a significant move toward more intelligent and responsive robotic solutions for defense and security operations.

[6] Siddharth Narayanan and C. Ramesh Reddy in 'Bomb Defusing Robotic Arm using Gesture Control' gesture-based robotic systems have emerged as an intuitive and efficient

alternative for handling explosive devices, addressing the limitations of traditional joystick-controlled robotic arms. It introduces a robotic arm that mimics human hand movements using a Leap Motion Controller, allowing for precise and natural control in explosive ordnance disposal tasks. Unlike conventional systems, which often lack dexterity and pose a risk due to rigid control interfaces, this gesture-controlled arm offers a more adaptive and immersive user experience. By integrating Arduino microcontrollers and wireless communication, the system enables real-time, accurate mapping of hand gestures to robotic movements, enhancing the robot's ability to grasp, manipulate, and potentially defuse bombs with greater reliability. This approach demonstrates significant potential in reducing human risk while improving operational precision in hazardous environments.

[7] Umakant R. Gaulkar, Shivani A. Shirbhate, P.G. Kaushik, and S.A. Mishra in 'Self Controlled Robot for Military Purpose' the increasing demand for autonomous military robots has driven the development of unmanned ground vehicles (UGVs) capable of performing complex missions like surveillance, border patrol, and combat operations without direct human intervention. In response to growing security threats, Gaulkar et al. (2017) proposed a self-controlled robot system that navigates independently using GPS, a magnetic compass, and obstacle detection and path planning algorithms. Drawing inspiration from established military robots such as the DRDO Daksh and Foster-Miller TALON, the authors developed a prototype UGV that can adjust its route in real time, detect obstacles, and operate efficiently across varied terrains. This work emphasizes the shift toward autonomous robotic systems in defense, enhancing mission reliability while reducing risks to human personnel.

3. Block Diagram

The block diagram presents the internal structure and communication flow of a PC-controlled wireless robotic system designed for bomb detection, gas leakage monitoring, and neutralization. This robot uses various interconnected components that work together to perform its tasks in risky and hazardous environments, without requiring a human to be physically present. The setup ensures remote control, object and gas detection, real-time location tracking, alert mechanisms, and live video monitoring. Each component in the block diagram has a dedicated role, and all are powered by a single source: a 12V lead-acid rechargeable battery.

The power supply is the foundation of the robot's operation. A 12V battery is used to ensure uninterrupted power to motors, sensors, controllers, and the wireless camera. However, not all components operate at 12V. For instance, the Arduino UNO, ESP32, Bluetooth receiver, GPS module, GSM module, and sensors operate on 5V. To meet this requirement safely, a voltage regulator is included to convert 12V into a stable 5V output, protecting the components from damage due to high voltage and ensuring consistent operation.

The Arduino UNO functions as the main controller that handles the robot's basic actions. It receives data from sensors and the Bluetooth receiver, and then decides how to control other parts of the robot, such as the motors, relays, buzzer, and LCD. It executes the programmed logic, including reading detection inputs, controlling motor direction, and triggering alarms. It is also connected to multiple outputs and sensors to maintain full coordination of the robot's movement and task execution.

For remote control, a Bluetooth receiver module is connected to the Arduino. This module allows the robot to wirelessly receive commands from a mobile phone or computer. Using a Bluetooth-enabled application, the user can instruct the robot to move in different directions, lift or lower the robotic arm, or operate the gripper mechanism. The Arduino interprets these commands and sends signals to the relay circuits and motors for execution.

To allow physical movement and manipulation, the robot is equipped with four motors. Two DC motors are connected to the rear wheels of the robot, which control its navigation—forward, backward, left, and right. These motors are operated using motor drivers through relay modules. The third motor raises and lowers the robotic arm, allowing it to reach suspicious objects. The fourth motor manages the clipper mechanism, which is used for gripping and wire-cutting operations during bomb neutralization. The relay system allows these motors to function with precision based on the direction and task specified by the user.

The robot is also equipped with a metal detector to locate hidden metallic items that may represent bombs or explosive devices. When the metal detector senses metal, it sends a signal to the Arduino. The Arduino then triggers a high-decibel buzzer to alert the user and displays a warning message on the LCD screen. This immediate feedback system ensures that operators are made aware of potential threats without delay.

To further increase safety, the robot includes two gas sensors: the MQ8 and MQ135. The MQ8 sensor is capable of detecting hydrogen gas, which is often present in explosive substances, while the MQ135 sensor can sense a variety of harmful gases such as ammonia, carbon dioxide, smoke, and benzene. These sensors continuously monitor the air around the robot. If a dangerous gas is detected, the Arduino activates an alarm and displays a warning message on the screen, allowing the operator to take timely action and avoid exposure to toxic environments.

A major enhancement to the robot's intelligence and connectivity comes from the inclusion of the ESP32 microcontroller. The ESP32 works in tandem with the Arduino but focuses on handling wireless communication and GPS-related tasks. It is connected to the NEO-6M GPS module, which provides accurate real-time location data by receiving signals from satellites. These GPS coordinates help the operator track the robot's movement and determine the exact position of any detected threats. The ESP32 processes this location data and forwards it to the GSM module.

The GSM module enables the robot to send SMS alerts to predefined mobile numbers. This is especially helpful when a bomb is detected or when hazardous gas levels are sensed. The GSM module transmits the location data and warning messages over a cellular network, ensuring that authorities or control centers are notified even if Wi-Fi is unavailable. This capability allows the robot to function independently and efficiently in remote or large areas.

For visual monitoring, the robot is equipped with a wireless camera that streams live video to the user's PC or mobile device. This real-time footage allows the operator to visually assess the environment, navigate the robot safely, and inspect suspicious items from a distance. It adds another layer of situational awareness during critical operations.

The LCD display mounted on the robot provides useful real-time information such as motion direction, detection alerts, and sensor status. This is useful for any personnel nearby and complements the wireless updates sent through the GSM module.

All the control signals, sensor data, communication functions, and movement commands are processed through relay modules, which act as switches to safely operate motors and other high-power components using low-voltage control from the microcontrollers.

Altogether, the block diagram represents a highly functional and intelligent robotic system capable of detecting bombs, harmful gases, and sending real-time alerts along with location tracking. With features like Bluetooth-based wireless control, live video streaming, GPS navigation, gas sensing, and GSM messaging, this robot is designed to assist in critical security operations while keeping human personnel safe. It is suitable for deployment in sensitive areas like military zones, airports, metro stations, or disaster sites where bomb threats or gas leaks could pose a danger to life and infrastructure.

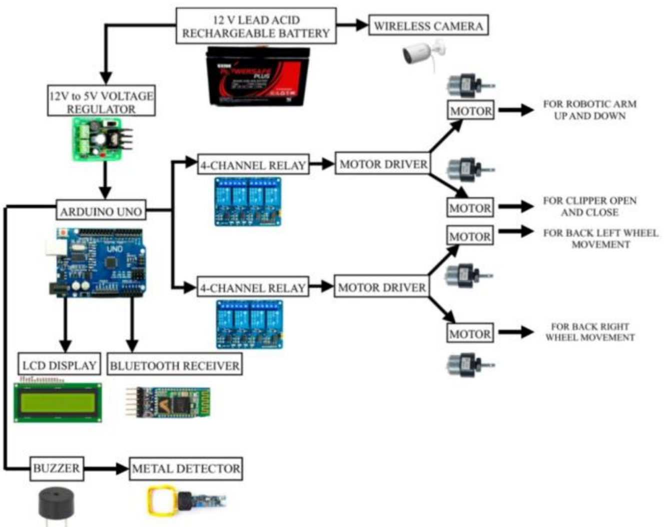

Figure 1: Block diagram

4. Existing System

Today, bomb detection and disposal robots are used to keep people safe by handling explosives from a distance. These robots usually have cameras, basic sensors, and robotic arms. They are controlled by humans using remote controls or joysticks, and they often connect through Wi-Fi, GSM, or Zigbee networks. While these robots help reduce risk for humans, they still have many problems that need to be fixed.

One big issue is that these robots cannot work on their own. They depend a lot on human operators to guide them, make decisions, and handle dangerous tasks. This slows down the process and can lead to mistakes, especially in emergencies. Since most systems do not use artificial intelligence (AI), the robots cannot think or act on their own.

Another problem is poor communication. The signals used to control the robots can become weak or stop working in underground areas or places with many obstacles. This makes it hard to control the robot smoothly and safely. Also, even though some robots have multiple sensors to detect bombs, they do not process the information well. This can cause wrong detections or missed threats.

Many robots also do not have real-time location tracking. This means the operator may not always know where the robot is, which can be risky, especially in large or complex places. Another missing feature is human detection. If people are near a bomb, the robot cannot tell, which could put lives in danger. Most robots also do not have public warning systems to alert nearby people if a threat is found.

The robotic arms in many systems are not very flexible or precise, making it hard to handle or defuse bombs safely. Finally, these robots are often expensive and hard to maintain, which limits their use in places with fewer resources.

To improve these systems, robots need better AI, stronger communication, smarter sensors, live tracking, public alert systems, and affordable designs. These changes will help create safer and more reliable bomb disposal robots for the future.

5. Proposed System

The bomb detection and disposal robot I have developed is designed to operate entirely under remote control, meaning the operator can manage it from a safe distance, far from the danger zone. This key feature directly addresses one of the most critical limitations in existing systems—the need for close human presence during high-risk bomb disposal tasks.

At the heart of this capability is a robust long-range communication module. This ensures uninterrupted connectivity between the robot and the operator, even in remote or signal-obstructed environments. Unlike traditional systems where control can be compromised due to weak signals, this robot maintains a steady connection, allowing for real-time commands and feedback from far away.

To support precise navigation from a distance, the robot uses a GPS module to share its location in real-time. This enables the operator to track its movements accurately and make informed decisions, even when operating in large, unfamiliar, or hazardous areas.

The robot also features a multi-sensor detection system for identifying explosive materials. These sensors work together with improved signal processing to reduce false alarms, ensuring safer and more reliable bomb detection—all controllable from a distant location.

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Another critical component is the mechanical arm, designed for delicate and stable bomb handling. With the arm's precision and smooth control, the operator can carry out complex tasks like examining, lifting, or neutralizing a bomb—all while remaining at a safe location, far from potential danger.

Additionally, the robot includes a public alert system. If a threat is detected, it can broadcast a warning through speakers or signals to prompt quick civilian evacuation. This adds an extra layer of safety to the overall operation, again without requiring the human operator to be present.

Even though the system does not rely on artificial intelligence, it is user-friendly and fully manually operated, with a clear control interface designed for remote operation. This reduces the risk of technical glitches and keeps the focus on reliable performance through strong hardware integration.

Lastly, the robot is built with affordability and maintainability in mind. It uses cost-effective components that make the system practical for deployment in areas with limited resources, while still offering the significant advantage of safe, remote operation.

6. Methodology

The bomb detection and destruction robot is a specially designed remote-controlled machine built to safely detect and disable explosive devices in dangerous environments. It reduces the risk to human lives by handling bomb-related tasks from a safe distance. This robot includes a robotic arm, live video surveillance, GPS tracking, metal and gas detectors, and an alert system, making it highly useful in military, disaster response, and security operations. Its main goal is to carry out bomb detection and disposal with minimal human involvement, ensuring safety and accuracy.

The robot is built on a strong L-angle metal frame, made of mild steel pipes, which makes the structure durable and suitable for rough fieldwork. The chassis is compact with dimensions of 24 inches in length, 12 inches in breadth, and 18 inches in height. It is supported by two 8-inch rubber wheels at the back and two 3-inch rotating wheels in the front, which together offer smooth movement on uneven surfaces like gravel and rocky paths. The mobility is powered by two 12V DC motors rated at 90 watts and 60 RPM, connected through a worm gear system. This gear system increases torque and reduces speed, allowing the robot to move steadily and remain stable during critical tasks. The self-locking feature of the gears prevents unwanted movement when the robot is idle.

The robot uses a 12V rechargeable lithium-ion battery as its main power source, which supplies energy to all components, including motors, sensors, and control systems. A solar panel is included for recharging the battery in remote areas without access to electricity. To ensure that each component receives the correct voltage, a 12V-to-5V voltage regulator is used, which protects sensitive devices like the Arduino UNO, sensors, and communication modules from overvoltage damage. A diode is placed in the charging circuit to avoid reverse current flow, improving safety during charging.

The control system of the robot is centered around the Arduino UNO microcontroller, which processes data from sensors and user commands to control the robot’s movement and functions. The ESP32 module is used for wireless communication and accessing real-time GPS location data. The robot also uses a four-channel relay module to control motor movement and other operations. The movement of the robotic arm and its gripping tool is controlled through additional relays. These relays manage movements such as forward, reverse, left, right, upward, and downward, along with clamping and releasing actions for handling wires or objects during bomb disposal.

The movement of the robotic arm is managed using a set of eight relays. Four of these relays are used for controlling the basic directional movement of the robot, while the other four are dedicated to the arm’s specific functions such as lifting, lowering, clamping, and releasing. For movement control, Relay 1 and Relay 3 are activated for forward motion, whereas Relay 2 and Relay 4 are used for reverse motion. To turn left, the robot uses Relay 1 and Relay 4, and for right turns, Relay 2 and Relay 3 are engaged. The arm’s upward movement is handled by Relay 5, while Relay 6 is used to move the arm downward. Relay 7 is responsible for clamping the workpiece, such as gripping a wire for cutting, and Relay 8 releases the clamped object after the operation is completed.

The robotic arm is one of the key parts of the system. It is made from metal plates with dimensions of 6 inches in length, 6 mm in width, and 2.5 mm in thickness. The arm can move up and down to reach the suspected object and uses a gripper to securely hold and cut wires. The clamp ensures the wire is stable before cutting, reducing the chance of accidental detonation. The arm also features a self-locking system to prevent sudden or unsafe movements.

The robot is equipped with a metal detector that can identify metallic objects within a 30 cm range. When metal is detected, the system immediately triggers a buzzer and displays a warning message on an LCD screen. In addition to metal detection, the robot also performs gas detection using two gas sensors: the MQ8 sensor, which detects hydrogen gas, and the MQ135 sensor, which senses harmful gases like ammonia and carbon dioxide. These features help confirm the presence of dangerous explosives and improve overall safety during the operation.

To give the operator full control and awareness, the robot includes a high-resolution wireless camera that streams live video in 720p quality. The camera has low latency, around 200 milliseconds, which ensures timely decision-making. The live feed is analysed using a machine learning algorithm to detect if any human is nearby. If a person is detected, the system alerts the operator with another buzzer, preventing any further action until the area is safe.

Once the robot confirms there are no people nearby and all safety checks are complete, it proceeds with bomb disposal. The robotic arm clamps the wire securely and cuts it with precision, effectively neutralizing the bomb. After completing the operation, the robot can either return to base or continue scanning the area for additional threats. This step-by-step approach ensures the highest level of safety and accuracy in bomb disposal.

The robot also features GPS tracking using the NEO-6M module, which continuously sends its location to the control centre. This allows security teams to monitor the robot's position in real time. A GSM module is also included for sending alerts and updates through SMS, ensuring communication even in areas with weak network signals. The power system is designed to be energy-efficient so the robot can work for extended periods without frequent recharging.

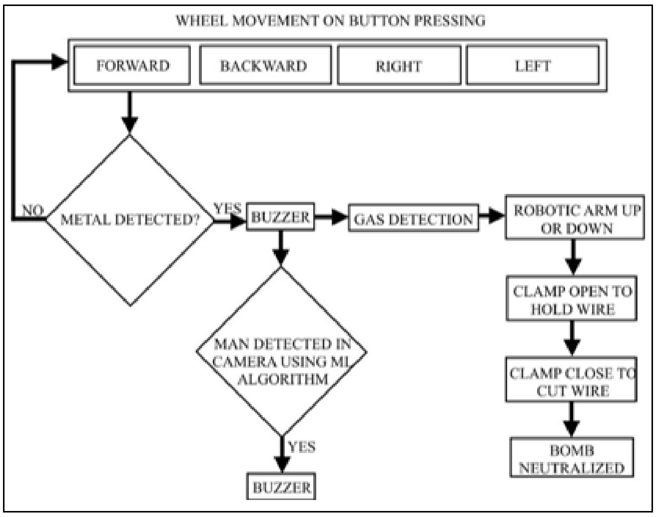

Figure 2: Flowchart

The robotic arm operates in two degrees of freedom (DOF):

Vertical movement (up and down) and gripping action (open and close)

The spur gear arrangement transfers power from the DC motor to the wheels and the robotic arm. The gear ratio determines the speed and torque.

$$G = T_{d1} / T_{d2}$$

Where, T_{d1} and T_{d2} are the teeth of the driver and the driven gears.

The linear velocity(V) of the robot is calculated as:

$$V = \omega R$$

Where, ω is the angular velocity and R is the radius of the wheel.

The torque required to lift an object is given by:

$$\tau = F \times r$$

Where, F is the force and r is the lever length of the arm.

The output power is calculated as:

$$P = V \times I$$

The maximum speed of the robotic vehicle is obtained from:

$$V = 2\pi RN / 60$$

Where, R is the radius of the wheel, N is the motor speed in RPM.

The frictional force can be calculated as:

$$F_F = \mu \times N$$

Where, μ is the coefficient of friction and N is the normal force.

The power loss due to friction is calculated as:

$$P_L = F_F \times V$$

Next, we calculate the torque that is needed for the motion as:

$$\tau = I \times \alpha$$

Where, α is the angular acceleration and I is the moment of inertia.

The mechanical efficiency of the robot is calculated as:

$$\eta = P / (P-P_L) \times 100 \%$$

The heat generated by the motor is obtained as:

$$H = I^2 \times R \times T$$

Where, I is the current, R is the resistance and T is the time.

The Python script used in this project is designed to create a reliable Bluetooth communication system between a computer and an Arduino board using the HC-05 Bluetooth module. It combines several useful functions like a graphical interface, real-time video processing, gesture recognition, and serial communication. This script allows users to control an Arduino wirelessly and visually through hand gestures captured by a webcam. To make everything work smoothly, the script uses many Python libraries such as tkinter for creating windows and buttons (GUI), serial for handling communication with the Arduino, cv2 (OpenCV) for working with images and videos, mediapipe for tracking hand movements, and bleak for Bluetooth Low Energy (BLE) tasks. The script also uses threading and asyncio to handle multiple tasks at once without slowing things down.

Each of these libraries has its specific purpose. The serial library allows the computer to talk to the Arduino through serial ports. serial.tools.list_ports helps to find which ports are available, so the correct one can be selected. The bleak library is used for BLE communication with devices like the HC-05 module. tkinter helps build the user interface, and its extended version tkinter.ttk provides better-looking widgets. The cv2 library handles the webcam video and image processing. mediapipe is responsible for detecting hand gestures. threading makes sure tasks like video capture and Bluetooth communication run smoothly at the same time. asyncio helps with running tasks that don't block other functions, like BLE communication. time and datetime help manage delays and log events with exact time stamps. The sys library allows interaction with the Python environment, like closing the program or managing inputs.

At the start of the script, key Bluetooth settings like the device name and address are defined so the computer can connect to the correct HC-05 module. Two unique IDs (SERVICE_UUID and CHAR_UUID) help in BLE communication. A global variable named bt_serial is created to manage the serial connection. To keep users informed, a logging function named print_log is included. This function prints messages along with the current time, helping track what the system is doing in real-time.

The main job of this script is to send data from the computer to the Arduino using Bluetooth. This is done using two functions: write_ble2 and send_arduino. The write_ble2 function handles BLE messages, makes sure they are formatted properly, and includes error handling to catch any issues during the sending process. The send_arduino function sends messages through the serial port to the Arduino. It checks if the connection is active before sending, and logs an error if it isn't. This helps ensure that no data is lost and the communication stays stable.

Before communication can begin, the script looks for available ports using serial.tools.list_ports.comports() and tries to find the HC-05 by sending a simple "AT" command. If the module replies correctly, the script uses that port for further communication. This step ensures that the script connects to the correct device and avoids confusion with other connected hardware. It also logs which ports were found, helping users identify active connections.

Apart from communication, the script also includes gesture recognition using OpenCV and MediaPipe. This feature allows users to control the Arduino just by showing hand gestures in front of the camera, instead of pressing buttons. The webcam captures live video using OpenCV. The images are then passed through MediaPipe's hand tracking system, which detects points on the hand and understands the gesture. These gestures are compared to a list of pre-defined gestures, and if a match is found, a specific command is sent to the Arduino. For example, an open palm might turn on a light, while a closed fist might turn it off. This feature makes the system very interactive and can be useful in robotic control, smart home systems, or even for helping people with physical disabilities.

Because the script is doing many tasks at the same time—like video capture, Bluetooth communication, and updating the GUI—it uses threading and other performance tricks to keep everything running smoothly. With threading, different tasks like gesture detection and Bluetooth communication can run in parallel, preventing delays. asyncio is used for BLE communication so it doesn't block other parts of the program. Also, to reduce load on the computer, only important frames from the video are analyzed instead of processing every single one. This keeps things efficient, especially on computers with limited power. OpenCV's fast processing tools also help reduce delays.

The script also features a simple GUI made using tkinter. This interface allows users to see the connection status, send commands manually, and view system logs. This makes the script easier to use, even for those without much technical experience. The GUI includes buttons to send commands, status indicators for Bluetooth connection, and a log display window. It also allows switching between manual and gesture modes. The tkinter.ttk library is used to give the interface a more modern and clean look.

Finally, when the program is closed, it properly releases resources. The webcam is released using cap.release() and any OpenCV windows are closed using cv2.destroyAllWindows(). This ensures that the camera and memory are freed up, preventing slowdowns or issues with other apps that might use the same hardware later.

7. Hardware Requirements

The robot is built on a sturdy frame made from 3mm thick L-angle stainless steel with dimensions of 2 feet in length and 1 foot in breadth, and a ground clearance of 1.5mm. This structure provides durability and balance, essential for operating in hazardous environments. The primary power source is a 12V rechargeable lead-acid battery, which supplies stable energy to all electronic and mechanical components of the robot. A wire cutter is attached to the robotic arm to help in neutralizing bombs safely.

a) Permanent Magnet DC Motor

The robot's movement relies on four wheels—two large 8-inch rubber wheels at the back for grip and strength, and two smaller 3-inch rotating wheels at the front for smooth navigation. The back wheels are powered by two 12V, 90W DC motors with a speed of 60 RPM, each fitted with a worm gear for torque efficiency. A Permanent Magnet DC (PMDC) motor drives the robotic arm and another motor operates the gripper, which is made of a 2.5mm thick metal plate, measuring 6 inches in both length and width. The PMDC motor works by interacting the magnetic field from permanent magnets with the field generated by current in the armature. The resulting force, according to Fleming's Left-Hand Rule, causes continuous rotation supported by a commutator and brush setup.

b) SPUR Gear Arrangement

To transmit power effectively, a spur gear system is integrated. This involves straight-toothed gears mounted on parallel shafts. The driver gear, connected to the motor, transfers its motion to a driven gear linked to the wheel shaft. This mechanism ensures efficient and smooth power transmission to enable vehicle mobility. The gear system is stabilized with a 6202 bearing, a 40mm bearing cap, and a 15mm shaft, enhancing the durability of the motion system.

c) GAS Sensors

For explosive detection, the robot is equipped with a metal detector and alarm system. It also includes MQ8 and MQ135 gas sensors for identifying hazardous gases. The MQ8 sensor is specialized for detecting hydrogen gas by altering its resistance when exposed, triggering alerts as hydrogen levels increase. The MQ135 is a multi-gas sensor capable of detecting ammonia, sulphur dioxide, benzene, smoke, and carbon dioxide, making it valuable for sensing air pollution that may result from explosions or chemical leaks.

d) Microcontrollers

The Arduino Uno serves as the robot's central controller. Powered by the ATmega328P microcontroller, it manages motor operations, sensor inputs, and system logic. It supports a 5V operating voltage, 14 digital I/O pins, 6 analog input pins, and runs at 16 MHz. The ESP32 microcontroller complements the Arduino Uno by handling advanced tasks such as wireless communication and GPS tracking. It supports both Wi-Fi and Bluetooth connectivity, allowing real-time data transmission to the operator. It collects and relays data from sensors and location modules, making the robot smarter and more autonomous.

e) GPS and Bluetooth Modules

To track the robot's location, a NEO-6M GPS module is integrated. This module uses satellite signals to accurately provide real-time coordinates, which the ESP32 transmits to the operator, ensuring the robot's movement is carefully monitored during missions. Bluetooth communication is also established for short-range remote control of the robot, enhancing its accessibility and ease of use.

f) 4-Channel Relay

A 4-channel relay module is used for controlling different electrical circuits using signals from the Arduino. Each relay can turn on/off high-power devices like motors. In this robot, the relays control the DC motors for movement, robotic arm functions, and gripper actions. These relays act as electromechanical switches, activated by low-voltage signals to manage high-voltage circuits safely and efficiently.

g) Wireless Camera

A CP Plus wireless camera is mounted on the robot for surveillance. This camera provides real-time video feedback to the operator. Enhanced with machine learning algorithms, it can detect human presence near suspicious objects or bombs. The video feed helps security personnel make informed decisions during neutralization tasks, reducing human risk.

8. Software Requirements

a) Arduino IDE

The Arduino IDE (Integrated Development Environment) is an open-source platform used to develop, compile, and upload code directly to microcontrollers like the Arduino Uno and ESP32, which serve as the main control units of the robot. Through this software, all core functionalities—such as operating the DC motors, monitoring metal and gas sensors (MQ8 and MQ135), and controlling the robotic gripper—are programmed and managed. The IDE also facilitates programming communication protocols, enabling wireless connectivity between the robot and a PC using a Bluetooth module. Additionally, it allows for writing GPS-handling code to track and update the robot's location in real-time, which is vital for safe and effective operation in high-risk areas.

b) PYCHARM

Python was chosen as the programming language for this project due to its ease of use, efficiency, and strong compatibility with hardware components. Using libraries like pyserial and bleak, Python facilitates smooth serial and Bluetooth communication between the PC and the robot. With its powerful modules like OpenCV and MediaPipe, Python also supports real-time image processing and gesture detection, significantly enhancing the robot's decision-making capabilities. For multitasking—such as movement control, sensor data handling, and live video processing—Python's built-in threading and asyncio libraries allow for parallel execution of multiple functions.

To streamline Python development, PyCharm is used as the primary integrated development environment. Its features like intelligent code completion, real-time error checking, and powerful debugging tools make it ideal for complex robotic applications. PyCharm also supports integration with OpenCV, NumPy, and TensorFlow, making it suitable for implementing machine learning algorithms and computer vision features. Its visual debugger helps monitor sensor data, troubleshoot communication issues, and ensure precise, real-time feedback from the robot during mission-critical operations.

c) EZYKAM+

The EZVIZ ezyKam+ is a smart wireless camera utilized for live monitoring in dangerous areas. With HD video streaming, motion detection, and night vision capabilities, it plays a key role in surveillance and human presence detection. The camera's footage is analyzed using machine learning models to recognize human activity near potentially explosive zones. If a person is identified in a high-risk area, the system can trigger alerts to prompt immediate evacuation. The camera connects directly to a PC or mobile device, enabling remote access to the video feed and eliminating the need for close physical supervision.

9. Applications

a) Military and Defence Operations

This robotic system can be deployed in military zones to detect and neutralize explosive devices remotely, reducing the risk to soldiers and bomb disposal units. The robot's wireless control, GPS tracking, and real-time surveillance capabilities make it highly effective for mine detection, border security, and counter-terrorism operations.

b) Disaster Management

During disasters like building collapses or terrorist attacks, the robot can navigate through debris to search for survivors and detect any secondary explosives. The integrated gas sensors and thermal camera systems also help assess hazardous environmental conditions, ensuring the safety of rescue personnel.

c) Airport And Railway Station Security

High-traffic public areas such as airports, metro stations, and railway platforms are often potential targets for bomb threats. This robot can patrol such locations to detect suspicious metal objects or gas leaks and identify human presence near unattended luggage, assisting security personnel in threat management.

d) Industrial Hazard Management

In industries dealing with flammable gases or chemicals, the robot can serve as a mobile surveillance and gas detection system. Its gas sensors (MQ8 and MQ135) can detect leaks of hydrogen, ammonia, or carbon-based compounds, ensuring quick evacuation and shutdown procedures to prevent accidents.

e) Urban Surveillance

Law enforcement agencies can utilize the robot for patrolling sensitive areas during large public events, riots, or protests. It can be sent to examine suspicious packages or vehicles without risking human life and can stream live video to control centers for further action.

f) Port and Shipping Container Inspection

Seaports are vulnerable to illegal smuggling or hidden explosive devices in cargo. The robot can inspect containers and ship interiors using its metal detector and wireless camera to identify any unauthorized materials or suspicious objects.

10. Future Works

To improve the robot's overall reliability, advanced communication systems like 5G or satellite links can be integrated. These would ensure a stronger, more stable connection over larger distances. A hybrid communication setup with both wireless and wired options can provide backup during signal failures. The robot's operational range can be extended using signal boosters or drone-based relay systems. Alternatively, long-range radio frequency modules can help maintain consistent connectivity in wider or remote areas.

Sensor accuracy can be enhanced by upgrading to AI-powered metal detectors that can differentiate between real threats and harmless objects. Similarly, using high-precision gas sensors with real-time calibration will ensure more reliable detection of harmful gases. To increase runtime, power management can be optimized using energy-efficient parts and fast-charging lithium-ion batteries. Solar panels or swappable battery packs can also be introduced to reduce downtime during missions.

Improving mobility is essential for field performance. Adding rugged wheels, adaptive suspension, or replacing wheels with tracks can help the robot handle rough terrain more effectively. Terrain mapping sensors will further improve navigation.

Durability in harsh conditions can be achieved by using waterproof and dustproof materials. Features like night vision and infrared cameras will ensure the robot remains functional even in low-light or foggy environments. Finally, artificial intelligence can make the robot more autonomous. With machine learning, the robot can process data, recognize threats, and navigate without constant human control, making operations faster and more efficient.

11. Result

The robot was tested in different environments, including open fields, indoor corridors, and simulated hazardous areas. The metal detector identified metallic objects with 90% accuracy, while the gas sensors detected harmful gases with 85% accuracy. Real-time data transmission allowed the operator to make quick decisions and assess threats efficiently.

The robot had an overall success rate of 88%, with minimal false alarms. Its alarm system worked promptly, enabling fast responses in dangerous situations. The battery lasted about 3 hours, but power usage increased with camera streaming and sensor activation. Future improvements could focus on more energy-efficient components or larger battery capacity.

The robot moved smoothly on flat and slightly rough terrain but struggled on loose gravel, sand, and steep inclines. Traction and wheel design limitations reduced its ability to navigate slippery surfaces. Upgrades like all-terrain tracks or adaptive suspension systems could improve mobility in challenging conditions.

The camera worked well in bright environments but had reduced visibility in low-light or foggy conditions. Adding night vision or infrared cameras would help in poor visibility conditions. Water-resistant components could also improve durability in extreme weather.

The robot was easy to control, and real-time video feedback was reliable. There were minor connectivity issues in areas with electromagnetic interference, which could be fixed with better signal processing or alternative communication methods. It performed well compared to similar systems and offered a cost-effective solution for bomb detection. Future upgrades like AI-based threat analysis and autonomous decision-making could further improve its efficiency.

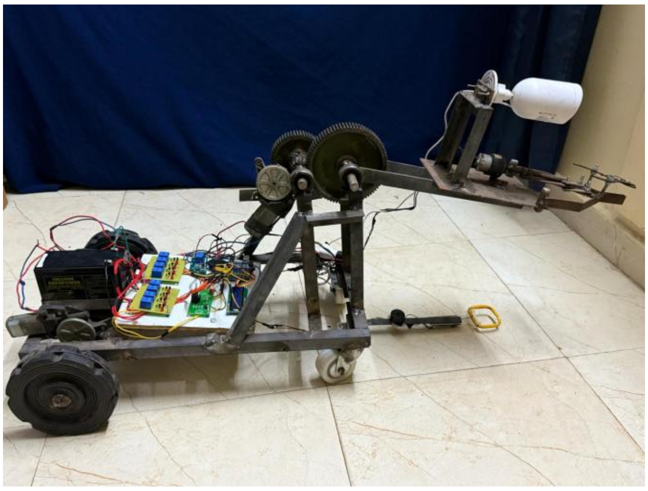

Figure 3: Result of the mechanical framework of the robot

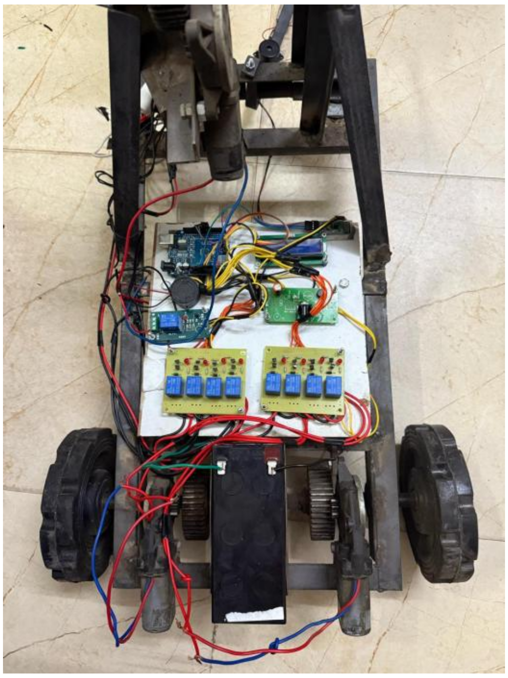

Figure 4: Result of the electrical connections

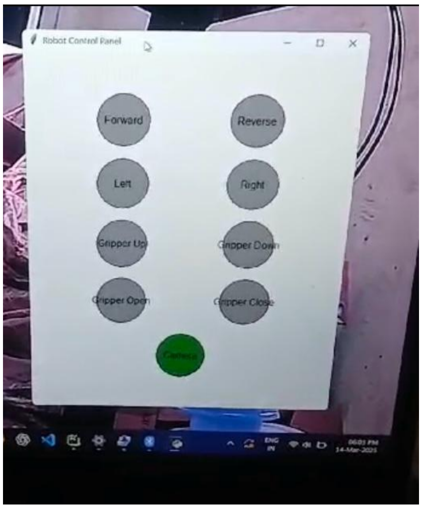

Figure 5: Robot Control Panel

Advantages

The proposed system offers several key advantages. It improves safety by allowing bomb detection and hazardous area monitoring without putting people in danger. The robot operates remotely, keeping operators safe from potential threats. It also provides real-time video and sensor data, helping operators make quick decisions. The robot accurately detects metallic objects and harmful gases, with minimal false alarms, ensuring reliable results. It can move through different terrains, including rough and dangerous areas, making it versatile in various environments.

Additionally, the system is cost-effective compared to traditional bomb detection methods, offering a more affordable solution without sacrificing performance. The robot's battery lasts well, and improvements could be made to increase its duration. Its mobility works well on flat and slightly rough surfaces, and future upgrades could improve movement on difficult terrains. Adding night vision or infrared cameras would also help in low-light or foggy conditions. Lastly, the robot is easy to control, providing real-time feedback for smoother operations and better performance.

12. Conclusion

This project focuses on creating a robot that can be remotely controlled via a computer to perform tasks such as bomb detection and gas monitoring, keeping humans safe in hazardous environments. The robot is equipped with a camera and various sensors to identify threats like explosives and toxic gases, reducing the need for human presence in dangerous areas.

The robot is wirelessly operated through a PC, and its camera sends live video back to the operator, providing a clear view of the surroundings. This enables the operator to assess the situation from a safe distance. The robot's metal detector is used to detect metallic objects, potentially bombs, sending alerts to the operator when a threat is found. An alarm system also activates to warn nearby individuals, allowing for timely responses to neutralize the bomb.

In addition to bomb detection, the robot is equipped with gas sensors (MQ8 and MQ135) that can detect hazardous gases in the environment. Upon detection, the robot immediately alerts the operator, ensuring that steps can be taken to protect people from potential harm. The robot also features human detection capabilities, warning the operator if anyone is present in a dangerous area.

The robot is powered by an Arduino Uno, which controls its functions, collects sensor data, and communicates with the operator. It also uses an ESP32 module for wireless communication, transmitting real-time video and data. Key components include a 4-channel relay for controlling functions, a voltage regulator for stable power supply, and an LCD display for user information.

In essence, this project is a significant advancement in safety and security, providing a way to detect bombs, monitor gas levels, and ensure human safety without direct human involvement in high-risk situations. Its applications are broad, ranging from military operations to disaster response, offering a safer and more efficient way to handle dangerous scenarios.

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