
REAL-TIME VIDEO STREAMING AND ROBOTIC BOMB DISPOSAL SYSTEM

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ABSTRACT

This project showcases a robot that can autonomously identify and disarm hazardous devices; it also has the capability to feed live footage. The ESP32-CAM module, a metal sensor, a motor driver, DC motors, a buzzer, and an Arduino microcontroller are all necessary parts of the robot that improve remote monitoring and surveillance. For accurate threat evaluation and command and control, the system allows for real-time visual input to a distant operator. The robot uses its sensors to survey its surroundings and provide a hand in the disposal operation if it detects what seems to be an explosive device. By using real-time video surveillance and automation, this smart and affordable solution enhances the efficiency and safety of bomb disposal operations while decreasing the likelihood of human exposure to dangerous scenarios.

Keywords: Bomb Disposal Robot, Live Video Streaming, Autonomous Threat Detection.

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I. INTRODUCTION

The increasing incidence of terrorist activities and the proliferation of explosive threats have necessitated the development of advanced technologies to ensure public safety and minimize risks to human life. Conventional bomb disposal techniques require trained personnel to physically approach and neutralize explosive devices, exposing them to severe danger and potential fatalities. To address these risks, robotic systems have increasingly been adopted as safer and more reliable alternatives for bomb detection and disposal operations, allowing hazardous tasks to be performed remotely with minimal human intervention [2], [5]. Such systems significantly reduce operator exposure while improving operational efficiency in hostile and unpredictable environments. Modern bomb disposal robots are typically equipped with real-time video transmission and teleoperation capabilities to enhance situational awareness and decision-making during critical missions. Robust low-latency video streaming techniques and adaptive bitrate transmission methods are essential to ensure uninterrupted visual

feedback under varying wireless conditions [1], [4], [10]. Live video feeds enable remote operators to visually inspect suspicious objects, navigate complex environments, and execute precise actions without direct physical engagement [3]. The integration of vision-based perception and remote monitoring has been shown to substantially improve the effectiveness of explosive ordnance disposal (EOD) operations [5], [8].

This project focuses on the design and development of a bomb disposal robot with live video streaming capabilities to enhance operational safety and situational awareness. At the core of the system is an Arduino microcontroller that integrates essential components such as a metal detection sensor, motor driver, DC motors, buzzer, and an ESP32-CAM module. Similar modular and sensor-driven robotic architectures have been successfully employed in EOD systems to support navigation, perception, and teleoperation in hazardous environments [5], [9]. The robot is capable of traversing potentially dangerous locations while transmitting real-time video footage to a remote operator over a wireless network, enabling continuous monitoring and

informed decision-making [1], [7].

The inclusion of a metal detection sensor allows the robot to identify metallic objects that may indicate the presence of explosive devices. Upon detection, the robot can be remotely guided to cautiously approach the target while issuing audible alerts through a buzzer to signal potential threats. Alert-based mechanisms and sensor fusion are widely used in bomb disposal robots to improve threat recognition and operator response time [6], [8]. Additionally, a relay-controlled DC pump may be employed to simulate or perform a basic neutralization process. Meanwhile, the ESP32-CAM module provides uninterrupted visual feedback via Wi-Fi-based live video streaming, supporting real-time assessment, remote manipulation, and secure robotic operation in hazardous scenarios [3], [7].

II. LITERATURE SURVEY

1. Autonomous Mobile Robot for Explosive Detection, R. Vignesh, A. Mohammed, 2018.

This study introduces an autonomous mobile robot equipped with ultrasonic and metal detection sensors for identifying suspicious metallic objects in hazardous environments. The robot is capable of independent navigation, reducing the need for direct human involvement in threat-prone zones. Such autonomous navigation and sensor-based decision-making are critical for real-time bomb disposal and hazardous-area robotics [2], [9]. By eliminating human proximity during detection tasks, the system significantly reduces risk to life, aligning with modern EOD robotic design principles [5]. This work establishes a strong foundation for integrating autonomous mobility with advanced communication, IoT connectivity, and real-time camera streaming technologies used in contemporary robotic systems [1], [7].

2. Design and Fabrication of Bomb Disposal Robot Using RF Technology, P. Dhanasekaran, R. Ramesh, 2019.

This paper focuses on the remote operation of a bomb disposal robot using RF-based communication modules and presents a detailed mechanical design of a robotic arm for handling or

defusing explosives. Long-range RF control enables operators to manage hazardous tasks from a safe distance, demonstrating the effectiveness of teleoperation in dangerous environments [2], [5]. Although the system emphasizes mechanical precision and operator-controlled actions rather than full autonomy, it highlights the importance of reliable communication links and robust hardware design in EOD robots [6]. The study provides a basis for transitioning from RF-based systems to Wi-Fi- and IoT-enabled platforms that support higher data rates, live video streaming, and improved responsiveness [1], [10].

3. Explosive Detection and Diffusion Robot with Live Streaming, Aman Verma, Nishant Patil, 2020.

This study proposes a bomb disposal robot incorporating an ESP32-CAM module for real-time video streaming along with metal detection sensors for explosive identification. The ability to transmit live video over Wi-Fi significantly enhances situational awareness and remote decision-making, which are essential for mission-critical robotic operations [1], [3], [4]. Additionally, the inclusion of a basic actuator-driven diffusion mechanism demonstrates the feasibility of integrating multiple functional components into a compact robotic platform [5]. This work illustrates how smart surveillance and bomb detection can be combined into a dual-purpose robotic system for security and emergency response applications [7], [8].

4. ESP32-CAM Based Wireless Surveillance Robot for Security Applications, S. Lakshmi, N. Raghav, 2021.

This paper discusses the deployment of ESP32-CAM modules in mobile robotic platforms for live wireless surveillance in inaccessible or high-risk areas. The system enables remote navigation and real-time video feedback, making it highly suitable for operations where human presence is unsafe [3], [7]. The study provides practical insights into Wi-Fi-based video streaming and mobile robot control, supporting the growing adoption of low-cost embedded vision systems in robotics [4]. Such real-

time visual monitoring capabilities are particularly valuable in bomb disposal scenarios, where operator decisions rely heavily on continuous and reliable visual information [1], [10].

5. Development of IoT-Based Bomb Detection Robot, A. Jain, K. Sundar, 2021.

This conference paper explores an IoT-enabled bomb detection robot designed to collect and transmit sensor data related to environmental conditions and potential explosive threats. By using platforms such as NodeMCU or ESP32, the system enables real-time data communication over the internet, improving scalability and remote accessibility [7], [10]. The proposed architecture supports monitoring and control through web or mobile interfaces, aligning with modern trends in cloud-connected and mission-critical robotic systems [3]. This work reinforces the potential of IoT-based autonomous and semi-autonomous robots for future emergency response, surveillance, and explosive threat mitigation applications [2], [9].

III. EXISTING SYSTEM

The existing bomb disposal systems largely depend on human-operated Explosive Ordnance Disposal (EOD) teams, who are often required to physically approach and inspect suspicious objects, thereby exposing themselves to substantial risk. Although robotic solutions have been introduced to reduce human involvement, many of these systems still rely heavily on manual teleoperation, offering limited autonomy and requiring operators to remain relatively close to hazardous zones [2], [5], [9]. Furthermore, several deployed robotic platforms suffer from constrained mobility in uneven or cluttered environments and lack robust navigation intelligence, which reduces their effectiveness in complex real-world scenarios [8], [9].

Another major limitation of existing bomb disposal robots is the inadequacy of real-time visual feedback. Many systems experience low-quality or delayed video transmission due to bandwidth constraints, inefficient communication protocols, or the absence of adaptive streaming mechanisms, which significantly affects situational awareness and

operational decision-making [1], [4], [10]. The lack of high-resolution, low-latency live video streaming can lead to misinterpretation of threats and delayed responses during critical missions [3]. Additionally, existing systems often lack advanced sensor integration for accurate obstacle detection and environmental perception, further limiting their operational reliability [5], [8].

Moreover, most commercially available bomb disposal robots are bulky, complex, and expensive, making them impractical for widespread deployment by local law enforcement or emergency response units. The high cost and limited scalability of these platforms restrict their adoption, particularly in resource-constrained environments [2], [10]. As a result, despite ongoing advancements, current bomb disposal systems still face challenges in terms of affordability, autonomy, real-time adaptability, and effective perception, highlighting the need for more compact, cost-effective, and intelligent robotic solutions [1], [7], [9].

IV. PROPOSED SYSTEM

The proposed system introduces an advanced bomb disposal robot equipped with live video streaming to enable safe, remote inspection and neutralization of explosive threats. The robot integrates an HD camera module for real-time video transmission over Wi-Fi or cellular networks, allowing operators to clearly observe the environment from a safe distance. Equipped with sensors for obstacle detection, a robust mobility platform, and a precision-controlled robotic arm, the system enhances navigation and manipulation in complex terrains. The robot can be remotely operated through a secure dashboard or controller, ensuring zero human exposure to danger during critical operations. By combining high-quality streaming, improved mobility, sensor-assisted navigation, and affordable components, the proposed system significantly enhances safety, accuracy, and operational efficiency in bomb disposal missions.

V. SYSTEM ARCHITECTURE

1. Sensor & Detection Modules (Edge Devices)

Each robotic unit is fitted with a multimodal sensing suite that provides situational awareness and threat characterization at the edge. Typical sensors include an HD RGB camera with low-light/NIR capability and a PTZ mount for framing; a thermal/IR camera for heat-signature detection; a wide-angle secondary camera for situational context; LIDAR or stereo depth sensors for obstacle mapping and short-range 3D reconstruction; ultrasonic / IR proximity sensors for close-in collision avoidance; IMU (accelerometer + gyro + magnetometer) for robust pose estimation; microphone array for audio capture and direction-of-arrival cues; gas/VOC sensors for suspicious chemical detection (optional, certified sensors only); and force/torque sensing plus tactile sensors on the manipulator wrist for safe manipulation. Local analog/electrical sensing (battery voltage/current, motor encoders, gripper current) completes the edge telemetry. A dedicated embedded controller handles low-latency sampling, local prefiltering, event detection (e.g., “target visual lock”, “arm contact detected”, “loss of comms”), and produces condensed telemetry (pose, threat-confidence, health status, video metadata) for the autonomy and comms layers.

2. Edge Processing & Local Autonomy Module

Onboard compute (see Fig. 5.1) processes sensor streams in real time so the operator is empowered with responsive assistance and the robot can operate safely under intermittent links. Functions include: video encoding and low-latency streaming (H.264/H.265 with hardware accel), vision pipelines for object/UX detection (person, package, wire-like shapes) and visual fiducial tracking, SLAM/occupancy-grid mapping for navigation, IMU+odometry sensor fusion, and closed-loop manipulator control with force feedback. Local autonomy modes provide layered behaviours: teleoperation assist (dead-man + stabilization), semi-autonomous approach & hold, waypoint navigation, and automated safe retreat on fault. The module runs health checks, enforces safety limits

(joint torque, motor temps), and exposes compact state summaries and annotated video frames to the communication layer to minimise bandwidth while preserving actionable detail.

3. Power Conditioning, Energy Storage & Actuation Management Layer

A hybrid power system supplies the mobility base, manipulator actuators, sensors, and comms stack. High-current battery packs (Li-ion / LiFePO4 with BMS) feed a DC bus with power distribution and protection (fuses, current limiting, thermal monitoring). Power conditioning includes isolated DC-DC converters for low-noise rails (3.3V/5V/12V), a backup UPS/supercapacitor for graceful shutdown during main-battery swap, and motor drivers (MOSFET/H-bridge or brushless ESCs) with regenerative braking support where applicable. Actuator management enforces safe motion profiles (soft-start, current/torque limits), coordinates manipulator end-effector power (vacuum, pneumatic, or electric grippers), and supports energy-aware mission policies (hold position vs. fold arm to conserve energy). The power layer also surfaces precise runtime estimates and warnings to the operator UI.

4. Communication & User Interface Layer

Designed for low-latency, resilient remote operations, the robot supports multiple radios and link fallbacks: primary high-bandwidth link (5 GHz Wi-Fi or proprietary mesh), secondary LTE/5G modem for wide-area coverage, and a low-rate telemetry channel (BLE or sub-GHz) for proximity handshakes. Communications are secured with mutual authentication and end-to-end encryption. Video streams use adaptive bitrate with prioritized keyframes and selectable ROI (region of interest) feeds to optimize latency vs. quality. The operator UI (desktop/tablet) presents synchronized multi-camera views, live annotated maps (SLAM overlay), health dashboards, and direct manipulator controls (joystick + trajectory presets + teach/playback). Local UX on the robot includes status LEDs, an OLED for state readout, and tactile alarms. Logging, evidence capture (time-stamped

video + metadata), and a secured “kill/stop” channel are included for safety and chain-of-custody.

5. Mechanical Interface & Mobility

The mechanical design is modular and mission-tunable: a tracked or articulated wheeled base for mixed terrain, low-center-of-gravity chassis for stability, and shock-damped suspension for rough environments. The manipulator is a multi-DOF arm with wrist pitch/yaw and a dexterous end-effector (multi-mode gripper and optional cutter/neutralization tool mount). Mechanical interfaces include quick-change tool plates, modular winch/tether attachment points, and physical armor/impact shields. Environmental sealing (IP-rated enclosures), thermal paths for heat dissipation, and EMI-conscious routing for high-voltage lines protect electronics. Mechanical amplification, dampers, and limit stops protect the arm during incidental impacts and ensure predictable, repeatable manipulation.

6. Cloud / Remote Monitoring & Analytics Backend (Optional for Fleet/Deployment Use)

For organizations operating fleets or maintaining an incidents archive, an optional backend aggregates per-robot telemetry, incident logs, and anonymized video metadata. Dashboards show utilization, time-to-intervention, and health metrics; analytics can cluster incident types, predict maintenance windows, and surface operator training needs. Secure OTA firmware and model updates (signed, versioned) allow incremental improvements to vision models and control logic. All remote communications adhere to strict access controls, audit logging, and evidence-preservation policies to ensure legal/regulatory compliance.

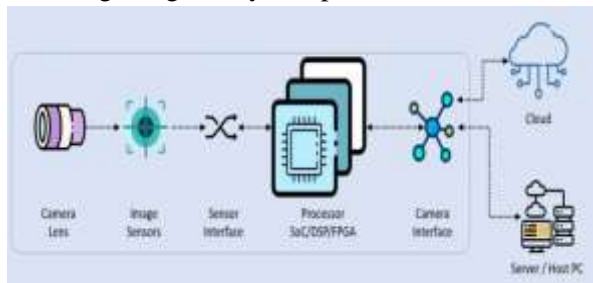


Fig. 5.1 — Compute & Control Module (Central

Decision Unit)

The compute backbone combines a high-performance SBC (e.g., NVIDIA Jetson / Intel NUC class) for perception and video with a real-time microcontroller (e.g., Cortex-M / STM32) for deterministic low-level control.

Key components and interfaces:

Sensor Interfaces (I²C / SPI / UART / ADC / GPIO)

Connect cameras, LIDAR/stereo units, IMU, force/torque sensors, gas sensors, encoders, and analog battery/voltage monitors. Provide timestamped, buffered input for fusion and low-latency control loops.

Power & Motor Control Interface (PWM / ESC / CAN / Current Sense)

Drives DC/BLDC motors, actuators and reads back encoder/tachometer and current for torque-limited control and safety enforcement.

Video Pipeline & Encoder (Hardware-accelerated H.264/H.265)

Handles multi-stream capture, ROI cropping, overlay of annotations, and adaptive streaming to the operator console.

Robot Motion Controller (Real-time MCU Task Loop)

Runs inverse kinematics, joint trajectory control, safety interlocks (soft stops, torque limits), and emergency stop monitoring.

Communications (Wi-Fi / LTE / Mesh / BLE)

Manages transport layers, link selection/failover, and encrypted tunnels for command-and-control and telemetry.

Power Management & BMS Interface

Reads precise battery health metrics (SoC, SoH, cell balancing), supervises UPS switchover and power-fail sequencing.

I/O & UX (Display, LEDs, Buttons, Haptics)

For local interaction, mode changes, and immediate operator feedback.

Storage & Evidence Capture (SSD with Secure Partitioning)

Stores high-resolution logs and signed video for post-incident review and chain-of-custody.

Mechanical Control Outputs (Drivers for Solenoids / Release Mechanisms)

For tool actuation, tether release, or mechanical neutralization modules; includes watchdogs and hardware interlocks.

EMC / Shielding & Antenna Placement

Physical layout and RF isolation to prevent interference between high-current motor lines and sensitive RF/sensor electronics.

VI. IMPLEMENTATION

The robot was successfully assembled with Arduino, ESP32-CAM, metal sensor, DC motors, and motor driver for complete functionality.



Fig. 6.1:Bomb Disposal Robot Prototype Chassis

The ESP32-CAM provided clear real-time video streaming over Wi-Fi, enabling remote threat assessment by the operator.



Fig. 6.2:OV2640 Camera Web Control Panel

The ESP32 CAM provided smooth and stable live video feed to the control device via Wi-Fi, enabling real-time visual monitoring.

VII. CONCLUSION

The development of the "Bomb Disposal Robot and Live Video Streaming" project successfully

demonstrates how robotics, embedded systems, and real-time communication technologies can be integrated to enhance public safety and reduce human risk in hazardous situations. The robot, powered by Arduino and equipped with essential components such as a metal detector, motor driver, and ESP32-CAM for video transmission, effectively performs tasks such as detecting metallic objects that may pose a threat, navigating through potentially dangerous environments, and providing real-time visual feedback to a remote operator. Through this project, a low-cost, practical solution has been developed for scenarios involving bomb threats and suspicious objects. The use of wireless video streaming ensures that users can assess the situation visually before taking any action, while the autonomous movement and sensor-based detection minimize human intervention in danger zones. This project not only meets its objective of creating a functional bomb disposal unit but also highlights the potential of IoT and robotics to revolutionize defense and surveillance systems.

VIII. FUTURE SCOPE

Future improvements to the bomb disposal robot can significantly enhance autonomy, reliability, and operational reach. Advanced AI-based vision models may allow the robot to automatically identify explosive components, suspicious wiring patterns, or hazardous chemical residues with higher accuracy. Integration of full autonomous navigation—powered by improved SLAM, 3D mapping, and terrain classification—can enable the robot to traverse complex environments without constant operator input. Future designs can incorporate more dexterous robotic arms with multi-fingered end-effectors, enabling finer manipulation of sensitive objects. The communication system can be expanded through 5G/6G networks, satellite links, and multi-link redundancy to support ultra-low-latency streaming even in remote or signal-challenged areas. Adding sensor fusion using thermal imaging, hyperspectral cameras, or X-ray modules could offer enhanced threat analysis before physical interaction. Swarm-based operation is



another future direction, where multiple robots coordinate to map large areas, relay communication, or support multi-angle inspection. Improvements in battery energy density, wireless charging pads, and modular hot-swappable power systems can extend mission duration. Finally, integration with cloud-based analytics, predictive maintenance, and real-time operator training simulations can evolve the robot into a highly adaptive, fully networked security solution for defense, policing, and disaster-response environments.

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