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TELEOPERATED BOMB DISARMING ROBOTIC ARM

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ABSTRACT

The increasing threat of explosive devices in public and sensitive environments has created a strong need for safer disposal techniques that minimize human involvement. This work presents the design and implementation of a teleoperated bomb disarming robotic arm, developed to perform hazardous tasks remotely while providing real-time visual feedback. The system is built around a Wi-Fi-enabled ESP32 microcontroller, integrated with a four-degree-of-freedom robotic arm and a mobile rover platform. Control is achieved through a web-based interface, allowing intuitive operation from a safe distance. Servo motors driven by a PWM controller enable precise manipulation of objects, while an ESP32-CAM module delivers live video streaming to the operator. Experimental results demonstrate reliable remote operation, reduced human exposure to danger, and effective handling of hazardous objects.

1. INTRODUCTION

Handling explosive materials and hazardous objects remains one of the most dangerous operations in both civilian and defense sectors. Traditionally, trained personnel are required to approach suspicious objects, exposing them to unpredictable risks despite strict safety measures.

To overcome these challenges, robotic systems have emerged as a safer alternative. These systems allow operators to control machines remotely, enabling inspection and handling of dangerous materials without direct human involvement. Teleoperated robots equipped with mobility, manipulation, and vision capabilities have proven particularly effective in such scenarios [1].

Advancements in real-time video transmission have further enhanced the usability of these systems by improving operator awareness and control accuracy [2]. Additionally, the integration of internet-based communication has enabled control through web applications, making such systems more accessible and user-friendly [3].

Recent developments have also introduced image processing and sensor-based detection techniques to improve object identification and handling [4]. Earlier robotic platforms, such as the wheelbarrow-type systems, demonstrated the practical benefits of remote-controlled operations in reducing human casualties [5].

The foundation of such robotic systems lies in established principles of robot modeling and control, supported by advancements in embedded systems and actuator technologies [6], [7]. Modern microcontrollers like ESP32 have significantly reduced system complexity by integrating wireless communication capabilities, making low-cost implementations feasible [8].

Despite these advancements, many existing bomb disposal robots are either expensive or overly complex, limiting their widespread adoption. This work aims to address these limitations by developing a simple, cost-effective, and efficient teleoperated robotic system that integrates mobility, manipulation, and real-time monitoring into a single platform.

2. METHODOLOGY / SYSTEM DESIGN

The proposed system is designed to safely manipulate hazardous objects through remote operation. It integrates hardware components, wireless communication, and control algorithms into a unified framework. The methodology is structured into system setup, communication, control, and execution stages.

2.1 SYSTEM OVERVIEW

The system operates on teleoperation principles, combining wireless communication, live video feedback, and robotic manipulation. It consists of three primary subsystems:

1. User Control Interface (Operator Side)
2. Robot Control Unit (ESP32 Based Rover System)
3. Visual Feedback System (ESP32-CAM Streaming Unit)

All these components work together to allow safe and efficient remote operation of the robot as in below Figure 1.

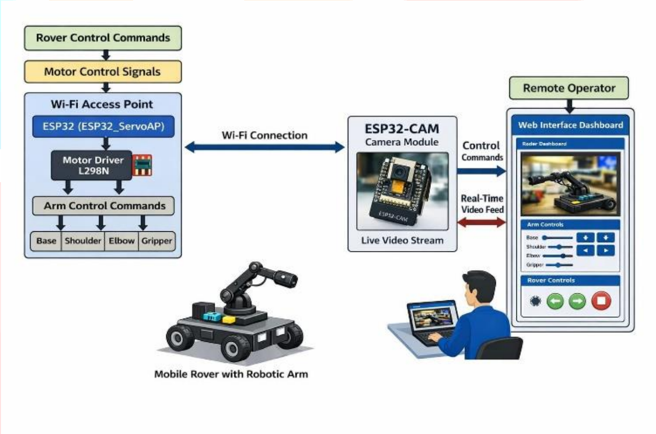

Figure 1: Teleoperated Bomb Disarming Robotic Arm System Overview

2.2 SYSTEM INTIALIZATION

Upon powering the system, the ESP32 initializes all connected modules, including motor drivers and communication interfaces. It creates a Wi-Fi access point, allowing users to connect through a smartphone or computer. Once connected, the operator accesses a web-based control dashboard to interact with the robot.

2.3 COMMUNICATION MECHANISM

Communication between the user and robot is established via Wi-Fi. The ESP32 hosts a web server that processes control commands sent as HTTP requests. These commands are executed with minimal delay, ensuring responsive system behavior. These includes:

2.4 ARM CONTROL PANEL

The robotic arm provides four degrees of freedom, enabling flexible object manipulation. Each joint is actuated using servo motors controlled via a PWM driver. A gradual motion control technique is implemented to ensure smooth transitions, minimizing mechanical stress and improving precision.

The robotic arm is controlled through sliders and switches that manage:

- Base rotation slider
- Shoulder slider
- Elbow slider
- Gripper toggle switch

These controls allow the operator to precisely position the robotic arm.

2.5 ROVER CONTROL PANEL

The rover employs a differential drive mechanism powered by DC gear motors. A motor driver module interprets control signals from the ESP32, allowing directional movement and navigation toward target objects.

The rover movement is controlled through directional inputs enabling:

Button	Function
↑	Move forward
↓	Move backward
←	Turn left
→	Turn right
■	Stop

When the operator presses any button or moves a slider, the browser sends an HTTP request to the ESP32 server and performs operation.

2.6 VISUAL FEEDBACK SYSTEM

An onboard camera continuously streams live video to the user interface. This real-time feedback enhances situational awareness and allows precise control of the robotic arm during operations.

2.7 OPERATIONAL WORK FLOW

The complete operation process occurs as follows:

1. The robot is powered on.
2. ESP32 creates a Wi-Fi network.
3. The operator connects to the network.
4. The operator opens the control dashboard.
5. Live video from ESP32-CAM appears on the screen.
6. The operator sends movement commands.
7. ESP32 processes commands.
8. Motors and servos execute the commands.
9. The robotic arm manipulates the target object

3. RESULTS

As shown in Figure 2, the developed system was successfully implemented and evaluated for remote operation tasks. The robot demonstrated smooth mobility in all directions with minimal latency. The robotic arm effectively performed object manipulation tasks with good accuracy, aided by smooth motion control.

The web-based interface proved to be user-friendly, allowing intuitive control even for non-technical users as shown in Figure 3, live video streaming enabled effective monitoring and guidance during operations.

Overall, the system showed reliable performance, low cost, and ease of use, making it suitable for hazardous applications such as bomb disposal, surveillance, and inspection.

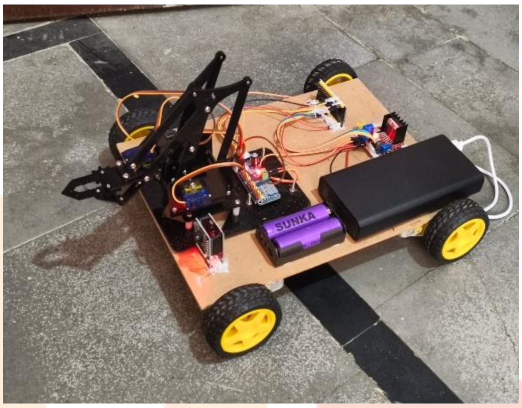

Figure 2: Developed teleoperated robotic arm prototype mounted on a mobile rover platform

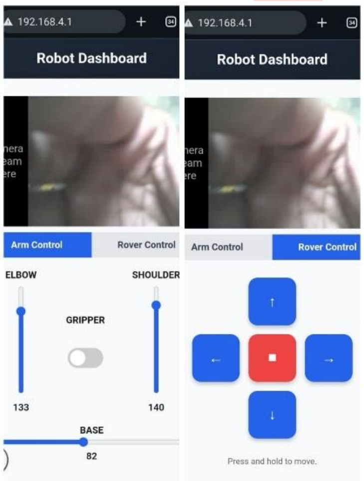

Figure 3: Web-based robot control dashboard showing arm control and rover navigation interface

4. DISCUSSION

The results confirm that a low-cost embedded platform can effectively support teleoperated robotic applications. The integration of mobility and manipulation capabilities enables the system to perform essential handling tasks in dangerous environments.

Compared to existing systems [1]-[4], the proposed design offers similar functionalities at a significantly reduced cost and complexity. While advanced systems incorporate AI and autonomous features, they require higher investment and design effort.

The inclusion of real-time video improves operational efficiency, although minor latency is observed. Limitations include restricted load capacity and terrain adaptability. Future enhancements may include autonomous navigation, obstacle detection, improved communication range, and structural improvements.

5. CONCLUSION

This work presents a teleoperated robotic system designed for safe handling of hazardous materials. The system integrates a mobile rover, a multi-degree-of-freedom robotic arm, and a web-based control interface powered by an ESP32 microcontroller.

Experimental validation demonstrates reliable remote operation, effective object handling, and real-time monitoring. Although limitations exist, the system provides a strong foundation for future improvements.

The proposed design highlights the potential of low-cost embedded systems in developing practical robotic solutions for hazardous environments.

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7. REFERENCES

[1] J. V. Carrillo, M. A. Garcia, and R. Torres, “Teleoperated Robot for Explosive Ordnance Disposal,” *International Journal of Robotics Research*, vol. 12, no. 3, pp. 45–52, 2024.

[2] R. Kumar, S. Verma, and A. Singh, “Real-Time Video Streaming Based Bomb Disposal Robot,” *International Journal of Engineering Research and Technology (IJERT)*, vol. 10, no. 6, pp. 234–238, 2023.

[3] S. Patel, K. Shah, and M. Desai, “IoT Based Bomb Disposal Robot Using Wireless Communication,” *International Journal of Advanced Research in Electronics and Communication Engineering*, vol. 9, no. 4, pp. 112–117, 2021.

[4] P. Kumar and V. Reddy, “Advanced Military Spying and Bomb Disposal Robot,” *International Journal of Scientific Research in Engineering and Management*, vol. 8, no. 2, pp. 89–95, 2024.

[5] M. W. Spong, S. Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*. Hoboken, NJ, USA: Wiley, 2006.

[6] B. Siciliano and O. Khatib, *Springer Handbook of Robotics*, 2nd ed. Cham, Switzerland: Springer, 2016.

[7] Espressif Systems, “ESP32 Technical Reference Manual,” 2023. [Online]. Available: https://www.espressif.com

[8] STMicroelectronics, “L298N Dual H-Bridge Motor Driver Datasheet,” 2022. [Online]. Available: https://www.st.com.