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Camera-Assisted Wi-Fi Robotic Arm

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Abstract: *Remote robotic manipulation has gained significant importance in industrial automation, surveillance, and hazardous environment operations. This paper presents the design and implementation of a camera-assisted Wi-Fi controlled mobile robotic arm capable of performing remote navigation and object manipulation. The proposed system integrates a three-degree-of-freedom robotic arm with a mobile robotic platform to perform pick-and-place tasks under wireless control. An ESP32 microcontroller functions as the central processing unit, handling wireless communication and motor control through L293D motor driver circuits. The robot is operated using the Blynk IoT mobile application, allowing users to control the robot's movement and arm articulation remotely through a Wi-Fi network. Real-time visual feedback is provided by an ESP32-CAM module, which streams live video to the user interface, enabling accurate navigation and object handling. A relay module is used for gripper actuation, while limit switches are incorporated to ensure safe mechanical operation. Experimental evaluation of the developed prototype demonstrates stable wireless communication, reliable video streaming, and smooth robotic manipulation. The proposed system offers a low-cost, modular, and scalable robotic platform suitable for remote surveillance, industrial handling, and educational robotics applications. The integration of wireless control, visual monitoring, and robotic manipulation provides a practical framework for future development of semi-autonomous and intelligent robotic systems*

Keywords: Wi-Fi Controlled Robot, ESP32 Microcontroller, ESP32-CAM, Robotic Arm, Blynk IoT Platform, Pick-and-Place System, Remote Monitoring

I. INTRODUCTION

Robotics has become a key technology in modern automation systems, enabling machines to perform complex operations with high accuracy and efficiency. In industrial environments, robotic manipulators are widely used for tasks such as material handling, assembly operations, and automated inspection processes. These systems significantly improve productivity and reduce the need for manual labor in repetitive or hazardous tasks [1]. In many real-world situations, direct human involvement in operational environments may be unsafe or impractical. Examples include disaster response areas, radioactive zones, and remote surveillance locations. In such cases, remotely operated robotic systems provide an effective alternative by allowing operators to control robots from a safe distance while performing necessary tasks [2]. Advances in wireless communication technologies have further enhanced the capabilities of remote robotic platforms.

The rapid development of the Internet of Things (IoT) has enabled robots to be controlled through internet-based communication networks. Microcontrollers such as the ESP32 provide built-in Wi-Fi connectivity, allowing robotic systems to receive commands from smartphone or web applications without requiring complex networking infrastructure [3]. This approach simplifies system design while providing flexible and user-friendly control mechanisms. Several researchers have implemented Wi-Fi based robotic platforms that enable remote navigation and manipulation using mobile applications. Another essential feature of modern tele-operated robots is visual feedback. When a robot is operating remotely, the operator requires real-time visual information to guide navigation and perform manipulation tasks accurately. Camera modules integrated with embedded processors can transmit live video streams to a control interface, allowing users to observe the robot's environment and control its movements effectively [4].

In this work, a camera-assisted Wi-Fi controlled mobile robotic arm is developed to combine wireless communication, robotic manipulation, and real-time visual monitoring within a single robotic platform. The system employs an ESP32 microcontroller as the central controller and an ESP32-CAM module for live video streaming. A three-degree-of-freedom robotic arm is mounted on a mobile platform driven by DC motors through L293D motor drivers, enabling both navigation and pick-and-place operations. The robot is controlled using the Blynk mobile application, providing a simple and effective wireless user interface. The developed system demonstrates a compact, low-cost, and modular robotic solution suitable for surveillance, remote handling, and educational robotics applications [5].

II. LITERATURE REVIEW

Recent research in wireless robotics has focused on integrating **IoT communication, embedded control systems, and camera-based monitoring** to enable remote robotic manipulation. Various studies have explored Wi-Fi controlled robotic arms and mobile robots to improve accessibility, flexibility, and safety in industrial and surveillance environments. Ahmed presented the design of an IoT-based robotic arm controlled using an ESP32 microcontroller and wireless communication, demonstrating the feasibility of remote robotic manipulation through internet connectivity. The study highlighted the advantages of integrating embedded controllers with wireless communication to simplify robotic system design and improve remote accessibility [1]. Cruz et al. developed a **Wi-Fi tele-operated robotic arm system** that allows users to control robotic movements remotely through a network interface. Their work demonstrated that wireless robotic control using microcontroller-based architectures can effectively support real-time manipulation tasks and remote monitoring applications [2]. Shalini and Kumar proposed a **camera-enabled IoT robotic platform** designed for remote monitoring and navigation. The system incorporated a wireless communication interface and camera module to provide real-time video feedback, allowing operators to control the robot more accurately during navigation and object manipulation tasks [3]. Lee and Park investigated the use of **ESP32-CAM modules for real-time video streaming** in embedded control systems. Their research demonstrated that low-cost camera modules integrated with microcontrollers can provide efficient video transmission for monitoring and remote control applications [4]. Sahu and Verma designed a **Wi-Fi based mobile surveillance robot** capable of remote navigation and environmental monitoring. Their system demonstrated reliable wireless communication and improved mobility for robotic platforms operating in remote or hazardous environments [5].

Although previous research has demonstrated the effectiveness of wireless robotic systems and camera-assisted monitoring, many existing designs focus either on robotic manipulation or mobile surveillance individually. The integration of **mobile robotic platforms, robotic arm manipulation, and real-time visual monitoring within a single compact system** remains an active area of research. The proposed camera-assisted Wi-Fi robotic arm addresses this gap by combining **wireless control, visual feedback, and pick-and-place manipulation capabilities** in a low-cost modular robotic platform.

III. SYSTEM ARCHITECTURE

The proposed camera-assisted Wi-Fi robotic arm system is designed as an integrated platform that combines wireless communication, robotic manipulation, and real-time visual monitoring. The system architecture consists of several interconnected modules including the ESP32 microcontroller, ESP32-CAM module, motor driver circuits, robotic arm mechanism, relay-controlled gripper, mobile drive system, and wireless control interface. These components work together to enable remote navigation and object manipulation through a Wi-Fi network. The ESP32 microcontroller acts as the central processing unit of the robotic system. It receives control commands from the Blynk mobile application through Wi-Fi communication and processes them to control the robot's movement and arm articulation. The ESP32 was selected due to its integrated Wi-Fi capability, sufficient processing power, and low cost, making it suitable for IoT-based robotic control applications [1], [3]. The mobility system of the robot is implemented using a differential drive configuration consisting of two DC motors connected to the wheels. These motors allow the robot to perform forward, backward, left, and right movements. The motors are controlled using an L293D motor driver

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integrated circuit, which acts as an interface between the microcontroller and the motors by providing the required current amplification and bidirectional motor control [2].

The robotic arm mounted on the mobile platform consists of three degrees of freedom (3-DOF) including the shoulder joint, elbow joint, and gripper mechanism. These joints allow the robotic arm to perform object lifting and pick-and-place operations. The gripper mechanism is actuated through a relay module, which enables the opening and closing of the gripper for object manipulation. To enhance remote operation capabilities, the system incorporates an ESP32-CAM module that provides real-time video streaming. The camera captures live images of the robot's environment and transmits them through the Wi-Fi network to the user interface. This visual feedback allows the operator to accurately guide the robot during navigation and manipulation tasks, which is essential for tele-operated robotic systems [4]. For safe mechanical operation, limit switches are installed at critical joints of the robotic arm. These switches prevent excessive movement of the arm and protect the mechanical structure from damage. When the arm reaches its mechanical limit, the limit switch interrupts the control signal to stop further motion.

The overall system is powered by a regulated power supply that ensures stable voltage for the microcontroller, motor drivers, camera module, and other electronic components. The integration of these hardware modules creates a compact and modular robotic architecture capable of performing remote navigation, visual monitoring, and object manipulation within a wireless network environment [5].

IV. BLOCK DIAGRAM

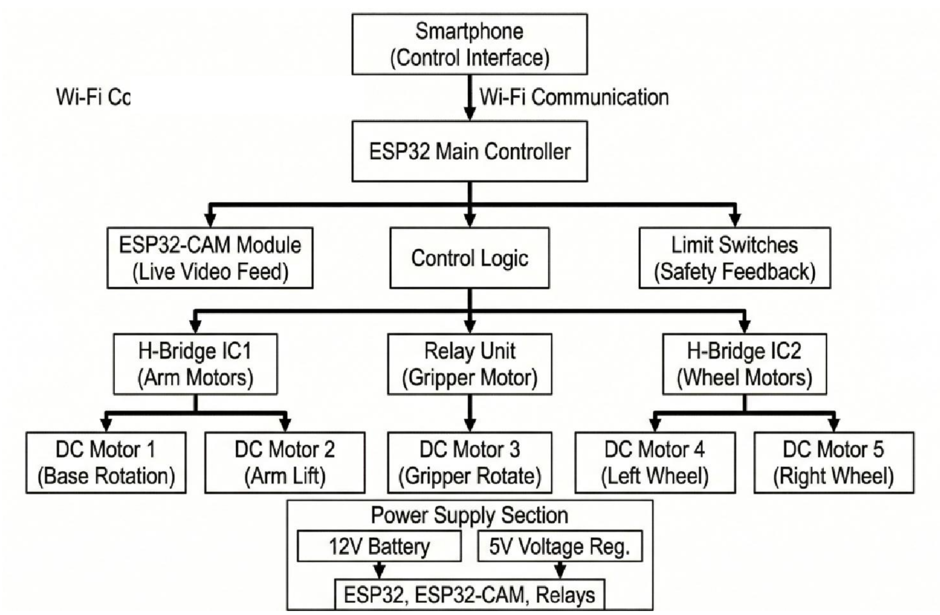

Fig. 1 Block Diagram of Camera Assisted Wi-Fi Robotic Arm

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V. CIRCUIT LAYOUT

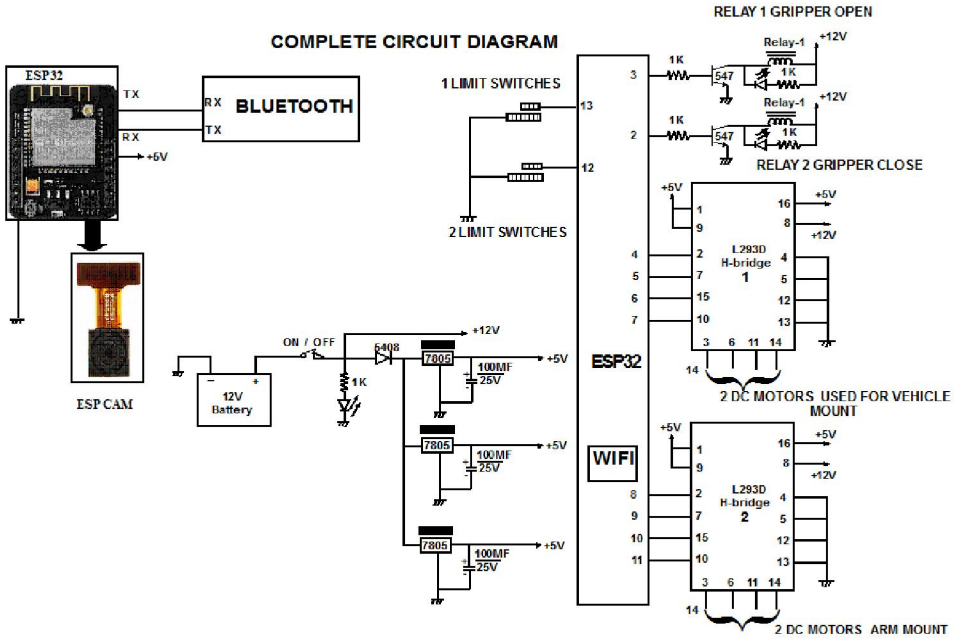
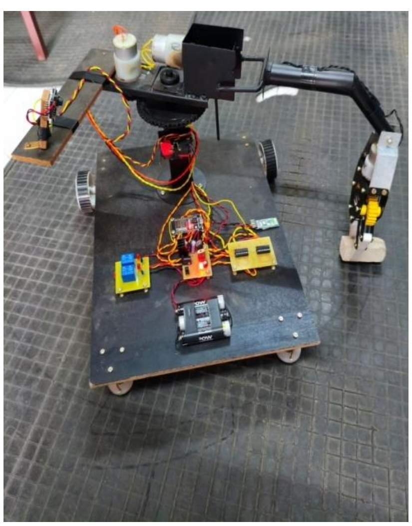
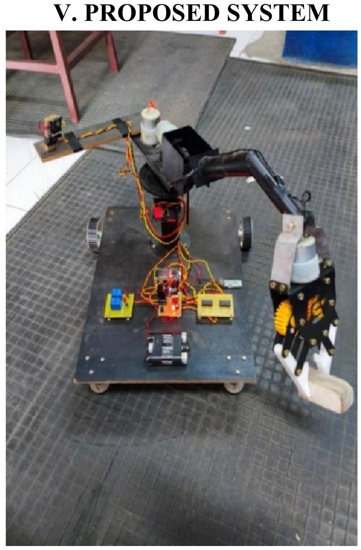


Fig. 2 Circuit Layout of Camera Assisted Wi-Fi Robotic Arm

V. PROPOSED SYSTEM





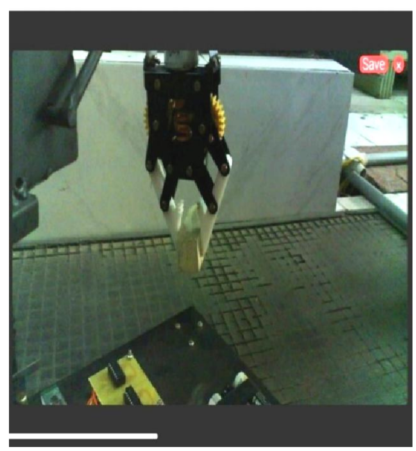


Fig 3: Prototype bending Arm to holding an Object
Fig 4: Prototype Rotating Arm while holding object
Fig 5: Camera Stream of Arm while lifting an Object

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Fig 6: Prototype bending Arm to holding an Object

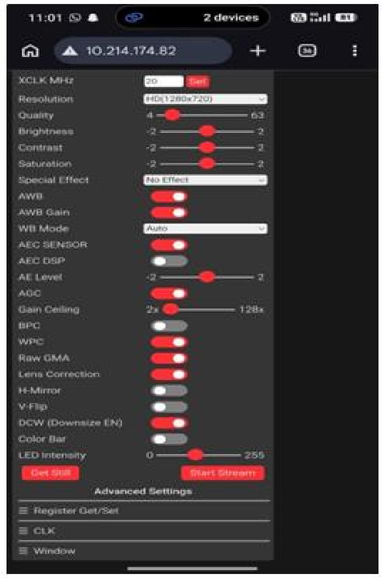

Fig 7: Prototype Rotating Arm while holding object

Fig 8: Camera Stream of Arm while lifting an Object

VI. RESULTS AND DISCUSSION

The developed prototype of the **camera-assisted Wi-Fi controlled robotic arm** was tested to evaluate its performance in terms of wireless control, robotic manipulation, and real-time visual monitoring. The system was operated through the **Blynk mobile application**, which allowed the user to send control commands to the ESP32 microcontroller through a Wi-Fi network. Experimental results demonstrated that the robot responded quickly to control inputs, enabling smooth movement of both the mobile platform and the robotic arm joints. During testing, the differential drive mobile platform successfully performed navigation tasks including forward motion, reverse motion, and directional turning. The **L293D motor driver** provided stable control of the DC motors, allowing the robot to move reliably within the operating range of the wireless network. The robotic arm mechanism was able to perform **pick-and-place operations**, where the arm joints rotated smoothly to lift and place objects using the relay-controlled gripper mechanism.

The integration of the **ESP32-CAM module** enabled continuous live video streaming from the robot to the user interface. This real-time visual feedback significantly improved the operator's ability to guide the robot during object manipulation and navigation tasks. The video feed allowed the user to observe the robot's surroundings and adjust movement accordingly, which is a key requirement for tele-operated robotic systems [3], [4].Limit switches integrated into the robotic arm mechanism ensured safe operation by preventing excessive rotation of joints. When the arm reached its mechanical limits, the limit switches successfully stopped further movement, protecting the structure from mechanical damage. Overall system testing confirmed reliable communication between the robot and the control interface within the Wi-Fi coverage area.

The experimental results demonstrate that the developed system effectively integrates **wireless communication, robotic manipulation, and real-time monitoring** into a compact robotic platform. The prototype successfully performed remote navigation and object handling tasks, validating the feasibility of using IoT-based embedded systems for tele-operated robotic applications [2], [5].

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VII. FUTURE SCOPE

Although the developed robotic system successfully demonstrates wireless control and remote manipulation capabilities, several improvements can further enhance its functionality and performance. Future work may focus on integrating **computer vision and artificial intelligence techniques** to enable automatic object detection and autonomous manipulation. By incorporating image processing algorithms, the robotic arm could identify objects and perform pick-and-place operations without requiring constant human control.

Another potential improvement is the addition of **obstacle detection sensors**, such as ultrasonic or LiDAR sensors, which would allow the robot to navigate safely in dynamic environments. This would enhance the robot's ability to operate in real-world scenarios such as warehouse automation, industrial inspection, and surveillance systems.

The system can also be upgraded by incorporating **motor encoders and closed-loop control algorithms**, such as PID control, to improve the precision and stability of robotic arm movements. This enhancement would allow the robot to perform more accurate manipulation tasks and handle delicate objects more effectively.

Furthermore, the robotic platform could be integrated with **cloud-based IoT platforms** to enable remote monitoring and control over the internet rather than being limited to local Wi-Fi networks. Such improvements would expand the system's applicability to large-scale industrial automation and remote robotics applications.

VIII. CONCLUSION

This paper presented the design and implementation of a **camera-assisted Wi-Fi controlled mobile robotic arm** capable of performing remote navigation and object manipulation tasks. The system integrates wireless communication, robotic manipulation, and live visual monitoring into a compact and efficient robotic platform. The **ESP32 microcontroller** successfully processes wireless commands received through the **Blynk mobile application**, enabling users to control the robot remotely through a Wi-Fi network.

The robotic arm mechanism, driven by **L293D motor drivers**, demonstrated smooth movement and reliable pick-and-place functionality. The **relay-controlled gripper mechanism** effectively handled objects, while the **ESP32-CAM module** provided continuous live video streaming to assist the operator during navigation and manipulation tasks. The inclusion of limit switches improved system safety by preventing excessive joint movement.

Experimental testing confirmed that the proposed system operates reliably within the Wi-Fi coverage area and can successfully perform coordinated mobility and object manipulation tasks. The developed prototype demonstrates that **a low-cost IoT-based robotic system** can effectively support remote handling and monitoring applications. The proposed design offers a practical solution for applications such as **industrial material handling, surveillance operations, hazardous environment exploration, and educational robotics laboratories** [1], [5].

REFERENCES

[1] A. Sharma, P. Singh, and R. Gupta, "Design and Development of IoT-Based Smart Robotic Arm for Remote Manipulation Using ESP32," International Journal of Advanced Robotic Systems, vol. 22, no. 1, pp. 1–10, Jan. 2025.

[2] M. K. Patel and S. R. Shah, "Wireless Tele-Operated Robotic Arm with Real-Time Monitoring Using IoT," IEEE Access, vol. 13, pp. 18540–18552, 2025.

[3] L. Chen, Y. Zhang, and H. Wang, "Low-Cost Camera-Assisted Mobile Robot for Remote Monitoring and Manipulation," Sensors, vol. 24, no. 3, pp. 1–15, 2024.

[4] R. Cruz, J. Fernandez, and M. Lopez, "Wi-Fi Based Tele-Operated Robotic Arm Using ESP32," International Journal of Advanced Robotic Systems, vol. 21, no. 4, pp. 1–9, 2024.

[5] S. Kumar and A. Verma, "IoT Enabled Mobile Robot with Live Video Streaming for Surveillance Applications," International Journal of Intelligent Robotics and Applications, vol. 8, no. 2, pp. 210–220, 2023.

[6] J. Lee and S. Park, "Real-Time Video Streaming Using ESP32-CAM for Smart Control Applications," IEEE Access, vol. 11, pp. 113220–113230, 2023.

[7] P. Shalini and A. Kumar, “Camera-Enabled IoT Robots for Remote Monitoring and Control,” International Journal of Engineering Research and Technology (IJERT), vol. 11, no. 9, pp. 1290–1295, 2022.
[8] R. Sahu and D. Verma, “Design of Wi-Fi Based Mobile Robot for Surveillance Applications,” International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 10, no. 5, pp. 2150–2155, 2022.
[9] T. Nguyen and K. Pham, “IoT-Based Tele-Operated Robotic Manipulator for Industrial Applications,” Journal of Robotics and Autonomous Systems, vol. 158, pp. 104–112, 2022.
[10] H. Al-Mansoori and M. Al-Harbi, “Development of a Wireless Controlled Robotic Arm for Hazardous Environment Operations,” International Journal of Robotics and Automation, vol. 37, no. 4, pp. 350–358, 2022.