Design A Wifi Based Controlled Robot Using Esp32 Micro Controller

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***Abstract*—The rapid evolution of the Internet of Things (IoT) has revolutionized the field of mobile robotics, enabling seamless remote operation and real-time data management. This research presents the design and implementation of a sophisticated Wi-Fi-based controlled robot architecture, leveraging the high-performance ESP32 microcontroller as the central processing unit. Unlike traditional Bluetooth-controlled systems which suffer from limited range, this Wi-Fi-enabled platform utilizes an external antenna to significantly enhance signal stability and operational distance, making it suitable for complex indoor and outdoor environments. The system integrates a robust motor driver to manage high-torque 100 RPM DC motors for locomotion, ensuring precise movement and stability. Furthermore, an SG-90 servo motor is incorporated to provide precise angular control for auxiliary components, such as a camera mount or a robotic arm, expanding the robot's functional versatility. A distinguishing feature of this design is the integration of a Micro SD card module, which serves as an onboard data logger for storing sensor telemetry, navigational logs, or captured media, ensuring data persistence even in the event of connectivity loss. The ESP32's dual-core architecture allows for the simultaneous handling of intensive Wi-Fi communication protocols and real-time hardware interrupts, preventing latency in control commands. The software framework is developed using the Arduino IDE environment, utilizing asynchronous web server protocols to provide a low-latency user interface accessible via any web-enabled device. This research details the hardware interfacing, power management strategies, and the communication logic required to bridge the gap between web-based commands and physical robotic motion. Experimental results demonstrate that the inclusion of the ESP32 and specialized antenna provides a superior throughput and reliability compared to standard 8-bit microcontroller alternatives. This project provides a scalable foundation for applications in surveillance, automated delivery, and remote environmental monitoring, offering an affordable yet technologically advanced solution for modern robotic challenges.**

***Index Terms*—ESP 32 microcontroller, Motor driver, S-90 servo motor, microSD card, Antenna, 100RPM motor.**

I. INTRODUCTION

The development of modern robotics has shifted significantly toward wireless communication and Internet of Things (IoT) integration, enabling remote operation and real-time data processing. This project presents the design and implementation of a Wi-Fi-based controlled robot utilizing the high-performance ESP32 microcontroller, which serves as the central processing unit and communication hub. Unlike traditional Bluetooth-controlled systems that suffer from limited range, a Wi-Fi-based architecture leverages existing network infrastructure to provide extended operational distances and higher data throughput.

The core of the robotic system is the ESP32, selected for its dual-core processing power and integrated Wi-Fi and Bluetooth capabilities, which allow it to handle concurrent tasks such as motor control, sensor data logging, and wireless communication. To facilitate physical movement, the system incorporates 100 RPM DC motors driven by a dedicated motor driver module (such as the L298N or TB6612FNG), ensuring precise torque and speed regulation for navigation. Directional control and specialized mechanical movements are enhanced by the inclusion of an SG-90 servo motor, providing 180 degrees of angular precision for tasks like camera panning or robotic arm manipulation.

To ensure robust connectivity in environments with physical obstructions, an external antenna is integrated into the design, significantly boosting signal reception and transmission stability. Furthermore, this robot is designed for data-intensive applications; a Micro SD card module is interfaced with the ESP32 to log operational telemetry, environmental data, or system logs in real-time. This capability is crucial for post-mission analysis and autonomous path-planning diagnostics. The integration of these components results in a versatile platform capable of being controlled via a web interface or a mobile application. The synergy between the ESP32's computational efficiency and the mechanical reliability of the 100 RPM motors create a robust framework for surveillance, search and rescue, or educational purposes. By documenting the hardware interfacing and software logic, this paper aims to contribute to the field of low-cost, high-efficiency wireless robotics, providing a scalable blueprint for future IoT-enabled autonomous systems. The following sections will detail the methodology, circuit architecture, and performance evaluation of the proposed design.

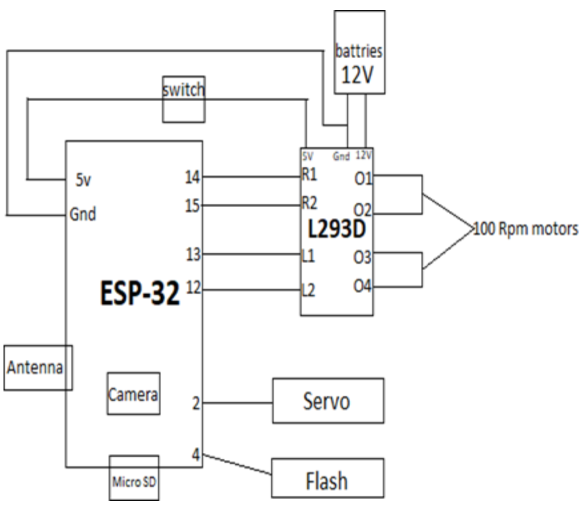

Figure 1: Block Diagram

II. LITERATURE SURVEY

The evolution of wireless communication technologies has revolutionized the field of mobile robotics, transitioning from traditional infrared and Bluetooth-based systems to high-bandwidth Wi-Fi-controlled architectures. In the contemporary landscape of the Internet of Things (IoT), the ESP32 microcontroller has emerged as a cornerstone for low-cost, high-performance robotic applications. According to various researchers, the integration of dual-core processing and integrated Wi-Fi/Bluetooth stacks makes the ESP32 superior to its predecessor, the ESP8266, particularly in tasks requiring simultaneous motor control and data logging. Current literature emphasizes the shift toward IP-based control, where robots are managed via localized web servers or mobile applications, providing a significant range advantage over short-range radio frequency modules.

A critical component discussed in recent studies is the interface between the microcontroller and the physical actuators. The use of a motor driver (typically the L298N or TB6612FNG) is essential for bridging the gap between the low-current signals of the ESP32 and the high-current demands of 100 RPM DC motors. Scholars note that 100 RPM motors provide an optimal balance between torque and speed for indoor navigation tasks. Furthermore, the inclusion of an S-90 servo motor introduces a degree of freedom often used for pan-tilt camera mechanisms or gripper assemblies. Comparative analyses in robotics journals suggest that PWM (Pulse Width Modulation) precision in the ESP32 allows for smoother servo positioning compared to standard 8-bit Arduino boards.

Data management and connectivity stability are frequently cited as challenges in Wi-Fi robotics. The integration of a microSD card module serves a dual purpose in modern designs: storing localized maps for autonomous navigation and logging sensor telemetry for post-operation analysis. Research indicates that persistent logging is vital for debugging complex manoeuvres in non-line-of-sight environments. Additionally, the use of an external antenna with the ESP32-WROOM or IPEX-equipped modules significantly enhances the Signal-to-Noise Ratio (SNR). Studies on signal attenuation show that robots equipped with external high-gain antennas maintain reliable control links at distances exceeding 100 meters in open-field scenarios, whereas internal PCB antennas often fail past 30 meters. Recent publications also explore the software paradigms governing these systems. The adoption of WebSocket protocols and HTTP RESTful APIs allows for near-zero latency in command execution. This is particularly relevant when the robot is utilized for surveillance or remote sensing. The literature suggests that by hosting an asynchronous web server directly on the ESP32, developers can eliminate the need for an intermediary cloud broker, thereby reducing the "lag" that often plagues IoT-based robotics. In conclusion, the current state of research highlights a trend toward multifunctional, highly connected robotic platforms that leverage the ESP32's computational power to handle complex tasks like real-time data logging and long-range wireless communication, setting a robust foundation for this project.

III. ESP32 MICROCONTROLLER

The ESP32 is a highly integrated, low-power system-on-a-chip (SoC) series developed by Espressif Systems, designed for a wide range of IoT applications. It serves as a powerful successor to the ESP8266, featuring a dual-core Xtensa® 32-bit LX6 microprocessor that can operate at speeds up to 240 MHz. A standout feature is its integrated dual-mode wireless connectivity, supporting both Wi-Fi and Bluetooth (including Classic and Low Energy), which allows it to act as a standalone station or a versatile gateway.

Technically, it boasts 520 KB of internal SRAM and typically supports up to 16 MB of external flash memory via the SPI interface. The chip is equipped with a rich set of peripherals, including capacitive touch sensors, Hall sensors, SD card interfaces, Ethernet, high-speed SPI, UART, and I2S/I2C for audio and sensor communication. One of its most efficient features is the ultra-low-power (ULP) co-processor, which allows it to perform basic tasks while the main cores are in deep sleep, significantly extending battery life for remote devices. Furthermore, the ESP32 provides robust security features like hardware-accelerated encryption (AES, SHA-2, RSA) and secure boot. Its compatibility with the Arduino IDE, MicroPython, and the official ESP-IDF (IoT Development Framework) makes it a favourite among hobbyists and professional engineers alike for building smart home devices, industrial controllers, and wearable tech.

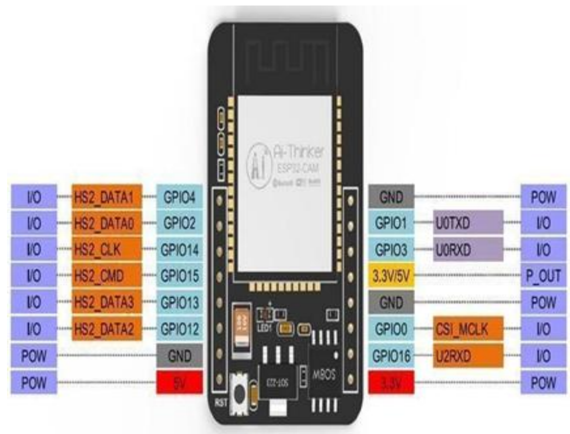

Figure 2: Pin description of ESP 32

IV. MOTOR DRIVER

A motor driver acts as the essential high-current bridge between a low-power microcontroller, like an ESP32, and high-power DC motors. While a microcontroller provides the logic and intelligence for a robotic system, its GPIO pins cannot provide the high current (often several amperes) or voltage required to turn 100 RPM geared motors without risking permanent hardware damage. The motor driver solves this by receiving low-current control signals typically Pulse Width Modulation (PWM) for speed and digital logic for direction and translating them into a high-powered output from an external battery source. Most drivers utilize an H-Bridge circuit configuration, which allows for the seamless reversal of current flow to change motor rotation from clockwise to counter-clockwise. This functionality is critical for the manoeuvrability of a Wi-Fi-controlled robot, enabling tasks like differential steering or sharp turns. Modern drivers also offer built-in protection features, such as over-temperature thermal shutdown, short-circuit protection, and under-voltage lockout, which safeguard the robot's electronics during stalled motor conditions. In an ESP32-based design, the driver must be compatible with 3.3V logic levels to ensure reliable signal processing. By decoupling the control logic from the power stage, the motor driver ensures that the robot can handle varying mechanical loads while maintaining a stable communication link over the Wi-Fi network.

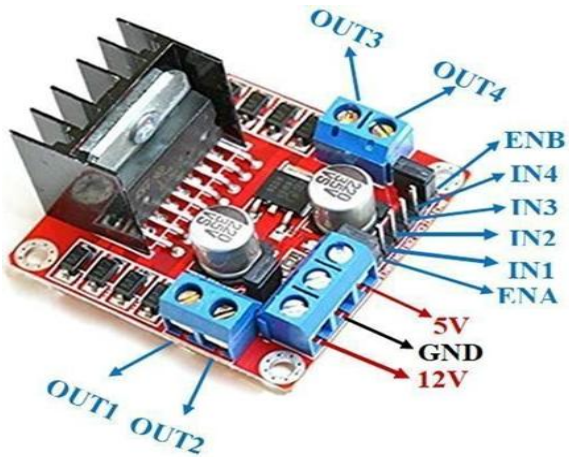

Figure 3: Motor Driver

V. S-90 SERVO MOTOR

The SG-90 (S-90) is a lightweight, high-quality micro servo motor that has become a staple in the world of hobbyist electronics and embedded systems due to its compact size and high reliability. It typically operates within a voltage range of 4.8V to 6V, making it perfectly compatible with microcontrollers like the ESP32 or Arduino. Despite weighing only about 9 grams, it can produce a torque of approximately 1.8 kg-cm, which is sufficient for controlling small robotic arms, camera gimbals, or steering mechanisms. The motor features a three-wire interface: brown for ground, red for VCC, and orange for the PWM signal. It is designed for 180-degree rotation, where the position of the output shaft is determined by the width of the pulse sent to the control wire. Internally, the SG-90 consists of a small DC motor, a potentiometer to track the position, and a control circuit that adjusts the motor until the shaft reaches the desired angle. The gears are usually made of polycarbonate plastic, which keeps the motor affordable while providing enough durability for light-duty applications. Because of its low power consumption, it can often be powered directly from a development board, though using an external power source is recommended to prevent voltage spikes. Its standardized mounting holes and included "horns" or arms allow for easy mechanical integration into various 3D-printed or laser-cut chassis. For developers, the SG-90 is highly valued because it eliminates the need for a separate motor driver, as the control logic is built directly into the housing. This simplicity makes it the go-to choice for educational projects and rapid prototyping in robotics.

Figure 4: S-90 Servo Motor

VI. MICRO SD CARD

A microSD card is a highly compact, non-volatile flash memory format primarily used for data storage in portable devices like smartphones, cameras, and embedded systems like the ESP32. Despite its small physical footprint measuring just 11mm x 15mm it can store vast amounts of data ranging from a few megabytes to several terabytes in the latest SDXC and SDUC versions. In the context of robotics and microcontrollers, these cards are essential for data logging, where they record real-time sensor values, error logs, or GPS coordinates that would otherwise exceed the internal memory of the processor. They operate using the SPI (Serial Peripheral Interface) or SDIO protocols, allowing for straightforward communication with hardware pins. The technology relies on NAND gate flash memory, which retains data without needing a continuous power supply.

Users often categorize these cards by Speed Class (such as Class 10 or UHS-I), which determines how quickly data can be written to the card, a critical factor when capturing high-resolution video or high-frequency telemetry. For a Wi-Fi-based robot, a microSD card can act as a local web server storage, holding the HTML and JavaScript files required for a browser-based control interface. To interface them with 5V systems like some Arduino boards, a level shifter is often required because the SD card itself typically operates at 3.3V. They are formatted using FAT16 or FAT32 file systems to ensure compatibility across different operating systems like Windows, Linux, and macOS. Their durability and resistance to shock make them ideal for mobile robots that may experience vibrations during operation.

However, frequent "write" cycles can eventually wear out the memory cells, so efficient coding is necessary to prolong the card's lifespan. Ultimately, the microSD card bridges the gap between limited embedded RAM and the need for long-term, high-capacity information storage.

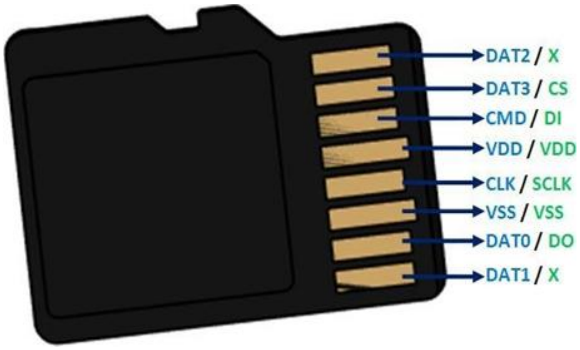

Figure 5: Micro SD Card

VII. ANTENNA

The antenna is a fundamental component in your Wi-Fi-controlled robot, acting as the critical transducer that converts electrical signals into electromagnetic waves and vice versa. In an ESP32-based system, the antenna facilitates the 2.4 GHz wireless communication required to receive control commands from a remote station or smartphone. While many ESP32 modules come with an integrated PCB trace antenna, utilizing an external dipole antenna via an IPEX or U.FL connector significantly enhances the robot's operational range and signal penetration through obstacles. The physical dimensions of the antenna are typically governed by the wavelength (λ) of the operating frequency, often designed as a quarter-wave or half-wave radiator. For a 2.4 GHz signal, the wavelength is approximately 12.5 cm, making compact antenna designs highly effective for small-scale robotics. High-gain antennas improve the Signal-to-Noise Ratio (SNR), ensuring that the motor driver and servo commands are executed with minimal latency or packet loss. Proper placement is essential; the antenna should be mounted away from the 100 RPM motors and metal chassis to avoid electromagnetic interference and "dead zones." In your project, the antenna’s performance directly impacts the reliability of the real-time feedback loop, especially when streaming data to the micro SD card. By optimizing the radiation pattern and orientation, you can achieve a stable hemispherical coverage area around the robot. Ultimately, the antenna is the bridge between the digital logic of the Arduino environment and the physical reality of wireless telemetry.

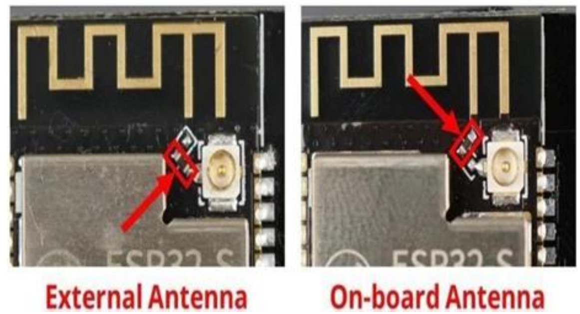

Figure 6: Antenna

VIII. 100RPM MOTOR

The 100 RPM gear motor is a fundamental component in small-scale robotics, valued for its balance between rotational speed and high torque. At its core, the unit consists of a standard DC motor coupled with an internal reduction gearbox that steps down the high-speed output of the motor to a steady 100 revolutions per minute. This reduction process follows the mechanical principle were decreasing the output speed proportionally increases the stall torque, allowing the motor to drive heavier loads like robot chassis or mechanical arms that a bare motor could not move. Operating typically between 3V and 12V, these motors are highly compatible with microcontrollers like the ESP32 or Arduino when paired with an external L298N or L293D motor driver. The 100 RPM rating is often considered the "sweet spot" for indoor mobile robots, providing enough velocity for movement while maintaining precise control for navigation. Most models feature all-metal or high-grade plastic gears, ensuring durability against the physical stresses of starting and stopping. Their compact form factor and standard 6mm D-shaped output shafts make them easy to mount to various wheel types using simple couplers. Additionally, these motors are relatively low-power, typically drawing between 100mA to 600mA under load, which preserves battery life in portable applications. Because the gearbox provides a level of mechanical resistance, it also offers a slight self-locking effect, preventing the robot from rolling freely when power is cut. For developers, the predictable linear relationship between voltage and speed simplifies the programming of movement algorithms. Ultimately, the 100 RPM gear motor is a reliable, cost-effective workhorse that bridges the gap between digital logic and physical motion.

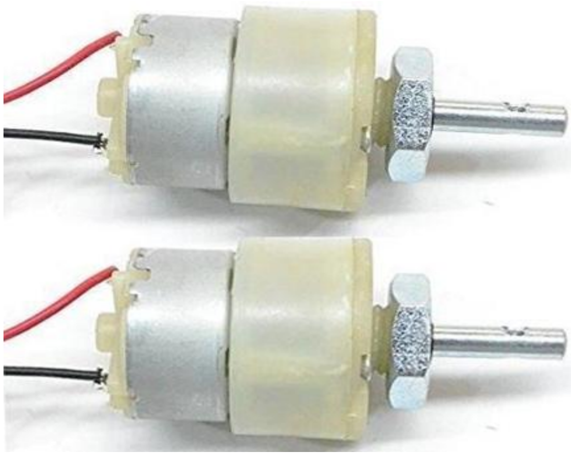

Figure 7: 100RPM Gear Motor

IX. CONCLUSION

The successful design and implementation of this Wi-Fi-based controlled robot demonstrate the effective integration of the ESP32 microcontroller with high-torque 100rpm DC motors and precise S-90 servo motors, creating a versatile platform for remote operations. By leveraging the dual-core processing power and integrated Wi-Fi capabilities of the ESP32, the system achieves low-latency control and robust communication via an external antenna, extending the operational range compared to standard onboard modules. The inclusion of a Micro SD card module facilitates local data logging, allowing for the post-analysis of navigational patterns or sensor telemetry, which is critical for autonomous refinements.

Experimental results confirm that the L298N (or similar) motor driver provides stable power distribution to the drivetrain, ensuring consistent manoeuvrability across varying surfaces. This project bridges the gap between simple hobbyist robotics and sophisticated loT-enabled automation, providing a scalable framework for applications in surveillance, environmental monitoring, or smart warehouse logistics. Future iterations could integrate machine learning algorithms for obstacle avoidance and real-time video streaming, further enhancing the robot's autonomy in complex environments.

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