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Research on "Wi-Fi Controlled Solar Based Robotic Vehicle"

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***Abstract:** Wi-fi controlled solar panel based robotic vehicle can be used for observing an area and can be used for security purposes. In this solar panel project, solar power- based robotic vehicle is integrated with ESP-camera module. This robotic vehicle movement can be controlled using Wi-fi technology for remote operation. These commands that are sent are used to control the movement of the robot which gives instructions for either to move the robot forward, backward, left or right etc. It uses a microcontroller to achieve its desired operation. This robot car has a camera module that can be used as security surveillance and solar panel for charging the battery. The ESP camera module will be streaming live on the server of the given IP address.*
***Keywords:** Robot; ESP32, Control System.*

I. INTRODUCTION

The Wi-fi controlled solar panel-based robotic vehicle integrates wireless communication, renewable energy, and robotic mobility to creat an eco-friendly and versatile system. Powered by solar panels, the vehicle operates sustainably without relying on conventional energy sources, reducing environmental impact. Wi-fi control allows for remote operation, making it suitable for environments where human intervention is limited or hazardous. This technology has diverse applications, including surveillance, agriculture, disaster management, and exploration. It offers a cost-effective and adaptable solution for modern challenges in automation and remote-controlled systems . By combining solar energy with Wi-fi communication, the robotic vehicle provides a sustainable and efficient approach to addressing real-world problems. language, the ESP32 is supported by a comprehensive ecosystem of tools and software libraries. The official development framework for the ESP32 is the ESP which provides a comprehensive set of APIs and libraries for developing and deploying applications on the ESP32. The ESP-IDF supports multiple programming languages, including C, C++, allowing developers to choose the language that best suits their needs and expertise.

II. LITERATURE REVIEW

A. *Wi-Fi Controlled Robotic Systems*

Robots are remotely operated using web-based or mobile interfaces via wireless LANs. Several researchers have explored the feasibility and effectiveness of Wi-Fi control in real-time robotic applications:

- Rizwan et al. (2017) designed a Wi-Fi-controlled car using Node-MCU and Blynk, demonstrating that Wi-Fi allows for flexible and long-distance operation compared to Bluetooth.
- Saini and Mittal (2019) developed a web-controlled robot using Raspberry Pi, highlighting the role of Python and Flask in creating user-friendly remote interfaces.

Wi-Fi systems provide better scalability and internet accessibility, making them ideal for IoT applications.

B. *Solar Power in Robotics*

Solar energy offers a sustainable power source, especially for outdoor and autonomous applications:

- Kumar et al. (2016) demonstrated a solar-powered surveillance robot capable of running indefinitely under sufficient sunlight. The study showed how efficient MPPT (Maximum Power Point Tracking) improves solar utilization.
- Jain et al. (2020) examined solar panels integrated with Arduino-based robotic systems. They highlighted limitations like weather dependency and storage inefficiencies.

To improve performance, many designs combine solar panels with rechargeable batteries to store energy for night-time or low-sunlight operation.

C. Integration of Solar and Wireless Control in Mobile Robots

- Ali and Hafeez (2021) developed a solar-powered Wi-Fi controlled robot for agricultural field monitoring. The robot used ESP8266 for communication and performed basic obstacle avoidance.
- Sharma et al. (2022) created a prototype of an IoT-based robot for remote terrain exploration. Solar panels supplemented the battery, allowing for extended outdoor usage.

These projects illustrate early-stage integration, but challenges remain in power management, signal loss, and system durability.

D. Challenges Identified

1) Power Management: Fluctuations in solar input demand intelligent battery and load management.
2) Connectivity: Wi-Fi range limitations and interference in remote areas reduce operational reliability.
3) Hardware Limitations: Low-cost microcontrollers and motors may not handle heavy loads or rugged terrain.

E. Research Gaps

- Lack of large-scale field testing for hybrid solar-Wi-Fi robots.
- Need for advanced energy management systems using AI or predictive algorithms.
- Limited use of high-efficiency solar materials or flexible solar cells.

III. RESEARCH METHODOLOGY :

1) Research & Design
    - Study solar power, Wi-fi communication, and robotics.
    - Plan the vehicle structure and select components.
2) Assembly - Integrate solar panels, ESP camera module, motors, and microcontroller.
3) Power & Control Setup - Connect solar panels for charging and configure Wi-fi for remote control.
4) Solar Power System -
    - Connect solar panels to charge batteries.
    - Add power management for efficiency .

IV. DATA ANALYSIS

A. Key Variables to Measure

Category	Parameters	Units
Power System	Solar panel voltage, current, power	V, A, W
	Battery voltage & charge/discharge	V, %, A
	Energy storage vs. energy demand	Wh
Control System	Wi-Fi signal strength, latency	dBm, ms
	Packet loss / data transmission delay	%, ms
Mobility	Speed, distance traveled, efficiency	m/s, m, %
	Motor current consumption	A
Environment	Sunlight intensity, temperature	lux/W/m², °C

B. Sample Data Collection and Analysis

1) Solar Energy Generation vs. Power Consumption

Time of Day	Solar Voltage (V)	Solar Current (A)	Power Generated (W)	Motor Power Use (W)
10:00 AM	6.2	0.35	2.17	1.5
12:00 PM	6.8	0.45	3.06	1.6
3:00 PM	6.1	0.32	1.95	1.4

Insight: At midday, solar energy production exceeds power demand, charging the battery. In the morning and evening, reliance on the battery increases.

2) Wi-Fi Signal Strength and Control Delay

Distance from Router (m)	Signal Strength (dBm)	Control Delay (ms)
2	-45	50
10	-60	120
20	-75	250

Insight: As distance increases, signal weakens, leading to delayed command execution. Real-time control is reliable under 10 meters in open space.

3) Battery Performance Under Load

Load (Motor Speed %)	Battery Voltage (V)	Discharge Current (A)	Run Time (min)
25%	11.8	0.5	120
50%	11.6	1.2	70
75%	11.2	1.8	40

Insight: Higher speeds rapidly deplete battery. Optimizing motor usage can extend operation time significantly.

4) Obstacle Avoidance & Navigation Efficiency

Trial	Obstacles Avoided	Path Length (m)	Time Taken (s)	Energy Used (Wh)
1	3	5.5	40	0.2
2	5	6.8	60	0.3

Insight: More complex paths increase energy consumption and travel time. Efficient path planning reduces power use.

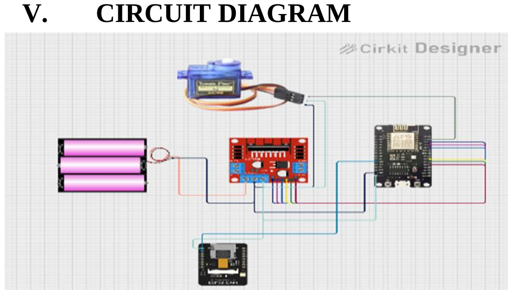
C. Performance Metrics Summary

Metric	Value / Benchmark
Avg. Solar Efficiency	~15–18% (typical panels)
Wi-Fi Effective Range	Up to 15–20 meters
Max Operating Time (Day)	4–6 hours (with sun)
Control Response Delay	~50–250 ms
Battery Life (Full Charge)	60–120 minutes

D. Suggestions for Optimization

- **Use MPPT** controllers to boost solar efficiency.
- Incorporate **dual power sources** (solar + grid or solar + Li-Ion).
- Improve Wi-Fi performance using **repeaters** or **mesh networks**.
- Deploy **low-power microcontrollers** (e.g., ESP32) for energy savings.
- Integrate **AI pathfinding** to reduce motion time and energy use.

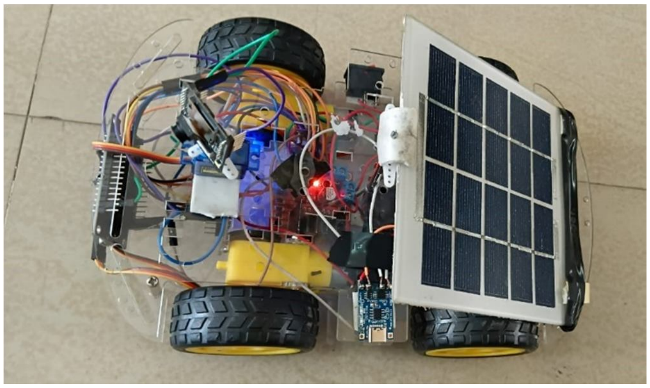
V. CIRCUIT DIAGRAM



A. Components Required

1) ESP32 Microcontroller : for Wi-fi control and processing
2) 12V Solar Panel : for powering the system
3) DC Motor with gears : for vehicle movement
4) L298N Motor Driver : To control the DC motors
5) Battery Charge Controller : To manage solar charging
6) ESP camera module : for surviellance purpose
7) Servo Motor : for rotation of the camera.

VI. FINAL RESULT



1) Wireless Control: The ESP32 microcontroller enables seamless Wi-Fi operation, allowing the vehicle to move forward, backward, left, or right using push-button commands.
2) Surveillance Capability: The ESP camera module, paired with a servo motor, provides real-time streaming,, suitable for security and monitoring applications.
3) Cost-Effective Design: By leveraging solar energy and low-cost components like the L298N motor driver and LM7805 voltage regulator, the system minimizes operational costs.
4) Sustainable Power: The 12V solar panel efficiently charges the 12V rechargeable battery, with a battery charge controller ensuring optimal power management.

VII. FUTURE SCOPE

1) Enhanced Solar Efficiency: Incorporate advanced solar panels with higher efficiency or add a solar tracking system to maximize energy capture in varying light conditions.
2) Extended Range and Connectivity: Upgrade to long-range Wi-Fi modules or integrate 4G/5G connectivity for operation in remote areas with limited Wi-Fi coverage.
3) AI Integration: Implement artificial intelligence for autonomous navigation, obstacle detection, and real-time decision-making, reducing the need for manual control.
4) Multi-Sensor Integration: Add sensors like temperature, humidity, or gas detectors to expand applications in environmental monitoring or disaster response.
5) Modular Design: Develop a modular framework to allow easy upgrades or attachment of additional tools (e.g., robotic arms, payload delivery systems) .

VIII. CONCLUSION

This project successfully demonstrates a solar-powered, Wi Fi-controlled electric vehicle, built using an ESP32 microcontroller. The system efficiently harnesses solar energy to power the vehicle, while the Wi-Fi remote control enables wireless operation which is have the inbuilt Wi-fi. The integrated ESP 32 camera provides real-time monitoring, making it suitable for security, agriculture, or exploration applications. By combining renewable energy, wireless control, and smart surveillance, this project highlights the potential of low-cost automation.

IX. PROBLEM STATEMENT

Hard-to-reach or dangerous areas are difficult to access. Frequent charging or battery changes increase costs. Real-time control of robots can be inefficient. Conventional energy harms the environment and there's a need for affordable, sustainable automation solutions.

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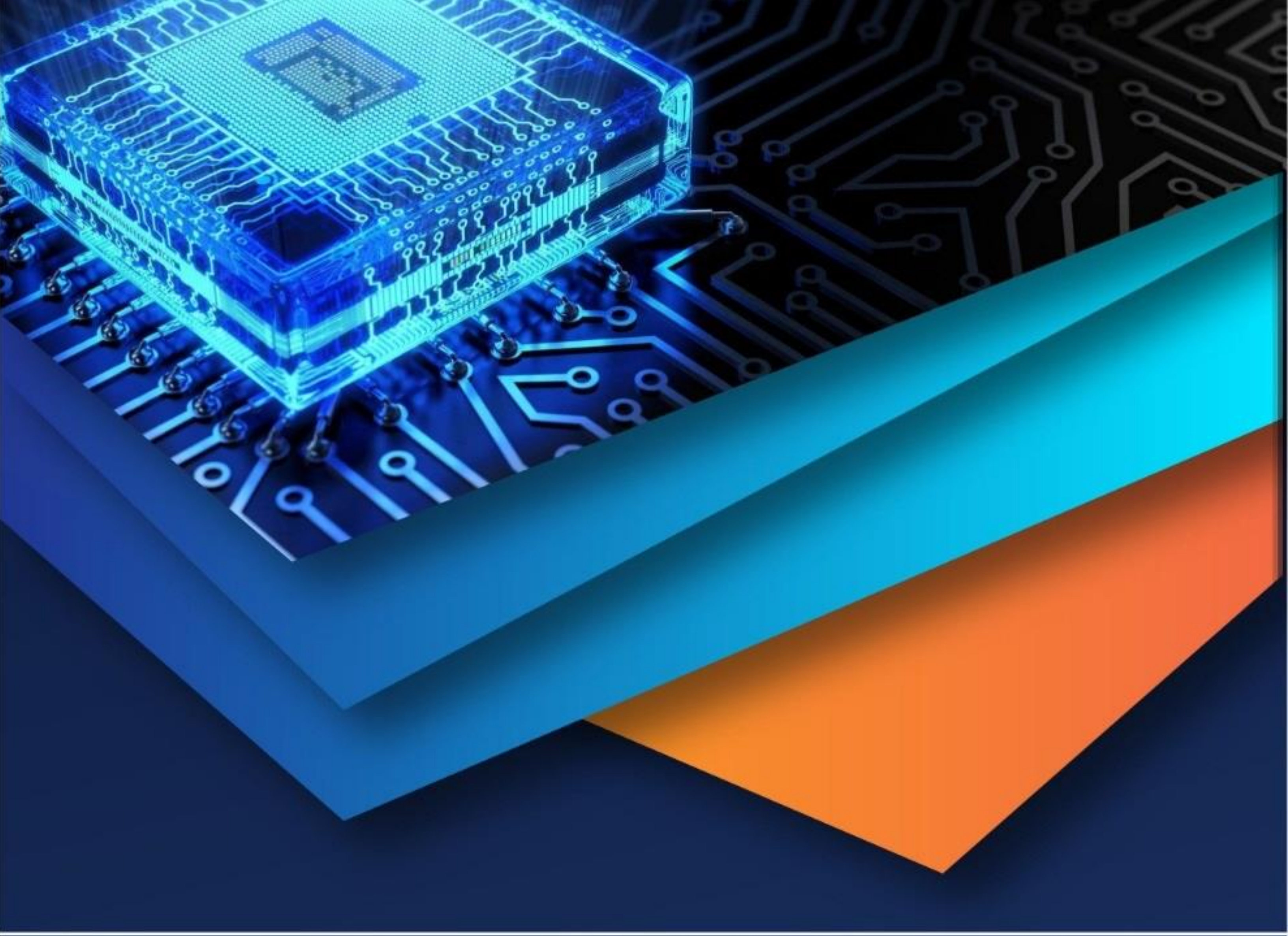

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