SolarBot: A Dual-Mode, Bluetooth-Enabled Two-Wheel Robot Powered by Renewable Energy

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Abstract
This research paper explores the development and deployment of a two-wheel drive robot car that leverages renewable solar energy stored in lithium-ion batteries. The system is designed with an L298N motor driver, an Arduino microcontroller, and an HC-05 Bluetooth module, providing the robot with both autonomous and manual control capabilities. The solar panel, integrated with a charging module and voltage regulator, is mounted on a zero PCB, ensuring a sustainable and uninterrupted power supply. The robot is equipped with ultrasonic sensors, enabling it to detect and navigate around obstacles automatically, ensuring a safe and efficient operation.
In its autonomous mode, the robot can navigate predefined paths, making real-time adjustments based on sensor input to avoid collisions. This feature is particularly useful for applications such as automated plant watering, where the robot can move through a garden and irrigate plants while avoiding obstacles. Additionally, the robot can be utilized as a floor cleaning device, capable of maneuvering around furniture and other objects. The RC Bluetooth app facilitates manual control, allowing users to operate the robot remotely for various tasks.
The project demonstrates a practical application of renewable energy in robotics, emphasizing the benefits of sustainable energy solutions and versatile operational modes. The use of a wooden platform provides a sturdy base for the robot's components, ensuring durability and reliability. This work contributes to the field of robotics by showcasing how solar power can be effectively harnessed to create energy-efficient, multifunctional robotic systems.

Keywords Solar-Powered Robotics, Autonomous Navigation, Obstacle Avoidance, Renewable Energy, Sustainable Technology

Introduction
In the realm of robotics, the integration of renewable energy sources and advanced control systems has become increasingly important. This paper introduces a novel two-wheel drive robot car that exemplifies these advancements by harnessing solar energy and providing versatile operational modes. The robot is designed to operate both autonomously and manually, showcasing a practical application of sustainable energy in robotics.
The robot is powered by a solar panel, which charges lithium-ion batteries through a dedicated charging module and voltage regulator mounted on a zero PCB. This design ensures a continuous and reliable power supply, highlighting the feasibility of solar energy in robotic applications. The core of the robot’s

functionality is built around the L298N motor driver, which manages the movement of the two wheels, and an Arduino microcontroller that orchestrates the robot's operations.
The robot's autonomous capabilities are driven by ultrasonic sensors that continuously scan the environment for obstacles. These sensors feed real-time data to the Arduino, which processes the information and adjusts the robot's path to avoid collisions. This obstacle avoidance system enables the robot to navigate predefined routes efficiently, making it suitable for tasks such as automated plant watering and floor cleaning.
For manual operation, the robot is equipped with an HC-05 Bluetooth module that allows users to control it via a smartphone or tablet using an RC Bluetooth app. This functionality provides the user with the flexibility to override autonomous control and manually guide the robot, making it versatile for various applications.
The integration of renewable energy in the robot's design not only promotes sustainability but also demonstrates how solar power can be effectively utilized in robotic systems. The robot's ability to switch between autonomous and manual modes enhances its adaptability, allowing it to perform a range of tasks from navigating complex environments to executing specific user commands.

Research Methodology

The research methodology for the development and evaluation of the solar-powered two-wheel drive robot car involves a systematic approach divided into four primary phases: design, implementation, testing, and analysis. This methodology is critical for ensuring that the robot operates effectively, efficiently, and in line with the intended functionalities.

1. Design Phase

a. System Design and Component Selection:

1. **Power System:**
   - Solar Panel Selection: A solar panel with suitable wattage and voltage ratings is chosen to ensure that it can efficiently generate power for the robot's components.
   - Charging and Regulation: A charging module coupled with a voltage regulator is integrated to manage energy flow from the solar panel to the lithium-ion batteries, ensuring a steady and reliable power supply.
2. **Control and Actuation:**
   - Motor Driver (L298N): The L298N motor driver is selected for its capability to control the robot's two-wheel drive system, providing bidirectional control and variable speed options.
   - Microcontroller (Arduino): An Arduino microcontroller is used to handle sensor inputs, control motor outputs, and manage Bluetooth communications.
3. **Sensors and Communication:**
   - Ultrasonic Sensors: Ultrasonic sensors are incorporated to detect obstacles and facilitate the robot's autonomous navigation.
   - Bluetooth Module (HC-05): The HC-05 Bluetooth module is employed to enable remote manual control via a smartphone application.
4. **Mechanical Design:**
   - Platform Construction: A wooden platform is designed and built to support all components securely, providing both structural integrity and durability.

- Assembly: All hardware components are mounted on the wooden platform, ensuring correct alignment and connectivity.

2. Implementation Phase

a. Hardware Assembly:

1. Power System Integration:
- Connect the solar panel to the charging module and voltage regulator.
- Integrate the lithium-ion batteries with the output of the voltage regulator.

2. Control System Assembly:
- Wire the L298N motor driver to the Arduino and the motors.
- Connect ultrasonic sensors to the Arduino for real-time obstacle detection.
- Install the HC-05 Bluetooth module to facilitate communication with the RC Bluetooth app.

3. Platform and Component Integration:
- Securely affix all components onto the wooden platform.
- Ensure that all connections and alignments are precise to prevent operational issues.

b. Software Development:

1. Programming the Arduino:
- Develop and upload Arduino sketches to control motor operations, process sensor data, and manage Bluetooth interactions.
- Implement algorithms for autonomous navigation and obstacle avoidance.

2. Bluetooth Application Configuration:
- Set up the RC Bluetooth app to enable manual control of the robot, allowing users to issue commands remotely.

3. Testing Phase

a. Functional Testing:

1. Power System Verification:
- Test the solar panel's effectiveness in charging the batteries.
- Confirm the voltage regulation to ensure a consistent power output.

2. Control and Drive System Evaluation:
- Assess the performance of the L298N motor driver in controlling motor functions.
- Test the Arduino's ability to process sensor data and manage motor controls accurately.

3. Sensor Functionality Testing:
- Evaluate the precision and reliability of the ultrasonic sensors in detecting obstacles and adjusting the robot's path.

4. Bluetooth Control Testing:
- Verify the communication between the HC-05 Bluetooth module and the RC Bluetooth app.
- Test the responsiveness and accuracy of manual control features.

b. Performance Assessment:

1. Autonomous Operation Evaluation:
- Analyze the robot's capability to follow predefined paths and avoid obstacles based on sensor data.
- Assess the efficiency of the obstacle avoidance and path correction algorithms.

2. **Manual Control Evaluation:**
- Test the responsiveness of manual control through the RC Bluetooth app.
- Evaluate the effectiveness of manual operation in various scenarios.

4. Analysis Phase

a. Data Collection and Analysis:

1. **Performance Metrics:**
- Collect data on the robot's performance in both autonomous and manual modes.
- Analyze the effectiveness of obstacle avoidance and the accuracy of manual control.

2. **Energy Efficiency:**
- Measure the robot's energy consumption during operation.
- Assess the impact of solar power on overall system performance.

b. Results Interpretation:

1. **Comparison of Results:**
- Compare the robot's performance across different modes and conditions.
- Identify areas for improvement based on performance data.

2. **Optimization and Recommendations:**
- Suggest design or software modifications to enhance performance and energy efficiency.
- Propose potential future improvements or extensions to the robot's capabilities.

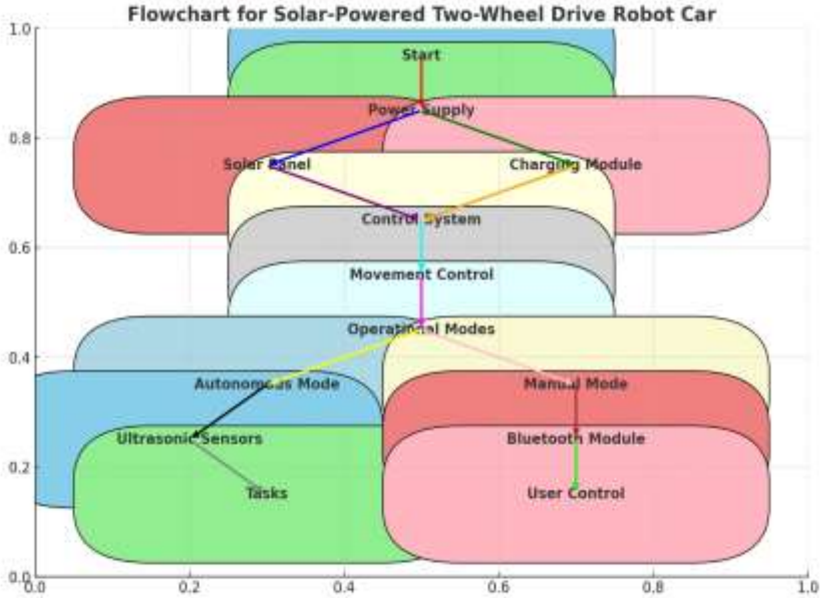

Figure 1 Final Project Image

Calculations

1. Energy Stored in Lithium-Ion Battery

Energy Calculation:

Energy(Wh)=Capacity(Ah)×Voltage(V)

Energy $_{\text{Li-ion}}$=2.2 Ah×3.7 V=8.14 Wh

2. Energy Stored in Disposable 9V Battery

Energy Calculation:

Energy(Wh)=Capacity(Ah)×Voltage(V)

Energy $_{\text{Li-ion}}$=0.5 Ah×9 V=4.5 Wh

3. Energy Comparison

Comparison Calculation:

Energy Comparison = $\frac{\text{Energy Li-ion}}{\text{Energy 9v}} = \frac{8.14}{4.5}$ =1.81

The comparison demonstrates that a lithium-ion battery system, when charged with solar energy, is more energy-efficient, cost-effective, and environmentally friendly compared to disposable 9V batteries. The lithium-ion battery not only provides a higher energy capacity but also significantly reduces long-term costs and environmental impact due to its reusability and lower frequency of disposal**.**

Conclusion

This research presented the development and evaluation of a two-wheel drive robot car powered by solar energy and lithium-ion batteries, capable of both autonomous and manual operation via an RC Bluetooth app. The primary objective was to demonstrate the efficiency and effectiveness of integrating renewable energy with advanced robotics for versatile applications.

1. **Energy Efficiency and Cost-Effectiveness:** The comparison between lithium-ion batteries and disposable 9V batteries highlighted significant advantages of the lithium-ion system. With a higher energy storage capacity of 8.14 Wh compared to 4.5 Wh of the disposable batteries, the lithium-ion setup not only provides extended operational time but also reduces long-term costs. The initial investment in lithium-ion technology, though higher, results in substantial savings over time due to its reusability and lower operational costs—82 INR annually compared to 1,968 INR for disposable batteries.
2. **Environmental Impact:** The project emphasizes environmental sustainability by utilizing solar energy, which mitigates the need for non-renewable power sources. The lithium-ion batteries, in combination with solar panels, offer a significant reduction in waste and resource consumption compared to single-use disposable batteries. This aligns with global efforts to adopt eco-friendly practices and reduce the environmental footprint of technological systems.
3. **Functional Versatility:** The robot's dual-mode operation—autonomous navigation with obstacle avoidance and manual control via Bluetooth—demonstrates its flexibility for various applications. Beyond basic movement and obstacle avoidance, the robot's potential extends to practical applications such as plant watering and floor cleaning. This adaptability underscores the value of integrating robotic systems with renewable energy solutions to address diverse needs effectively.
4. Technical Performance: The implementation of the L298N motor driver, Arduino microcontroller, and ultrasonic sensors contributed to the robot's precise control and navigation. The successful integration of these components with a solar-powered energy system demonstrates the viability of using renewable

sources in practical robotics applications. The system's ability to stop and alter its path in response to obstacles exemplifies the effective use of sensor data for dynamic decision-making.

5. **Future Prospects:** This research opens avenues for further exploration in enhancing the robot's capabilities. Future work could involve optimizing energy efficiency, expanding the range of automated tasks, and integrating advanced sensors and AI algorithms for improved autonomous decision-making. Additionally, exploring alternative renewable energy sources and more advanced battery technologies could further enhance the robot's performance and sustainability.

In conclusion, the development of a solar-powered, lithium-ion battery-driven robot car with both autonomous and manual control capabilities represents a significant advancement in integrating renewable energy with robotics. This project not only demonstrates technical feasibility but also provides a foundation for future innovations aimed at creating more sustainable and versatile robotic systems.

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