International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

Autonomous Robot Car for Vision-Guided Wireless EV Charging

CH. Surya Teja, M. Pavani, B.B.S.P.R.L Sameera, D. Sai Aravind
Department of Electronics and Communication Engineering, Ideal Institute of Technology, Kakinada, India.

Abstract - This paper presents the design and development of an autonomous robot car capable of performing wireless charging for electric vehicles using vision-based alignment. The system aims to reduce manual effort in conventional charging methods and address the limitations of static wireless charging systems that require precise positioning.

The proposed model integrates an ESP32-CAM module for detecting a predefined green tape placed near the charging area, which is used as a visual reference for alignment. An ultrasonic sensor is utilized to maintain appropriate vertical positioning of the transmitter coil. A mecanum wheel-based drive system enables flexible movement and alignment of the robot.

The control operations are handled by a microcontroller, which coordinates navigation, alignment, and charging processes. Wireless power transfer is implemented using inductive coupling between transmitter and receiver modules. Experimental results demonstrate that the system can successfully navigate, detect the green tape, perform basic alignment, and initiate charging under controlled conditions. The proposed system provides a simple and cost-effective approach towards autonomous charging and serves as a foundation for further improvements.

Keywords - Wireless Power Transfer (WPT), Electric Vehicles (EV), ESP32-CAM, Autonomous Robot Car, Vision-Based Alignment

I. INTRODUCTION

With more people switching to electric vehicles, we really need easier ways to charge them. Plugging in cables every time is a bit of a inconvenience and stops everything from being fully automated and requires human need. While wireless charging is advantageous, the current static pads are picky – if you aren't parked exactly right above the pad, the power transfer efficiency drops. We realized that instead of making the driver park perfectly, we could make a robot car that does the aligning for them even if they are not parked correctly.

Our project uses an ESP32-CAM to look for a specific green tape on the floor. Once it sees the tape, the car moves left, right, or forward accordingly to line itself up. We even built a rack mechanism with an ultrasonic sensor so the robot can lift the charging coil to the perfect distance from ground in order to solve the ground clearance problem. By using mecanum wheels, we gave the robot the ability to slide sideways, which is much easier than doing a 3-point turn just to align a coil [5].

The system operates in a sequence that includes forward movement, height verification, vision-based alignment, and activation of wireless charging. All operations are controlled by an Arduino UNO, which processes sensor inputs and generates control signals for movement and charging.

The main objective of this work is to develop a low-cost prototype that demonstrates autonomous navigation, visual alignment, and wireless power transfer in a single system. The proposed model successfully performs basic alignment and charging under controlled conditions. Although the current implementation achieves approximate alignment, it provides a foundation for future improvements in precision, adaptability, and real-time control for autonomous charging systems.

II. PROPOSED SYSTEM

The proposed system consists of an autonomous robot car designed to perform wireless electric vehicle charging without human intervention [1], [2], [4]. Our design is all about making a smart, budget-friendly car that can charge an EV without any human help. It combines a camera for 'eyes', sensors for distance, and a wireless power module. The whole thing runs on a mecanum wheel base, which is great because it can move in any direction-including sideways-to get that perfect alignment. The brain of the operation is an Arduino UNO that talks to motor drivers to control the movement [12]. This capability allows the system to perform basic alignment adjustments based on visual feedback.

An ESP32-CAM module is employed for vision-based detection of a predefined green tape placed near the charging location. The camera processes the captured image and determines the relative position of the tape within the frame. Based on this information, directional commands such as left, right, or center are transmitted to the controller, enabling alignment of the robot with respect to the receiver coil.

To ensure proper vertical positioning, an ultrasonic sensor is used to measure the distance between the transmitter coil and the ground surface. If the measured height exceeds a predefined threshold, a rack and pinion mechanism is activated to adjust the position of the transmitter coil. This helps in improving the coupling between the transmitter (TX) and receiver (RX) coils. The wireless charging system is implemented using inductive coupling between a transmitter coil mounted on the robot and a receiver coil placed at the charging station. A relay circuit is used to control the activation of the transmitter coil, allowing charging to occur only after alignment is achieved.

The overall operation of the system follows a sequential control strategy. Initially, the robot moves towards the charging area, performs height verification, activates the vision system for alignment, and then proceeds to the final charging position.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

After a predefined charging duration, the robot returns to its initial position.

The proposed system focuses on simplicity, cost-effectiveness, and demonstration of core functionality. While the alignment is not fully precise, the system successfully illustrates the concept of autonomous wireless charging using vision-based guidance.

III. COMPONENTS USED

The hardware and software components used in the proposed system are listed in Table I and Table II.

Table I
Hardware Components Used

S.No	Component	Specification	Purpose
1.	Arduino UNO	ATmega328P or Compatible	Main controller
2.	ESP32-CAM	WiFi + Camera	Vision detection
3.	Ultrasonic Sensor	HC-SR04	Distance measurement
4.	Motor Drivers	L293D, L298N	Motor control
5.	DC Metal Gear Motors	6V geared	Robot movement
6.	Mecanum Wheels	Omni-directional	Flexible motion
7.	Relay Module	5V Relay	Charging control
8.	Wireless TX Module	9-12V, 43mm round, 1.3A	Generates magnetic field
9.	Wireless RX Module	5V/2A or 12V/700mA, 43mm	Power reception
10.	Rack & Pinion	Mechanical lift	Height adjustment
11.	Power Supply	12V 5A Power Adapter	System power

Table II
Software Tools and Programming Used

S.NO	Software	Specification	Purpose
1.	Arduino IDE	Development Tool	Writing & uploading code
2.	C Programming (Embedded Systems)	Programming language	Control logic
3.	ESP32-CAM Firmware	Image processing	Green Tape Detection

IV. SYSTEM ARCHITECTURE

The overall system architecture of the proposed autonomous robot car for wireless EV charging is composed of multiple functional modules, including sensing, vision processing, control, actuation, and power transfer units. The architecture is designed to enable coordinated operation between hardware components for navigation, alignment, and charging.

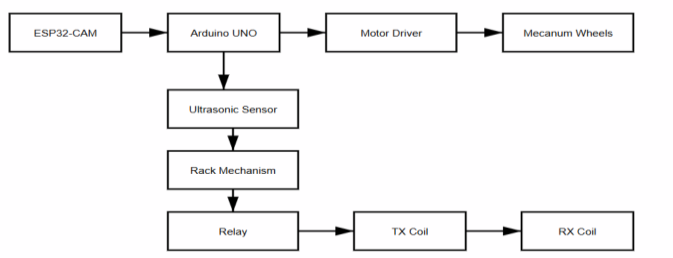

Fig. 1. System architecture of the proposed autonomous charging system

The central control unit of the system is the Arduino UNO microcontroller, which manages all operations including motor control, sensor interfacing, and relay switching. It receives input signals from sensors and the vision module and generates appropriate control signals for actuators.

The vision processing unit is implemented using an ESP32-CAM module. It captures real-time images and performs color-based detection of a predefined green tape. Based on the position of the detected tape, the ESP32-CAM transmits directional commands such as left, right, or center to the Arduino controller through serial communication.

The sensing unit consists of an ultrasonic sensor used for height measurement. It determines the distance between the transmitter coil mounted on the robot and the ground surface. This information is used to decide whether the rack mechanism needs to be activated for vertical adjustment.

The actuation unit includes motor drivers connected to the mecanum wheel system, enabling multi-directional movement of the robot. The same unit also controls the rack and pinion mechanism responsible for lifting or lowering the transmitter coil based on sensor input.

The power transfer unit consists of a transmitter coil mounted on the robot and a receiver coil placed at the charging station. Wireless energy transfer is achieved through inductive coupling. A relay circuit is used to control the activation of the transmitter coil, ensuring that charging occurs only after proper positioning.

All modules are integrated to operate in a sequential manner, where sensor data and vision feedback are continuously processed to guide the robot towards the charging position. The architecture ensures coordination between motion control, alignment, and power transfer processes.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

V. METHODOLOGY

The system operates based on a sequential control strategy integrating motion, sensing, vision processing, and wireless power transfer. The methodology is designed to enable the autonomous robot car to navigate towards the charging location, perform alignment, and initiate wireless charging without human intervention.

Initially, the robot is programmed to move forward for a predefined duration to approach the charging area. This movement is controlled by the Arduino UNO through motor drivers connected to the mecanum wheel system. The forward motion ensures that the robot reaches a position close to the receiver coil.

Once the robot reaches the approximate charging location, the ultrasonic sensor is activated to measure the vertical distance between the transmitter coil mounted on the robot and the ground surface. If the measured height exceeds a predefined threshold value, the rack and pinion mechanism is triggered to lift the transmitter coil. This adjustment helps in achieving better coupling between the transmitter and receiver coils.

After height verification, the ESP32-CAM module is activated to perform vision-based alignment [3]. The camera captures real-time images and applies a simple color detection algorithm to identify a predefined green tape placed near the charging area. Based on the position of the detected tape within the frame, the system determines whether the robot is aligned or requires adjustment.

If the tape is not centered, the robot performs corrective movements using lateral or directional motion enabled by the mecanum wheels. This process continues until the tape is approximately centered, indicating alignment with the receiver coil.

Once alignment is achieved, the robot moves forward for a short offset duration to position the transmitter coil directly above the receiver coil. After positioning, the relay circuit is activated, initiating wireless power transfer through inductive coupling between the transmitter and receiver coils.

The charging process is maintained for a predefined duration, after which the relay is deactivated. Finally, the robot moves backward for a fixed duration, returning to its initial position and completing the operation cycle.

The methodology emphasizes simplicity and feasibility, focusing on demonstrating the concept of autonomous wireless EV charging using basic sensing and vision techniques. While the alignment process is not highly precise, it effectively validates the proposed approach under controlled conditions.

VI. IMPLEMENTATION

The robot car - autonomous wireless EV charging system is developed using embedded hardware components and programmed control logic. The system integrates an Arduino UNO microcontroller, ESP32-CAM module, motor drivers, ultrasonic sensor, relay circuit, and wireless power transfer coils [7], [8], [11].

The Arduino UNO acts as the central controller, coordinating motion, sensor inputs, and charging operations. Motor drivers control the mecanum wheels, enabling forward, backward, and lateral movement.

The ESP32-CAM performs vision-based detection using a simple color thresholding algorithm to identify a predefined green tape [6], [13]. Based on the tape position, directional commands are transmitted to the Arduino through serial communication.

The ultrasonic sensor measures the distance between the transmitter coil and the ground surface. Based on a predefined threshold, a rack and pinion mechanism adjusts the vertical position of the transmitter coil.

Wireless power transfer is achieved using a transmitter and receiver module operating based on inductive coupling with an effective range of 3-6 mm [8], [11]. A relay module controls the power supply, activating charging only after alignment is achieved.

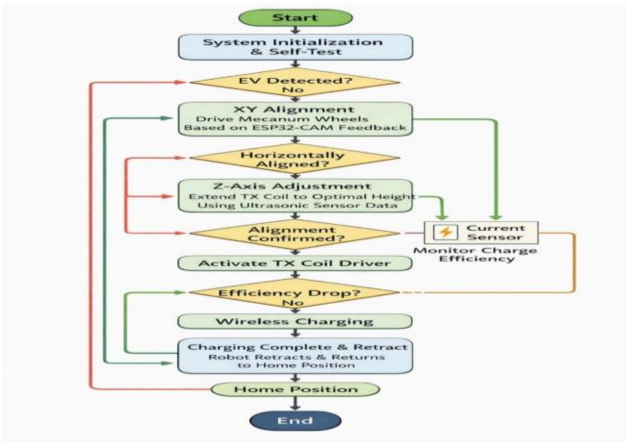

Fig. 2. Flowchart of the autonomous wireless EV charging process

The system follows a sequential control logic including forward movement, height detection, alignment, and charging as illustrated in Fig. 2. After a fixed charging duration, the robot returns to its initial position.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

VII. RESULTS AND DISCUSSION

The prototype of the developed system is shown in Fig. 3.

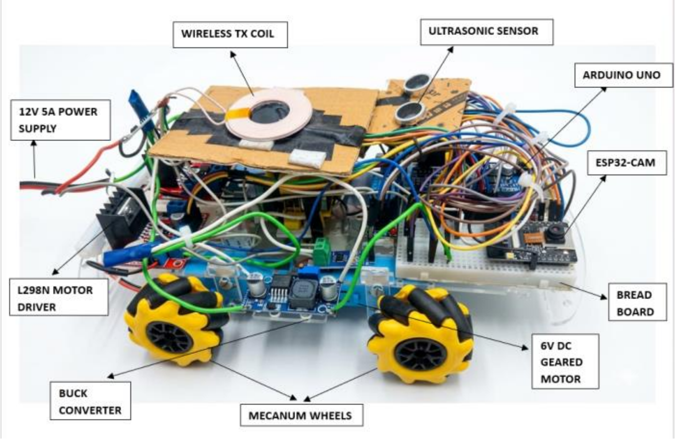

Fig. 3. Prototype of the autonomous robot car for wireless EV charging

When we tested our prototype in the lab under controlled conditions, it actually worked – the car found the tape and finished the whole charging cycle on its own.

The ESP32-CAM module was good at spotting the green tape and provide directional feedback for alignment. Based on the detected position, the robot performed necessary adjustments and reached an approximate alignment with the receiver coil. The ultrasonic sensor effectively measured the height and controlled the rack mechanism to position the transmitter coil appropriately.

Once alignment was achieved, the relay circuit activated the transmitter coil, enabling wireless power transfer through inductive coupling. The charging process was maintained for a fixed duration of 10 seconds, demonstrating the feasibility of contactless energy transfer.

The system performance depends on environmental factors such as lighting conditions and tape visibility. Even though the alignment isn't 100% perfect yet, it proves that a low-cost robot can handle wireless charging without any human need [9].

VIII. FUTURE SCOPE

The designed system demonstrates the feasibility of autonomous wireless EV charging; however, several improvements can be made to enhance its performance and real-world applicability.

The current implementation uses a simple color-based detection algorithm for alignment, which is sensitive to lighting conditions.
This may be further improved by incorporating advanced vision techniques such as OpenCV-based image processing or machine learning models for more accurate and robust detection.

The alignment mechanism in the present system is approximate and based on predefined movements. Future work can focus on implementing closed-loop feedback control using additional sensors to achieve precise positioning between the transmitter and receiver coils.

The system currently operates based on fixed timing sequences for movement and charging. This can be enhanced by introducing real-time monitoring and adaptive control strategies to improve efficiency and reliability.

Further improvements can be made in the wireless power transfer system by optimizing coil design and alignment to increase power transfer efficiency. Integration with actual electric vehicle systems and higher power levels can also be explored [10].

Additionally, the system can be extended to support fully autonomous navigation using advanced techniques such as SLAM (Simultaneous Localization and Mapping) and obstacle detection for operation in real-world environments.

Overall, these enhancements can transform the proposed prototype into a more intelligent, efficient, and practical autonomous charging system suitable for future EV infrastructure.

IX. CONCLUSION

This paper presents the design and implementation of an autonomous robot car for vision-guided wireless electric vehicle charging. The system integrates vision processing, sensing, motion control, and wireless power transfer into a unified platform to enable charging without human intervention.

The developed prototype successfully demonstrates forward navigation, basic alignment using visual feedback, and initiation of wireless charging through inductive coupling. The use of an ESP32-CAM module for tape detection and an ultrasonic sensor for height measurement contributes to achieving functional alignment and positioning of the transmitter coil.

Although the alignment achieved is approximate, the system validates the feasibility of autonomous wireless charging using a low-cost embedded platform. The results indicate that such systems can reduce user dependency and improve the convenience of EV charging.

In the end, we have shown that you can build an autonomous charging robot car just like our car without needing super expensive equipment. By combining vision detection with a flexible wheel system, our car can find a charging spot and align its coils without a human ever touching it. While we can still improve the precision, this project demonstration is a great proof-of-concept for the future of EV infrastructure.

ACKNOWLEDGMENT

The authors would like to thank our Head of the Department, **Dr. N. Rajesh Babu,** and our project guide, **Ms. B. Venkata**

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 04 , April - 2026

Ratnam for their guidance and support throughout the development of this project.

REFERENCES

[1] SAE International, "Wireless Power Transfer for Electric Vehicles (SAE J2954)," 2020.

[2] Z. Bi, T. Kan, C. Mi, Y. Zhang, Z. Zhao, and G. A. Keoleian, "A review of wireless power transfer for electric vehicles: Prospects to enhance sustainable mobility," Applied Energy, vol. 179, pp. 413-425, 2016. Available: https://doi.org/10.1016/j.apenergy.2016.07.003

[3] P. Corke, "Robotics, Vision and Control," Springer, 2017.

[4] N. Mohan, "Power Electronics: Converters, Applications and Design," Wiley, 2003.

[5] T. D. Nguyen, "Kinematic Modeling and Stable Control Law Designing for Four Mecanum Wheeled Mobile Robot Platform, Based on Lyapunov Stability Criterion", Engineering and Applied Sciences, vol. 8, no. 5, pp. 83-89, 2023. Available: https://doi.org/10.11648/j.eas.20230805.11

[6] M. G. Satria Adiguna, "Color and Size Sorting System with an ESP32-Based Robot Arm," Journal of Electrical Engineering Energy and Information Technology, vol. 11, no. 2, pp. 73-80, 2023. Available: https://doi.org/10.26418/j3eit.v11i2.68483

[7] Y. Özüpak, "Analysis of the Model Designed for Magnetic Resonance Based Wireless Power Transfer Using FEM," Journal of Engineering Research, 2022. DOI: 10.36909/jer.17631. Available: https://doi.org/10.36909/jer.17631

[8] V. Sari, "Design and Implementation of a Wireless Power Transfer System for Electric Vehicles", Issue 3, Article 110. Available: https://doi.org/10.3390/wevj15030110

[9] S. Shinde, "Wireless Electric Vehicle Charging Robot (Movable Charging Station)," International Research Journal of Innovations in Engineering and Technology, vol. 6, no. 2, pp. 39-41, 2022. Available:https://irjiet.com/Volume-6/Issue-2-February-2022/Wireless-Electric-Vehicle-Charging-Robot-Movable-Charging-Station-/951

[10] I. A. Ayoade and O. M. Longe, "Design and experimental analysis for a high-power wireless charging system design for electric vehicles," Frontiers in Future Transportation, 2026. Available: https://doi.org/10.3389/ffutr.2026.1739974

[11] Y. Özüpak, "Analysis of An Inductive Coupling Wireless Power Transfer System With a Finite Element Method For Charging Application Of Electric Vehicles," Bitlis Eren Üniversitesi Fen Bilimleri Dergisi, vol. 11, no. 1, pp. 209-219, 2022. Available: https://doi.org/10.17798/bitlisfen.1220387

[12] Arduino, "Arduino UNO Datasheet," Available: https://www.arduino.cc

[13] Espressif Systems, "ESP32-CAM Technical Reference," Available: https://www.espressif.com