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IOT-BASED SOLAR WIRELESS POWER TRANSFER SYSTEM FOR ELECTRIC VEHICLES

Ch. Srilatha[1], **Dr. M. Ajay Kumar**[2]

Student, Department of Computer Science Engineering, ALIET, Vijayawada[1]

Associate Professor, Department of Electrical and Electronics Engineering, ALIET, Vijayawada[2]

Abstract: An autonomous robotic vehicle system is developed using the ESP32 microcontroller to enable intelligent, sensor-based navigation without human intervention. This smart vehicle is designed to detect obstacles, make real-time decisions, and navigate automatically based on sensor input. The system integrates various components such as ultrasonic sensors, IR sensors, and a motor driver module to control motion and avoid collisions.

The ESP32 processes the sensor data and sends control signals to drive the motors through the L298N motor driver. It also supports IoT capabilities by transmitting data wirelessly for remote monitoring and control. A GPS module is incorporated for real-time location tracking, enhancing the system's mobility features. Power is supplied via a rechargeable battery, enabling wireless and portable operation.

Additionally, automation features such as obstacle detection, motor control, and potential wireless communication make this system scalable for integration with future technologies like AI and cloud-based navigation.

Keywords: Autonomous Vehicle, ESP32, Ultrasonic Sensor, IR Sensor, Motor Driver, GPS Module, IoT, Obstacle Avoidance, Smart Navigation

I. INTRODUCTION

With advancements in automation and intelligent systems, autonomous vehicles have become a major focus in modern transportation and robotics. These vehicles can navigate and operate without human intervention by using sensors, controllers, and decision-making algorithms.

This project aims to develop a compact, low-cost autonomous robotic vehicle using the ESP32 microcontroller. The vehicle is capable of detecting obstacles using ultrasonic and IR sensors and navigating accordingly without any manual control. The ESP32 serves as the central controller, processing data and controlling motor actions via a motor driver module.

Additionally, the system includes a GPS module for real-time location tracking and IoT capabilities for remote monitoring and potential future expansions like cloud control and AI integration. The entire setup is powered by a rechargeable battery, making it wireless, portable, and suitable for real-time demonstrations.

This project demonstrates how embedded systems and wireless communication can be integrated into an intelligent vehicle to enhance automation, safety, and decision-making in real-world applications.

1.2 Background and Motivation

In recent years, autonomous vehicles have gained significant attention due to their potential to revolutionize transportation, reduce accidents, and increase operational efficiency. These systems use sensors, microcontrollers, and smart algorithms to perform tasks that typically require human decision-making, such as navigation, obstacle avoidance, and path planning.

Traditional vehicles require manual control, which is prone to human error, fatigue, and limitations in reaction time. On the other hand, **autonomous robotic vehicles** can react quickly, operate continuously, and make intelligent decisions based on real-time sensor inputs.

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The motivation for this project stems from the increasing need for **low-cost, sensor-based autonomous platforms** for use in education, research, smart cities, and automation applications. By using the **ESP32 microcontroller**, which offers both processing power and built-in Wi-Fi/Bluetooth, the system becomes not only intelligent but also **IoT-ready**.

1.3 OBJECTIVES

The primary goal of this project is to design and implement an autonomous robotic vehicle that can navigate intelligently without human intervention. The specific objectives include:

- To develop a compact and cost-effective autonomous vehicle using the ESP32 microcontroller.
- To integrate ultrasonic and IR sensors for real-time obstacle detection and collision avoidance.
- To control the movement of the vehicle using a motor driver module and DC motors.
- To implement GPS tracking for real-time location monitoring of the vehicle.
- To utilize IoT (Internet of Things) capabilities of ESP32 for wireless monitoring and control.
- To provide a battery-powered, fully portable robotic platform suitable for smart automation environments.
- To lay the foundation for future enhancements like AI-based navigation and camera-based vision.

1.4 Scope of the Paper

This project focuses on building a smart, sensor-based autonomous robotic vehicle capable of navigating without human control. The key scope includes:

- Implementation of real-time obstacle detection and avoidance using ultrasonic and IR sensors.
- Use of ESP32 microcontroller for central processing, control, and IoT connectivity.
- Integration of motor driver modules and DC motors to handle vehicle movement.
- Addition of a GPS module for live location tracking.
- Wireless operation through rechargeable battery power, making it portable and mobile.
- Development of a base model suitable for educational use, research, and potential real-time applications like delivery bots, surveillance systems, or smart mobility.
- Provision for future enhancements, such as camera-based navigation, voice control, AI integration, and cloud-based data logging.

1.5 Significance of the Study

The development of an autonomous vehicle using the ESP32 microcontroller plays a significant role in the field of embedded systems and smart automation. This project demonstrates how low-cost components can be integrated to build an intelligent robotic system capable of navigating without human intervention. By using sensors like ultrasonic and IR, the vehicle can detect obstacles and avoid collisions in real time, improving both safety and efficiency. The inclusion of ESP32 adds wireless communication capabilities, allowing for IoT-based monitoring and control. This makes the system ideal not only for academic learning and research but also for real-world applications such as delivery robots, surveillance systems, and automated mobility solutions. Furthermore, the project promotes the use of compact, power-efficient, and scalable designs that can be enhanced with additional features like GPS, cameras, or AI, making it a strong foundation for future innovation in autonomous robotics.

II. LITERATURE SURVEY

Dinh Hoa Nguyen et al.[1] This research presented a robotic system designed using wireless sensor networks for autonomous navigation. Their approach to obstacle detection using ultrasonic sensors directly influenced this project’s implementation of sensor-based movement. In the proposed system, ultrasonic and IR sensors work together to detect obstacles in real-time and guide vehicle motion. The literature validated the idea of enabling autonomy through local sensing, which aligns with the ESP32’s ability to handle real-time sensor data and motor control efficiently.

2. S. Boopalan et al.[2] The study introduced a robotic system equipped with a vision camera and gas sensors to detect hazardous conditions. Although the sensors and application differed, their emphasis on multi-sensor fusion and automated decision-making inspired the integration of multiple sensors in this project. The proposed vehicle uses a simpler yet effective set of sensors (ultrasonic, IR, GPS), making it lightweight and cost-effective while still achieving autonomous behavior. The concept of system response to environmental input directly contributes to the navigation logic used in this work.

3. Tushar et al.[3] Their work focused on solar-powered dynamic wireless charging for electric vehicles using embedded systems and coils. While not directly related to navigation, it demonstrated the importance of combining mobility with automation and embedded control, which is relevant to the autonomous vehicle design in this project. Moreover, their

system lacked advanced monitoring and communication features. The present project fills that gap by incorporating IoT-based ESP32 control and real-time GPS tracking, offering both intelligence and connectivity.

4. R. Kamal[4] His book on embedded systems provided the theoretical and practical background for working with microcontrollers, sensors, and communication modules. Concepts such as sensor interfacing, serial communication, and PWM motor control were crucial in programming and operating the ESP32 module. The detailed architecture and programming techniques discussed in the book helped shape the software logic of the project and ensure reliable coordination between sensors and actuators.

5. D.A. Patil and S.V. Agiwal[5] This paper presented a mapping robot that navigates using a digital compass and ultrasonic sensors. Their method of reading sensor data for real-time direction control influenced the algorithm developed for obstacle avoidance in the current vehicle. Though the proposed project replaces the digital compass with GPS for modern tracking, the idea of sensor-guided navigation and embedded decision-making was directly inspired by this work, helping in implementing a reliable autonomous path-control system using ESP32.

III. COMPONENTS AND THEIR FUNCTIONS

There are important components used for the project on wireless charging for EVs are:

i. ESP32 Microcontroller
ii. Ultrasonic Sensor
iii. L298N Motor Driver Module
iv. DC Motors (Wheels)
v. Power Supply (Battery)
vi. GPS Module
vii. Motor Driver

i. ESP32 Microcontroller

The ESP32 is a powerful micro-controller with built-in Wi-Fi and Bluetooth capabilities, used for IoT (Internet of Things) applications. It enables wireless communication between the system and external devices like smartphones or cloud platforms. In this project, the ESP32 is used to monitor and control system parameters such as voltage, current, and battery status in real time. It collects data from sensors and sends it over the internet for remote access and analysis. This helps in improving system efficiency, enabling smart control, and providing better user interaction.

Fig 3.1 3.3 ESP32 Microcontroller

ii. Ultrasonic Sensor

Used to determine the real-time geographical location of the vehicle. The GPS sends latitude and longitude coordinates to the ESP32, which can then transmit this information to the cloud via Wi-Fi for tracking purposes.

Fig 3.2 Ultrasonic Sensor

iii. Motor Drive:

A motor driver is an electronic device used to control the speed and direction of a motor. It acts as an interface between the microcontroller (Arduino Uno) and the motor, as the controller cannot supply enough current to drive the motor directly. In this project, the motor driver is used to operate the DC motors of the electric vehicle. It receives control signals from the Arduino and accordingly drives the motors forward, backward, or stops them.

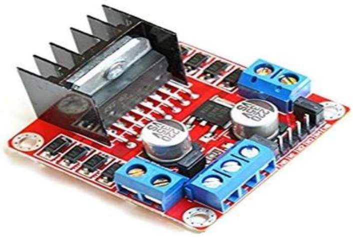

Fig 3.3 Motor Driver

iv. Electric Vehicle

These motors are responsible for moving the vehicle. When driven by the motor driver, they rotate the wheels, enabling the vehicle to move forward, reverse, or turn. The number of motors depends on the chassis design (usually 2 or 4).

Fig 3.5 DC Motor

v. Power Supply (Rechargeable Battery)

The power supply unit, typically a rechargeable Lithium-ion or Li-Po battery, serves as the backbone of the entire autonomous vehicle system by providing the essential electrical energy required to operate all the electronic components. This includes the ESP32 microcontroller, various sensors (such as ultrasonic and IR), the motor driver, and the DC motors used for movement.

The battery is selected based on the voltage and current ratings required by the system. For example, a 7.4V or 12V battery with a sufficient ampere-hour (Ah) rating ensures that the vehicle can operate continuously for a reasonable amount of time without recharging. It is crucial that the power supply be stable and reliable because voltage fluctuations can affect the functioning of sensitive components like the ESP32 and GPS module.

Fif 3.6 Power Supply (Rechargeable Battery)

vi. IOT

IoT (Internet of Things) refers to a network of connected devices that can collect, share, and exchange data through the internet. It allows systems to be monitored and controlled remotely in real time. In this project, IoT is implemented using the ESP32 to track parameters like voltage, current, and battery status. The collected data can be viewed on a mobile app or cloud platform, enabling better monitoring and decision-making. This makes the system smart, efficient, and easy to control from anywhere.

vii. GPS MODULE

Used to determine the real-time geographical location of the vehicle. The GPS sends latitude and longitude coordinates to the ESP32, which can then transmit this information to the cloud via Wi-Fi for tracking purposes.

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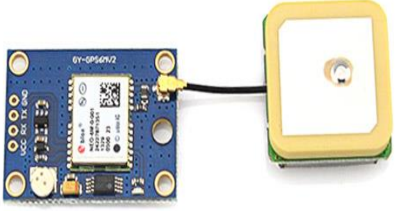

Fig 3.8 GPS Module

IV. WORKING

- Power Supply Initialization
  The vehicle is powered by a rechargeable battery that supplies voltage to the ESP32, motor driver, and sensors.
- Microcontroller Activation (ESP32)
  Once powered, the ESP32 initializes and starts reading data from all connected sensors like ultrasonic, IR, and GPS modules.
- Obstacle Detection (Ultrasonic & IR Sensors)
  The ultrasonic sensor measures distance to obstacles, while IR sensors detect surface lines or close-range objects. ESP32 processes this data in real time.
- Navigation Decision-Making
  Based on sensor input, the ESP32 decides the vehicle's movement (forward, turn, stop) and sends commands to the motor driver.
- Motor Control
  The L298N motor driver receives direction and speed signals from ESP32 and powers the DC motors accordingly to move the vehicle.
- GPS Location Tracking
  The GPS module sends location data to the ESP32, which can then be uploaded to an IoT platform for remote monitoring.
- IoT Integration via Wi-Fi
  ESP32 transmits system parameters like location, obstacle status, or fault alerts to a cloud platform using Wi-Fi.
- Autonomous Operation
  The vehicle continuously navigates and monitors its surroundings without human intervention, using programmed logic on the ESP32.

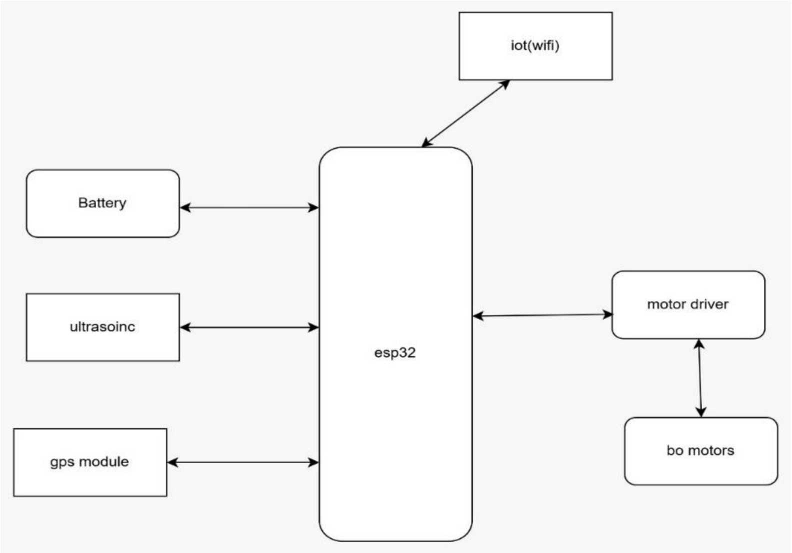

Fig 4 Block Diagram

V. RESULTS

The first graph represents the variation of Latitude (LT) with respect to time. The X-axis shows time, ranging from approximately 08:35 to 11:55, while the Y-axis shows latitude values around 16.5085 to 16.5089 degrees. Latitude indicates the north–south position of a location on the Earth. In this graph, the latitude value gradually increases over time, which means the device or vehicle is slowly moving toward the north direction. The change is small and smooth, indicating steady movement rather than sudden displacement. Therefore, this graph demonstrates that the system is tracking the real-time northward movement of the vehicle using GPS data.

Fig 5(A) Latitude (LT)

At the beginning (around 1st March), the current values fluctuate widely between about 19 and 29 units, indicating unstable conditions such as varying solar input or coil misalignment. As time progresses, the current slightly decreases to around 25 units and then increases again, reaching close to 31 units, which suggests improved power transfer efficiency.

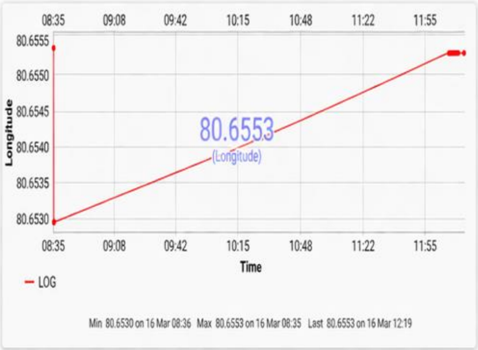

Fig 5(B) Longitude (LOG)

The third graph represents the variation of Distance (DST) with respect to time. The X-axis shows time, ranging from approximately 08:35 to 11:55, while the Y-axis shows distance values, likely measured in cente meters or meters using a distance sensor such as an ultrasonic sensor. In this graph, the distance values fluctuate significantly, starting around 20–40 units and later showing sudden increases and decreases, including peaks above 50 and drops close to zero. These variations indicate that the vehicle or device is encountering obstacles at different distances while moving. When the distance decreases, it means an object is closer to the sensor, and when the distance increases, the object is farther away or no obstacle is present. Therefore, this graph demonstrates real-time obstacle detection and changing proximity conditions during the movement of the vehicle.

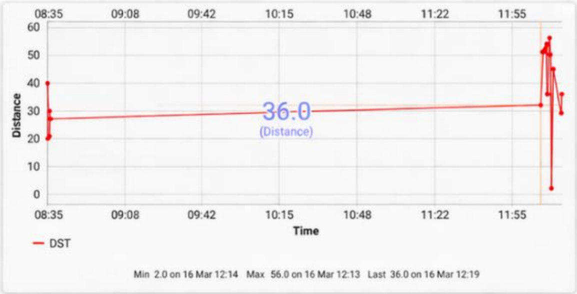

Fig 5(C) Distance

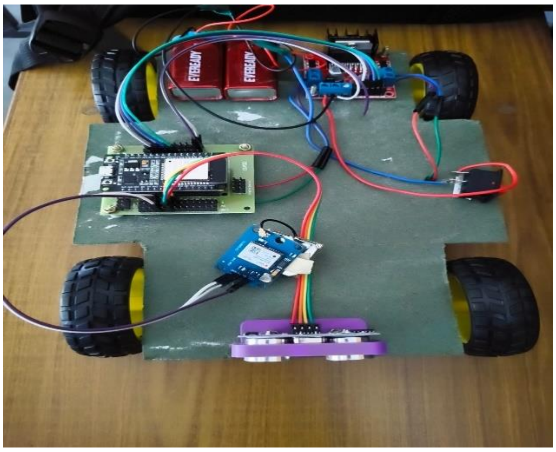

Fig 5(D) Autonomous Vehicle

VI. CONCLUSION

In conclusion, the developed autonomous vehicle system meets the intended objectives by providing real-time tracking, obstacle detection, and controlled self-navigation using the ESP32 platform. The project highlights the potential of embedded systems and IoT technologies in building intelligent transportation solutions, robotic platforms, and smart mobility applications. With further enhancements, this system can be adapted for practical uses such as automated delivery vehicles, surveillance robots, agricultural automation, and assistive mobility devices, thereby contributing to the advancement of autonomous and smart systems in the future.

This project successfully demonstrates the design and development of an autonomous vehicle system using the ESP32 microcontroller, integrating GPS technology for real-time location tracking and an ultrasonic sensor for obstacle detection and avoidance. The system is capable of continuously monitoring its geographical position through latitude and longitude data while simultaneously sensing nearby obstacles to ensure safe navigation. The experimental results confirm that the GPS module provides accurate and stable positioning information, as observed from the smooth variation in latitude and longitude values during vehicle movement. This indicates that the vehicle can determine its path and direction reliably in real time.

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