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Design and Implementation of Automated Car Parking System

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Abstract — **The rapid growth in urban vehicle density has created a critical need for efficient and intelligent parking systems. This paper presents the design and implementation of an automated car parking system using an ESP32 microcontroller. The system integratesultrasonic and infrared (IR) sensors for real-time obstacle detection and accurate identification of available parking spaces. Vehicle motion is precisely controlled using the L298N, enabling autonomous and reliable parking operations. Wireless communication through Bluetooth and Wi-Fi enables remote control and monitoring of the system, enhancing user convenience and flexibility. An LCD display provides real- time feedback, while a buzzer and LED indicators ensure safety through effective audio-visual alerts. A webcam module is also incorporated for live monitoring and future integration with advanced vision-based techniques. The system is powered by a portable power source, ensuring mobility and ease of implementation. The proposed system demonstrates accurate performance, reduced human intervention, and efficient real-time response. It offers a cost-effective, scalable, and practical solution for smart parking applications in modern urban environments.**

Keywords—**Automated Car Parking System, Bluetooth Communication, Embedded Systems, Obstacle Detection, Smart Parking Technology, Wi-Fi Communication.**

I. INTRODUCTION

An automated car parking system is designed using the ESP32 microcontroller, which offers powerful processing capabilities along with integrated Wi-Fi and Bluetooth for seamless wireless communication. This enables the system to be controlled, monitored, and upgraded easily, making it highly suitable for modern smart parking applications. The system focuses on minimizing human intervention while maximizing

Together, these sensors provide reliable environmental awareness, allowing the system to make precise and intelligent parking decisions The movement of the vehicle is controlled using the L298N motor driver, which enables smooth and accurate control of the motors. It ensures proper direction control, speed regulation, and stability of the vehicle during parking operations. This contributes to better maneuverability and reduces the chances of abrupt or unsafe For user interaction and safety feedback, the system incorporates an LCD display, buzzer, and LED indicators. The LCD provides real-time information such as system status, distance measurements, and parking instructions. The buzzer acts as an alert system to warn users of nearby obstacles or critical situations, while LEDs visually indicate system states like parking mode, obstacle detection, and successful parking completion. These features enhance user awareness and improve overall system safety.Additionally, a webcam is integrated into the system for monitoring purposes. It allows real-time video surveillance of the parking process, which can be useful for both users and administrators.Furthermore, the system is scalable and can be enhanced with additional features like mobile app integration, cloud connectivity, and IoT-based data.

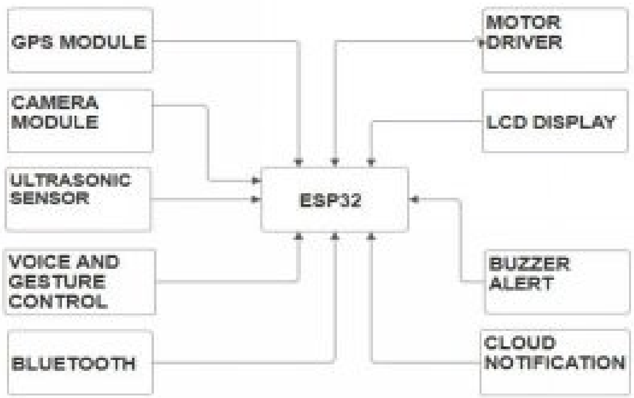

Fig. 1. Block Diagram of the Automated Car Parking System.

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II. SYSTEM DESIGN

A. Hardware Overview

The system is built around the ESP32 microcontroller and integrates a GPS module, camera module, ultrasonic sensor, voice and gesture control, Bluetooth, motor driver, LCD display, buzzer alert, and cloud notification. Its wireless capability enhances flexibility and ease of control. The compact design and low power consumption make it suitable for practical deployment. Overall, the system provides an efficient, scalable, and smart solution for modern parking challenges.

The system flowchart below describes the full operational sequence from power-on through sensor initialization, control mode selection, movement, obstacle detection, and system shutdown.

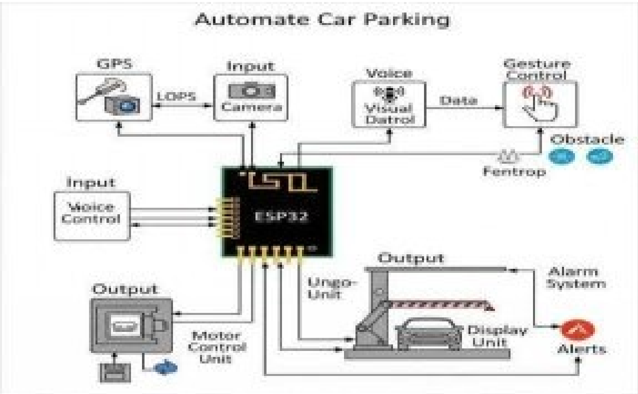

Fig. 2. Circuit Diagram of the Automated Car Parking System.

III. METHODOLOGY

A. Autonomous Mode

In autonomous mode, the system operates without human intervention. The ESP32 continuously collects data from the ultrasonic and IR sensors to detect obstacles and identify available parking spaces. When a suitable slot is detected, the control algorithm processes the sensor inputs and generates appropriate control signals. The L298N drives the DC motors to perform forward, reverse, and turning movements automatically. Real-time distance monitoring ensures accurate alignment and collision avoidance. Once properly positioned, the system stops the motors and activates the buzzer and LED to indicate successful parking.

B. Manual Control via Mobile App

In manual mode, the vehicle can be controlled remotely through a mobile application using Bluetooth or Wi-Fi connectivity. The user sends directional commands such as forward, reverse, left, right, and stop. These commands are received by the ESP32 and translated into motor control signals through the L298N driver module. The LCD display provides system status updates, while the webcam enables live monitoring during manual operation.

C. Alert and Safety Mechanism

The system includes an integrated safety mechanism to prevent collisions and ensure secure operation. The ultrasonic and IR sensors continuously monitor the surroundings critical distance, the system immediately stops the motors and activates the buzzer and LED indicators. This real-time alert system enhances operational safety and minimizes the risk of damage during parking maneuvers.

D. Power Management and Safety Features

The system is powered using a portable power bank, ensuring mobility and ease of deployment. Efficient voltage regulation is maintained to provide stable power to the ESP32, sensors, and motor driver. The design focuses on low power consumption for prolonged operation. Safety features include continuous monitoring through ultrasonic and IR sensors, enabling immediate response to obstacles. In critical situations, the system automatically stops the motors via the L298N and activates the buzzer and LED indicators to prevent collisions and ensure safe operation.

E. Visual Monitoring via ESP32-CAM

The system incorporates an ESP32-CAM module for real-time visual monitoring of the parking process. It captures live video footage, allowing users to observe vehicle movement and surroundings remotely via Wi-Fi. This enhances system awareness and provides additional support during both manual and autonomous modes. The visual data can also be utilized for future integration with computer vision algorithms, enabling advanced features such as object detection, lane tracking, and intelligent parking assistance. The camera stream can be accessed through a web interface or mobile device for convenient monitoring.

IV. CONSTRUCTION

The construction of the Automated Car Parking System is carried out through systematic integration of mechanical structures, electronic modules, sensing units, and communication components into a compact wireless prototype vehicle. A durable chassis platform is used to mount all hardware components securely. The ESP32 serves as the central control unit positioned strategically to ensure efficient wiring and signal distribution. The DC motors are rigidly fixed to the wheel assembly and interfaced with the L298N.

The ultrasonic sensor is mounted at the front section of the vehicle to provide accurate distance measurement and parking slot detection. IR sensors are installed at appropriate positions to assist in close-range obstacle detection and alignment during parking. The ESP32-CAM module is positioned at an elevated and stable angle to capture real-time visual data. A 16×2 LCD display is mounted on the upper surface for real-time status readings. The buzzer and LED indicators are integrated to generate audio-visual alerts during obstacle detection and parking completion.

A detailed overview of each component used in the system is provided below to explain their specific roles and interconnections.

Microcontroller (ESP32): The ESP32 acts as the central control unit of the automated car parking system. It processes input data from sensors, executes control algorithms, and sends commands to the motor driver and other output devices. Its built-in Wi-Fi and Bluetooth capabilities enable wireless

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communication for remote control and monitoring.

Motor Driver (L298N): The L298N is used to control the DC motors that drive the vehicle. It receives control signals from the ESP32 and regulates the direction and speed of the motors, enabling forward, reverse, and turning movements required for automated parking.

IR Sensor Module: The IR sensor module is used for obstacle detection and close-range sensing. It helps the system detect nearby objects and assists in maintaining proper alignment during the parking process, ensuring safe and accurate vehicle positioning.

Ultrasonic Sensor Module (HC-SR04): The ultrasonic sensor is responsible for measuring the distance between the vehicle and nearby obstacles. It works by emitting ultrasonic waves and calculating the time taken for the echo to return. This information helps the system identify available parking spaces and avoid collisions during navigation.

ESP32-CAM Module: The ESP32-CAM module provides real-time visual monitoring of the parking operation. It captures live video and transmits it through Wi-Fi, allowing users to observe the vehicle's movement and surroundings remotely. This feature enhances system monitoring and supports future computer vision applications.

V. WORKING

The working of the Automated Car Parking System is based on real-time sensing, intelligent decision-making, and precise motor control. The ESP32 acts as the central processing unit, continuously receiving inputs from sensors, and executing control logic accordingly.

Initially, the system scans the surrounding environment using the ultrasonic sensor to measure distance and detect available parking spaces. If the measured distance exceeds a predefined threshold, the system identifies it as a valid parking slot. Simultaneously, IR sensors monitor nearby obstacles to ensure safe navigation and assist in accurate alignment of the vehicle.

Once a parking space is detected, the ESP32 processes the sensor data and sends control signals to the L298N, which drives the DC motors. The vehicle then performs automated movements such as forward motion, turning, and reverse parking. Continuous feedback from sensors allows real-time adjustments, ensuring smooth and collision-free parking.

The system supports both autonomous and manual operation. In manual mode, the user can control the vehicle through a mobile application using Bluetooth or Wi-Fi. In autonomous mode, the system performs parking operations independently. The LCD display provides real-time information such as distance, system status, and parking confirmation. The buzzer and LED indicators are activated when obstacles are detected or when parking is successfully completed. Additionally, the ESP32-CAM module enables live video streaming for remote monitoring.

VI. RESULTS AND OBSERVATIONS

A. Functional Testing

The functional testing of the automated car parking system was conducted to evaluate the performance, accuracy, and reliability of individual components as well as the overall system. The ESP32 successfully coordinated all modules, ensuring smooth communication between sensors, motor driver, and output devices. The ultrasonic sensor demonstrated accurate distance measurement within the effective range, enabling reliable detection of parking slots. IR sensors effectively identified nearby obstacles and assisted in proper alignment during parking. The L298N provided stable and precise control of the DC motors, allowing smooth forward, reverse, and turning movements.

Wireless communication through Bluetooth and Wi-Fi was tested for manual control and monitoring, showing responsive and stable performance within the operational range. The LCD display accurately presented real-time data such as distance and system status, while the buzzer and LED indicators responded promptly during obstacle detection and parking completion. The ESP32-CAM module successfully streamed live video, enabling effective visual monitoring. Overall, the system performed reliably under different test conditions, demonstrating accurate sensing, efficient control, and safe automated parking functionality.

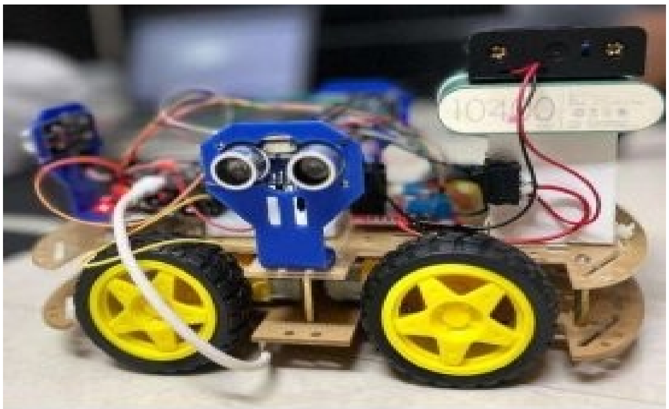

Fig. 3. Prototype of the Automated Car Parking System.

VII. CONCLUSION

This paper presented the design and implementation of an automated car parking system using an ESP32 microcontroller. The system successfully integrates ultrasonic and IR sensors for real-time obstacle detection and parking slot identification, with precise motor control via the L298N driver. Wireless connectivity through Bluetooth and Wi-Fi enables both autonomous and manual parking modes. The inclusion of an LCD display, buzzer, LED indicators, and an ESP32-CAM module ensures real-time feedback and visual monitoring. The system demonstrated reliable performance in functional testing, offering a cost-effective, scalable, and practical smart parking solution for modern urban environments.

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