Next Gen Parking System Management

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Abstract - The rapid increase in the number of vehicles in urban areas has created significant challenges in managing parking spaces efficiently. This paper presents a Next Gen Parking System that automates the detection and management of parking slots using sensor-based technology. The system utilizes IR and ultrasonic sensors along with an ESP32 microcontroller to monitor vehicle presence and provide real-time parking availability information. An LCD display is used to indicate the status of parking slots, helping drivers quickly identify vacant spaces. The proposed system reduces traffic congestion, minimizes human effort, and improves the overall utilization of parking areas. Additionally, the system can be extended with IoT-based features such as online booking and remote monitoring for enhanced functionality in smart city applications.

Index Terms—ESP32, Internet of Things (IoT), IR Sensor, Ultrasonic Sensors, Servo Motor.

I.INTRODUCTION

With the rapid growth of urbanization and the increasing number of vehicles, efficient parking management has become a major concern in modern cities. Traditional parking systems rely heavily on manual monitoring, which often leads to inefficiencies such as increased traffic congestion, time wastage, and poor utilization of available parking spaces. Drivers typically spend a significant amount of time searching for vacant parking slots, which contributes to fuel consumption and environmental pollution.

To address these challenges, smart parking systems have emerged as an effective solution by integrating sensor-based technologies and automation. These systems are capable of detecting vehicle presence and providing real-time information about parking availability. The advancement of embedded systems and Internet of Things (IoT) technologies has further enhanced the efficiency and scalability of such systems. In this paper, a Next Gen Smart Parking System is proposed, which uses IR and ultrasonic sensors along with an ESP32 microcontroller to monitor parking slot occupancy. The system provides real-time updates through display modules, enabling users to quickly identify available slots. This approach reduces human intervention, improves parking efficiency, and contributes to better traffic management.

II.LITERATURE SURVEY

With the advancement of technology, several smart parking systems have been developed to address the growing problem of parking management in urban areas. Earlier parking systems relied on manual supervision, which often resulted in inefficiency, human errors, and increased congestion. To overcome these limitations, researchers introduced sensor-based systems using technologies such as RFID, infrared (IR), and ultrasonic sensors to automatically detect vehicle presence.

Recent studies have focused on integrating Internet of Things (IoT) technologies into parking systems to provide real-time data and remote accessibility. IoT-based parking solutions allow users to check slot availability, reserve parking spaces, and navigate to the desired location using mobile applications or web platforms. These systems improve user convenience and optimize parking space utilization.

For instance, an IoT-based smart parking system uses embedded controllers and sensors to monitor parking slots and control entry and exit gates efficiently. Similarly, research on IoT-driven parking management systems highlights features such as online booking, authentication, and energy-efficient lighting systems. Advanced approaches also include

face recognition and vehicle identification techniques to enhance security and provide multi-location parking management.

However, many existing systems are complex and expensive, making them difficult to implement on a small scale. Therefore, there is a need for a cost-effective and efficient smart parking solution that can be easily deployed. The proposed system addresses these challenges by using simple sensors and a microcontroller to provide real-time parking information in an efficient and affordable manner.

III.RESEARCH METHODLOGY

The proposed Next Gen Smart Parking System is designed using a sensor-based approach combined with an embedded controller to monitor and manage parking slots efficiently. The methodology involves detecting vehicle presence, processing the data, and displaying real-time parking availability to users.

Initially, IR sensors are installed in each parking slot to detect whether a vehicle is present or not. These sensors continuously monitor the slot status and send signals to the microcontroller. Additionally, ultrasonic sensors are placed at the entry and exit points to detect vehicle movement and manage the opening and closing of the gate.

An ESP32 microcontroller is used as the central processing unit of the system. It collects data from all sensors, processes the information, and determines the availability of parking slots. Based on the processed data, the system updates the status of each slot as occupied or vacant.

3.1 System Design Approach

The proposed smart parking system is designed using a modular and sensor-based approach. Each parking slot is equipped with an IR sensor to detect vehicle presence. The sensors continuously send data to the ESP32 microcontroller for processing. Ultrasonic sensors are used at entry and exit points to detect vehicle movement. Based on this input, the system controls a servo motor for automatic gate operation. The microcontroller analyses the data to determine slot availability. An LCD display is used to show real-time parking status. This helps users quickly identify vacant slots. The system reduces human effort and improves efficiency. The design also supports future IoT integration for remote monitoring.

3.2 Requirement Analysis

The smart parking system requires both hardware and software components for proper operation. The hardware requirements include IR sensors, ultrasonic sensors, ESP32 microcontroller, LCD display, and a servo motor. These components are essential for detecting vehicle presence and controlling the system. The software requirements include programming using Embedded C or Arduino IDE for controlling the ESP32. The system also requires proper power supply and circuit connections for stable operation. Real-time data processing is needed to update parking slot availability. The system should be reliable, cost-effective, and easy to maintain. It must handle multiple parking slots efficiently. User-friendly display of information is also an important requirement. Additionally, the system should support future upgrades such as IoT integration and remote monitoring.

3.3 Hardware Selection

The hardware components are selected based on cost, efficiency, and ease of implementation. The ESP32 microcontroller is chosen for its high performance and built-in Wi-Fi capability. IR sensors are used in each parking slot due to their low cost and reliable object detection. Ultrasonic sensors are selected for accurate distance measurement at entry and exit points. A servo motor is used for automatic gate control because of its precise angle movement. An LCD display with I2C interface is chosen to reduce wiring complexity. All components operate at low voltage, ensuring energy efficiency. The selected hardware is easily available and compatible with each other. The system design ensures minimal power consumption and stable performance. These components also allow future expansion and IoT integration.

3.4 System Architecture Development

The system architecture is designed to integrate sensors, controller, and output modules efficiently.

IR sensors are placed in each parking slot to detect vehicle presence.

Ultrasonic sensors are installed at entry and exit points for vehicle detection.

All sensor data is sent to the ESP32 microcontroller for processing.

The microcontroller acts as the central unit to manage the entire system.

Based on the input data, it determines slot availability and gate control.
A servo motor is used to automate the opening and closing of the gate.
The processed information is displayed on an LCD module in real time.
The architecture ensures smooth communication between all components.
It is scalable and supports future IoT-based enhancements.

3.4 Circuit Design and Integration

The circuit design integrates all hardware components into a single functional system. IR sensors are connected to the input pins of the ESP32 to detect vehicle presence in each slot. Ultrasonic sensors are interfaced with trigger and echo pins for distance measurement. The ESP32 microcontroller processes all input signals and controls the output devices. A servo motor is connected to a PWM pin for automatic gate operation. The LCD display is interfaced using the I2C protocol to reduce wiring complexity. Proper power supply connections are ensured for stable operation of all components. Resistors and connecting wires are used for safe and reliable circuit design. All modules are integrated on a common platform for efficient communication. The complete circuit is tested to ensure accuracy and proper functionality.

3.5 Software Development

The software for the smart parking system is developed using the Arduino IDE for programming the ESP32 microcontroller. Embedded C is used to write the control logic for sensor data processing and system operation. The program continuously reads input from IR and ultrasonic sensors to detect vehicle presence and movement. Based on the sensor inputs, the software determines the availability of parking slots. Control signals are generated to operate the servo motor for gate automation. The LCD display is programmed to show real-time parking status. Efficient algorithms are used to ensure quick response and accurate detection. Proper libraries are included for sensor interfacing and display control. The code is structured for easy debugging and modification. Error handling is implemented to ensure reliable system performance. The software is tested under different conditions to verify accuracy. The design also allows future upgrades such as IoT integration and remote monitoring.

3.6 Prototype Development

The prototype of the smart parking system is developed to demonstrate the working model of the proposed design. A small-scale setup is created with multiple parking slots using IR sensors for detection. The ESP32 microcontroller is used to control and process all sensor inputs. Ultrasonic sensors are installed at entry and exit points to detect vehicle movement. A servo motor is integrated to automate gate opening and closing. An LCD display is used to show real-time parking availability. All components are connected using proper wiring on a breadboard or PCB. The prototype is tested with different scenarios to ensure accurate slot detection. Adjustments are made to improve sensor sensitivity and system performance. The working model successfully demonstrates automation and efficiency. The prototype also serves as a base for future enhancements and real-time applications.

3.7 System Testing

The system testing is conducted to ensure the proper functioning of all components and overall system performance. Each hardware component, including sensors, ESP32, servo motor, and LCD display, is tested individually. Integration testing is performed to verify communication between all modules. The IR sensors are tested for accurate detection of vehicle presence in each slot. Ultrasonic sensors are checked for correct distance measurement at entry and exit points. The servo motor operation is tested for smooth gate opening and closing. The LCD display is verified for real-time updates of parking availability. The system is tested under different conditions to ensure reliability. Any errors or delays are identified and corrected during testing.
The final system ensures accurate, efficient, and stable performance.

3.8 Performance Evaluation

The performance of the smart parking system is evaluated based on accuracy, efficiency, and reliability. The IR sensors are tested for their ability to correctly detect vehicle presence in each slot. The ultrasonic sensors are evaluated for precise detection of vehicle movement at entry and exit points. The response time of the system is measured to ensure real-time updates. The ESP32 microcontroller is assessed for its processing speed and stability. The servo motor

performance is checked for smooth and timely gate operation. The LCD display is evaluated for clarity and correctness of information. The system is tested under different environmental conditions to ensure consistent performance. Power consumption is analyzed to confirm energy efficiency. The overall system demonstrates improved parking management and reduced human effort. The evaluation confirms that the system is reliable and suitable for real-world applications.

IV.PROJECT DEFINITION

The project focuses on developing a smart parking system to manage parking spaces efficiently. The system is designed to automatically detect vehicle presence using sensors. It aims to provide real-time information about available and occupied parking slots. The ESP32 microcontroller is used to process sensor data and control system operations. The system reduces the time required for drivers to find parking spaces. It minimizes traffic congestion in parking areas. The project also reduces human effort by automating the monitoring process. An LCD display is used to show parking status clearly. The system is designed to be cost-effective and easy to implement. It can be further enhanced with IoT features for remote access and smart city applications.

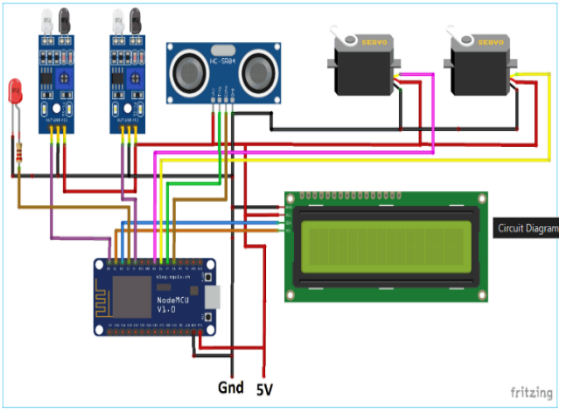
V.SCOPE OF PROJECT

The scope of the project focuses on developing an efficient and automated parking management system. It can be implemented in places such as shopping malls, offices, and public parking areas. The system helps in reducing traffic congestion caused by searching for parking spaces. It improves the utilization of available parking slots through real-time monitoring. The project is scalable and can be expanded to handle larger parking areas. It supports future integration with IoT technologies for remote access and monitoring. The system can be enhanced with mobile applications for online booking. It also allows integration with cloud storage for data analysis. The design is cost-effective and suitable for small to medium-scale implementation. Overall, the project contributes to smart city development and improved urban infrastructure.

VI.PRINCIPLE

The working principle of the smart parking system is based on sensor-based detection and automated control. IR sensors are used to detect the presence of a vehicle in each parking slot. When a vehicle occupies a slot, the sensor sends a signal to the ESP32 microcontroller. The microcontroller processes this data to determine whether the slot is occupied or vacant. Ultrasonic sensors are used to detect vehicle movement at entry and exit points. Based on this detection, the system controls the gate using a servo motor. The processed information is displayed on an LCD screen in real time. This allows users to easily identify available parking spaces. The system operates automatically with minimal human intervention. Overall, the principle ensures efficient parking management and reduced congestion.

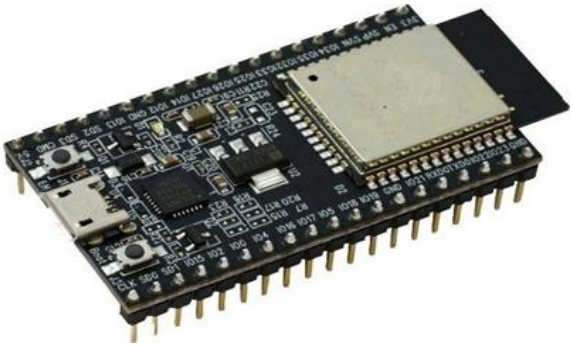
VII.CONSTRUCTION



The circuit consists of a NodeMCU (ESP32) as the main controller. IR sensors are connected to digital input pins to detect vehicle presence in parking slots. Each IR sensor sends HIGH or LOW signals based on object detection. An ultrasonic sensor (HC-SR04) is connected using trigger and echo pins to detect vehicle movement at entry/exit. Two servo motors are connected to PWM pins for automatic gate control. An LCD display with I2C interface is connected using SDA and SCL pins for output display. All components share a common ground (GND) connection. A 5V power supply is used to power the sensors, LCD, and servos. The NodeMCU processes all sensor inputs and controls outputs accordingly. The circuit ensures real-time monitoring and automated parking management.

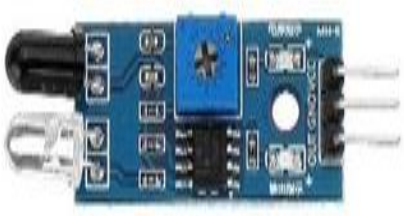
VIII.CONSTRUCTION DETAILS

A) ESP-32 MICR0CONTROLLER



The ESP32 acts as the main controller of the system.
It processes data received from sensors and controls outputs.
It has built-in Wi-Fi for future IoT integration.
It supports multiple GPIO pins for interfacing components.
It ensures fast and efficient real-time processing.

B) IR SENSOR MODULE

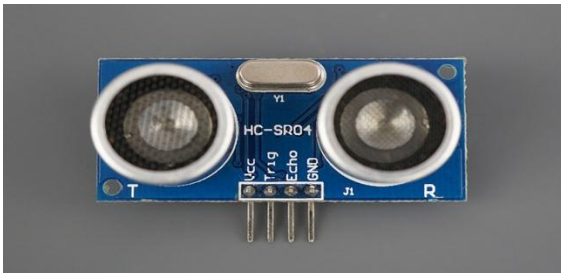


IR sensors are used to detect vehicle presence in each slot.
They work based on infrared light reflection.
Output changes when an object is detected.
They are low-cost and easy to interface.
Used for accurate slot occupancy detection.

C) SERVO MOTOR

Used for automatic gate opening and closing.
Operates based on PWM signals from controller.
Provides precise angular movement.
Consumes low power and is efficient.
Ensures smooth entry and exit operation.

D) ULTRASONIC SENSOR (HC-SR04)



Used to measure distance using sound waves.
Detects vehicles at entry and exit points.
Works with trigger and echo signals.
Provides accurate distance measurement.
Helps in automatic gate control.

E) LCD DISPLAY (16x2 with I2C)

Displays parking slot availability.
Uses I2C protocol to reduce wiring.
Connected via SDA and SCL pins.
Provides real-time system status.
Easy to interface with microcontroller.

F) POWER SUPPLY

Provides required voltage to all components.
Typically 5V supply is used in the circuit.

Ensures stable and continuous operation.
Common ground is shared across components.
Prevents voltage fluctuation issues.

IX.WORKING

The system operates by continuously monitoring parking slots using IR sensors.
Each IR sensor detects the presence of a vehicle in its respective slot.
The sensor sends signals to the ESP32 microcontroller.
The microcontroller processes this data to determine slot availability.
An ultrasonic sensor detects vehicles at the entry and exit points.
Based on this detection, the system controls the servo motor to open or close the gate.
The updated parking status is displayed on the LCD screen in real time.
Drivers can easily identify vacant slots without searching manually.
The system reduces traffic congestion and saves time.
Overall, it provides an automated and efficient parking management solution.

X.ADVANTAGES

The system provides automatic detection of parking slots without human intervention.
It reduces the time required for drivers to find available parking spaces.
Traffic congestion in parking areas is minimized.
The system improves efficient utilization of parking space.
It reduces manpower and operational cost.
Real-time information is displayed to users through the LCD.
The system is cost-effective and easy to implement.
It offers high accuracy in detecting vehicle presence.
The design is scalable and can be expanded for larger areas.
It supports future enhancements such as IoT integration and remote monitoring.

XI.APPLICATIONS

The system can be used in shopping malls for efficient parking management.
It is suitable for office buildings and corporate campuses.
Can be implemented in airports for organized vehicle parking.
Useful in hospitals to manage emergency and visitor parking.
Applied in smart city infrastructure projects.
Can be used in residential apartments for parking control.
Helpful in railway stations and bus terminals.
Can be deployed in public parking areas and complexes.
Suitable for event venues and stadiums.
Can be integrated with IoT systems for advanced parking solutions.

XII.RESULT

The developed smart parking system successfully detects vehicle presence in each parking slot.
The IR sensors accurately identify whether slots are occupied or vacant.
The ESP32 microcontroller processes the data efficiently in real time.
The ultrasonic sensor effectively detects vehicles at entry and exit points.
The servo motor operates smoothly for automatic gate control.
The LCD display shows correct and updated parking availability.
The system reduces the time required to find parking spaces.
It minimizes traffic congestion in parking areas.
The overall system performance is stable and reliable.
The prototype demonstrates an efficient and automated parking management solution.

XIII.CONCLUSION

The smart parking system provides an effective solution for modern parking challenges.
It automates the process of detecting and managing parking slots.
The use of sensors ensures accurate and real-time monitoring.
The ESP32 microcontroller enables efficient data processing and control.
The system reduces traffic congestion and saves time for users.
It minimizes human effort and operational complexity.

The prototype demonstrates reliable and stable performance.
The design is cost-effective and easy to implement.
It can be expanded for larger parking areas and smart city applications.
Future enhancements can include IoT integration and mobile-based control systems.

IV.FUTURE SCOPE

The system can be enhanced with IoT integration for remote monitoring.
A mobile application can be developed for real-time slot booking.
Cloud storage can be used for data analysis and management.
Integration with GPS can help users navigate to parking locations.
Online payment systems can be added for automated billing.
AI-based algorithms can improve parking prediction and optimization.
Camera-based vehicle detection can enhance security.
The system can be expanded to multi-level parking structures.
Energy-efficient components can be used to reduce power consumption.
It can be integrated into smart city infrastructure for large-scale deployment.

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