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Design and Implementation of a Real-Time Smart Parking System Using IoT for Efficient Urban Mobility

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Abstract: ***The rapid growth of vehicles in cities has greatly increased parking-related problems, such as congestion, wasted space, and time spent finding available parking spots. This paper outlines the design and implementation of a Smart IoT-Based Car Parking System that uses the MQTT communication protocol for real-time monitoring of parking slots and automated gate control. The proposed system includes IR sensors for detecting slot occupancy, an ultrasonic sensor for spotting vehicles at the entrance, and a servo motor for operating the gate automatically. An Arduino microcontroller connected to an ESP Wi-Fi module allows wireless communication with an MQTT- based mobile dashboard. The developed prototype delivers real-time updates on parking slots, improves efficiency, cuts down on manual work, and provides a scalable solution for modern smart parking needs.***

Keywords: Smart Parking, IoT, MQTT Protocol, Arduino, IR Sensor, Ultrasonic Sensor, Servo Motor, Parking Automation.

I. INTRODUCTION

With the growing number of vehicles in urban areas, parking management has become a major issue. Traditional parking systems often need manual supervision and do not provide real-time information about slot availability. This leads to traffic jams and inconvenience for drivers. Adding Internet of Things (IoT) technologies to parking systems offers an efficient and automated solution to these problems. IoT-based parking systems use sensors, wireless communication modules, and cloud or mobile interfaces to check parking occupancy and automate operations. [1], [2].

This project suggests a Smart IoT-Based Car Parking System that includes:

- IR Sensors for detecting parking slot occupancy
- Ultrasonic Sensor for vehicle detection at the entry gate
- Servo Motor for automated gate control
- ESP Wi-Fi Module for internet connectivity
- MQTT Protocol for real-time data transmission
- Mobile Application Dashboard for user monitoring

II. LITERATURE SURVEY

Numerous IoT-based parking systems have been proposed in recent years to tackle urban parking problems. Sensor-based parking systems have shown better vehicle detection accuracy and occupancy monitoring. Wireless communication technologies like Wi-Fi, GSM, and Bluetooth have allowed for remote parking management. Cloud- integrated parking systems offer centralized data storage and analytics for smart city applications. MQTT-based IoT communication systems have been effective for low-bandwidth and real-time embedded applications.

However, many existing parking systems still face issues, including:

- High implementation cost
- Complex hardware integration
- Lack of easy mobile-based monitoring
- Limited scalability for educational prototypes

The proposed system solves these problems with a cost-effective and modular IoT- based design.

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III. METHODOLOGY

A. Problem identification

Traditional parking systems face challenges such as:

- No real-time slot monitoring
- Manual gate operation
- Driver time wastage
- Traffic congestion near parking areas

The need for an automated and low-cost parking solution led to the development of this system.

B. System design

The proposed parking system includes these hardware and software parts:

- Arduino Microcontroller
- ESP Wi-Fi Module
- IR Sensors
- Ultrasonic Sensor
- Servo Motor
- LCD/LED Display
- MQTT Mobile Dashboard

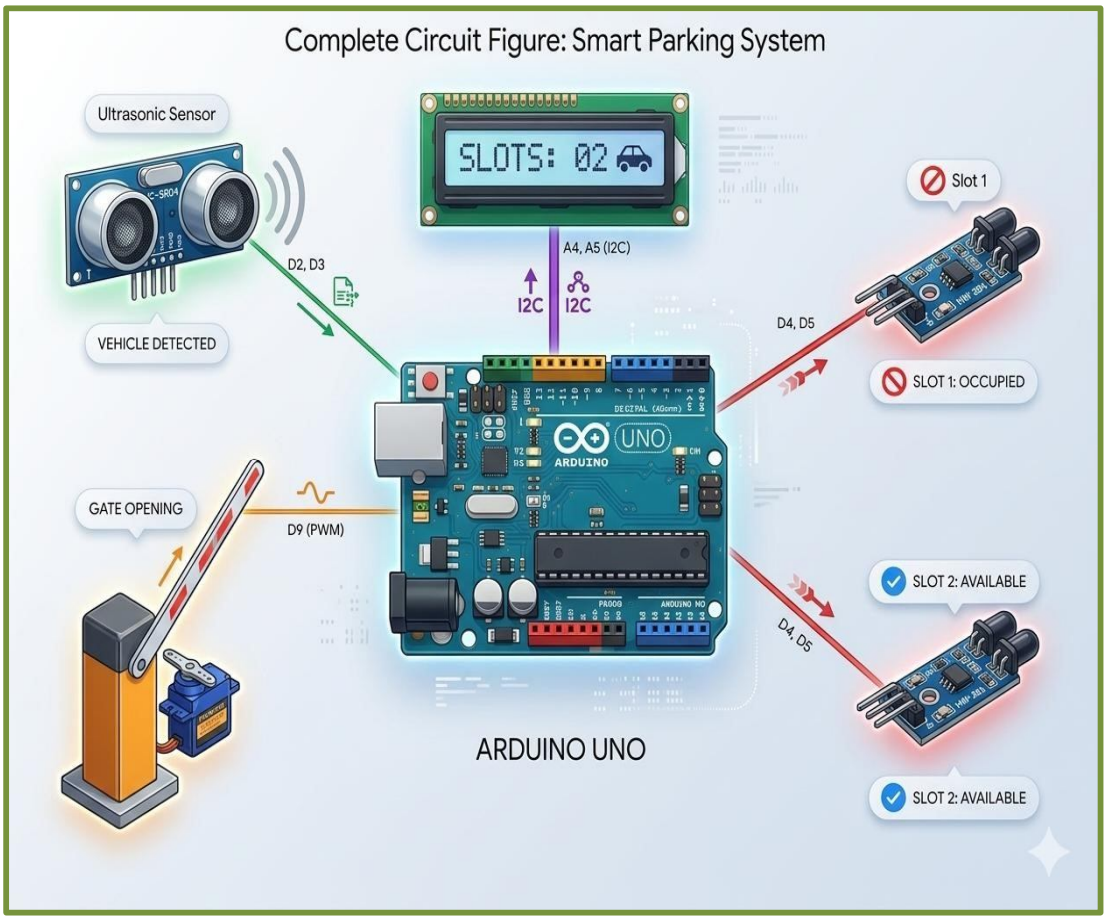


Fig. 1 System design

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C. Working process flowchart

System Operation:

When a vehicle approaches the entry gate, it is first detected by an ultrasonic sensor that triggers the system's logic. The system immediately verifies the availability of parking slots using real-time data collected from IR sensors placed in each bay. If a free slot is confirmed, a servo motor rotates to open the gate; otherwise, the gate remains closed to prevent overcrowding.

Throughout the process, the IR sensors continuously monitor occupancy and instantly push status updates to both a local LCD screen and an MQTT-based mobile app for remote tracking.

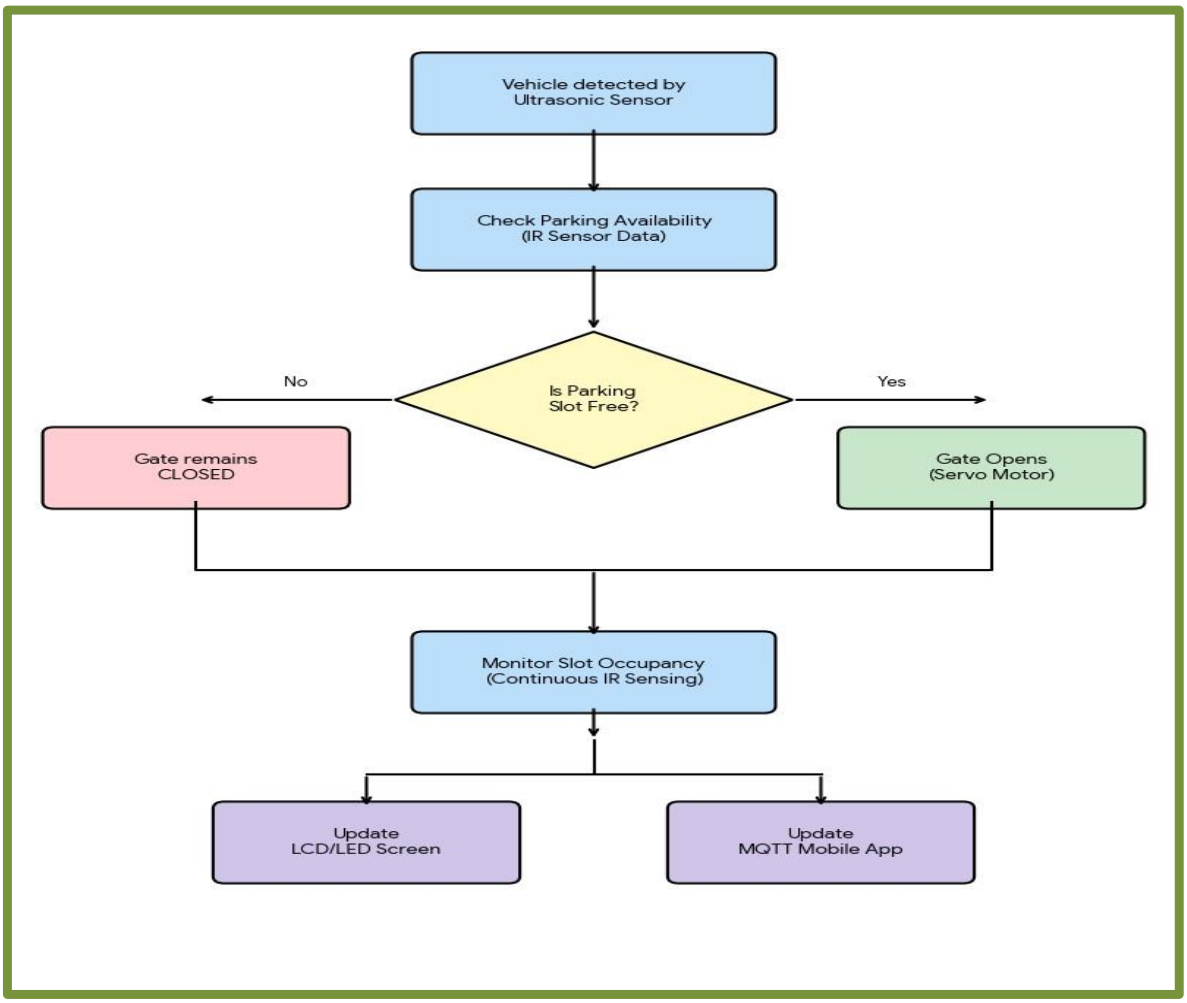


Fig. 2 Working process flow chart

D. Mqtt communication

The MQTT protocol is employed for lightweight real-time communication between the parking hardware and user dashboard. Instead of devices talking directly to each other, it communicate through a central broker, which ensures data is delivered efficiently even over unstable networks. It is highly valued for its minimal power consumption and small data overhead, making it the perfect choice for remote sensors and mobile applications.

MQTT Broker: test.mosquitto.org Topics Used:

rj1 → Parking Slot 1 Status rj2 → Parking Slot 2 Status

MQTT ensures low-latency and efficient communication suitable for embedded IoT applications.

E. Algorithm

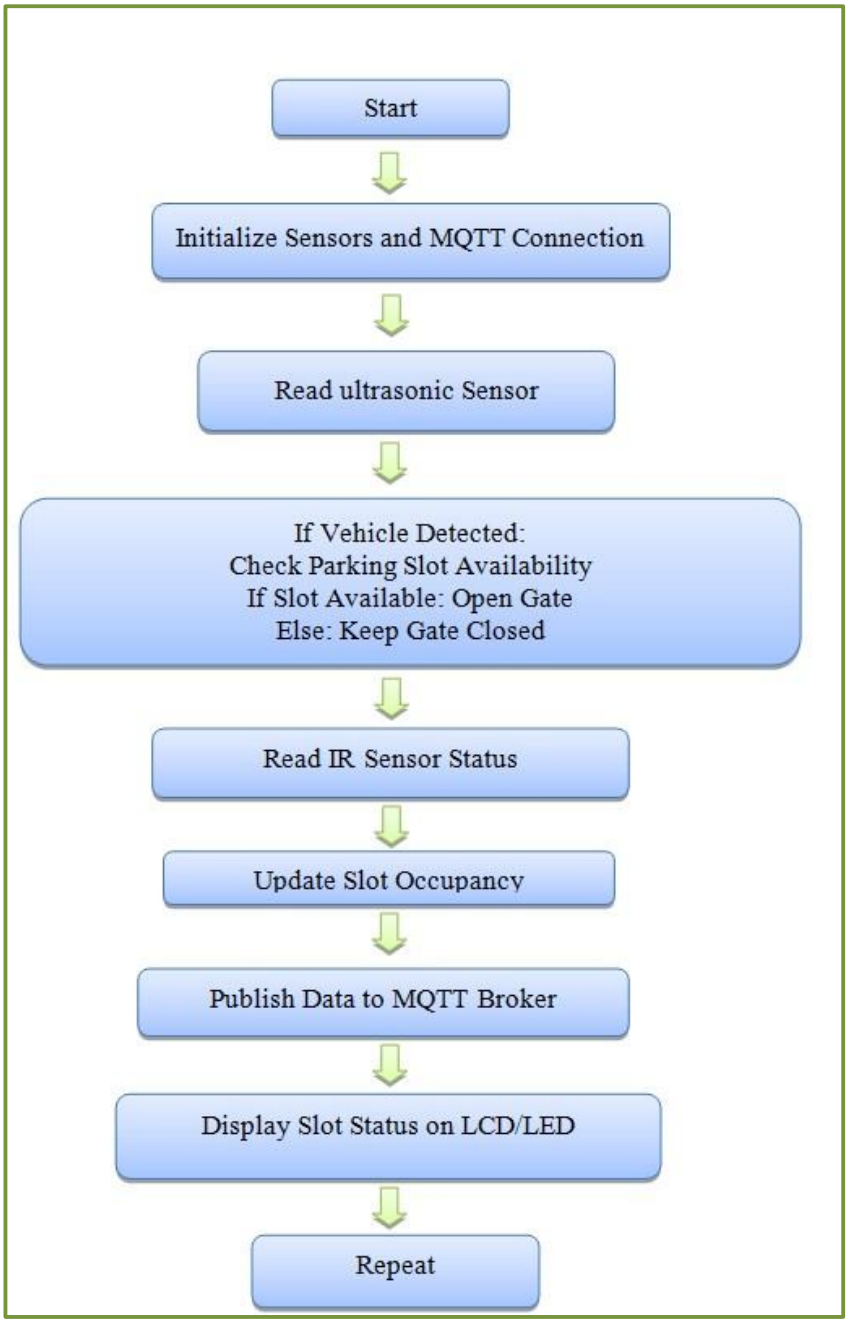


Fig. 3 Functional algorithm

IV. DESCRIPTION OF COMPONENTS

A. Arduino Microcontroller

The Arduino acts as the main controller of the system. It handles all the inputs from the sensors and decides what should happen next. For example, it checks if parking slots are available and then controls the gate and display accordingly. It also sends data to the Wi-Fi module.



Fig. 4 Arduino uno

B. Ir sensors

IR sensors are used in each parking slot to detect whether a car is present. When a vehicle is parked, the sensor detects it through reflected infrared light. These sensors are simple and work well for short distances, which makes them suitable for this project.



Fig. 5 IR sensor

C. Ultrasonic sensor

The ultrasonic sensor is placed near the entrance to detect vehicles coming in. It measures the distance of an object using sound waves. When a car comes close enough, it alerts the system so it can check if parking is available.



Fig. 6 Ultrasonic sensor

D. Servo motor

The servo motor is used to control the gate. It opens when parking space is available and stays closed when the parking is full. It works based on signals from the Arduino and can move to specific angles.



Fig. 7 Servo motor

E. Esp wi-fi module

The ESP module helps connect the system to the internet. It sends information like parking availability to an online platform. This allows users to check the status remotely.



Fig. 8 ESP8266

F. Lcd/led display

The display shows the number of available and occupied parking slots. It updates automatically, so users can quickly see the parking status without needing any extra device.



Fig. 9 LCD display

V. FABRICATED MODEL

The model created is a small-scale parking layout model consisting of two parking spaces, automated access gates, sensor placement, and wireless monitoring using the MQTT dashboard. This was successfully developed using actual components that were programmed in the Arduino IDE software and the MQTT Dashboard software.

VI. RESULTS AND DISCUSSION

The developed prototype was tested under multiple operating conditions.

A. Observations

- Accurate vehicle detection using ultrasonic sensor
- Reliable slot occupancy detection via IR sensors
- Smooth gate control through servo motor
- Real-time status updates on MQTT Dashboard
- Minimal communication delay during data transmission

B. Advantages

- Low-cost implementation
- Easy hardware integration
- Real-time parking monitoring
- Scalable for larger parking systems
- User-friendly interface

C. Limitations

- Dependent on stable Wi-Fi connectivity
- Sensor accuracy may reduce under harsh environmental conditions
- Online booking feature currently not integrated

VII. CONCLUSION

The Smart IoT-Based Car Parking System successfully demonstrates the implementation of a low-cost, real-time, and automated parking management solution using IoT and MQTT protocol. The system effectively detects parking slot occupancy, automates gate control, and provides live parking status updates through a mobile application. This prototype can serve as a foundation for larger-scale smart parking infrastructure in educational, residential, and commercial environments.

VIII. FUTURE SCOPE

Future enhancements to the system may include:

- Online Parking Slot Booking
- Payment Gateway Integration
- Cloud Database Logging

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- Camera-Based Vehicle Recognition
- AI-Based Parking Prediction
- Integration with Smart City Infrastructure
- Multi-Level Parking Support

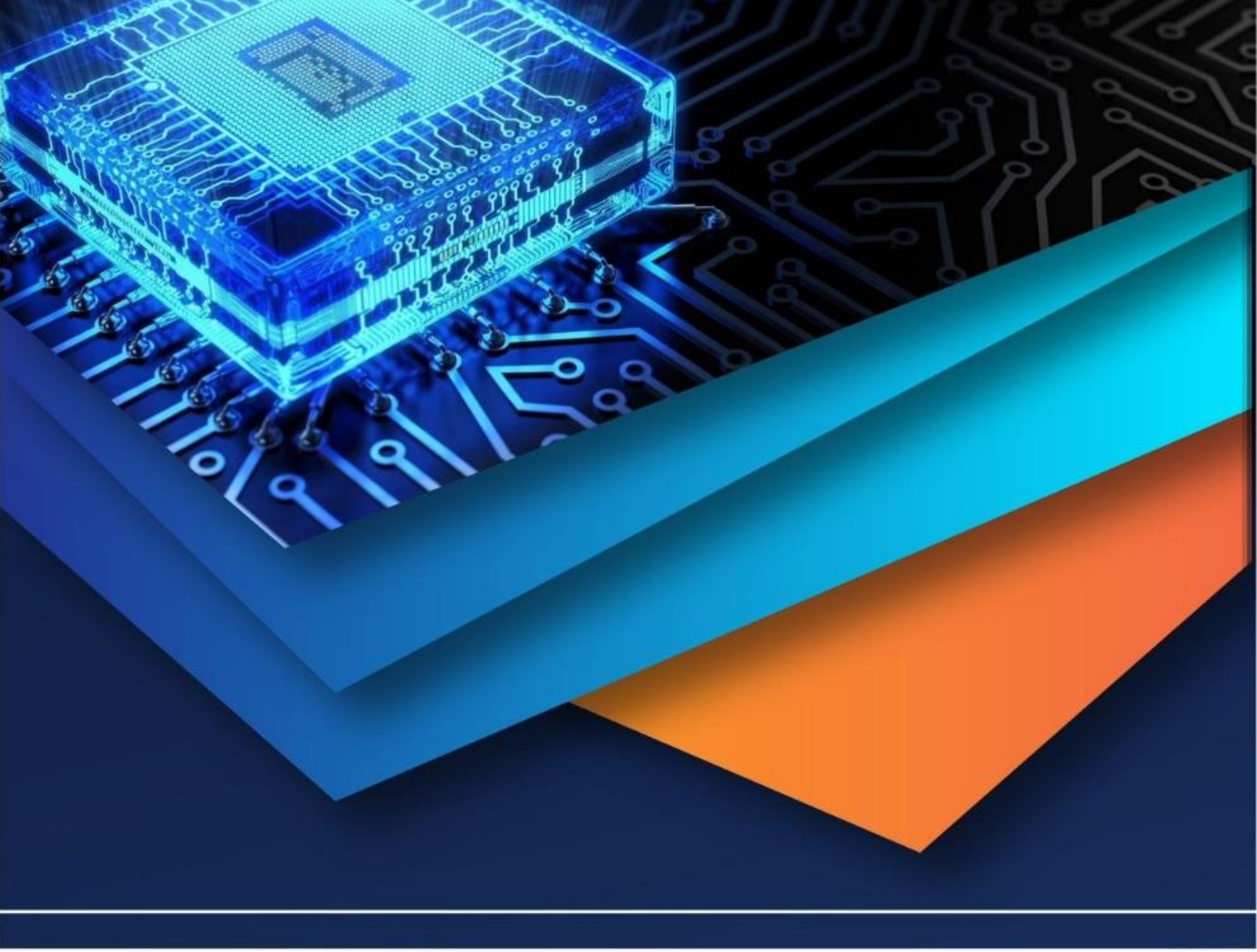
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