QR-BASED SMART PARKING SYSTEM USING ARDUINO

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***Abstract*— Current parking systems involve huge manpower for management and requires user to search for parking space floor by floor. This project aims to develop a Smart Parking System that utilizes QR code technology and IR sensors to enhance vehicle management and optimize parking space utilization, with Arduino serving as the main microcontroller. The purpose of this smart parking system is to streamline the vehicle parking process by providing real-time slot availability and guiding vehicles to empty spaces within the parking area. In this system, when a vehicle enters the parking facility, it scans a QR code at the entrance and displays the outline of the available parking slot. This method employs sensors to monitor slot occupancy and ensures accurate, up to-date information on vacant slots. After scanning the QR code, the driver is directed to an available slot, reducing time spent searching and minimizing congestion. The project utilizes IR sensors, QR code scanning and LCD display to provide a seamless parking experience. The results show that this QR-based smart parking system improves parking efficiency, saves time, and reduces traffic within parking areas, making it a feasible and scalable solution for modern parking challenges.**

Keywords—Smart parking system, QR code technology, IR sensors, Arduino microcontroller.

INTRODUCTION

In today's Modern World, the demand for efficient parking solutions is growing significantly due to increasing vehicle usage and limited parking spaces. Traditional parking systems often face challenges such as time-consuming manual processes, inefficient space utilization, and congestion caused by vehicles searching for vacant slots. These inefficiencies not only lead to frustration for drivers but also contribute to increased fuel consumption and environmental pollution. To address these issues, we present the QR-Based Smart Parking System Using Arduino, a state-of the-art solution designed to revolutionize parking management. This system integrates QR code technology, Arduino microcontrollers, IR sensors, and LCD displays to automate and streamline the parking process. The core concept of the project involves the use of QR codes for real-time parking slot identification and guidance. When a vehicle arrives, it is detected by IR sensors at the entrance gate, which opens automatically. The driver then scans a QR code displayed at the entrance using their mobile phone. Upon scanning, the system displays the available parking slots and a navigation route on the driver's mobile screen. By following this route, the driver is directed to an empty slot, ensuring efficient parking. This system reduces the time spent searching for a vacant spot, optimizes parking space utilization, and enhances the overall user experience.

LITERATURE SURVEY

Traditional Parking Systems face several challenges, such as time wasted by drivers searching for vacant slots, poor space utilization, and high dependency on manual labor for slot allocation and gate operations. These inefficiencies often lead to frustration for both users and operators. As such, the need for automated, efficient, and scalable parking systems has become increasingly apparent [1].

IoT-Based Parking Systems have been introduced to address these inefficiencies by integrating interconnected devices like sensors and cloud computing to monitor and manage parking spaces in real-time. These systems enable users to remotely check slot availability and even reserve spaces. However, the high costs of implementing IoT devices and integrating them across multiple locations remain significant limitations of this technology [2].

RFID-Based Systems offer automation for vehicle identification and access control by attaching RFID tags to vehicles, which are detected by RFID readers at entrances for fast and secure parking access. Although these systems

automate entry and exit, they fail to provide real-time updates on parking slot availability and do not offer navigation assistance for drivers, which limits their efficiency in large parking areas [3].

QR Code-Based Systems represent a more cost-effective solution. QR codes can be scanned using any smartphone, eliminating the need for additional hardware. These systems link directly to real-time data, providing parking slot availability and navigation guidance. However, these systems require integration with sensors for accurate real-time monitoring, and their effectiveness is dependent on the backend configuration for dynamic updates [4].

Sensor-Based Systems, such as infrared (IR), ultrasonic, and camera-based sensors, are commonly used for slot occupancy detection. IR sensors are inexpensive and reliable for detecting vehicles, while ultrasonic sensors provide greater accuracy but are more expensive. Camera-based systems offer advanced features like license plate recognition, enhancing security. However, these systems face challenges, including environmental factors that affect sensor performance and high costs, especially with camera-based solutions [5].

Cloud-Based Parking Management Systems enable centralized data management across multiple parking lots, allowing remote access. These systems offer real-time monitoring and are often integrated with mobile apps for a seamless user experience. However, they rely heavily on stable internet connectivity and incur high operational costs due to cloud service dependencies [6].

PROBLEM FORMULATION

To design and develop a "Smart Parking System" using a combination of QR code technology, IR sensors, and an Arduino microcontroller to enhance parking space utilization and provide real-time parking slot availability.

PROBLEM DEFINITION

Traditional parking systems are often inefficient and inconvenient for users due to their reliance on manual processes. These systems require significant manpower, which can lead to delays and mistakes. Drivers often spend a lot of time searching for an available parking space, which causes frustration and adds to traffic congestion in parking areas. Additionally, traditional systems do not provide real-time information about parking slot availability, resulting in poor space utilization. These issues lead to wasted time, increased fuel consumption, and an unsatisfactory parking experience. Solving these problems is essential for creating more efficient and user-friendly parking management systems.

OBJECTIVE OF PROJECT

1. Provide Real-Time Updates on Slot Availability: Using IR sensors, the system constantly monitors the occupancy status of parking slots. This information is updated in real-time, ensuring that drivers have access to accurate data about available spaces.

2. Improve Parking Efficiency and User Satisfaction: By streamlining the parking process and minimizing time spent searching for slots, the system enhances user convenience and satisfaction. It also reduces congestion, making parking areas more organized and efficient.

SCOPE OF PROJECT

This project is versatile and can be implemented in a variety of environments, including Shopping Malls, Airports, Residential Complexes and Ensures efficient parking during peak hours, reducing congestion and improving customer experience. Provides real-time slot availability to assist travelers in parking quickly, minimizing delays. Offers a smooth parking experience for residents and their guests by automating the parking process.

DRAWBACKS OF EXISTING SYSTEM

1. High Costs: Implementation of advanced systems, such as IoT or RFID, is expensive
2. Complexity: Integration of multiple technologies makes these systems complex and difficult to maintain.
3. Lack of Real-Time Navigation: Many systems fail to provide clear guidance to available slots.
4. Dependency on Connectivity: Most systems require continuous internet connectivity, which can be unreliable in certain areas.

PROPOSED SYSTEM

The **QR-Based Smart Parking System Using Arduino** is designed to overcome the limitations of traditional and existing smart parking systems. This system provides a cost-effective, user-friendly, and scalable solution that streamlines parking processes through automation, real-time updates, and guided navigation. By integrating technologies like QR codes, IR sensors, and Arduino microcontrollers, it ensures efficient parking management with minimal manual intervention.

Key Features of the Proposed System

1. QR Code-Based Slot Identification
    - A QR code displayed at the parking entrance provides real-time information about available slots and navigation routes when scanned by the driver.
    - This ensures a seamless user experience without requiring additional hardware for identification.
2. Real-Time Monitoring

- IR sensors installed in each parking slot detect whether the slot is vacant or occupied.
- This data is processed in real-time and used to update the system on slot availability.

3. Automated Gate Control
    - IR sensors at the entrance detect incoming vehicles and automatically open the gate for authorized access, eliminating the need for manual gatekeepers.

4. Navigation Guidance
    - After scanning the QR code, the driver receives navigation instructions on their mobile device to the nearest available parking slot.
    - This feature reduces time spent searching for slots and minimizes congestion within the parking area.
5. Cost-Effective Design
    - The system uses affordable components like Arduino, IR sensors, and QR codes, making it feasible for implementation in various environments, such as malls, airports, and residential complexes.
6. Environmentally Friendly
    - By reducing vehicle movement within the parking area, the system decreases fuel consumption and carbon emissions, contributing to a greener environment.

SYSTEM DESIGN

The system is designed to address the inefficiencies of traditional parking systems by automating vehicle entry, slot allocation, and navigation. It integrates hardware components like Arduino microcontrollers, IR sensors, and servo motors with software capabilities such as QR code generation and real-time data updates.

Key Components:

- Arduino Uno: Acts as the central processing unit to control sensors, motors, and displays.
- IR Sensors: Detect vehicle presence at the entry and monitor slot occupancy.
- Servo Motor: Automates gate opening and closing based on slot availability.
- LCD Display: Shows real-time slot information at the entrance.
- QR Codes: Provide drivers with slot availability and navigation instructions via smartphones.

Architecture:

- Entry Point: An IR sensor detects vehicles approaching the gate. If a slot is available, the Arduino signals the servo motor to open the gate.
- Slot Monitoring: IR sensors placed at each slot continuously send status updates to the Arduino.
- QR Code Integration: A Python-based script dynamically generates QR codes, which drivers scan at the entrance to get parking details.
- User Guidance: The scanned QR code redirects the driver to a navigation route, ensuring quick access to the assigned slot.

FIG.1. ARCHITECTURE DIAGRAM

Workflow

1. Vehicle detection by IR sensor at the entrance.
2. QR code scan by the driver provides real-time slot availability and directions.
3. If a slot is available, the servo motor opens the gate for entry.
4. IR sensors at parking slots update their occupancy status dynamically.
5. The LCD display reflects the current number of vacant slots.
    - The system design includes an architectural overview and the use of Unified Modeling Language (UML) diagrams, such as class diagrams, use case diagrams, sequence diagrams, and activity diagrams.

METHODOLOGY

The QR-Based Smart Parking System follows a structured methodology to ensure effective design, implementation, and operation.

Traditional parking systems are inefficient and frustrating for users. The goal is to create a system that automatically manages parking and helps drivers find empty slots quickly. The system uses components like Arduino Uno as the main controller, IR sensors to detect vehicles, a servo motor for gate control, an LCD display to show free slots, and QR codes to guide drivers to vacant spaces.

To build the system, all components are connected to the Arduino. IR sensors are placed at the entrance and in each parking slot. A servo motor is installed at the gate, and an LCD screen is set up at the entrance. The program is written using the Arduino IDE to read sensor data, control the gate, and display slot availability on the LCD. Python is used

to generate QR codes containing parking slot details and navigation instructions.

Testing involves checking if sensors detect vehicles accurately, ensuring the servo motor opens and closes the gate smoothly, and validating QR codes to guide drivers to the correct slot.

The system works as follows: when a car arrives, the entrance sensor detects it. If a slot is free, the gate opens, and the LCD shows available slots. The driver scans the QR code to see the nearest empty slot and its location. Once the car parks, the slot sensor updates the system to mark the slot as occupied.

Finally, the system is tested with real users, and feedback is gathered to fix any issues and improve usability. This ensures an efficient, automated parking system that saves time and reduces frustration for drivers.

UML DIAGRAMS

UML stands for Unified Modelling Language. The UML diagrams for the QR-Based Smart Parking System effectively illustrate its functionality and interactions.

TYPES OF UML DIAGRAM

UML diagrams commonly created in visual modelling tools include:

A. USECASE DIAGRAM

Actor:

- Driver (primary user)
- System components (IR sensors, Arduino, LCD, QR Code, Servo Motor)

Use Cases:

- Detect vehicle arrival
- Scan QR code for slot availability and navigation
- Display available slots on the LCD
- Control gate via servo motor
- Monitor slot occupancy

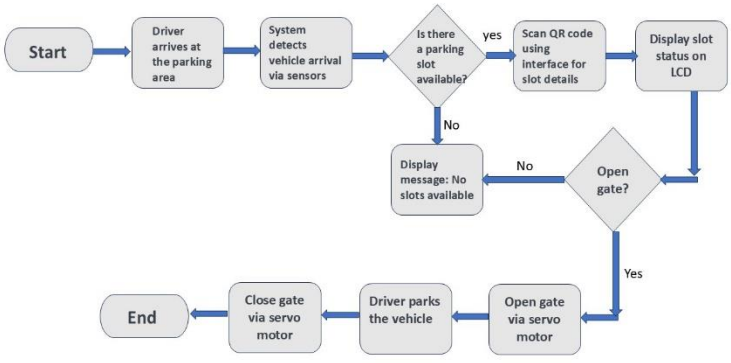


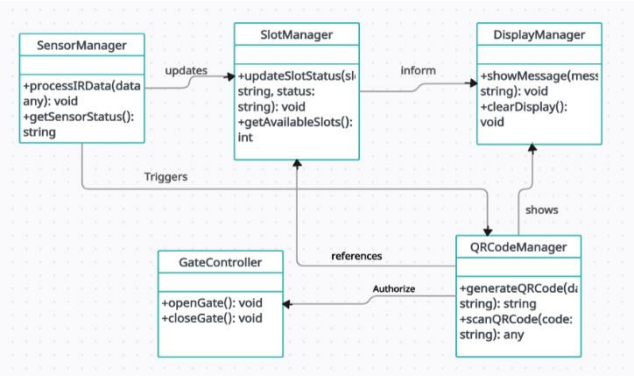
FIG. 2. USE CASE DIAGRAM

B.CLASS DIAGRAM

This diagram shows the structure of the system, including its classes and relationships.

Classes:

- SensorManager: Handles data from IR sensors (entrance and slots).
- SlotManager: Tracks slot availability and updates the system.
- QRCodeManager: Generates QR codes with real-time slot information.



- DisplayManager: Manages output to the LCD display.
- GateController: Controls the servo motor for gate operations

FIG. 3. CLASS DIAGRAM

C. SEQUENCE DIAGRAM

This diagram illustrates the step-by-step flow of the system when a car arrives and parks.

1. The SensorManager detects a car at the entrance.
2. SlotManager checks for available slots.
3. If a slot is free, QRCodeManager generates a QR code with slot details.
4. The driver scans the QR code, and DisplayManager shows the slot information on their phone.
5. GateController opens the gate for entry.
6. Once the car parks, SensorManager updates the slot status as occupied

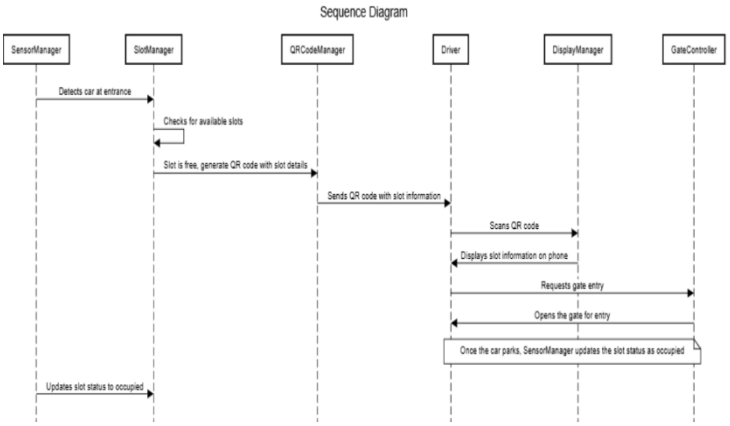


FIG. 4. *SEQUENCE DIAGRAM*

D.ACTIVITY DIAGRAM

This diagram outlines the workflow of the system:

1. Start when a vehicle approaches the parking area.
2. Entrance IR sensor detects the vehicle.
3. Check for slot availability.
    - If a slot is available:
        - Display available slots on the LCD.
        - Generate a QR code.
        - Open the gate.
    - If no slot is available:
        - Display "No Vacancy" on the LCD.
4. Driver scans the QR code for navigation.
5. Car parks, and the slot status updates.
6. End.

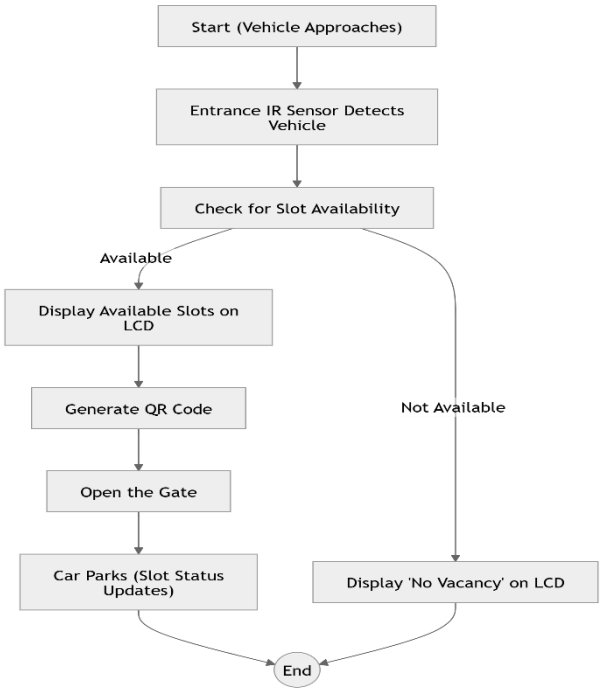


FIG. 5. ACTIVITY DIAGRAM

IMPLEMENTATION

The Smart Parking System is designed to detect vehicle presence, allocate available parking slots, generate QR codes for real-time slot data, and control the gate operation to allow vehicle entry. The system integrates both hardware and software components to provide an efficient, user-friendly experience

- **Vehicle Detection**: The system utilizes IR sensors placed at the entrance and each parking slot. When a vehicle approaches, the entrance IR sensor detects its presence and triggers the system to check for available parking slots. If a slot is available, the gate control mechanism is activated to open the gate for the vehicle's entry.
- **Slot Monitoring**: Each parking slot is monitored by an individual IR sensor that detects whether the slot is occupied. If a car is parked in the slot, the sensor updates the system to reflect that the slot is now occupied. The system also uses the data from these sensors to manage parking space efficiently and avoid overbooking.
- **QR Code Generation**: Once a free parking slot is identified, a Python script generates a dynamic QR code containing real-time parking data, including available slots and navigation routes to the nearest empty slot. The QR code is displayed at the entrance for drivers to scan. The QR code provides drivers with a seamless experience by showing detailed navigation instructions on their smartphone for easier parking.
- **Gate Control**: Upon scanning the QR code, the system validates the parking slot availability. If a free slot is found, the servo motor is triggered to open the gate, allowing the vehicle to enter. If no slot is available, the system displays a "No Vacancy" message on the LCD, guiding drivers on where to park.
- **Parking and Status Update**: Once the vehicle is parked in the allocated slot, the IR sensor of the slot updates the system to mark it as occupied. This real-time data update ensures that the slot management system reflects the current availability of parking spaces.

Hardware and Software Testing: The system undergoes thorough testing to ensure that all components work as intended. The hardware components, including sensors, servo motor, and LCD, are verified for proper connections and functionality. The software components are debugged using the Arduino IDE's Serial Monitor, ensuring accurate sensor data and proper slot updates. The Python QR code script is tested for compatibility and real-time updates. Finally, integration testing ensures that the entire system works seamlessly, with smooth communication between hardware and software.

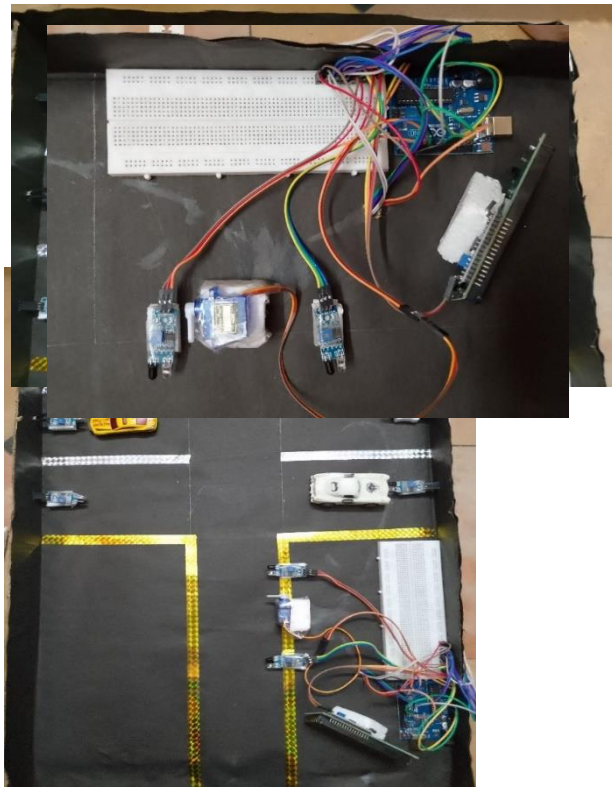
Deployment: The system is installed in a designated parking area, ensuring optimal placement of sensors and control mechanisms. The user-friendly interface allows drivers to scan the QR code and follow the navigation instructions on their smartphone. This system improves parking space utilization, reduces congestion, and enhances the overall user experience by providing a real-time, automated solution for parking management.

The Smart Parking System ensures an efficient and functional parking solution, optimizing space usage and providing a hassle-free experience for drivers. The combination of hardware and software components, along with real-time data updates and user-friendly navigation, makes the system a highly effective tool for modern parking management.

RESULT

The QR-Based Smart Parking System using Arduino was successfully implemented and tested, meeting its objectives of automating parking management and enhancing user convenience. QR codes were effectively generated with Python, providing real-time slot availability and navigation routes for drivers. IR sensors accurately detected vehicle

presence, ensuring real-time slot status updates. The servo



motor successfully controlled the gate operation, opening when a slot was available and displaying "No Vacancy" when full. The LCD display provided accurate information on slot availability. User feedback indicated high satisfaction, with fast access to parking data and smooth navigation. The system's advantages include time savings, automation, and scalability, making it adaptable to larger areas. Error handling, including sensor recalibration and fine-tuning the gate control, was successfully managed. The system demonstrated efficient performance across various test scenarios, highlighting its potential for real-world deployment in malls, airports, and residential complexes.

FIG. 6. PARKING AREA DIAGRAM

FIG. 7. PARKED CARS DIAGRAM

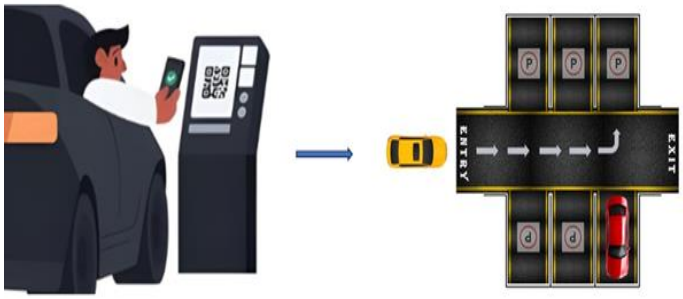


FIG. 8. CONNECTION DIAGRAM

FIG. 9. QR SCANNING AND EMPTY SLOT NAVIGATION ROUTE DIAGRAM

FIG. 10. LCD SHOWING AVAILABLE SLOTS

FIG. 11. SLOT 1 IS FULL

FIG. 12. PROCESS OF PARKING CAR AFTER SCANNING QR

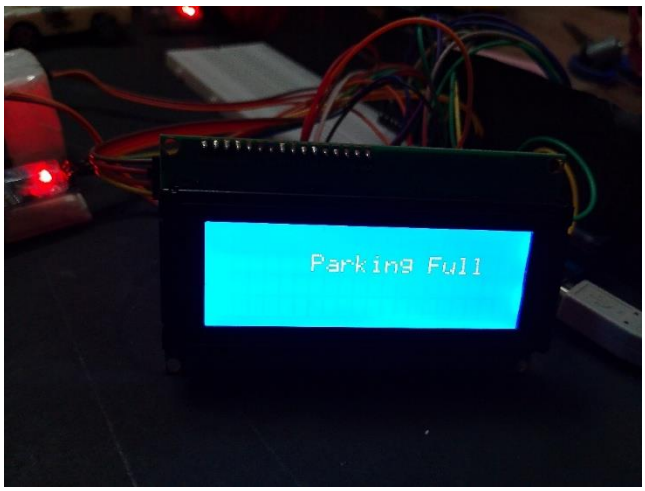


FIG. 13. LCD SHOWING PARKING IS FULL

FUTURE SCOPE

The future scope of the Smart Parking System includes developing a fully functional website to streamline parking management. This platform will feature user authentication for secure registration and bookings, real-time slot monitoring with a dynamic map, slot reservation for pre-booking, payment integration for seamless online transactions, and navigation support to guide users to their slots. Additionally, camera integration will enhance security with features like live monitoring, license plate recognition, event recording, and motion detection alerts, ensuring secure access and surveillance. These upgrades will optimize parking operations and provide robust security for users and administrators.

REFERENCES

We would like to thank these authors for their help in making this project come to life. Without their papers and insight into this field, it would've been difficult to progress through this project. The only way I can thank these authors is by adding them as my reference.

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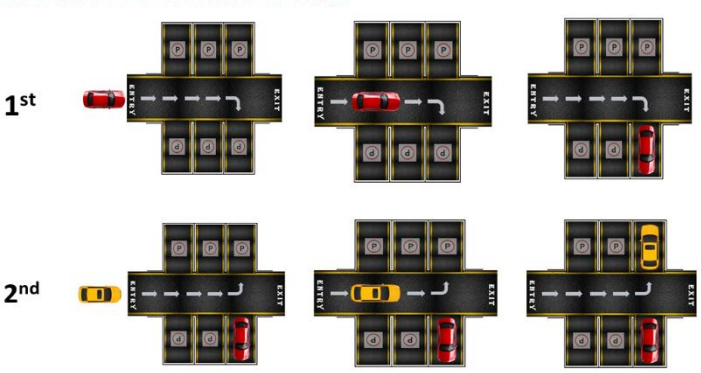

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Online Resources:

- *Arduino Official Website* (https://www.arduino.cc/): Key resource for Arduino boards, sensors, and tutorials for hardware setup and microcontroller programming.
- *Python QR Code Library* (https://pypi.org/project/qrcode/): Used to generate QR codes for parking slot information and navigation.
- *PlantUML* (https://plantuml.com/): Utilized for creating UML diagrams, including Use Case, Sequence, and Class Diagrams to design the system.

Websites and Articles:

- *"How QR Codes Work"* (https://www.qr-code-generator.com/): Guide for creating QR codes, which was vital for real-time slot monitoring and navigation.
- *"Introduction to IR Sensors"* (https://learn.sparkfun.com/tutorials/ir-sensor): Tutorial explaining the working principle of IR sensors used to detect vehicle presence.
- *Lucidchart* (https://www.lucidchart.com/): Tool for designing UML diagrams, which assisted in mapping the system's software structure and interactions.
- **Software and Tools**:
  - *Arduino IDE* (https://www.arduino.cc/en/software): Used for programming the Arduino board and integrating hardware components.
- **Books**:

- *"Arduino: A Technical Reference"* by Jörn Düson: Provided in-depth guidance on using Arduino for embedded systems.
- *"Practical Electronics for Inventors"* by Paul Scherz and Simon Monk: Offered comprehensive information on selecting sensors and components for the system.

These references played a crucial role in shaping the design, functionality, and implementation of the QR-Based Smart Parking System using Arduino

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