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# To Design a Secure IoT-Based Smart Car Parking System Using Face Recognition

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**ABSTRACT:** The rapid growth of urbanization and the increasing number of vehicles in modern cities have created significant challenges in managing parking spaces efficiently. Traditional parking systems rely on manual processes that result in delays, billing errors, and security vulnerabilities. This paper presents the design and implementation of a secure IoT-based smart car parking system that uses face recognition technology for contactless user authentication. The system leverages Python-based computer vision libraries, including OpenCV and the face\_recognition framework, to detect and verify authorized users at parking entry and exit points. Upon successful authentication, an IoT-enabled gate mechanism controlled by a microcontroller automatically manages vehicle access. An automated finance module calculates parking charges based on entry and exit timestamps, ensuring accurate and transparent billing. A real-time SMTP-based notification module sends email alerts to users and administrators for entry confirmation, exit details, billing receipts, and unauthorized access attempts. All parking events and transaction records are stored digitally and exported as Excel reports for administrative monitoring and auditing. The system eliminates manual intervention, enhances security, improves billing accuracy, and offers a reliable, scalable smart parking solution suitable for modern smart city applications.

**KEYWORDS:** Smart Parking, Face Recognition, IoT Gate Control, OpenCV, Python, SMTP Notification, Automated Billing, Excel Reports, Biometric Authentication, Computer Vision.

## I. INTRODUCTION

The rapid growth of urbanization and the continuous increase in vehicle ownership have created serious challenges in managing parking spaces efficiently. In metropolitan cities, commercial areas, educational institutions, hospitals, shopping malls, and residential complexes, parking congestion has become a major issue. Traditional parking systems rely heavily on manual processes such as ticket issuance, physical verification, and human supervision, which often result in long waiting times, traffic congestion, billing errors, and security vulnerabilities. These limitations highlight the urgent need for an intelligent, automated, and secure parking management solution.

With the advancement of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and computer vision, smart parking systems have emerged as an effective solution to overcome the drawbacks of conventional parking methods. Smart parking systems aim to optimize parking operations by reducing human intervention, improving access control, ensuring accurate billing, and providing real-time monitoring. Among various authentication techniques, biometric-based identification has gained significant attention due to its reliability and uniqueness.

Face recognition, in particular, offers a contactless, fast, and secure method for user authentication, making it highly suitable for modern smart parking applications. The proposed system replaces traditional manual verification with an



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automated facial authentication mechanism. A camera installed at the parking entry captures the user's facial image, which is then processed using computer vision techniques. The system utilizes Python-based libraries such as OpenCV and face recognition frameworks to compare the captured face with pre-stored authorized user data. Based on the matching result, the system grants or denies access automatically, thereby preventing unauthorized vehicle entry.

In addition to secure access control, the system integrates IoT-based gate automation to manage vehicle entry and exit smoothly. Once authentication is successful, the gate is controlled automatically through a microcontroller-based setup using motors or relays. This automation minimizes human involvement, reduces operational delays, and ensures a seamless parking experience. An automated finance module calculates parking charges, an SMTP-based notification module delivers real-time email alerts, and an Excel report module maintains organized records for administrative monitoring and auditing.

### II. LITERATURE REVIEW

“**Viola and Jones (2001)**” introduced a real-time object detection framework using Haar-like features and cascade classifiers. Their work laid the foundation for face detection systems by enabling fast and efficient identification of human faces in images. The algorithm is widely used due to its low computational complexity and real-time performance. This technique is commonly integrated with face recognition systems to detect facial regions before recognition and is significant for smart parking systems requiring real-time facial detection.

“**Schroff, Kalenichenko, and Philbin (2015)**” proposed FaceNet, a deep learning framework for face recognition and verification. The model maps facial images into an embedding space using deep convolutional networks. FaceNet achieves high accuracy even under varying lighting and facial expressions. Its application is highly relevant to secure parking systems where user identity verification is crucial, reducing false positives and negatives, and improving access control accuracy in IoT-based parking solutions.

“**Bradski (2000)**” introduced the OpenCV library, which provides a comprehensive set of tools for real-time computer vision applications. OpenCV supports image processing, face detection, and feature extraction. It enables developers to implement efficient face recognition systems using Python. In smart parking systems, OpenCV simplifies facial image acquisition and preprocessing, ensuring compatibility with camera-based authentication modules and making it suitable for real-time IoT applications.

“**Al-Fuqaha et al. (2015)**” conducted an extensive survey on Internet of Things architectures, protocols, and applications. The study highlights the role of IoT in enabling automation and real-time monitoring systems. It emphasizes seamless communication between sensors, controllers, and software platforms. This research is applicable to automated parking systems using IoT-enabled gate control, supporting real-time data exchange between face recognition modules and hardware components.

“**Patel et al. (2018)**” proposed an IoT-based smart parking system using sensor networks for vehicle detection. The system focused on parking slot availability and monitoring. Although it did not include biometric authentication, it demonstrated the effectiveness of IoT automation in reducing congestion and improving parking efficiency. The research provides a base architecture for IoT-based parking management which aligns with modern smart city requirements.

“**Singh and Sharma (2020)**” developed an automated billing system for parking management using IoT technology. The system calculated parking fees based on entry and exit time. Automation reduced human errors and improved transparency. The research demonstrated improved operational efficiency through digital billing, supporting the inclusion of automated finance modules in smart parking systems.

“**Rao et al. (2021)**” proposed a smart surveillance and alert system using email and cloud-based notifications. The system provided real-time alerts for security events, improved monitoring, and reduced response time. This concept is directly relevant to parking systems requiring instant alerts for unauthorized access, validating the use of SMTP-based notifications to ensure administrators are informed instantly.



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### III. METHODOLOGY

#### A. EXISTING SYSTEM

Traditional parking systems use manual ticket-based entry and exit methods. Parking access is controlled by human operators or security staff, leading to delays and congestion during peak hours. These systems lack secure authentication mechanisms, allowing unauthorized vehicles to enter parking areas without proper verification. Parking fee calculation is performed manually in most cases, leading to billing errors and payment disputes. Records are maintained using paper-based or basic digital methods, making data retrieval and management difficult. Real-time monitoring of parking activities is not available, and existing systems do not support automated alert mechanisms. High manpower is required to manage parking operations, which increases operational costs and dependency on humans. Integration with IoT and AI technologies is not supported, limiting automation and intelligence of the system.

#### B. DISADVANTAGES

Manual parking systems cause long waiting times at entry and exit points, leading to traffic congestion and user inconvenience.

1. Dependence on human operators increases the possibility of errors in verification and billing, reducing system reliability.
2. Lack of proper authentication allows unauthorized vehicle access, significantly reducing overall parking security.
3. Manual ticket handling can result in ticket loss or damage, creating confusion and disputes during vehicle exit.
4. Parking fee calculation is often inaccurate due to manual methods; billing disputes frequently arise between users and management.

#### C. PROPOSED SYSTEM

The proposed system is a secure IoT-based smart car parking solution that uses face recognition for contactless user authentication. A camera installed at the parking entry captures the user's face, which is processed using Python-based computer vision algorithms. The system uses OpenCV and the face recognition library to extract unique facial encodings and compare them against stored authorized user data. Upon successful authentication, a control signal is sent to the IoT gate control module, which activates the servo motor or relay to open the parking gate automatically.

An automated finance module records entry and exit timestamps and calculates parking charges based on predefined tariff rules, including overstay penalties and subscription-based pricing. The SMTP notification module sends real-time email alerts to users and administrators for entry confirmation, exit details, billing receipts, and unauthorized access attempts. All parking events, user details, billing information, and transaction logs are systematically stored and exported as Excel reports using Python libraries such as Pandas and OpenPyXL. The system significantly reduces manual intervention, enhances security, improves billing accuracy, and offers a reliable, scalable solution suitable for modern urban environments and smart city applications.

#### D. ADVANTAGES

1. Face recognition provides high-level security for parking access; only authorized users are allowed to enter the facility.
2. The system eliminates manual ticket-based parking processes, reducing delays and human intervention significantly.
3. Automated IoT gate control ensures smooth vehicle entry and exit, improving overall traffic flow inside parking areas.
4. Unauthorized access attempts are detected and blocked instantly, with real-time administrator alerts generated automatically.
5. The automated finance module ensures accurate and transparent parking fee calculation, minimizing billing errors and disputes.
6. Real-time SMTP email notifications keep users and administrators fully informed about all parking activities and security events.
7. Excel-based reports provide complete transparency in transactions, simplifying auditing and administrative decision-making.
8. The system reduces manpower requirements significantly and lowers operational costs through comprehensive automation.



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9. Contactless face recognition improves hygiene and user convenience by eliminating the need for physical tokens or cards.
10. The system is scalable for large parking facilities and supports future expansion, aligning with smart city requirements.

### E. DESIGN OF THE SYSTEM

The system architecture of the smart car parking system is designed to provide a secure, automated, and efficient platform. It consists of six integrated modules: Face Recognition Module, IoT Gate Control Module, Finance Module, SMTP Notification Module, Excel Report Module, and Admin Monitoring Interface, all working together seamlessly to deliver a complete smart parking solution.

The image and video input subsystem uses a high-resolution camera installed at the parking entry and exit gates to capture real-time facial images or video streams. The Face Recognition Module, built using Python with OpenCV and face\_recognition libraries, performs preprocessing, feature extraction, and identity verification by comparing facial encodings against the Authorized User Database. On successful authentication, a control signal is transmitted to the IoT Gate Control Module, where an ESP32 or Arduino microcontroller activates the servo motor or relay to open the gate automatically.

The Finance Module records entry and exit timestamps and computes parking charges based on predefined tariff rules. The Notification Module uses SMTP protocol to send real-time email alerts to users and administrators. The Excel Report Module uses Pandas and OpenPyXL to export all parking events and billing records into organized Excel files. The Admin Monitoring Interface provides a centralized dashboard for real-time oversight of all system activities. Overall, the architecture ensures smooth performance, strong security, and effective automation. The block diagram illustrating the complete system architecture is shown in Fig. 1.

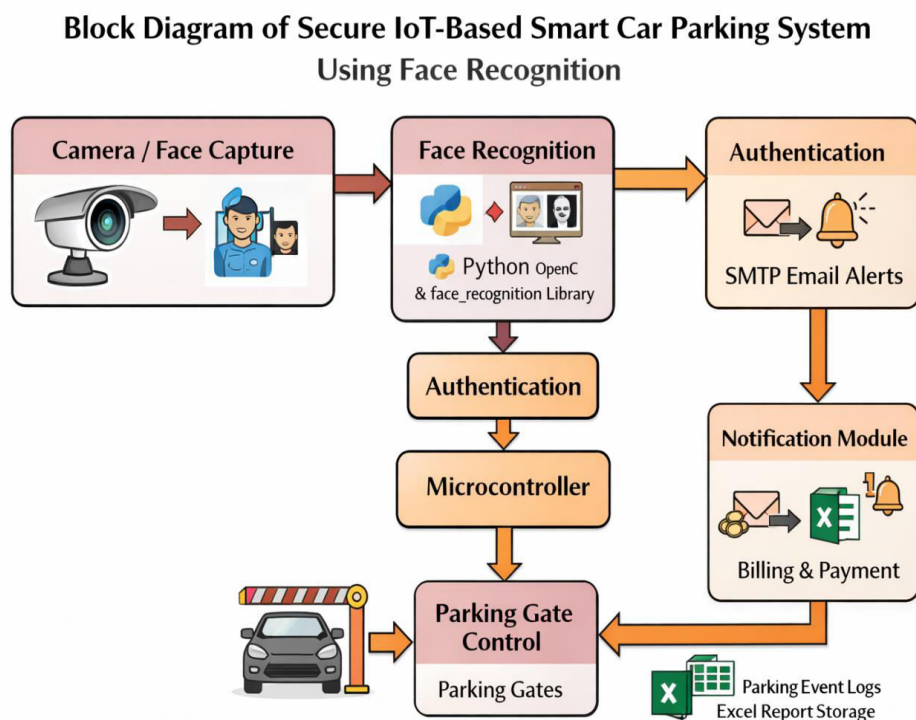


Fig. 1: Block Diagram of Secure IoT-Based Smart Car Parking System using Face Recognition



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### IV. IMPLEMENTATION

#### MODULE DESCRIPTION

##### 1. FACE RECOGNITION MODULE

The Face Recognition Module is the core security component of the proposed system and is responsible for identifying and verifying users based on their facial features before allowing access to the parking area. It eliminates the need for physical tokens, ID cards, or manual verification, thereby enhancing security and user convenience. The module operates using a high-resolution camera installed at the parking entry and exit points to capture real-time facial images of users.

Once the facial image is captured, it is processed using Python-based computer vision techniques. Image preprocessing steps such as resizing, grayscale conversion, and noise reduction are performed to improve recognition accuracy. The system uses OpenCV along with the face\_recognition library to extract unique facial encodings. These encodings are compared with stored facial data of authorized users maintained in the system database. If a match is found within an acceptable confidence threshold, the user is authenticated successfully. The module is designed to work efficiently under varying lighting conditions and different facial expressions, ensuring fast processing so that vehicle movement is not delayed. In case of an unauthorized face or mismatch, the module denies access and triggers the notification system immediately.

##### 2. IOT GATE CONTROL MODULE

The IoT Gate Control Module is responsible for automating the physical entry and exit gates of the parking system. This module works in coordination with the Face Recognition Module to control gate operations based on authentication results. It consists of a microcontroller (ESP32 or Arduino), a motor or relay mechanism, and gate hardware integrated through IoT technology. The module ensures that the gate opens only when a valid authentication signal is received from the Face Recognition Module.

When the Face Recognition Module confirms a valid user, a control signal is sent to the IoT Gate Control Module. The microcontroller processes this signal and activates the motor or relay to open the parking gate automatically. After the vehicle passes through, the gate closes automatically to maintain security and prevent unauthorized entry. This automated process eliminates the need for human involvement, significantly reduces waiting time at entry and exit points, and ensures smooth vehicle flow. The module also ensures real-time communication between software and hardware components, enhancing system reliability and smooth operation even during peak hours.

##### 3. FINANCE MODULE

The Finance Module is designed to automate the parking fee calculation and billing process. In traditional parking systems, fee calculation is often manual, leading to errors, disputes, and lack of transparency. The proposed Finance Module eliminates these issues by accurately calculating parking charges based on entry time, exit time, duration of stay, and predefined tariff rules. When a vehicle enters the parking area, the system records the entry timestamp. Similarly, the exit timestamp is recorded when the vehicle leaves.

The Finance Module computes the total parking duration and calculates the fee accordingly. It also supports additional features such as overstay charges, subscription-based pricing, and penalty calculation if required. This ensures accurate and fair billing for all users. The automated billing process increases transparency and trust between users and administrators. All financial transactions are recorded digitally, reducing the possibility of manipulation or fraud. The Finance Module integrates seamlessly with the notification and reporting modules, ensuring that billing details are communicated effectively and stored securely for future reference.

##### 4. NOTIFICATION MODULE (SMTP)

The Notification Module plays a vital role in real-time communication between the system, users, and administrators. This module uses the Simple Mail Transfer Protocol (SMTP) to send automated email alerts related to parking activities. It ensures that important events are communicated instantly without the need for manual intervention. The module sends notifications for various events such as successful entry confirmation, exit details, parking fee receipts, payment reminders, and unauthorized access attempts.



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Users receive timely updates regarding their parking status, while administrators are alerted about security-related incidents in real time. This improves awareness, responsiveness, and system transparency significantly. In case of unauthorized access or failed face recognition, the Notification Module immediately sends an alert to the administrator, enabling quick action to prevent security breaches. By providing real-time alerts, the module enhances system safety and improves overall user satisfaction, while reducing the need for continuous manual monitoring.

### **5. EXCEL REPORT MODULE**

The Excel Report Module is responsible for systematic data storage and report generation. All parking-related information such as user details, entry and exit timestamps, parking duration, billing amounts, and transaction history is stored digitally in an organized manner. This module uses Python libraries such as Pandas and OpenPyXL to export the stored data into Excel format, making it easy for administrators to access, analyze, and manage records efficiently.

Excel-based reporting provides transparency and simplifies auditing processes significantly. Administrators can generate daily, weekly, or monthly reports to analyze parking usage patterns, revenue generation, and system performance. The reports help in identifying peak usage hours, frequent users, and areas for potential system improvement. The Excel Report Module reduces paperwork, minimizes the risk of data loss, and ensures better data accuracy, easy retrieval, and long-term storage for management decision-making.

### **6. ADMIN MONITORING MODULE**

The Admin Monitoring Module provides a centralized interface for administrators to monitor and manage the entire parking system comprehensively. This module allows administrators to view real-time parking activities, user authentication status, gate operations, billing details, and system alerts. It acts as the control center of the smart parking system, providing complete visibility and oversight of all operations. Administrators can manage authorized users, update facial data, view reports, and monitor system health.

Real-time dashboards provide instant insights into parking occupancy, entry and exit logs, and security events. This improves operational efficiency and decision-making capabilities. The Admin Monitoring Module enhances system control and reliability by enabling administrators to respond quickly to issues such as unauthorized access, system faults, or billing discrepancies. By providing complete visibility and control, this module ensures smooth and secure operation of the smart parking system at all times.

## **V. RESULT**

The proposed Secure IoT-Based Smart Car Parking System was successfully designed, implemented, and tested under real-time conditions. The system integrates face recognition technology, IoT-enabled gate control, automated billing, and real-time notifications to ensure efficient, secure, and user-friendly parking management. The results indicate that the system meets all objectives of improving security, reducing human intervention, and providing accurate billing while maintaining high operational efficiency.

During testing, the Face Recognition Module demonstrated high accuracy in identifying authorized users. Live video feeds from the entry camera were processed in real time using Python-based OpenCV and face\_recognition algorithms. The system successfully authenticated authorized users within seconds, allowing smooth vehicle entry and exit. Unauthorized faces were consistently rejected, and alerts were sent immediately to the administrator, confirming the effectiveness of the security mechanism. Recognition accuracy remained robust under varying lighting conditions and different facial expressions, validating the reliability of the biometric authentication approach.

The IoT Gate Control Module performed as expected, with gates opening automatically after successful authentication and closing after vehicle passage. The servo motor mechanism responded quickly to control signals, ensuring smooth and precise gate operation with minimal delay. Real-time gate status updates were visible on the admin monitoring interface, allowing administrators to track vehicle movements efficiently. The Finance Module provided accurate automated billing for each parking session, computing fees correctly based on parking duration. The SMTP Notification Module delivered real-time email alerts reliably. Excel reports were generated successfully, providing organized and transparent records for administrative monitoring and auditing purposes.



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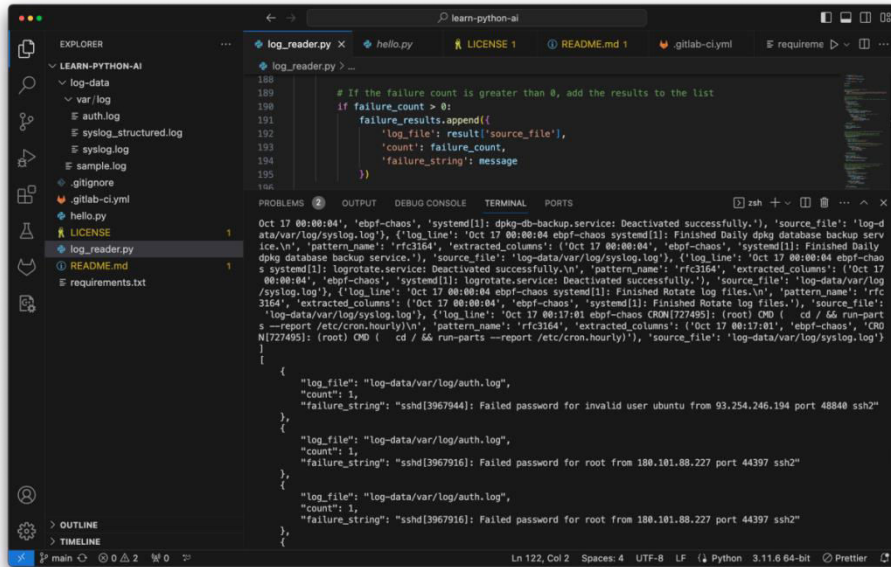


Fig. 2: Python Implementation — Face Recognition and System Modules in VS Code

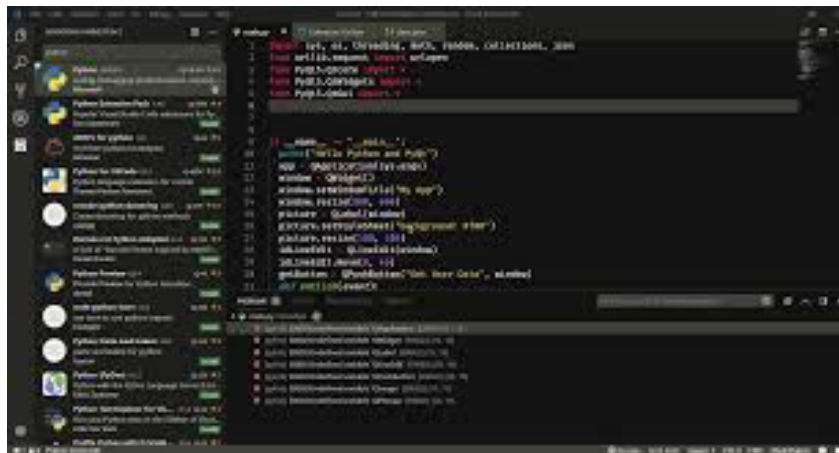


Fig. 3: PyQt5 Admin Monitoring and Gate Control Interface

## VI. CONCLUSION

The proposed Secure IoT-Based Smart Car Parking System using Face Recognition represents a significant advancement over traditional parking management methods. The implementation of face recognition technology for vehicle authentication ensures high-level security by granting access only to authorized users. By replacing manual ticket-based verification with automated biometric authentication, the system eliminates delays, reduces human error, and provides a contactless, convenient experience for users. This approach aligns with the requirements of modern smart cities, where efficiency, security, and automation are key priorities in urban infrastructure development.

Through real-time testing, it was observed that the Face Recognition Module consistently achieved high accuracy in identifying registered users, even under challenging lighting conditions and varying facial expressions. Unauthorized access attempts were successfully detected and blocked, with alerts dispatched through the SMTP Notification Module, ensuring that administrators remained informed of potential security threats in real time. The automated Finance Module ensured accurate and transparent billing, eliminating disputes and reducing administrative workload. Excel-based reports provided complete transparency and simplified auditing and decision-making processes.



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The IoT Gate Control Module operated smoothly and reliably, automating vehicle access with minimal delay and reducing the need for human operators at the gate. The Admin Monitoring Module provided centralized oversight of all system activities, enabling quick responses to incidents and improving operational efficiency. The platform supports scalability, handling multiple concurrent users without performance degradation, making it a robust and reliable solution for modern urban parking management. Overall, this system enhances parking security, encourages comprehensive automation, and delivers an intelligent parking solution suitable for large-scale smart city deployments.

### VII. FUTURE ENHANCEMENT

The system can be enhanced by integrating cloud-based storage for centralized data management and remote monitoring across multiple parking locations simultaneously. A dedicated mobile application can be developed to allow users to check real-time parking availability, view billing details, make payments, and receive push notifications conveniently from their smartphones, significantly improving user accessibility and experience. Advanced deep learning models such as FaceNet or ArcFace can be integrated to further improve face recognition accuracy under challenging conditions such as low lighting, partial occlusion, or significant changes in appearance.

License plate recognition (LPR) can be added as a secondary authentication method to complement face recognition and further strengthen access control security. Integration with online payment gateways can enable automated digital fee collection, eliminating manual payment processing. Real-time occupancy detection using IoT sensors such as ultrasonic or infrared sensors can guide users to available parking slots, reducing congestion and improving user convenience. Multi-location support can allow administrators to manage multiple parking facilities from a single centralized dashboard, making the system suitable for large urban deployments.

Reporting and analytics features can be enhanced to provide administrators with detailed insights into peak usage hours, revenue trends, frequent users, and system performance metrics for data-driven decision-making. Integration with smart city infrastructure such as traffic management systems and city-wide IoT platforms can further expand the system's capabilities. Machine learning-based anomaly detection can be implemented to proactively identify unusual parking patterns or potential security threats. These improvements will evolve the proposed platform into a comprehensive, intelligent, and fully automated parking management solution suitable for next-generation smart city environments.

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