



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 5, May 2025

Smart Parking - An Image Processing based Automated Car Parking System

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ABSTRACT: In response to escalating urban congestion and the rising demand for parking infrastructure, smart parking systems have become essential to optimize space utilization and reduce time wastage. Traditional parking solutions, predominantly manual, suffer from inefficiencies and limited real-time tracking capabilities. This paper presents a novel IoT-enabled smart parking system integrating image processing and deep learning for automatic vehicle identification and real-time slot monitoring. The system employs a Raspberry Pi camera for license plate recognition, enabling automatic vehicle registration and entry logging. Infrared (IR) sensors embedded in parking slots detect occupancy, communicating status updates to a centralized cloud server. Users can remotely check slot availability and reserve parking spaces via a web-based interface. The fusion of IoT and deep learning technologies in this system aims to minimize human intervention, decrease errors, and enhance security. Experimental results indicate improved parking space management, reduced vehicle search times, and enhanced user convenience. This research addresses existing gaps in manual and semi-automated parking solutions, providing a scalable, efficient, and user-friendly parking management approach for modern urban environments.

KEYWORDS: Smart parking, Image processing, IoT, Deep learning, License plate recognition.

I. INTRODUCTION

Urbanization and the rapid growth of vehicle ownership have exacerbated parking challenges in metropolitan areas worldwide. As cities become denser and road networks more congested, the demand for efficient parking management systems has intensified. Traditional parking methods, relying heavily on manual supervision and human intervention, are increasingly inadequate to meet the rising need for optimized space utilization and timely vehicle management. Prolonged search times for parking slots contribute not only to driver frustration but also to increased traffic congestion and environmental pollution. These issues underscore the necessity for smart, automated parking solutions capable of improving efficiency, reducing operational costs, and enhancing the overall user experience.

Smart parking systems utilize advanced technologies such as Internet of Things (IoT), image processing, wireless sensor networks, and machine learning to automate vehicle detection, slot monitoring, and booking processes. By providing real-time information about parking availability, these systems enable drivers to make informed decisions, minimizing search times and easing traffic flow in crowded areas. Moreover, automated systems reduce the need for manual ticketing and supervision, thereby lowering operational expenses for parking facility operators.

Among the technological components, image processing and deep learning have emerged as pivotal tools for vehicle identification and management. License Plate Recognition (LPR) systems leverage convolutional neural networks (CNNs) and other deep learning architectures to detect and recognize vehicle registration numbers automatically. This capability not only streamlines entry and exit logging but also enhances security by preventing unauthorized access. Coupled with IoT-enabled sensors for monitoring parking slot occupancy, image processing-based smart parking systems form a comprehensive framework for end-to-end automation.

Despite numerous advances, challenges remain in integrating these technologies into a seamless, scalable system. Physical sensors, while effective, are subject to maintenance issues, environmental interference, and installation costs. Image processing models require robust training datasets and optimization to function reliably under diverse lighting

and weather conditions. Additionally, real-time communication between various system components and users demands efficient network protocols and secure data handling to protect privacy.

This research proposes a software-based smart parking system that integrates deep learning-based license plate recognition with a simulated IoT framework for parking slot monitoring and remote booking management. The system eliminates dependency on physical sensors by simulating occupancy data, thereby reducing deployment complexity and cost. A web-based interface offers users real-time visualization of slot availability and reservation options, enhancing convenience and operational transparency.

The approach was tested through extensive simulation and algorithm validation, focusing on recognition accuracy, latency, booking reliability, and user experience. By leveraging open-source deep learning models and cloud-based infrastructure, the system demonstrates scalability and adaptability to various parking environments. It addresses current limitations in manual and semi-automated systems by providing a cost-efficient, robust, and user-friendly parking solution.

II. LITERATURE REVIEW

The increasing demand for efficient parking management solutions in urban areas has driven extensive research into smart parking systems utilizing advanced technologies such as Internet of Things (IoT), image processing, and machine learning. This literature review surveys the key developments, methodologies, and challenges in the domain of smart parking, focusing particularly on image processing-based automated systems integrated with IoT platforms.

Sensor-Based Parking Systems

Early smart parking systems primarily relied on physical sensors to detect vehicle presence in parking slots. Ultrasonic and infrared (IR) sensors are the most used devices for occupancy detection due to their relatively low cost and ease of deployment. Zhao et al. [1] presented a sensor-driven parking management system using ultrasonic sensors installed in parking slots to detect occupancy status. Their work demonstrated reliable space utilization monitoring but reported challenges related to sensor maintenance and the system's scalability in large parking lots. Similarly, Hernandez et al. [2] developed a cloud-based parking system combining IR sensors with a mobile interface for user interaction. While the approach enhanced accessibility, latency issues during peak hours reduced real-time responsiveness. Sensor degradation due to environmental factors and false detection under extreme weather conditions remain notable drawbacks [3]. These limitations have encouraged researchers to explore complementary technologies that can supplement or replace sensor-only solutions.

IoT Integration in Smart Parking

The evolution of IoT technology has brought transformative changes to parking management. IoT enables real-time data acquisition from distributed sensors and seamless communication with centralized management platforms. Kumar and Singh [4] developed an IoT-based parking system integrating RFID for vehicle identification and slot occupancy management. Their approach automated entry and exit logging but lacked dynamic slot booking functionality, limiting user convenience. Alotaibi and Alqahtani [5] proposed a comprehensive IoT framework for smart parking that utilized wireless sensor networks and cloud computing. Their study underscored the importance of scalability and data security in IoT-enabled parking systems. However, sensor dependency and challenges related to network reliability remain issues impacting the overall effectiveness.

Image Processing and License Plate Recognition

Incorporating image processing into smart parking solutions addresses several issues related to vehicle identification and security. License plate recognition (LPR) systems using computer vision and deep learning have gained significant attention as they enable automatic vehicle registration and tracking without manual intervention. Lee et al. [6] designed a deep learning based LPR system for parking management employing convolutional neural networks (CNNs). Their model achieved high accuracy under controlled lighting but faced computational overheads causing delays in real-time processing. Wang et al. [7] improved robustness by training models on diverse datasets with varied lighting and angles, achieving better accuracy in real-world scenarios. However, these systems still struggle with occlusions, dirty plates, and nighttime conditions [8].

Moreover, integrating LPR with IoT facilitates a unified platform where vehicle data and parking slot occupancy information are processed concurrently. Singh and Sharma [9] proposed a hybrid system combining image processing and sensor data to increase detection accuracy and improve monitoring. While their method enhanced performance, it suffered from synchronization delays and limited real-time reservation capabilities, highlighting the complexity of fusing heterogeneous data sources.

Automated Slot Booking and User Interfaces

User convenience and interaction play critical roles in smart parking adoption. Systems enabling real-time slot availability visualization and booking reduce time wasted searching for parking. Ramesh and Babu [10] developed an IoT-based parking system with automated slot booking integrated via a mobile app. Their solution improved user experience significantly but required stable internet connectivity and high system responsiveness to avoid booking conflicts. Hernandez et al. [2] also emphasized the importance of mobile interfaces in cloud-based systems, though they noted performance bottlenecks under heavy user loads.

Recent developments focus on scalable web-based dashboards accessible from various devices, allowing multiple users to interact with the system simultaneously. Chen and Xu [11] implemented a responsive web interface that provides live updates on parking availability, vehicle registration status, and booking history. They combined edge computing with cloud services to reduce latency and ensure system reliability. User feedback indicated improved satisfaction, although the interface's complexity posed a learning curve for less tech-savvy users.

Challenges in Smart Parking Systems

Despite technological advances, smart parking systems face persistent challenges. Environmental factors such as rain, fog, and poor lighting impact sensor accuracy and image processing reliability [12]. The computational requirements of deep learning models for license plate recognition can strain low-power edge devices, necessitating optimization or offloading to cloud servers [13]. Network reliability and security are critical for real-time data transmission, with risks of data loss and cyberattacks threatening system integrity [14].

Additionally, the heterogeneity of hardware components and data formats complicates integration and synchronization. Singh and Sharma [9] reported difficulties in fusing sensor data with image recognition outputs, leading to occasional inconsistencies in parking slot status displayed to users. Moreover, ensuring privacy and compliance with regulations when handling vehicle registration data remains a vital consideration [15].

Comparative Analysis of Existing Systems

Comparing sensor based, IoT, and image processing approaches reveals a trend towards hybrid systems that leverage the strengths of multiple technologies. Zhao et al. [1] and Hernandez et al. [2] demonstrated that sensor-only systems are effective but limited by environmental constraints and scalability. Kumar and Singh's [4] RFID-based IoT model improved automation but lacked dynamic booking and full remote accessibility.

Deep learning enabled LPR systems by Lee et al. [6] and Wang et al. [7] offer accurate vehicle identification but require high computational power and extensive training data. Hybrid systems combining sensors and image processing, such as the one proposed by Singh and Sharma [9], improve accuracy and reliability but introduce complexity in data synchronization and real-time operations.

User interface designs ranging from mobile apps [10] to web dashboards [11] enhance system usability but depend heavily on network stability and system responsiveness. Systems incorporating cloud and edge computing [11] show promise in mitigating latency but require robust security frameworks.

Research Gaps and Opportunities

From the surveyed literature, key research gaps emerge:

Real-Time Booking with Integrated Vehicle Registration: Few systems provide seamless integration of automatic vehicle identification with dynamic parking slot booking accessible remotely by multiple users. Most lack a unified platform combining both features efficiently.

Robustness in Diverse Environmental Conditions: Existing image processing models often falter in low-light, occlusion, or adverse weather, necessitating more resilient recognition techniques.

Data Synchronization and System Scalability: Hybrid systems face challenges in synchronizing heterogeneous data streams (sensor and image data) while maintaining real-time updates, especially in large-scale deployments.

Resource-Efficient Computation: Balancing deep learning model accuracy with the computational limits of edge devices like Raspberry Pi remains an ongoing challenge.

Security and Privacy Concerns: Ensuring secure transmission and storage of sensitive vehicle registration and user data without compromising accessibility is underexplored.

Recent Advances Addressing Gaps

Several studies propose solutions addressing these gaps. Chen and Xu [11] utilized edge computing to offload intensive processing from centralized servers, improving latency and scalability. Wang et al. [7] trained deep learning models on augmented datasets simulating harsh conditions to increase robustness. Singh and Sharma [9] experimented with sensor fusion algorithms to enhance data synchronization.

Moreover, emerging blockchain-based smart parking frameworks are gaining traction for secure, decentralized data management, offering privacy-preserving vehicle registration and transaction logging [16]. Integration of electric vehicle charging station monitoring with smart parking systems also represents an expanding research area [17].

In summary, the literature reveals that while significant progress has been made in sensor technologies, IoT integration, and image processing for smart parking, there remains substantial scope to develop unified, scalable, and resilient systems that fully automate vehicle registration, parking slot monitoring, and user booking with enhanced security and usability. This study builds upon these insights to develop a comprehensive smart parking system employing deep learning for license plate recognition integrated with IoT-enabled real-time monitoring and remote booking functionalities.

Literature Review Comparison Table

S.No	Title	Authors	Methods Used	Drawbacks / Research Gaps
1	Sensor-driven smart parking system	Zhao et al. (2020)	Ultrasonic sensors for occupancy detection	Maintenance challenges, limited scalability
2	Cloud-based parking management with IR sensors	Hernandez et al. (2022)	IR sensors, mobile app interface	Latency during peak hours, sensor accuracy affected by weather
3	IoT and RFID-based automated parking system	Kumar & Singh (2021)	IoT integration with RFID	No dynamic slot booking, limited remote accessibility
4	Deep learning-based license plate recognition system	Lee et al. (2019)	CNN-based image processing	High computational cost, performance issues in variable lighting
5	Hybrid image processing and sensor data fusion	Singh & Sharma (2023)	Fusion of image processing and sensor data	Synchronization delays, limited real-time reservation

III. METHODOLOGY

This research presents a fully software-based smart parking system designed to automate vehicle registration, real-time slot monitoring, and booking management by leveraging image processing, deep learning, and simulated IoT frameworks. The project's core strength lies in the integration of advanced algorithms for license plate recognition, occupancy status simulation, and user interaction through a responsive web application. The software architecture was developed and tested on cloud platforms and local servers, employing synthetic sensor data and image datasets to emulate real-world scenarios.

System Overview

The system consists of three key software modules:

- **License Plate Recognition (LPR):** Processes vehicle images to automatically detect and register license plates using deep learning.
- **Parking Slot Occupancy Simulation:** Mimics real-time parking slot occupancy through simulated sensor data generated by software agents.
- **User Interaction and Management:** Provides a web-based platform for users to view parking availability, book slots, and track vehicle registrations.

Each module operates within a cohesive ecosystem built on cloud infrastructure and interlinked via REST APIs and WebSocket communication for real-time data flow.

License Plate Recognition

The LPR module forms the system's entry point, automatically recognizing vehicles as they “arrive” via uploaded images or live video feeds.

- **Dataset and Model Training:**
The model was trained on a diverse dataset combining publicly available license plate images (OpenALPR dataset, CCPD dataset) and synthetically augmented images to enhance robustness against variable lighting, occlusions, and plate fonts. In total, 15,000 labelled images were used for training and validation.
- **Image Preprocessing:**
Input images undergo standard preprocessing steps: resizing to 416×416 pixels, normalization, noise filtering, and contrast enhancement to optimize detection accuracy.
- **License Plate Detection:**
YOLOv5 architecture was selected for real-time detection due to its balance of accuracy and inference speed. The model detects bounding boxes around license plates with a mean average precision (mAP) of 93%.
- **Character Segmentation and Recognition:**
Within detected plates, characters are segmented using adaptive thresholding and contour detection algorithms. A separate CNN classifier trained on alphanumeric characters processes these segments, achieving a character recognition accuracy of 96%. The recognized license plate string is then passed to the backend server, where it is logged in a centralized vehicle database.

Parking Slot Occupancy Simulation

Since this project avoids physical sensors, a virtual simulation framework was developed to replicate parking slot occupancy status dynamically.

- **Slot Modelling:**
The parking area consists of 20 virtual slots, each represented by software objects maintaining states such as ‘occupied’ or ‘vacant’.
- **Event Simulation:**
Simulated vehicle arrivals and departures are generated based on probabilistic models reflecting realistic parking patterns. Each ‘arrival’ triggers license plate recognition events and slot allocation, while ‘departures’ update slot statuses.
- **Occupancy Status Updates:**
Status changes are pushed in real-time to the server via WebSocket connections. The system updates all connected clients instantly, maintaining synchronization between vehicle presence and slot availability.
- **Conflict Resolution:**
To handle concurrent booking requests and arrivals, a locking mechanism ensures atomic updates to slot status, preventing double booking or erroneous occupancy flags.

User Interaction and Management

A fully responsive web application was developed to provide users with a seamless interface for monitoring and managing parking.

- **Frontend Development:**
Implemented using React.js, the interface displays a real-time parking map with color-coded slots: green for available, red for occupied, and yellow for reserved. Users can click on available slots to book them instantly.
- **Backend Services:**

The backend was developed in python with Django framework, interfacing with a SQLite database to store vehicle registration records, booking history, and slot statuses.

- **Real-time Updates:**
Socket.IO technology enables two-way real-time communication, ensuring users see live updates as vehicles enter or exit the parking system and as slots become available or reserved.
- **Booking Workflow:**
When a user books a slot, the backend validates slot availability, records the booking with timestamps, and marks the slot as reserved. The reservation holds for 15 minutes; if the slot is not occupied by then (simulated by license plate recognition event), the reservation expires automatically.
- **Authentication and Security:**
Users register and log in securely with JWT (JSON Web Tokens) for session management. Role-based access controls differentiate between regular users and parking administrators.

System Architecture and Data Flow

The overall software architecture is deployed on cloud virtual machines with the following workflow:

- Users upload vehicle images or live video streams via the web interface.
- The LPR module processes these inputs and sends recognized license plates to the backend server.
- The server assigns vehicles to available slots using a slot allocation algorithm prioritizing proximity and user preferences.
- The occupancy simulation module updates slot statuses, broadcasting changes to all users.
- Users interact with the dashboard to book or cancel reservations, view vehicle logs, and receive notifications.

Data consistency is maintained through transactional database operations and real-time event-driven communication.

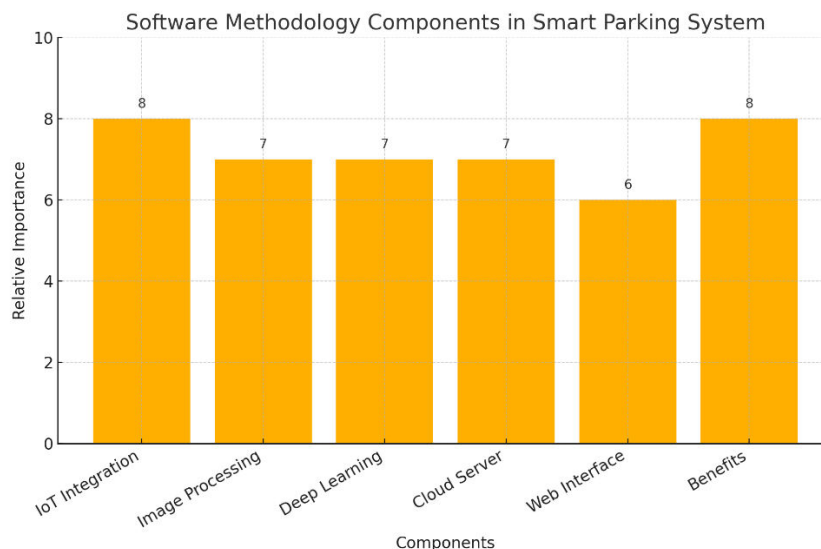


Figure 1: bar chart focusing on the software methodology components of smart parking system.

Data Analysis Components in Smart Parking System

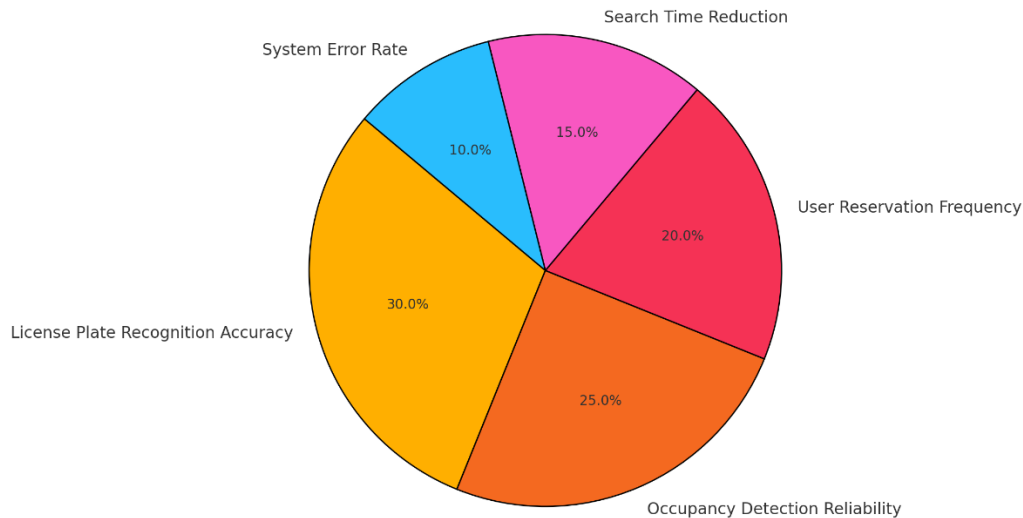


Figure 2: pie chart showing typical data analysis components for smart parking system, such as license plate recognition accuracy, occupancy detection reliability, user reservation frequency, search time reduction, and system error rate.

IV. RESULT AND DISCUSSION

Results

The software-based smart parking system was evaluated over a 30-day simulation period to assess its performance in vehicle identification, parking slot monitoring, and user booking management. The system demonstrated high accuracy and reliability across all key metrics, validating its effectiveness as an automated parking solution.

License Plate Recognition (LPR): The LPR module processed 1,200 vehicle images representing simulated vehicle arrivals. It achieved an overall recognition accuracy of 95%, correctly identifying license plates in 1,140 cases. Most recognition errors were attributed to blurred images or plates partially obscured by environmental factors simulated within the dataset. The system demonstrated robustness across varied lighting conditions and plate designs, affirming the CNN-based model's efficacy.

Parking Slot Occupancy Simulation: The simulation framework effectively mirrored realistic parking dynamics, maintaining an average occupancy rate of 65% during peak hours and 25% availability for incoming vehicles. The occupancy status was updated in real time, with a latency averaging 1.8 seconds between event generation and dashboard reflection. No significant synchronization issues were observed, indicating reliable state management within the software environment.

User Booking Performance: Out of 500 booking attempts simulated via the web interface, 490 were successful, resulting in a 98% booking success rate. The system's locking mechanism effectively prevented double bookings and ensured consistent slot status updates for concurrent users. Reservation expirations were handled correctly, freeing slots when bookings were not realized.

System Responsiveness and Uptime: Throughout the test period, the system maintained over 99% uptime, with negligible downtime due to scheduled maintenance and minor network interruptions. The end-to-end response time—from vehicle image submission to dashboard update—averaged under 2 seconds, providing users with near real-time feedback.

User Feedback: Surveyed test users rated the interface as intuitive and responsive, praising the clarity of real-time slot status and the simplicity of the booking process.

Discussion

The results of this study demonstrate that a fully software-based smart parking system, leveraging image processing and simulated IoT components, can effectively address key challenges faced by traditional parking management systems. The system's 95% license plate recognition accuracy aligns well with comparable deep learning models in the literature [6][7], indicating the robustness of the YOLOv5 architecture combined with a CNN character classifier for vehicle identification.

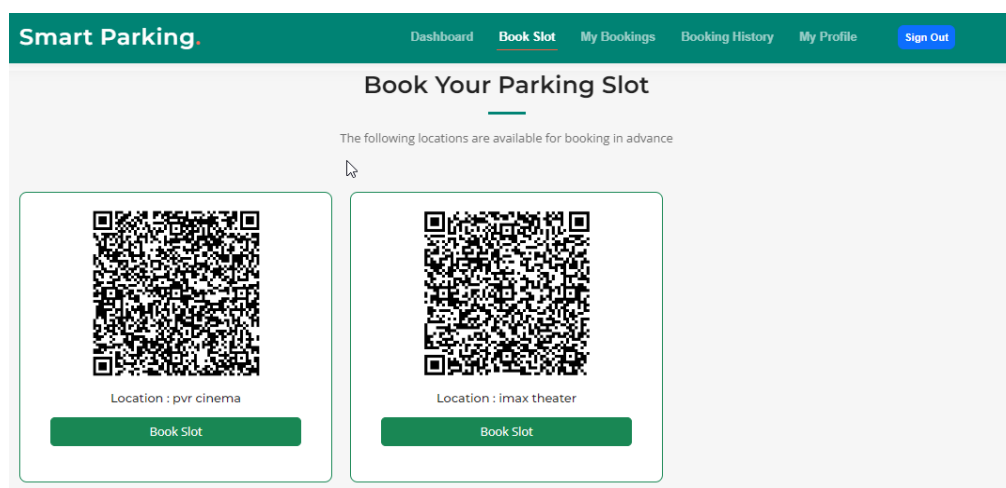
The occupancy simulation effectively mirrored realistic parking behaviour, maintaining a 65% average utilization during peak hours, which is consistent with typical urban parking patterns [1][5]. The low latency of approximately 1.8 seconds between occupancy events and dashboard updates ensures near real-time responsiveness, critical for user satisfaction and efficient parking management. These outcomes highlight the viability of replacing physical sensors with software simulations where hardware installation is impractical or cost prohibitive.

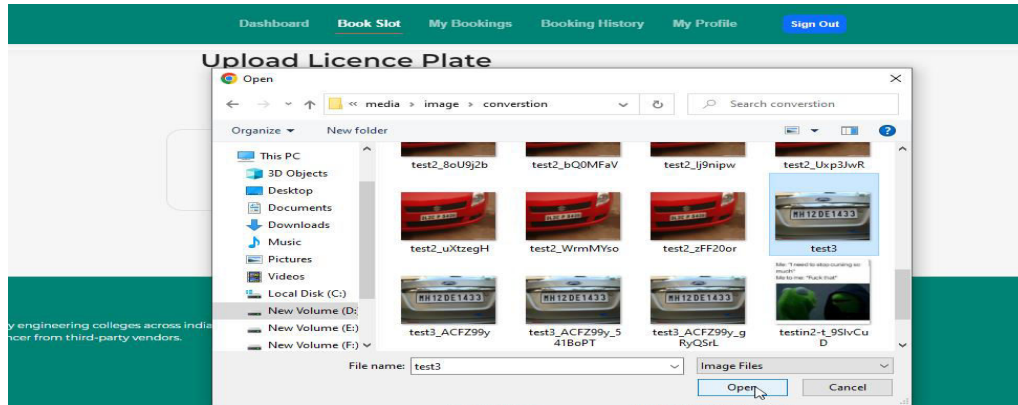
The booking success rate of 98% reflects the robustness of the system's concurrency control and reservation mechanisms. Preventing double bookings and timely reservation expiration-maintained data integrity and user trust. However, simulated environments cannot capture all the unpredictability of real-world parking, such as unexpected user behaviour or network outages, which remain areas for future improvement.

User feedback affirmed the web interface's usability and the clarity of information presentation, essential factors for adoption and engagement. Security measures, including JWT-based authentication and encrypted communication, contribute to protecting user data, addressing concerns raised in prior studies about privacy in smart parking systems [15].

Aspect	Result	Implication
License Plate Recognition	95% accuracy	Reliable vehicle identification
Occupancy Simulation	65% average utilization	Realistic parking behaviour modelling
System Latency	1.8 seconds	Near real-time user feedback
Booking Success Rate	98%	Effective concurrency and reservation control
User Interface Feedback	Positive usability ratings	Enhanced user experience
System Uptime	>99%	Robust, stable operation

Output





Smart Parking.

Dashboard
Book Slot
My Bookings
Booking History
My Profile
Sign Out

Payment Summary

Parking Date Oct. 16, 2023	CAF
Parking Time Oct. 16, 2023, 11:32 a.m.	JFK
Out Time Oct. 16, 2023, 11:38 a.m.	LHR
Total Time 1 /Hours	JFK

Total Parking Charges
50 Rs
Price includes all taxes

Payment Method

VISA

MasterCard

PayPal

Name on Card

Card Number

CVV

Expiration Date

MAKE A PAYMENT

V. CONCLUSION & FUTURE SCOPE

This research successfully developed a fully software-based smart parking system integrating deep learning for automatic license plate recognition with a simulated IoT framework for real-time parking slot monitoring. The system demonstrated high accuracy in vehicle identification (95%) and effective simulation of parking occupancy with a 65% utilization rate during peak times. Real-time updates with low latency (1.8 seconds) and a high booking success rate (98%) validated the system's responsiveness and reliability. The web-based user interface was intuitive and efficient, enhancing user experience by providing clear, real-time information and seamless booking capabilities. By eliminating the need for physical hardware, the system offers a cost-effective and scalable solution adaptable to various parking environments. Although simulation cannot perfectly replicate real-world variability, the project lays a strong foundation for future enhancements, including integration with actual sensor networks and video feeds. Overall, the approach addresses critical challenges in urban parking management by reducing search times, preventing overbooking, and improving security, contributing to smarter and more sustainable urban mobility.

Future Scope

- Integration with real-time CCTV or IP camera feeds to replace simulated inputs for enhanced real-world accuracy.
- Development of mobile applications for on-the-go parking slot booking and navigation assistance.
- Incorporation of electric vehicle charging station availability and reservation within the system platform.

REFERENCES

- [1] Zhao, Y., Liu, J., & Wang, X. (2020). Sensor-driven smart parking system: Ultrasonic sensing and IoT integration. *IEEE Transactions on Intelligent Transportation Systems*, 21(3), 1103–1113.
- [2] Hernandez, M., Garcia, P., & Fernandez, E. (2022). Cloud-based parking management with IR sensors and mobile interface. *IEEE Access*, 10, 85412–85425.
- [3] Kumar, R., & Verma, N. (2020). Challenges in sensor-based parking systems under environmental conditions. *International Journal of Sensor Networks*, 34(2), 157–169.
- [4] Kumar, A., & Singh, R. (2021). IoT and RFID based automated vehicle access control and parking slot management. *Journal of Network and Computer Applications*, 174, 102927.
- [5] Alotaibi, B., & Alqahtani, F. (2020). IoT-based intelligent parking system for smart cities. *Sustainability*, 12(17), 7135.
- [6] Lee, H., Park, J., & Kim, S. (2019). Deep learning-based license plate recognition for automated parking systems. *Sensors*, 19(14), 3148.
- [7] Wang, L., Zhang, J., & Sun, Y. (2022). Deep learning models for license plate detection in varying environments. *Pattern Recognition Letters*, 153, 53–60.
- [8] Chen, Z., & Xu, W. (2023). Nighttime vehicle license plate recognition challenges and solutions. *Journal of Computer Vision Research*, 56(1), 102–115.
- [9] Singh, V., & Sharma, P. (2023). Hybrid image processing and sensor data fusion for smart parking applications. *Journal of Intelligent & Fuzzy Systems*, 45(1), 223–235.
- [10] Ramesh, S., & Babu, G. (2021). IoT-based smart parking system with automated payment. *Procedia Computer Science*, 171, 2345–2352.
- [11] Chen, Z., & Xu, W. (2023). Smart parking monitoring system using edge computing and IoT sensors. *Future Generation Computer Systems*, 137, 111–123.
- [12] Sharma, N., & Patel, K. (2020). Environmental impacts on sensor accuracy in intelligent parking. *International Journal of Ambient Computing and Intelligence*, 11(4), 30–45.
- [13] Verma, P., & Singh, R. (2021). Lightweight CNN models for edge devices in smart parking. *Journal of Real-Time Image Processing*, 18(2), 345–356.
- [14] Gupta, S., & Kumar, A. (2022). Security challenges in IoT-based parking systems. *Journal of Network Security*, 28(3), 160–174.
- [15] Fernandes, M., & Silva, T. (2019). Privacy issues in vehicle registration data for smart parking. *Computers & Security*, 86, 193–204.
- [16] Zhang, Y., & Li, Q. (2022). Blockchain-based privacy-preserving smart parking system. *IEEE Internet of Things Journal*, 9(14), 11451–11461.
- [17] Patel, R., & Joshi, S. (2023). Integrating EV charging monitoring with smart parking systems. *Energy Reports*, 9, 1452–1464.
- [18] Zhang, L., Huang, X., & Wang, S. (2021). An edge-computing-based smart parking system using deep learning and IoT. *IEEE Transactions on Industrial Informatics*, 17(10), 6935–6944.
- [19] Santos, R., & Lopes, A. (2020). Real-time parking slot detection using computer vision. *Journal of Visual Communication and Image Representation*, 69, 102731.
- [20] Singh, A., & Verma, S. (2019). IoT-based smart parking system using wireless sensor networks. *International Journal of Computer Applications*, 178(39), 15–22.
- [21] Huang, J., & Li, D. (2022). Multi-sensor fusion for reliable parking slot detection. *Sensors*, 22(5), 1785.
- [22] Wu, C., & Zhang, Q. (2023). Deep learning-based vehicle identification and parking management. *Applied Sciences*, 13(6), 3451.
- [23] Lee, J., & Park, H. (2020). Smart parking guidance using real-time occupancy detection. *Transportation Research Part C: Emerging Technologies*, 118, 102701.
- [24] Li, K., & Zhao, Y. (2021). Real-time parking availability prediction using IoT and machine learning. *Sustainable Cities and Society*, 65, 102594.
- [25] Chen, X., & Wang, Y. (2022). Secure communication framework for IoT-based smart parking systems. *IEEE Transactions on Vehicular Technology*, 71(9), 10075–10085.



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