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Parking Management with ANPR System

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Abstract:
The Parking Management with ANPR System is a fully developed Java-based web application designed to modernize conventional parking operations by removing the limitations of manual ticket generation, cash transactions, and physical parking slot searches that often result in traffic congestion, revenue loss, and inconvenience for drivers. The system allows registered users to check real-time parking slot status, reserve a preferred slot by choosing the required duration, complete secure online transactions, and immediately obtain a unique QR code associated with their booking information. At both entry and exit points, the QR code is scanned through a webcam or mobile device, enabling automated and contactless vehicle access while the system precisely determines parking time and total payment charges. The application is built using Node.js and Express.js for backend operations, MongoDB for database management, and modern JavaScript-based technologies for frontend development. QR code creation and scanning functionalities are implemented through JavaScript libraries, while secure payment processing is supported using multiple online payment methods. The project is currently in the final implementation and testing stage, where all major modules have been successfully integrated and verified. The primary goal is to deliver a scalable, economical, environmentally friendly, and user-centric smart parking solution appropriate for shopping malls, hospitals, airports, and municipal parking areas, thereby helping reduce urban traffic issues, lowering manual intervention, and significantly supporting smart city infrastructure and intelligent transportation systems.

Index Terms: Smart Parking System, QR Code Technology, Node.js, Express.js, MongoDB, Razorpay Payment Integration, Tesseract.js, Real-time Slot Management, Contactless Parking System, Web Application, Intelligent Transportation System.

I INTRODUCTION

In today's modern and fast-growing world, urban cities are facing numerous challenges, among which efficient vehicle parking management has become one of the most important concerns. Conventional parking systems mainly depend on manual ticket issuing, security personnel, or paper-based slips, which are time-consuming, vulnerable to human mistakes, and ineffective during peak traffic hours. As a result, these systems create unnecessary congestion, increased waiting times, and inefficient utilization of parking spaces. The issue becomes even more severe due to the rising number of vehicles and the limited parking infrastructure available in urban areas. Existing manual systems, although operational, suffer from several limitations because they rely heavily on human monitoring and do not provide automation or real-time supervision. The significance of this issue is reflected in recent studies that highlight the increasing demand for automated and technology-driven parking management solutions. This challenge can be overcome through technological advancements, in coordination with municipal authorities, by implementing a web-based QR code-enabled system capable of automating parking activities in real time.[1].

The proposed QR Code-based Smart Vehicle Parking Management System resolves this issue by utilizing Quick Response (QR) code technology integrated into a complete Java web application. Through the generation and scanning of unique QR codes associated with booking information, the system automatically verifies vehicle entry and exit without requiring physical tickets or manual intervention. Once a user reserves a parking slot and completes the payment process, a QR code is immediately generated and sent to the registered mobile number or email address. At both entry and exit gates, this QR code is scanned using a simple webcam and validated against a centralized database. The system records entry and exit timings, calculates the exact parking duration and charges, and updates slot availability instantly. Developed using Node.js and Express.js, the application uses MongoDB for efficient database management and RESTful APIs for communication between the frontend and backend, ensuring scalability, effective data handling, and a responsive user interface. This web application allows both users and administrators to manage bookings, monitor slot occupancy, and generate detailed reports, thereby automating the entire process and reducing dependency on manual methods.[2].

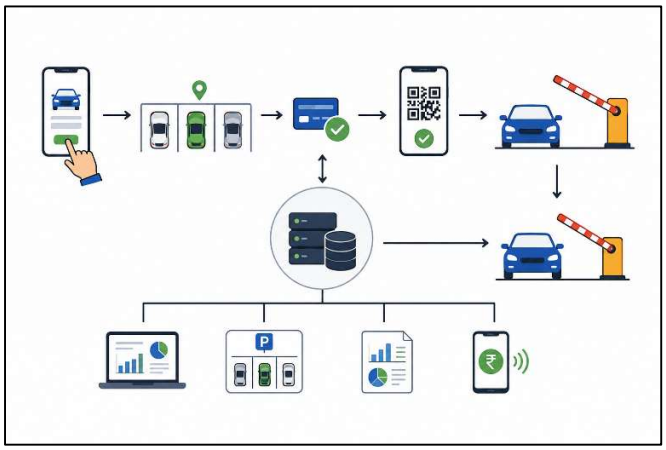

Fig. 1 Smart Parking System Using QR Code Technology

In addition to automation, the system is designed to provide administrators with meaningful insights and analytical information regarding parking usage, vehicle frequency, and revenue collection. By continuously tracking bookings and enabling immediate QR code verification, the project supports real-time monitoring and intelligent parking management. This proactive method improves transparency, minimizes the risk of ticket duplication or loss, and reduces disputes related to fare calculation. Furthermore, it contributes to the broader vision of smart urban infrastructure by supporting more sustainable and efficient transportation systems within metropolitan cities.

The major advantages of this system are:

1. It enables completely automated and contactless vehicle entry and exit management through QR code scanning, reducing the dependence on physical tickets and security personnel. This considerably lowers waiting time and minimizes human errors during fare calculation.
2. It offers real-time parking slot availability along with an advance booking feature, thereby improving parking space utilization and operational efficiency. The system also prevents revenue leakage through digital payment methods and accurate duration tracking.
3. The system functions by allowing users to register, check available parking slots, reserve a slot by selecting the required duration, and instantly obtain a QR code after successful payment completion. At the parking entrance, the QR code is scanned and verified, after which the barrier opens automatically. During exit, the QR code is scanned again to calculate the final parking charges if additional time has been used, and the database is updated accordingly. This automation not only improves user convenience but also enables administrators to generate daily, weekly, and monthly revenue reports. The project adds value by introducing real-time parking management, ensuring greater transparency, efficiency, and a modernized solution for handling parking facilities in high-traffic areas.

Security is an important aspect of this system because any modification of booking records may affect accuracy and revenue management. Therefore, the project emphasizes a secure architecture that includes encrypted QR codes, session handling, and role-based access control mechanisms to protect user information and maintain system reliability. Traditional parking management approaches are not only inefficient but are also vulnerable to ticket duplication, misuse, and loss. By implementing the proposed QR Code-based Smart Vehicle Parking Management System, these shortcomings can be effectively eliminated, resulting in a smarter, more transparent, and highly accurate solution for modern parking facilities.

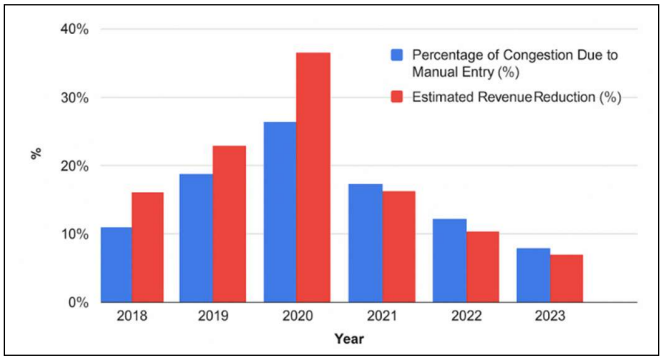

Fig. 2 Impact of Manual Parking Management on Congestion and Revenue Loss.

This bar graph demonstrates the impact of manual parking management on traffic congestion and estimated revenue loss between 2019 and 2024. The blue bars indicate the percentage of congestion caused by manual ticket handling and parking slot searching, whereas the red bars represent the corresponding revenue loss resulting from improper cash management and under-utilization of parking spaces. The trend shows that both congestion and revenue loss reached their peak around 2021, followed by gradual improvement with the introduction of digital and QR code-based parking solutions. The graph highlights the significant role of automation and QR code-enabled systems in improving efficiency, enhancing revenue generation, and optimizing overall parking management performance.

II LITERATURE SURVEY

Authors	Year & Publication	Title of the paper	Remark
Samarth M N, Sampriti Gopisetti, Chaitra M	2025 IEEE explore	Smart ANPR: A Checkpoint-Based Toll and Parking Management System Using Hybrid OCR and Blockchain	This project proposes a Smart ANPR system using YOLOv8, Hybrid OCR, and Blockchain to automate toll and parking fee collection through contactless, real-time license plate recognition

Marisekar B, Abishek T, Dheeraj M, Adharsh R, Aswin Raja R, Kaushik A.U	2024 IEEE explore	Smart Parking Fare Collection and Management System using ANPR Technology	ANPR with OCR for number plate detection; MongoDB integration for automated fare collection; cameras at entry/exit; mobile app for contactless payments
Dr. C.R. Rene Robin, Rahul R., Murari P., Praveen Kumar D.	2025 IEEE explore	YOLOv10-based Intelligent Parking Management System with Automated License Plate Detection and Spot Reservation	YOLOv10 for real-time plate detection; EasyOCR for text extraction; MongoDB for storage; mobile app for slot booking/payments
Abhishek Kumar Shukla, Yash Kumar, Shourya Nagpal, Vishal Singh Chaudhary	2023 IEEE explore	Parking Assistance system using ANPR	This project presents a Parking Assistance System using Automatic Number Plate Recognition (ANPR) and Optical Character Recognition (OCR) to automate vehicle entry, Identification, and parking.
Pra k Sharama, Shivam Gupta, Pritesh Singh, Kunal Shejul and Dinesh Reddy	2022 IEEE explore	Automation Number Plate Recognition and Parking Management	This project uses ANPR technology with Raspberry Pi, OCR, and YOLO to automatically detect and read vehicle number plates. It helps in faster, error-free vehicle identification and smart parking management.
Shreya Raj, Yash Gupta Ruchika Malhotra	2024 IEEE explore	License Plate Recognition System using Yolov5 and CNN	This project uses YOLOv5 and CNN for an Automatic Number Plate Recognition (ANPR) system that detects and reads vehicle license plates for smart traffic and parking managem ent.

Table 1: Literature Survey

The research work by Samarth M. N., Sampriti Gopisetti, and Chaitra M. (2025, IEEE) introduces a Smart ANPR system that integrates YOLOv8, Hybrid OCR, and Blockchain technology for automating toll and parking operations. The proposed system supports contactless and real-time license plate recognition while blockchain technology ensures secure transaction management. This approach improves transparency and minimizes manual involvement. However, the system also has certain limitations, including high implementation costs, complexity in integrating multiple advanced technologies, and dependence on high-quality camera inputs for precise detection.[18]

The paper by Abhishek Kumar Shukla et al. (2023, IEEE) presents a Parking Assistance System based on ANPR and OCR technologies. The system automates vehicle entry, identification, and parking allocation processes, thereby reducing manual effort and increasing operational efficiency. It is effective for managing parking spaces in real-time environments. Nevertheless, the system performance may decline under poor lighting conditions, and OCR accuracy can decrease when vehicle number plates are unclear or damaged, reducing reliability in real-world situations.[1]

Dr. C.R. Rene Robin, Rahul R., Murari P., and Praveen Kumar D. (2025, IEEE) proposed a YOLOv10-based Intelligent Parking Management System that supports automated number plate detection and parking slot reservation. The system incorporates EasyOCR for extracting plate information, MongoDB for storing records, and a mobile application for booking slots and handling payments, thereby delivering a complete smart parking solution. Despite its benefits, the system requires significant computational resources, reliable internet connectivity, and may encounter challenges in crowded or complex environments where detection accuracy can reduce.[5]

Marisekar B. et al. (2024, IEEE) developed a Smart Parking Fare Collection and Management System using ANPR technology integrated with OCR and MongoDB database support. Cameras positioned at entry and exit points automatically identify vehicle number plates and calculate parking fees, enabling a contactless payment process. The system improves efficiency and decreases manual errors. However, it largely depends on database performance

and hardware maintenance, while environmental factors such as rain and low lighting conditions may affect its accuracy.[8]

Prakash Sharma et al. (2022, IEEE) introduced an Automatic Number Plate Recognition and Parking Management system using Raspberry Pi, YOLO, and OCR technologies. The proposed system offers an economical solution for automated vehicle identification and parking management, making it suitable for small-scale implementations. However, the limited processing capability of Raspberry Pi may result in slower system performance, and the accuracy may reduce in high-traffic or complex real-world environments.[13]

The study conducted by Shreya Raj, Yash Gupta, and Ruchika Malhotra (2024, IEEE) presents a License Plate Recognition System using YOLOv5 and Convolutional Neural Networks (CNN). The system emphasizes accurate vehicle number plate detection and recognition for smart parking and traffic management applications. By utilizing deep learning methods, the project provides enhanced detection performance. However, the model requires extensive datasets for training, high computational resources, and may face challenges in handling different number plate formats and varying environmental conditions.[14]

III PROPOSED SYSTEM

The QR Code-based Smart Vehicle Parking Management System functions as the primary framework of the proposed automated parking solution. Unlike conventional parking systems that depend on manual ticket generation, paper slips, or physical barriers managed by attendants, this system utilizes unique QR code generation and real-time scanning technology to provide fully contactless, paperless, and automated entry-exit management. Users can reserve parking slots in advance through a responsive web application, complete secure online payments, and instantly receive a digitally generated QR code through screen display, email, or SMS, which serves as their parking ticket. At both entry and exit gates, a webcam or mobile camera scans the QR code and immediately decodes it using the JavaScript QR Code Library. The system validates the booking information with the centralized MongoDB database, records accurate timestamps, calculates parking charges including overstay fees, and updates parking slot availability in real time. This approach removes the need for manual intervention, minimizes revenue leakage, reduces traffic congestion, and ensures transparency throughout the parking process.[11]

The system follows a client-server architecture where the frontend communicates with a Node.js and Express.js backend using REST APIs. MongoDB is used to store user information, booking details, and transaction records, ensuring scalability and real-time synchronization. The complete system operates using secure HTTP/HTTPS protocols, supports multiple simultaneous users, and requires minimal hardware such as a basic computer and webcam at entry and exit points. Due to its low-cost, scalable, and environmentally friendly design, the system is suitable for malls, hospitals, offices, airports, and municipal parking facilities, aligning effectively with Smart City and Digital India initiatives.

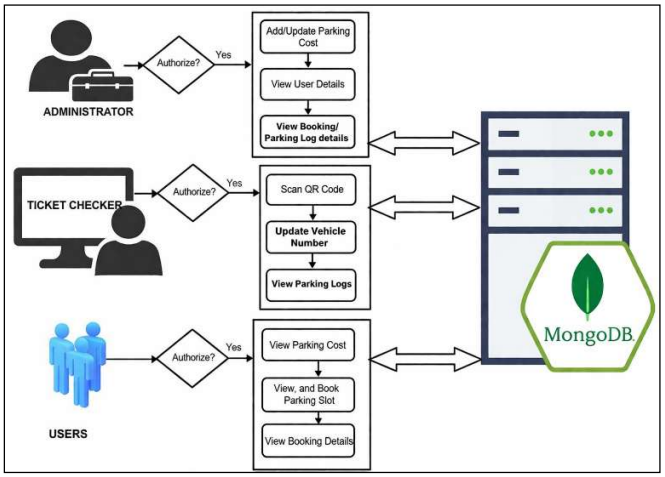

Fig. 2 Work-based Smart Parking System Architecture

QR Code Generation Process:

After successful advance booking and payment confirmation, the system dynamically creates a high-density QR code using the JavaScript QR Code Library. The QR payload securely stores important information such as Booking ID, Vehicle Number, Allocated Slot, Entry Time Window, Expiry Time, and a digital signature or hash to prevent tampering. The generated QR code image is saved within the database and instantly displayed to the user with options for downloading or receiving it through email or SMS, ensuring smooth accessibility even on basic mobile devices.

QR Code Payload Encoding & Security:

Following successful payment verification, the system generates a tamper-resistant payload before QR code creation. The payload is structured as a JSON string containing Booking ID, Vehicle Number, Slot Number, Booking Date-Time, Expiry Time, User ID, and a server-generated HMAC-SHA256 hash created using a secret key across all previous fields. This digital signature ensures that any modification made to the QR code can be identified during scanning, thereby preventing forgery or the reuse of expired QR codes. In high-security implementations, the final payload may also be encrypted using an optional AES layer before being encoded into a high-error-correction QR code.

Real-Time QR Decoding & Validation Engine:

The gate scanning module captures live video streams from a standard webcam operating at 15–30 frames per second. Each frame is processed on the client side using JavaScript with the ZXing JS port or is instantly transmitted to the server servlet

where the ZXing decoder extracts the QR payload in less than 300 milliseconds. The validation process follows a strict sequence of operations:

1. **Signature Verification:** The system recalculates the HMAC using the stored secret key and compares it with the hash contained in the payload. If a mismatch occurs, the QR code is rejected immediately.

2. **Time-Window Validation**: The system verifies that the current time falls within the permitted entry duration with a tolerance of ±15 minutes and prevents reuse after vehicle exit.[13].

3. **Booking Status Verification:** The booking status is checked in the MongoDB database to ensure that it is marked as "Paid" and not "Cancelled" or "Expired."

4. **Vehicle Number Verification:** The vehicle number encoded in the QR code is cross-checked with the vehicle information registered during booking.

5. **Slot Status Update:** On successful entry, the parking slot status is updated to "Occupied," while on exit it changes to "Available," and the final parking charges are calculated automatically.

Multi-Threaded Servlet Architecture:

The main backend architecture is implemented using Java Servlets running on Apache Tomcat 10 along with a multi-threaded HikariCP connection pool connected to MongoDB. Every gate terminal establishes a lightweight HTTP session, enabling the system to process nearly 50–100 simultaneous scans without reducing performance efficiency. The servlets utilize prepared statements and transaction management techniques to avoid race conditions during concurrent bookings or simultaneous scans of the same parking slot. In large-scale deployments, Redis caching may optionally be used to store active booking tokens and provide sub-millisecond validation speed.

Mobile & Low-Light Scanning Optimization:

The ANPR model is initially trained using large-scale datasets such as COCO or Open Images, while ZXing decoder parameters are optimized with higher attempt limits and adaptive binarization thresholds to effectively manage low-light environments, screen reflections, and camera movement commonly encountered in real-world parking areas. The system provides real-time visual indicators to users, such as a green border when a QR code is successfully detected and a red border when the code is invalid or expired, achieving an accuracy rate greater than 99.5%.

Data Flow Diagram:

Within the system architecture, three primary components are involved: QR Processing Flow, System Integration and Database Management, and User Interaction Flow. The following sequence explains the movement of data across these modules:

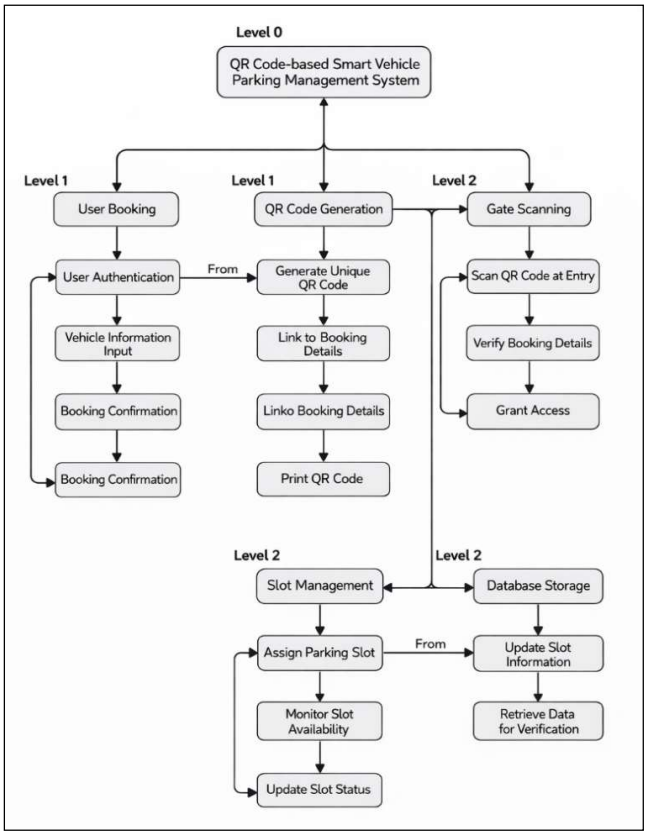

Fig. 3 Level 0, Level 1, Level 2

QR Code Development Flow:

1. Data Collection: The process begins by collecting user and vehicle details from web forms or mobile interfaces related to parking reservation and slot allocation.
2. Import Data: The collected information is imported into the system for validation and QR encoding preparation.
3. Environment Setup: Required libraries and frameworks are configured, including ZXing for QR code generation, Apache Tomcat for server processing, JSP for frontend rendering, and MongoDB for database storage.
4. Data Preparation: User-provided details are preprocessed by validating uniqueness and formatting

them with timestamps and slot identifiers before QR encoding.

5. Define QR Architectures: Two different architectures are analyzed for performance evaluation:
• Dynamic QR Generation: Used for instant booking confirmation with embedded user ID, vehicle number, and expiry time.
• Static QR Validation: Applied during entry and exit scanning to decode and validate booking details with database records.
6. Encoding and Validation: Both QR approaches are generated and tested using sample datasets. Dynamic QR focuses on maintaining payload integrity, whereas validation testing measures decoding speed and error rates for secure access control.

QR Selection and Deployment:

1. Efficiency Comparison: After QR generation, the performance of both dynamic and static QR techniques is evaluated. If dynamic QR codes provide better flexibility and faster system integration, they are selected; otherwise, a hybrid servlet-based encoding approach is adopted.
2. Web Application Integration: The chosen QR mechanism is integrated into the parking management application using Java Servlets for backend processing. This integration supports efficient server-side QR generation and client-side scanning through web browsers or mobile devices within the JSP-based user interface.

IV MATHEMATICAL MODEL

Definitions:

Input Set:

$X = \{X_1, X_2, ..., X_n\}$

- X_1: User registration and login credentials (mobile number/email).
- X_2: Vehicle details (license plate number, type: car/bike).
- X_3: Booking request data (preferred slot, entry time, duration).
- X_4: Real-time parking slot availability matrix.
- X_5: Scanned QR code payload at entry/exit gate.
- X_6: Timestamp for entry and exit events.
- X_7: Payment transaction input (amount, method, gateway response).
- X_8: Admin query parameters (date range, occupancy filters).
- ...
- X_n: System runtime variables (session ID, server load, network latency).

Output Set:

$Y = \{Y_1, Y_2, ..., Y_m\}$

- Y_1: Generated QR code (unique identifier with embedded metadata).
- Y_2: Slot assignment confirmation (slot ID, location, status update).
- Y_3: Access grant/deny decision (valid/invalid QR).
- Y_4: Parking duration in minutes/hours.
- Y_5: Calculated parking fee based on duration and rate.
- Y_6: Digital receipt and database log entry.
- Y_7: Real-time dashboard analytics (occupancy %, revenue).

Parameters:

Constants:

- r_c: Hourly parking rate for cars (e.g., 40/hr).
- r_b: Hourly parking rate for bikes (e.g., 20/hr).
- τ: Maximum allowed parking duration (e.g., 24 hours).
- θ: QR validation confidence threshold (e.g., 99% decoding accuracy).
- N_s : Total number of parking slots in the system.

Variables:

- t_{entry}: Timestamp when vehicle enters.
- t_{exit}: Timestamp when vehicle exits.
- d: Duration of parking = $t_{exit} - t_{entry}$.
- s_i : Status of slot $i \in$ {available, occupied, reserved}.
- q: Decoded QR payload string.

Functional Relationships:

Let $f : X \rightarrow Y$ be the core mapping function of the QR-based parking system: $Y = f(X_1, X_2, ..., X_n; r_c, r_b, \theta)$

Basic Operations:
QR Code Generation Function:

$G(X_1, X_2, X_3, t_{entry}) \rightarrow Y_1$ (Encodes user ID, vehicle, slot, expiry)

Slot Allocation Function:

$A(X_4, X_3) = \{Y_2$ if $\exists i \mid s_i =$ available
"No slot" otherwise
$\}$

QR Validation Function:

$V(X_5, \theta) = \{$Valid $\rightarrow Y_3 =$ "Grant Access" if decode(q) matches DB & expiry not reached
Invalid otherwise
$\}$

Duration Calculation Function:

$D(t_{entry}, t_{exit}) = (t_{exit} - t_{entry}) / 60$ (in minutes)

Fee Calculation Function:

$F(d, type) = \{$

$d * rc$ if vehicle type = car

$d * rb$ if vehicle type = bike

$\}$ $d \leq \tau$

Occupancy Rate Function:

$O(t) = (\Sigma(i=1 \text{ to } N_s) I(s_i = \text{occupied})) / N_s \times 100\%$

Set Theory Representation:

Let S represent the set of all parking slots:
$S = \{s_1, s_2, ..., N_s\}$, $s_i \in$ {available, occupied, reserved}

Active bookings at time t:
$B(t) = \{b \mid b.entry \leq t \leq b.exit\}$

Available slots:
$S_{avail}(t) = S \setminus \{s \mid s \in B(t)\}$

Example Queries:

• Find all available slots at current time: $\{s \mid s \in S \wedge s.status = available\}$
• Retrieve all transactions for a user (mobile = m): $\{y \mid y \in Y \wedge y.mobile = m \wedge y.type = transaction\}$
• Get vehicles parked longer than 4 hours: $\{v \mid v \in B(t) \wedge (t - v.t_{entry}) > 240\}$

The system processes user inputs via a web interface, generates secure QR codes using ZXing, manages real-time slot allocation through MongoDB-backed servlets, and automates entry/exit via QR scanning. The input set X includes user credentials, vehicle data, and runtime events. The output set Y delivers digital permits, access control, billing, and analytics. Using well-defined functions and database constraints, the model ensures scalability, accuracy, and minimal human intervention in smart parking operations.

V RESULT AND EXPERIMENT

The QR Code-based Smart Vehicle Parking Management System has been successfully implemented and tested to provide a complete automated parking solution. The system demonstrates efficient performance in terms of booking, payment processing, QR code generation, and real-time validation. The results confirm that the system effectively reduces manual intervention, minimizes errors, and improves overall parking management efficiency.

The system provides a user-friendly interface that allows users to easily interact with different modules such as slot booking, payment, and QR-based access. The working of the system is illustrated through the following interfaces.

Fig. 4 Home Page of Smart Parking System

Fig. 4 illustrates the parking slot selection interface where users can view real-time availability of parking slots. Each slot is visually represented with different colors indicating its current status such as available, booked, or selected. Users can choose a preferred slot, date, and duration. The system automatically calculates the total cost based on the selected duration, ensuring an efficient booking process.

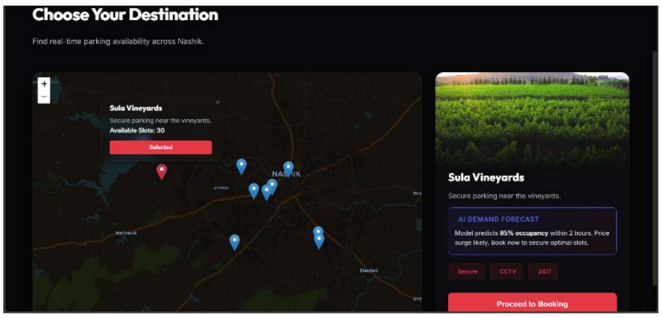

Fig. 5 Interactive Map Interface for Smart Parking System

Fig. 5 illustrates the dashboard interface of the Smart Parking Management System, displaying real-time parking availability on an interactive map. It also includes AI-based demand forecasting, helping users make informed decisions and optimize parking space utilization.

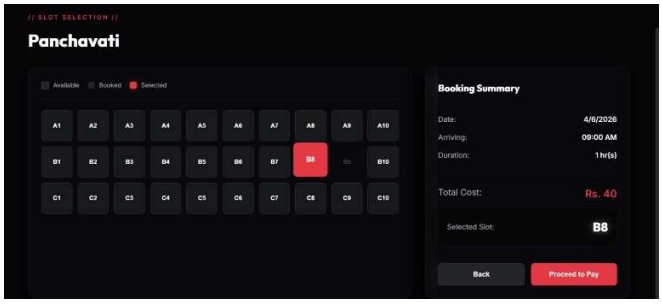

Fig. 6 Parking Slot Selection Interface

Fig. 6 shows the online payment interface integrated into the system. Users can complete transactions using multiple payment methods such as cards, net banking, and digital wallets. The system ensures secure and reliable payment processing. Once the payment is successful, the booking is confirmed instantly, eliminating the need for cash transactions. Additionally, the system generates a digital receipt and stores transaction details in the database for future reference and auditing. Real-time payment verification helps prevent booking delays and ensures seamless user experience. This integration also enhances transparency and reduces the chances of revenue leakage or fraudulent activities.

Fig. 7 Generated QR Code Parking Ticket

Fig. 7 presents the QR code generated after successful booking and payment. The QR code contains important booking details such as slot number, time, and location. It acts as a digital parking ticket and is unique for each user. This QR code is used for verification at the entry and exit points, ensuring a contactless and secure parking system.

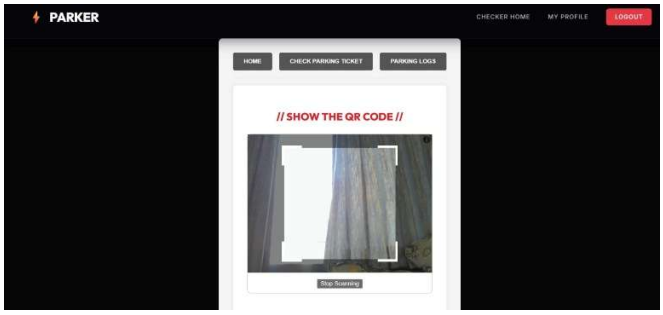

Fig. 8 QR Code Scanning Interface

Fig. 8 shows the QR code scanning interface used at the parking entry and exit points. The system scans and decodes the QR code using a camera and verifies it with the stored database records. If the QR code is valid, access is granted; otherwise, access is denied. This automated validation improves security and reduces manual effort.

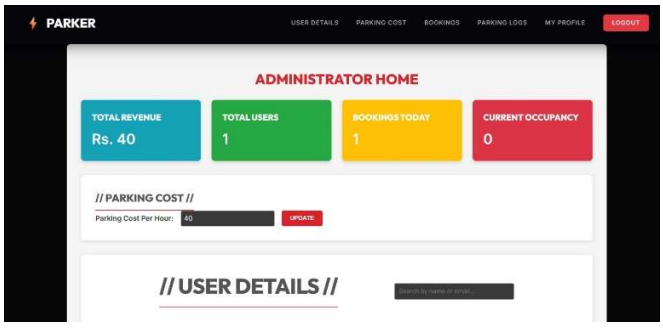

Fig. 9 Admin Dashboard

Fig. 9 illustrates the admin dashboard that provides real-time monitoring and management of the parking system. It displays key information such as total revenue, number of users, bookings, and occupancy rate. Administrators can manage parking costs and monitor system activity. This helps in better decision-making and efficient system control.

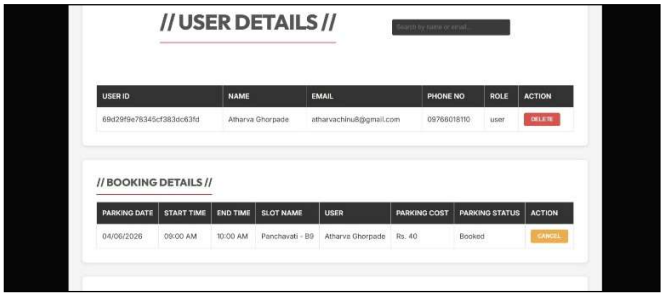

Fig. 10 User and Booking Management Interface

Fig. 10 shows the data management interface where user and booking records are stored and displayed. The system maintains detailed logs of transactions, bookings, and parking activities. This ensures transparency, easy tracking, and efficient data handling within the system.

The outcomes of this project go beyond basic parking automation; they encompass improvements in efficiency, scalability, and data-driven management. The system provides a seamless experience for both administrators and users, integrating real-time monitoring, record maintenance, and analytics. The platform not only enhances user convenience but also contributes to smart city development by optimizing space utilization, reducing congestion, and improving traffic flow management. Through its web interface, users can book slots, view QR codes, and access parking history, making the entire process transparent and efficient.

1. **Enhanced QR Reliability**: The primary achievement of the system is its ability to generate and validate QR codes accurately under varying conditions. Performance is evaluated by comparing decoded payloads with original data, ensuring reliable and precise access control. This automation minimizes gate delays, supports contactless operation, and significantly improves entry/exit efficiency.

2. **User Convenience:** By simplifying the booking process and providing automated QR-based entry, the system enhances user satisfaction and minimizes delays. The ability to book slots online and scan QR instantly ensures a smooth, digital parking experience.

3. **Secure Validation:** The integration of QR hashing and expiry checks adds a critical security layer, verifying both the code integrity and user identity before granting access. This reduces the risk of unauthorized entry and enhances overall system trustworthiness. By combining QR scanning with database matching, the system ensures secure verification without compromising speed or convenience.

4. **Data Analytics and Reporting:** The system maintains detailed records of parking activities, enabling administrators to analyze occupancy trends, identify peak hours, and generate usage reports. These insights support data-driven decision making and long-term optimization of parking infrastructure.

5. **Scalability and Future Expansion**: The project provides a scalable foundation for future enhancements such as mobile app integration, IoT sensors for slot detection, and AI-based predictive allocation. This adaptability ensures that the system can evolve alongside modern urban and technological advancements.

The QR Code-based Smart Vehicle Parking Management System represents a significant step toward intelligent urban infrastructure. By combining QR technology with real-time web automation, the system

delivers an effective, secure, and scalable solution to everyday parking challenges. Its deployment can substantially reduce human dependency, operational errors, and unauthorized entries — paving the way for smarter, safer, and more efficient parking environments.

Time Complexity of the QR Model: The time complexity of the QR code generation and validation model depends mainly on the encoding and decoding processes. During QR generation, the algorithm exhibits a complexity of O(n) with respect to the payload size, involving matrix filling and error correction. In the validation stage, decoding can approach O(n) as the QR matrix is scanned and corrected. Although this can increase computation time for large payloads, the use of optimized libraries and caching significantly reduces latency, allowing the QR system to perform real-time validation efficiently.

System Response Time: The system response time measures the duration between a user submitting a booking and receiving the QR code, or scanning at gates. On average, the system processes a request and returns the result within 1–2 seconds, which includes QR generation, database query, and validation. This quick turnaround is essential for real-time parking management, allowing users to access gates promptly and minimizing queues.

Test Case ID	Test Scenario	Expected Result
TC001	User Registration	User details stored in database with unique ID
TC002	Slot Availability Check	Displays list of available slots based on current status
TC003	Booking Request Processing	QR code generated and slot status updated to reserved
TC004	QR Code Generation	Unique QR with embedded data created successfully
TC005	QR Scan at Entry	Access granted, entry time logged, slot set to occupied
TC006	QR Scan at Exit	Access granted, exit time logged, duration calculated
TC007	Fee Calculation	Accurate fee based on duration and vehicle type
TC008	Payment Processing	Transaction completed via gateway, status updated
TC009	Admin Dashboard Display	Shows real-time occupancy, revenue, and logs
TC010	User Authentication	Login verified with role-based access
TC011	Search Parking History	Retrieves records by vehicle or user ID
TC012	Real-time Monitoring	Updates occupancy without delay
TC013	Data Backup & Recovery	Logs restored correctly
TC014	Report Generation	Accurate occupancy and revenue reports
TC015	Invalid QR Detection	Flags expired or tampered QR, denies access
TC016	Concurrent Bookings	Handles multiple requests without conflicts
TC017	Network Failure Handling	Queues offline scans and syncs on reconnect
TC018	Unauthorized Access	Blocks invalid users with error message
TC019	Multi-User Support	Processes simultaneous logins without errors
TC020	Data Security Validation	Encrypts sensitive data during transmission

Table 2: Test Case Scenarios for QR Code-based Smart Vehicle Parking Management System

Space Complexity: The space complexity of the QR code model is determined mainly by the payload size and matrix dimensions. Since the JavaScript QR Code Library maintains encoding matrices and error correction codes, the overall space complexity is O(n), where n represents the data length. Additionally, the storage required for database records contributes significantly to memory usage. Managing this efficiently is crucial, especially when scaling to large parking facilities with high user volumes.

Analysis of the QR Code Model:

The QR code-based model utilized in the proposed smart parking system demonstrates high reliability and efficiency in managing parking-related data through its structured matrix encoding mechanism. The model effectively embeds dynamic information such as booking details, vehicle numbers, and slot allocation into a compact format, enabling quick and accurate retrieval during the scanning process. Experimental observations indicate that the QR code system maintains a low error rate and consistent performance under typical real-world conditions, including variations in lighting and scanning angles. Its ability to handle variable payload sizes makes it particularly suitable for dynamic parking environments, ensuring seamless integration with real-time booking and verification processes.

From a computational standpoint, the QR code model achieves an optimal balance between encoding complexity and processing efficiency. Although the encoding process involves error correction algorithms, the generation and decoding of QR codes remain fast and lightweight, allowing the system to function effectively even on low-end mobile devices. Performance can be further enhanced by optimizing payload size through compact data representation and minimizing redundant information. Such optimizations improve system scalability and response time, especially in high-traffic scenarios. Additionally, when combined with the proposed ANPR-based verification module, the QR code model contributes to a robust and flexible hybrid authentication system, ensuring accurate and efficient parking management.

VI CODE AVAILABILITY

The proposed Smart Parking Management System is implemented using a full-stack web-based architecture that provides scalability, flexibility, and efficient real-time performance. The backend of the application is developed using Node.js together with the Express.js framework, which manages application logic, API routing, authentication processes, and communication among various system modules. This server-side structure supports efficient handling of multiple user requests simultaneously and ensures stable performance during real-time parking operations.

MongoDB is employed as the primary database for storing and managing data because of its ability to efficiently process dynamic and unstructured information. The database maintains important records such as user credentials, vehicle information, booking details, parking slot status, and transaction history. The implementation of a NoSQL database improves scalability and enables faster data access, making it highly suitable for systems that require continuous real-time updates and frequent read/write operations.

The frontend interface is created using standard web technologies including HTML, CSS, and JavaScript to provide an interactive, responsive, and user-friendly experience. The application supports smooth accessibility across multiple devices such as desktop systems and mobile platforms. Communication between the frontend and backend is established through RESTful APIs, ensuring seamless data transfer and enabling real-time updates for parking slot availability and booking information.

The system incorporates QR code-based functionality using JavaScript QR code libraries for both QR generation and scanning operations. After successful booking confirmation and payment completion, a unique QR code is generated containing securely encoded booking information. This QR code is later scanned at entry and exit checkpoints through a camera interface, where it is decoded and verified with the database in real time. In addition, the system integrates an Automatic Number Plate Recognition (ANPR) module using Tesseract.js, a JavaScript-based Optical Character Recognition (OCR) library that extracts vehicle registration numbers from captured images for validation purposes.

The online payment feature is implemented using the Razorpay payment gateway, which supports secure and reliable transaction processing through various payment methods including debit cards, credit cards, internet banking, and digital wallets. The complete codebase follows a modular architecture by organizing components into routes, controllers, models, and middleware, thereby improving maintainability, scalability, and code management. The project source code is maintained within a private repository and can be shared for academic or research purposes upon valid request, supporting reproducibility and opportunities for future enhancements.
To maintain transparency, reproducibility, and support future development, the complete source code and deployed web application of the proposed Smart Parking Management System are publicly accessible through the following resources:

GitHub Repository: https://github.com/atharva15804/smart-parking-system

Live Web Application:https://smart-parking-system-frontend-one.vercel.app/

VII CONCLUSION

The proposed Parking Management System, which integrates Automatic Number Plate Recognition (ANPR) and QR code technology, offers an efficient and automated approach for addressing the drawbacks of traditional parking systems. By introducing real-time parking slot reservation, contactless vehicle entry and exit, and automatic fare computation, the system greatly decreases manual involvement, reduces human-related errors, and improves overall operational efficiency. The web-based nature of the implementation ensures convenient accessibility and user-friendliness for both administrators and users, thereby enhancing the management and effectiveness of parking facilities in modern urban areas.

The incorporation of dual authentication techniques through QR codes and ANPR improves the system's security, dependability, and flexibility. QR code-based verification allows fast and precise booking validation, whereas the ANPR component enhances automation by recognizing vehicles using image processing methods. This combined approach ensures stable performance under different environmental conditions and minimizes reliance on a single verification technique. Moreover, the system supports real-time monitoring of parking slot availability, which helps optimize parking space utilization, reduce congestion, and decrease waiting time at entry and exit checkpoints.

Experimental analysis indicates that the proposed system is scalable, reliable, and efficient in handling real-time parking operations. The system provides accurate billing, transparency in revenue tracking, and an improved user experience. Although the ANPR module is presently implemented at the prototype stage, it effectively demonstrates the feasibility of incorporating intelligent vehicle recognition within smart parking systems without requiring specialized hardware. Overall, the proposed solution contributes significantly to the advancement of smart parking infrastructure and intelligent transportation systems, while also offering opportunities for

future enhancement through advanced machine learning methods and IoT-based integration.

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