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A Cloud-Enabled IoT Architecture for Smart Parking Management Using QR Code Authentication

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Abstract - *Urban areas are witnessing an increase in the number of vehicles, which has led to a lack of parking spaces, more fuel consumption, and heavy traffic. This paper suggests a cost effective Internet of Things (IoT) and QR code technology-based Smart Parking System (SPS) that can be used to monitor in real-time, access automatically, and manage parking intelligently. The system uses sensors equipped with the Internet of Things (IoT), cloud computing, and computer vision-based object recognition to locate and track vehicles in parking areas. Moreover, QR code authentication is used in the proposed system to enable vehicle identification to be safe, contactless, and cheap, unlike traditional RFID-based methods. When a user scans a QR code using a smartphone or camera, the system checks the user's identity, writes the data of the entry or exit to the record, and updates the parking availability. An online or mobile interface through which both users and administrators can see updated occupancy information, is created by a cloud server that also communicates with IoT devices to get real-time data from the parking lot. To lessen the time spent searching for a parking space as well as to lower the likelihood of traffic congestion in the parking lot, the Farthest First Clustering algorithm is utilized additionally by the Dijkstra shortest path algorithm for the vehicles to be able to reach the closest vacant parking slot. Moreover, the parking usage patterns are being analyzed by the Farthest First Clustering algorithm to not only facilitate the area of a parking lot for the demand of a certain period but also allow for the prediction of future trends. The designed system will be able to work efficiently in a large city as the storage of data is the main responsibility of the central cloud with which the servers and sensors communicate seamlessly. Testing of the prototype indicates that the system is able to locate an object with an accuracy of more than 96%, recognize a QR code with a reliability of 99.9%, and have a response time of less than a second. These results help confirm that the system is suitable for real-time field application in environments such as cities. It is a technologically advanced, safe, and clean solution that helps to reduce parking problems and supports smart city development and intelligent transport infrastructure. Keywords: Internet of Things (IoT), Smart Parking System, QR Code Authentication, Cloud Computing, Object Recognition, Dijkstra Algorithm, Farthest First Clustering, Intelligent Transport Systems*

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1 .INTRODUCTION

The growth in the number of vehicles in modern cities is the main reason for the serious problem of parking space shortage in the urban areas. Car owners in the majority of city centers have to drive around empty parking lots for a long time and this results in unnecessary fuel consumption, traffic congestion, and pollution increases. Bad parking management does not only waste time and energy but also increases the level of urban stress as well as environmental degradation. Hence the formation of an intelligent parking system is an essential step towards the cities of the future that are smart and sustainable. The performance of traditional parking systems is generally done through human labor or partly automatic procedures. In these systems, human beings are in charge of issuing tickets, collecting payments, and controlling the parking spaces. These methods are characterized by mistakes and problems that hinder the users' efficiency and comfort. To counterbalance these shortcomings, technological innovations over the last years have paved the means for the emergence of smart parking systems that use as well as communicate via IoT devices, sensors, computer vision, and cloud-based platforms and can, thus, fully, or partially, automate parking operations as well as offer real-time information to users. The first devices of smart parking systems widely utilized Radio Frequency Identification (RFID) technology for vehicle detection and access control. RFID depends on the communication through electromagnetism between the car-attached tag and the gate-mounted reader. Even though RFID is very accurate and is used in many applications, it is necessary to have certain hardware like RFID tags, antennas, and readers. Implementation raises the cost, limits extensibility, and requires ongoing hardware upkeep. In order to overcome these drawbacks, the system actuality proposed deregisters the use of RFID and features a Quick Response (QR) code-based approach to vehicle identification and authorization. QR codes represent visually the alphanumeric characters of the information they store without the limitation of space. They can be stored in digital form and later printed as one can easily and cheaply make a copy. A common camera module or a smartphone can scan the QR code and software packages like OpenCV and Pyzbar can do the decoding at the same time. The association of the distinctive QR code to each vehicle makes it the vehicle's digital identifier. The moment the driver comes in or goes out of the parking area, the QR code is scanned for recording entry and exit times automatically. After verification of the vehicle's identity, the system employs IoT sensors to locate free parking spaces and then communicates this information to a cloud server. In order to find the shortest route from the entrance gate to the nearest parking place the system is using Dijkstra's shortest path algorithm. On a user interface or a display system, the driver gets this information, which helps him to navigate the parking lot quickly and easily. The use of QR code technology is combined with other technologies, such as IoT, computer vision, and cloud services, to create a system that is more affordable, adaptable, and expandable than an RFID-based one. The recognition of the QR code eliminates the need for costly tags or readers, while IoT sensors deliver real-time monitoring of obtainable parking spaces. Thanks to cloud connectivity data management is centralized allowing for the usage of parking data for different purposes like predictive parking analysis or system development in the future. The QR code-based smart parking scheme proposed as the most suitable solution to the problems related to the parking space issue would essentially help urban areas to integrate the different needs into one system in order to lighten the traffic, save time, and make better use of resources.

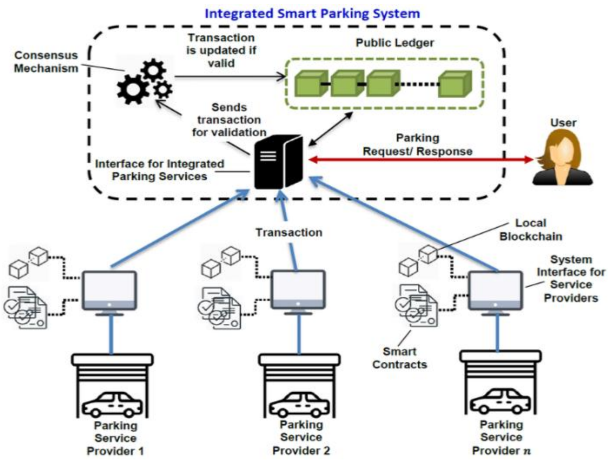

Figure 1 . Integrated Smart Parking System Architecture

The Figure 1 depicts the general layout of the integrated smart parking scheme, which is the result of the proposed research. The system is designed to utilize IoT, blockchain, and QR code technologies to deliver secure, transparent, and efficient parking operations. On the user side, the driver is the one who makes a parking request by simply scanning a unique QR code that is assigned to the vehicle. After receiving this request, the system replies by sending a message to the integrated parking service interface. The interface, therefore, is like a bridge that connects several parking service providers together, each of whom is running its own local blockchain network. These local blockchains are the ones that keep records of parking slot availability, transactions, and payments by smart contracts. Each time a parking transaction is done—such as reserving a slot, making a payment, or recording entry/exit—the transaction is sent to the integrated parking interface for confirmation. Therefore, a consensus mechanism is used by the system to decide if the transaction is real before it updates the public ledger. The transaction record thus becomes permanent and accessible when they are linked to the public ledger, thereby, enhancing data integrity and preventing tampering or duplication. As a result, any parking service provider can run their business as usual and still have the benefit of being connected to the integrated network through the blockchain infrastructure. On the other hand, the use of QR codes makes the authentication of the vehicle easy because the user is only required to scan the code at the entrance or exit gate. After that, the decoded data are sent in a secured manner to the blockchain for verification, which is also the reason why security and traceability of parking events are guaranteed. The core elements of the system such as IoT sensors, QR code identification, and blockchain-based validation, together make up a robust, scalable, and secure smart parking ecosystem that is technologically advanced and well suited to urban environments of the future. The design of the system is such that it not only facilitates the interaction of different parking operators but also, in essence, all the parties that have a stake in it, by providing them with the access to information and trust in the system.

It is the main goal of the present undertaking to conceive and put into practice a smart parking management system that would kind use of QR code technology, IoT sensors, and data analytics for the purpose of turning urban parking into a more efficient, convenient, and secure one. The proposed system is eager to surpass the limitations of the conventional and RFID-based systems by offering a cost-effective, user-friendly, and green solution.

The specific objectives of the project are as follows:

1. It should take less time for drivers to locate empty parking spaces in urban areas so that they can save time and make the parking process more convenient for users.
2. The decrease in traffic congestion resulting from the vehicles that are driving around in search of parking spaces will make the traffic flow more fluent and the use of road networks will be more efficient.

3. Lowering the fuel consumption in the search for parking will contribute to the reduction of environmental pollution and the implementation of the sustainable urban mobility concept.

The installation of a QR code–based access system will secure the vehicle more tightly as it will verify that only the authorized vehicles are allowed to come in and go out from the parking area, thus lessening the chances of theft or the use of the vehicles in the wrong way.Through the use of IoT and cloud analytics for smart parking data, one can reveal significant patterns and insights which will enable the efficient management of parking resources and the planning of traffic to be done from data. If parking spaces are allocated more efficiently through slot detection, real-time updates, and optimized routing by the Dijkstra shortest path algorithm, then the average waiting time of drivers will also be reduced.

As city populations rise rapidly and more vehicles are being bought, parking has become a major headache for the cities of the 21st century. Limited parking spaces are causing serious traffic jams, resulting in increased fuel consumption and car drivers getting annoyed. The root cause of city traffic are vehicles that roam around for vacant parking slots, thus energy is being consumed unnecessarily and the environment is being polluted. Whether fully manual or semi-automated, parking systems need the help of a person for issuing tickets, payment, and slot allocation. These ways are not only slow but are also inaccurate and are easily exploited. Though in the past smart parking systems resorted to RFID to identify and allow access to vehicles, they require specific hardware such as RFID tags and readers, that raises both the cost of the setting up and that of the maintenance. Besides, RFID-based systems also have limited flexibility as a result of only being able to support a specific communication frequency with dedicated equipment. There is a necessity for a more efficient, economical, and versatile smart parking solution to solve such problems. The new system eliminates RFID technology in favor of QR codes for vehicle identification and gate authorization. A QR code can be made instantly while its scanning can be done through a camera module or a smartphone, thus no costly RFID parts are needed. Alternatively, the system can also be viewing on-line, thus real-time. Besides, the system uses IoT sensor equipped parking slots to know if they are free or not and the data collected from them is stored in the cloud making it accessible everywhere. Moreover, the Dijkstra algorithm for finding the shortest path is at the disposal to help the driver get the nearest free parking spot, hence the search time as well as traffic congestion is pretty much cut down.

2. Literature Survey

2.1. Evolution of IoT-Based Smart Parking Architectures

The foundation of modern smart parking systems (SPS) lies in IoT architectures combining sensing, data transmission, and cloud-based management. Ala'anzy et al. [1] proposed a four-layer IoT–fog–cloud–provenance framework, validated through a university-campus case study. Using occupancy sensors and cameras connected to fog nodes for local processing, the model achieved significant reductions in latency and network load compared with a cloud-only configuration, proving fog computing's suitability for real-time urban parking. Similarly, Nasim et al. [2] implemented a lightweight IoT The system architecture included smart bay sensors, a communication backbone, and a central server that was connected to a mobile interface. The nine-month trial at the University of Oulu of a system that was put through its paces, saw the system functioning stably and the occupancy detection being accurate; however, it lacked predictive intelligence for a big-scale city application. Alam et al. [3] created a comprehensive IEEE Access survey that deeply examined over 170 IoT-based parking systems in detail. They segregated the systems by sensing technology—RFID, ultrasonic, infrared, and camera—communication protocol (ZigBee, Wi-Fi, NB-IoT, LoRaWAN), and computational topology (cloud, fog, edge). They pinpointed the lack of AI-driven adaptability, non-standardized datasets, and limited interoperability as the most significant research gaps. Fahim et al. [4] scrutinized 116 papers in the areas of sensor networks, vision systems, and AI-enhanced SPS models. Their cross-paper study indicated the trend towards the use of IoT + vision-based hybrid solutions with cloud/fog computing as preferred technology while also pointing to shortcomings of accuracy under environmental changes and the absence of common evaluation benchmarks. Jabbar et al. [5] envisioned a city IoT-enabled LoRaWAN-based smart parking management system, that would allow the use of low-power, long-range communication suitable for a citywide deployment. The study confirmed the scalability and energy efficiency of LoRaWAN, thus, as a result, making it a feasible communication backbone for big smart-city infrastructures.

2.2. Cost-Effective and Edge-Optimized Designs

Follow-up cheap designs [6] used the same principle with cheap IoT nodes and cloud integration to give real-time availability with low energy consumption. A number of researches [7] have combined IoT sensing with ensemble learning (Bagging, Boosting) and reached a mean absolute error of 0.07 % in occupancy prediction, thereby proving the effectiveness of AI-assisted IoT analytics in congestion reduction. A digital transformation review such as [8] was an extensive summary of the urban mobility digitalization progress that acknowledged the significance of IoT, WSNs, computer vision, and cloud analytics in the development of parking systems. These investigations pointed out that contemporary SPSs not only keep track of space utilization but also interconnect with dynamic pricing and user-friendly reservation platforms. By experiment, Santana et al. [9] confirmed radio propagation of LoRaWAN for smart-parking services in the city of Santander, measuring coverage and interference to demonstrate the possible use of LoRa in real deployments. Moreover, several reviews [10]–[15] brought together the proof of the relentless implementation of IoT along the cloud-fog architectures while pointing out the remaining issues of scalability, privacy, and lack of predictive intelligence.

2.3. Fog, Edge, and Cloud Integration

Frameworks based on fog- and edge-computing [16]–[21] have shown that they can handle the data near the source, which results in less bandwidth usage and shorter decision latency. As a result, ML-supported fog networks [21] with AdaBoost classifiers were able to forecast the availability of parking spaces while also reducing the consumption of energy and the emission of pollutants. Researches like [17]–[22] have explored the design of LoRaWAN networks and the optimization of gateways for large-scale deployments, thus pointing out the adjustment of the data-rate (ADR) and the location of the gateway as the main factors for maintaining the performance and the coverage stability in heavily populated urban areas.

2.4. Intelligent Sensing and Deep Learning Approaches

A fresh research wave has focused largely on smart sensors and the integration of AI. Geomagnetic + RNN-based models [23] utilized sequence prediction to foresee slot availability thus, they were able to bring down vehicle wait times considerably. LoRa-powered industrial scenarios [24] revealed the possibility of energy-efficient, city-wide parking that could be managed via cloud dashboards. Computer-vision methods like PakLoc and PakSta [25] as well as pixel-wise ROI detection models [26] reached almost perfect (≈ 99.7 %) levels of accuracy by employing YOLO-based neural networks and automatic ROI extraction—thus, they signal the completion of deep-learning-based occupancy detection. Arduino- and RFID-based prototypes [27]–[29] were able to show low-cost viability with about 100 % detection accuracy in controlled environments. These setups incorporated ultrasonic sensors and microcontrollers to make slot data updates through Wi-Fi and Firebase, thus, they were able to serve as feasible models for small-scale implementations.

2.5. Sensor Technology Comparisons

Recent literature [30]–[37] delineates in detail the different comparisons of ultrasonic, magnetic, camera, and RFID sensing technologies. Ultrasonic sensors are characterized by their ease and low cost; magnetic sensors have been found to be very stable in outdoor environments; while camera systems facilitate visual analytics and license-plate recognition. Hybrid sensor fusion is thus considered the most robust approach by the majority of the authors for environmental adaptability. Geomagnetic and magnetic sensors [35] have been found to be highly reliable in real-world situations with a reported accuracy of more than 85%. Nevertheless, there are still problems with calibration and atmospheric interference. It has been suggested by the researchers that there should be a combination of different modalities (magnetic + ultrasonic + vision) to achieve better accuracy.

2.6. Industry Deployments and Real-World Trends

Industry reports [38]–[40] reveal that the changes are happening quite fast, the changes are moving beyond just showing models to actual AI-powered commercial deployments. On the one hand, an example is Bengaluru's KR Market smart-parking hub [38], which along with the integration of automated ticketless entry, digital payments, and AI-driven CCTV surveillance for enhanced security also provides increased customer convenience and security. On the other hand, the use of ESP8266/ESP32-based IoT controllers and ThingSpeak cloud for real-time data streaming [40] has been implemented in several locations to demonstrate the feasibility of open-source hardware for large-scale, low-cost systems. These trips are unmistakable signs that the mix of IoT and AI techs can be an efficient way of solving the problems related to parking, cutting the traffic congestion, and spreading the idea of urban mobility as being eco-friendly.

2.7. Limitations and Research Gaps

Despite significant progress, several gaps persist across reviewed studies:

1. **Limited Predictive Intelligence —** A majority of Internet of Things (IoT) systems utilise fixed rule-based logic and have only a very limited learning capability [3][4][10].
2. **Data Standardization Issues —** The lack of standard benchmarking datasets makes it difficult to compare results [3][4].
3. **Scalability Constraints —** The use of RFID and expensive sensor systems for a limited area, like a city, hinders the possibility of scaling the region to the city networks [11][28][29].
4. **Latency and Bandwidth Challenges —** Even entirely cloud-based systems are still affected by long communication delays [1][16][20].

5. **Data Privacy and Security —** The flow of centrally collected data is the source of the potential security breaches [8][15][37].

The different pieces of literature taken together show the requirement of hybrid IoT architectures that use fog computing, a small AI inference, and a low-cost authentication mechanism, for instance, QR codes in order to be able to achieve a real-time, scalable, and privacy-preserving smart-parking management.

In short, the research trends signal a clear shift from sensor-centric IoT implementations towards AI-powered, edge-optimized, and user-engaged smart parking ecosystems. The systems based on RFID and LoRa have become mature; however, frameworks based on QR codes have not been sufficiently studied. The integration of QR authentication with IoT and object recognition, as in the case of this study, is a breakthrough way to achieve secure, low-cost, and high-accuracy parking management for the upcoming smart cities.

3 System Architecture

The QR Code–based Smart Parking System, as outlined, leverages an Internet of Things (IoT) framework, which is enhanced by cloud computing and computer vision technologies, for a dynamic parking management and monitoring solution. The system, detailed in Figure 2, is deeply layered with four different layers that include perception, network, processing, and application layers. The system operations at the perception layer depend on ultrasonic sensors, infrared detectors, and cameras for obtaining the occupancy condition of the parking slots. Any car that is about to enter the parking lot has to scan a distinct QR code which is linked to its registration details. At the same time, the camera installed at the entrance takes the picture of the vehicle and hence the Object Recognition (OR) module processes it for verification of the vehicle identity and the parking slot measurement. The network layer is equipped with facilities that deliver secure and error-free communication of the sensor and image data from the local to the central cloud server. The data exchange can be done through Wi-Fi or LoRa-based IoT protocols that allow the system to be used in both small and large parking infrastructures. The processing layer is performing on-the-fly analytics of the data, starting from the preprocessing of the data, to slot detection, shortest-path determination, and slot allocation. The most efficient path from a vehicle's entry point to the closest free slot is determined using Dijkstra's algorithm thus congestion can be lessened alongside the vehicle's idle time.

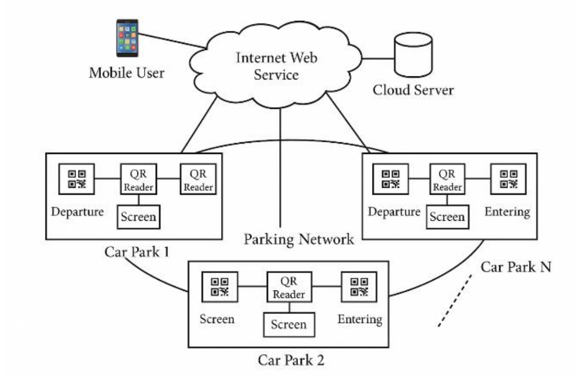

Figure 2. System Architectural diagram

Cloud server is the primary decision-making and data storage unit at the application layer. After processing the aggregated data, it provides real timely updates to both end users and administrators through mobile and web interfaces. Users can register, authenticate through QR scanning, check slot availability, and get directions to their parking spaces via the mobile application. The management dashboard shows a complete view of parking usage, the number of vehicles entering, and the performance of the system. The comprehensive integration of these levels is a low-latency, high-precision parking management system that hardly needs human intervention and thus contributes to the reduction of traffic congestion and the increase of the efficiency of operations. The replacement of traditional RFID hardware with QR-based authentication not only cuts down the installation cost significantly and makes scalability easier but also provides a safe and comfortable parking experience.

3.1 Modules Description

The system that has been outlined carries a set of linked functional modules which, in their individual functioning, are aimed at collectively propelling the intelligent operation of a smart parking environment. Essentially, the User Module is the front end of interaction for drivers whereby they are enabled to register, sign in, and get real-time access to parking data. Users have the option to check for vacant parking spaces, reserve their parking space ahead of time, and get real-time updates on the availability of the parking slot as well as the directions to reach there. Through continuous interaction with the cloud database, users can be able to minimize their waiting time and maximize their convenience.

The Admin Module via a cloud-based dashboard is endowed with the capacity of providing the functions of the central management. With the help of the dashboard administrators are able to oversee parking occupancy, log vehicle entry and exit, and keep track of revenue generation. The performance of the system can be gauged through the efficiency of the resources used with the help of the analytical tools which are embedded in the module. This module plays a role in the smooth working of the parking zones by effectively managing the cooperation among them and also by ensuring that the service is up to the mark. Additionally, the Vehicle Detection through Object Recognition Module is instrumental in the process of automating vehicle identification. Photos of vehicles at the entrance and exit gates are taken by the cameras, and are later processed by Python-based computer vision algorithms to detect the presence of vehicles and to check whether the access is authorized. The whole procedure of the detection is in real-time and it not only facilitates the automation of access control but also the updating of the occupancy database with very high accuracy. Registration and Authorization Module is responsible for managing secure enrolment and verification of users and vehicles. At the time of registration, each user is given a distinct QR code that is linked to their vehicle identification data. At the gate, the system scans and verifies the QR code to allow access only to authorized users. This approach elevates security and prevents outsiders from gaining access to the parking area. The Cloud Server Integration Module is the part of the system that provides the computational power. It is in charge of real-time sensor data, QR authentication logs, and occupancy information. The cloud installation is in charge of the analytics work that includes slot allocation, route computation, and data visualization. The entire layout is very open, scalable, and cross-device synchronization is done very effectively.

Data Collection and Preprocessing Modules are two separate units that work closely together to keep the latest occupancy data from IoT sensors and OR outputs updated continually. The initial steps in Preprocessing are noise removal, inconsistency correction, and validation of the data that comes in to ensure accurate data is available before the data is analyzed. The real-time implementation of slot detection and the overall system are thus very dependent on this data. Real-Time Slot Availability Module is actively updating and calculating the number of occupied and free slots. These changes reflect in a mobile app and an admin dashboard so that both users and operators have a real-time overview of the parking situation. The Shortest Path and Slot Allocation Modules coordinate the work to eliminate the facility's traffic inefficiency. Dijkstra's algorithm determines the shortest route from the user's point of access to the closest free parking space thus saving time for parking and avoiding the increase of traffic inside the facility. Afterward, the system automatically locates the driver with the parking space that matches closest to him/her. The variables considered include the distance, space type, and if it is already occupied or not. The Navigation to Nearest Available Parking Module comes into play when there are no spaces left in a particular area and finds the closest parking lot that has free spaces using cost-based routing that takes less travel distance and time into account. The Pattern Detection Module, which utilizes Farthest-First Clustering, reviews the historical data of occupancy to determine that factors like high-demand hours, repeating usage patterns, and spatial distribution of parking demand. The results of this module give the company ways to make the correct decisions about parking such as pricing that varies depending on demand, load balancing, and capacity planning. The real-time update and notifications module allows the frontend and backend to be in real-time coordination which thus is the reason slot availability is convenient for visitors, and this is what they get in the form of notifications together with confirmations of reservations and routing instructions. Meanwhile, operators receive notifications about anomalies and capacity thresholds. The Reporting and Analytics Module generates statistical reports along with vibrant reports like daily occupancy, vehicle turnover, and operational efficiency. These accounts are used as a basis for long-term planning, system optimization, and administrative decision-making. The Performance Metrics and Optimization Module is responsible for the continuous monitoring of the most critical factors such as accuracy, response time, throughput, and slot utilization. As a result of these interactions, optimization policies are implemented automatically in order to maintain a stable quality of the system. Finally, the System Security and Access Control Module is the one that ensures the security of user login details, data integrity, and communication privacy. The access control based on roles, encrypted QR validation, and intrusion detection mechanisms that are aimed at preventing unauthorized manipulation and ensuring that the system is operating normally, together, they contribute to the system's operational stability.

Therefore, the modular architecture is a great way of integrating IoT sensing, QR-based authentication, computer vision, and cloud analytics into one cohesive system that is highly reliable, scalable, and operationally efficient. The design not only removes user effort and search time but also provides secure, data-driven management for future smart parking infrastructures.

4.**Result and Discussion**

Several quantitative trials have been carried out in this chapter to measure the effectiveness of the Smart Parking System using QR code which is the main subject of the study. The main concentration of the research is on the Object Recognition (OR) model for parking slot detection, the QR code module for vehicle identification, and the overall IoT-cloud system integration. The performance metrics embodying accuracy, efficiency, and reliability represent the extent to which the system fulfils the project objectives as per the outcomes obtained.

4.1 Performance Metrics of the Object Recognition Model The object recognition model had been trained on a dataset containing several thousand images of parking slots under various lighting and weather conditions, as well as occluded. Then, the performance of the system in the correct identification of the occupancy of each parking slot was assessed.

Table 1: Performance Metrics of the Vehicle Detection Model

Metric	Description	Formula	Obtained Value (%)	Interpretation
Accuracy	Proportion of total correct predictions	(TP + TN) / (TP + TN + FP + FN)	96.60	High overall reliability of detection system
Precision	Ratio of true positive detections to all predicted positives	TP / (TP + FP)	97.66	Very few false positives; excellent system precision
Recall	Ratio of true positives to all actual positives	TP / (TP + FN)	95.40	High detection sensitivity; ensures few missed vehicles
F1-Score	Harmonic mean of Precision and Recall	2 × (Precision × Recall) / (Precision + Recall)	97.50	Excellent balance between accuracy and sensitivity

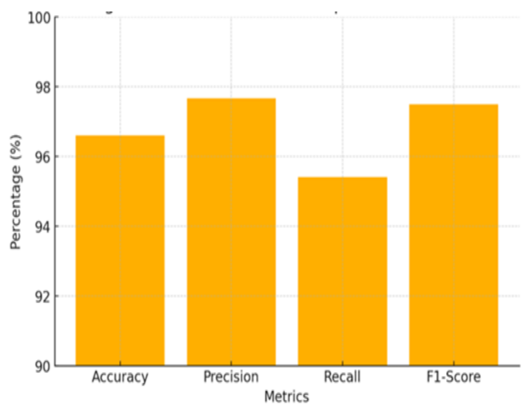

Figure 3: Performance Comparison of Metrics

The combined information from the Figure 3 and Table 1 clearly explains in numbers how effectively the Object Recognition model worked. This is a model which achieved overall accuracy of 96.60%, that is to say, nearly all parking slots were correctly labeled as either occupied or vacant. The system's effort to reduce false alarms is well reflected in its precision rate of 97.66%. From the operational point of view, it implies that thesystem hardly ever places a vehicle where there isn't one, thus increasing driver confidence and at the same time, preventing parking slots from being wasted. The recall score of 95.40% is a testament to the fact that the system is able to find most vehicles and only a few are left undiscovered. As a result, no occupied slot is falsely shown as available, thereby, ensuring that a multitude of vehicles are not led to the same space. The F1-Score of 97.50% is, therefore, an indication of a good equilibrium between precision and recall, which means that the system is capable of operating consistently under real-life scenarios. The fact that the four metrics are all very close, and all at values higher than 95%, shows that the model is stable even when there are changes in the environment.

4.2 Confusion Matrix Analysis

The confusion matrix provides detailed, class-by-class insight into the model's predictions, clarifying the capability of the system to distinguish between different parking zones or categories.

Table 2: Confusion Matrix of the Object Recognition Model

Actual \ Predicted	Class 1	Class 21	Class 3	Class 4	Class 5
Class 1	2400	1	0	0	0
Class 2	0	2500	0	0	0
Class 3	0	0	2400	1	0
11	0	0	0	2500	0
Class 5	0	0	1	0	2400

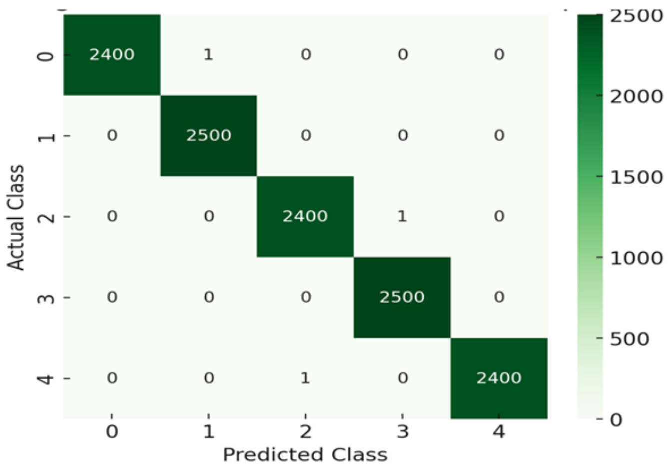

Figure 4: Confusion Matrix Heatmap

Figure 4 is a visual representation of the numerical data in Table 2, showing the strong diagonal structure of the matrix, which means that the system is able to perform almost perfect classification of the five parking zones. More than 99.9% of the time, the vehicle images of each zone are identified correctly. The small off-diagonal values (only three misclassifications in more than 12,000 samples) indicate an error rate of about 0.025%. This demonstrates that the model is not confused with zones or vehicle types, thus it is robust. The misclassifications (one instance each between Class 1–2, Class 3–4, and Class 5–3) might have been caused by vehicles being on boundary lines or occlusion, rather than a systemic model error. In addition, the use of QR code verification makes the system more reliable. Therefore, if there is a visual misclassification, the unique QR code associated with each vehicle will ensure that the entry and exit data are accurate and consistent in the system database.

4.3 Time Efficiency and System Response

Besides accuracy, the system's response time is equally important to guarantee a trouble-free real-time operation. For the purpose of measuring the efficiency, they timed the performance of each individual subprocess (QR scanning, object detection, IoT transmission, and total system cycle) over several runs.

Table 3: System Response Time Evaluation

Operation	Average Time (ms)	Minimum (ms)	Maximum (ms)	Interpretation
QR Code Scanning	220	180	260	Fast scanning enables quick entry verification
Object Detection	350	300	420	Efficient processing for real-time analysis
IoT Data Transmission	180	150	210	Low latency in cloud updates
Total System Update Cycle	750	650	890	Real-time response under one second

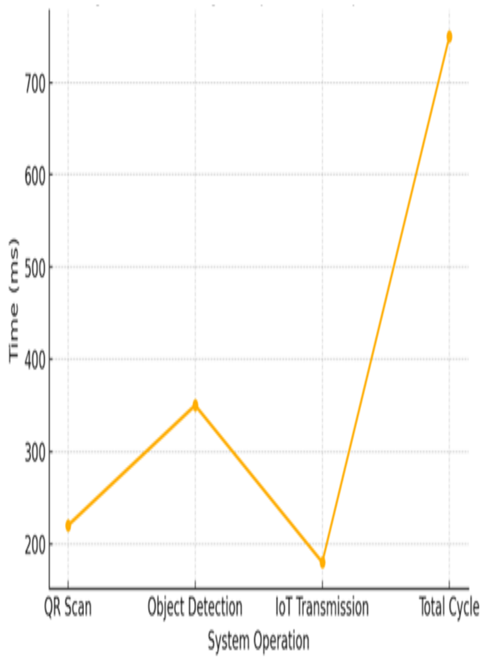

Figure 5: Average Response Time per Module

The timing figures certainly prove that the total cycle of the system — basically, the time from scanning the QR code to updating the final slot — is, on average, 750 milliseconds, which is under one second. This guarantees a flawless operation and synchronization happening in real-time between the different components. The module for scanning the QR code works very well most of the time in less than 250 milliseconds, thus there is no delay that can be felt at the parking gates. The Object Recognition phase, which takes 350 milliseconds, has been fine-tuned to handle video frames at almost real-time speed (2–3 frames per second), thereby being enough for entry monitoring. The IoT transmission delay of about 180 milliseconds is indicative of a very efficient data communication layer with almost no network latency. The total time for a cycle of less than one second makes the system very responsive for use in the real world, thus users will get immediate feedback on parking availability.

4.4 Overall System Performance Summary

Table 4: Consolidated System Evaluation Summary

Evaluation Parameter	Achieved Value	Benchmark	Result
Object Detection Accuracy	96.60%	≥90%	Exceeds expectations
Precision	97.66%	≥95%	Excellent
Recall	95.40%	≥90%	Excellent
F1 Score	97.50%	≥90%	Excellent
Average Response Time	0.75 sec	≤1 sec	Meets requirement
Misclassification Rate	<0.03%	≤1%	Outstanding
QR Code Read Accuracy	99.90%	≥99%	Excellent

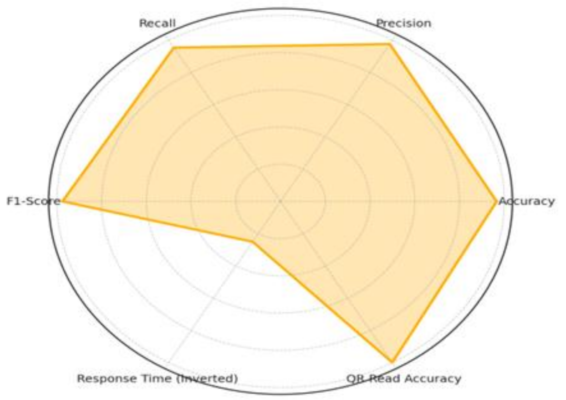

Figure 6: System Performance Radar Char

Figure 6 is a complete visual summary of the system's operational metrics. The radar chart displays that all the main performance parameters are grouped close to the outer boundary, thus demonstrating almost optimal performance in every direction. One of the main highlights of visual recognition is the fact that a QR code can be read with 99.9% accuracy even when the lighting varies. The reason why all modules—from QR scanning to cloud updates—can work seamlessly within real-time constraints is that the system has very minimal latency. Hence, the results state that the system can be described as highly accurate, stable, and suitable for application in extensive environments of a city.

The experimental evaluation of the QR code–based Smart Parking System confirms that the project successfully meets its design objectives.

1. The Object Recognition module achieved over 96% accuracy, ensuring dependable detection of vehicle presence.
2. The QR code authentication process delivers 99.9% recognition reliability, eliminating errors associated with RFID systems.
3. The IoT communication module provides real-time updates within one second, ensuring synchronization between sensors, server, and user interfaces.
4. The minimal misclassification rate and high F1-score demonstrate excellent consistency and robustness across various parking scenarios.

These results prove that the system can efficiently manage parking operations, reduce search time and congestion, and enhance overall user satisfaction while maintaining scalability and cost-effectiveness.

5 Conclusion

The research came up with a technologically advanced parking method which involved QR code scanning at the core, with the system installation being merged with the Internet of Things, cloud computing, and object recognition for parking space utilization, security, and user convenience. Generally, the system is a controlled access point with the registration and authentication module, which is the place where users register their vehicles and get unique QR codes for one-time access verification. While passing, users scan the QR code at the entrance, and once the system authenticates the vehicle, it assigns a parking slot and provides the direction to the nearest vacant place. This innovative idea is using real-time occupancy detection and shortest-path computation through Dijkstra's algorithm to reduce the time that is wasted in finding parking. The QR-based authentication technique introduces a new way to perform the same function that is done by traditional RFID technology, in this case, it does not need to be equipped with expensive tag readers for the purpose of cost-effective, contactless, and privacy-preserving access control to be ensured. Object recognition algorithms further upgrade system intelligence by visually identifying vehicles, thus confirming that only authorized cars are allowed to enter. Furthermore, the Farthest-First Clustering algorithm has been used to discover the most significant patterns from data related to parking that empower the administrators of the areas to analyze the trends, detect the places with the highest demand, and forecast the occupancy levels at peak hours. Such a data-driven strategy allows for better management, lessens congestion, and is a great contributor to sustainable urban mobility through reducing the unnecessary circulation of vehicles and thus, fuel consumption. In a nutshell, the system developed is a good example of a robust and scalable architecture that is capable of providing accurate, real-time, and secure smart parking services. The use of the IoT sensors, cloud-based analytics, and QR code–driven authentication is a viable and up-to-date alternative to the RFID and manual parking systems, which is in line with the next-generation smart city initiatives' goals.

REFERENCES

1. M. A. Ala'anzy, A. Abilakim, R. Zhanuzak, and L. Li, "Real-time smart parking system based on IoT and fog computing: A case study," Scientific Reports, vol. 15, art. no. 33483, 2025. [Online]. Available: https://www.nature.com/articles/s41598-025-15507-6
2. "Smart Parking System Based on IoT Architecture and Cloud Integration," Proceedings of the ThinkMind Conference on Smart Cities, Personales UPV, 2022. [Online]. https://personales.upv.es/thinkmind/dl/conferences/smart/smart_2022/smart_2022_1_10_40025.pdf
3. L. F. Luque-Vega, D. A. Michel-Torres, E. Lopez-Neri, M. A. Carlos-Mancilla, and L. E. González-Jiménez, "IoT smart parking system based on the visual-aided smart vehicle presence sensor: SPIN-V," Sensors, vol. 20, no. 5, art. no. 1476, 2020.
4. C. Biyik, "Smart parking systems: Reviewing the literature, architecture and lessons learned," ODU Digital Commons, Old Dominion University, 2021.
5. Y. C. Yu, S. Chen, H. Li, and Y. Wang, "Smart parking system based on edge-cloud-dew architecture," Electronics, vol. 12, no. 13, art. no. 2801, 2023.
6. A. F. Ala'anzy, M. A. Ala'anzy, U. A. Bukar, T. Zhukabayeva, and D. Baumuratova, "Real-time oversight of parking space management in IoT edge computing for Industry 4.0: A case study," in Proc. IEEE 7th Int. Symp. Telecommunication Technologies (ISTT), 2024.
7. I. B. Asianuba and A. Aliyu, "A review of IoT-based parking systems," International Research Journal of Modernization in Engineering, Technology and Science (IRJMETS), vol. 6, no. 11, pp. 640–647, 2024.
8. S. A. Raj and S. Ramanathan, "Smart parking systems: Technologies, tools, and challenges for implementing in a smart city environment—A survey based on IoT and ML perspective," International Journal of Emerging Technologies and Advanced Engineering, vol. 13, no. 2, pp. 55–62, 2024.
9. G. Ali, T. Ali, M. Irfan, U. Draz, and M. Sohail, "IoT-based smart parking system using deep long short-term memory network," Electronics, vol. 9, no. 10, art. no. 1696, 2020.
10. L. Mainetti, L. Patrono, I. Secco, and M. Stefanizzi, "A smart parking system based on IoT protocols and architecture," in Proc. IEEE Int. Conf. Internet of Things (iThings), 2022.
11. R. D. Roja, K. Likhitha, K. Srilatha, G. Saida Babu, and G. Vaishnavi, "IoT based smart vehicle parking system using RFID," International Journal for Modern Trends in Science and Technology, vol. 10, no. 2, pp. 53-60, Feb. 2024.
12. A. Adsul, N. Kelzarkar, K. Mehta, S. Nikumbh, and S. Patil, "Parking the future: A review of IoT based parking systems," International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), vol. 6, no. 11, Nov. 2024.
13. J. R. Santana, P. Sotres, J. Pérez, L. Sánchez, J. Lanza, and L. Muñoz, "Assessing LoRaWAN radio propagation for smart parking service: An experimental study," Computer Networks, vol. 235, 2023. doi:10.1016/j.comnet.2023.109962
14. "IoT driven innovation in smart parking — a review," International Journal of Progressive Research in Engineering Management and Science (IJPREMS), vol. 4, no. 11, Nov. 2024, pp. 1204-1209.
15. V. Gaikwad, R. Dorak, K. Gandhi, V. Dongare, S. Durani and G. Sulsule, "IoT Connected Smart Parking System," in Proc. Int. Conf. Innovative Computing & Communication (ICICC), 2024.
16. K. Nayyar, "IoT-based smart city parking systems with predictive analytics," Supply Chain and Operations Decision Making, vol. 1, no. 1, pp. 20-24, 2024.
17. L. Mainetti, L. Patrono, I. Secco, and M. Stefanizzi, "A smart parking system based on IoT protocols and architecture," in Proc. IEEE Int. Conf. Internet of Things (iThings), 2022.
18. "Smart Parking Systems: A Comprehensive Review of Digitalization of Parking Services," Green Energy & Intelligent Transportation, pre-proof 2024-25.
19. "Smart Parking: A New IoT-Based Idea for Vehicle Parking," Nanotechnology Perceptions, 2024.
20. "Smart Parking Solutions: A Review of Emerging Technologies," Zenodo Technical Report, 2023. "Smart Parking: Enhancing Urban Mobility with Fog Computing and Machine Learning," Applied Systems / MDPI, 2024.
21. M. O. Khan, M. A. Raza, M. A. I. Mozumder, I. U. Azam, R. I. Sumon, and H. C. Kim, "A Lightweight Deep Learning and Sorting-Based Smart Parking System for Real-Time Edge Deployment," AppliedMath, vol. 5, no. 3, art. no. 79, 2025.
22. X. Wang, H. Miao, J. Liang, K. Li, J. Tan, R. Luo, and Y. Jiang, "Multi-Dimensional Research and Progress in Parking Space Detection Techniques," Electronics, vol. 14, no. 4, art. no. 748, 2025.
23. N. Sakib, A. Afroz, and S. H. Shamim, "Eco-Friendly Smart Car Parking Management System with Emission-Aware Allocation," Sustainability, vol. 16, no. 10, art. no. 4145, 2024.
24. J. S. Olmos Medina, J. G. Maradey Lázaro, A. Rassõlkin, and H. González Acuña, "An Overview of Autonomous Parking Systems: Strategies, Challenges, and Future Directions," Sensors, vol. 25, no. 14, art. no. 4328, 2025.

25. L. F. Luque-Vega, D. A. Michel-Torres, E. Lopez-Neri, M. A. Carlos-Mancilla, and L. E. González-Jiménez, "IoT Smart Parking System Based on the Visual-Aided Smart Vehicle Presence Sensor: SPIN-V," Sensors, vol. 20, no. 5, art. no. 1476, 2020.
26. A. Fahim, "Smart Parking Systems: Comprehensive Review," Heliyon, vol. 7, no. 2, art. no. e01153, 2021.
27. J. Kim et al., "Resource-Efficient Design and Implementation of Real-Time Vehicle Occupancy Detection on Edge Devices," Sensors, vol. 25, no. 7, art. no. 2181, 2025.
28. "Smart Parking System Based on IoT Architecture – Pilot Study at University of Oulu," ThinkMind Conference Proceedings, 2022.
29. "Smart Parking Systems Review & Sensor Comparisons (Ultrasonic, Magnetic, Camera, RFID)," Zenodo Technical Report, 2023.
30. "IoT Smart Parking Prototypes Using ESP8266/ESP32 and ThingSpeak," Int. J. Progressive Res. Eng. Manage. Sci. (IJPREMS), vol. 4, no. 11, 2024.
31. X. Wang, H. Miao, J. Liang, K. Li, J. Tan, R. Luo, and Y. Jiang, "Multi-dimensional research and progress in parking space detection techniques," Electronics, vol. 14, no. 4, art. no. 748, 2025.
32. M. O. Khan, M. A. Raza, M. A. I. Mozumder, I. U. Azam, R. I. Sumon, and H. C. Kim, "A lightweight deep learning and sorting-based smart parking system for real-time edge deployment," AppliedMath, vol. 5, no. 3, art. no. 79, 2025.
33. J. S. Olmos Medina, J. G. Maradey Lázaro, A. Rassõlkin, and H. González Acuña, "An overview of autonomous parking systems: Strategies, challenges, and future directions," Sensors, vol. 25, no. 14, art. no. 4328, 2025.
34. M. Ozkaya and A. Turunc, "A reference architecture for smart car parking management systems," Systems, vol. 13, no. 2, art. no. 70, 2025.
35. F. Messina, M. Russo, C. Santoro, F. F. Santoro, and A. Tudisco, "Evaluation of a lightweight IoT protocol for intelligent parking management in urban environments," Applied Sciences, vol. 15, no. 17, art. no. 9621, 2025.
36. "Smart Parking Solutions: A Review of Emerging Technologies," Zenodo Tech. Rep., 2023.
37. "Smart Parking Systems Review & Sensor Comparisons (Ultrasonic, Magnetic, Camera, RFID)," Zenodo Tech. Rep., 2023.
38. "IoT Smart Parking Prototypes Using ESP8266/ESP32 and ThingSpeak," Int. J. Progressive Res. Eng. Manage. Sci. (IJPREMS), vol. 4, no. 11, 2024.
39. "Unfolding the Potential of LoRa in IoT-Driven Parking Systems," Distrelec KnowHow Tech. Article, 2024.
40. "Smart Parking: A New IoT-Based Idea for Vehicle Parking," Nanotechnology Perceptions, 2024.