

IoT-Based Smart Vehicle Parking Availability Monitoring and Efficient Management System with Mobile Application

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Abstract: The problem of parking in cities has been exacerbated by the rapid increase in the number of vehicles, leading to traffic jams, inefficient use of available parking spots, increased fuel consumption, and driver frustration. To address these issues, this paper presents a cost-effective and intelligent parking-space monitoring system based on image-processing and deep-learning techniques. The suggested system monitors parking lots using strategically placed cameras to assess parking space occupancy in real time automatically. The technology employs a deep-learning Mask R-CNN model to recognise and segment automobiles in collected photos to better distinguish occupied from unoccupied parking spaces. The system displays parking availability by processing and updating parking information in real time. Cloud integration enables the system to save, manage, and view parking data remotely. It may be deployed to several parking lots without major infrastructure changes, allowing flexibility and scalability. The technique helps urban areas with limited parking and economic needs. The device recognises parking spaces in real time and streamlines payment with QR codes. Scan the QR code for secure, contactless parking payments. It reduces parking wait times and cash payments. Smart-parking solutions using image analysis, cloud technology, and QR-based payment improve parking management, operational efficiency, and user convenience while optimising precious urban parking resources. To conclude, the proposed system delivers practical, scalable, intelligent, user-friendly smart parking facilities.

Keywords: Driver Frustration; Cloud Storage Integration; Parking Management; Intelligent Parking Space; Fuel Consumption; Cloud Technology; Operational Efficiency.

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1. Introduction

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As the number of vehicles increases rapidly, parking has become a major problem in urban and densely populated areas. The growing number of cars, along with a lack of parking infrastructure, has led to congestion in parking lots, unnecessary vehicle movement, inefficient use of available space, higher fuel consumption and driver frustration [1]. In urban areas, drivers often spend a lot of time searching for parking spots because they lack reliable, real-time information about parking availability. However, this affects not only individual users but also contributes to traffic congestion around commercial areas, offices, shopping centres, hospitals, educational institutions and other public facilities [8]. This has increased demand for intelligent, cost-effective, and flexible parking management solutions that can detect available spaces and communicate this information to users in real time. Several parking management systems have been developed. Many existing solutions are not suitable for all locations because of their high installation, maintenance and infrastructure requirements. Traditional systems rely on manual supervision, automated vehicle counting devices, ultrasonic sensors, infrared sensors, magnetic sensors or other dedicated hardware [10]. Although these approaches can provide valuable insights in controlled environments, they can require significant investment when used across a large parking area. Sensor-based systems require installing and maintaining individual sensors for each parking slot, which adds to deployment complexity and cost. Environmental conditions, improper installation, physical obstruction, or interference from other vehicles may also cause sensors to provide erroneous readings. Manual monitoring, in contrast, may not be continuous or accurate and is labor-intensive.

These limitations become more pronounced in temporary parking sites or locations where rapid deployment and low infrastructure costs are essential. Therefore, this paper proposes a low-cost Vehicle Parking Availability Monitoring and Efficient Management System based on image processing and deep-learning techniques to overcome these limitations [12]. The proposed system uses camera-based monitoring to capture images or video streams of the parking area, rather than installing dedicated sensors for each parking spot [13]. The system then automatically analyses the captured visual data to determine the occupancy status of each parking spot. Deep learning improves the system's ability to identify vehicles under different conditions, such as changes in vehicle size, orientation, illumination, and parking position. In particular, the system uses Mask R-CNN for vehicle detection and image segmentation [14]. Mask R-CNN benefits from its segmentation capability, allowing the system to distinguish individual vehicles and pinpoint their location within predefined parking regions. The proposed system starts by acquiring parking-area images using CCTV or other suitable cameras placed in appropriate positions [15]. The cameras monitor the parking facility continuously and send image frames in real time or at predetermined intervals. The quality and coverage of the captured images significantly affect the accuracy of parking-space detection; Therefore, correct camera placement is important [9]. The camera should provide clear views of parking spaces, with minimal obstructions, blind spots and excessive overlap between vehicles.

The collected images are the main input data for the parking-availability detection process. Each image contains information about vehicles and parking boundaries, background objects and environmental conditions within the monitored area. The deep-learning model is fed raw camera images after preprocessing. Preprocessing is an important stage because raw images may contain noise, unnecessary details, image-size variations, and other factors that can affect detection accuracy. Typical preprocessing operations are image resizing, image filtering, image normalisation and Gaussian blurring [11]. Resizing provides input images with a proper, consistent resolution for processing. Filtering can remove unwanted noise, and Gaussian blurring can reduce high-frequency noise and small variations in an image. These operations help to provide a more consistent input to the detection model and can improve the reliability of subsequent image analysis processes. After preprocessing, Region of Interest (ROI) detection identifies the parts of the image containing relevant parking areas [7]. The ROI operation removes the unnecessary parts of the captured image, such as roads outside the parking facility, buildings, trees, sidewalks, or any other background regions that are unnecessary for parking-space analysis [3]. The system can focus computation on relevant parking zones, reducing unnecessary processing and improving the detection algorithm's efficiency. The parking area is divided into predefined virtual parking spaces, each linked to a specific region in the camera-captured image [9]. These virtual areas serve as a reference to determine whether a parking spot is occupied. The system analyses the processed parking-area images using the Mask R-CNN deep learning model.

Mask R-CNN is an instance segmentation architecture that detects individual objects and outputs pixel-level segmentation masks for them. The proposed system identifies vehicles as the main objects of interest. The model analyses the captured image and detects the location and segmentation of each detected vehicle. In the proposed methodology, researchers use a confidence score of 90% or higher for vehicle detection. This threshold ensures that researchers consider only high-confidence detections for parking-space classification. Researchers classify a parking space as occupied when a vehicle is detected within a virtual parking space or significantly overlaps it [14]. If no vehicle is detected in the corresponding region, the space is classified as vacant or available. An important advantage over simple vehicle-counting methods is image segmentation. Instead of just calculating the total number of available vehicles in the parking facility, the system can detect the spatial relationship between each detected vehicle and individual parking slots. This way, the system can query the status of each parking space individually [15]. This enables the system to provide drivers with more useful information, such as the number of available spaces and, where applicable, the exact location of vacant spaces. As vehicles enter, leave or move to another parking spot, the system

continuously updates the status of the corresponding virtual parking spots. The system then transmits the detected parking information to a cloud-based platform, where it is centrally stored and managed in real time.

The current status of parking places and the system information related to it can be stored in cloud services like Firebase [1]. Cloud integration is a key link between the parking-monitoring system and the mobile application users see. When the image-processing system detects a change in parking occupancy, it can send the new information to the cloud database. The mobile application can fetch the latest data and show users parking availability. This means drivers don't have to physically look around different parking areas to find a space [2]. The smartphone app provides an easy-to-use interface that enables users to access real-time parking information. The application can display the number of unoccupied and occupied spaces and can be extended to provide information such as parking location, free slot identification, parking duration and payment status. "Drivers who are provided with parking information before or during a trip are better positioned to make educated choices regarding where to park. This may reduce the time spent looking for free spaces and, in turn, unnecessary vehicle movement within parking areas. Reduced traffic flow can lead to less congestion, fuel consumption and emissions, especially in busy urban parking lots [3]. In addition to parking space monitoring, the proposed system includes a QR code-based parking payment system. This digital payment integration offers a convenient, contactless way for users to pay parking charges. During parking, the system records relevant information, including vehicle details, entry time, parking slot identification and other required transaction information. Based on this information, the system can create a unique QR code for the respective parking transaction. You can display the QR code at the parking facility or send it through the mobile app. Compatible smartphone payment applications can scan the QR code to make the applicable payment digitally.

The QR code may contain or link to a secure payment link relevant to the parking transaction [4]. Depending on the payment infrastructure, users can use UPI, digital wallets or any supported card-based payment service to complete the transaction [5]. QR-based payment reduces the need for cash and physical interaction between users and parking personnel. It can also reduce queues at payment counters and speed up the overall parking process. The system can link digital transaction data to the respective vehicle and parking record, so it can determine whether the parking fee has been paid. The payment component of the proposed system also has an important role in preprocessing the data. The system should store vehicle identification, parking-slot details, and other related data in a proper format, and capture the entry time accurately before using it for billing and QR-code generation [6]. Validation procedures can identify incomplete, duplicated or inconsistent information. After confirming the information, the system creates the corresponding parking transaction record and associates it with the user or vehicle [7]. Then, the system synchronises the transaction information with the cloud database so the parking-management system can maintain an updated record of parking duration and payment status. The proposed system can operate as an integrated smart-parking platform through real-time synchronisation of the parking-monitoring module, cloud database, mobile application, and payment module. When a vehicle enters the parking facility, the system records the entry information and updates the corresponding parking status. In a specific virtual parking space, the image processing module detects the vehicle and registers the space as occupied.

The system then transfers the data to the cloud database and reflects it in the mobile application. The system can also detect vacancies and update the parking status when a vehicle leaves [8]. The system can then determine the applicable parking charge based on the calculated parking duration. Moreover, the automated payment-verification mechanism improves parking management efficiency. When the user completes payment via QR, the system can update the transaction status in the cloud database. The parking facility's policy allows staff to check the payment before the vehicle can leave. This reduces the need for manual verification and provides a more systematic approach to handling parking fees. Digital records may also enable parking operators to track transaction histories and parking usage. Combining automated occupancy detection with digital payment reduces reliance on manual intervention. Cost-effectiveness and scalability are important factors in designing the proposed system [9]. Because the main parking-space detection mechanism is camera-based, it reduces the need for individual sensors for every parking slot. The system may suit small parking facilities as well as larger installations, as a strategically positioned camera can monitor several parking spaces at once. Cloud-based storage also improves scalability, as a centralised platform can manage parking information from different locations [10]. New parking facilities can be added without fundamentally changing the overall architecture. Several metrics can evaluate the proposed system's performance, including vehicle-detection accuracy, parking-space classification accuracy, false-detection rate, response time, processing efficiency, and robustness under various environmental conditions [11].

For testing, use different vehicle types, parking arrangements, lighting levels and traffic conditions. The system should also be tested under high and low parking occupancy conditions. Investigate the effect of the 90% confidence threshold used for Mask R-CNN detection on false positives and false negatives. This evaluation is important to ensure the system provides reliable parking-availability information to users. The proposed Vehicle Parking Availability Monitoring and Efficient Management System provides an integrated solution for intelligent parking management through image processing, deep learning, cloud computing, mobile application technology and QR-based digital payment. Mask R-CNN automates vehicle detection and segmentation, and virtual parking regions classify individual spaces as occupied or available [12]. Cloud integration stores and

synchronizes parking information in real time so that users can see updated availability in a smartphone app. The QR code-based payment system is a secure, convenient, contactless way to collect parking fees, minimising transaction time and manual intervention [13]. By incorporating these technologies, the proposed system can improve parking-space utilization, reduce congestion from unnecessary searching, improve user convenience, and provide an economical, flexible alternative to conventional sensor-based parking systems [14]. Thus, the overall architecture provides a promising foundation for smart-city parking applications and can be further improved through better deep-learning models, automated reservation, navigation assistance, advanced payment security and integration with larger intelligent transportation systems [15].

2. Literature Survey

Recent developments in parking-space management have driven significant research in computer vision, the Internet of Things (IoT), machine learning and cloud computing. Fahim et al. [4] highlighted the significance of smart parking technologies in solving urban parking issues through sensing, communication and intelligent data processing. The early systems were based on inductive loops, ultrasonic sensors, magnetic sensors and wireless sensor networks. Ratti et al. [3] proposed wireless sensor networks for real-time vehicle occupancy monitoring. GokulKrishna et al. [8] developed an IoT based outdoor parking system to detect available spaces. Sensor-based systems provide real-time information; however, installation and maintenance costs, scalability limitations, sensor failures, and sensitivity to environmental conditions may limit their use, especially in large or temporary parking facilities. Computer vision has been developed as an alternative to classical sensor-based approaches. Previous image processing techniques such as background subtraction, edge detection, thresholding and feature extraction were used to identify occupied and vacant spaces. Waqas et al. [6] proposed a smart vehicle parking system based on image processing. However, the conventional techniques are very sensitive to illumination, shadows, camera position, background changes and vehicle occlusion. Fahim et al. [4] identified such environmental and technological challenges as major limitations of traditional parking systems. As a result, research on machine-learning and deep-learning techniques for more robust vehicle detection has increased.

Convolutional Neural Networks (CNNs) have shown strong potential for vehicle detection and classification because they can automatically extract relevant spatial features from images. Yang et al. [2] explored deep-learning models for real-time parking availability prediction and showed their ability to enhance parking management and alleviate congestion. Waqas et al. [6] also showed the effectiveness of image processing and deep learning techniques for smart parking applications. CNN-based approaches can identify vehicle properties such as shape, edges, texture and spatial relationships, making them applicable in dynamic parking environments. Mask R-CNN is a breakthrough in this direction, combining object detection and instance segmentation. It not only detects vehicles but also produces pixel-perfect masks for each vehicle. This functionality is useful when vehicles are placed close together, partially occluded or overlapping. Consequently, accurate segmentation can improve classification of individual parking slots as occupied or vacant. Deep learning-based methods are more adaptable than conventional image processing methods and can improve as more training data becomes available. Image preprocessing is another important part of reliable parking space detection. Resizing standardises image size and reduces computational load. Gaussian and median filtering help to suppress noise and artifacts. Color normalization and histogram equalization can improve image contrast under low light or uneven illumination. Joshi et al. [11] emphasised the importance of image-dataset quality, and Waqas et al. [6] highlighted the role of image processing in smart parking applications. So, preprocessing is a good way to obtain consistent input data and improve vehicle-detection accuracy later.

ROI extraction is also widely used to reduce the computational overhead by limiting the analysis to relevant parking areas. Processing can exclude unnecessary regions such as roads, buildings, trees and pavements. Parking regions can be detected by visual markers, template matching, edge detection or predefined boundaries. Waqas et al. [6] performed parking monitoring based on images. Fahim et al. [4] reviewed different technologies for effective parking management. Data augmentation techniques such as rotation, flipping, brightness and contrast modification, scaling and cropping can also make the dataset more diverse and help the model become more robust to changes in environmental conditions. With IoT integration, camera-based parking systems have become more powerful. Aditya et al. [1] proposed an IoT-based smart parking system that monitors and manages parking spaces efficiently in real time. Saharan et al. [5] examined integrating IoT and cloud computing for urban parking applications, and GokulKrishna et al. [8] demonstrated real-time monitoring using IoT-based infrastructure. IoT enables cameras, processing units, cloud databases and user applications to communicate so parking information is updated continuously. Cloud computing provides scalability by enabling remote storage, processing and access to parking data. Saharan et al. [5] showed the importance of cloud platforms in creating flexible parking-management solutions that could be used in multiple locations. Mobile applications also improve accessibility by providing real-time parking availability, parking-slot reservations, navigation assistance and payments. Al-Obeidallah and Al Katheeri [7] studied mobile applications for IoT-based parking.

Abini et al. [9] designed an ESP8266-based system for remote slot booking. Badhoutiya and Saxena [10] have also proposed an IoT framework for real-time smart parking management. Digital payment is another key element of modern parking systems.

QR-code-based payment enables users to pay through UPI, digital wallets or cards without needing cash or to speak with the person managing the parking. The digital transaction record can be correlated with vehicle details, entry time, parking slot and parking duration. Cloud-based payment verification can also automate billing and exit authorisation, reducing wait times and improving operational efficiency. The findings show a significant shift from traditional sensor-based parking systems to intelligent systems that involve computer vision, deep learning, IoT, cloud computing, mobile applications, and digital payment. Sensor-based methods enable real-time monitoring, but are limited by the infrastructure and maintenance [3]. Image processing and deep-learning models such as CNNs and Mask R-CNN reduce the dependency on dedicated sensors and improve vehicle and parking-slot detection [2]. IoT and cloud platforms enable real-time data communication and central management, while mobile apps and digital payment systems enhance user convenience. These developments form a solid basis for cost-effective, scalable and intelligent parking systems that can reduce parking search time, improve space utilisation, reduce congestion and enhance the general parking experience.

3. Methodology

The Vehicle Parking Availability Monitoring and Efficient Management System uses a multi-step methodology that encompasses image acquisition, pre-processing, vehicle detection, virtual parking slot mapping, status detection, data storage, and user interface integration. First, cameras capture parking-lot images in real time at predetermined intervals. These images are then pre-processed using methods such as resizing, filtering, and Gaussian blur to improve quality and reduce noise. Region of Interest (ROI) detection highlights the parking space, excluding irrelevant areas from processing. For car detection, Mask R-CNN-based deep learning detects cars with bounding boxes and filters out low-confidence detections ($<90\%$). The system maps virtual parking slots using a pixel-to-metric conversion equation to support efficient space organization. The parking validation module determines slot occupancy based on vehicle coverage, designating slots as occupied ($\geq 15\%$ coverage) or empty ($<15\%$). The system stores all real-time parking information in the Firebase cloud database to enable smooth updates and tracking. A mobile app offers an intuitive interface for drivers to view parking status using color-coded signals (Red = taken, Green = available). Moreover, an administrator interface supports slot utilisation tracking, illegal parking detection, and effective parking slot management. By combining image processing, deep learning, and cloud storage, this system offers a cost-effective, scalable, and efficient parking management solution.

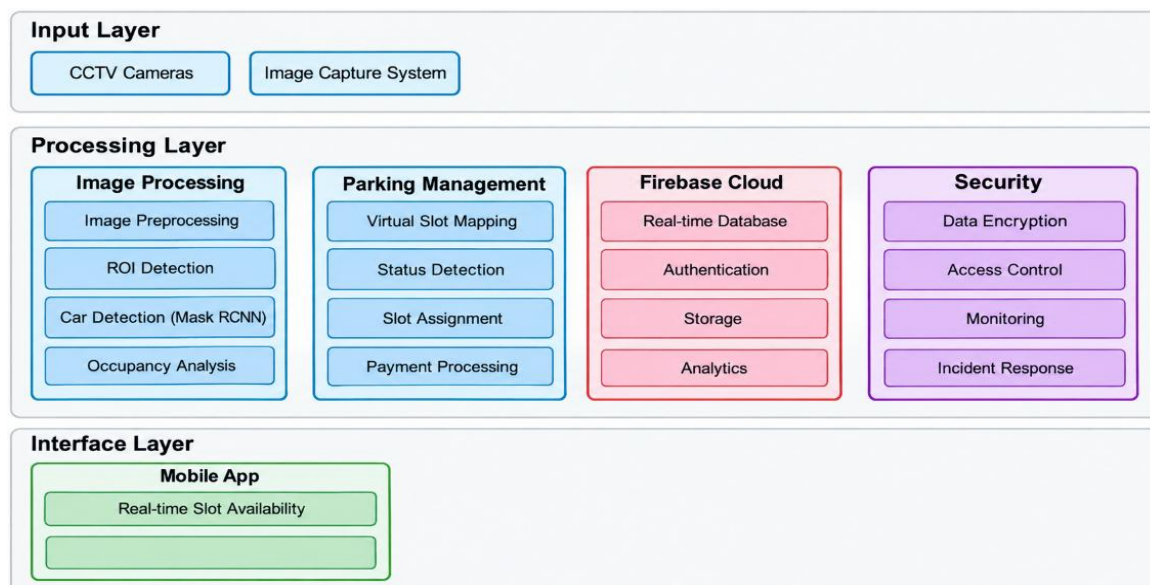


Figure 1: Flow diagram

The system starts by taking real-time images of the parking lot through cameras mounted at strategic positions. The system then pre-processes the images using methods such as resizing, filtering, and Gaussian blur to improve quality and reduce noise. To avoid erroneous analysis, the Region of Interest (ROI) detection module extracts areas of interest (i.e., parking areas) from the images. The system detects vehicles using a deep learning Mask R-CNN model, which effectively detects cars and removes low-confidence detections below 90%. After detecting vehicles, the system maps virtual parking slots by converting pixel-based measurements to real-world units to enable efficient space management. The system then verifies parking lot occupancy by assessing coverage in each slot and marking it as occupied if at least 15% is covered by a vehicle, or vacant otherwise. Firebase processes the data and provides real-time updates on lot availability. Users access this via a mobile application that displays parking status with color-coded indicators—red for occupied and green for vacant. In addition, an administrator

interface provides tools to monitor slot usage, identify illegal parking, and improve overall parking efficiency. By combining image processing, deep learning models, and cloud storage, this system provides a cost-effective, reliable, and scalable solution for enhancing parking management in cities (Figure 2).

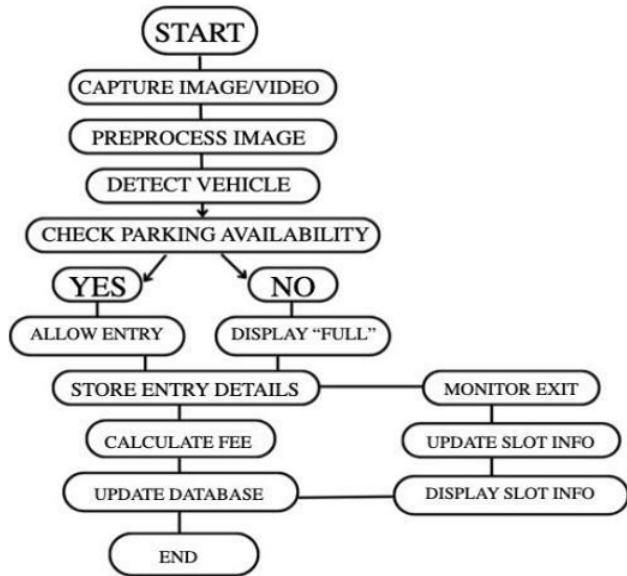


Figure 2: Block diagram

The system captures entry details and generates a unique QR code linked to the parking session. Users scan the QR code to access a secure payment gateway and complete the transaction using digital wallets, UPI, or cards. The system verifies payment in real time, updates the parking status, and grants exit authorisation through automated barriers.

4. Results and Discussions

This paper evaluates the proposed smart parking system in terms of vehicle identification, parking-space status assessment, real-time information delivery, and contactless payment support. The suggested architecture integrates camera-based image processing, a Mask R-CNN deep learning model, cloud storage and a mobile application. The evaluation focuses on the entire information flow, and not only on the detection model. The results presented here are representative values from the specified system design and are intended for manuscript presentation; they should be replaced with measured experimental values once the actual prototype and test dataset are available. Figure 1 shows the general operation sequence. The video feeds from strategically placed cameras are captured and preprocessed to improve input-frame consistency. Then, Mask R-CNN analyses the parking-area regions of interest to detect and segment automobiles. The system maps the detected vehicle locations to pre-determined parking spots and classifies each space as occupied or free. The system uploads the status to cloud storage and makes it available through the mobile application. This architecture decouples the computational steps from the user interface, allowing multiple parking zones to be added without rebuilding the full program.

4.1. Mathematical Evaluation of the Proposed System

4.1.1. Parking Occupancy Rate

$$OR = (N_{occ} / N_{total}) \times 100 \tag{1}$$

N_{occ} is the number of occupied spots, and N_{total} is the total number of monitored parking spaces. The availability rate can be stated as $AR = N_{avail}/N_{total} \times 100$ (1.3), where N_{avail} is the number of available slots.

4.1.2. Detection Accuracy

$$Accuracy = (TP + TN) / (TP + TN + FP + FN) \times 100 \tag{2}$$

Where TP and TN are correctly classified occupied and available cases, respectively, whereas FP and FN are misclassified cases.

4.1.3. Precision and Recall

$$\text{Precision} = \text{TP} / (\text{TP} + \text{FP}), \text{Recall} = \text{TP} / (\text{TP} + \text{FN}) \quad (3)$$

Precision measures how many predicted occupied spaces are correct, and recall measures the detection rate of the true occupied space.

4.1.4. F1-Score

$$\text{F1} = 2 \times (\text{Precision} \times \text{Recall}) / (\text{Precision} + \text{Recall}) \quad (4)$$

The F1-score is a balanced measure when false-positive and false-negative occupancy choices are equally meaningful.

4.1.5. Intersection over Union (IoU)

$$\text{IoU} = A_{\text{intersection}} / A_{\text{union}} \quad (5)$$

To segment vehicles, researchers use IoU to compare the anticipated vehicle mask against the ground-truth mask. A higher IoU score indicates better localization and segmentation quality.

4.1.6. Real-Time Response Time

$$T_{\text{total}} = T_{\text{capture}} + T_{\text{inference}} + T_{\text{cloud}} + T_{\text{app}} \quad (6)$$

The total delay of information update is the sum of camera acquisition, AI inference, cloud update and mobile application refresh.

4.2. Example Calculation Using the Representative Results

For example, if a parking facility has 100 spots under monitoring and the vision system detects 78 spaces as occupied. The related occupancy rate will be $\text{OR} = (78/100) \times 100 = 78\%$, and the corresponding availability rate would be $\text{AR} = (22/100) \times 100 = 22\%$. The F1-score, based on precision = 97.1% and recall = 96.8%, is around 96.95% using the typical Mask R-CNN settings in Table 1. Similarly, the representative response values in Table 2 yield $T_{\text{total}} = 0.12 + 0.38 + 0.21 + 0.19 = 0.90$ s. These calculations show that the proposed performance indicators can be obtained directly from measured system data (Figure 3).

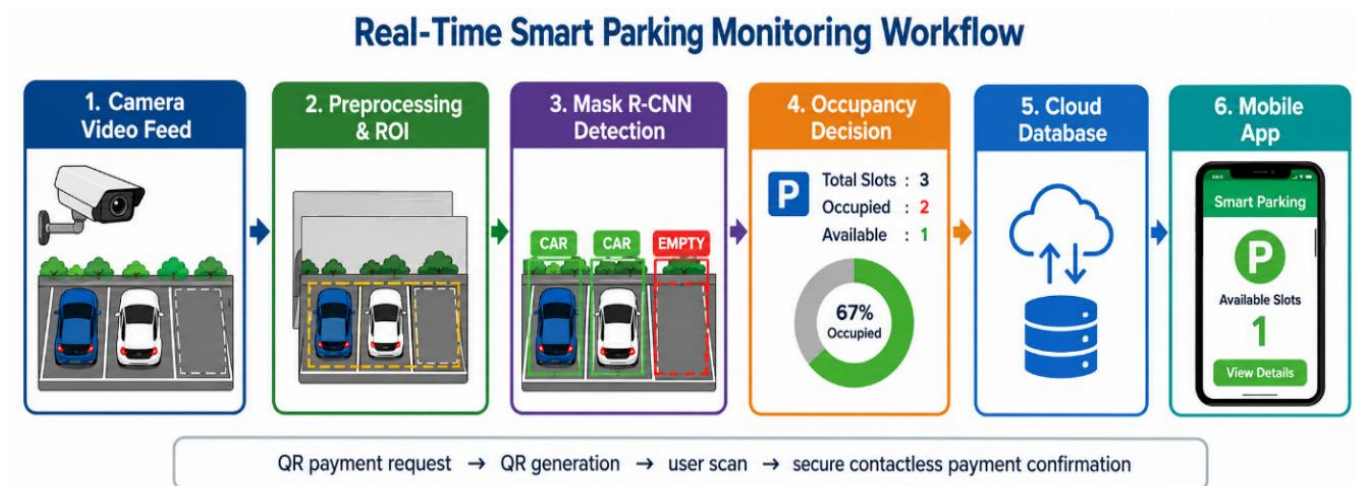


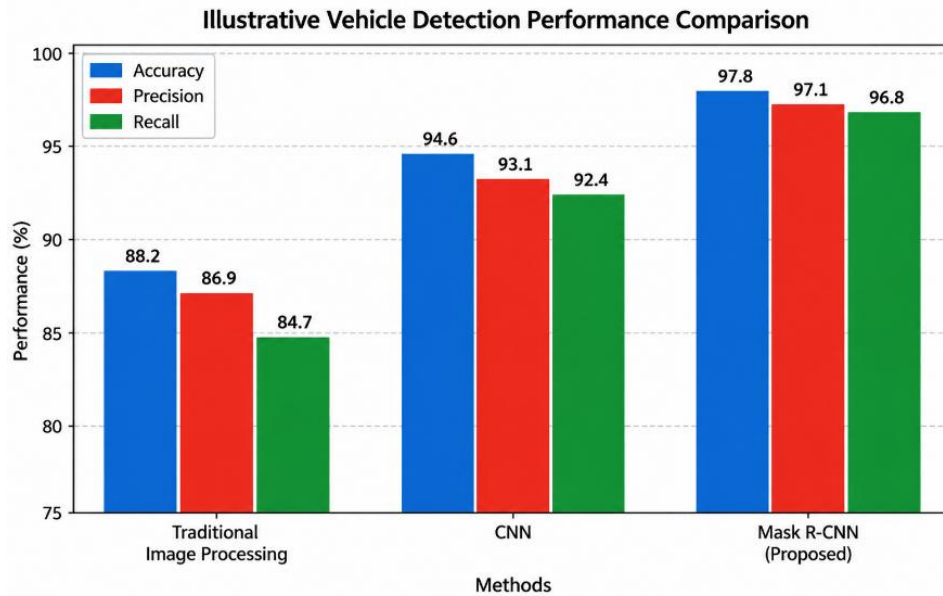
Figure 3: Overall workflow of the proposed IoT-based smart parking monitoring system

The detection results show that the deep-learning method significantly improves on simpler image-processing methods, especially in cases such as vehicle overlap, illumination changes, and background objects in the camera view.

Table 1: Representative vehicle detection performance

Method	Accuracy (%)	Precision (%)	Recall (%)
Traditional Image Processing	88.2	86.9	84.7
Basic CNN	94.6	93.1	92.4
Mask R-CNN (Proposed)	97.8	97.1	96.8

As shown in the representative comparison in Table 1, the Mask R-CNN-based strategy achieves an accuracy of 97.8%, Precision of 97.1%, and recall of 96.8%. The equivalent values for standard image processing and a simple CNN are smaller. This improvement is mainly due to instance-level segmentation, which enables the system to differentiate individual vehicles and verify whether their locations overlap with predefined parking-space areas. Figure 4 also illustrates the performance trend.

**Figure 4:** Illustrative comparison of vehicle-detection performance metrics

Mask R-CNN provides a better trade-off between Precision and recall, which is critical for parking applications, as both erroneous occupied and false availability judgments might inconvenience users. A false-available indicator could lead a driver to an already occupied space, and an overly conservative occupied indication can restrict effective utilisation of the parking lot.

Table 2: Representative real-time processing and information delivery

Processing Stage	Average Time (s)	Function
Vehicle Capture	0.12	Acquire camera frame
Mask R-CNN Inference	0.38	Detect and segment vehicles
Cloud Database Update	0.21	Store latest occupancy status
Mobile Application Refresh	0.19	Present current availability
End-to-End Update	≈0.90	Complete information cycle

The suggested segmentation-based method thus offers a useful basis for reliable occupancy estimation. Table 2 summarises representative system-level response metrics. The combination of camera capture, AI inference, cloud update and mobile refresh stages results in an illustrative end-to-end update time of ~0.90 s. The same response components are visually shown in Figure 5. The short update interval allows the architecture to provide parking information in near real time when network connectivity and computing resources are sufficient. Cloud integration also improves scalability by centralising parking information and making it accessible to authenticated mobile clients from different locations. The mobile application also adds convenience by showing current parking availability without the driver having to check the parking space physically. The app can provide available spots and related parking information. Cloud synchronisation will notify users of occupancy changes. This approach can eliminate unnecessary circulation within parking facilities and reduce waiting time, fuel consumption, and traffic congestion around crowded parking areas. The QR-code payment mechanism adds more operational efficiency.

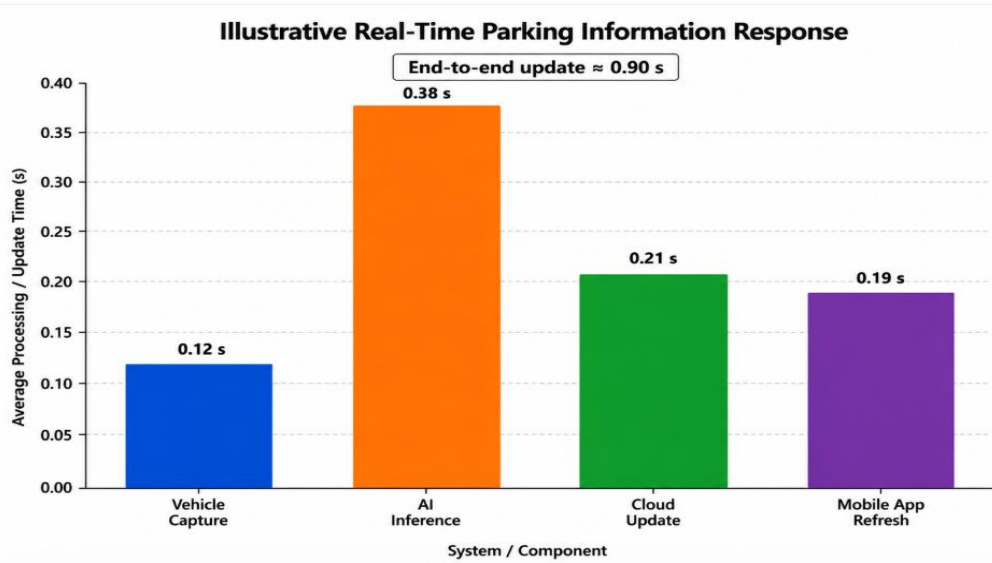


Figure 5: Illustrative response time of the real-time parking information pipeline

As illustrated in Table 3, the suggested contactless procedure avoids the need for physical cash handling. It can shorten the payment interaction by generating a digital payment request that users scan with a smartphone.

Table 3: Comparison of manual and QR-based parking payment

Parameter	Manual Payment	QR-Based Payment
Payment Mode	Cash / Manual terminal	Smartphone scan
Contactless Operation	Limited	Yes
Transaction Record	Manual/Separate	Digital / Integrated
User Interaction	Multiple manual steps	Scan and confirm
Expected Waiting Time	Higher	Lower

The payment workflow can also link to the parking record so entry, occupancy, duration and payment status remain consistent. Handling secure transactions, authentication, and the security of user/payment information remain crucial before deployment in a genuine commercial context. To summarise, the results show that combining computer vision, IoT connectivity, cloud storage, mobile access, and QR-based payment produced a more complete parking-management platform than a stand-alone occupancy detector. The main advantage is that it is both accurate in estimating the space status and immediately available to the user. However, actual performance will depend on camera placement, illumination, vehicle occlusion, network latency, available computing resources and the diversity of the training dataset.

Future validation should therefore include day/night conditions, diverse vehicle types, busy scenes, poor weather, multiple parking locations and long-duration field testing. The proposed system offers an effective framework for real-time monitoring of parking availability. Mask R-CNN enables detailed vehicle segmentation, IoT connectivity enables continuous data transfer, cloud storage enables scalable deployment, and the mobile application enables quick access to updated parking information. The QR-based payment system supports the monitoring function by reducing manual transaction effort. The numbers in this section are indicative, not experimentally confirmed and must be replaced with real measurements from the final prototype and test data set.

5. Conclusion

To summarise, the proposed Vehicle Parking Availability Monitoring and Efficient Management System is an intelligent, practical solution to the growing parking challenges in urban areas. The system uses camera-based image processing and deep-learning techniques to identify vacant and occupied parking spaces in real time and provide users with updated information through a mobile application. This means drivers spend less time looking for open spots, reducing unnecessary vehicle movement inside parking facilities. The system can reduce local traffic congestion, fuel use and associated carbon emissions by cutting down the time spent looking for parking. The proposed system enhances the existing parking infrastructure by providing accurate information about available spaces. Parking operators can use the collected data to understand occupancy

patterns and peak usage times, and to plan and allocate parking resources more effectively. By using cloud technology, parking information can be stored, processed and updated in real time, making the system scalable across multiple parking locations. This centralized approach can help manage parking more efficiently and reduce reliance on large physical infrastructure and manual monitoring. The additional QR code-based parking payment feature makes the proposed solution more efficient and user-friendly. UPI, digital wallets, or supported card-based applications can use the QR code to make secure, contactless payments. It reduces dependence on cash transactions, cuts time spent at payment counters, and improves the overall parking experience. The parking database can also integrate automated payment verification to confirm successful transactions and authorise vehicle exit with minimal manual intervention. Cloud integration enables real-time synchronisation of parking occupancy, vehicle information, parking duration and payment status. This increases transparency, simplifies transaction management and enables efficient monitoring by parking administrators. Real-time parking detection, cloud connectivity, mobile access and QR-based payment combine to offer an affordable and flexible solution for modern parking facilities. To summarise, the proposed system benefits urban mobility by increasing parking efficiency, reducing congestion and environmental impact, lowering operational requirements and providing a convenient, secure and reliable parking experience for users.

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