Journal of Research and Innovation in Technology, Commerce and Management
Vol. 3 Issue 6, June 2026, pp. 36025-36031
ISSN: 3049-3129(Online)

Real-Time Parking Slot Occupancy Detection using CNNs and Computer Vision in Smart Cities

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Cite as: Ruhiat Sultana, MD Asma, Sayeed Bin Amodi, Patan Sohail, & Mohd Faizan Ur Rahman. (2026). Real-Time Parking Slot Occupancy Detection using CNNs and Computer Vision in Smart Cities. Journal of Research and Innovation in Technology, Commerce and Management, Vol. 3(Issue 6), 36025–36031. https://doi.org/10.5281/zenodo.20773539

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Abstract: Urban parking inefficiencies have been exacerbated by rapid growth in vehicles based on human supervision. Smart parking system proposed utilizes computer vision and deep learning to identify occupied parking slots without per-slot hardware. Live video feeds from IP cameras are analyzed in a Flask-based micro service using OpenCV and a pre-trained Convolutional Neural Network. Every slot is virtually split and examined, with occupancy status determined by a confidence threshold improving classification accuracy and reducing false positives. The system has a three-layer architecture, users can make bookings using a web interface and receive a receipt with a specific QR code for entry and exit authentication.

Experimental comparisons shows high reliability and lower user wait times, making it ideal for high-density urban areas. Administrators get live monitoring and slot analytics, allowing for optimal space utilization. SmartPark presents a pragmatic, future-proof answer that is congruent with smart city objectives and sustainable urban transport.

Keywords. *Smart Parking System, Real-Time Slot Detection, Computer Vision, Convolutional Neural Network (CNN), QR Code Verification*.

I. INTRODUCTION

With the growth in urban population and the rise in the prevalence of automobile ownership, proper management of parking facilities has emerged as an important problem for urban cities worldwide. Traditional parking systems, depending mostly on manual observation or sensor-based systems, are likely to be devoid of real-time information, leading to poor utilization of parking spaces, increased traffic congestion, and user dissatisfaction. Additionally, in the majority of cases, these systems are not scalable and economically viable for big or multi-level parking scenarios [1][2].

Advances in computer vision and artificial intelligence in recent times have made it possible to develop smart parking systems that can identify the presence of vehicles without the use of embedded sensors. Employing technologies such as Convolutional Neural Networks(CNNs) and real-time video processing, modern systems can dynamically monitor parking space occupancy with high accuracy[1][6].Further, the integration of web technologies with sophisticated detection systems allows for seamless user interaction and remote operation of the systems, making the deployable in smart city infrastructures.

SmartPark is a computer vision, IP camera-based, and CNN model-based real time smart parking system that identifies the occupancy status of pre-defined parking slots by the presence of cars. It uses a Flask-based micro service to process video streams, employing a confidence threshold to calculate the slot occupancy status. The system architecture is a React.js frontend, Node.js backend, and MongoDB database system providing an end-to-end complete user experience- based. Users can book slots in real time and receive QR codes for contactless entry and exit verification, providing heightened security and convenience. This paper discusses the design, implementation, and evaluation of Auto Park, and shows how it provides a cost-effective, scalable, and accurate alternative to traditional parking solutions [4][5][14]

II. LITERATURE SURVEY

In this current study, we propose an intelligent parking system that employs real-time video processing, deep learning-based algorithms, and QR-based authentication to improve car parking solutions in urban areas. Auto Park system is designed to replace conventional sensor-based or manually operated systems with a scalable, accurate, and user-focused solution. The thought process behind the system is inspired by several recent studies that have employed advanced technologies to analogous fields.

In an earlier work [1], a computer vision system based on OpenCV and CNNs had been implemented to track occupation of parking spaces. The method was to create individual masks for each space and pass through incoming

frames to determine their occupation. The system worked fine, if it was within a controlled setup, but did not have booking and access control features. Aerial images were employed in another work [2] to identify the presence of vehicles in large parking lots with gray scale processing and convolutional neural networks. Although this method was very accurate (over 94%), it was not very interactive and did not have a user interface for real-time booking and feedback [3].

Similarly, an IoT solution using RFID and IR sensors was applied to automatic car parking management in[4]. Although the system provided contactless entry and real-time status reporting, the system had large hardware requirements per slot, hence high deployment and maintenance costs.

Another system based on mobile [5] utilized the ESP8266 Wi-Fi module and Firebase to enable users to book slots through an Android application and use the parking lot through QR codes. SmartPark extends this capability by connecting real-time visual data with the verification and booking process. Current research by Saini et al.[6] and Sharma et al.[7] has demonstrated the application of YOLOv3 and SSD architectures for vehicle detection in real-world urban environments [8]. In addition, Bhatt et al. [10] [11] and Lee et al. [12] introduced self-parking systems based on stereovision, SLAM, and LiDAR technologies [9].

Building on the success of earlier studies, SmartPark is a merger of established technologies within an integrated system—a scalable, sensor-less, and AI-driven platform intended for parking automation [13] ,[14]. It merges the advantages of vision-based detection, real-time booking, and secure QR-based entry within an economically sustainable system for commercial, institutional, and urban environments. arrhythmia or healthy person [15].

III PROPOSED WORK

The system, Park, is built to provide a real-time, smart, and scalable parking management solution by integrating deep learning, computer vision, and modern web technologies. Its fundamental purpose is to identify parking space availability precisely without physically installing sensors in each slot, and to provide a seamless booking and access experience using a secure QR code-based system.

At the center of the system is an IP camera placed above the parking slot, which is tasked with capturing a live video stream of the parking lots. The video stream is processed by a micro service built on Flask, which extracts image frames and performs preliminary preprocessing using OpenCV. A pre- trained Convolutional Neural Network (CNN) processes the preprocessed frames, classifying each parking space as "occupied" or "free" according to a pre-set confidence level. This approach provides stable detection performance even in the face of changing lighting and environmental conditions.

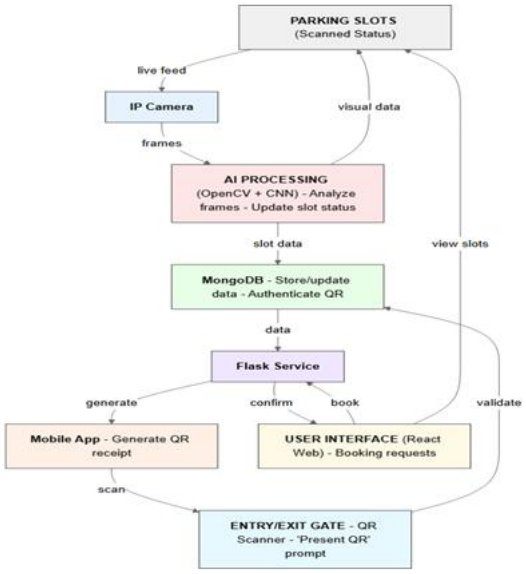

Fig 1: Architecture for Smart Park

The processed slot status is transmitted to the Node.js and Express.js- based backend system. The backend serves as the intermediary between the AI engine, the user interface, and the MongoDB database. All such information as slot availability, user credentials, vehicle information, and booking history is stored in an organized manner in MongoDB to facilitate rapid retrieval and maintain system performance consistency.

The frontend, which is built in React.js, provides an easy-to-use interface to sign up, monitor real-time availability of parking slots, and make reservations. Once a reservation is booked, the system creates a digital receipt containing an embedded QR code that contains booking meta data. The QR code will be scanned at the entry and exit points of the parking lot for safe access verification and verification of the slot start us in real-time. In addition, the system also has an administrator interface for monitoring slot usage, setting options, and reporting SmartPark is also more versatile, cheaper, and more effective thantraditional model using RFID tags, ultra Sonics sensors, or manual operators. It is particularly tailored for high-density commercial locations, institutional campuses, and city centers that require scalable and real-time parking solutions.

By replacing hardware-based approaches with vision-based automation, two-step QR verification, and use of a robust three-tier architecture, SmartPark is a contemporary system that complies with the efforts of smart city and intelligent transport.

IV RESULTS

1. Dataset Collection

To train and test the vehicle detection model used in SmartPark, two separate datasets were prepared one for training and the other for validation. The training dataset contains 1,436 labeled images, which are divided into two classes: car and non-car. A third set of 360 images, divided into the same two classes, was utilized for validation. The division between the training and validation datasets ensures that the model can be tested on unseen data, thus providing an estimate of its performance and robustness in the real world.

Table 1.Sample data collection for training purpose

SNo	Class	Training Set	Validation Set
01	Car	796	200
02	Noncar	640	160

2. Classical Result

The trained CNN model achieved a classification accuracy of 96.4% on the validation dataset. During live stream testing through the Flask micro service, the model maintained an effective balance between speed and precision. Slots were identified as free or occupied in real time with minimal delay(average response time of ~300 ms per frame). A confidence threshold of 0.5 was used to decide final classification. If the model prediction exceeded this threshold, the slot was marked as occupied; otherwise, it was considered free. This approach significantly reduced false positives, especially in scenarios involving shadows, partial vehicle views, or angled perspectives.

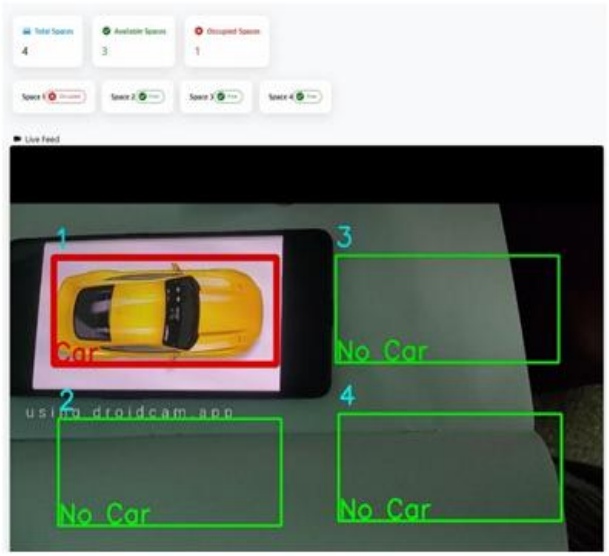

Fig 2: Slot identification using CNN and OpenCV

3.Performance Analysis

SmartPark was contrasted with standard parking systems that utilize ultrasonic sensors or RFID-based entry systems. Findings show that Auto Park outperforms traditional methods in scalability, detection accuracy, and user-friendliness.

Table 2. performance analysis against traditional systems

Metric	Traditional Systems	SmartPark
Slot Detection Accuracy	80–88%	95–97%
Maintenance Cost	High	Low
Scalability	Limited	High
Access Security	Moderate	High
Real-Time Monitoring	Partial	Full with live stream

Compared to hardware specific systems, which end to deteriorate with time and require constant maintenance, park vision- based system naturally scales with the size of the parking lot and requires only one IP camera for complete surveillance.

Fig 3 Auto Park vs Traditional Parking Systems

4. Cost Analysis

SmartPark demonstrates staggering cost savings in every aspect of operation over conventional parking systems. The system saves 80% in hardware costs due to its innovative use of a single IP camera to monitor numerous parking slots, abandoning the use of individual slot sensors. Maintenance expenses are totally

eliminated because Parking utilizes open-source technologies instead of proprietary technologies. Maintenance expenses are reduced by 81% since the system utilizes a vision-based method that avoids the frequent maintenance that physical sensors require in conventional systems.

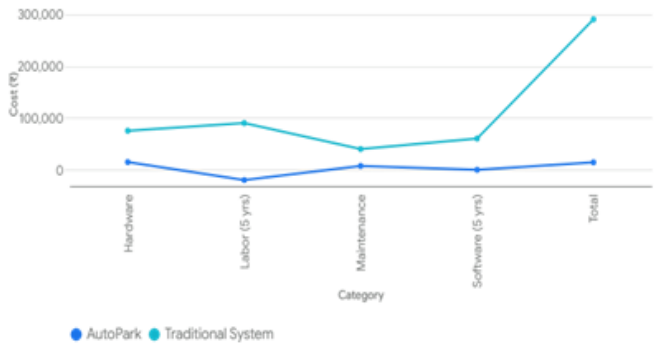

Fig 4: Cost comparison with Traditional Parking Systems

It enhances operating efficiency by lowering the amount of labor needed, hence saving 122% in the form of reduced staffing levels. Combined, these efficiencies as seen in figure 4 it provide an astonishing 95% savings in cost of ownership over traditional parking systems, making SmartPark a revolutionary solution for long-term parking.

V. CONCLUSION

AutoPark has established itself as a logical and efficient alternative to conventional parking systems as a real- time, accurate, and cost-effective means of parking space management. Employing a CNN-based classification model combined with OpenCV and Flask, the system achieved a high validation accuracy rate of 96.4%. The inclusion of QR-based authentication adds a layer of security and automation to user-friendliness and operational efficiency.

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