

# Park-Insight: Parking Vacancy Detection System

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**Abstract:** “Park-Insight” applies the technology deep learning, combined with computer vision, in building efficient scalable solutions for parking space management, making a Convolutional Neural Network which can be used in a model that categorizes occupied versus free parking in a given video feed input based in real-time; it's based on open processing of video data using OpenCV and has given power in this system web interface through Flask so that access for users would become user-friendly. This automated system saves time searching, reduces the rate of traffic congestion, and optimizes the efficiency of parking. It will benefit operators, ensuring that space usage is optimized to deliver valuable insights with a modern and intelligent solution in managing urban parking.

**Keywords:** Parking management, Deep learning, CNN, Real-time detection, Smart city, OpenCV, Flask, VGG16, Sustainability

## I. INTRODUCTION

Parking was an extremely challenging problem in cities associated with large populations and dense vehicle populations, contributing to the strain on the parking infrastructure. Too much time would be wasted by drivers searching for an available parking space with personal frustration implications to broader systemic inefficiencies. This resulted in further traffic congestion, fuel consumption, and environmental degradation. Traditional parking systems were associated with heavy labour use and tended to make errors while failing to optimize space utilization effectively. This project portrays an AI-powered, CNN-based parking vacancy detection system that detects vacant parking based on video footages. Contrary to the currently used sensor-based or manual methods, this scalable and low-cost AI solution uses OpenCV for image processing and Flask to provide a friendly web interface. This, in itself, ensures real-time parking updates and simplifies the experience of users while allowing the operators to optimally utilize the available resources.

## II. LITERATURE SURVEY

P.R. de Almeida et al. (2015) introduced PKLot dataset that contains highly diverse parking lot images under varied conditions. Nowadays, this dataset is a general resource available to support the task of the parking detection research by providing adequate robust machine learning model training [1]. F. Caicedo et al. in (2012) presented the models that ensured both live and historical data to predict real-time parking availability. It was determined that such models achieved a substantial improvement in accuracy for urban parking environments [2]. J. Jermurawong et al. (2014) established that low-cost parking monitoring with a single camera is feasible, where occupancy can be monitored without extensive cost on hardware [3]. K.-C. Lan et al. (2014) conceptualized a sensor-based system wherein real-time driving guidance towards any available parking spots minimizes their search times with reduced congestion, as proposed here [4]. E. Rahtu et al. (2012) presented a method called LPQ that, in addition, improved the rate of parking detections under difficult imaging conditions where light is poor [5]. G. Amato et al. (2016) employed smart camera networks with CNNs for detecting parking space in large-sized facilities with a high accuracy rate [6]. D. Delibaltov et al. in 2013 proposed a technique for parking lot occupancy determination based on cameras mounted on lamp posts. It is reported to have low cost infrastructure along with an acceptable detection rate under changing lighting and weather conditions [7].

Q. Wu et al. in the year 2007 introduced an inter-space correlation-based robust parking space detection model. The method, by focusing on spatial dependencies of parking spaces, has significantly enhanced accuracy in complicated scenarios [8]. S. Banerjee et al. in 2011 designed a real-time car parking system that uses image processing techniques. It mainly focused on low computational overhead that is deployable in resource-constrained environments [9]. Yong Ma et al. (2025) did an in-

depth survey on detection methods of parking space centered on the developments of machine learning and computer vision methods. This paper reveals a way forward of how parking has been improved by evolving into technological solutions [10]. Nicholas True (2025) discussed parking space detection from still images focusing on edge devices and lightweight algorithms. This indicated the feasibility of deploying detection models in resource-limited areas, such as smaller parking lots [11]. J. Jermurawong et al. (2025) proposed a statistical approach to parking vacancy detection, taking into account 24-hour analysis for predicting peak hour usage and optimizing parking management plans [12]. Chin-Kit Ng et al. (2025) developed a mobile application for detecting an outdoor parking space. Within this research work, the data regarding the parking are processed in real-time through cloud computing. It is accessed on any smartphone at any end-user's hand [13]. Debaditya Acharya et al. (2025) proposed a real-time parking occupancy detection using deep learning techniques. Their model uses convolutional neural networks with very high detection rate across diverse environments [14]. S. K. Singh et al. (2023) developed a machine learning-based system to detect vacant parking spaces. The authors' approach integrates various data streams, including sensor inputs and image processing, to optimize smart parking solutions [15]. Qiangwen Xu et al. (2022) proposed applying deep learning for smart city applications toward parking vacancy detection. Their proposed model aims at being scalable and robust in a high-density urban environment [16].

### III. METHODOLOGY

This addresses the design of a deep learning framework based on CNNs and transfer learning for parking vacancy detection. The datasets annotated, for instance, PKLot, will be used for training and validation purposes. The augmentation techniques applied are rotation, scaling, and brightness for the data, which help to increase the generalizability of the model along with performance. VGG16 architecture will be fine-tuned, making use of transfer learning to optimize classification between occupied and vacant spaces. The system has been deployed by having a Flask-based backend which supports real-time updates through web interfaces. It uses metrics for accuracy, precision, and recall to check the system and test its robustness under various environmental conditions. The framework incorporates preprocessing steps to address occlusions and

shadows in parking lot images, ensuring better feature extraction. A learning rate scheduler is used to dynamically adjust the learning rate to accelerate convergence while avoiding overfitting. Batch normalization layers are added to enhance the stability of training by normalizing activations. Dropout regularization is also implemented to prevent overfitting by randomly dropping neurons during training. Finally, the system uses OpenCV for image processing. It allows for real-time detection and analysis of parking spaces with much efficiency.

It also lays greater emphasis on image preprocessing for enhanced model performance. Video frames captured from cameras installed at the parking lot are resized to standard dimensions, normalized, and underwent different data augmentation techniques such as horizontal flips, zooming, and rotation. All these ensure the model generalizes well across the diverse environmental conditions, including variations in lighting and weather scenarios. In fine-tuning VGG16 using ImageNet pre-trained knowledge in the parking space detection task, custom layers would be added for this adaptation of the network to both of the binary classification tasks: to distinguish an occupied space from a vacant space. The proposed model is implemented and trained using stochastic gradient descent at a low learning rate with the use of momentum to achieve stable convergence. The training process is executed in real-time augmentation to make it more robust, and subsequently, by using the accuracy and loss metrics in visualization, its progress is followed and possible pitfalls such as overfitting are detected.

### IV. SYSTEM ARCHITECTURE

"Park-Insight" detects free parking spaces with a modular and multi-layer system design. Input Layer begins by capturing video streams using high-definition cameras installed all over the parking lot. Before processing, raw video streams pass through an Image Pre-processing Module via the OpenCV technique. Such pre-processing includes noise reduction, edge detection, and application of image segmentation techniques to produce better quality images for further analysis. Once these images were processed, they then passed to the Deep Learning Module, where the final act of classifying the parking spots as Vacant or Occupied was taken. Classification of the parking lot is performed through the CNN VGG16 model fine-tuned on a plethora of environmental data sets, including PKLot. Historical

values of each result with appropriate time stamps were logged into the centralized database.

The system backend was developed using Flask, and the user interface was a Real-Time Monitoring Dashboard that showed the number of available and occupied spaces at the parking lot in the current time. Furthermore, it used graphical presentations for parking plans that were updated in real-time. This also means the system uses an integrated feedback mechanism to enhance performance further, taking in users' inputs along with other data collected on operation, feeding these into a training pipeline, thereby improving the model accuracy through successive iterations. Scalable is also another word used in describing this system as it can be implemented in any scale or complexity for any parking lot while being able to operate efficiently and accurately. Adaptive algorithms used in the system dynamically adapt detection parameters in real time depending on environmental changes like lighting or weather. The mechanism of ROI mapping is implemented for complex parking lot layouts so that individual parking spaces can be correctly defined and monitored. The architecture of the system is multi-parking lot, so administrators can track multiple locations under a single dashboard.

Anomaly detection algorithms are added to detect abnormal parking behavior or system failure, making the system reliable for operation. Hardware acceleration techniques are also used to minimize energy by accelerating the processing of video streams on GPU-enabled devices. Automated reporting tools are also implemented within the system, detailing analytics of parking trends to help strategic decision-making. The last aspect is that there is a secure API that allows incorporation of third-party applications, including a navigation system or a payment gateway, in the functioning of the system.

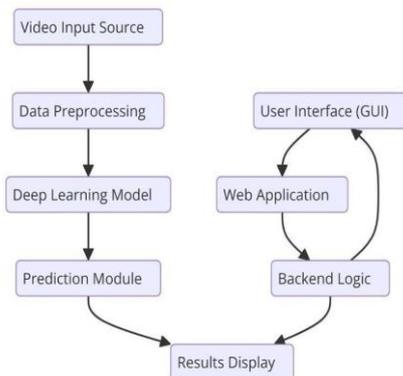


Fig 4.1 System Architecture

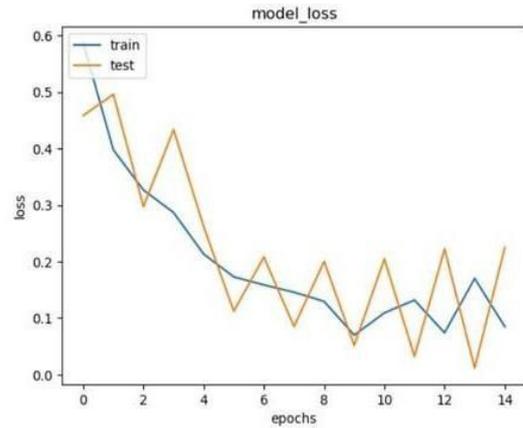


Fig 4.2 Loss

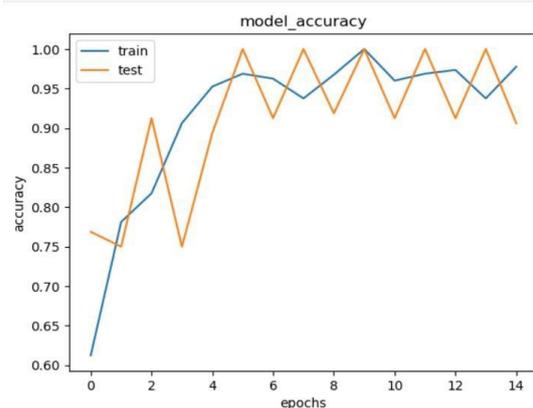


Fig 4.3 Accuracy

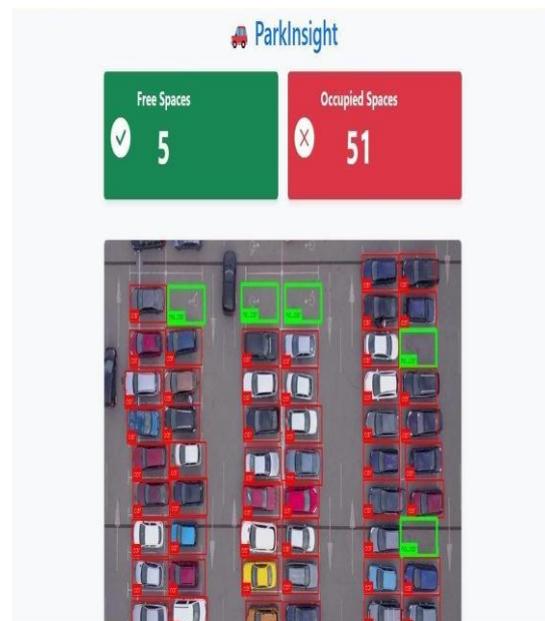


Fig 4.4 Output

## V. CONCLUSION

“Park-Insight” increases significantly the efficiency and effectiveness of managing urban parking lots using deep learning and computer vision techniques.

With advanced CNNs and real-time image processing, the system has the capability of accurately determining parking space occupancy, thus saving on the amount of time that drivers spend in trying to look for parking space; this would ultimately reduce traffic congestion, saves on fuel, and helps to mitigate the adverse impacts on the environment. Through a user-friendly interface powered by Flask, this system bridges gaps between parking lot operators and users so that there are smooth communications, resource optimization, and scaling is good with variation in facility sizes while maintaining consistent performance. Real-time data analytics helps to give insights for better decisions. The Park-Insight system paves the way to smarter mobility solutions in cities. The system equips sustainable parking practices in modern cities with efficient improvements as further enhancements will include IoT sensor integration, predictive analytics, and mobile application development to further heighten the parking experience of all stakeholders.

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