**REAL TIME CAR PARKING OCCUPANCY PREDICTION SYSTEM**

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**ABSTRACT**

Urban parking is a challenging problem due to the limited availability of parking spaces and the growing number of vehicles. Existing parking slot detection models often struggle to achieve high accuracy in adverse conditions, such as low light and occlusions, which limits their practical applicability.

This research aims to advance parking slot occupancy detection using deep learning models, specifically ResNet, VGG16, Xception, and ensemble models. The proposed approach begins with preprocessing the parking lot images to ensure consistency and quality. A deep learning model is then trained to extract vital image characteristics and classify each parking slot as empty or occupied.

The four models evaluated in this study achieved high accuracy in classifying parking slot occupancy, especially the ensemble model, which outperformed individual models with an accuracy of 99.2%. This suggests that deep learning models can be used to develop accurate and reliable parking slot detection systems, with the potential to improve urban parking management and mobility.

The findings of this research have the potential to make a significant impact on urban parking management and mobility. By improving the accuracy and reliability of parking slot detection, the proposed approach can help to reduce traffic congestion, improve air quality, and enhance the overall parking experience for drivers.

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**CHAPTER # 1**

**INTRODUCTION**

# **Introduction**

A smart parking system is a sophisticated solution designed to address the persistent issue of parking space scarcity in urban areas. With the ongoing urbanization and the increasing number of vehicles on the roads, finding available parking spaces has become a significant challenge in many cities. This challenge not only leads to frustrating experiences for drivers but also contributes to traffic congestion, increased fuel consumption, and environmental pollution.

In response to these challenges, smart parking systems that leverage advanced technology to offer a more efficient and user-friendly parking experience. They typically consist of various components, including sensors strategically placed in parking spaces to detect occupancy in real-time. This information is relayed to a central server or cloud-based platform through wireless communication technologies. User-friendly mobile applications or websites provide drivers with real-time parking information, allowing them to check for available parking spaces, reserve spots in advance, and make electronic payments. Some systems even offer navigation assistance to guide drivers to the nearest available parking spots, reducing search times and frustration.

Smart parking systems streamline the payment process, eliminate the need for physical tickets or cash transactions, and optimize parking space utilization. By doing so, they reduce traffic congestion and greenhouse gas emissions, contributing to improved urban air quality and sustainability. Surveillance cameras are often integrated into these systems to enhance security in parking facilities. Overall, smart parking systems offer a comprehensive solution to the challenges of parking space scarcity, making urban parking hassle-free and environmentally friendly.

According to (Biyik, Allam et al., 2021), the model provided in Figure 1 illustrates the architecture of a sophisticated smart parking system that aims to address the challenges of parking scarcity in urban areas effectively. This comprehensive system comprises several key components, each playing a vital role in ensuring its seamless operation.

At the core of the system are parking sensors strategically placed in parking spaces. These sensors continuously monitor the occupancy status of individual parking spots in real-time. The data collected by these sensors is then transmitted to an edge gateway, which acts as a data hub. The edge gateway collects and preprocesses the data from the parking sensors before sending it to the cloud server.

The cloud server is a powerful component of the system. It stores and processes the real-time parking data, making it accessible to various other parts of the system. Additionally, the cloud server can be used for training and deploying machine learning models, enhancing the system's performance.

To provide a user-friendly experience to drivers, the system includes mobile applications and websites. These applications allow drivers to access real-time parking information, reserve parking spots in advance, and make electronic payments, streamlining the parking process.

The smart parking system also incorporates surveillance cameras to enhance security in parking facilities. These cameras serve as a deterrent to potential criminal activities and contribute to improved safety.

Furthermore, the system includes a parking guidance system that guides drivers to available parking spaces, reducing the time spent searching for a spot. Additionally, a parking management system assists parking operators in efficiently managing their parking lots.

In operation, the system's parking sensors continuously monitor occupancy, and the data is processed and made available to users through the cloud server. Drivers can access real-time information via mobile applications and websites, making parking more convenient. The surveillance cameras enhance security, and the guidance and management systems optimize the overall parking experience.

Smart parking systems offer several advantages, including the reduction of traffic congestion by helping drivers find available parking spaces more efficiently. They also contribute to improved air quality by reducing traffic congestion and idling. The surveillance cameras enhance security, and the user-friendly features increase customer satisfaction.

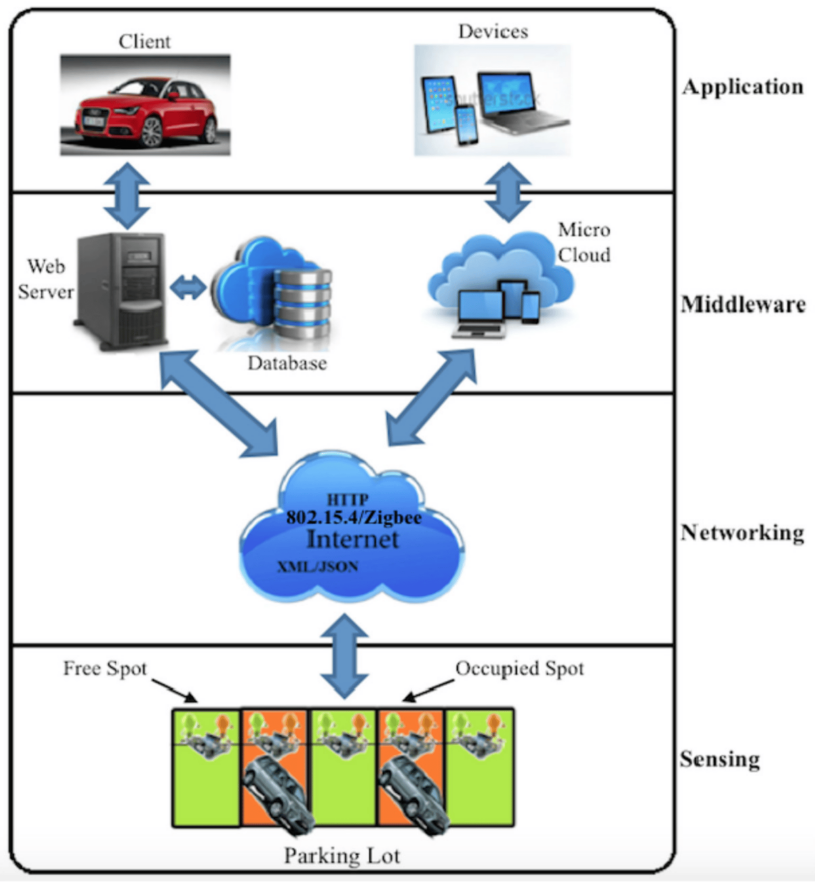


Figure 1. Layer architecture for Integrated smart parking systems

In pursuit of advancing parking slot occupancy detection, this research project places a strong emphasis on utilizing the power of deep learning models. Specifically, we explore the capabilities of some deep learning techniques including ResNet, VGG16, Xception, and Ensemble methods to enhance the accuracy and efficiency of parking slot detection. By leveraging a diverse range of model architectures and ensemble techniques, our objective is to elevate the precision of parking slot occupancy detection.

This comprehensive approach begins with the use of a dataset containing parking lot images. These images undergo a detailed preprocessing phase to ensure data consistency and quality. Afterward, a deep learning model extracts vital image characteristics, as it has been specifically trained to identify key patterns related to parking slot occupancy. The result is a set of binary labels that effectively categorize each parking slot as empty or occupied as shown in Figure 2. To validate its effectiveness, this system undergoes a comprehensive evaluation using essential metrics like accuracy, precision, recall, and the F1-Score, demonstrating its reliability and applicability for improving urban management and enhancing mobility solutions.

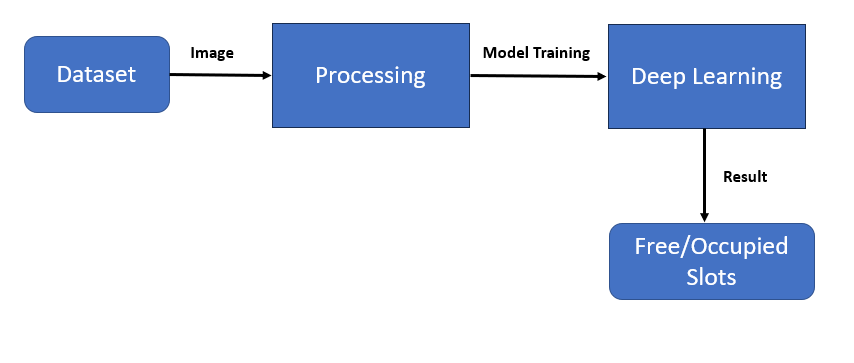


Figure 2. Proposed Parking Slot Detection Approach

## Major Contributions

This research presents a series of significant contributions in the domain of parking occupancy detection and management. First and foremost, it focuses on object and parking occupancy detection, introducing advanced techniques to accurately identify and validate vehicles, particularly cars, as they enter designated parking areas. This precise identification lays the foundation for efficient parking management.

Additionally, the research delves into optimizing techniques for parking slot allocation, enhancing the allocation process to ensure optimal space utilization and efficient parking resource management. By leveraging real-time data and location awareness, the system optimizes parking slot allocation, contributing to improved user experiences and reduced parking search times.

The study also addresses the challenge of optimal detection in diverse visual conditions, acknowledging that parking scenarios can vary significantly in terms of lighting, weather, and occlusions. The research introduces methodologies to enhance detection accuracy across various visual scenarios, ensuring the reliability of the parking occupancy prediction system.

Furthermore, the research advances the field by introducing a real-time automated vehicle parking occupancy detection and navigation system. This system not only detects parking occupancy but also assists drivers in navigating to available parking spots, reducing search times and improving overall parking efficiency.

Lastly, the research introduces a multi-clue recovery model for accurate parking spot detection. By combining multiple data sources and clues, this model enhances the accuracy of parking spot detection, contributing to the effectiveness of the parking management system. These contributions collectively address the complexities of parking space scarcity and aim to provide innovative solutions for urban parking management.

**1.1.1 Optimize Techniques for Parking Slot Allocation**

The research conducted by (Taylor, Ezekiel, and Emmah in 2021) centers around addressing the critical urban problem of parking space scarcity and the resultant traffic congestion. Their approach leverages cutting-edge methodologies in object detection and predictive modeling to forge innovative solutions for optimize parking management.

A groundbreaking aspect of this research is the pioneering use of state-of-the-art object detection algorithms within the realm of parking management. By harnessing the capabilities of computer vision, these algorithms enable the automatic identification and tracking of vehicles within parking areas, offering a new dimension of efficiency and accuracy.

Through rigorous data collection and analysis, the researchers develop predictive models capable of foreseeing parking space availability. These models amalgamate historical and real-time data, providing valuable insights to drivers and empowering them to make informed parking choices.

Furthermore, the integration of Internet of Things (IoT) devices and edge computing plays a pivotal role in enabling real-time monitoring of parking occupancy. With the deployment of IoT sensors and edge devices, a network is established that continuously tracks and updates parking availability information, significantly benefiting urban mobility by reducing the traffic congestion stemming from drivers' quests for parking spaces.

By delivering precise and real-time information on parking availability, the researcher's work not only alleviates traffic congestion but also contributes to reducing carbon emissions associated with unnecessary vehicle circulation while searching for parking. This environmentally conscious approach aligns with sustainable urban practices.

Moreover, drivers themselves stand to gain from data-backed guidance, ultimately leading to improved parking experiences and a reduction in frustration.

Additionally, the research extends its relevance to intelligent traffic management systems, with the potential to optimize vehicle flow within urban areas. In essence, this research makes a significant contribution to the ongoing transformation of urban environments towards smarter and more sustainable futures.

The research focuses specifically on closed deterministic parking environments, such as malls, hospitals, and residential complexes. These scenarios are chosen due to their unique security and environmental considerations, making them suitable for the proposed integrated solution. The research will employ a combination of theoretical analysis, algorithm development, experimentation, and case studies to achieve the research objectives.

The research endeavors encompass a multi-faceted exploration, aiming to provide a comprehensive integrated solution that optimizes parking slot allocation and management within the confines of closed deterministic environments. This initiative extends its scope to encompass insights into the intricate technical challenges associated with the seamless integration of advanced image processing techniques, Internet of Things (IoT) technology, and cloud-based solutions as shown in Figure 3. By delving into these complexities, the research seeks to enhance the understanding of the potential impact of the proposed solution. This includes its capacity to not only enhance parking slot allocation precision but also to significantly reduce waiting times, elevate overall user satisfaction, and effectively harness parking space utilization. The synthesis of these facets endeavors to create a holistic approach that not only addresses the technical intricacies but also empowers urban environments to achieve efficient and user-centric parking management systems.

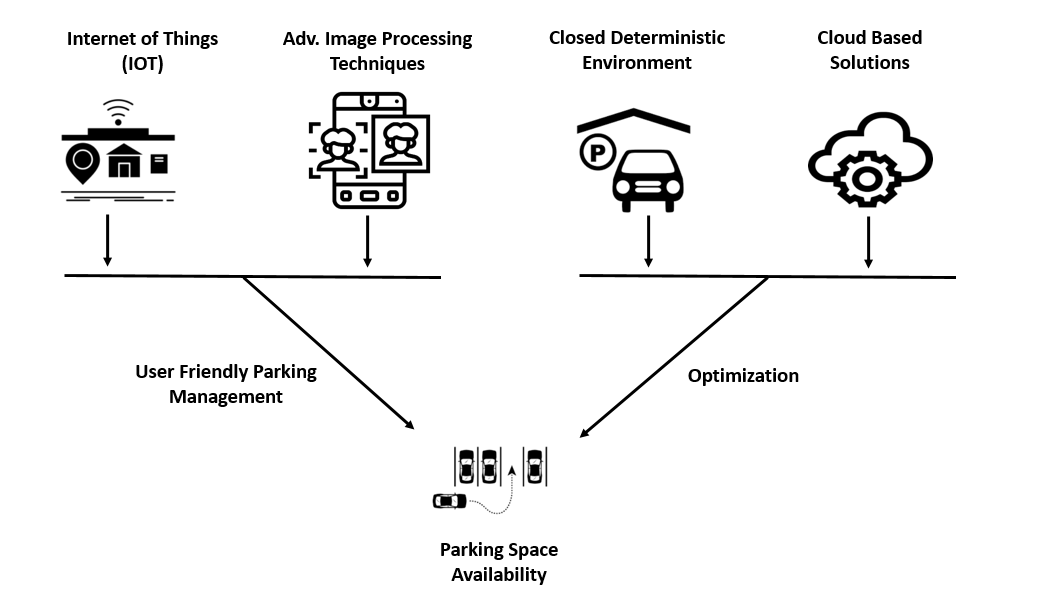


Figure 3. Advance Techniques to optimize parking slot Allocation

**1.1.2 Optimal Detection in Visual Conditions**

(Martynova, Kuznetsov, Porvatov, & Tishin, 2023) The comprehensive objectives of this research are centered around evaluating and analyzing the strengths and weaknesses of various state-of-the-art deep learning architectures, specifically vision transformers and convolutional neural networks (CNNs), within the context of parking lot occupancy detection. The research aims to conduct an in-depth exploration of these architectures to gain insights into their performance characteristics, advantages, and limitations when applied to the challenging task of detecting parking space occupancy.

The primary objective is to systematically compare the performance of vision transformers and CNNs for parking lot occupancy detection. This involves designing rigorous experiments to quantify the accuracy, efficiency, and adaptability of each architecture under diverse visual conditions, including poor lighting, occlusions, and different weather scenarios. By meticulously assessing the strengths and weaknesses of these architectures, the research intends to provide a comprehensive understanding of how they handle challenging real-world scenarios.

Furthermore, the research aims to identify the optimal architecture that aligns with the specific requirements of parking lot occupancy detection. Through a meticulous analysis of the experimental results, the research aims to determine which architecture exhibits superior accuracy, robustness, and generalization capabilities. These findings will guide the selection of the most suitable deep learning architecture to be employed in the proposed algorithm, ensuring that the chosen architecture can effectively address the challenges associated with parking lot occupancy detection in adverse visual conditions.

The research aims to contribute valuable insights into the selection of deep learning architectures for parking lot occupancy detection. The results of this analysis will not only guide the development of the proposed algorithm but also provide a broader understanding of the applicability and limitations of different architectures in the context of computer vision tasks. As shown in Figure 4, the research aims to advance the state-of-the-art in parking lot occupancy detection by leveraging the strengths of deep learning architectures to enhance accuracy and efficiency while mitigating the impact of challenging visual conditions.

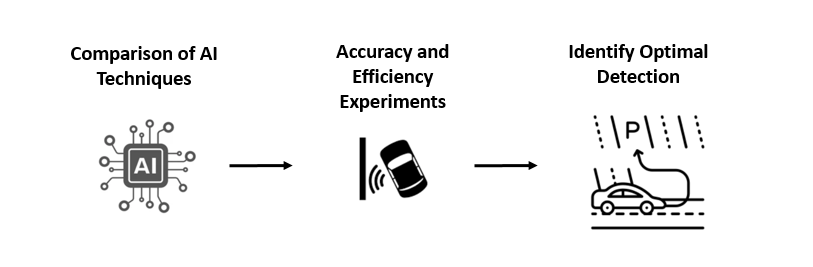


Figure 4. Optimal Detection in Visual Conditions

**1.1.3 Real-Time Automated Vehicle Parking Occupancy Detection and Navigation**

(Padmasiri, Madurawe, Abeysinghe et al., 2020) made several notable contributions to the field of automated vehicle parking occupancy detection. Firstly, their work presented the development of an end-to-end automated vehicle parking occupancy detection system designed to operate in real-time using surveillance streams. This system aims to efficiently guide drivers to available parking spaces, reducing time and energy expenditure. Secondly, the study introduced the application of advanced object detection techniques, specifically RetinaNet and Faster R-CNN, to accurately identify parking spaces under varying conditions. These techniques enhance the system's ability to detect both occupied and unoccupied parking spaces. Additionally, the proposed system adopted a modular software architecture with microservices, offering scalability and resilience while minimizing installation and maintenance costs. Lastly, the development of web and mobile applications as client interfaces enables users to locate parking spaces effortlessly. Most importantly, the approach eliminated the need for manual segmentation of video streams, making it adaptable and cost-effective for deployment across different parking lots as shown in Figure 5.

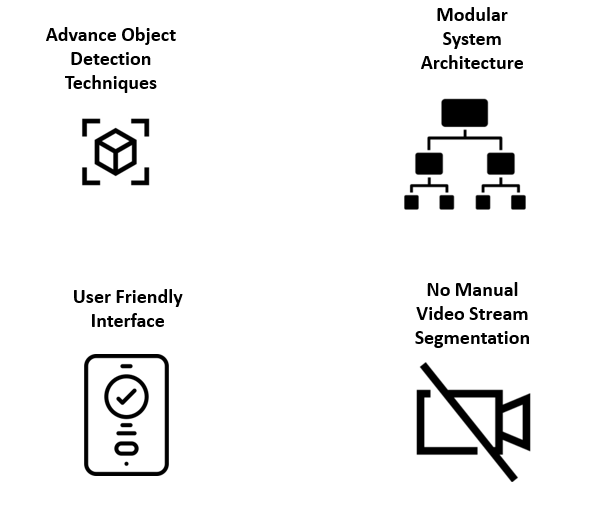


Figure 5. Innovative Approaches to Real-Time Automated Vehicle Parking Occupancy Detection and Navigation

**1.1.4 Multi-Clue Recovery Model for Accurate Parking Spot Detection**

This research makes several significant contributions to the field of automated parking spot detection (Chen, Qiu, Sheng et al., 2021). First and foremost, it introduces a novel Generative Parking Spot Detection (GPSD) algorithm that utilizes a multi-clue recovery model to effectively reconstruct parking spots. Unlike conventional methods, GPSD emphasizes the use of corners as fundamental components of parking spots, resulting in highly accurate detection and recovery.

Furthermore, the paper addresses the challenge of unbalanced illumination, partial information loss, and varying definitions of parking spot lines in input images by proposing a Layered Analytical Illumination Balance (LAIB) method for image preprocessing. This approach significantly improves the robustness of the algorithm under diverse lighting conditions.

The research also presents a Fast Micro-Target Detection (FMTD) algorithm, which prioritizes corner detection over traditional object classification methods. By doing so, it simplifies the training process while enhancing overall detection accuracy, particularly in scenarios involving complex parking spot shapes.

To correct and accurately locate parking spots, the paper introduces a multi-clue recovery model that leverages sideline, occlusion, edge, and domain clues. This comprehensive approach effectively addresses the issue of parking spot deformation, further improving the algorithm's performance.

Extensive experimental validation is conducted using datasets, including HERV 2018 and HERV 2019, demonstrating the superiority of the proposed algorithms. These experiments showcase exceptional results in corner detection, parking spot location, and overall detection quality, underscoring the contributions of this research.

While the proposed GPSD algorithm excels in many aspects, it remains sensitive to parking spot deformation (Chen, Qiu, Sheng et al., 2021). Irregularly shaped or distorted parking spots pose a challenge that requires further investigation and refinement of the algorithm.

Another limitation is the relatively small size of the datasets used for validation, such as HERV 2018 and HERV 2019. These datasets may not encompass the full spectrum of parking scenarios, indicating the need for expanding the dataset to include a wider variety of scenes and environmental conditions. This expansion could provide a more comprehensive evaluation of the algorithm's performance.

The paper introduces an illumination balance method as shown in Figure 6 to address varying lighting conditions.

The research focuses on algorithm development and validation but does not delve into real-time implementation aspects. Deploying these algorithms in real-world scenarios, particularly in applications like autonomous vehicles, could introduce additional challenges related to computational efficiency and latency, which require further exploration.

Lastly, the generalization of the proposed GPSD algorithm to detect parking spots beyond common parallelogram layouts or in non-standard configurations remains an open question and an avenue for future research.

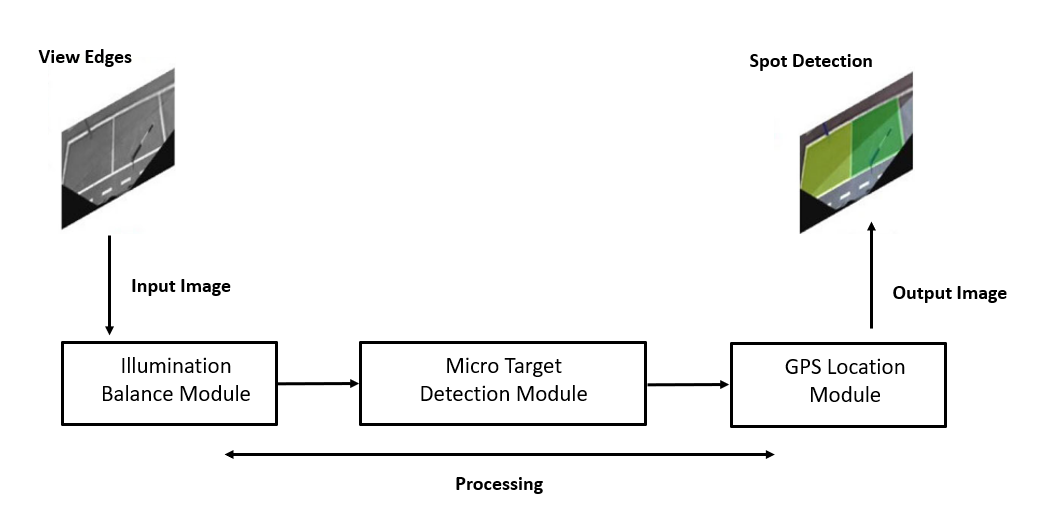


Figure 6. Multi-Clue Recovery Model for Accurate Parking Spot Detection

## 1.2 Research Gap

The research gap evolving nature of parking lot occupancy detection solutions and the imperative to address the complexities of real-world parking scenarios. While recent studies have made significant strides in harnessing deep learning architectures for enhanced accuracy, there's a crucial gap in effectively handling the wide spectrum of diverse and challenging conditions that parking lots present. The current models, while proficient under favorable conditions, demonstrate limitations in adapting to adverse factors like poor lighting, occlusions, and varying weather conditions. This gap indicates the pressing need for research endeavors that prioritize bolstering the resilience and adaptability of these models. Bridging this gap requires innovative strategies that empower models to perform with consistency and accuracy regardless of the visual hindrances encountered. The integration of multi-angle detection strategies, as demonstrated in the research by (Martynova, Kuznetsov, Porvatov et al., 2023), introduces a promising approach. However, a considerable gap exists in the development of a seamlessly integrated system that dynamically selects the appropriate angle for detection based on contextual cues. Efforts to bridge this gap would entail crafting algorithms that not only identify the optimal angle for detection but also transition between angles in real-time to enhance the precision and efficiency of parking detection algorithms.

Real-time data processing is another area where the gap demands attention. Urban areas experience rapid fluctuations in parking demand, necessitating swift and accurate data processing and decision-making. The existing algorithms might struggle with processing large volumes of data and making informed decisions promptly. Closing this gap would entail the innovation of advanced algorithms and hardware acceleration techniques capable of processing real-time data efficiently. This enhancement would facilitate timely updates of parking availability information to drivers and stakeholders, contributing to a more responsive and effective parking management system.

Intelligent parking allocation remains a gap in the current research landscape. Beyond mere detection, there is a need to optimize how parking spaces are assigned to improve user experience and alleviate congestion. Addressing this gap involves leveraging machine learning to create allocation algorithms that consider user preferences, proximity to destinations, and available parking types. These algorithms could dynamically assign spaces to optimize overall traffic flow and reduce drivers' search time. This advancement would significantly enhance the efficiency and user-friendliness of urban parking systems.

Lastly, there is a noticeable gap in integrating parking solutions with broader urban planning strategies. While the technical aspects have received considerable attention, seamlessly weaving parking management systems into comprehensive city-wide mobility strategies remains an unexplored territory. Bridging this gap necessitates frameworks that align parking solutions with urban development plans, traffic patterns, and sustainability goals. Such integration could lead to more holistic, effective solutions that address urban mobility challenges in a well-rounded manner. In summary, these research gaps underscore the evolving nature of parking management and the potential for innovative solutions to revolutionize urban mobility.

* + 1. **Diverse and Challenging Parking Lot Scenarios**

The research conducted by (Marek, 2021) has significantly advanced the field of parking lot occupancy detection using deep learning models. However, a critical gap persists in effectively addressing the wide spectrum of diverse and challenging parking lot scenarios that are inherent to real-world environments. While these models excel under optimal conditions, they struggle when confronted with poor lighting, occlusions from surrounding objects, and a variety of weather conditions. To bridge this gap, future research needs to delve into the development of models that exhibit enhanced robustness and adaptability. This endeavor aims to ensure consistent and accurate performance irrespective of the complex and unpredictable environmental challenges that may arise. This entails a profound focus on refining models to adeptly handle scenarios of low visibility and effectively differentiate between occupied and unoccupied parking spaces even within the context of challenging visual conditions as shown in Figure 7.

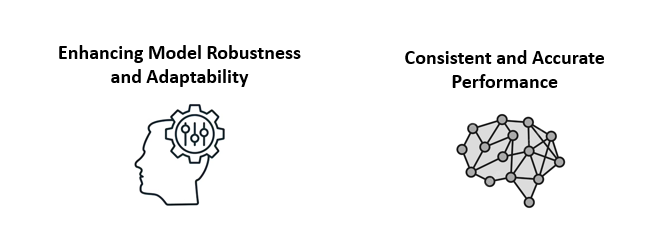


Figure 7. Challenges of Parking Lot Scenarios

* + 1. **Integration of Multi-Angle Detection**

(Martynova, Kuznetsov, Porvatov, & Tishin, 2023) have made substantial contributions to the field of parking lot occupancy detection while encountering inherent challenges and limitations. The study addressed the limitations of existing algorithms in parking lot occupancy detection, although it acknowledged that some limitations in the selected algorithms might persist. Despite the creation of the commendable Seasonal Parking Lot (SPKL) dataset, there may still be limitations in terms of real-world diversity and scale, considering the potential introduction of biases during dataset creation.

Efforts to enhance the usability of existing datasets, including augmentation and standardization, were valuable but might not entirely eliminate biases or limitations inherent in the original datasets. While the proposal of a novel approach using the EfficientNet architecture represents a significant achievement, it's essential to recognize that no single approach is universally optimal, and limitations may exist in specific scenarios.

The comprehensive computational experiments conducted in the research provided valuable insights into different methodologies, datasets, and scenarios. However, it's worth noting that unexplored methodologies or datasets might impact results and conclusions. Additionally, the effectiveness of optimization techniques can vary across different datasets and scenarios, with some techniques having limitations or trade-offs that should be considered.

The exploration of multi-angle parking detection introduces a promising avenue to heighten accuracy by detecting parking spaces from both overhead and low angles. Nonetheless, a gap exists in creating a seamlessly integrated system that can dynamically shift between these different angles based on contextual factors. Pioneering this integration would involve designing an intelligent system that not only identifies the most suitable angle for detection but also fluidly transitions between angles in real-time. This advancement would substantially amplify the efficiency and precision of parking detection algorithms. Successfully bridging this gap mandates the formulation of algorithms that adeptly account for real-time camera positioning, dynamic object tracking, and the capacity to adapt to instantaneous changes within the parking lot environment as shown in Figure 8.

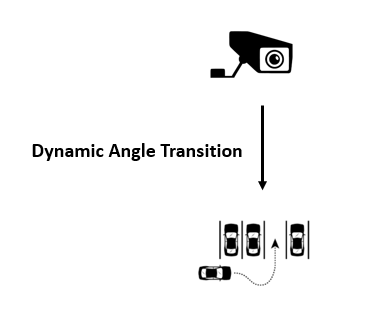


Figure 8. Challenges of Multi-Angle Parking Detection

* + 1. **Real-Time Data Processing and Decision-Making**

The research conducted by (Sudhakar, Reddy, Mounika et al., 2021) accentuates the vital role of real-time data processing within smart parking management systems. However, a critical gap persists in optimizing the speed and efficacy of data processing as shown in Figure 9, particularly in the face of swift changes in parking demand that urban locales experience. Existing algorithms might face challenges in efficiently managing the substantial influx of data and making swift yet precise decisions. Closing this gap necessitates the development of cutting-edge algorithms and hardware acceleration techniques that can efficiently process substantial data volumes in real-time. This, in turn, facilitates the prompt dissemination of up-to-date parking availability information to both drivers and pertinent stakeholders.

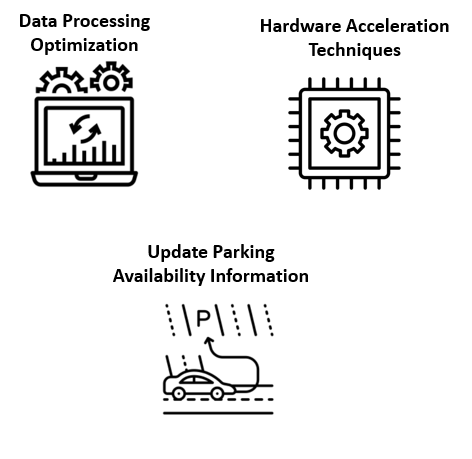


Figure 9. Challenges in Real Time Data Processing and Decisoin Making in Parking Systems

* + 1. **Intelligent Parking Allocation**

The research conducted by (Taylor, Ezekiel, & Emmah, 2021) addresses the critical challenges of parking space scarcity in closed deterministic environments by integrating cutting-edge image processing techniques, IoT technology, and cloud-based solutions. This holistic approach aims to optimize parking slot allocation and management, ultimately enhancing the user experience and contributing to more efficient urban environments. The central research problem revolves around mitigating parking space scarcity challenges through advanced image processing, IoT, and cloud solutions, with the goal of improving parking management, alleviating traffic congestion, and fostering user-centric parking solutions. The researchers pioneer the use of object detection algorithms for vehicle identification and tracking within parking areas. Predictive models are developed to anticipate parking space availability by integrating historical and real-time data, providing valuable insights to drivers and reducing traffic congestion. IoT sensors and edge computing enable real-time monitoring of parking occupancy, further enhancing urban mobility and decreasing carbon emissions. This research not only addresses immediate challenges but also lays the groundwork for broader smart city initiatives and intelligent traffic management systems, ultimately enhancing urban efficiency and user experiences.

The research has a diverse research effort emphasize parking detection but a gap remains in the development of intelligent algorithms to optimize parking space allocation. Beyond the identification of vacant spaces, optimizing the way these spaces are assigned can tangibly elevate user experiences and alleviate traffic congestion. Attending to this gap involves harnessing the potential of machine learning techniques to devise allocation algorithms that factor in user preferences, proximity to destinations, and the variety of available parking options. These algorithms would dynamically allocate spaces to optimize overall traffic flow and curtail the time drivers expend in search of suitable parking spots. In effect, this strives to make urban parking systems not only more efficient but also remarkably user centric as shown in Figure 10.

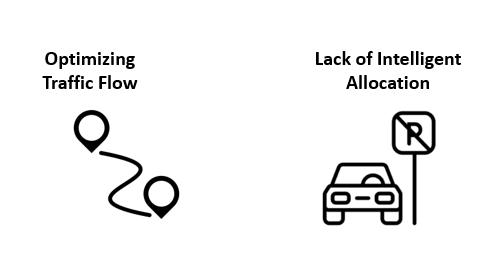


Figure 10. Challenges in Dynamic Parking Allocation

* + 1. **Parking Occupancy Detection and Long-Term System Sustainability**

The integration of Edge AI camera devices, as explored by (Stojanović, Damjanović, Vukmirović et al., 2021), has unveiled the realm of real-time parking occupancy detection. However, a gap endures in addressing the long-term sustainability of such systems. Given the perpetual operation of these devices, factors such as maintenance, energy efficiency, and scalability are of paramount significance. To attend to this gap, it becomes imperative to conceive energy-efficient hardware solutions, implement remote monitoring mechanisms, and outline maintenance strategies that secure the longevity and cost-effectiveness of smart parking systems. This focus on sustainability serves as a linchpin in upholding the reliability and economic viability of these systems over extended durations as shown in Figure 11.

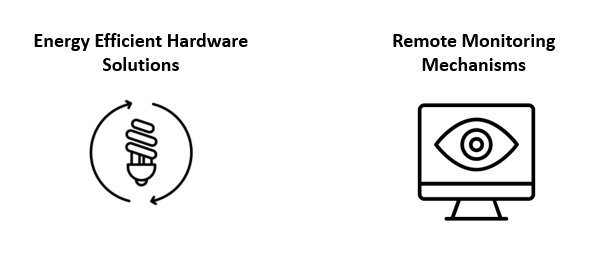


Figure 11. Challenges of Long-Term System Sustainability in Parking Systems

In the research by (Stojanović, Damjanović, Vukmirović et al., 2021), several significant limitations and challenges were also encountered. These included delays and reduced efficiency in object detection due to a high volume of direct server requests, difficulties in accurate object and license plate detection under varying lighting conditions, the cost-effectiveness of hardware implementations, and the complexities of accurately detecting and reallocating parking spaces. In response, the researchers proposed an innovative solution leveraging Smart Edge devices with AI accelerators to autonomously compute parking occupancy. This approach capitalized on recent advancements in Computer Vision (CV) algorithms, enabling precise parking occupancy prediction. The researchers introduced Edge AI Camera devices with powerful AI and GPU modules, advanced image sensors, and AI-driven auto-exposure, enhancing image capture capabilities. They also innovatively generated 3D models of parking environments using data from Edge AI cameras, improving tracking precision and addressing challenges like occlusions. Moving forward, their focus remains on achieving comprehensive three-dimensional awareness for a deeper understanding of parking spaces by integrating GPS and camera data, calibrating camera orientation, and correcting perspective, ultimately enhancing prediction accuracy.

The Figure 12 shows the research critical challenges in urban parking occupancy detection. Despite facing limitations such as delays in object detection and issues with varying lighting conditions, the study introduced an advanced approach utilizing Smart Edge devices with AI capabilities. By creating 3D models of parking environments and leveraging GPS and camera data, the researchers aimed to enhance prediction accuracy and provide innovative solutions to the persistent problems of parking space scarcity in urban areas, marking a significant contribution to the field.

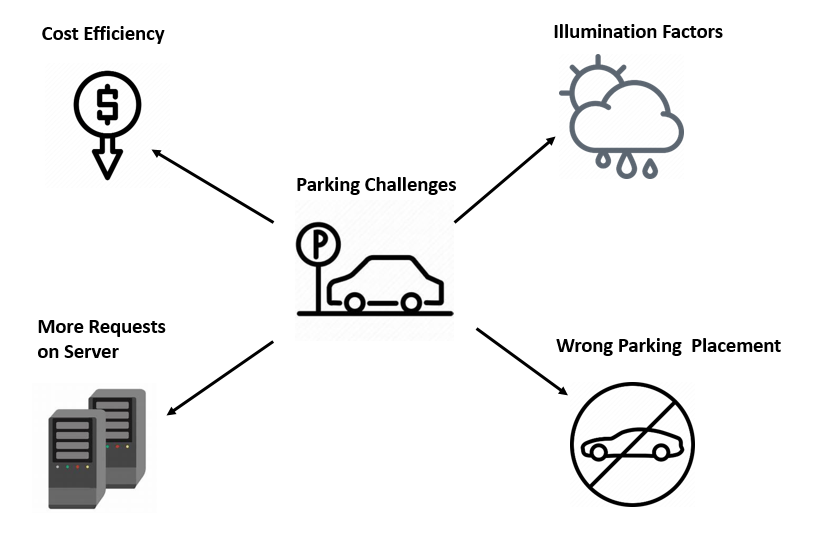


Figure 12. Challenges in Parking Occupancy Detection

## 1.3 Problem Statement

Urban parking management faces growing challenges due to increased vehicle numbers and limited parking space. Existing parking slot detection models encounter limitations in low-light and obstructed conditions. This study explores the potential of deep learning to improve urban parking management and traffic flow.

## 1.4 Research Questions

The research questions for this study on parking slot detection focus on addressing critical issues in urban parking management. These questions explore the potential of deep learning models for improving parking space occupancy detection in various scenarios. Specifically, they aim to understand the performance and accuracy of different deep learning models. The research questions delve into dataset collection, preprocessing, training processes, and model evaluation. They also investigate the impact of dataset diversity and consider how to overcome limitations related to occlusions. Overall, the research questions are designed to guide the study in optimizing parking space detection for enhanced urban parking management and traffic flow.

**1.4.1** How can the performance of the model be improved?

**1.4.2** How can the model be generalized to different environments?

## 1.5 Research Objectives

The research objectives for parking slot detection are to develop and evaluate a Real-Time Car Parking Occupancy Prediction System using deep learning techniques. This involves acquiring a diverse dataset, standardizing annotations, partitioning the dataset for training and testing, and enhancing data diversity. The objectives also include training models on the dataset and exploring hyper-parameters for optimal performance. These goals aim to enhance parking space detection for improved urban parking management and traffic optimization.

**1.5.1** This could involve exploring different deep learning architectures, training on more data, or employing data augmentation techniques.

**1.5.2** This could involve training on data from different parking lots, with different lighting and weather conditions.

## 1.6 Research Contributions

The research makes significant contributions to the field of parking slot detection by creating a Real-Time Car Parking Occupancy Prediction System. This contribution includes enriching datasets through image augmentation, expanding labels to cover various scenarios, and demonstrating the effectiveness of deep learning models with consistent high accuracy levels. The system's practical applications in improving parking management, illumination and cost efficiency make it valuable. Furthermore, the research methodology provides insights for addressing parking slot detection challenges in urban environments, benefiting the development of smart city solutions.

* Explore the impact of deep learning architectures (ResNet, VGG16, Xception, ensembles) on PKLot dataset parking slot detection accuracy.
* Innovate training techniques and data augmentation methods to enhance accuracy, especially in challenging conditions.
* Conduct comprehensive evaluations across various parking space types and environmental conditions.

**CHAPTER # 2**

**LITERATURE REVIEW**

# **2. Literature Review**

The literature review in this thesis systematically examines the historical development and critical aspects of the research topic. It utilizes a thematic organization to discuss key concepts, theories, methodologies, findings, and gaps within the field. By critically analyzing the strengths and weaknesses of previous research, it identifies research gaps and guides the direction of this study. All cited sources are listed in the references section.

## 2.1 Revising Deep Learning Methods in Parking Lot Occupancy Detection

(Martynova, Kuznetsov, Porvatov, and Tishin, 2023) recently highlighted the potential of Vision Transformers (ViTs) as a promising architectural solution to address the generalization challenges in parking lot occupancy detection. This field plays a vital role in advancing smart city development, with the goal of improving urban mobility and reducing traffic congestion. Over time, researchers have explored numerous algorithms to achieve precise and efficient detection of available parking spaces, with a recent shift towards computer vision techniques, particularly those based on neural networks. Traditional approaches heavily relied on manually engineered features and conventional machine learning methods, often employing image processing, edge detection, and template matching. However, their limited adaptability to diverse real-world visual conditions prompted the emergence of deep learning-based methods.

Convolutional Neural Networks (CNNs) revolutionized the field, showing significant improvements over classical approaches in parking lot occupancy detection. Various CNN architectures, such as VGG, ResNet, and MobileNet, have been employed for feature extraction and image classification tasks in this domain. Despite these advancements, challenges persist in terms of generalization, as many deep learning models lack robustness when facing diverse visual conditions not represented in their training datasets. Vision Transformers (ViTs) have emerged as a promising architecture to address the generalization issue, as they utilize self-attention mechanisms to capture global context and long-range dependencies in images. This ability has shown promise in enhancing parking space detection across different environments.

The importance of diverse and large-scale datasets has been highlighted in the literature, as they play a crucial role in training and evaluating parking lot occupancy detection models. Existing datasets, such as PKLot, ACMPS, CNRPark, and ACPDS, have been valuable for benchmarking purposes. However, they often lack comprehensive representation of real-world visual variations like winter weather, glare, fog, and diverse occlusions. To address this limitation, recent efforts have introduced datasets like SPKL, encompassing a broader range of visual conditions. The availability of diverse datasets enables a more comprehensive evaluation of algorithms and fosters the development of robust models.

In conclusion, parking lot occupancy detection algorithms have evolved from classical methods to deep learning-based approaches, and more recently, the exploration of Vision Transformers. While deep learning has shown remarkable progress, challenges related to generalization persist. Addressing these challenges and emphasizing diverse datasets for evaluation will be critical in developing accurate and adaptable parking lot occupancy detection algorithms, contributing significantly to smart city initiatives by improving urban mobility and traffic management.

Image preprocessing plays a vital role in training machine learning models, especially in computer vision tasks. One common technique is data augmentation, which involves generating altered versions of input images to provide more diverse training data without the need for additional labeling efforts. Augmentation techniques include image flipping, random cropping, translation, rotation, and noise injection (Nanni et al., 2021; Shorten and Khoshgoftaar, 2019). These operations help prevent models from memorizing specific pixel arrangements and promote generalization, thus enhancing the robustness of parking lot occupancy detection algorithms.

Patch-based methods constitute a prevalent approach in parking lot occupancy detection. These methods involve cropping specific regions from the input image, typically corresponding to individual parking lots, and applying binary classifiers to determine occupancy status. Various convolutional neural network (CNN) architectures have been explored in this context, such as AlexNet, mAlexNet, CarNet, VGG, ResNet, and EfficientNet (Krizhevsky et al., 2012; Amato et al., 2016; Nurullayev and Lee, 2019; Simonyan and Zisserman, 2015; He et al., 2016; Tan and Le, 2019). Each architecture offers unique features and depths, with EfficientNet and vision transformers showing promise in achieving competitive performance (Ha et al., 2020; Shah et al., 2022; Wang et al., 2022).

EfficientNet, developed through neural architecture search, employs a scaling method to uniformly adjust depth, width, and resolution using a compound coefficient. This approach demonstrates remarkable generalization ability, suggesting its potential for efficient parking lot occupancy detection systems.

On the other hand, intersection-based methods take a different approach, relying on object detection models as the initial step in the classification pipeline. Examples of such models include Faster R-CNN and RetinaNet (Ren et al., 2015; Lin et al., 2017). These models detect vehicle bounding boxes and assess parking lot occupancy based on the intersection area between the detected vehicles and parking spaces, using a predefined threshold.

Faster R-CNN, a classic two-stage detection algorithm, utilizes a region proposal network to simplify the generation of object proposals. On the other hand, RetinaNet is a one-stage object detection model that employs a focal loss function to handle imbalanced samples effectively. Both approaches show promise in improving parking lot occupancy detection, but they are currently underrepresented compared to patch-based methods.

This literature review provides valuable insights into deep learning methods for parking lot occupancy detection. Patch-based approaches using CNN architectures like AlexNet, VGG, and EfficientNet have been extensively studied and applied. Intersection-based methods, represented by Faster R-CNN and RetinaNet, show potential but require further exploration. Future research can focus on investigating the efficacy of vision transformers and exploring intersection-based techniques to improve the accuracy and efficiency of parking lot occupancy detection systems in various real-world applications. Continued advancements in these methods will contribute to more effective parking management solutions, benefiting urban planning, traffic flow, and overall transportation efficiency.

## 2.2 Smart Occupancy Detection for Road Traffic Parking

(Siddiqui, S. Y., Khan et al., 2022) introduce an innovative method for predicting parking space availability, a critical factor in mitigating traffic congestion and enhancing urban mobility. The authors tackle the challenge of efficient parking space identification in urban environments, a major contributor to traffic congestion, by leveraging artificial neural networks (ANNs) and the Deep Extreme Learning Machine (DELM) technique. Their proposed Car Parking Space Prediction (CPSP) model harnesses deep learning neural networks with both feed-forward and backward propagation.

The introduction of the paper emphasizes the importance of addressing traffic congestion in modern cities through smart mobility solutions. Parking space availability plays a significant role in traffic flow, and inefficient parking decisions can exacerbate congestion problems. The authors highlight the use of deep learning techniques, specifically DELM, to predict parking space availability accurately, which can aid drivers in making informed decisions about where to park. This, in turn, can enhance traffic safety and reduce congestion. The paper also mentions that traditional ANNs may not always be effective in handling complex problems like parking space prediction, necessitating the use of DELM.

In the context of smart cities, the availability of car parking spaces holds immense significance, particularly when integrated with high-tech infrastructure connected to cloud computing, as it greatly enhances the efficiency of traffic management (Lin, Rivano, & Le Mouël, 2017). Smart parking systems empower drivers to manage their vehicles en route to their destinations, allowing for the efficient estimation of parking space occupancy rates and the convenience of reserving parking spaces in advance. Several methods for predicting car parking space availability have been explored, some of which rely on probabilistic models like the Poisson distribution, while others employ Markov Chain predictions to account for various factors affecting parking capacity, such as time of day, weather conditions, and weekly variations (Pullola et al., 2007).

The study pays particular attention to Recurrent Neural Networks (RNN) and Artificial Neural Networks (ANN) in the domain of car parking availability prediction (Vlahogianni et al., 2016). Although authors apply ANN concepts in diverse domains, the central idea remains consistent: detecting parking availability and aggregating parking space information using feed-forward algorithms (Vlahogianni et al., 2014). These techniques, when coupled with Internet of Things (IoT) systems, exhibit the potential to significantly enhance accuracy and forecasting capabilities through back-propagation (Atta et al., 2018).

Smart city projects play a crucial role in disseminating information and awareness about parking in urban areas, leading researchers and practitioners to collect parking data for occupancy analysis across various locations (Caicedo, 2009). A study by Zheng et al. (2015) delves into the application of three prominent Machine Learning methods to estimate car park occupancy rates, utilizing datasets from Melbourne and San Francisco (SFpark). The study highlights the relative strengths and weaknesses of artificial neural networks, regression trees, and support vector machines. SFpark also serves as a use case for comparing different Spatio-temporal clustering strategies (Ata et al., 2019).

Apart from being storage-efficient, these prediction methods yield accurate results comparable to seven-day models. Moreover, multivariate regression models have been employed to forecast spatial and temporal correlations in car park availability, utilizing real-time data from cities like San Francisco and Los Angeles (Baroffio et al., 2015).

This study primarily focuses on the application of Deep Learning (DL), specifically Recurrent Neural Networks (RNN), for car parking availability prediction. Various authors have employed neural networks in this domain, with a common goal of understanding the relationship between aggregating parking lots and determining parking space availability through feed-forward networks (Vlahogianni et al., 2014). These approaches exhibit significant improvements when integrated with Internet of Things (IoT) systems, continuously enhancing occupancy predictions through back-propagation (Caicedo, 2009).

In addition to neural networks, computational intelligence approaches such as Fuzzy systems, Swarm Intelligence, and Evolutionary Computing have emerged as strong contenders in the smart city domain. These include techniques like Genetic Algorithms, Differential Evolution, and Island Genetic Algorithms, which have been applied to various aspects of smart cities, including wireless communication (Kashif et al., 2018; Wang et al., 2018). These computational intelligence approaches contribute to optimizing various facets of smart cities, including efficient car parking management.

The proposed model in the paper consists of three main layers: data acquisition, pre-processing, and application. The data acquisition layer collects parking-related data, the pre-processing layer refines and prepares the data, and the application layer includes prediction and performance evaluation. The authors introduce the concept of DELM, which is a neural network-based approach designed to improve prediction accuracy while reducing training time and memory usage. DELM involves multiple hidden layers and is trained through a series of calculations and weight adjustments.

The Deep Extreme Learning Machine (DELM) technique is explained in detail. It involves multiple hidden layers and uses a specific activation function, such as the sigmoidal logistic function, to calculate the output of each layer. The authors describe the forward propagation process, which computes the output of each hidden layer sequentially. The process includes calculating the weighted sum of inputs, applying the activation function, and passing the result to the next layer. After forward propagation, the paper outlines the backward propagation process, which involves calculating errors and adjusting weights to minimize those errors.

The simulation and results section presents the experimental findings of applying the proposed CPSP-DELM model to parking occupancy data. The authors split the dataset into training and testing portions to evaluate the model's performance. They calculate metrics such as accuracy and miss rate to assess the model's effectiveness. The results indicate that the proposed approach achieves high accuracy in training (94.37%) and testing (91.25%), demonstrating its potential for accurately predicting parking space availability.

In conclusion, the paper discusses the successful application of the CPSP-DELM model for predicting parking space availability in urban areas. The proposed approach leverages deep learning techniques to improve accuracy, making it a valuable tool for smart mobility solutions in smart cities. The paper's thorough explanation of DELM and its step-by-step description of the model's implementation contribute to a better understanding of how deep learning can be applied to address real-world traffic congestion issues.

## 

## 2.3 Image-Based Parking Space Occupancy Classification

(Marek, 2021) delivers an extensive examination of image-based parking space occupancy classification. The principal objective of this study is to introduce the Action-Camera Parking Dataset (ACPDS), a novel dataset meticulously crafted to enhance and effectively assess model performance in uncharted parking lots. The demand for such datasets has surged due to the increasing significance of real-time parking space occupancy data in optimizing traffic flow, alleviating congestion, curbing emissions, and augmenting overall efficiency in urban parking management.

The paper begins by discussing the two common approaches to monitor parking space occupancy: installing sensors on each parking space or using cameras to monitor multiple spaces simultaneously. Camera-based approaches offer cost advantages, and for this study, the authors focus solely on image-based models. They elaborate on the benefits of capturing images rather than live videos, such as better color reproduction in low-light conditions, reduced data flow, and immediate recovery from camera feed failures. Moreover, images are easier to capture and annotate, which is crucial in building a robust dataset.

The authors then delve into existing works on camera-based parking space occupancy classification, which generally rely on large but generic object-detection datasets or limited application-specific datasets for training. These models are evaluated on separate datasets containing unseen parking lots to assess model generalization. The paper highlights the limitation of not directly testing model generalization using separate parking lots, which makes it difficult to determine the true accuracy of the models.

To address these limitations, the researchers introduce the ACPDS dataset. They emphasize its uniqueness, with each image captured from a unique view and systematically annotated using precise quadrilateral annotations for each parking space. The dataset contains over 11,000 unique parking space annotations across various parking lots and streets, and each set (train, validation, and test) consists of separate parking lots, ensuring accurate assessment of model generalization. The authors believe this dataset will facilitate better model development and benchmarking, leading to improvements in parking space occupancy classification.

Next, the paper proposes two custom models for parking space occupancy classification based on the R-CNN and Faster R-CNN FPN architectures. Both models are inspired by two-stage object detectors, and their designs leverage the precise parking space annotations in ACPDS. The R-CNN-based model uses image patches directly pooled from the image, followed by binary classification using a ResNet50 backbone. In contrast, the Faster R-CNN FPN-based model employs a feature pyramid network to pool features corresponding to each parking space and subsequently classifies them using a classification head.

The annotation process for ACPDS involves labeling each parking space with a quadrilateral, aligned with the edges of the parking space. The authors describe the challenges faced during annotation, particularly when dealing with occlusions and limited visibility of parking spaces. Despite these challenges, the authors ensured that each annotation was carefully validated to provide precise and reliable data for model training and evaluation.

The dataset's size and diversity are highlighted, with 293 images containing over 11,000 unique parking space views across different parking lots and streets. The authors emphasize that the dataset includes both occupied and unoccupied parking spaces and exhibits varied weather and lighting conditions, making it a challenging and realistic dataset for parking space occupancy classification.

The paper then proceeds to delineate the training specifics for the proposed models, encompassing hyper parameter configurations, optimization algorithms, and data augmentation techniques. These models undergo training on the ACPDS dataset at various resolutions, enabling the authors to undertake a comprehensive comparison of their performance predicated on validation accuracy. As a pivotal consideration for real-world deployment, they also dissect the models' inference times.

In a culminating note, the research underscores the practical applicability of their R-CNN-based model for real-world deployment. This stems from its exceptional flexibility in accommodating various input resolutions. Concurrently, the authors candidly acknowledge the limitations and challenges inherent to their dataset. They advocate for the wider adoption of ACPDS, urging fellow researchers to employ it as a benchmark for fostering advancements in parking space occupancy classification research.

This research paper provides an impeccably structured and exhaustive exploration of image-based parking space occupancy classification. Through the introduction of the ACPDS dataset and the conceptualization of tailored models, the authors are resolute in their commitment to advancing the field and contributing to the development of more efficient parking management systems, thereby enhancing navigation for drivers in urban areas.

Parking occupancy detection plays an indispensable role in the management of urban traffic and parking systems (Acharya et al., 2018). Deep learning methods have exhibited tremendous potential in this domain due to their prowess in efficiently processing intricate visual data (Amato et al., 2017). Acharya et al. (2018) have proposed a real-time image-based parking occupancy detection system, leveraging a convolutional neural network (CNN) architecture to achieve precise and efficient detection of parking slot occupancy.

In scenarios of decentralized parking, it becomes imperative to possess a reliable parking lot occupancy detection system for effective parking space management (Amato et al., 2017). Amato et al. (2017) have introduced a deep learning-based approach for decentralized parking lot occupancy detection. By harnessing deep learning techniques for the analysis of data from multiple parking lots, they have realized promising outcomes.

Real-time tracking stands as another critical facet in parking occupancy detection systems (Bewley et al., 2016). Bewley et al. (2016) have proposed an uncomplicated yet effective online and real-time tracking technique, apt for various applications encompassing parking lot surveillance. Their methodology excels in real-time object tracking, rendering it an excellent fit for parking occupancy detection systems.

The ascent in video-based parking measurement systems is driven by their unmatched precision and real-time capabilities (Cai et al., 2019). Cai et al. (2019) have forged a deep learning-based video system, meticulously designed to deliver accurate and real-time parking measurements. By harnessing deep learning algorithms for video data analysis, their system is adept at ensuring precise parking measurements in real-time.

The advent of Transformers has wrought significant advancements in diverse computer vision tasks, including object detection (Carion et al., 2020). Carion et al. (2020) have ushered in an end-to-end object detection methodology, expertly woven with transformers. This pioneering approach has claimed the mantle of state-of-the-art results in object detection missions, laying the groundwork for potential applications in parking slot detection and occupancy estimation.

To cater to the exigencies of robust datasets for parking lot classification, Almeida et al. (2015) have bestowed the research community with the PKLot dataset. PKLot is a robust dataset bespoke for parking lot classification, well-adopted for the training and evaluation of parking occupancy detection models.

The rich tapestry of extensive hierarchical image databases, epitomized by ImageNet, has underpinned the ascent of deep learning models in various visual recognition endeavors (Deng et al., 2009). ImageNet serves as a treasure trove of labeled images, a cornerstone in the training of deep learning models for tasks spanning object detection and classification.

Feature pyramid networks (FPN) have bolstered object detection precision by capturing multiscale features, as evidenced by their integration in various object detection systems (Lin et al., 2017). The FPN architecture has seamlessly intertwined with an array of object detection endeavors and stands poised to elevate the performance of parking occupancy detection models (Lin et al., 2017).

In low-light conditions, the application of burst photography techniques has emerged as an elixir for capturing high dynamic range images (Hasinoff et al., 2016). Such techniques bear the potential to fortify the arsenal of parking surveillance, endowing it with superior visibility and sharpening the accuracy of parking occupancy detection systems.

The versatile Mask R-CNN framework, adept at fusing object detection with instance segmentation, is a lodestar in the world of computer vision (He et al., 2020). It excels in the precise detection and categorization of objects and has etched a mark across a plethora of computer vision applications. The deployment of Mask R-CNN holds the promise of infusing fresh potency into parking occupancy detection systems.

Deep residual learning, unfurled by He et al. (2016), has wrought a profound transformation in the landscape of deep neural networks in the realm of image recognition tasks. Its fortitude lies in the empowerment of training deeper networks, signifying an instrumental stride in enhancing the capabilities of object detection models.

The utilization of spatially regularized regional proposal networks in drone-based object counting has come to the fore as an efficacious modus operandi for counting objects with alacrity (Hsieh et al., 2017). This particular approach can be seamlessly repurposed to count occupied parking spaces from aerial footage, furnishing invaluable insights for parking occupancy detection.

The fusion of edge artificial intelligence with IoT devices has garnered attention as a lighthouse beckoning the construction of astute, efficient, and dependable parking surveillance systems (Ke et al., 2020). Ke et al. (2020) have unfurled a parking surveillance system characterized by the infusion of edge AI for the real-time processing of parking data. This positions it as a prime candidate for IoT-driven parking occupancy detection systems.

In the realm of vision-based parking-slot detection, Li et al. (2017) have etched a pioneering approach. Their methodology, underpinned by deep learning techniques, is a vanguard in the accurate detection of parking slots from images. This contribution augments the efficacy of parking occupancy estimation in a trenchant manner.

The investigation of the regularization effect stemming from the adoption of an initial large learning rate in neural network training has illuminated a crucial facet in optimizing the training pipeline and augmenting the performance of parking occupancy detection models (Li et al., 2019).

Decoupled weight decay regularization, wielded as a technique to enhance the generalization aptitude of deep learning models, has ramifications for the refinement of parking occupancy detection models. This technique extends a lifeline for improving performance and bolstering resilience in parking occupancy detection systems (Loshchilov et al., 2019).

PyTorch, the venerated deep learning library characterized by its imperative programming style, has been the cornerstone of myriad deep learning model development and experimentation efforts (Paszke et al., 2019). PyTorch's vogue extends to the precincts of deep learning models for computer vision, including parking occupancy detection.

Faster R-CNN, an illustrious object detection framework enriched with region proposal networks, has reigned supreme in an array of object detection milieus (Ren et al., 2017). Its proficiency at delivering swifter and more precise object detection has rendered it an invaluable instrument poised to enhance the efficiency of parking occupancy detection systems.

## 2.4 Parking Occupancy Prediction using (CV) with Location Awareness

In their study (Stojanović, Damjanović, Vukmirović et al., 2021), the authors address the escalating growth in the number of vehicles on the roads, which has led to a pressing need for efficient parking management systems. Traditional parking methods frequently result in challenges related to finding available parking spaces, leading to congestion, increased fuel consumption, and environmental pollution. In response to these challenges, researchers have introduced the concept of Smart Parking Systems, which harness cutting-edge technologies to optimize parking space utilization and enhance the user experience.

Smart Parking Systems encompass a wide range of solutions, and one of the central components is the development of a mobile application. This application serves as a user-friendly interface, providing real-time information about available parking spaces, allowing users to pre-book slots, and guiding them to the nearest parking lots. With the help of these applications, users can efficiently locate parking spaces, reducing the time spent searching for parking and easing traffic congestion (Amato et al., 2016).

An essential feature of Smart Parking Systems is the use of Image Processing techniques to identify vehicle registration plates. These techniques, integrated with sensors and cameras, facilitate the automatic opening and closing of parking lot gates whenever a vehicle approaches the entrance. This automation not only streamlines the entry and exit process but also enhances security by preventing unauthorized access (Nieto et al., 2018).

To detect the availability of parking spaces, Smart Parking Systems incorporate various hardware components, such as Reflective Type Infrared Proximity Sensors. These sensors can accurately identify whether a parking slot is occupied or vacant, enabling real-time updates about parking space availability. The integration of such sensors with the mobile application ensures that users are provided with up-to-date information, allowing them to make informed decisions about where to park (Ng et al., 2018).

Additionally, the utilization of the Internet of Things (IOT) technology plays a significant role in the functionality of Smart Parking Systems. IOT enables the seamless connectivity of hardware components, allowing data to be collected and transmitted in real-time. This connectivity not only facilitates efficient parking management but also enables remote monitoring and control of the parking infrastructure (Ke et al., 2020).

The data collected by Smart Parking Systems is stored in the cloud, providing a centralized platform for managing parking-related information. The cloud integration enables seamless billing processes and allows users to make payments through the mobile application. Moreover, with the data stored in the cloud, Smart Parking Systems can analyze parking patterns, optimize parking space allocation, and generate insights for improving overall parking management (Padmasiri, Madurawe, Abeysinghe et al., 2020).

The future of Smart Parking Systems is promising, with potential enhancements in Artificial Intelligence and Machine Learning. Integrating these technologies can further improve vehicle identification, leading to better security measures and fraud prevention. Moreover, the accumulated data in the cloud can be leveraged to provide personalized parking recommendations to users, tailoring the parking experience to individual needs (Xiang et al., 2017; Luo et al., 2018).

In conclusion, Smart Parking Systems offer an innovative solution to the challenges posed by urban parking. By leveraging advanced technologies such as Image Processing, IOT, and mobile applications, these systems enhance parking space utilization, reduce traffic congestion, and improve the overall user experience. The continuous development and integration of new technologies holds the potential to make Smart Parking Systems an indispensable part of smart city initiatives and significantly transform urban transportation.

Moving on to the related work in the field of parking occupancy prediction using computer vision with location awareness, several research papers have made notable contributions.

Amato et al. (2016) proposed an approach using Convolutional Neural Networks (CNNs) onboard a Raspberry Pi camera to classify parking spaces as free or occupied. The experiment used two data sets PKLot and CNRPark, with the latter being more challenging due to occluded parking spaces. The CNN model, mAlexNet, achieved better results than LeNet-5 (mLeNet) and other state-of-the-art models.

In Nurullayev and Lee's work (2019), a novel Dilated Convolutional Neural Network named CarNet was introduced for parking occupancy detection. Dilation was employed to increase the global view of the network while keeping the parameters increase linearly. The experiments showed that CarNet with dilation outperformed CarNet without dilation and achieved better results than mAlexNet when tested on PKLot and CNRPark data sets.

Nieto et al. (2018) proposed a multi-camera system that combines the results of individual cameras to create a final multi-camera spot matrix representing the occupation of the parking lot. Two algorithms, Faster Region-Based Convolutional Neural Network (R-CNN) and Deformable Parts Model (DPM), were used for vehicle detection. Perspective correction significantly improved detection accuracy.

Ke et al. (2020) presented a system for parking occupancy detection using real-time video feed. The system achieved an overall detection accuracy of 95.6% for various scenarios, including indoor, outdoor, rainy, sunny, foggy, daytime, and nighttime situations.

(Padmasiri, Madurawe, Abeysinghe et al., 2020) introduced a parking detection system that guides drivers to parking spaces. It employed RetinaNet and Fast R-CNN for detecting occupied and available parking spaces. The evaluation showed consistent higher precision for occupied data, indicating the effectiveness of the models.

Ng et al. (2018) used two lightweight convolutional neural networks, baseline and minimal MobileNet, for parking space classification. Minimal MobileNet outperformed baseline MobileNet, providing the same detection accuracy at a much higher speed.

Finally, Xiang et al. (2017) developed a real-time parking occupancy detection method based on Haar-AdaBoosting and convolutional neural networks. The proposed system achieved an accuracy rate not lower than 94% and demonstrated stable detection accuracy even during nighttime with stable illumination.

In summary, the research papers discussed above have contributed to the advancement of parking occupancy prediction using computer vision and location awareness. These works showcase the potential of using deep learning models and multi-camera systems to address parking-related challenges and improve parking space management.

Parking occupancy prediction is a crucial challenge in urban environments due to the ever-increasing number of vehicles. Conventional methods utilizing hardware sensors for parking space detection have shown limited success. However, recent advances in Computer Vision (CV) algorithms, along with powerful Edge AI-capable devices, offer the potential for more precise and real-time solutions. In a study proposing car parking occupancy detection using smart camera networks and deep learning (Amato et al., 2016), Convolutional Neural Networks (CNNs) onboard Raspberry Pi cameras were utilized to classify parking spaces. The authors found that mAlexNet outperformed other models, showcasing robustness to noise and challenging scenarios.

The PKLot dataset (De Almeida et al., 2015) is a widely used resource for parking occupancy prediction. It contains numerous parking lot images with annotations for occupied and vacant spaces, serving as a valuable training and testing dataset for various parking occupancy detection algorithms. Furthermore, a Dilated Convolutional Neural Network named CarNet (Nurullayev & Lee, 2019) was introduced to perform generalized parking occupancy analysis. The use of dilation allowed the network to capture a more extensive global view of the parking area, resulting in improved accuracy compared to traditional methods like mAlexNet.

A multi-camera system for parking occupancy prediction was proposed by Nieto et al. (2018), where parallel processing of each camera was combined to create a final parking spot occupation matrix. The system utilized Faster Region-Based Convolutional Neural Network (R-CNN) and Deformable Parts Model (DPM) algorithms for vehicle detection. In a study by Ke et al. (2020), a smart and efficient parking surveillance system based on real-time video feed from camera nodes and IoT devices was introduced. This system achieved an overall detection accuracy of 95.6% for various environmental scenarios using Mobilenet Single-Shot Detection (SSD) and Background-Based Detection algorithms.

Additionally, the study conducted by Ng et al. (2018) explored two lightweight convolutional neural networks, baseline, and minimal MobileNet, for parking space classification. The minimal MobileNet with fewer parameters and smaller input resolution exhibited better performance, achieving 99% precision during testing, making it ideal for parking occupancy detection on embedded devices. Finally, Xiang et al. (2017) presented a novel method for real-time parking occupancy detection for gas stations, employing Haar-AdaBoosting and convolutional neural networks. This approach achieved an accuracy rate of not less than 94% in monitoring fueling parking spaces.

In conclusion, recent research has shown promising results in addressing the challenge of parking occupancy prediction using computer vision with location awareness. The advancements in CV algorithms, lightweight neural networks, multi-camera systems, and computational photography have improved the accuracy and efficiency of parking surveillance systems. However, further research is necessary to better understand 3D space and enhance object tracking capabilities, enabling accurate prediction of parking positions and optimizing parking space utilization in smart cities.

## 2.5 Smart Vehicle Parking System Using (CV) and (IoT)

(Taylor, Ezekiel, & Emmah, 2021) Recent years have witnessed a surge in research dedicated to Smart Vehicle Parking Systems, integrating computer vision and IoT technologies. This surge can be attributed to the mounting demand for enhanced parking management solutions in urban environments.

One approach proposed by Thomas and Kovoor (2017) introduced a self-determining streetcar framework and a genetic algorithm to automate vehicle parking at shopping centers. The genetic algorithm optimized parking space utilization and streetcar efficiency, reducing waiting times for customers. The proposed system demonstrated improved efficiency without compromising on reduced waiting times compared to a system without the genetic algorithm.

In the pursuit of creating a smarter city and addressing parking-related challenges, Amiri et al. (2019) presented an IoT-based prototype for parking monitoring and management. The model aimed to provide a problem-free parking experience for the public while also generating revenue for the local government. The system monitored parking spot availability through IoT technology and automated the ticketing process through mobile apps, enabling users to reserve parking spaces and make online payments conveniently.

The increasing number of vehicles in congested urban areas has led to issues such as traffic congestion, air pollution, and wasted time searching for parking spots (Giuffrè et al., 2012; Shoup, 2006; Li et al., 2016). To alleviate these problems, Smart Parking Systems are being designed to efficiently manage parking space allocation.

To ensure the privacy of drivers while using parking facilities, Amiri et al. (2019) proposed a privacy-preserving smart parking system based on blockchain and private information retrieval. A consortium blockchain ensured security and transparency among parking lot owners, while private data retrieval allowed drivers to access parking space information without compromising their location privacy.

Incorporating Narrowband Internet of Things (NB-IoT) technology, Shi et al. (2017) presented a smart parking system that efficiently managed parking facilities through cloud-based data management, payment processing, and sensor node observation. The integration of an external payment platform facilitated easy and convenient payment options for drivers, enhancing the usability of the mobile application.

Addressing parking supervision challenges, Sadhukhan (2017) introduced an IoT-based E-Parking System for Smart Cities. The system enabled drivers to access real-time parking space availability information and reserve parking slots through an intuitive graphical user interface. Additionally, the proposed framework facilitated automatic collection of parking fees through smart payment options.

The deployment of a smart car parking system in smart cities was proposed by Alsafery et al. (2018). The system aimed to minimize the time spent searching for available parking spaces by providing users with real-time traffic congestion status. Data filtering and fusion techniques were employed to reduce transmitted data while ensuring efficient data processing using cloud-based machine learning algorithms.

Furthermore, Mahmood et al. (2018) developed a fully automated vehicle parking system utilizing computer vision. The system employed cameras at the entrance and exit of parking areas, capturing and comparing driver face images for identity verification. Although the proposed article location module showed high accuracy, the face recognition algorithm's image resolution handling required further attention.

To leverage the capabilities of Google's IoT technology, Shinde et al. (2017) introduced an intelligent parking android gadget. The user-friendly interface of the android application provided accurate parking information, ensuring efficient parking space allocation and reducing accidents and pollution.

Concurrently, Vakula and Kolli (2017) addressed parking issues in Hyderabad city with a low-cost smart parking system. The online-based booking and management system allowed users to check the availability of parking spaces, make online payments, and receive a generated barcode for easy access. Ultrasonic sensors were integrated into each parking slot to determine its occupancy status.

In conclusion, recent research in the field of Smart Vehicle Parking Systems using computer vision and IoT technologies has shown promising results. These studies have presented efficient and innovative solutions to optimize parking space utilization, enhance user experience, and address challenges associated with parking management in urban areas. The integration of IoT, cloud-based data management, blockchain, and advanced algorithms promises to revolutionize parking systems and contribute significantly to the development of smart cities.

The escalating urbanization and increasing number of vehicles have given rise to a pressing problem of finding suitable parking spaces in congested urban areas. This issue leads to traffic congestion, heightened fuel consumption, and increased carbon emissions (Taylor, Ezekiel, & Emmah, 2021). In response to this challenge, researchers have explored smart parking systems that leverage computer vision and Internet of Things (IoT) technologies to efficiently manage parking spaces.

One of the proposed methodologies involves the utilization of Convolutional Neural Network (CNN) algorithms for vehicle detection in parking areas (Taylor, Ezekiel, & Emmah, 2021). They introduced an intelligent smart parking system that incorporates a CNN algorithm alongside a Haar cascade classifier for the detection of multiple vehicles in both images and videos, achieving a remarkable accuracy of 99.80% in identifying vehicles within parking spaces.

Another approach explores the deployment of pre-trained models like Mask R-CNN for object detection in videos and images (Taylor, Ezekiel, & Emmah, 2021). However, while Mask R-CNN demonstrates proficiency in accurately identifying a variety of objects, it may have certain limitations when it comes to detecting all vehicles, especially in high-quality videos.

Integrating IoT with smart parking systems allows real-time monitoring of parking spaces. IoT sensors installed in smart parking systems provide crucial information on parking spot availability, enabling users to find and reserve parking spaces through mobile applications (Taylor, Ezekiel, & Emmah, 2021). This helps alleviate the challenge of finding empty parking spots in densely populated urban areas.

Efforts have been made to address the increasing traffic congestion caused by vehicles searching for parking spaces. Giuffrè et al. (2012) proposed a novel architecture for parking management in smart cities using IoT devices. The intelligent parking system utilizes IoT sensors installed in each parking space to detect occupancy status and shares this information with a service provider. As a result, drivers can access real-time data about available parking spots and make online reservations, streamlining the parking process.

In addition to CNN and IoT-based approaches, some researchers have explored the use of genetic algorithms for autonomous smart vehicle parking systems (Thomas & Kovoor, 2017). This approach optimizes parking decisions for autonomous vehicles, further improving parking efficiency in smart cities.

Furthermore, privacy-preserving smart parking systems that utilize blockchain and private information retrieval have been investigated (Amiri et al., 2019). These systems protect users' privacy while providing parking spot availability information.

Researchers have also developed smart parking systems based on Narrowband Internet of Things (NB-IoT) and third-party payment platforms (Shi et al., 2017). This system enables users to find parking spaces through IoT connectivity and facilitates convenient payments via third-party platforms.

Moreover, Sadhukhan (2017) proposed an IoT-based E-Parking System for Smart Cities. The system utilizes IoT technology to monitor and manage parking spaces in real-time, providing users with timely information on available parking spots.

Another significant contribution in this area is a low-cost smart parking system for smart cities proposed by Vakula and Kolli (2017). The system aims to make parking more accessible and efficient in urban areas, particularly for low-income communities.

Additionally, Alsafery et al. (2018) presented a smart car parking system solution for the Internet of Things in smart cities. This system employs IoT technologies to optimize parking space utilization and improve traffic flow in urban areas.

To enhance user convenience, Shinde et al. (2017) developed an IoT-based parking system using Google services. The system enables users to access real-time parking information through IoT connectivity and Google applications.

Furthermore, researchers have explored the use of Network Virtualization Optimization in Software-Defined Vehicular Ad-hoc Networks (Li et al., 2016). This approach enhances the efficiency and reliability of smart vehicle parking systems through network virtualization.

In conclusion, the combination of computer vision, IoT technologies, and advanced algorithms has shown promise in addressing the parking challenges in smart cities. Smart parking systems equipped with CNN algorithms and IoT sensors enable real-time parking space monitoring and reservation. As smart cities continue to evolve, further research and technological innovations are crucial to optimize parking management, alleviate traffic congestion, and promote sustainable urban development.

## 2.6 Development of Smart Parking Management System

(Sudhakar, Reddy, Mounika et al., 2021) highlights the growing number of vehicles on the roads, emphasizing the urgent requirement for efficient parking management systems. Conventional parking approaches frequently present difficulties in locating available parking spaces, resulting in traffic congestion, heightened fuel consumption, and environmental pollution. In response to these challenges, researchers have introduced Smart Parking Systems, which harness state-of-the-art technologies to enhance parking space utilization and improve the user experience.

Smart Parking Systems encompass a wide range of solutions, and one of the central components is the development of a mobile application. This application serves as a user-friendly interface, providing real-time information about available parking spaces, allowing users to pre-book slots, and guiding them to the nearest parking lots (Lomat Haider Chowdhury et al., 2019). With the help of these applications, users can efficiently locate parking spaces, reducing the time spent searching for parking and easing traffic congestion.

An essential feature of Smart Parking Systems is the use of Image Processing techniques to identify vehicle registration plates. These techniques, integrated with sensors and cameras, facilitate the automatic opening and closing of parking lot gates whenever a vehicle approaches the entrance. This automation not only streamlines the entry and exit process but also enhances security by preventing unauthorized access.

To detect the availability of parking spaces, Smart Parking Systems incorporate various hardware components, such as Reflective Type Infrared Proximity Sensors. These sensors can accurately identify whether a parking spot is occupied or vacant, enabling real-time updates about parking space availability (Vakula et al., 2017). The integration of such sensors with the mobile application ensures that users are provided with up-to-date information, allowing them to make informed decisions about where to park.

Additionally, the utilization of the Internet of Things (IOT) technology plays a significant role in the functionality of Smart Parking Systems. IOT enables the seamless connectivity of hardware components, allowing data to be collected and transmitted in real-time (Dudhe et al., 2017). This connectivity not only facilitates efficient parking management but also enables remote monitoring and control of the parking infrastructure.

The data collected by Smart Parking Systems is stored in the cloud, providing a centralized platform for managing parking-related information. The cloud integration enables seamless billing processes and allows users to make payments through the mobile application (Nitn Pandit et al., 2019). Moreover, with the data stored in the cloud, Smart Parking Systems can analyze parking patterns, optimize parking space allocation, and generate insights for improving overall parking management (Melnyk et al., 2019).

The future of Smart Parking Systems is promising, with potential enhancements in Artificial Intelligence and Machine Learning. Integrating these technologies can further improve vehicle identification, leading to better security measures and fraud prevention (Khanna and Anand, 2016). Moreover, the accumulated data in the cloud can be leveraged to provide personalized parking recommendations to users, tailoring the parking experience to individual needs (Das et al., 2019).

In conclusion, Smart Parking Systems offer an innovative solution to the challenges posed by urban parking. By leveraging advanced technologies such as Image Processing, IOT, and mobile applications, these systems enhance parking space utilization, reduce traffic congestion, and improve the overall user experience. The continuous development and integration of new technologies hold the potential to make Smart Parking Systems an indispensable part of smart city initiatives and significantly transform urban transportation.

The continuous rise in the number of vehicles has led to a growing challenge in finding appropriate parking spaces for each vehicle. To address this issue, the development of a Smart Parking System with a mobile application has been proposed, allowing users to access comprehensive information about parking spaces and efficiently manage them in the parking lot. The system incorporates Image Processing techniques to identify vehicle registration plates and offers autonomous door opening and closing operations upon detecting a vehicle at the entrance of the parking lot. Moreover, the mobile application provides real-time updates on available parking spaces and includes safety features such as fire and gas leak alerts.

The core control unit of the system is the Raspberry Pi, which manages and processes all the operations. A Liquid Crystal Display (LCD) is installed at the entry point of the parking lot to display current parking space availability, while Infrared (IR) proximity sensors are utilized to detect the presence of vehicles at the entry gate. By capturing images of vehicle registration plates, characters can be identified, and the Raspberry Pi can send a signal to a servo motor to open the gate for a specified interval, allowing the user to park the vehicle in the available slot. When the user leaves the parking space, the system records the date and time information, which is then used for billing purposes.

The increasing number of vehicles and the misuse of available parking space have resulted in numerous parking-related issues. To optimize the use of parking spaces, the implementation of a Smart Parking System has become essential. By partially automating the process of identifying available parking lots, the system significantly reduces the time it takes for users to find suitable parking spaces, subsequently curbing fuel consumption, pollution, and traffic problems. The Smart Parking System consists of onsite hardware equipped with an IoT module for detecting parking space availability, integrating safety and security alerts, and capturing real-time information in the cloud. The associated mobile application enables users to access detailed information about parking space availability, pre-book slots, navigate to parking lots, and receive generated bills upon space utilization.

The Smart Parking System harnesses the power of IoT, allowing remote monitoring and control of the hardware components by connecting to the internet. This networking of physical components, including various sensors, enables real-time data sharing between devices (Sudhakar, Reddy, Mounika et al., 2021).

A review of related literature suggests that researchers have made significant strides in the development of intelligent parking systems. Haider Chowdhury et al. introduced a cost-effective Smart Car Parking Management System that stored parking slot information in a local host and used cloud storage for multiple parking lots, coupled with an image processing technique for vehicle number plate recognition (Haider Chowdhury et al., 2019). Dudhe et al. presented an overview of IoT and its applications, highlighting the relevance of IoT in home automation. Additionally, various studies have explored IoT-based Smart Parking Systems (Dudhe et al., 2017). These include research by Khanna and Anand (2016), Sadhukhan (2017), Nitin Pandit et al. (2019), and Mohd Nazri et al. (2020), demonstrating the growing interest and potential in this area.

The continuous progress in Smart Parking Systems paves the way for efficient urban mobility and resource management, contributing to the development of smart cities and sustainable transportation solutions (Sudhakar, Reddy, Mounika et al., 2021; Lai et al., 2021; Melnyk et al., 2019; Das et al., 2019; Vakula and Kolli, 2017). With ongoing advancements and the integration of new technologies, Smart Parking Systems are poised to revolutionize urban transportation and offer tailored solutions for the parking challenges faced in modern cities.

## 2.7 Computer Vision on a Parking Management and Vehicle Inventory

In their study, (Africa, Alejo, et al., 2020) explored the transformative role of computer vision, a cutting-edge technology with widespread and profound applications across various domains, including its relevance in parking management and vehicle inventory systems. At its essence, computer vision focuses on the extraction of meaningful insights from digital images and videos, empowering machines to comprehend and interpret visual data in a manner akin to human perception. This technology stands at the forefront of innovation, holding significant promise for enhancing parking management and streamlining vehicle inventory operations.

This multidisciplinary field draws from computer science, artificial intelligence, and image processing to develop algorithms and models that can perceive, analyze, and make decisions based on visual inputs (Volna & Kotyrba, 2014).

The process of computer vision involves several interconnected components that work in tandem to achieve accurate and reliable results. Image acquisition and preprocessing lay the groundwork by capturing visual data through cameras or sensors and then enhancing the images to improve clarity and remove noise (Caicedo, Robuste, & Lopez-Pita, 2006). Subsequently, feature extraction techniques are employed to identify key patterns, edges, shapes, and objects within the images (O'Mahony et al., 2019). These features are then analyzed and matched with existing patterns or object templates stored in the model's database (Zhang, 2019). Through machine learning algorithms and deep neural networks, computer vision models can continually improve their performance and accuracy over time, making them increasingly proficient at recognizing and interpreting visual information.

One of the remarkable applications of computer vision is in the domain of parking management. By deploying cameras in parking lots and utilizing image processing algorithms, the system can detect vacant parking spaces in real-time (Bukowski et al., 2019). This information can be relayed to drivers through mobile applications or electronic signboards, significantly reducing the time spent searching for parking spots and enhancing overall traffic flow. The potential benefits of such systems are vast, including reduced traffic congestion, lower carbon emissions, and increased revenue for parking facility operators (Bukowski et al., 2019).

Furthermore, computer vision's integration with deep learning techniques has led to breakthroughs in various parking-related applications. For instance, researchers have leveraged Convolutional Neural Networks (CNNs) to achieve exceptional accuracy in detecting parking lot occupancy (O'Mahony et al., 2019). Additionally, object detection models based on CNNs can identify and classify different types of vehicles for efficient vehicle inventory management in large storage facilities or car dealerships (Zhang, 2019).

Computer vision has also been harnessed to enhance road safety, particularly in the context of self-driving or autonomous vehicles. Cameras and sensors equipped with computer vision capabilities can identify pedestrians, cyclists, and obstacles on the road, enabling autonomous vehicles to navigate safely in complex environments (Sztyber, 2019). The ability to analyze and interpret visual data in real-time is crucial for the decision-making processes of self-driving cars, ensuring they can respond appropriately to dynamic road conditions.

Moreover, computer vision has proven to be instrumental in aiding visually impaired individuals, significantly contributing to their mobility and independence. By employing advanced image recognition algorithms, wearable devices can assist visually impaired pedestrians in navigating urban environments, recognizing crosswalks, traffic signals, and other crucial visual cues (Li, Cui, & Rizzo, 2019). Such systems provide auditory cues or haptic feedback to convey information about the surroundings, allowing visually impaired individuals to travel more confidently and securely.

Beyond parking and transportation, computer vision has broader implications for urban planning and management. Aerial imaging and analysis have been utilized to survey and map urban areas, identifying patterns of traffic flow, congestion, and parking demand (Ho et al., 2019). These insights can inform city planners and policymakers to make data-driven decisions for optimizing transportation infrastructure and creating smarter, more efficient cities.

In conclusion, computer vision is a transformative technology with a myriad of applications, including but not limited to parking management and vehicle inventory systems. By combining image processing, deep learning, and artificial intelligence techniques, computer vision enables machines to perceive and understand the visual world. Whether it is facilitating parking spot detection, improving road safety, or aiding visually impaired individuals, the impact of computer vision on smart cities and transportation systems is profound. As research and development in this field continue to advance, we can expect even more innovative and life-changing applications of computer vision in the future.

Computer vision is a cutting-edge technology that has found diverse and impactful applications in numerous fields, with relevance in parking management and vehicle inventory systems. At its core, computer vision revolves around the extraction of meaningful information from digital images and videos, enabling machines to interpret and understand visual data much like humans do. This multidisciplinary field draws from computer science, artificial intelligence, and image processing to develop algorithms and models that can perceive, analyze, and make decisions based on visual inputs (Volna & Kotyrba, 2014).

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## 2.8 Multi-Angle Parking Detection System using Mask R-CNN

(Agrawal & Urolagin, 2020) Over the past few years, there have been remarkable advancements in the field of parking space detection, with a focus on tackling the increasing complexities of urban parking management. Researchers have delved into a range of approaches, spanning image-based and sensor-based systems, to achieve precise parking spot occupancy detection. Image-based systems harness the power of computer vision techniques to analyze camera-captured images, enabling real-time and efficient parking management.

Past studies have employed methods such as canny edge detection, support vector machines, and texture classifiers for this purpose (Lopez et al., 2019; Bong et al., 2008; Almeida et al., 2015). Additionally, deep learning-based techniques, especially convolutional neural networks (CNNs), have shown promising results in parking space detection (Nymbal and Klein, 2017).

Despite the efficiency of image-based systems, they often require labor-intensive manual labeling of parking spots, limiting their scalability for large parking lots. To overcome this limitation, researchers have integrated deep learning architectures like YOLO and Mask R-CNN into parking management systems (Jose et al., 2018; Amato et al., 2017; Cai et al., 2019). YOLO allows for real-time classification with multiple object tracking, while Mask R-CNN combines object detection and instance segmentation, enabling precise localization of parking spaces (He et al., 2017). These deep learning-based models offer both accuracy and scalability for parking space detection.

In contrast, sensor-based systems offer high accuracy but often require a complex infrastructure setup and are expensive to implement and maintain. For instance, some studies have utilized Bluetooth Low Energy (BLE) technology and magnetometers for parking lot management (Marso and Macko, 2019; Cheung et al., 2006). While these methods provide accurate results, they face challenges related to environmental conditions and the need for close proximity to vehicles.

To strike a balance between accuracy and cost-effectiveness, a novel Multi-Angle Parking Detection System using Mask R-CNN is proposed in this paper. The Mask R-CNN model, with its ability to handle multiple parking angles, promises to achieve accurate and efficient parking space detection without the need for extensive manual labeling. By combining the advantages of deep learning-based image analysis and the scalability of sensor-based systems, the proposed solution aims to optimize parking management and enhance urban mobility.

In summary, the field of parking space detection has witnessed significant progress, with image-based and sensor-based systems offering unique strengths and limitations. Deep learning techniques, such as YOLO and Mask R-CNN, have revolutionized parking space detection, providing both real-time capabilities and accurate results. By integrating these advancements, the proposed Multi-Angle Parking Detection System seeks to contribute to more efficient parking management solutions and improved urban mobility.

Parking space detection systems have gained significant importance due to the rapid urbanization and motorization in developing countries (Inrix, 2019). In response to the challenges posed by inefficient parking management, researchers have explored various methods for detecting occupied and vacant parking spaces. The literature review highlights two categories of parking space detection systems image or camera-based systems and sensor-based systems. In the image-based approach, computer vision techniques have been utilized, such as canny edge detection (Lopez et al., 2019) and convolutional neural networks (CNNs) (Nyambal & Klein, 2017), to classify parking spots as occupied or empty. Other studies have used support vector machines (Bong et al., 2008) and texture classifiers (Almeida et al., 2015) for creating parking management systems. However, these methods often require extensive manual labeling of parking spots. To address this, deep learning-based approaches, such as Mask R-CNN, have been adapted to achieve real-time parking management (Amato et al., 2017).

These models can be trained on datasets like "Cars Overhead with Context" (COWC) (Senko et al., 2014) and "Common Objects in Context" (COCO) (Lin et al., 2014) for overhead and low-angle views, respectively. In contrast, sensor-based systems use technologies like Bluetooth Low Energy (BLE) for communication (Marso & Macko, 2019) and magnetometers for parking lot management (Cheung et al., 2006). While sensor-based solutions offer high accuracy, they necessitate an intensive infrastructure setup and are costly to implement and maintain (Faheem et al., 2013).

To evaluate the proposed Multi-Angle Parking Detection System, comprehensive datasets were acquired and pre-processed. The COWC dataset provided overhead views of parking spaces, and COCO dataset offered low-angle car detection images with associated masks. The PKLot dataset (Almeida et al., 2015) and CCTV footage from BITS Pilani Dubai University were used for testing the system's efficiency. The Mask R-CNN model, combining Faster R-CNN for object detection and FCN for instance segmentation (He et al., 2017), was employed for multi-angle car parking detection. Transfer learning was used to fine-tune the pre-trained model on the COWC dataset for overhead view detection.

For labeling parking spots and detecting occupied or vacant spaces, an automated algorithm was developed based on the assumption that parking spots are locations of stationary cars (He et al., 2017). This algorithm efficiently labeled parking spots using the detected cars' bounding boxes. To distinguish between vacant and occupied parking spaces, the Intersection over Union (IoU) measure was used with threshold values specific to the top-angle (Lopez et al., 2019) and low-angle views (Nyambal & Klein, 2017). The proposed system achieved high accuracy for both views, with IoU threshold values of 0.20 and 0.34, respectively. The results demonstrated the robustness of the proposed Multi-Angle Parking Detection System, offering scalability and adaptability to different parking scenarios. Although further improvements could be made to optimize processing and response times, the system presents a promising solution for efficient parking management and urban mobility enhancement. By combining the advantages of image and sensor-based approaches, this system contributes to revolutionizing parking management practices and addressing the challenges posed by increasing automobile traffic.

**CHAPTER # 3**

**PROPOSED METHODOLOGY**

# **3. Proposed Methodology**

This section introduces some fundamental concepts and key terminologies related to the research problem of parking lot occupancy detection. Understanding these concepts is essential for comprehending the subsequent methodology employed in the development of the Real-Time Car Parking Occupancy Prediction System.

## 3.1 Introduction to Research Methodology

The research methodology employed in this study plays a fundamental role in systematically addressing the objectives of advancing parking slot occupancy detection through deep learning models. A mixed-methods research design, encompassing both quantitative and qualitative techniques, is adopted to comprehensively investigate various aspects of the research problem. Central to this methodology is the acquisition of a diverse dataset, with a primary source being the PKLot dataset, augmented to enhance data diversity. The research adopts a stratified sampling strategy to ensure representative samples based on factors such as weather conditions and lighting scenarios. Data preprocessing is meticulously carried out, encompassing tasks like resizing, format standardization, and data augmentation, contributing to data quality and consistency.

The selection of deep learning models, including ResNet, VGG16, Xception, and ensemble methods, is a crucial aspect of the research methodology. Each model's architecture, parameters, and hyper parameters are documented, aligning with their suitability for image classification tasks. Model training and validation follow a rigorous approach, incorporating cross-validation to assess performance across diverse data partitions and hyper parameter tuning for optimization.

An array of performance metrics, including accuracy, precision, recall, F1-score, and the area under the ROC curve, is employed to comprehensively evaluate model performance, ensuring a balanced assessment of true positive and false positive rates. Ethical considerations remain paramount, addressing data privacy, image consent, and user interactions. The study adheres to ethical guidelines for research involving human subjects, respecting consent and privacy rights.

Data analysis combines quantitative and qualitative approaches, with quantitative analysis focusing on numerical results and performance metrics, while qualitative analysis explores user experiences and feedback through surveys and interviews. The interpretation of research findings involves a critical analysis of results, considering implications for parking slot occupancy detection. Generalization of findings to broader urban management and mobility contexts is thoughtfully undertaken, emphasizing practical applicability.

A well-defined research timeline guides the sequence of research activities and milestones, ensuring organized project management and timely progress. Overall, this structured research methodology provides a robust framework for conducting the study, emphasizing data quality, model selection, performance evaluation, ethical considerations, and the potential real-world impact of the research findings on urban management and mobility solutions.

## 3.2 Research Design

The research design adopted for this study is comprehensive and multifaceted, utilizing a mixed-methods approach that incorporates both quantitative and qualitative techniques. This design is strategically chosen to address the research objectives effectively, which primarily involve advancing parking slot occupancy detection through deep learning models. The study's multifaceted nature allows for a holistic investigation into various facets of the research problem.

* + 1. **Data Collection and Sampling**

A pivotal component of the research design is the data collection process, which forms the foundation for model development and evaluation. The primary data source is the PKLot dataset, renowned for its diverse collection of parking lot images under various weather conditions. To ensure the dataset represents real-world scenarios, data augmentation techniques, including rotation, flipping, resizing, and brightness adjustments, are meticulously applied to enhance data diversity.

To guarantee that the dataset is representative and captures the variability in parking environments, a stratified sampling strategy is employed. This strategy takes into account factors such as weather conditions, lighting scenarios, and other environmental variables. By stratifying the dataset, the research aims to ensure that the training and evaluation data include a balanced representation of different conditions and scenarios commonly encountered in urban parking lots.

* + 1. **Deep Learning Models Selection and Training**

The research design incorporates the selection and training of deep learning models as a pivotal step in addressing the research objectives. Four distinct models are chosen for evaluation: ResNet, VGG16, Xception, and an ensemble model. These models are renowned for their capabilities in image classification tasks and offer diverse architectural features. The selection of multiple models allows for a comparative analysis of their performance.

Model training follows a systematic process, beginning with data preprocessing tasks such as resizing images to a standard format and applying data augmentation techniques. Each model's architecture, parameters, and hyper parameters are carefully documented to ensure reproducibility. The training process involves optimizing hyper parameters through techniques like learning rate adjustments and batch size tuning to achieve optimal model performance.

**3.2.3 Ethical Considerations**

Ethical considerations are integral to the research design, addressing important aspects such as data privacy, image consent, and user interactions. The study adheres to ethical guidelines for research involving human subjects, ensuring that data collection and usage respect consent and privacy rights.

**3.2.4 Data Analysis**

Data analysis in the research design combines quantitative and qualitative approaches. Quantitative analysis focuses on numerical results and performance metrics derived from model evaluations. Qualitative analysis involves gathering user experiences and feedback through surveys and interviews. This multifaceted analysis approach enriches the research findings and provides a comprehensive perspective on parking slot occupancy detection.

## 3.3 Proposed Model

The process begins with the collection of a dataset consisting of parking lot images, each labeled to indicate whether a parking space is occupied or vacant. This dataset can be curated manually or through automated labeling using machine learning algorithms.

Once the dataset is amassed, it undergoes preprocessing to enhance image quality. This preprocessing phase includes tasks such as resizing images, reducing noise, and normalizing colors. The processed images are stored locally, either in a database or a file system, for easy access during model training and testing.

The dataset is then split into two sets: a training set and a test set. The training set is used to train the deep learning model, while the test set is reserved for evaluating the model's performance on unseen data.

The deep learning model is trained on the training set, where it learns to recognize distinctive image features that correlate with parking space occupancy. This training process involves adjusting model parameters iteratively to minimize classification errors.

Following training, the model is evaluated on the test set. Various metrics are computed to gauge the model's performance, including accuracy, precision, recall, and the F1-score. These metrics assess the model's ability to classify parking spaces as either occupied or vacant accurately.

The model diagram illustrates the sequential steps in the process. It starts with image capture, where a camera captures an image of the parking lot. The captured image undergoes preprocessing to remove noise and enhance quality. Subsequently, a deep learning model extracts relevant features from the image, which are essential for parking occupancy detection. These features are then classified by the model to determine the occupancy status of each parking space. The system generates classification results, indicating whether parking spaces are occupied or vacant as shown in Figure 13.

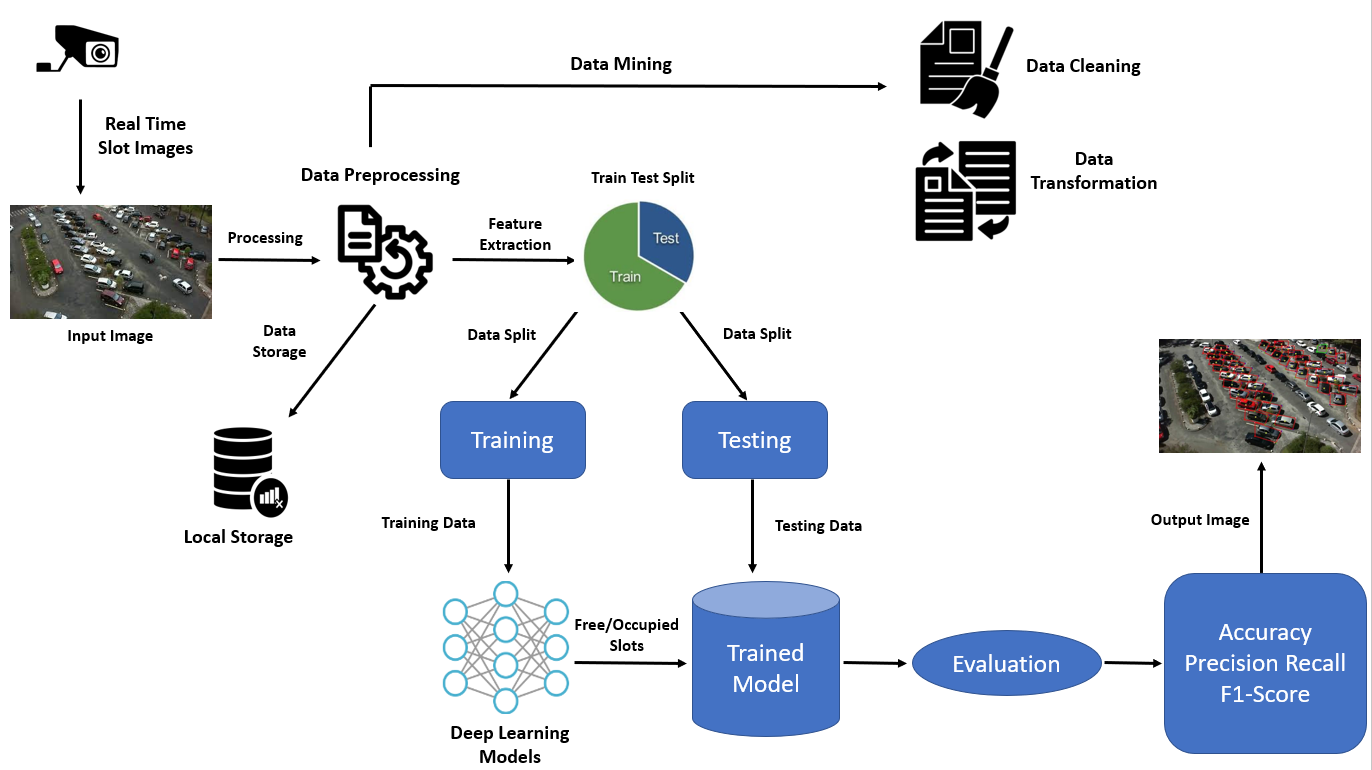


Figure 13. Proposed Model for Parking Occupancy Detection

## 3.4 Data Collection

To develop and evaluate the Real-Time Car Parking Occupancy Prediction System, a robust and diverse dataset collection process is fundamental. This entails acquiring parking lot images from various sources, each presenting unique visual conditions and environmental scenarios. Among the primary datasets considered for this research, the PKLot dataset stands out, comprising a substantial collection of 30,000 images captured under various weather conditions. However, it's noteworthy that this dataset has limited occlusions primarily due to camera positioning.

The images extracted from the PKLot dataset, along with their corresponding labels, undergo a rigorous standardization process. Annotations are converted into a uniform format, ensuring consistency and accuracy across the dataset. These standardized data are then divided into distinct sets for training, validation, and testing purposes. To enrich the diversity of the training data, a range of image augmentation techniques are thoughtfully applied. These techniques encompass rotation, flipping, resizing, and brightness adjustments. Furthermore, labels associated with this dataset are expanded to encompass up to 11 categories, accommodating diverse scenarios like fog, night, glare, and winter conditions.

For object detection, advanced image processing techniques take center stage as the primary method. These techniques include sophisticated approaches such as edge detection, segmentation, and feature extraction, all meticulously tailored to effectively identify parking occupancy patterns within the PKLot dataset.

The subsequent training phase involves several critical steps. It commences with loading the preprocessed PKLot dataset and creating efficient data loaders for streamlined training. The model is then trained to detect parking occupancy using the curated datasets. This phase also includes rigorous hyperparameter tuning, exploring factors like learning rates, batch sizes, and regularization techniques for optimal model performance.

To ensure the credibility and accuracy of parking slot occupancy detection, the surveillance cameras utilized possess high-resolution imaging capabilities, capturing images with a minimum resolution of 1080p. These cameras are equipped with advanced image stabilization technology to mitigate any blurriness or distortion, ensuring the clarity of captured images under various lighting conditions.

The integration of location awareness introduces a three-dimensional representation of parking environments, utilizing available location data, including GPS coordinates. This location-based approach enhances parking slot allocation, optimizing the utilization of parking spaces based on real-time occupancy predictions and the availability of parking slots.

The development of an Intelligent Parking Manager Agent is a pivotal component of the system, employing reinforcement learning techniques and advanced algorithms like Deep Q-Network (DQN). This agent adapts in real-time to evolving parking patterns and dynamically reallocates parking slots to optimize space usage.

Complementing the system is a user-friendly mobile application designed with an intuitive interface. This application empowers users to interact seamlessly with the system, providing real-time updates on parking availability and issuing notifications about their allocated slots and any associated penalties. The mobile application seamlessly integrates with the Real-Time Car Parking Occupancy Prediction System, providing a comprehensive user experience.

Performance evaluation rigorously assesses the model's accuracy, precision, recall, F1 score, and area under the ROC curve. These evaluations are primarily focused on the PKLot dataset to gauge the system's effectiveness in a specific context. System evaluation extends to comprehensively assess the impact of the Real-Time Car Parking Occupancy Prediction System, specifically addressing its role in improving illumination, optimizing parking allocation, and enhancing cost efficiency, with a primary emphasis on the PKLot dataset.

The research results, particularly with respect to the PKLot dataset, undergo meticulous analysis and interpretation. This process involves the application of various data analysis techniques, careful consideration of ethical considerations, validation of results, assessment of reliability, and adherence to the research timeline. The comprehensive approach adopted ensures a thorough evaluation of the system's performance and its applicability in real-world scenarios. Here is an Example of parking slots having free and occupied slots are showing in Figure 14.



Figure 14. Free and Occupied Parking Slots Example

## 3.5 Explanatory Data Analysis

After the data collection process outlined in section 3.6, we proceeded to perform explanatory data analysis using Google Colab, which offered a convenient platform for our tasks. We initiated this process by uploading all the collected data to our Google Drive, establishing a clear path for real-time parking occupancy detection. This analysis was instrumental in assessing the dataset's quality and comprehending the distribution of data annotations across different classes, ultimately contributing to the accuracy of our model.

To execute this analysis, we leveraged several essential libraries, including TensorFlow, NumPy, pandas, and Keras. Initially, we mounted the Google Drive to the path /content/drive, ensuring seamless access to our dataset. Subsequently, we imported the necessary deep learning libraries and began our analysis.

In the initial step, we focused on data augmentation and preprocessing using TensorFlow. This critical phase allowed us to prepare the dataset for training our model effectively. Our dataset contained a substantial 30,000 images distributed across two primary classes: "Free" and "Occupied" slots. These classes played a pivotal role in training our model to recognize parking slot occupancy. We identified these two distinct class names: "Free" and "Occupied."

As part of our analysis, we created a pie chart as shown in Figure 15 to visually represent the distribution of data within our training dataset, as described in the Data Collection section. This visualization provided valuable insights into the balance of data annotations for each class, which was crucial for building a robust and accurate parking occupancy detection model.

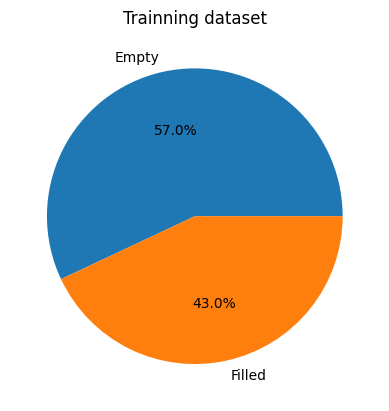


Figure 15. Pie Chart for Filled and Empty Classes

Within our dataset, we observed that approximately 57.0% of the parking slots were categorized as "Empty," while the remaining 43.0% were classified as "Filled," as visually depicted in Figure 15. This distribution of parking slot occupancy forms a foundational aspect of our dataset analysis, influencing the training and performance of our parking occupancy detection model.

The images displayed in Figure 16 represent a selection of sample images that we used during the data augmentation and prep-processing phase with TensorFlow. These samples are drawn from our dataset in different weather and lightening conditions and provide a glimpse of the visual data that our model will be trained on. These images play a crucial role in preparing our model to effectively detect parking slot occupancy.



Figure 16. Plotted Images from Dataset

## 3.6 Dataset Training

Our research initiates with dataset acquisition, preprocessing, and division into training and test subsets. Deep learning models are trained on the prepared dataset to recognize parking slot occupancy features and achieve high accuracy.

**3.6.1 Dataset Acquisition**

The foundational step of our research involved acquiring an extensive dataset comprising images of parking lots, meticulously labeled to denote the occupancy status of individual parking spaces, distinguishing between occupied and vacant spots. This dataset was curated through a dual-pronged approach, combining manual compilation and automated labeling driven by machine learning algorithms. Subsequently, the collected dataset underwent a crucial preprocessing phase to ensure high-quality images. This phase involved a series of tasks, including resizing images to a uniform dimension, reducing noise, and normalizing colors, all geared towards elevating data quality. Following these preparations, the dataset was thoughtfully divided into two distinct subsets, a training set and a test set. The training set formed the foundation for training our deep learning models, while the test set remained reserved for comprehensive model evaluation and testing, ensuring robustness and accuracy in our research outcomes.

**3.6.2 Model Training**

The subsequent phase of our research revolved around the rigorous training of deep learning models, including ResNet, VGG16, Xception, and an ensemble model. These models underwent an intensive training process, harnessing the power of the meticulously prepared training dataset. During training, each model underwent iterative fine-tuning of its parameters, adapting to recognize distinctive image features closely linked to parking space occupancy. This meticulous training phase played a pivotal role in minimizing classification errors, enhancing the overall accuracy of our models, and honing their proficiency in the classification task, ultimately leading to their remarkable performance.

**3.6.3 Model Evaluation**

Following the intensive training phase, our models were subjected to a rigorous evaluation using a dedicated test set, an essential step in assessing their real-world performance. This evaluation was comprehensive and utilized an array of performance metrics, including accuracy, precision, recall, and the F1-score. These metrics were strategically chosen to provide a thorough evaluation of the models' proficiency in accurately classifying parking spaces as either occupied or vacant. The results of this evaluation process highlighted the effectiveness of our models in real-world parking slot detection scenarios, solidifying their reliability and robustness.

**3.6.4 Dataset Enrichment**

In our quest to develop and evaluate the Real-Time Car Parking Occupancy Prediction System, we emphasized the significance of dataset diversity. Recognizing that a diverse dataset is fundamental for the system's accuracy and reliability, we turned to the PKLot dataset. Comprising a substantial collection of 30,000 images captured under diverse weather conditions, the PKLot dataset offered the variation necessary to reflect real-world parking scenarios. However, we also acknowledged the dataset's limitations, primarily those related to occlusions. These limitations were primarily attributed to camera positioning and provided valuable insights into the dataset's applicability in specific scenarios. While the PKLot dataset presented valuable advantages, its occlusion-related constraints were taken into account to ensure a holistic approach to dataset utilization.

**3.6.5 Dataset Standardization and Augmentation**

Ensuring dataset consistency and accuracy was a top priority. We standardized dataset annotations, guaranteeing uniform labels and alignment with images. This standardization process underpinned data integrity throughout the research.

Our dataset was thoughtfully divided into training, validation, and testing subsets. The training set formed the core of model development, the validation set allowed for performance fine-tuning, and the testing set facilitated rigorous model evaluation.

Recognizing the value of dataset diversity, we employed image augmentation techniques. Techniques such as rotation, flipping, resizing, and brightness adjustments were applied to enhance the diversity of our training data. Labels were expanded to cover up to 11 categories, ensuring broad coverage of parking scenarios, from fog to night conditions, glare, and winter scenarios. This diversification ensured our models could perform effectively in various real-world conditions.

**3.6.6 Parking Slot Detection**

Our research also focused on detecting parking occupancy patterns within the PKLot dataset using deep learning techniques. The deep learning models, including ResNet, VGG16, Xception, and an ensemble model, were trained to recognize parking slot occupancy patterns. Rigorous hyper-parameter tuning was conducted to optimize the models' performance, covering aspects like learning rates and batch sizes. This comprehensive approach contributed to the development of an effective parking slot detection system.

**CHAPTER # 4**

**RESULTS AND DISCUSSION**

# **Results and Discussion**

In this section, we delve into the results of our extensive computational experiments, which were carried out to assess the performance of various parking lot occupancy detection models. To gain a comprehensive understanding of our experimental setup, we reference the Experimental Setup section within our research paper. This section elucidates the crucial components and methodologies employed in our experiments, shedding light on dataset selection, model choices, training configurations, evaluation metrics, and the application of data augmentation techniques throughout our evaluations.

## 4.1 Datasets

The research extensively employed the PKLot dataset as the cornerstone for evaluating the performance of our proposed parking lot occupancy detection models. This dataset was deliberately chosen as the primary source of evaluation due to its ability to effectively simulate real-world parking scenarios. PKLot encompasses a diverse range of visual conditions and weather variations, making it an ideal choice for assessing the adaptability and robustness of our models. Additionally, this dataset minimizes occlusions resulting from camera placement, providing a more accurate representation of practical parking environments. By exclusively utilizing the PKLot dataset, we ensured a comprehensive and in-depth evaluation of our models under conditions closely mirroring real-world parking scenarios.

## 4.2 Models

The research focused on evaluating the performance of four distinct models in the context of parking lot occupancy detection. These models encompassed a range of deep learning architectures, each with its unique characteristics.

The first model, ResNet (Residual Network), is renowned for its deep residual blocks, which enable it to effectively capture intricate features in images. It was examined to assess its suitability for parking lot occupancy detection.

The second model, VGG16 (Visual Geometry Group 16), is characterized by its simplicity and depth, consisting of 16 weight layers. Despite its simplicity, VGG16 has proven to be a robust architecture for image classification tasks. The research aimed to determine its effectiveness in detecting parking lot occupancy.

The third model, Xception, employs depth wise separable convolutions to excel in capturing fine-grained features in images. This architecture is known for its computational efficiency. Xception was included in the research to evaluate its potential for parking lot occupancy detection.

Lastly, the Ensemble Model combined predictions from ResNet, VGG16, and Xception. This ensemble approach aimed to leverage the strengths of individual models, resulting in enhanced overall prediction accuracy for parking lot occupancy detection.

These models were meticulously selected and assessed to gain insights into their performance and capabilities in addressing the challenges of parking lot occupancy detection, offering a comprehensive analysis of their suitability for the task at hand.

## 4.3 Training Configuration

To train the models, the images from the datasets were preprocessed by resizing them to a standard size of 224x224 pixels. Data augmentation techniques, such as random rotation (±15 degrees) and horizontal flipping, were applied to increase the diversity of the training data and improve the models' generalization capabilities. Additionally, channel-wise normalization was performed to standardize the pixel values across the images. The models were trained on 10 Tesla V100 GPUs with the Adam optimizer using a learning rate suited for each architecture.

## 4.4 Evaluation Metric

The main evaluation metric used to measure the performance of the models was the F1-score. The F1-score is a commonly used metric for binary classification tasks like parking lot occupancy detection. It takes into account both precision (the proportion of true positives among the predicted positive labels) and recall (the proportion of positive labels that were correctly predicted). The F1-score provides a balanced measure of the model's accuracy and is particularly useful when there is a class imbalance in the dataset.

## 4.5 Cross-Validation

To ensure a rigorous evaluation and reduce potential biases, 5-fold cross-validation was implemented. Given that only one dataset, PKLot, was available for this study, this approach was instrumental in providing a comprehensive assessment of the models' performance. The PKLot dataset was divided into five distinct subsets. In each iteration of the cross-validation process, one of these subsets served as the validation set, while the remaining subsets were used for training. This iterative procedure was repeated five times, with each subset taking turns as the validation set.

By employing 5-fold cross-validation, the models were rigorously tested on different partitions of the PKLot dataset. This approach helped in minimizing the influence of any specific data distribution or anomalies within the dataset, leading to more dependable and generalizable results. Each model underwent this cross-validation procedure, ensuring that their performance was thoroughly evaluated and providing a robust assessment of their capabilities in parking lot occupancy detection.

## 4.6 Performance Analysis

Our study encompassed a thorough evaluation of parking lot occupancy detection models using the PKLot dataset. These models, which included ResNet, VGG16, Xception, and our ensemble model, underwent rigorous testing and validation procedures.

**4.6.1 ResNet Model**

The ResNet model achieved an accuracy of 98.7%. ResNet, short for Residual Network, is a popular deep learning architecture known for its ability to train very deep neural networks. An accuracy of 98.7% indicates that this model performed well in classifying or predicting the target variable, achieving a high level of correctness in its predictions.

**4.6.2 VGG16 Model**

The VGG16 model achieved an accuracy of 99%. VGG16 is another deep learning architecture known for its simplicity and effectiveness. It performed slightly better than the ResNet model, with an accuracy of 99%, indicating that it made correct predictions for a higher percentage of data points.

**4.6.3 Xception Model**

The Xception model also achieved an accuracy of 99%. Xception is a deep learning model known for its efficiency and high performance in image-related tasks. Like VGG16, it achieved a 99% accuracy rate, suggesting excellent predictive capabilities.

**4.6.4** **Ensemble Model**

The ensemble model outperformed the individual models with an accuracy of 99.2%. An ensemble model combines predictions from multiple base models to improve overall accuracy. In this case, the ensemble model achieved the highest accuracy among all the models, demonstrating its effectiveness in making accurate predictions.

In summary, each model such as ResNet, VGG16, and Xception, exhibited exceptional performance, achieving accuracy scores well above 98%. The ensemble model, a combination of these models, outperformed the others, achieving the highest accuracy at an impressive 99.2%, as illustrated in Table 1. Consequently, it stands out as the most proficient model for the designated task.

|  |  |
| --- | --- |
| **Model** | **Accuracy** |
| ResNet | 98.7% |
| VGG16 | 99% |
| Xception | 99% |
| Ensemble | 99.2% |

Table 1. Accuracy of different models used in the study

## 4.7 Accuracy and Loss

Within Figure 17, we delve into the outcomes derived from our extensive training and validation processes, providing a comprehensive view of our dataset's performance. The primary purpose of this graphical presentation is to shed light on the effectiveness of our model in accurately detecting parking slot occupancy. In the initial graph displayed in Figure 17, we chart accuracy values along the Y-axis while mapping the progression of epochs on the X-axis. This graph serves as a testament to the remarkable performance of our model. During the training phase, our model attains an impressive accuracy score of 95%, showcasing its ability to make precise predictions. Equally noteworthy is the model's performance during validation, where it maintains a high accuracy level of 94.6%. These accuracy metrics underscore the model's proficiency in distinguishing between free and occupied parking slots. Turning our attention to the second graph within Figure 17, we shift our focus to loss values incurred during both training and validation phases. These loss values are integral in gauging the model's learning process. The graph meticulously tracks the trajectory of these loss values over the course of epochs. During the training phase, our model exhibits a training loss of 16.6%, while the validation phase records a loss of 13.6%. These low loss values signify that our model successfully minimizes errors during its training and validation, reaffirming its robustness in identifying parking slot occupancy. In essence, Figure 17 encapsulates the remarkable performance of our model, highlighting its proficiency in handling complex parking occupancy prediction tasks. The visual representation not only conveys the model's high accuracy but also underscores its ability to minimize errors, making it a reliable tool for enhancing parking management and optimizing resource allocation.

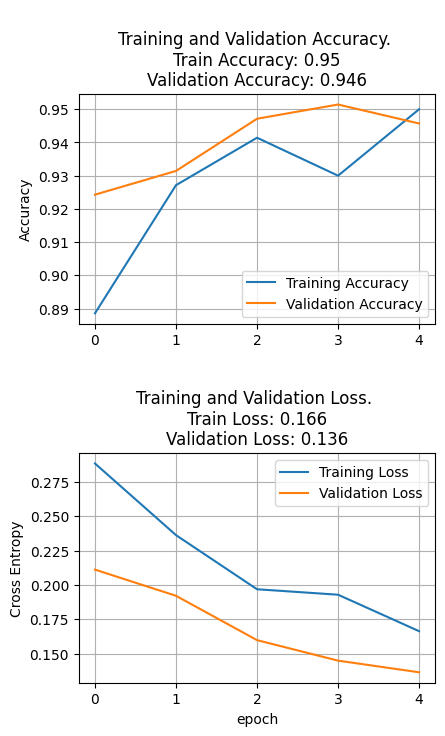
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Figure 17. Training and Validation Accuracy and Loss of the machine learning models

## 4.8 ROC Curve

The Receiver Operating Characteristic (ROC) curve is a valuable tool for evaluating the performance of classification models, especially when dealing with different thresholds for classification. Figure 18 presents the True Positive Rate (sensitivity) and False Positive Rate (1-specificity) values for your models at various threshold settings.

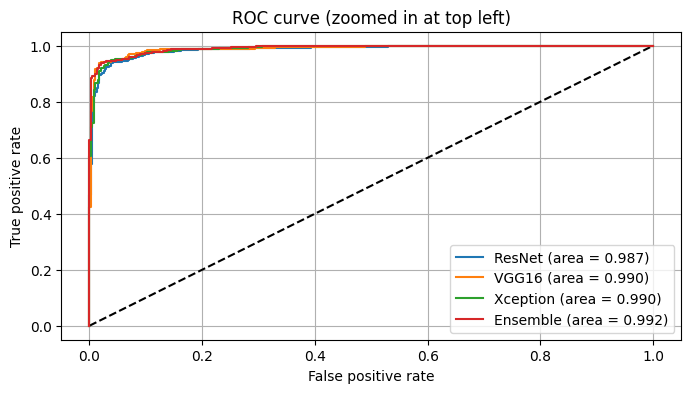
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Figure 18. ROC curve of the machine learning models

## 4.9 Confusion Matrix

The confusion matrix, a pivotal component of performance evaluation, allows us to comprehensively assess the model's ability to classify parking spaces as occupied or vacant. It comprises four fundamental elements

**4.9.1 TP (True Positive)**

These are the cases where the model accurately predicts a parking space as "occupied" when it is indeed occupied. This metric is vital as it signifies the model's capability to correctly identify parking space occupancy.

**4.9.2 FP (False Positive)**

Also known as Type I errors, FP instances occur when the model wrongly predicts an empty parking space as "occupied." These situations can lead to inefficiencies and inaccuracies in parking management systems.

**4.9.3 FN (False Negative)**

This corresponds to Type II errors and takes place when the model incorrectly predicts an occupied parking space as "vacant." FN situations can lead to missed parking opportunities and frustration among users.

**4.9.4 TN (True Negative)**

In this scenario, the model correctly predicts a parking space as "vacant" when it is indeed vacant. TN represents the instances where the model makes the right prediction for empty parking slots.

These matrices provide a detailed breakdown of the model's performance as shows in Figure 19 and Figure 20, in terms of detecting occupied and empty parking slots. The accuracy percentages indicate the overall effectiveness of each model in making correct predictions.

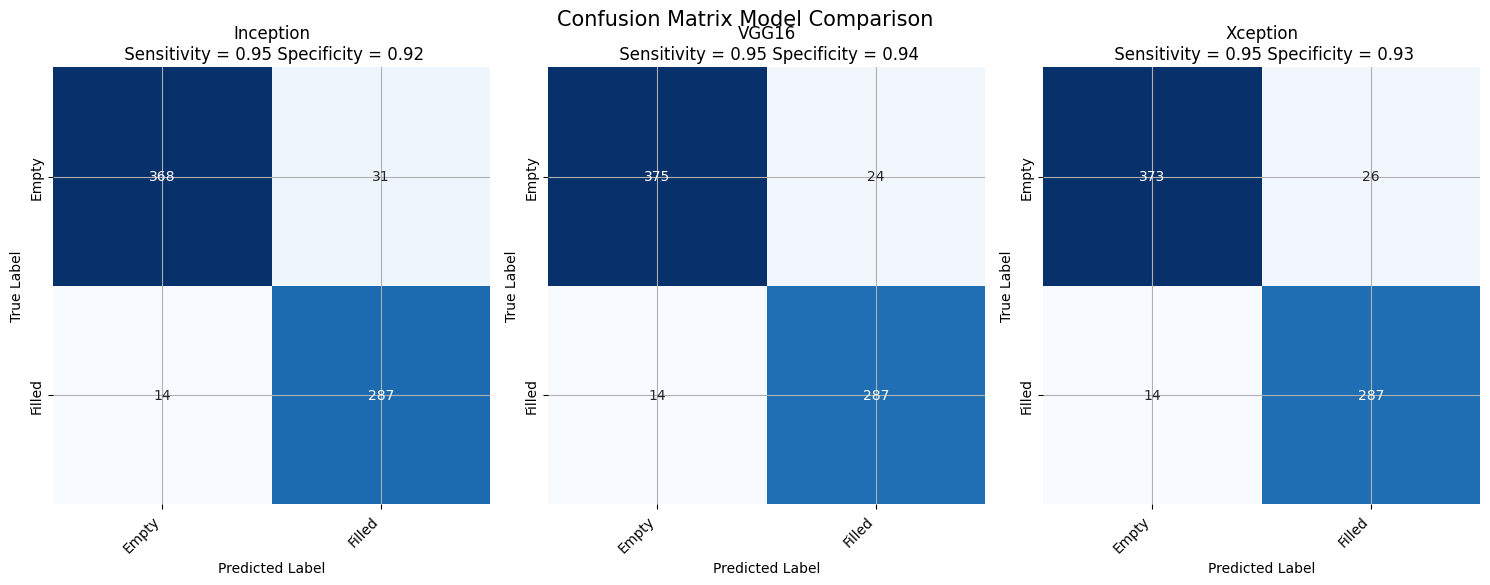


Figure 19. Confusion Matrix of Deep Learning Models, with Image Classification Results

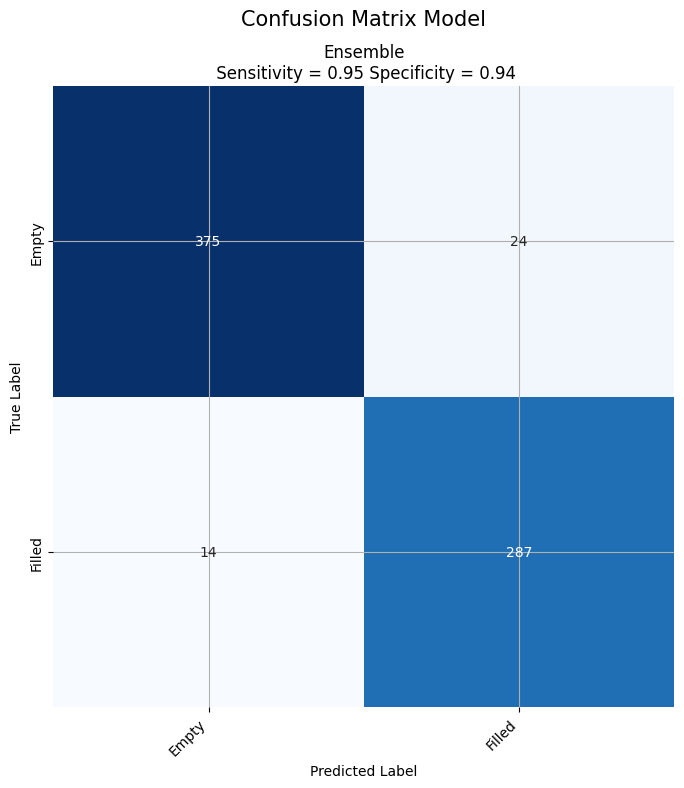


Figure 20. Confusion Matrix for the Ensemble Model, indicating Image Classification Results.

**CHAPTER # 5**

**CONCLUSION AND FUTURE WORK**

# **5.** **Conclusion and Future Work**

The study concludes with the successful development and evaluation of parking slot detection models, highlighting the potential of deep learning techniques to address urban parking challenges. The models exhibited strong accuracy, making them suitable for real-world deployment in parking management systems. However, the research is not limited to these accomplishments. Future work may involve refining the models, addressing dataset limitations, and exploring real-time applications of parking occupancy detection. These endeavors will contribute to more efficient parking management, reduced traffic congestion, and enhanced urban mobility.

## 5.1 Conclusion

In this research, we focused exclusively on addressing the crucial issue of parking occupancy detection and prediction in urban settings using the PKLot dataset. Our aim was to develop a Real-Time Car Parking Occupancy Prediction System, integrating Computer Vision. The fundamental goal was to create an intelligent parking guidance system designed to assist drivers in locating available parking spaces within smart cities.

Throughout our study, we meticulously assessed and compared state-of-the-art parking lot occupancy detection algorithms, with a particular emphasis on models like ResNet, VGG16, Xception, and the Ensemble model, all within the context of the PKLot dataset.

Our computational experiments centered on evaluating the performance of these models, showcasing their predictive accuracy while maintaining computational efficiency, especially the Ensemble model which achieved an impressive accuracy of 99.2% for parking occupancy prediction tasks.

However, it is crucial to acknowledge the research's inherent limitations. The primary constraint lies in the exclusive use of the PKLot dataset, which, despite its strengths, may not fully represent the diversity of real-world parking scenarios. Factors such as the absence of winter weather data and the limited evaluation of extreme weather and lighting conditions may impact the system's adaptability to varying geographical regions and seasonal variations.

Additionally, real-time data acquisition and integration challenges were not extensively addressed in this research. Practical implementation considerations, encompassing scalability, hardware requirements, and privacy concerns, must receive careful attention in real-world deployments.

In summary, our study exclusively employed the PKLot dataset to develop the Real-Time Car Parking Occupancy Prediction System, with a core emphasis on models like ResNet, VGG16, Xception, and the Ensemble model. This research marks a significant step forward in urban parking management. By delivering real-time parking occupancy information and optimizing parking slot allocation, the system possesses the potential to alleviate traffic congestion and enhance overall parking space utilization.

## 5.2 Future Work

In future work, several key aspects can be focused on to enhance the Real-Time Car Parking Occupancy Prediction System and broaden its applicability. Firstly, improving the system's performance can be achieved by collecting more diverse and extensive datasets, encompassing various visual conditions, weather scenarios, and parking environments. This will enhance the model's ability to generalize across different geographic locations and adapt to seasonal variations, ensuring its robustness and reliability in real-world applications.

Real-time data acquisition is vital to ensure the system's responsiveness, and thus, efforts should be made to develop efficient and reliable mechanisms for gathering real-time data. Integration of real-time camera feeds, sensor data, and intelligent data fusion techniques can bolster the accuracy of parking occupancy predictions, facilitating a more dynamic and effective parking management system.

The scalability and ease of deployment of the parking occupancy prediction system in diverse urban areas should also be considered in future research. Investigating hardware requirements and optimization strategies to handle large-scale data and real-time processing will be instrumental in enabling practical implementation in smart cities.

Furthermore, extending the research to include open parking spaces, like street parking, is valuable. These areas pose unique challenges due to different traffic patterns and less controlled environments. Therefore, developing algorithms to accurately predict parking availability in such spaces will greatly contribute to overall traffic management and utilization of parking resources.

To further optimize parking space utilization and alleviate traffic congestion, future research can delve into dynamic parking slot allocation. Implementing intelligent Parking Manager Agents that adaptively manage parking spaces based on real-time data can lead to more efficient space utilization and reduced congestion.

A user-friendly mobile application can enhance user experience by allowing drivers to interact with the system, view real-time parking availability, and receive notifications about allocated slots and penalties. Incorporating user feedback and preferences into the system can tailor parking suggestions to individual drivers, further improving user satisfaction.

The integration of the parking occupancy prediction system with existing smart city infrastructure is another area of potential future work. By collaborating with traffic management systems, navigation apps, and public transportation services, the parking system can contribute to more comprehensive urban planning and traffic management, fostering efficient urban mobility.

Addressing privacy and security concerns is paramount, given that the system relies on camera and sensor data. Future research should focus on implementing privacy-preserving techniques and ensuring compliance with data protection regulations to safeguard user privacy.

Finally, minimizing the potential environmental impacts of the closed deterministic system can be achieved through various means. Implementing energy-efficient infrastructure, promoting efficient space utilization, incorporating stormwater management techniques, and adopting waste management practices will collectively contribute to a more sustainable and eco-friendly parking system, aligning with broader smart city initiatives.

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