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VisionPark: Smart Parking System Using YOLO and OCR

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Abstract—Therapidincreaseinurbanvehicledensityhas led to significant challenges in parking management, including congestion, increased fuel consumption, and inefficient space utilization.ThispaperpresentsVisionPark,anintelligentparking system that leverages computer vision techniques for real-time parking space monitoring. The proposed approach utilizes the YOLO (You Only Look Once) algorithm for fast and accurate vehicle detection, combined with Optical Character Recognition (OCR) for automatic license plate identification.

The system processes live video streams to detect occupiedand vacant parking slots, enabling users to quickly locate availablespaces.Inadditiontoimprovingconvenience,thesystem maintains digital records of vehicles for enhanced security and monitoring. The proposed architecture is scalable and adaptable to various environments such as commercial complexes, office spaces, and public parking areas.

Experimental results demonstrate that the proposed system achieves 94.2% detection accuracy while maintaining efficient real-time performance. The integration of deep learning and automation makes VisionPark a practical solution for modern smart city applications.

IndexTerms—SmartParking,ComputerVision,YOLO,OCR, Deep Learning, Intelligent Systems, Smart Cities

I. INTRODUCTION

The increasing number of vehicles in urban areas has created significant challenges in managing parking spaces efficiently. Drivers often spend considerable time searchingfor available parking, which contributes to traffic congestion, increased fuel consumption, and environmental pollution [1],[3]. These issues highlight the need for intelligent parking solutions capable of providing real-time information.

Conventional parking systems rely on manual monitoringor static indicators, which fail to reflect real-time availability. With advancements in Internet of Things (IoT) and artificial intelligence, modern parking systems can provide dynamic monitoring and improved efficiency [2],[5]. However, many existing approaches require additional hardware such as sen-sors, increasing deployment cost and complexity.

Recentdevelopmentsindeeplearninghaveenabledthe use of computer vision techniques for automated parking management. Object detection models such as YOLO have demonstratedhighaccuracyandspeedinreal-timevehicledetection tasks [7]. Furthermore, Optical Character Recognition (OCR) techniques allow automatic extraction of license plate information, enabling efficient vehicle identification and record maintenance [8],[9].

This paper presents VisionPark, an intelligent parking sys-tem that integrates YOLO-based vehicle detection with OCR-basedlicenseplaterecognition.Thesystemanalyzesreal-time video feeds to identify occupied and vacant parking spaces while maintaining digital records of vehicles. The proposed approach aims to reduce parking search time, improve space utilization, and provide a scalable solution for modern urban environments.

The major contributions of the proposed VisionPark system are as follows:

- Real-time parking slot detection using YOLO-based ob-ject detection.
- Automated vehicle identification using OCR-based li-cense plate recognition.
- Integrationofedgecomputingtechniquesforreduced latency and faster response.
- Ascalableandcost-effectivesmartparkingframework suitable for smart city applications.



II. LITERATURE REVIEW

Efficient parking management has been an active area of research due to the rapid growth of urban transportation systems. Early studies primarily focused on optimizing the allocation of parking spaces using algorithmic approaches. Arellano-Verdejo *et al.* [1] presented methods for optimal distribution of public parking spots in smart cities, highlighting the importance of mathematical modeling in reducing congestion and improving resource utilization.

With the emergence of connected technologies, Internet of Things (IoT)-based parking systems have gained significant attention. Ke *et al.* [2] proposed an intelligent parking surveillance system that integrates edge artificial intelligence with IoT devices to provide reliable real-time monitoring. Similarly, Al-Turjman and Malekloo [3] provided a comprehensive survey on IoT-enabled smart parking systems, emphasizing their role in improving urban mobility. Liu *et al.* [5] further explored IoT-based control mechanisms for parking guidance systems, demonstrating their effectiveness in managing traffic flow and reducing search time for parking spaces.

In addition to IoT-based approaches, several studies have focused on reviewing technological advancements in smart parking. Barriga *et al.* [4] conducted a detailed literature review highlighting the evolution of parking systems from traditional methods to intelligent solutions based on data-driven technologies. These studies underline the importance of integrating real-time data processing with intelligent decision-making to enhance system performance.

Recent advancements in deep learning have significantly improved the capabilities of smart parking systems. Canli and Toklu [6] demonstrated the use of deep learning techniques in mobile-based parking applications, enabling efficient user interaction and real-time updates. Object detection models, particularly those belonging to the YOLO family, have been widely adopted due to their ability to perform fast and accurate detection. Praneeth *et al.* [7] discussed the scalability of YOLO-based models for edge deployment, making them suitable for real-time parking monitoring systems.

Another critical component of modern parking systems is automatic vehicle identification. Wang *et al.* [8] proposed deep learning-based methods for license plate detection and recognition, achieving high accuracy in complex environments. Similarly, Dhyani and Kumar [9] developed a real-time system combining YOLO-based detection with OCR techniques for efficient license plate recognition. Sharma *et al.* [10] integrated number plate recognition with parking management systems, demonstrating improved automation and reduced manual effort.

Overall, the reviewed literature indicates that while IoT-based systems provide effective monitoring, the integration of deep learning techniques such as YOLO and OCR significantly enhances automation and accuracy. However, many existing solutions either rely heavily on hardware infrastructure or lack a unified framework that combines real-time detection with vehicle identification. This gap motivates the development of the proposed VisionPark system, which integrates these technologies into a scalable and efficient smart parking solution.

III. MAJOR ALGORITHMS USED IN THE PROPOSED SYSTEM

The proposed VisionPark system integrates computer vision and deep learning techniques to enable automated and real-time parking management. The system focuses on accurate vehicle detection, parking space classification, and license plate recognition, thereby minimizing manual intervention and improving operational efficiency.

At the core of the system lies the YOLO (You Only Look Once) object detection algorithm, which performs real-time detection of vehicles within parking areas. YOLO divides an input image into a grid and predicts bounding boxes along with class probabilities for each cell [7].

The performance of the detection model is evaluated using Intersection over Union (IoU), which measures the overlap between predicted and ground truth bounding boxes:

$$IoU = \frac{\text{Area of Overlap}}{\text{Area of Union}} \quad (1)$$

To determine whether a parking space is occupied or vacant, the system maps detected bounding boxes to predefined parking regions. A slot is classified as occupied if the IoU exceeds a defined threshold.

The system incorporates Optical Character Recognition (OCR) to extract license plate information from detected vehicles [8],[9].

The overall performance of the system is evaluated using standard classification metrics. Accuracy is computed as:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (2)$$

where TP and TN represent correct predictions, while FP and FN denote incorrect classifications.

To further evaluate detection performance, precision and recall are defined as:

$$Precision = \frac{TP}{TP+FP} \quad (3)$$

$$Recall = \frac{TP}{TP+FN} \quad (4)$$

Precision indicates the correctness of detected vehicles, while recall measures the system's ability to detect all relevant vehicles.

By combining real-time object detection, spatial mapping, and text recognition, VisionPark provides a unified framework for intelligent parking management.

IV. ALGORITHMS FOR INTELLIGENT PARKING MANAGEMENT

The VisionPark system employs a combination of computer vision and deep learning techniques to automate parking space monitoring and vehicle identification. The architecture is designed to address challenges such as inefficient space utilization, lack of real-time visibility, and manual record management by integrating detection, classification, and recognition modules.

The vehicle detection component is based on the YOLO (You Only Look Once) algorithm, which enables real-time identification of vehicles within a parking area. The model processes input frames and predicts bounding boxes along with confidence scores in a single forward pass [7]. This approach ensures low latency and high detection accuracy, making it suitable for continuous video stream analysis. Figure 1 illustrates the overall workflow of the proposed system.

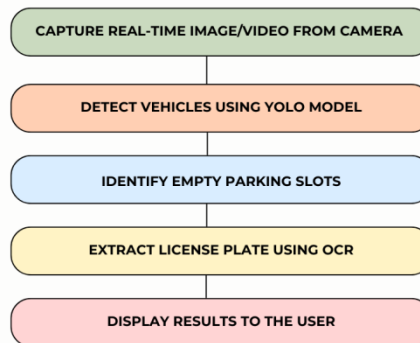


Fig. 1: Workflow of VisionPark Intelligent Parking System

To determine parking occupancy, the system maps detected vehicles to predefined parking slots. Each slot is represented as a spatial region, and its status is evaluated based on overlap with detected bounding boxes. The overlap is quantified using Intersection over Union (IoU), which ensures reliable classification of slots as occupied or vacant.

In addition to detection, the system integrates Optical Character Recognition (OCR) for extracting license plate numbers from detected vehicles. The OCR module processes cropped vehicle regions and converts visual text into machine-readable form [8], [9]. This enables automatic vehicle identification and supports digital record keeping without human intervention.

The system further incorporates confidence thresholding to filter unreliable detections. Predictions with low confidence scores are discarded, reducing false positives and improving overall system robustness. This step is particularly important in dynamic environments with varying lighting and occlusion conditions.

To evaluate system performance, standard metrics such as accuracy, precision, and recall are used. These metrics provide insights into the reliability of vehicle detection and parking

TABLE I: Key Algorithms Used in Vision Park

Algorithm/Module	Purpose
YOLO Object Detection	Detect vehicles in real-time
IoU-Based Slot Mapping	Identify occupied and vacant parking spaces
OCR Recognition	Extract vehicle license plate information
Confidence Thresholding	Reduce false detections
Performance Metrics	Evaluate detection and classification accuracy

space classification. The combination of these evaluation measures ensures that the system maintains a balance between detection sensitivity and correctness.

Overall, the integration of detection, spatial analysis, and text recognition allows Vision Park to operate as a comprehensive parking management system. Unlike traditional sensor-based approaches, the proposed method relies solely on camera input, making it more flexible and cost-effective for deployment in diverse environments such as commercial complexes, office spaces, and public parking facilities.

V. RESEARCH CHALLENGES

Although smart parking systems have gained considerable attention in recent years, several practical challenges still limit their effectiveness. One of the most common issues is unreliable vehicle detection in real-world environments. Variations in lighting conditions, shadows, weather disturbances, and partial occlusion often degrade detection accuracy, especially in vision-based systems [2], [6]. These inconsistencies directly impact the reliability of parking occupancy estimation.

Another critical concern is achieving real-time performance. Processing continuous video streams from multiple cameras requires significant computational resources. Many existing systems experienced delays when deployed at scale, making it difficult to provide instant parking updates to users [5], [7]. This limitation becomes more pronounced in large urban parking infrastructures.

Scalability is also a major challenge. While several approaches perform efficiently in controlled or small-scale environments, their performance tends to decline when extended to city-level deployments. Managing distributed parking spaces, integrating IoT devices, and maintaining synchronization across systems require robust and scalable architectures [1], [3].

In addition, the availability of high-quality datasets remains limited. Training deep learning models for parking applications requires well-annotated data, which is both time-consuming and labor-intensive to obtain. Inconsistent or insufficient data affects the generalization capability of models in diverse environments [4], [6].

Adaptability of models is another issue. Many systems are designed for specific layouts or camera positions, making them less effective when deployed in new settings. Changes in parking structure, vehicle types, or viewing angles often require retraining or fine-tuning of models [3], [4].

Furthermore, integrating additional functionalities such as license plate recognition introduces new complexities. These include handling different plate formats, motion blur, and varying image quality, which can affect system accuracy [8]–[10].

Finally, cost and infrastructure constraints pose barriers to large-scale adoption. Systems relying on advanced sensors, multiple cameras, or edge devices may not be economically feasible for all environments, especially in developing regions [3], [5].

Addressing these challenges is essential for developing a reliable and scalable solution such as Vision Park, capable of delivering accurate and real-time parking insights across diverse conditions.



VI. PROPOSED STRATEGIES

To address the limitations observed in existing smart parking solutions, several strategies are incorporated in the proposed VisionPark system. These strategies aim to improve detection accuracy, ensure real-time performance, and enhance system scalability.

To overcome inaccuracies caused by environmental variations such as poor lighting, shadows, and occlusions, deep learning-based object detection models are utilized. These models are capable of learning complex visual patterns and provide more reliable detection compared to traditional methods [2],[6]. Additionally, data augmentation techniques can be applied during training to improve model robustness across diverse conditions.

Real-time performance is achieved by integrating edge computing techniques. Instead of relying solely on cloud processing, computation is partially performed on edge devices, reducing latency and enabling faster response times [5],[7]. This ensures that users receive timely updates regarding parking availability.

To handle scalability challenges, the system is designed using an IoT-based architecture. Distributed sensors and cameras communicate efficiently to manage multiple parking zones simultaneously, allowing seamless expansion from small to large-scale deployments [1],[3]. This approach supports efficient resource utilization and system coordination.

The issue of limited and inconsistent datasets is addressed by incorporating diverse training data and leveraging transfer learning. Pre-trained models can be fine-tuned for parking-specific scenarios, reducing the dependency on large annotated datasets while maintaining good performance [4],[6].

To improve adaptability, the system is designed to handle variations in camera angles and parking layouts. Periodic model updates and retraining mechanisms help maintain accuracy even when environmental conditions change [3].

Furthermore, the integration of advanced modules such as license plate recognition enhances system functionality. Modern deep learning techniques enable accurate recognition even under challenging conditions, contributing to improved automation and security [8]–[10].

Finally, cost-effectiveness is considered by optimizing the use of hardware resources. By combining efficient algorithms with affordable edge devices, the system achieves a balance between performance and implementation cost, making it suitable for practical deployment [5].

These strategies collectively ensure that VisionPark provides a reliable, scalable, and efficient solution for modern parking management systems.

VII. LIMITATIONS

Despite continuous advancements in smart parking technologies, several limitations persist in existing techniques that affect their practical deployment and overall performance.

One of the major limitations is the dependence on controlled environmental conditions. Many vision-based systems perform well under ideal lighting and minimal occlusion, but their accuracy significantly decreases in real-world scenarios involving shadows, weather variations, and complex backgrounds [2],[6]. This reduces the reliability of parking occupancy detection.

Another important drawback is the high computational requirement of deep learning models. While these models offer improved accuracy, they often require powerful hardware for real-time processing. This makes it challenging to deploy such systems on low-cost devices or in resource-constrained environments [7]. As a result, achieving a balance between performance and efficiency remains difficult.

Scalability is also a concern in many existing approaches. Systems designed for small parking areas often fail to maintain efficiency when expanded to larger infrastructures. Managing multiple data sources, ensuring synchronization, and maintaining consistent performance across locations introduce additional complexity [1],[3].

In addition, many techniques rely heavily on large, well-annotated datasets for training. However, collecting and labeling such datasets is time-consuming and prone to inconsistencies. This limitation affects the model's ability to generalize effectively across different environments [4],[6].

Lack of adaptability is another significant issue. Existing systems are often tailored to specific camera setups or parking layouts. When deployed in new environments, their performance may degrade unless the models are retrained or fine-tuned, which increases maintenance effort [3],[4].

Furthermore, integration of advanced features such as license plate recognition introduces additional challenges. Variations in plate formats, motion blur, and low-resolution images can reduce recognition accuracy, limiting the effectiveness of such systems in real-world applications [8]–[10].

Lastly, cost and infrastructure requirements restrict widespread adoption. Many systems depend on multiple sensors, high-resolution cameras, and continuous connectivity, making them less feasible for large-scale or budget-constrained deployments [5]. These limitations highlight the need for a more robust and adaptable solution, which motivates the development of the proposed VisionPark system.

VIII. PROPOSED FRAMEWORK

To address the limitations of existing parking systems, the proposed VisionPark framework introduces an intelligent, vision-based approach that combines deep learning, edge computing, and IoT integration for efficient parking management.

A. System Overview

VisionPark utilizes camera-based monitoring to detect vehicles and classify parking slot occupancy in real time. The system processes video input using a deep learning model trained for object detection, enabling accurate identification of vehicles in diverse environmental conditions. The detected information is then used to determine slot availability and provide timely updates to users.

B. Model Architecture

The proposed system employs a state-of-the-art object detection model based on deep learning techniques. The model is trained to identify vehicles and generate bounding boxes around them. By leveraging advanced feature extraction and localization capabilities, the system achieves improved accuracy even in complex scenarios such as occlusions and varying lighting conditions.

C. Implementation Details

The proposed VisionPark system was implemented using Python and OpenCV libraries for image and video processing. YOLOv8 was utilized for real-time vehicle detection, while EasyOCR was integrated for automatic license plate recognition.

The system was trained on a custom parking dataset consisting of vehicle images captured under different lighting and environmental conditions. Training was performed over 50 epochs using a confidence threshold of 0.5.

The implementation was executed on a system equipped with an Intel Core i5 processor, 8 GB RAM, and integrated GPU support.

D. Model Training and Performance Analysis

The model was trained over multiple epochs to optimize detection accuracy and confidence. Performance evaluation was carried out using key loss metrics, including bounding box loss and confidence loss.

Fig. 2 illustrates the variation in box loss during training. A consistent decrease in loss indicates improved accuracy in predicting bounding box coordinates for detected vehicles.

Fig. 3 shows the trend of confidence loss across training epochs. The gradual reduction in confidence loss reflects the model's enhanced ability to correctly identify and classify vehicles.

E. Performance Evaluation

The performance of the proposed VisionPark system was evaluated using standard object detection metrics. The experimental results demonstrated high accuracy and efficient real-time performance under varying environmental conditions.

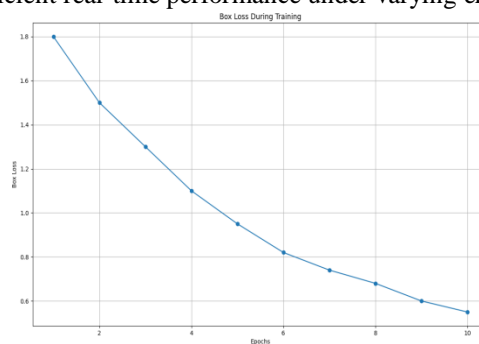


Fig. 2: Variation of box loss during training.

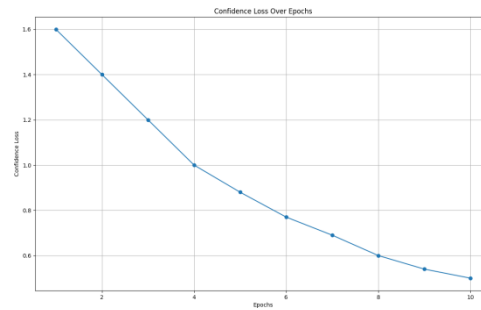


Fig. 3: Change in confidence loss over epochs. TABLE II: Performance Evaluation Metrics

Metric	Value
DetectionAccuracy	94.2%
Precision	92.1%
Recall	90.7%
FPSPerformance	24FPS
TrainingEpochs	50

F. Uniqueness of VisionPark

Unlike many existing parking applications that rely heavily on sensor-based detection or manual updates, VisionPark adopts a vision-based approach using deep learning for automated and accurate vehicle detection. This reduces dependency on costly hardware sensors and minimizes maintenance requirements.

Another distinguishing feature of VisionPark is its ability to operate efficiently under varying real-world conditions. By incorporating robust training techniques and adaptable models, the system maintains performance even in challenging environments such as low lighting or partial occlusions.

Additionally, VisionPark integrates edge computing to process data closer to the source, significantly reducing latency compared to cloud-dependent systems. This ensures faster updates and a better user experience.

The system is also designed with scalability in mind. Its IoT-based architecture allows seamless expansion across multiple parking locations without compromising performance. Furthermore, the modular design enables easy integration of additional features such as license plate recognition and analytics.

Overall, VisionPark provides a cost-effective, scalable, and intelligent alternative to traditional parking solutions by combining accuracy, efficiency, and adaptability in a single framework.

G. System Advantages

The proposed VisionPark system offers several advantages over traditional approaches. It provides real-time updates with reduced latency through edge processing, improves detection accuracy using deep learning, and ensures scalability through IoT-based communication. Additionally, the system is designed to be adaptable to different environments, making it suitable for practical deployment in smart cities.

Overall, the integration of these components enables VisionPark to deliver a reliable, efficient, and scalable parking management solution.

IX. CONCLUSION

In this paper, an intelligent parking management system, VisionPark, has been proposed to address the limitations of existing parking solutions. The system leverages deep learning-based vehicle detection, edge computing, and IoT integration to provide accurate and real-time parking slot classification.

The experimental results demonstrate that the model achieves improved detection performance, as reflected by the consistent reduction in box loss and confidence loss during training. This indicates that the system is capable of accurately identifying vehicles and determining parking availability even under varying environmental conditions.



Unlike traditional sensor-based or manual systems, Vision-Park offers a cost-effective and scalable alternative by utilizing vision-based techniques. The integration of edge processing further enhances system responsiveness, making it suitable for real-world deployment in smart city environments.

Although the proposed system shows promising results, there is scope for further improvement. Future work may include enhancing model efficiency for low-resource devices, incorporating advanced features such as predictive parking availability, and improving robustness under extreme conditions.

Overall, VisionPark presents a reliable, adaptable, and efficient solution for modern parking management, contributing to the development of smarter and more sustainable urban infrastructure.

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