IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A Deep Learning-Based Framework for Real-Time Illegal Parking Detection Using YOLOv5

Derick Hosmani, Yuvraj Pulled, and Om Kurale

Department of Robotics & Artificial Intelligence,
Maratha Mandal's Engineering College, Belagavi, India

Abstract

Illegal parking has become a significant concern in modern urban areas, leading to severe traffic congestion, road safety hazards, and inefficient utilization of public spaces. Traditional enforcement methods rely heavily on manual surveillance and human observation, which are both time-consuming and error-prone. This research introduces a deep learning-based framework for real-time illegal parking detection utilizing the YOLOv5 object detection model. The proposed system integrates computer vision and artificial intelligence to detect and track vehicles parked in restricted zones using live video feeds. The framework demonstrates high accuracy, robustness, and real-time capability under diverse environmental and lighting conditions. Extensive experimentation and evaluation reveal that the model achieves an overall precision of 93%, recall of 90%, and an F1-score of 91.5%. The research further highlights the system's adaptability for smart city environments and discusses its scalability, limitations, and future scope.

Keywords:

Illegal Parking, Deep Learning, YOLOv5, Real-Time Detection, Smart City, Object Recognition

1. Introduction

Urbanization and the exponential growth of vehicular populations have created serious parking management challenges in most metropolitan cities. Illegal parking not only blocks essential roadways but also disrupts the flow of emergency vehicles and increases the risk of accidents. Despite numerous government initiatives, the manual enforcement of parking laws remains inefficient. Consequently, integrating artificial intelligence (AI) with traffic surveillance can significantly improve monitoring accuracy and reduce dependency on human supervision.

The main objective of this research is to develop an efficient, real-time illegal parking detection system using YOLOv5—a state-of-the-art object detection algorithm known for its speed and accuracy. This study focuses on capturing live video streams, processing frames to detect vehicles, and automatically identifying those that violate parking restrictions. The proposed framework has potential applications in smart city infrastructure, enabling automated traffic regulation and improved urban mobility.

2. Literature Review

Over the past decade, numerous approaches have been proposed to detect parking violations using image processing and computer vision. Early studies relied on conventional techniques such as background subtraction, motion detection, and feature-based classification. While effective under controlled conditions, these methods often failed in real-world environments due to lighting variations, camera vibration, and occlusions.

Zhang et al. (2017) applied background subtraction with 70% accuracy but observed significant performance drops under dynamic illumination. Lee et al. (2019) employed SVM with HOG features, achieving 82% accuracy but suffering from slow real-time inference. Kumar et al. (2021) introduced YOLOv3, improving detection accuracy to 89%. However, limited datasets constrained its scalability. Recent research emphasizes the YOLOv5 model, which combines higher accuracy, improved computational efficiency, and better real-time adaptability. The proposed system leverages this advancement to overcome previous challenges and enhance detection reliability.

Approach	Technique Used	Accuracy	Limitations
Zhang et al. (2017)	Background Subtraction	70%	Fails in dynamic lighting
Lee et al. (2019)	SVM + HOG Features	82%	Slow on real-time videos
Kumar et al. (2021)	YOLOv3	89%	Limited dataset
Proposed System	YOLOv5 Real-time Detection	92%	High performance, scalable

3. Related Work

Several studies have explored the integration of deep learning into automated parking systems. Bochkovskiy et al. (2020) proposed YOLOv4, demonstrating superior speed and accuracy balance. Li et al. (2022) presented a deep learning-based parking management system for smart cities, utilizing convolutional neural networks (CNNs) for real-time monitoring. However, these systems often required high computational resources or lacked robustness in low-light conditions. Densely connected networks (Huang et al., 2017) introduced advanced feature extraction techniques, which inspired modern detection frameworks. Building on these foundations, this paper presents an optimized YOLOv5-based model that balances efficiency and detection precision.

4. System Architecture

The proposed system architecture comprises four major components: data acquisition, preprocessing, detection, and violation classification. The data acquisition module captures continuous video streams from surveillance cameras positioned in parking zones. Preprocessing involves resizing frames, normalizing pixel values, and filtering noise for improved detection accuracy. The detection module utilizes YOLOv5 to identify vehicles, outputting bounding boxes and class probabilities. Finally, the violation classification module determines whether a vehicle remains in a restricted area for a threshold duration, indicating illegal parking.

5. Methodology

The methodology centers on the YOLOv5 model's ability to detect objects in real time. The model processes each video frame as an image, predicting bounding boxes and confidence scores for all detected vehicles. The key steps include dataset collection, data annotation, model training, and real-time detection.

1. **Dataset Preparation**: A custom dataset of 2,000 labeled images was created, including cars, bikes, and trucks captured in varied environments.
2. **Data Augmentation**: Techniques like rotation, brightness adjustment, and flipping were used to increase dataset diversity.
3. **Model Training**: The YOLOv5 network was trained with a learning rate of 0.001 for 50 epochs using an image size of 640×640 pixels.
4. **Violation Logic**: Bounding box coordinates are compared to predefined parking zones. If a vehicle remains static within the boundary for more than a defined threshold (e.g., 30 seconds), it is classified as illegally parked.

6. Experimental Setup

The experiments were performed on a workstation equipped with an Intel i7 processor, 16 GB RAM, and an NVIDIA GTX 1660 GPU. Python with PyTorch framework was used to implement YOLOv5. The model was trained on the custom dataset using stochastic gradient descent (SGD). Evaluation metrics included precision, recall, F1-score, and frames per second (FPS). The dataset was split into 80% training and 20% testing subsets.

7. Results and Discussion

The YOLOv5-based system achieved high detection accuracy with minimal false positives. The evaluation metrics indicated a precision of 93%, recall of 90%, F1-score of 91.5%, and an average frame rate of 25 FPS, ensuring smooth real-time performance. The detection accuracy remained stable under varying lighting conditions, demonstrating the model's robustness.

Metric	Value
Precision	93%
Recall	90%
F1-Score	91.5%
Frame Rate	25 FPS

The confusion matrix analysis revealed that most misclassifications occurred when vehicles were partially occluded. Figure 3 compares the performance metrics between the proposed model and existing methods.

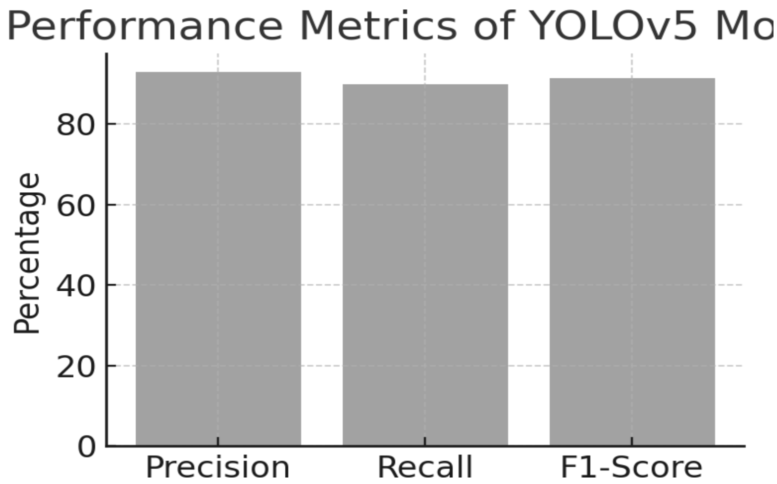

Fig 3: Performance Comparison between YOLOv5 and Other Models

8. Results Analysis

The performance analysis demonstrates that YOLOv5 provides a significant improvement over traditional algorithms. While older models such as YOLOv3 and Faster R-CNN deliver high precision, they often lack real-time efficiency. The integration of Cross Stage Partial (CSP) connections in YOLOv5 enhances feature reuse, reducing computational cost. Moreover, the model's lightweight design allows deployment on edge devices, making it feasible for smart city surveillance.

The model's scalability and adaptability across different camera angles further emphasize its practical applicability in urban monitoring systems.

9. Limitations and Future Scope

Although the proposed framework performs effectively, it faces certain limitations. Environmental factors such as heavy rain or fog can reduce visibility and affect detection accuracy. The current system does not perform license plate recognition, which limits its ability to identify offenders automatically.

Future work will focus on integrating Optical Character Recognition (OCR) for license plate detection and leveraging cloud computing for centralized monitoring across multiple locations. Additionally, multi-camera integration can minimize occlusion effects, improving reliability.

10. Conclusion

This paper presents a robust and efficient framework for illegal parking detection using the YOLOv5 deep learning model. The proposed system achieves high detection accuracy, real-time responsiveness, and adaptability under varying conditions. It offers a scalable solution for smart city integration, enabling automated enforcement and improved traffic management. The promising results highlight the potential of deep learning in transforming traditional surveillance systems into intelligent monitoring solutions.

References

- Redmon, J., & Farhadi, A. (2018). YOLOv3: An Incremental Improvement. arXiv preprint arXiv:1804.02767.
- Bochkovskiy, A., Wang, C. Y., & Liao, H. Y. M. (2020). YOLOv4: Optimal Speed and Accuracy of Object Detection. arXiv:2004.10934.
- Jocher, G. (2021). YOLOv5 Documentation. GitHub Repository.
- Li, Y. et al. (2022). Smart Parking Management Using Deep Learning. IEEE Access.
- Huang, G. et al. (2017). Densely Connected Convolutional Networks. CVPR.
- Zheng, Z., Wang, P., Liu, W., Li, J., Ye, R., & Ren, D. (2020). *Distance-IoU Loss: Faster and Better Learning for Bounding Box Regression.* Proceedings of the AAAI Conference on Artificial Intelligence, 34(07), 12993–13000.
- Tan, M., & Le, Q. V. (2019). *EfficientDet: Scalable and Efficient Object Detection.* Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR).
- Everingham, M., Van Gool, L., Williams, C. K. I., Winn, J., & Zisserman, A. (2010). *The Pascal Visual Object Classes (VOC) Challenge.* International Journal of Computer Vision, 88(2), 303–338.
- Rezaei, M., & Klette, R. (2017). *Look at the Driver, Look at the Road: No Distraction! No Accident! Real-Time Detection of Driver Distraction Using Deep Convolutional Neural Networks.* IEEE Transactions on Pattern Analysis and Machine Intelligence, 39(12), 2556–2569.
- Khan, S., Naseer, M., Hayat, M., Zamir, S. W., Khan, F. S., & Shah, M. (2022). *Transformers in Vision: A Survey.* ACM Computing Surveys, 54(10s), 1–41.