Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 9, No.1, September : 2024

CHALLENGES AND SOLUTIONS IN MULTI-OBJECT TRACKING: A REVIEW OF PEDESTRIAN AND PARKING VIOLATION DETECTION SYSTEMS

Kavita Soni, Research Scholar, Department of CSE, SAGE University Indore.
Dr. Atul Nandwal, Associate Professor, Institute of advance Computing -CORE, SAGE University Indore.

ABSTRACT
This review paper provides an in-depth review of the difficulties and approaches associated with multi-object tracking, emphasizing parking violation and pedestrian detection systems. The article examines the developments in AI-driven technologies, including YOLOv8, Deep SORT, and Hybrid-SORT, which have proven essential to enhancing tracking systems' effectiveness and accuracy. By eliminating problems like incorrect parking and inefficient space utilization, these solutions are essential for enhancing pedestrian safety at street crossings and optimizing parking space utilization. In order to minimize traffic congestion, lower CO2 emissions, and enhance urban mobility, the evaluation emphasizes the significance of implementing AI and tracking algorithms. The conversation also emphasizes the need of ongoing innovation and the creation of affordable alternatives to satisfy the ever-growing needs of urban settings. This study intends to assist future research in improving monitoring and detecting algorithms, raising the visibility and efficiency of parking facilities, and investigating probabilistic models by analyzing present approaches and recommending areas for improvement. The development of smart cities ultimately depends on improvements in multi-object monitoring systems, which lead to more secure, more effective metropolitan areas and higher standards of existence.
Keywords: Parking Space Optimization, Object Detection, Hybrid Tracking Methods, Traffic Congestion Reduction.

I. Introduction

Parking surveillance involves monitoring and managing parking spaces to optimize availability and enhance user experience. It includes real-time detection of parking slot occupancy using advanced technologies in India, parking has become a major issue due to the increasing number of vehicle registrations and the rapid increase in vehicle ownership has led to parking problems in cities across the country. To meet the parking demand, malls and convenience stores strive to effectively manage the limited parking spaces available to the public. In a fast-paced environment like 7-Eleven, where parking options are limited, it is crucial to record the parking time of each vehicle in the parking lot. The issue of illegal parking has become a concern for convenience store managers and the public. Parking violations include parking in restricted areas and exceeding the prescribed time limit.

Most current research focuses on helping drivers find parking spaces. Many models have been developed to help drivers find nearby parking spaces in real time

Daily parking problems can be summarized as:

1. Lack of designated parking spaces in some buildings, resulting in insufficient parking spaces for employees and visitors.
2. Traffic congestion caused by visitors looking for parking spaces.
3. Improper parking, where drivers do not use the parking spaces designated for them.[4]
4. This situation may occur in different locations,,such as parking lots with designated parking spaceor public streets with specific parking regulations.

Effective solutions to these Challenges should be:

1. Implement dynamic parking allocation to reduce the shortage of available parking spaces.
2. Ensure that vehicles are parked in accordance with regulations and solve the problem of illegal parking.[4]

Parking surveillance systems employ various methods and technologies to monitor and manage parking spaces efficiently.
Like CCTV camera, High-definition cameras, night vision capabilities, and video analytics software for motion detection and license plate recognition (LPR). IoT Sensors for providing real-time data, RFID (Radio Frequency Identification) technology for card readers, ticket dispensers, and automated barrier mechanisms. Cloud computing, machine learning algorithms, mobile apps, and integrated IoT devices. Used for Integrated systems that combine multiple technologies to manage parking spaces, monitor usage, and provide real-time data to users.[12]
Many tasks have been performing for any parking surveillance like classification, object detection and object tracking.[15]

Object Detection:
Object detection identifies and locates objects within images or videos by drawing bounding boxes around them. Common methods include:

- **Traditional Methods:** Haar Cascades and Histogram of Oriented Gradients (HOG) is used for Early face detection, Pedestrian detection.
- **Deep Learning-Based Methods:**
  - **Convolutional Neural Networks (CNNs):** General object detection.
  - **Region-Based CNN (R-CNN) & Fast R-CNN:** Object detection in images and videos with improved speed.
  - **YOLO:** Real-time detection with high speed and accuracy.
  - **SSD & RetinaNet:** Balancing speed and accuracy, addressing class imbalance.
  - **Mask R-CNN:** Combines object detection with instance segmentation.
  - **Feature Pyramid Networks (FPN):** Detects objects at different scales.
  - **Detection Transformers (DETR):** Simplifies object detection using transformers.
  - **Edge Detection and Segmentation-Based Methods:** Precise boundary identification.

Object Tracking:

- **Kalman Filters:** Predict future positions.
- **Particle Filters:** Handle non-linear tracking.
- **SORT & Deep SORT:** Real-time tracking of multiple objects, enhanced with appearance data.
- **Multi-Object Tracking (MOT):** Monitors multiple objects simultaneously.
- **Optical Flow:** Estimates motion vectors.
- **Mean-Shift & CAMShift:** Tracks based on color and intensity.
- **Correlation Filters:** Robust tracking under varying conditions.
- **Trackers with Deep Learning:** Uses neural networks for accurate tracking.
- **Hybrid Methods:** Combines techniques for better accuracy.
- **Background Subtraction:** Detects and tracks moving objects by subtracting the background.

II. Literature

Introduce a real-time illegal parking detection algorithm that leverages in-vehicle cameras, providing a more cost-effective and adaptable solution compared to traditional methods like manual patrolling and CCTV. The research includes the creation of a new dataset with over 10,000 labeled images and a novel labeling technique called "minimal illegal units" to enhance detection precision. Tested in Singapore, the algorithm showed robust performance across different lighting conditions. The study underscores the potential of this method to improve urban traffic management, with future plans to expand the dataset and incorporate advanced image enhancement techniques[1]

Review research on parking resource allocation, emphasizing challenges from urbanization and increasing vehicle ownership. They highlight gaps in parking planning, particularly during the early stages, as prior studies have mainly focused on pricing, behavior, and reservation systems. Shared parking is recognized as a strategy for optimizing existing spaces. The authors introduce a two-level grid model to address demand-supply imbalances, aiming to minimize construction costs, shorten user walking distances, and optimize parking allocation. The study leverages big data and machine learning to enhance demand forecasting and resource management.[2]

In urban environments, it is essential to monitor and enforce parking time limits to keep order and ensure the optimal management of parking spaces. As computer vision technologies have advanced over time, many automated systems have utilized object detection and tracking algorithms to successfully perform real-time monitoring and enforcement. The first talks about YOLO, which is a series of convolutional neural networks, and how it has been gradually fine-tuned to the current state it is in, with high accuracy and real time performance. The latest version, YOLOv8, is the most recent iteration of the network, and delivers improved detection performance. Using YOLOv8 and the combination of Deep SORT/OC-SORT with strong tracking algorithms can successfully monitor and track vehicles to detect parking time violations.[3]

Neat parking management is crucial for urban mobility and the wellbeing of smart cities. Issues of inefficiency, no access to real-time information, and manual monitoring are always present in traditional parking management systems. Above problem can be solved by using a smart real-time parking control and monitoring system which dynamically allocates parking slot as well as based on current parking situation using our AI (Artificial Intelligence technology) based application, any specific slot can be book. [4]

MOT (Multi-Object Tracking) approaches often rely heavily on strong cues like high-resolution images and robust detection models. While effective, these methods can be computationally expensive and may falter in environments with poor visibility or low-quality data. The introduction of weak cues such as motion patterns, low-resolution images, and contextual information aims to supplement strong cues, providing a more robust tracking system. Hybrid-SORT leverages these weak cues to improve tracking accuracy and efficiency.[5]

Predicting pedestrian walking speed at street crossings is very important for improving traffic control, pedestrian security, and city planning. This shapes the baseline architecture where addition of state of the art computer vision techniques such as YOLOv4 (You Only Look Once version 4) and Deep SORT (Simple Online and Real-time Tracking with a deep association metric) provide a robust framework for pedestrian tracking and estimating speeds at increasing real-time. This algorithm may be implement able in Automated measurements system for pedestrian walking speed measurement at one stage and two stage cross street crossing, As a top view captured image.[11]

A multilevel strategy, which integrates multiple techniques and levels of analysis, offers a robust solution to these challenges by improving the precision and reliability of people tracking systems. By integrating multiple levels of analysis and incorporating contextual information, this strategy addresses the limitations of traditional methods and enhances tracking accuracy and reliability. Continued research and development in this field promise further advancements, making people tracking systems more effective and versatile across various applications.[12]

Efficiently manage the transfer and parking of cars within a parking lot to optimize for space utilization, reduce congestion, and improve overall user satisfaction. Designing a reinforcement learning-based intelligent to solved the problem by constructing a Markov decision process and using a dynamic planning-based reinforcement learning algorithm (Deep Q-Networks (DQN), Double DQN, or Proximal Policy Optimization (PPO) car transfer planning system for parking lots involves several steps, from defining the problem to implementing and testing the solution.[13]

To better understand the work done in this filed a comparative study has been performed which not only compare about the problems and proposed solutions but also enlist the advantage and disadvantage of proposed solutions. It is shown in table1.

Reference	Problem Domain	Proposed Approached (Method)	Implementation Strategy	Dataset Detail	Research Gap	Limitation	Result	Conclusion
[1]	Illegal parking detection and enforcement	Voting-based detection with deep learning networks	Use in-vehicle cameras and a novel labeling method for detection	Dataset with 10,000+ labeled images	Challenges with illumination changes and distance detection	High human labor costs, installation challenges for CCTV	Strong resistance to changing illumination conditions, effective detection with new dataset	Algorithm effectively detects illegal parking and reduces labor costs.
[2]	Parking resource allocation for PEVs and V2G integration	MCMCS and MCS for stochastic parking planning	Design probabilistic models for parking lot planning and incorporate V2G	Not specified	Need for V2G integration and better systematic planning	V2G incorporation not considered, existing studies lack systematic planning	Alleviated supply-demand imbalance, effective in developing regions	Feasibility and effectiveness demonstrated in real-world scenarios.
[3]	Low-cost time violation tracking using CCTV	YOLOv8 and DeepSORT/OC-SORT algorithms for object detection and tracking.	Utilizes state-of-the-art detection and tracking techniques.	Four different Four surveillance datasets with performance metrics (HOTA, DetA, AssA, MOTA, IDF1)..	Application of SOTA detection techniques and object tracking	Human labor and CCTV limitations, need for technology adaptation	MOTA scores: DeepSORT (1.0, 1.0, 0.96, 0.90), OC-SORT (1, 0.76, 0.90, 0.83)	Low-cost time violation tracking with YOLOv8 and DeepSORT/OC-SORT is effective.
[4]	Inefficient parking utilization, congesti	AI-based slot allocation and booking,	Plate detection and recognition using IoT	Field-tested data analysis	Cost flexibility and improved efficiency	Limited visibility, confusing signage, varying costs	Vehicle plate detection accuracy measured, transmission delay and	AI-based smart parking system improves efficiency with cost-

	on, CO2 emissions, and security.	with motion and range-finder sensors.	devices				processing delay evaluated	flexible solutions.
[5]	Challenges in Multi-Object Tracking (MOT) with weak cues	Hybrid-SORT with weak cues like confidence and height state.	Utilize confidence and height state as weak cues in object tracking.	MOT17, MOT20 DanceTrack	Resolving occlusion and clustering issues.	Challenges with ambiguous strong cues during occlusion	Outperforms OC-SORT in multiple datasets with superior performance	Hybrid-SORT improves MOT by effectively using weak cues.
[6]	Parking space allocation and congestion minimization	Markov decision process with dynamic RL-based planning	Use real-time data and robust RL models for parking management	Real-world and simulated data	Need for long-term optimization in dynamic environments	Data quality, model generalization, and computational complexity	Improved parking management, reduced congestion, enhanced user satisfactin	RL-based system enhances parking space management and reduces congestion
[7]	Smart parking systems, especially in airports	Inverse perspective mapping (IPM) and YOLOv5 for vehicle detection.	4-point-based coordinate mapping and deep learning algorithms.	Simulated at Macao International Airport	Lack of smart technology focus in airport parking	Manual camera placement and analysis difficulties	Accuracy rate of 97.03%, mean distance error of 8.59 pixels	Effective camera-based parking system with high accuracy and low error.
[8]	Analyzing and improving 3D multi-object tracking methods.	Simple Track framework with improved NMS, GIoU, and Two-stage Association.	Enhance NMS, GIoU, and association modules in 3D tracking	Waymo Open Dataset, nuScenes	Need for deeper analysis of 3D MOT methods	Benchmark limitations and failure cases analysis	Achieved state-of-the-art results with minimal modifications	Simple Track offers a strong baseline with improved tracking capabilities
[9]	improved	Kalman Filter for	Reduced parking	Public and	Improve parking	Data quality,	Reduced parking time	improves existing

	efficiency, Enhancing parking duration, space size, and path continuity.	estimating traveled distance Monte Carlo method	time ,space requirements Improved path continuity and maneuverability	private datasets	duration, space size, and path continuity. .	computational complexity	and space requirement and Improved path continuity and parking duration	methods. Utilizes UKF for estimating traveled distance with smaller error.
[10]	Work on low lighting Address.	Object detection algorithm Clustering methods	Enhances parking spot utilization and reduces search time.	Real time data	Need to development in indoor areas with low lighting conditions	Low lighting in indoor areas	YOLOV4 and OPTICS achieved 95% accuracy in detecting occupied slots.	Proposed system for indoor parking used object detection and clustering.
[11]	Pedestrian safety and speed estimation	YOLOv4 and Deep SORT for pedestrian detection and speed estimation.	Track multiple pedestrians using Kalman filtering and Hungarian algorithm	Public and private datasets with bird's-eye-view video images	Accuracy in groups and crosswalk timings	Tracking limitations, issues with group pedestrians, crosswalk entry/exit times, manual intervention	mAP of 90.61%, Average pedestrian speed on subway stairs: 1.27 m/s	Pedestrian speed estimation with YOLOv4 and Deep SORT shows promising results.
[12]	Enhancing people tracking accuracy and robustness	Hierarchical tracking based on SORT algorithm	Employ hierarchical structure for bounding box association	UFPR-Planalto801 dataset	Need for real-time processing and high accuracy tracking	Limited long-term association effectiveness	Enhanced tracking accuracy and robustness in complex scenarios	Improved tracking with hierarchical approach based on SORT.
[13]	Parking space allocation and congestion minimization	Markov decision process with dynamic RL-based planning	Use real-time data and robust RL models for parking management	Real-world and simulated data	Need for long-term optimization in dynamic environments	Data quality, model generalization, and computational complexity	Improved parking management, reduced congestion, enhanced user satisfaction	RL-based system enhances parking space management and reduces congestion

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 9, No.1, September : 2024

[14]	Inefficient traditional LPR systems for real-time detection.	Deep learning-based object detection algorithm with Coordination	Enhances parking management using deep learning-based object detection.	30,000 images of cars, Korean license plates, access badges Collected from parking areas.	Lack of labeled datasets for DL-based OD models.	DL models require large, labeled datasets for training it is costly.	Mean average precision achieved: 92.16% efficiently in urban environments.	Proposed SHINE system effectively manages accessible parking space

III. ANALYSIS

The parking management and object tracking strategies shown in the table each make use of distinct techniques and approaches to solve certain problems. The examination highlights patterns and similarities among the research as well as clear variations in their approaches and outcomes. We understand that various sorting algorithms (Deepsort, OCsort, hybride sort, etc.) are used in approaches for parking management, object tracking, detection, and classification. For object tracking, YOLO technology such as YOLOv8, YOLOv5, YOLOv4, etc., is used. For classification, Kalman Filtering, window tracker, etc., is used. These approaches yield promising results, high accuracy, robustness, and real-time performance. Other areas of emphasis include maximizing the use of parking spaces through AI-driven dynamic slot allocation, IOT-based deep learning techniques, and achieving high detection and classification accuracy while enhancing security. Future work should focus on advance optimizing detection and tracking algorithms for diverse conditions, expanding the application of probabilistic models in complex parking scenarios, and exploring the integration of machine learning techniques to reduce dependency on labeled data. Additionally, improving visibility and signage within parking facilities and reducing the computational costs of these systems while maintaining high performance are critical areas for future research.

IV. Conclusion

Urban parking issues could be greatly resolved by utilizing artificial intelligence, parking system advancements, and other technology. These solutions improve motor vehicle safety, decrease emissions and traffic jams, offer immediate payment alternatives, and maximize space utilization. Recent research demonstrates how useful innovations like object detection and tracking algorithms like YOLOv8 and Deep SORT are for keeping an eye on parking laws and time limits. The literature highlights the necessity of ongoing technological advancement and integration to address issues such inadequate visibility at crossings, ineffective manual controls, and pedestrian safety. Future studies should concentrate on creating large-scale, inexpensive solutions, boosting the capability of monitoring systems, and coming up with fresh approaches to effectively handle parking and distribution. .. All things considered, smart parking systems are an essential part of the larger picture related to urban connectivity and smart city development, and new developments have the potential to significantly reduce parking congestion and improve the quality of life for users in urban settings. In conclusion, smart parking systems are essential to the development of smart cities and urban mobility, and ongoing advancements have the potential to further ease parking congestion and enhance the general urban user experience

.

References

[1] Peng, X., Song, R., Cao, Q., Li, Y., Cui, D., Jia, X., Lin, Z. and Huang, G.-B (2022). Real-Time Illegal Parking Detection Algorithm in Urban Environments. 23(11). https://doi.org/10.1109/tits.2022.3180225
[2] Guo, H. et al. 2022. Parking Resource Allocation Optimization Framework Based on a Two-Level Grid Model. 2022, (May 2022). DOI:https://doi.org/10.1155/2022/5977168.
[3] Sharma, N., Baral, S., Paing, M. P., & Chawuthai, R.. (2023). Parking Time Violation Tracking Using YOLOv8 and Tracking Algorithms. 23(13). https://doi.org/10.3390/s23135843
[4] Elfaki, A. O., Messoudi, W., Bushnag, A., Abuzneid, S., & Alhmiedat, T.. (2023). A Smart Real-Time Parking Control and Monitoring System. 23. https://doi.org/10.3390/s23249741
[5] Yang, M., Han, G., Yan, B., Zhang, W., Qi, J., Lu, H., & Wang, R.. (2023). Hybrid-SORT: Weak Cues Matter for Online Multi-Object Tracking. abs/2308.00783. https://doi.org/10.48550/arxiv.2308.00783
[6] Liu, B., Kan, S., & Chan, C.. (2023). Camera-Based Smart Parking System Using Perspective Transformation. 6(2). https://doi.org/10.3390/smartcities6020056
[7] Z. Pang, Z.Li2, N. Wang Tu.Simple (2023). SimpleTrack: Understanding and Rethinking 3D Multi-object Tracking. https://doi.org/10.1007/978-3-031-25056-9_43
[8] Zaki, A., Towfek, S. K., Gee, W., Zhang, W., & Soliman, M. A.. (2023). Advancing Parking Space Surveillance using A Neural Network Approach with Feature Extraction and Dipper Throated Optimization Integration. 6(2). https://doi.org/10.54216/jaim.060202
[9] Kasemtaweechok, C., Srimaruang, C., Uaonnamphetr, P., & Phongrusamepane, A.(2023, December 15). Automatic Vehicle Parking Availability System for Indoor Environments .https://doi.org/10.1145/3638837.3638850
[10] Smohammadi , A.khosravi , P.Ssarhadi , & F.Tavakkoli. (2023). An Automatic Parking Algorithm Design Using Multi-Objective Particle Swarm Optimization. 11. https://doi.org/10.1109/access.2023.3276858
[11] Ghomashchi, H., Paterson, J., Novak, A. C., & Dutta, T.. (2024). Estimating pedestrian walking speed at street crossings using the YOLOv4 and deep SORT algorithms: Proof of principle.. 119. https://doi.org/10.1016/j.apergo.2024.104292
[12] Cristiano B. de Oliveira, Joao C. Neves, Rafael O. Ribeiro, David Menotti(2024), A Multilevel Strategy to Improve People Tracking in a Real-World Scenario, International Conference on Computer Vision Theory and Applications (VISAPP), Vol. 4,pp.1-8.
[13] Feng Guo1 , Haiyu Xu2 , Peng Xu2 and Zhiwei Guo2(2024),Design of a reinforcement learning-based intelligent car transfer planning system for parking lots, Mathematical Biosciences and Engineering, Vol. 21, Issue 1,pp.1058-1081.
[14] Neupane, D., Bhattarai, A., Aryal, S., Bouadjenek, M. R., Seok, U.-M., & Seok, J.. (2024). Shine: A deep learning-based accessible parking management system. 238. https://doi.org/10.1016/j.eswa.2023.122205
[15] Shanmugamani, R. (2018). Deep learning for computer vision: Expert guide to PyTorch, TensorFlow, and Keras. Packt Publishing.