Pawale Gauri Sandip 2026, 14:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Ai-Based Smart Parking And Traffic Prediction Systems: A Review Of Occupancy Detection, Availability Forecasting And Spatio-Temporal Traffic Models

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Abstract—Urban growth and rising vehicle numbers have created severe traffic congestion and shortages of parking space, leading to longer travel times, higher fuel consumption, pollution and driver frustration; a significant share of urban traffic consists of drivers searching for parking. This paper reviews AI-based smart parking and traffic prediction systems. It examines parking occupancy detection with in-ground sensors and with camera images classified by deep convolutional networks on public parking datasets, prediction of future parking availability with spatio-temporal models, and traffic flow forecasting from classical regression and decision trees to deep learning and graph neural networks that model road networks. The roles of cloud computing and mobile applications in guiding drivers are discussed. A five-layer architecture combining parking and traffic sensing, data integration, an AI prediction engine, a recommendation and guidance layer and user and authority applications is proposed, with research gaps, objectives, a comparison of techniques and challenges such as sensor cost, data quality, privacy and integration with existing infrastructure. The review concludes that integrating parking availability with traffic prediction can reduce cruising, waiting time and emissions while improving the use of parking facilities.

Index Terms—Smart parking, parking occupancy detection, traffic prediction, deep learning, graph neural networks, IoT, smart city, intelligent transportation

I. INTRODUCTION

In busy commercial areas of Indian cities, drivers often circle for many minutes looking for a parking space, adding to congestion and pollution. Shoup [1] analysed "cruising for parking" and showed that it can account for a substantial share of traffic in congested districts. At the same time, some car parks remain underused because drivers do not know about them.

Smart parking systems detect which spaces are free and guide drivers to them, and traffic prediction systems anticipate congestion so that drivers can choose better routes and times. Lin *et al.* [2] surveyed smart parking solutions covering sensing, communication and services. AI improves both occupancy detection and prediction.

This paper reviews AI-based smart parking and traffic prediction and proposes an integrated architecture.

II. BACKGROUND AND RELATED WORK

1. Components

Fig. 1 summarizes the components: occupancy sensing, availability prediction, traffic flow prediction and driver guidance.

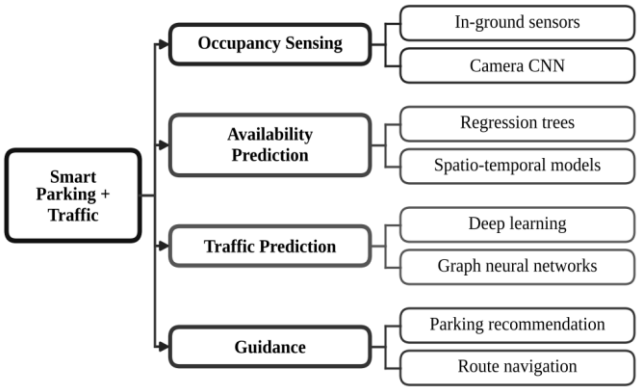


Fig. 1. Components of AI-based smart parking and traffic prediction.

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2. Sensing Options

In-ground magnetic or ultrasonic sensors detect a vehicle over each space; cameras cover many spaces at once and use image classification; and crowdsourced data from mobile apps provide additional signals.

3. Review Of Related Studies

Occupancy detection. De Almeida *et al.* [3] released PKLot, a large dataset of parking-lot images under different weather conditions, and showed that texture features with classifiers can detect occupancy. Amato *et al.* [4] used compact CNNs running on smart cameras for decentralized occupancy detection and introduced the CNRPark dataset, achieving high accuracy with low computation.

Availability prediction. Rajabioun and Ioannou [5] predicted on-street and off-street parking availability with multivariate spatio-temporal models, and Zheng *et al.* [6] compared regression trees, neural networks and support vector regression for car parks in smart cities, finding regression trees accurate and efficient.

Traffic prediction. Lv *et al.* [7] showed the benefit of deep learning for traffic flow prediction. Yu *et al.* [8] proposed spatio-temporal graph convolutional networks, and Li *et al.* [9] modelled traffic as diffusion on a road graph. Jiang and Luo [10] surveyed graph neural networks for traffic forecasting and found them the leading approach on standard benchmarks. Table I summarizes these works.

Ref.	Authors	Year	Technique Used	Merits	Demerits
[1]	Shoup	2006	Analysis of cruising for parking	Cruising adds major traffic	Economic analysis
[3]	de Almeida et al.	2015	PKLot dataset	Robust occupancy benchmark	Fixed camera views
[5]	Rajabioun and Ioannou	2015	Spatio-temporal availability models	On- and off-street prediction	Sensor data needed
[6]	Zheng et al.	2015	Comparison of predictors	Regression trees effective	Single city
[7]	Lv et al.	2015	Deep traffic flow prediction	Outperforms shallow models	Freeway data
[4]	Amato et al.	2017	Compact CNN on smart cameras	Decentralized accurate detection	Occlusion issues
[8]	Yu et al.	2018	Spatio-temporal GCN	Fast accurate traffic forecasts	Fixed graph
[10]	Jiang and Luo	2022	Survey of GNN traffic models	GNNs lead benchmarks	Survey only

TABLE I Summary of Literature Survey

III. RESEARCH GAP AND OBJECTIVES

1. Identified Research Gaps

- Per-space sensors are costly to deploy across a whole city.
- Camera-based detection is affected by occlusion, lighting and weather.
- Parking and traffic predictions are rarely combined in a single service.
- On-street parking in India is often informal and unmarked.
- Location data from drivers raise privacy concerns.

2. Objectives Of The Review

1. To review parking occupancy detection methods.

2. To examine parking availability and traffic prediction models.

3. To propose an integrated smart parking and traffic prediction architecture.

4. To compare techniques in accuracy, cost and scalability.

5. To identify challenges and future directions.

I. Design of the Proposed System

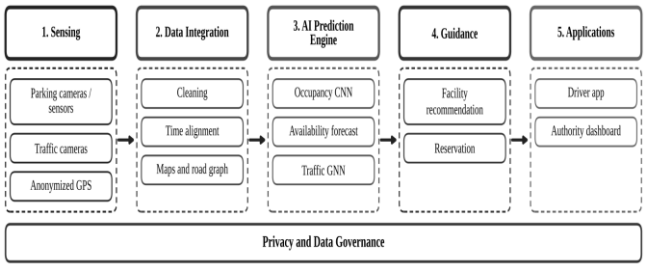


Fig. 2 shows the proposed architecture.

Fig. 2. Proposed integrated smart parking and traffic prediction architecture.

3. Sensing Layer

Cameras and sensors in parking lots, traffic cameras and loop detectors on roads and anonymized GPS data from navigation apps provide inputs.

4. Data Integration Layer

Data are cleaned, time-aligned and stored in the cloud with a map of parking facilities and the road network.

5. Ai Prediction Engine

A CNN classifies occupancy from camera images, a time-series model forecasts availability for the next 15 to 60 minutes and a graph neural network predicts traffic speed on each road segment.

6. Guidance Layer

A recommender suggests the parking facility that minimizes total time, combining predicted travel time and availability, and supports reservations.

7. Application Layer

Drivers use a mobile app with navigation; authorities use dashboards to manage pricing, enforcement and traffic.

8. Methodology

Fig. 3 describes the workflow. For each candidate facility j, the expected total time is

$$T_j = \hat{T}_{travel(j)} + T_{walk(j)} + (1 - \hat{p}_j) \cdot T_{search} \quad (1)$$

where $\hat{p}_j$ is the predicted probability that a space will be available on arrival. The facility with minimum T_j is recommended. Prediction accuracy is evaluated with mean absolute error, and occupancy detection with accuracy and F1-score.

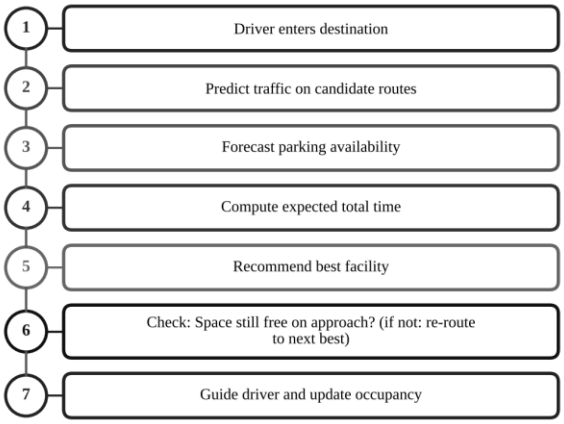


Fig. 3. Smart parking guidance workflow.

IV. DISCUSSION AND COMPARISON

Table II compares techniques. Per-space sensors are accurate but expensive, camera-based CNNs cover many spaces cheaply, regression trees forecast availability efficiently and graph neural networks give the best traffic forecasts.

Technique	Task	Cost	Accuracy
Per-space sensors	Occupancy	High	Very high
Camera + CNN	Occupancy	Low–Medium	High
Regression trees	Availability forecast	Low	Medium–High
LSTM	Traffic forecast	Medium	High
Graph neural network	Network traffic forecast	Medium	Very high

TABLE II Comparison of Parking and Traffic Techniques

V. CHALLENGES AND FUTURE DIRECTIONS

Table III summarizes challenges. Future directions include dynamic pricing based on predicted demand, integration with public transport, automated

enforcement and support for electric-vehicle charging spots.

Challenge	Mitigation
Sensor cost	Camera coverage; crowdsourcing
Weather and occlusion	Robust CNNs; multiple views
Informal parking	Video analytics of street segments
Data quality	Validation; sensor fusion
Privacy	Anonymization; aggregate data

TABLE III Challenges and Mitigation

VI. CONCLUSIONS

Smart parking and traffic prediction address two closely linked urban problems. The reviewed literature shows accurate occupancy detection with CNNs, reliable availability forecasting and state-of-the-art traffic prediction with graph neural networks. Combining these capabilities in one service that guides drivers to available parking along the fastest route can reduce cruising, waiting time, fuel use and emissions.

1. Acknowledgment

The authors express their sincere gratitude to the Department of Artificial Intelligence and Data Science, Jaihind College of Engineering, Pune, for providing the facilities, guidance and encouragement needed to carry out this work. The authors also thank the faculty members and colleagues whose valuable suggestions helped improve the quality of this review.

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