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ORIGINAL ARTICLE

Smart parking systems technologies, tools, and challenges for implementing in a smart city environment: a survey based on IoT & ML perspective

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Abstract
Smart Parking systems are inevitable considering the growing population, particularly in the urban areas. Most of the people prefer to use private transportation for their convenience which results in an increased number of vehicles and hence increased traffic. Also cruising for parking is one of the most chaotic tasks leading to traffic congestion and increased consumption of time, fuel, and energy. This paper analyzes the smart parking solutions from a technical perspective related to Internet of Things and Machine Learning which are the two popular advancing areas. A detailed survey on the current state of art developments in smart parking systems incorporating the above-mentioned areas is included. In addition, the paper explores the role of smart parking in a smart city environment and the benefits of espousing parking 4.0. Furthermore, the current challenges in SPS, the possible solutions and future scopes in its implementation are also presented.

Keywords Smart parking systems (SPS) · Smart city (SC) · Machine learning (ML) · Internet of Things (IoT) · Sensors · Parking 4.0

Abbreviations

3D	Three Dimensional
AI	Artificial Intelligence
API	Application Programming Interface
CAGR	Compound Annual Growth Rate
CNN	Convolutional Neural Network
DELM	Deep Extreme Learning Machine
DL	Deep Learning
DNN	Deep Neural Network
EC	Edge Computing
EM	Ensemble Model
EV	Electronic Vehicle
EV	Electric Vehicle
FC	Fog Computing
FCN	Fully convolutional network
FRCNN	Faster RCNN
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IoT	Internet of Things
IR	Infrared
IT	Information Technology
ITS	Intelligent Transportation System
LCD	Liquid Crystal Display
LED	Light Emitting Diode
ML	Machine Learning
M2M	Machine to Machine
MRCNN	Mask RCNN
NN	Neural Network
PMS	Parking Management Systems
QoS	Quality of Service
RCNN	Region-based Convolutional Neural Network
SC	Smart City
SPS	Smart Parking Systems
SSD	Single Shot Detector
SVM	Support Vector Machines
VANET	Vehicular Ad hoc Network
WSN	Wireless Sensor Network
YOLO	You Only Look Once

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1 Introduction

Smart cities are those with IT driven infrastructure and it helps in enhancing the quality of life of its inhabitants. Smart parking's are inevitable as far as smart cities are considered and they make the cities safer, habitable and congestion less. The status quo of urban transportation is undergoing a rapid change, as new technologies and business models are being introduced into the market. Also, the existing transportation and mobility systems are expected to endure a massive transformation. As more people live in urban areas compared to rural settings, the role of designing an intelligent parking ecosystem is essential in determining the quality of life in future cities [32]. Some of the advantages of developing SPS are:

- It helps to optimize parking spaces and enables effective & data driven decision making.
- Improves the quality of existing transportation systems by reducing the traffic.
- Lowers the negative environmental impacts by reducing harmful emissions due to traffic congestion.
- Enhances user experience by reducing time, energy, and fuel wastage due to elevated traffic.
- Boosts economic development and reduces vehicle vandalism through real-time monitoring of parking areas.
- Provides integrated payments and enhances new business models with newer technologies.
- Effective utilization of parking spaces and on-demand allocation of parking slot as per user requirements thereby reducing parking search time.

The COVID-19 pandemic has radically disrupted people's travel habits. Due to the heightened awareness of the risk of infection, many people stay away from using public transportation. So, the count of personal vehicles is expected to rise even more as a symbol of safety and autonomy. For the reason of the reduced travel demand owing to the imposition of stringent rules and regulations, a higher portion of private vehicle use will probably reduce the distances travelled by people. In fact, less driving and hence less traffic congestion can be expected at these times [33].

SPS make use of various technologies and these systems are already implemented in numerous environments. It also utilizes a variety of complementary technologies such as sensors, Deep Learning (DL), augmented reality, and different routing algorithms [15]. Advancing technologies like Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) helps in efficiently managing urban environments thus reducing the complexity in parking and the search time. It also provides trustworthy data regarding the people's parking demands and customer patterns to the parking officials [53]. IoT is a paradigm that interconnects devices, people, or networks and has ushered in a new epoch where a wide variety of devices or appliances are interconnected and shares information. It helps the devices to be intelligent i.e., allows the devices to communicate without human arbitration. Data is processed and stored in a decentralized manner with the help of cloud or edge devices. IoT acts as the core technology involved in designing a SPS [50]. Some of the benefits of incorporating IoT in SPS are user can make parking reservations beforehand with the help of parking apps, information about vacant spots can be identified with the help of connected sensors and edge devices, parking time extensions can be done with the help of connected platforms, identifying various parking zones, and alerting drivers to avoid violations, and to provide efficient citywide parking utilization [79].

ML is another core technology that is widely used in SPS. ML is a subset of AI which delivers the system with the ability to learn and improve a task from its past experiences without overtly programming the system [75]. It makes use of various intelligent algorithms to predict the status of a particular parking bay. Some advantages of integrating ML with IoT SPS are reduced latency, developing real-time applications without centralized servers, and developing reliable and robust parking applications [44]. DL is a subset of ML which make use of multiple NN architectures or intense processing algorithms for data processing. It considerably reduces the number of sensors or cameras used in parking areas. Here parking predictions can be made with real-time data analytics [16].

There are several review papers that encompass different aspects involved in the development of SPS. In [71], authors have reviewed various types of SPS based on vehicle detection techniques. It also provided a comparison on algorithms, methodologies, and classification techniques and analyzed the status of SPS based on the commonly used methods. In [26], authors analyzed the technical perspective of smart parking incorporating sensor types and various technologies. Authors in [68] presented a narrative review in real-time application advancement based on mean stack web application technology. They focused on cross-platform applicability of SPS in real-time. A review on recent technologies, identifying each SPS component and trends are explored in [24]. Authors have provided an overview of existing IoT technical details, applications, and latest emerging trends in SPS.

In [91] authors have provided an in-depth survey on IoT based diverse parking solutions and recent progresses in smart parking. Big data analytics, key tools, and challenges are also identified. An in-depth review on recent advances in sensing and communication technology in parking is delivered in [26, 38]. It includes various parking facility management services and their technicality, protocols, and standards used in terms of IoT. Various smart parking technologies, sensors, and applications for open parking lots are reviewed in [74]. Authors have discussed how smart parking revolutionized human life and what are the future technological enhancements required. The paper [49] projects various aspects in smart parking and widely used systems by end users. It also includes a review of different technologies and components used for SPS.

In [38], authors aim to provide a comprehensive study, comparison, and analysis of SPS in terms of technologies, sensors used, network and user interfaces, computational approaches and the service provided. This paper [65] provides a brief idea about the various techniques that have come up to sort various routine problems of parking and flaws. In [10], authors gave an overview about the concept and different functionalities of SPS.

They have presented the developments in parking infrastructures, technologies around parking availability monitoring, parking reservations and dynamic pricing and their utilization in different settings. In [28] authors examined at energy-efficient automated systems, reservation and parking guidance, and AI-based smart parking solutions. The study in [97] looked at current communication technologies and prospective system features for a smart parking solution that could address issues with the university's existing smart parking systems.

The literature on the usage of smart parking sensors, technologies, and applications is reviewed in [28]. A machine vision and embedded system combination is suggested as the best choice for open parking lots by the authors. This study [93] reviews the literature on the use of smart parking sensors, technologies, and applications and evaluates how well suited they are for open parking lots. They have also included various SPS applications. Each of these papers has a different focus, covering topics like the various types of SPS, hardware and software requirements, parking applications, technologies employed, etc. Then, in Table 1, the scopes of the review papers are contrasted with the contribution of our paper.

The motivation for writing this survey paper is that even though these papers provided a detailed survey, they lacked in providing an overall picture of the key aspects required in designing a SPS. Here, we present all the essential components required for devising an SPS so that it helps an academic or industrial person to understand the basics and in-depth technologies used to design a SPS. This survey also discusses and analyzes the state-of-the-art communication technologies that can be used for SP. Furthermore, the detailed stages of development required for building such systems are also provided that can be easily understood by technical as well as non-technical persons which helps in building a solid foundation for the readers who are most interested in the implementation of SPS. The outline of the contribution of this paper are as follows:

Table 1 Compared to our paper, the scope of comparable surveys is provided

References	SPS technologies and sensors	Hardware requirements	Software requirements	Parking 4.0 insights	SPS tools	Parking application	Challenges	Future scope
[71]	✓	–	–	–	–	✓	–	✓
[26]	✓	–	–	–	–	–	–	✓
[68]	✓	–	✓	–	✓	–	–	✓
[24]	–	–	–	–	✓	✓	✓	✓
[91]	–	–	–	–	✓	✓	–	✓
[26]	–	✓	–	–	–	✓	✓	✓
[38]	–	–	–	–	✓	✓	–	–
[74, 75]	✓	–	✓	–	✓	✓	–	✓
[49]	✓	–	–	–	✓	–	✓	–
[38]	✓	✓	✓	–	–	–	✓	–
[65]	-	✓	–	–	✓	–	–	✓
[10]	✓	–	✓	–	–	✓	✓	✓
[28]	-	–	–	✓				–
[97]	✓	✓	–	–	✓	–	–	✓
[28]	-	–	✓	–	–	✓	✓	✓
[93]	✓	–	–	–	✓	–	✓	✓
Our paper	✓	✓	✓	✓	✓	✓	✓	✓

(i) Core components and significant technologies utilized for designing a smart parking system along with its categories are discussed along with the benefits and shortcomings of SPS which aids in understanding the fundamentals and in-depth technologies required to develop an SPS for an academic or industrial individual.
(ii) An insight into the domain of Parking 4.0, its key driving technologies, and characteristics compared to traditional parking systems are provided.
(iii) Discusses relevant sensors, application domains, software, and hardware involved in IoT, and ML based smart parking.
(iv) Provides a narrow glimpse of different tools and the available parking applications developed in various countries.
(v) Furthermore, current challenges, the solutions to address these research challenges, challenges from user perspective and their possible solutions, ethical issues and future trends related to the implementation of SPS have also been discussed.

The rest of the article is organized as follows: Sect. 2 describes a basic smart parking eco-system and how it is categorized according to the mechanisms utilized. Section 3 discusses the layered architecture adopted for ML and IoT integrated smart parking systems. It also describes the participants involved in each layer and their functionalities. In Sect. 4, a brief introduction to parking 4.0 and their features compared to the traditional parking systems are discussed. A detailed analysis on the smart parking implementation papers in the field of IoT and ML along with various technologies, hardware and software platforms, sensors utilized are reviewed in Sect. 5. In ML implemented papers, a detailed list of different datasets applied, and the obtained model accuracy is also provided. Different smart parking technologies, sensors along with the available smart parking applications implemented in various countries are provided in Sect. 6. In Sect. 7, current challenges, and future research opportunities in SPS are discussed. Finally, Sect. 8 concludes the paper.

2 Smart parking systems (SPS)

All of us have been in a situation of searching for a parking spot especially while visiting malls and spending a lot of time waiting for the other vehicle to locomote. Also, the increase in the number of vehicles per year adds to congestion which no one can avoid. SPS comes to rescue in these situations which adds intelligence to the existing car parking systems. The basic information flow in a SPS is represented in Fig. 1.

To find a parking space easily, it's important to know the traffic and information flows. It requires proper communication between the parking infrastructures and users to have a clear-cut knowledge of the city traffic and the parking statuses [69]. Figure 2 shows the average amount of time spent by a person searching for a free space. Decisions about the parking status can be taken before the vehicle arrives at the parking location. Pre-trip decision process depends on the availability of information about a parking lot and the distance and time required for parking according to user preferences.

Integrated parking network with advanced technologies helps the user in these circumstances to take appropriate decisions. Whenever a vehicle leaves the parking lot, the parking modules communicate with each other and update the status in the database about parking availability.

Intelligent parking is a critical element in smart cities and smart mobility context. Various parking surveys forecast that the current tempo of suburbanization and motorization will lead to an explosion in the user parking needs. IoT analytics expectancy on the growth of smart parking market globally is represented in Fig. 3. As per the above report, CAGR of SPS is estimated to increase by 14% i.e., to have a growth from 1.9 to 3.8 billion USD by 2023. It shows the total money expended on the worldwide deployment, outlay and the shipment of various SP hardware devices. Also, 30–45% of traffic in urban areas are caused by vehicles searching for vacant spaces [69].

SPS can be categorized into different types according to the mechanisms used for parking. Some of them are centralized parking systems, parking reservation and guidance systems, agent-based parking systems, crowdsourcing systems, and electrical vehicle parking systems.

2.1 Centralized parking systems

In this type of parking system, a central server controls the entire system. The sensors or cameras present in the parking lots will send the information captured to this central server and it further processes the data and sends the required information to the users or to the display panels. And the needed data is sent to the cloud for storage [85]. One disadvantage of using such systems is that once the centralized server fails, it fails the entire system [15].

2.2 Parking reservation & guidance systems

Here a user can make parking reservations ahead of their arrival at the destination. Usually, the user communicates with the parking lot with the help of mobile phones or web pages [52]. Once a parking reservation is made it also guides the user to reach that spot. In some systems if the user didn't

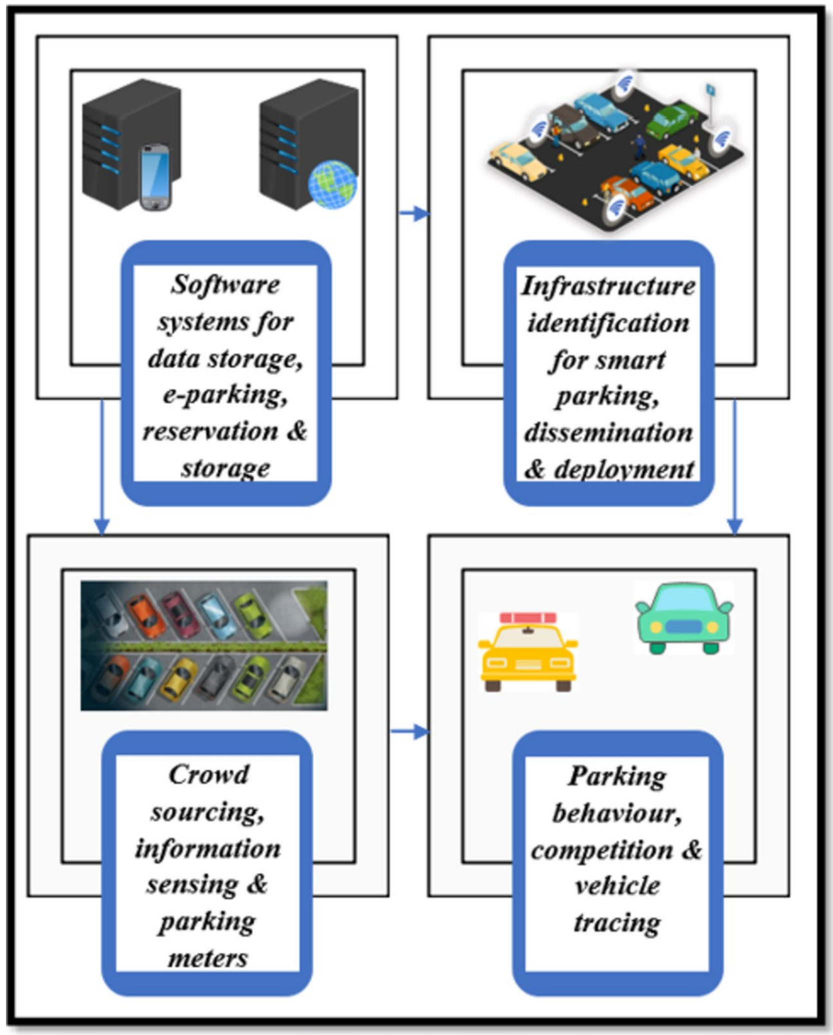

Fig. 1 Information flow in SPS

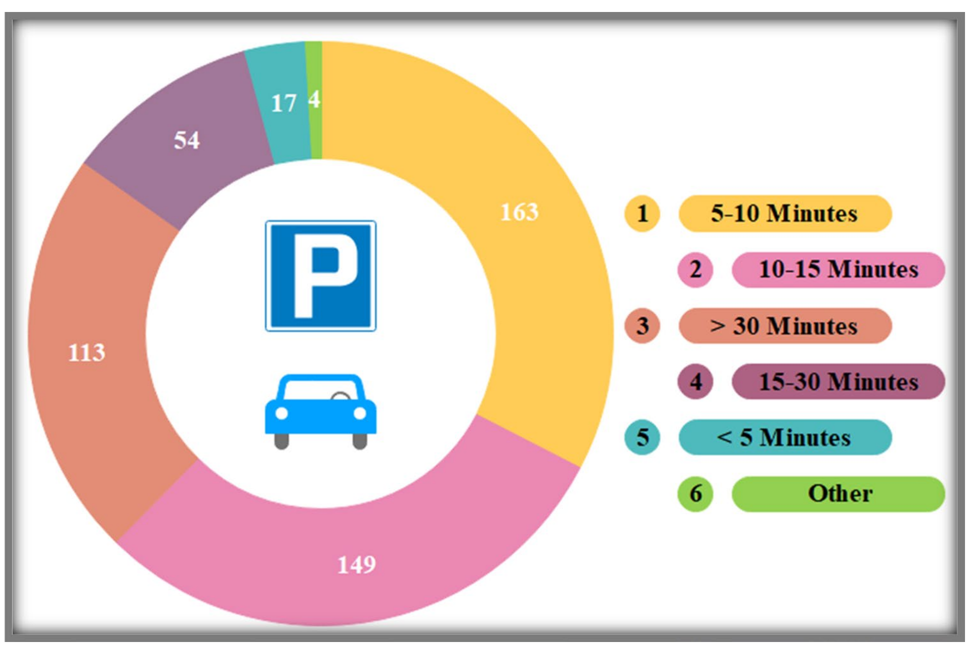

Fig. 2 Time expended in search of vacant parking space [69]

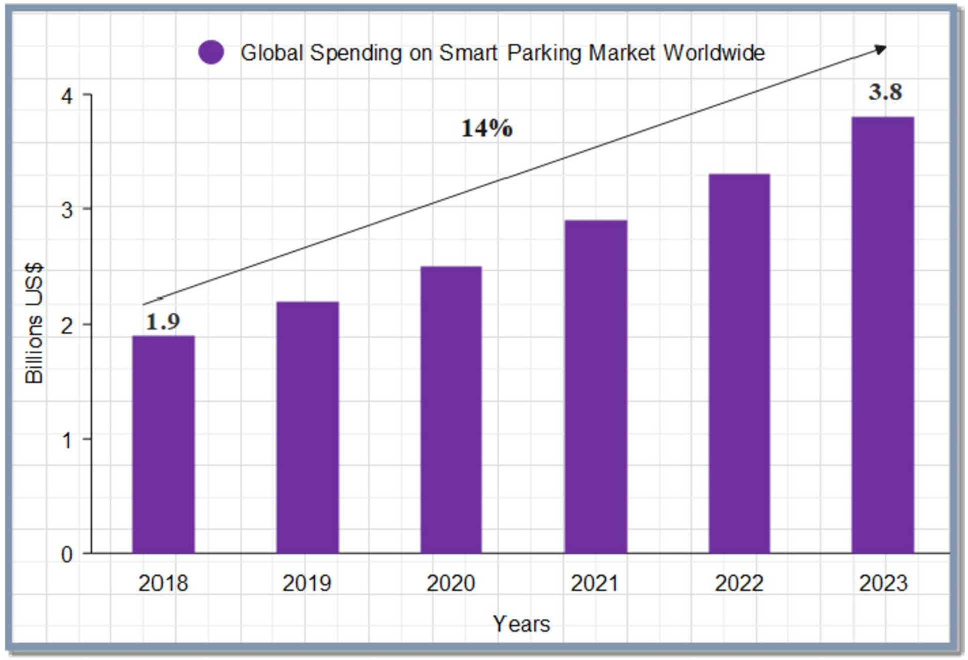

Fig. 3 IoT analytics on smart parking market report 2019–2023 [29]

make a prior reservation, it guides the user to the nearest empty slot available at that time thereby reducing the search time in finding an empty spot for parking [85].

2.3 Crowdsourcing systems

Currently multiple crowdsourcing approaches are explored to identify empty parking slots in real time. Rather than employing expensive sensors or cameras in the roads, these systems collaborate with a pool of persons who spend lot of time in driving or through other users with a smart phone to update about the current parking status within their reachability [30]. Other technique is to collect real time data from various users using different parking applications and to use predictive models to foresee the parking statuses [3].

2.4 Electrical vehicle parking systems

As the popularity of EV are increasing, many parking garages have started to include dedicated EV charging units to meet the growing demands [28]. These charging stations contains cameras or sensors to identify whether it is occupied or free and then this information is passed to the parking server. Once the real-time status is obtained, the server calculates shortest route to reach the charging bay and updates the information to the user with the help of web or mobile app [80].

2.5 Other techniques

In agent-based systems, agents on behalf of both drivers and parking lots interacts with each other and do the negotiations on parking policies, prices, finding optimal routes etc. This method involves using complicated algorithms and game theory techniques thereby increasing the implementation cost. Hence, they are least used compared to other parking methods [73].

In dynamic-pricing systems, the parking prices are increased or decreased based on the demand and availability of a parking space. Here real time parking data are utilized for price calculation to overcome the traffic congestion [46]. Various SMS based reservation systems are also available where user can make prior parking reservations.

3 SPS architecture

SPS does not have a single unified architecture and researchers have proposed various architectures based on the type of parking spaces or according to the requirements of parking authorities [2]. A basic IoT and ML integrated SPS architecture comprises of multiple application platforms integrated into an embedded structure as represented in Fig. 4. The major components in this layered architecture are as follows.

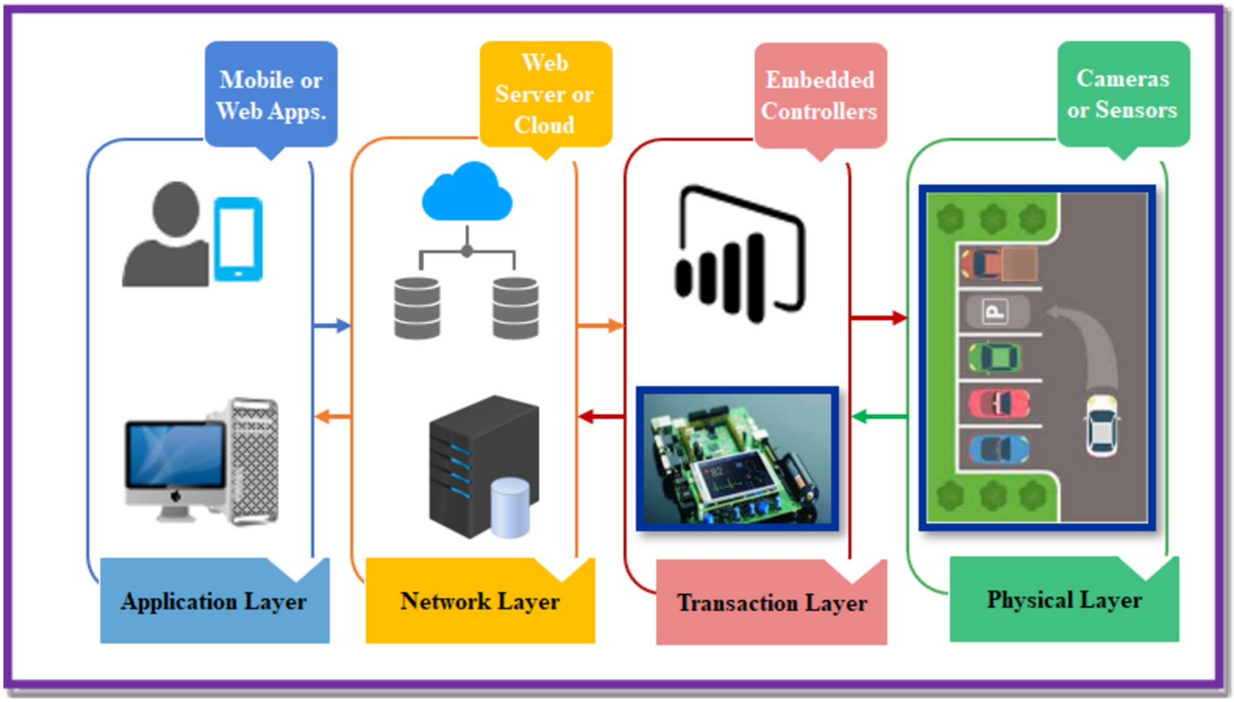

Fig. 4 IoT and ML integrated SPS architecture

3.1 Physical layer

This layer consists of a set of physical sensors or cameras installed in the parking spaces to identify the presence of a parked vehicle. They provide a cost-effective and intelligent solution for parking space occupancy detection [11]. When the parking sensors detect the presence of a vehicle, the sensors trigger an event, before sending data to a remote server. Data from these nodes are sent using different technologies to the remote gateway server for storage.

3.2 Transaction layer

This is the embedded controller or the edge device that deals with data processing. The data from the previous layer i.e., data from multiple sensors are received and analyzed to determine the occupancy status of each parking slot. Once done, the processed data is sent to the parking screens for the users to identify the vacant spots and to the cloud device for storage. It also checks the authenticity of the users in case they have made parking reservations [18].

3.3 Network layer

This is the middleware layer that provides data storage and computing resources for the car parking service. It consists of central web servers and databases or cloud devices. They ensure flawless communication among various parking centres and users. The user reservation requests as well as the parking status from previous layers are stored in this layer [35].

3.4 Application Layer

This is the topmost layer that deals with user interactions and parking reservation requests. The user interacts with the system with the help of a mobile application or web application. Users can search for parking space availability before travelling and can make reservations at different parking locations. Also, the parking service provider sends the parking related information (availability of spaces) to this layer and deals with end user services. It can also send the driving directions to the user with a complete map depending on the application and the services provided [48].

4 Parking 4.0

Parking can be thought of as a service industry evolved across generations with varying trends. Parking 1.0, which is the first generation, provides the users with a simple space-renting service model controlled manually, where a parking attendant will collect money and provide the parking tickets [66]. The next generation Parking 2.0 partially automated the parking services by mechanizing the fee collection and the reviewing systems [62]. Then comes Parking 3.0 which is the current generation where the users can monitor the current parking status of a parking slot and can make independent decisions on reserving a slot, ticketing, and fee payment according to their needs [89].

As the parking demands are growing day by day, increasing the parking capacity especially in the urban areas is a challenging task. The scarcity in the available urban space adds to this difficulty which makes no further room for improvement. To address this issue Parking 4.0 is introduced to increase the parking efficacy with an urban optimization strategy incorporating a variety of mobility and space dimension techniques [82].

Due to the increasing demands in on street and off-street parking, many companies from ITS, automation, telecom, and automotive sectors are showing more interest in SPS. Integration of IoT and AI aids in developing various technologically innovative solutions which can add intelligence to the existing parking systems. Figure 5 represents the core technologies used in this scenario.

Some of the key drivers for Parking 4.0 are as follows:

- Traffic congestion, growing demands for off-street parking in urban areas, and the escalating needs of smart infrastructure in public-private areas such as shopping malls, airports, entertainment parks, offices, campuses etc. adds to the need for intelligent SPS.
- The need for technologically zealous parking services with dedicated sensors, cameras etc. for data collection and communication with control centers.
- The integration of SPS with other smart city business models such as street lighting, parking meters etc. to overcome the economic barriers, to grow the piggybacking on previously deployed systems, and to improve the overall city parking revenue.

Parking 4.0 is expected to merge the finest of Industry 4.0 and Business 4.0 with newer technologies, advanced business analytics, and experienced engineering skills. These SPS comprises of parking status monitoring, parking reservation and guidance to the reserved space, pricing

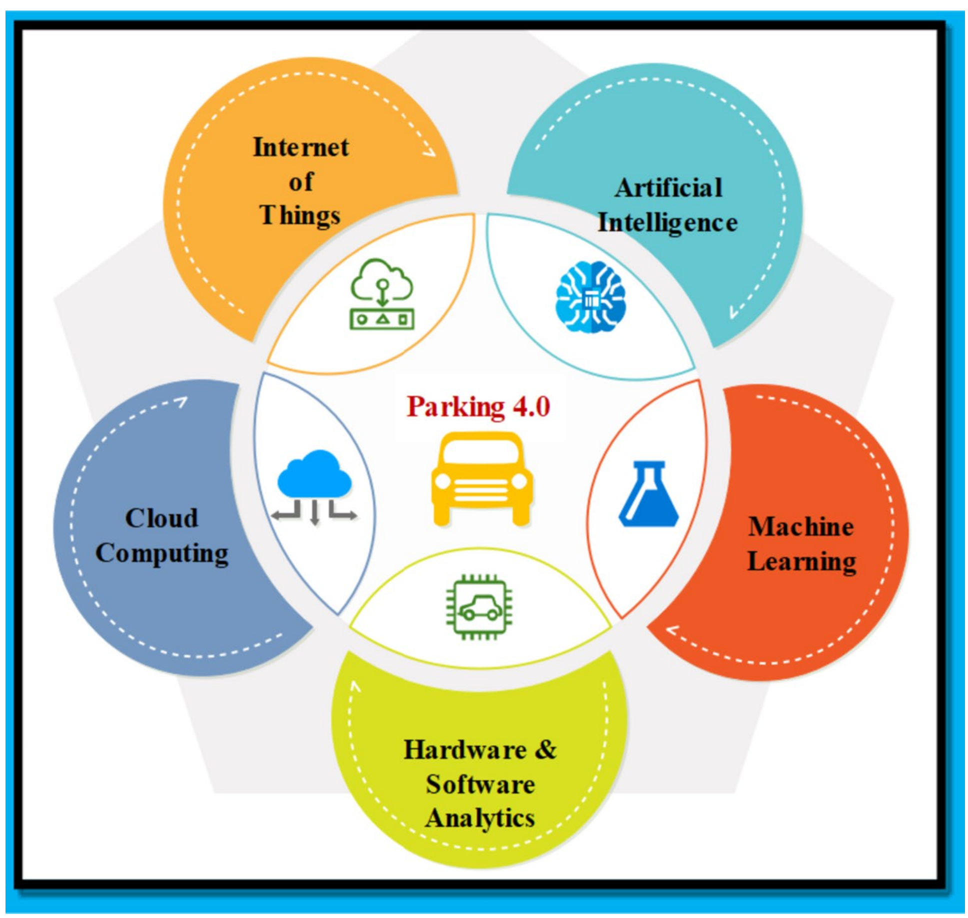

Fig. 5 Smart parking 4.0 technologies

and policy regulation mechanisms and parking space optimization [45]. This helps to reduce the overall time required for parking and guides the person to the nearest empty slot. It also deals with report generation, integration of payment and support management system and system management (providing timely maintenance and service) [77].

Compared to the traditional parking systems some of the advanced features offered by these SPS are as follows:

- ☐ Up-to-date parking status monitoring.
- ☐ User preferred parking reservation with guidance to that slot.
- ☐ Rapid access to SPS and re-scheduling of parking services.
- ☐ Multipurpose parking systems (EV charging, Waiting & pickup areas for taxis or self-drive car company services).
- ☐ Robot-taxi, robot-valet parking services and automated vehicle services.
- ☐ Parking demand and policy management.
- ☐ Automated parking and overstay violation detection management.
- ☐ Improved software analytics.
- ☐ Bundled applications and services from parking & car sharing service providers.
- ☐ Providing monetization engines and brokering services connecting data producers & consumers.
- ☐ Forecasting parking patterns in different zones to improve QoS.
- ☐ Integrated traffic control management system in a SC eco-system.
- ☐ Interconnected parking lots.
- ☐ Provides 3D-Garage which utilizes less land space.

These are some of the finest features that are expected to meet by means of Parking 4.0. Also, by combining IoT with parking, the parking status, reservations, and updates can be accessed by the users with the help of cloud storage. In addition, with these intelligent parking systems, the status of every single parking space in the city can be identified thereby efficiently utilizing city's idle resources.

5 IoT & ML in smart parking systems

ML models, especially the DL models, comprise complex prototypes with large number of parameters and heavy computational resources. Even though the integration of ML on embedded devices (edge computing) is a challenging task, they are better for large scale IoT applications in a SC [23]. Since the data are processed at edge, these applications don't require data to be sent to the centralized servers and thereby

Table 2 Represents different ML techniques used for parking status detections along with the detection accuracy, classification algorithms, and the datasets used

References	ML models	Datasets	Datasets
[91]	Dilated CNN	PKLot, CNRPark + EXT	97.24
[26]	RCNN	PKLot, CNRPark	97.97
[38]	Pre-processed MRCNN	CNRPark	91.01
[74]	Select & Prune FCN	DeepPS	98.00
[49]	Deep CNN	PKLot, CNRPark, CNR-Park + EXT	98.07
[38]	MRCNN	COCO	94.00
[65]	Hybrid EM	DeepPS	95.20
[10]	DELM	NA	94.37
[28]	Faster RCNN	PKLot, Barry Street	99.00
[97]	Customized DL-NN	PKLot, CNRPark	99.50
[28]	SSD-CNN	CNR, CARPK	95.00
[93]	Faster RCNN	PKLot, COCO	99.00
[69]	SVM	Customized Dataset	99.96
[69]	SVM	PKLot, CNRPark + EXT	96.59

reducing the latency [60]. Authors have proposed different interpretations of SPS adopting various advanced technologies, dedicated sensors, cameras for wider coverage, smart phones, single board computers etc. Some of the ML based SPS implementations and their features are discussed below (Table 2).

In [70], authors have proposed a new architecture for predicting car occupancy status called CarNet which uses dilated CNN. Dilated CNN is a dilation applied to normal CNN with defined bands to extract high-frequency features from an image dataset by increasing the receptive viewpoint of the network. Rather than learning too deep here they have used a 3-layer architecture with larger window size to identify whether the parking slot is empty or full. Since it is a narrow architecture, the detection rate is faster compared to other methods. In [103], authors have designed an automatic parking space detection mechanism using RCNN based on image segmentation. Here a selective search mechanism is applied to extract just 2000 regions from an image to CNN. They applied ZFNet architecture which uses small filters to reduce the strides of convolution resulting in the reduction of the overall computational cost.

A pre-processed Mask-RCNN mechanism is used in [64] for car parking status detection. Here convolution operation is done once per image to generate the feature map and then the region of proposals are identified and wrapped into squares. Then using Pooling layer, these proposals are reshaped to fixed size and fed to the fully connected layer. Then SoftMax layer is used to predict the class of proposed region along with bounding box and offset values.

Authors in [67] proposed a smart parking slot detector using CNN which uses a select and prune mechanism for faster detection. The strategy is to select the best receptive fields and prune the unnecessary channels after training each epoch. This approach can even detect corners and line features of parking slots efficiently using a fully CNN. A decentralized visual parking lot occupancy detection method for cameras using deep-CNN is proposed in [9]. This helps to reduce the overall communication overhead and the computing bottlenecks that prevail in a centralized parking architecture. Patches for the parking lots in different weather conditions were prepared on which the classification algorithms are run, and the proposed model produced better classification results than AlexNet.

In [83], authors have developed a DL object detection model for detecting vacant parking spots regardless of the quality and position of the cameras. They made use of MRCNN for object detection. Research conducted in [84] proposed an optimized parking management system based on advanced video processing techniques which provides a parking slot number to vehicles at the entry point. It eliminates the need for human assistance for allocating parking space. Another approach for smart occupancy detection for road traffic parking using extreme DL is presented in [95]. Here DNN is combined with extreme learning machines along with logistic stack and logical autoencoders for improved detection accuracy by reducing the overall training time and memory usage. This model can also be deployed easily in a resource-constrained infrastructure.

A spatio-temporal analysis of detected vehicles using FRCNN for parking slot delineation is suggested in [56]. This vision-based method is economical compared to other sensor or counter based mechanisms. Here a pre-trained CNN is fine-tuned with datasets for occupancy detection. Also, this eliminates the need of localizing the vehicles, and further reduces the problem of object detection to an image classification problem that substantially reduces the computational constraints. In [27], authors proposed an economical SPS based on cameras, EC, data analytics and advanced DLL algorithms. Customized DL-NN is used for license plate detection, vehicle tracking and to charge the car accordingly. This intelligent algorithm helps to significantly reduce the cost of existing systems and provides a more flexible solution. A proof-of-concept method using SSD-CNN to detect cars in parking lot is proposed in [72]. An application was developed to validate the quantity of cars detected and a vision map is developed for standardizing the input data formats using ground truth image annotations. Another service called Skynet is built to analyze and summarize the car count statistics over time on multiple parking lot images. Single shot CNN approach specially the YOLO is used for classification.

A SPS framework using FRCNN was developed in [58], which focuses on detecting the cars in a parking lot and identifying their locations using cameras. They make use of FRCNN for empty slot detection on different weather conditions and the labelling is done using pre-instance segmentation. In [102], authors presented a video-based and cost-effective outdoor parking lot classification system. This method can be easily applied to any parking infrastructure with surveillance cameras. Moreover, the system evaluates various outdoor experiments with multiple image features and ML algorithms supporting precise and real-time classification which gives recommendations based on their best patterns.

In [100], authors proposed a ML approach for automated detection of empty slots in delineated parking areas where the boundaries are not well defined. SVM is used for classifying slots by generating the bag of features along with a background subtraction algorithm. Also, the proposed method is robust against large intra-class variabilities of vehicles and the wide variations in vehicle pose plus scale in each parking lot.

IoT acts as one of the primary technologies used for SPS. Some of the SPS implementations using IoT are

Table 3 Represents different SPS methodologies and the hardware and software requirements of each system along with algorithms implemented

References	Hardware used	Sensors used	Other techniques
[29]	Raspberry PI 3	Ultrasonic Sensors	Image Processing
[69]	Arduino Nano	IR Sensors	–
[85]	Microcontroller	Magnetic Sensor	Genetic Algorithm
[15]	–	–	Scheduling Algorithm
[52]	Fog Nodes, Microcontroller	–	Image Processing
[85]	Raspberry PI 3	Ultrasonic Sensors	–
[30]	–	Wireless Sensors	–
[3]	Raspberry PI 3B	–	Haar-Feature-based Cascade Classifier
[80]	Arduino Mega	Ultrasonic Sensors	–
[73]	Raspberry PI 3	IR Sensors	ML Algorithms
[46]	Arduino Nano	IR Sensors	–
[2]	Arduino Uno	IR Sensors	–
[11]	Arduino Uno	Ultrasonic Sensors	Novel Algorithm
[18]	Raspberry PI 3B	Ultrasonic Sensors, Magnetometers	–
[35]	Raspberry PI 3B	–	YOLO
[48]	Jetson TX2	–	YOLO
[66]	Arduino Uno R3, Raspberry PI 3	Proximity Sensors	–
[62]	–	Ultrasonic Sensors	–
[89]	Raspberry PI 4	Ultrasonic Sensors	Image Processing
[82]	Lora WAN beacon device	Libelium Sensor	Stochastic Gradient Descent Algorithm
[45]	Raspberry PI 3	PIR sensors, Magnetometer	Image Processing
[77]	–	–	Ensemble Learning
[23]	RFID tags	RFID	–
[60]	Raspberry PI 4	Ultrasonic Sensors	–
[70]	Arduino Uno	IR Sensors	–

discussed below (Table 3). In [90], authors have designed a smart parking system using image processing and AI. To ensure ticketless parking, cameras and ultrasonic sensors were deployed in locations for license plate number recognition along with ticketless parking. Parking information and user recommendations were provided with the help of big data analysis and neural network algorithms. Here in [39], authors designed a novel SPS using a mobile app, Arduino, RFID, and IR sensors. Users can search and block the desired parking slot through an app and once user reaches the lot, they are authenticated using RFID tags attached to the cars. Upon exit, the amount to be paid is determined based on the time the service was used with the help of IR sensor data, and further the payment is processed using the linked in-app wallet. This technology improves overall efficiency, reliability, expediency and lowers the pollution and search time for parking spaces.

In [21], navigation and reservation based smart parking platform using genetic optimization for SC is proposed. Smart parking module acquires the parking slot condition and sends to the server and genetic algorithm is used to determine the nearest free parking slot from identifying the user position. Also, smart phone GPS is used to get the current position of the user. Authors in [54] proposed a SP algorithm based on driver behavior and estimates the vehicle parking length. It allocates grids to vehicles based on three policies i.e., worst-fit, best-fit and parking behavior forecast and maximizes the benefits for parking slots. According to the user's current location, it allocates a slot estimating the user arrival time.

A fog enabled car parking architecture is designed in [51]. FC reduces the overall latency and reduces the network usage in the overall car parking system. Simulation is done using iFogSim which is an IoT tool kit and image processing algorithm is used to identify the empty parking slots. Microsoft Azure services are used for data storage and a microcontroller act as a bridge between the cameras and fog nodes. IoT SPS based on visual aided smart vehicle presence sensor called SPIN-V is proposed in [58]. The entire SPS architecture is divided into 3 parts: An intelligent vehicular presence sensor (SPIN-V), Intelligent parking system for user slot allocations (SEI-UVM), and a monitoring system for gathering information about users and parking system (OBNiSE). Each parking slot has a SPIN-V module installed for detecting the presence of vehicles and using SEI-UVM module user can book parking space in real-time along with route recommendations. In [12], authors proposed an intelligent parking method (ADIP) to improve the efficiency of parking systems in Abu Dhabi malls. ADIP consists of a system controller that manages the entire parking system, web server, and wireless sensors for collecting parking status along with parking time. It also has an android mobile application using which the user can make parking reservations.

In [57], authors have implemented a SPS in a midsize university parking lot. Cameras are used for identifying status of the parking lots and MySQL database is used for storing parking data. Also, an application called Park Fast is developed for interacting with the parking slot. Intelligent parking system using Arduino embedded over Wi-Fi is developed in [78]. With the help of IR sensors, the system gets the status of parking slot whether it is occupied or vacant which sends the collected data to the microcontroller. These information's are updated into the central database. Each parking slot is provided with a unique id to identify them easily on the network. Here in [14], an integration of multiple sensor and fog nodes are made for collecting parking information and data filtering & fusion are used for evaluating data. Data are processed locally at fog nodes and the needed information is only sent to the cloud server for storage. Whenever a user sends a parking request, allocates nearest slot to the user along with the road traffic status.

A SP management system using cloud is proposed in [37]. AWS IoT service is availed in the system to track the users connected to the system and to back-up the information's stored in the cloud. Also, a mobile application acts as interface between user and the SPS. In [42], authors proposed a system incorporating IR sensor in each parking slot to gain information about the vacant slot. The user can pre-book parking slot and every user is provided with a username and password. The system will alert the parking controller in case of any misuse. Authors in [81] introduced a novel SPS that helps users automatically find a free parking space at the least cost and a new algorithm is proposed to calculate the user parking cost by considering the distance and the total number of free places in the car park. And a new car park is suggested if the requested car park is full along with the parking address and directions.

In [94], a multi-layered architectural system is developed with multiple sensors to detect vehicle and gather environmental data. Edge gateways are used for processing information and LoRa for long range communication along with cloud for data storage. Real time parking information is provided to users using parking screens installed in car parks. A new pipeline for SPS is proposed in [51] for efficient slot detection in extreme lighting conditions and occlusions. An SSD-Mobile net detector is implemented using TensorFlow Lite on the IoT devices with transfer learning and a novel tracking algorithm is devised to operate on the server side for vehicle tracking in parking garages. The proposed study in [31] make use of a method that can precisely identify street parking occupancy in various weather conditions. It adopts YOLO v3 based Mobile Net v2 to recognize occupancy status and can achieve stable parking occupancy detection in real-time. The authors presented a flexible solution using open hardware and software platforms in [17] to develop an economical SPS for metropolitan areas. It consists of parking sensors, gateways (hardware & software hubs), web-based system for collecting parking information, and a mobile application for end-user communication. A novel secure SPS by integrating WSN, RFID and IoT is designed in [1]. The system uses WSN to determine car park status and includes smart parking, monitoring, controlling and management solutions.

In [19, 20], authors designed a SPS in which cameras installed at entry point capture the image of license plates and the image processing entity transforms it into text layout and then assigns a parking slot and this information is stored in databank. When a vehicle is parked in the assigned parking slot, Raspberry PI unit processes this raw data and hold it into a database through the internet via Ethernet Port. The iOS application offers the precise route to the assigned parking slot and the application then proceeds the assigned parking slot number as an input and displays the route to the parking slot.

In [88], a novel cost-effective proof-of-concept method for SP is proposed. Here a LoRa-based SP sensor device measures parking lot occupancy and this information is sent over a radio channel to three Lora WAN gateways that collects measurements of signal strength from five sensors placed in a university parking lot. The Hidden Markov Model with Viterby algorithm and DL approach based on Neural Networks is used for estimating parking lot occupancy. Authors in [44] proposed a semi-automatic SPS based on IoT and ML techniques. Sensors are used to detect vehicles and the availability of parking slot which is shared with server for remote access. Display panels show the availability of parking slots in a specified car park and guides user to that specific slot. A new system that integrating IoT and ensemble methods to optimize the prediction of the parking space availability is proposed in [99].

A unique automated parking system to reduce human resources is introduced in [92]. Here people can easily find parking spots using a website or application using Google maps. An RFID card is assigned to each vehicle based on which users are routed to their reserved slots. A similar method is proposed in [20] comprising of an RFID Reader, ultrasonic sensors, GSM module, GPS unit, LED display, and the speakers. The entire system is controlled by the Raspberry Pi 4 device. A simple parking system with IR sensors for space detection is designed in [76] that can be easily implemented in malls, multi-store buildings, apartments etc. to regulate parking allotment especially during peak hours. Once the vehicle arrives in the front gate, the IR sensors detect the empty spaces and displays it in the LCD screen in the entrance. Then the driver can easily identify the empty parking spots and all the processing is done by the Arduino microcontroller.

Rather than these approaches, a variety of other algorithms are also used for parking detection in smart parking environment as follows.

- Static Algorithms: These algorithms are used for finding empty spaces according to user preferences, but once the route is fixed, it cannot be changed. These algorithms can quickly calculate the route or shortest distance between two preferred points . It utilizes Dijkstra's algorithm, A* algorithm, ANN etc. to calculate the routes. Another king is the genetic algorithm which makes use of the principles of population using crossover, mutation, and natural selection.
- Dynamic Algorithms: These algorithms can react to varying conditions in the context where they operate. Even though they cannot re-plan a trajectory towards parking space, they perform better and are easier to implement compared to static algorithms. Also, these are used in scenarios where a user enters a parking area and is provided with the nearest empty slot. Multi agent algorithms also comes under this where the algorithms can perform independent actions based on user-preferences [70].
- Real-time Algorithms: It involves re-planning the route according to the updated status information of the parking areas. The complexity in implementing these algorithms is high as it involves constantly updating the parking statuses, but it reduces the overall search time by drivers [64]. Different ML and DL algorithms such as CNN, MRCNN etc. come under this.

6 Smart parking system tools

SPS tools comprise various sensor technologies, hardware and software chosen accordingly as per the kind of car park or the interest of the parking lot owners. These tools are used for the efficient identification of parking information and to enhance parking efficiency. Some of the commonly used sensor types and programming languages by different SPS are listed in Fig. 6.

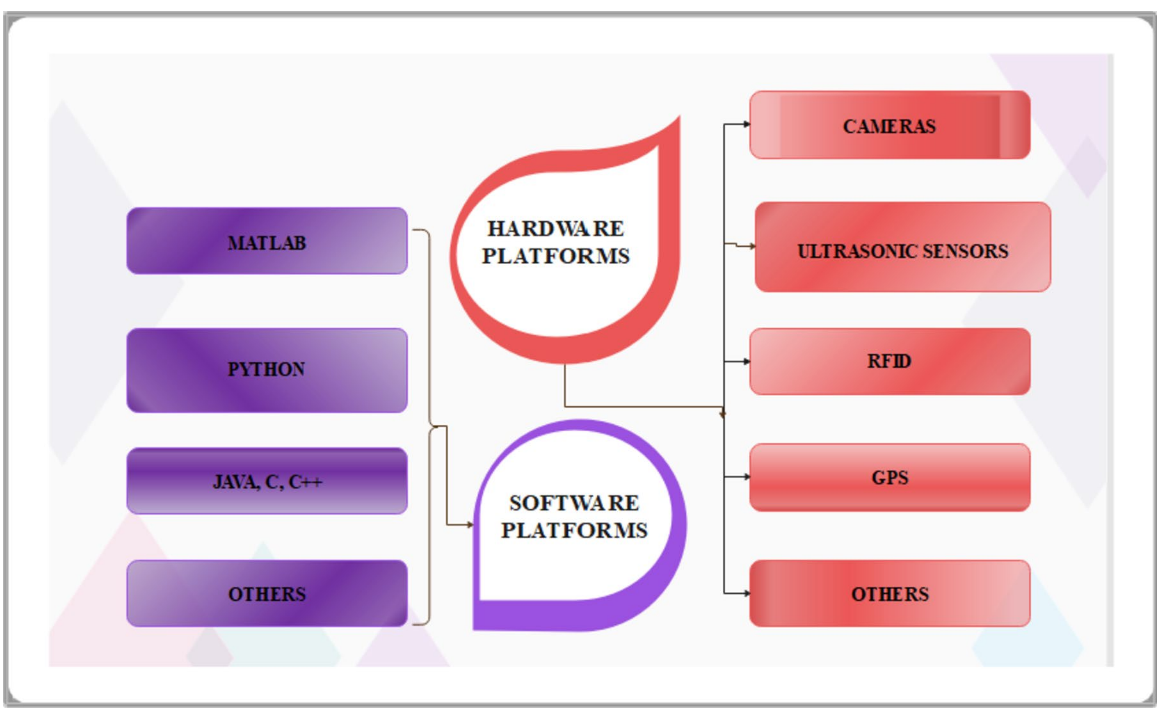

Fig. 6 SPS hardware platforms and software platforms

6.1 SPS sensors

Smart Parking sensors provide an intelligent solution for analyzing, guiding, and enforcement of cost-effective parking in an urban environment. Sensors are a widely used tool in most of the car parking systems for finding the presence of a vehicle. They are of different types varying from in-ground, surface-mount to overhead vehicle indicator detection sensors. These sensors could be easily installed in any configuration, despite any location topography, and requirements, from on-street parking to multi-level car parks or a fusion of both. This technology allows us to accurately capture a vehicle's arrival and departure times.

- ☐ **In-ground sensors:** These are the universal method for monitoring parking status, and it consists of a network of wireless sensor nodes operating below the ground surface. The sensor behaviour can be tailored as per individual parking lot requirements [4]. They can provide timely data collection and communication, ease of deployment, high coverage, concealment, and reliable services. These in-ground sensors monitor individual parking lots and communicate occupancy status to corresponding gateways, which in turn send this live status information to the Cloud platforms, enabling real-time parking information to be viewed on multiple devices. However, these sensors are prone to abrupt failure and provide false results.
- ☐ **Surface-mount sensors:** These are non-intrusive sensor types consisting of encapsuled thin surface covering cables which can be easily mounted on any flat or curved surfaces. These sensors work exactly like their ground counterparts and optimizes parking utilization with reduced emissions [74, 75]. But designing such sensors becomes significantly more difficult because of the following reasons. For the safety of both vehicles and pedestrians, it must first be rather thin. Second, the enclosure needs to be strong enough to bear large mechanical loads.
- ☐ **Overhead-indicator sensors:** These are employed commonly in multi-storey parking and provide simple, cost-effective, and efficient parking services. It consists of overhead color-coded LED's indicating each parking space status that can be easily viewed at a glance by the users [59]. Parking sensors relay live status of vehicles to the cloud, which in turn channels this information for formulating the report analytics of the entire car park. But a large emitter, a receiver, and a bigger battery pack need to fit in the enclosure during the implementation.

6.2 SPS technologies

SPS Technologies are the tools that facilitate the user in identifying and occupying vacant parking spot [36]. It includes identifying proper parking bays utilizing AI and ML techniques, image processing, cloud-based parking systems, vehicular ad hoc networks, edge and fog computing-based

Table 4 Provides the features of various SPS technologies

SPS	Highlights	Pros	Cons
Intelligent Car Parks with ML Techniques	Different occupancy detection algorithms are used to identify vacant spots Recommends top-k parking slots to user	Can handle multi-dimensional and multiple varieties of data No human intervention and wider applicability	High quality data sets required else susceptible to errors Carefully choose the algorithms else prone to errors
Car Parks with Image Processing Techniques	Cameras installed are used for capturing the vehicle images Video frames are compared for parking identification	Captures multiple images in single time Max. 4–5 cameras sufficient for single parking area Economical and efficient	Overlapping of images Successive processing of video frames Difficult to detect in low lighting conditions
Cloud based Car Parks	Local processing on-boards Required images or videos are streamed to the cloud server	Economies of scale Flexible storage Up to date & secure	Higher BW required for extended services Active internet connectivity is required
Mechanical Car Parks	Rotary shafts are required to park the vehicle Need the help of authorized persons for parking	Efficient compared to conventional parking systems Feasible for urban areas	Increased construction and maintenance cost Higher chances of breakdown
Car Parks with GSM module	Sensors communicate information to the GSM module Information's are communicated with the help of mobile application	Secure as designated persons can only get into the parking spot SMS based parking reservations and cost effective Low power consumption	Active internet connectivity is required Misuse of card if lost

Table 5 Lists different types of sensors used by SPS along with their advantages, disadvantages, and suitability

Sensor types	Advantages	Disadvantages	Appropriate for Open SPS	Appropriate for Closed SPS
IR Sensors	Reliability against nearby parked vehicles, vehicle movements and electromagnetic interferences Stable for long duration parking's	Immune to environmental conditions as lighting scenario, dust/dirt on enclosures and aperture in enclosures	✘	✓
RFID tags	Only authorized vehicles are permitted to enter the parking lot	Fails to provide parking occupancy status	✘	✓
Ultrasonic Sensors	Wider emitter beam More integral measurements and accurate identification of vehicles	High power consumption Wider mechanical dimensions Immune to varying environmental conditions	✘	✓
Radar	Less vulnerable to random reflections Reliable in any lighting scenarios & apertures in enclosure	More expensive Less sensitive to thin obstructions Shorter battery life requiring high frequency circuits	✓	✘
Magnetic Sensors	Reliable in any lighting scenarios & apertures in enclosure	Reduced battery life Expensive to maintain on large scale	✓	✘
GPS	Guides the users to parking spots	Jamming of GPS signals	✓	✘
Inductive Loop Detectors	Good performance in intersections and freeways Reliable, accurate and low cost	Multiple detectors required for a single location Disrupts traffic	✓	✘

systems, GPS based systems and mechanical car parking systems etc. Some of the features, advantages, and disadvantages of these SPS technologies are listed in Table 4.

Various approaches used for recognizing parking slot statuses are as follows:

(1) IoT based SPS consists of various sensors, storage units, and computational devices that can communicate and transfer data among themselves without any human intervention [55]. It can be either a wired or wireless connection through which these devices connect with each other. Various sensors used along with their advantages and disadvantages are provided in Table 5.

(2) ML based SPS make use of various datasets for extracting and identifying the occupancy status. These systems can even predict the parking status for coming days, monitor the traffic congestion and can even provide alternative solutions. IoT and ML techniques can be blended to provide various intelligent parking services [84].

(3) Image processing based SPS make use of cameras instead of ground sensors. Cameras are used to capture the image data in real-time and later processed to extract different features such as occupancy status, license plate recognition for registering the vehicles and calculating the parking cost, providing congestion reports etc. They are suitable for open parking lots and are prone to occlusion, distortion, shadow, and light effects.

(4) WSN based SPS comprises of a WSN module for gathering the sensor data for classifying the parking slot status. It then sends the slot information to the

Table 6 Some of the available smart parking applications and its technologies

Parking Applications	Country	Technologies Used
App Clips	UAE	SMS
AppyParking	UK	Magnetometer
Best Parking	USA	Inground sensors
EasyPark	Canada	Inground sensors
EasyPark Group	Sweden, Denmark etc	Crowdsourcing
Getmyparking	India	Inground sensors, GPS
MeterFeeder	machine vision	ML, GPS
Open Spot	USA	Crowdsourcing
Park.Me	Austria, Germany	Inground sensors
ParkAssist	USA	M4 smart sensors, LPR
Parker	USA	Inground sensors, ML
ParkiFi	USA	Magnetometer
ParkMe	Japan, USA, UK, Germany, Brazil	Inground sensors
ParkMobile	USA	Inground sensors
Parkopedia	USA, Germany, Sweden etc	Inground sensors
ParkWhiz	Pittsburg	QRCode
PaybyPhone	France	Inground sensors
PParkE	India	GPS
SFPark	USA	Inground sensors
SmartParking	New Zealand	Inground sensors, RFID
SpotHero	USA	Inground sensors

corresponding embedded server which further communicates these data to the central webserver along with the location status. The central webserver stores this information in its database and displays the parking status to the users [25].

(5) GPS and GSM based SPS provide a guidance facility that routes users to a designated parking spot. It also helps in reserving a parking space in prior for reducing the waiting time. These are not stand-alone applications but needed to be used with other SPS technologies [96]. Various parking applications used in different countries and their technologies used are listed in Table 6. Using these applications users can make parking reservation requests in prior and in some cases, it provides the route to reach the reserved parking slot.

(6) VANET based SPS works similarly as mobile ad hoc networks. Here vehicles act as the mobile nodes and make use of various routing protocols for secured vehicular communications. They can even detect congestion by calculating the average speed of the vehicles and reduces the search time and fuel consumption of vehicles [40]. They can be applied in both open and closed parking lots but are costlier compared to other parking detection mechanisms. Also, security is a major concern since it involves inter-vehicular communications [87]. All the vehicles should be a part of the VANET network for effective and timely communication.

(7) Fuzzy logic based SPS predicts the parking occupancy status based on multi-valued logic. The predicted results may not be accurate as it is based on historic data and hence, they needed to be clubbed with various ML, computer vision or sensor-based systems [63] to be used in real-time.

7 SPS challenges & future research directions

Nowadays over half of humankind lives in cities and this ratio is expected to increase even more over coming years. The gap between parking demand and parking supply in urban areas is the basic notion that causes parking challenges. This will create problems with mobility and pollution letting down the quality of life. Moreover, the amount of connected, autonomous and EV are likely to increase and will soon show up in the parking areas [71]. A deeper look into these issues shows that these challenges spring up not only because of the lack of parking spaces, but inefficiency in utilizing the available spaces [41]. To solve these problems, it requires smarter solutions and technological innovations for the cities to be more intelligent and economical. Some of the challenges and its possible solutions are:

- ☐ Accepting new technologies: Parking is always considered as a momentary affair involving a hard cash exchange. Adopting newer technologies into an existing ethos will take more time to establish [5]. Even though many parking technologies exist, only a few countries have adopted intelligent SPS.
- ☐ Deliverance of newly found tools and techniques: Service providers use various technological platforms for delivering parking services. It involves multiple hardware's, telecommunication systems, application interfaces, traffic control systems, and dynamic messaging systems . Enabling these devices from multiple vendors and their integration is a colossal task. And the greatest challenge is to implement a cost-effective, smart, and scalable SPS [34].
- ☐ Problem with electronic payment vendors: On-site parking meters are prone to numerous security issues and threats. These payment processors provide permit based electronic payment, normally for a fee [71]. So, scalability is a major concern regarding these vendors, i.e., the transaction processor fails to provide support for extensive geographical, market and service areas, with marginal cost [47]. IoT enabled parking's should also support M2M communication of real time data to identify the scenario of different parking spaces.
- ☐ Reliability of application programming interfaces: SP authorities should establish a reliable API with online access using which customers can access the parking services in real-time through a variety of channels, including the web, mobile applications, connected personal navigation devices or through car telematics services [101].
- ☐ Lack of proper infrastructure: Different sensors and cameras used for smart parking requires a solid infrastructure, advanced hardware, and communication technologies [13]. Hence the obsolete infrastructure cannot meet the demands of an IoT enabled SP.
- ☐ Mobility issues: Vehicle guidance can be provided in car parks so that people can park quickly and safely [43]. Promoting EV and implementing smart EV charging stations that can communicate with vehicle or owner through mobile applications thereby reducing the waiting time and traffic [8].
- ☐ Standards, Interoperability and Coexistence: Providing intelligence to devices in SPS by adopting various evolving technologies and smart algorithms helps them to automatically discover the parking spaces when a vehicle leaves the bay without human intervention [86]. Cross-domain interoperability should be considered more utilizing semantic web technologies and interworking application programming interfaces for further development. Also, designing a comprehensive multi-service IoT and ML integrated network and security

architecture that can aggregate data from different use-cases can help in accelerating the concept of SP thereby improving the quality of life .

- ☐ Privacy and security concerns: As the number of smart devices are increasing day by day, the amount of real-time data emitted by these are also growing [6]. And these devices will collect data including user-sensitive information's from parking lots, CCTV cameras, EV charging points, GPS etc. and even holding valuable insights from SC, which will pose a threat to the privacy and security of personal information of the citizens [98].
- ☐ User preferred parking and re-scheduling: Even though some of the applications have included user preferred location of parking, most of the systems fails to identify user preferences for a requested slot or to establish an efficient route to an available space [7]. The establishment of a multi-objective optimization is to be considered that includes different user preferences such as parking at the earliest available space, avoiding congested parking areas, parking near destinations etc. Also, intelligent, and real-time algorithms are needed to be designed that can reschedule the pre-planned route due to some events [22]. These events can be traffic jams, damaged traffic lights, detours, constructions, parking occupancy etc.
- ☐ Sustainable parking lots: Research works should be carried out on developing environmentally friendly and energy conservative SPS [61]. These parking systems aid in improving water quality, increasing ground water supply, and lessening the urban heat island effect. Their environmental impact is considerable compared to the traditional methods and helps to reduce pollution to a greater extent.

7.1 Requirements of users in a smart parking ecosystem

Due to increasing urbanization and rise in car ownership, secure parking spots are in increasingly high demand. The drivers' parking experience is being negatively impacted by the rising number of vehicles on the road. Hence drivers that use the conventional parking system suffer significant losses in terms of money, productivity, and time spent looking for parking spaces especially in heavily populous locations which in turn aggravates them and increases traffic on the roads. From this it's clear that traditional parking systems are not able to give drivers a seamless parking experience with low traffic especially on the highways. This underlines the justification for implementing cutting-edge technologies to modernize the urban transportation infrastructure that can resolve the drivers' issues. Some of the benefits user can enjoy by implementing SPS are:

- ☐ Reduction in parking space search time: Municipalities can control and lessen the amount of street traffic generated by parking searches by implementing SPS. This feature can make parking quicker and less of a headache by making sure that there are fewer automobiles driving around trying to find a parking space and can also guarantee parking safety.
- ☐ Reduction in the fuel, time, and cost consumption: Drivers can be directed directly to available parking spaces in metropolitan areas with integrated SPS. This removes the need to travel farther distances in search of parking spaces thereby saving drivers money, fuel consumption and improving their parking experience.
- ☐ Reduced parking stress: The drivers can use SPS to find out whether there are any parking spots nearby where they wish to go. This lessens the uncertainty and stress involved with locating a suitable parking space close to the target location.
- ☐ Reduced carbon footprint: The discharge of individual environmental footprint, especially the release of carbon dioxide, is ultimately decreased when SPS are integrated into metropolitan settings. In addition to not directly affecting human life, the reduction in personal carbon footprint release from cars can also contribute to climate change.
- ☐ Increased user experience: Ensure that users have a seamless experience by implementing user-friendly SPS with simple payment methods, clear signage, meek navigational systems and providing park and ride facilities and demand-based pricing.

7.2 Ethical issues in a SPS

- ☐ Technical Challenges: Making sure the users of the SPS always get accurate information is a major task. Drivers may go to locations other than the allocated parking spots because of inaccuracy or delays in getting the data, which causes chaos and confusion on the roads. Making it possible for all these devices from countless suppliers to communicate with one another and connect to a single platform is the biggest challenge in reducing the cost and complexity of IoT smart parking. The requirement for several sensors to be online to collect data for a single booking window is another issue with deploying a smart parking management system. It appears difficult to have a variety of routers etc., which is required. SPS needs experts with IoT knowledge and the ability to provide quick troubleshooting. Deploying such complex smart solutions calls for the best guidance to complete the projects properly is another major challenge.
- ☐ Organizational Challenges: Awareness and acceptance in implementation of SPS requires an evolution in culture that will take time. Also, installing SPS infrastructure

needs a substantial capital commitment which refrains most of them from implementing the same.

- Breach of privacy, accuracy, and accessibility: How much data should a vehicle exchange with the SPS regarding ownership, destination, occupants, etc. should be considered while implementing an SPS. Who is responsible if an accident occurs because of information exchange errors, who owns the information exchanged through the network, can this information be analysed and sold, and in the event of an accident, what information and to which entities could be disclosed, under what circumstances, all needed to be taken into consideration during the implementation. Only concerned staff or departments should have access to information processing.
- Social Inclusion: All members of society must benefit from the implementation of smart city programs, not simply those with resources or those who are more accustomed to using technology.
- Implementation of SPS with existing navigation applications: The local parking system cannot guarantee the creation of a unique mapping app and must operate with the current one.

All these challenges are to be considered while designing an efficient and user-friendly SPS. Table 7 lists out the details of the studies conducted.

8 Conclusion

Urbanization and the increase in population has decreased the urban parking spaces and it heightened the traffic congestion to a larger extent. Traffic congestion and parking search exhausts the people and will certainly depress the quality of life. Traffic also increases carbon emissions thereby creating a negative impact on the environment. Adding to the time wasted along with the fuel consumption and harmful emissions, this cruise for parking hunt creates a greater economic loss. Due to the unavailability of the parking spaces many drivers tend to park unethically or even results in cancelling the planned activity. Some SC have already implemented SPS, whereas some are in their trial stages but still many of them have not even started implementing these methods. And so, by adapting newer technologies such as smart sensors, acclimating to IoT and intelligent algorithms in ML & DL, using local signage and advanced navigation techniques, mobile applications etc. can definitely transform the current situation of city parking systems.

SP is an efficient mechanism that helps in monitoring parking occupancy. It also guides the user to the nearby parking bay in a cost-effective manner. It makes use of various sensors to provide precise and real-time information about various parking garages. By leveraging the advancing technologies such as AI, ML, EC etc. into it helps to minimize the parking search thereby reducing complexity of parking and providing the city officials with precise real-time data on parking behaviors and customer habits. SP solutions offers a comprehensive dashboard to urban officials and parking owners where real-time data analytics are used to obtain parking insights. It also aids in efficiently utilizing the resource as well as in personal planning. Future parking systems may be an intelligent and autonomous system integrating different players from industries with a provision of diverse services.

The objective of this paper is to provide a thorough summary on SP eco-system to help the researchers to know the basics and in-depth knowledge of various technologies, architectures, and other evolutionary patterns used in the development of SPS. As per the comprehensive review and analysis conducted in the research, it's evident that SPS with manifold tactics will dominate in future SC. We have also discussed various challenges and the assimilation of various

Table 7 A summary of studies conducted with respect to SPS architecture, tools, implementation, and challenges

SPS Parameters	References	Concepts Covered
Features	[10, 15, 16, 24, 26, 28, 32, 33, 38, 44, 49, 50, 53, 65, 68, 71, 74, 75, 79, 91, 97]	Information flow in a basic SPS
Categories	[15, 29, 52, 69, 85, 93]	According to the models implemented
Architecture	[3, 30, 80, 85]	Includes the layered architecture integrating IoT and ML
Parking 4.0	[2, 11, 18, 46, 73]	Characteristics, advantages, and deployment
IoT in SPS	[9, 23, 35, 45, 48, 60, 62, 64, 66, 67, 70, 77, 82, 83, 89, 103]	SPS implemented using IoT
ML in SPS	[12, 14, 17, 21, 27, 31, 37, 39, 42, 51, 54, 56–58, 72, 78, 81, 84, 90, 94, 95, 100, 102]	SPS implemented using ML
Sensors	[1, 19, 44, 88, 99]	Long-range and short-range and types of sensors
Technologies	[20, 64, 70, 76, 92]	Crowdsourcing and others
Challenges	[4, 5, 13, 25, 34, 36, 40, 41, 47, 55, 59, 63, 71, 75, 84, 87, 96, 101]	Features of SPS, challenges, and future directions

advancing technologies that can be used in the development of new parking systems which benefit the future researchers and other persons interested in implementing SPS.

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