A Review on Outdoor Parking Systems Using Feasibility of Mobile Sensors

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Abstract. An efficient outdoor parking system is a crucial need for smart cities to monitor the occupancy of outdoor parking. Currently, there are many external sensors-based parking systems available for indoor parking. These external sensors either need to be installed at the parking slot or attached with vehicles at fixed positions. Hence, the deployment cost is very high for such implementation. Due to high cost and complex network configuration, external sensors are not preferred for Smart Outdoor Parking Systems (SOPS). Several SOPS have been deployed to solve outdoor parking problems. Understanding existing SOPS approaches is essential to develop a robust and effective outdoor parking system. In this paper, we present a review of the various SOPS. We have addressed the most important aspects including technical, economical, accuracy, open issues and challenges of the existing SOPS. Based on the review, a recommendation has been proposed to improve outdoor parking system.

Keywords: Outdoor parking · Smartphone-embedded sensors
Smart parking system · Sensors fusion · Activity recognition

1 Introduction

Parking has been a serious problem in urban cities. The number of vehicles is increasing day by day with the growth of population and economic development. It is extremely difficult and frustrating for drivers to find a parking place in congested areas. According to a study by Parknet [1], it costs $78 billion per year in the form of 4.2 billion lost hours and 2.9 billion for gas in busy roads in the U.S. Another study by White [2] showed that 45% of the traffic generated by automobiles circulation for finding parking places had caused a series of problems like air pollution, traffic congestion, and waste of energy in the New York City. The lack of outdoor parking system leads to a number of illegal parking, heavy traffic on roads, and causes distress for drivers. Hence, monitoring

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outdoor parking availability is a significant mission for developing smart city which can guide drivers to find empty parking spaces easily.

Most of the existing outdoor parking systems used tokens or tickets that count the number of cars entering and leaving the parking premises. Many of these systems used external sensors such as sensor under the road surfaces [3], or sensor attached to the side of the vehicles [4]. These methods were implemented to provide outdoor parking occupancy information. Nevertheless, these solutions could neither reduce drivers' anxiety to find a parking space nor provide satisfactory parking management for outdoor parking. Therefore, there is an urgent need for a solution for outdoor parking for a smart city.

We have presented a review on outdoor parking systems using four different approaches; namely computer vision, GPS, wireless based and smartphone-based systems. We have given an insight into the flexibility and cost of implementing these SOPS to provide a precise overview to design a more flexible and cost efficient SOPS. The remainder of the review paper is organized as follows: In Sect. 2, we divide different SOPS into four categories according to their deployment techniques. The categories are vision-based techniques, GPS/Satellite-based techniques, wireless network-based techniques and smartphone-based techniques. Section 2.3 demonstrates a comparison and discussion of the different approaches, in Sect. 3, a recommendation is provided and finally the conclusion is drawn in Sect. 4.

2 Categorization of Smart Outdoor Parking Systems

2.1 Vision-Based Techniques

Vision-based parking system has become attractive with the rapid development in the image processing and computer vision fields [5]. The core idea of vision-based SOPS is to use image processing and computer vision techniques to analyze CCTV video streams [5]. It analyses the content captured by the video cameras to detect and find empty parking space. Hampapur et al. [6] presented an object recognition with adaptive background subtracting and striking movement discovery method to identify moving vehicles. The background subtraction method subtracted the current image from a reference image to find region of interest (ROI). Adaptive background subtraction continuously updated the background changes and generated a mask of where the images were stable. The method detected entering and leaving of cars by identifying the location of the vehicles. Wu et al. [7] described an approach that combined Principal Component Analysis with wavelet change for feature extraction and applied Support Vector Machine (SVM) for vehicle recognition. Bong et al. [8] presented a bi-stream empty parking slot detection approach, in which one stream examined the number of pixels within a certain intensity threshold to determine the presence of a car in the parking slot and other stream eradicated false detection produced by shadows of vehicles, utilizing edge detection and median filter. A ParkLotD system was introduced by Ichihashi et al. [9] to enable a camera-based system for practical outdoor parking detection with high performance. The cameras return real-time available parking spaces and adaptive background subtraction was used to overcome illumination and shadow effects. Similarly, Lin et al. [10] demonstrated a vision-based parking method for outdoor parking which set up cameras around the parking zone, sends real-time information to a center database that enabled drivers to discover available parking spaces or monitor the parked space through wireless communication device. The system used a statistical method in color image sequences to find out the suitable color for each parking space and the foreground was extracted using color information.

Overall, vision-based techniques are better than sensor based techniques in terms of cost since it does not require additional sensors in each parking slot [11]. In addition, vision-based SOPS is easy to deploy because the cameras setup does not require intricate configuration. Furthermore, vacant parking spots can be identified precisely by analyzing the parking space images. However, there are also some limitations with vision-based systems. The cameras must be in the positions from where they can monitor the whole parking area. Sometimes, high-resolution cameras are high-priced [12]. Figure 1 below demonstrates the block diagram of vision based SOPS.

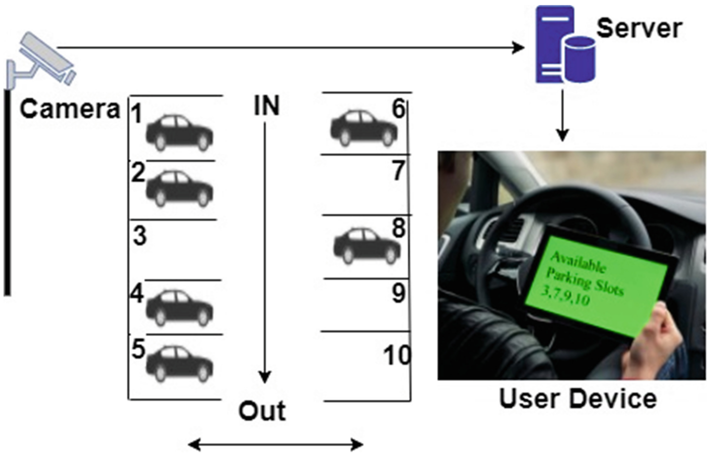

Fig. 1. Block diagram of vision based SOPS

2.2 GPS/Satellite-Based Techniques

The Global Positioning System (GPS) is a location system based on a constellation of around 24 satellites circling the earth at heights of approximately 11,000 miles. GPS gives exact positioning 24 h a day, anywhere in the planet. GPS calculates distance between a GPS satellite and a GPS beneficiary by measuring the amount of time it takes for a radio signal to travel from the satellite to the recipient. Many smart outdoor parking systems take advantage of GPS services to find parking locations. It provides information about the location and availability of parking spaces near the destination of the driver by transmitting signal from satellite to the receivers. A block diagram of GPS based SOPS is shown below in Fig. 2. A number of GPS-based smart outdoor parking systems have been proposed. Gahlan et al. [13] designed a parking management approach by using GPS whose primary purpose was to determine the location and to send available parking spaces to the driver. The system could also provide feedback about the current location of the drivers. A scientific solution based on past and current status of the drivers was presented by Pullola et al. [31] by utilizing Poisson process to model vacancies of available parking slot. The system helped drivers to choose the place with maximum probability of being available. A location-based parking system was presented by Chon et al. [14] to find the nearest available parking lots for the drivers. The system helped to find parking place in areas like campus, airports. However, the system did not provide information about availability of parking spots.

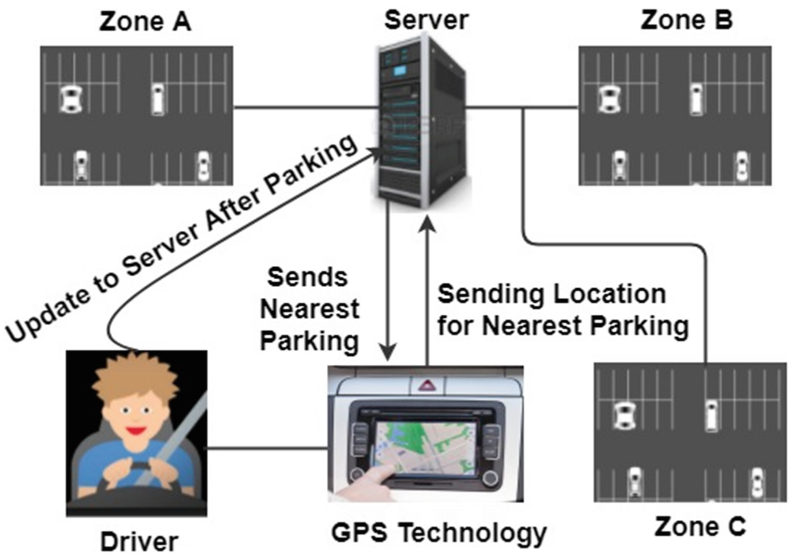

Fig. 2. Block diagram of GPS based SOPS

The good side of GPS-based technology is that it provides real-time location services and guides towards the destination. Thus, it is flexible to use and can obtain knowledge of unknown parking places. Besides, it eliminates the need to install expensive sensors for getting parking places. Conversely, GPS receives location data from the satellite which takes times due to transmission delays. In addition, it depends on the weather to receive clear signals from the satellite. Apart from that, GPS does not guarantee a parking place as it can only provide information about the current state of the parking zone [16].

Overall, vision-based techniques are better than sensor based techniques in terms of cost since it does not require additional sensors in each parking slot [11]. In addition, vision-based SOPS is easy to deploy because the cameras setup does not require intricate configuration. Furthermore, vacant parking spots can be identified precisely by analyzing the parking space images. However, there are also some limitations with vision-based systems. The cameras must be in the positions from where they can monitor the whole parking area. Sometimes, high-resolution cameras are high-priced [12]. Besides, the tracking systems might sometimes give false positive result due to occlusion effects and lighting conditions.

2.3 Wireless Network-Based Approach

Wireless network (WN) is a computer network that uses radio waves for connecting devices, business network and applications. There is an increased interest in wireless-based parking system. The use of WN in smart outdoor parking systems enables people to avoid costly process of introducing sensors and cables. Hanif et al. [15] demonstrated a smart outdoor parking system that allowed users to book their parking slot through Short Message Services (SMS). A wireless communication instrument named micro-remote terminal unit (micro-RTU) was used to confirm booking with details such as lot number and password. Password was used to enter into parking area with a validity of certain period of time. A microcontroller named Peripheral Interface Controller (PIC) was used to automate the system that was capable of storing information of vacant parking spaces, controls entree to the parking area by allowing or denying access. Besides, a system to monitor the entry and exit of vehicles for outdoor parking zones was presented in [17]. It utilized wireless network of photo electronics sensors and a network technology called 6LowPAN over IEE802.15.4 for communication among devices such as computers, routers and mobile devices. 6LowPAN stands for IPv6 over Low-Power Personal Area Network and it allows IPv6 packets to be carried efficiently using small link layer. Gu et al. [18] presented a system named Street Parking System to monitor road side parking spaces using wireless communication with magnetic sensors and ZigBee technology. The system used 3-axes magnetic sensor and an algorithm based on cyclic detection state machine for detecting parking vehicles. A similar outdoor parking system was proposed by Reve et al. [19] that used infrared sensors and radio frequency for communication. Figure 3 below shows a block diagram of wireless based SOPS.

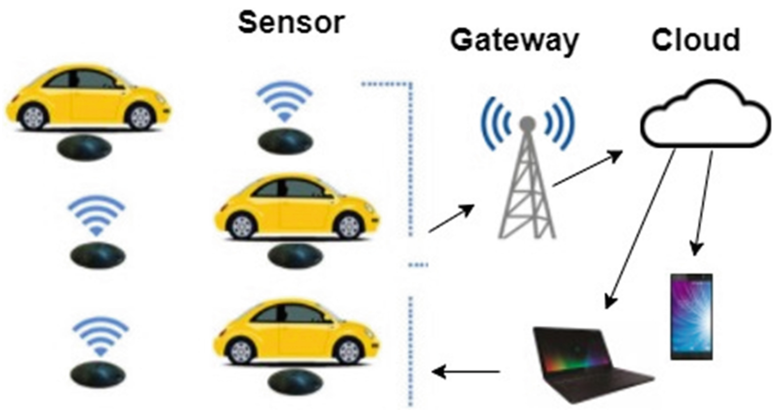

Fig. 3. Block diagram of wireless based SOPS

Wireless technology provides a number of advantages. The wireless technology can be found in homes, workplaces and cars. Therefore, the deployment of wireless based parking is rampant. Besides, the technology can be used for both outdoor and controlled zone parking systems. WN-based SOPS can detect the passage of cars and communicate with the data center in real-time.

Wireless sensors network-based technique is considered a low cost solution for smart parking. But it typically consists of various sensors such as fluxgate magnetic detector, active infrared detector which are expensive to implement. For example, a study described a method that used wide-area sensor network which had video cameras, microphone, and motion detector [20]. When many drivers use WN-based smart parking systems, the bandwidth of the infrastructure becomes overloaded. Again, there is chance of interference and signal distortion due to external factor such as dust, storm, and fogs.

2.4 Smartphone-Based Techniques

In the past few years, smartphones experience a vast technological growth with the incorporation of new hardware and embedded sensors. Modern smartphones are equipped with various sensors such as accelerometer, barometer, gyroscope and GPS. Smartphone sensors are being used for crowdsensing which collects information from user's mobile. A number of SOPS have proposed to utilize crowdsensing capability [21–26]. Context recognition or user activity recognition technology is used in such systems. Activity recognition can effectively detect activities such as walking, standing, driving, and running. The flow of detected activities, e.g. driving-standing-walking infers the activity when a driver is parking. Analyzing activity recognition for parking can be implemented without using costly sensors. The architecture of smartphone-based SOPS is demonstrated in Fig. 4 below.

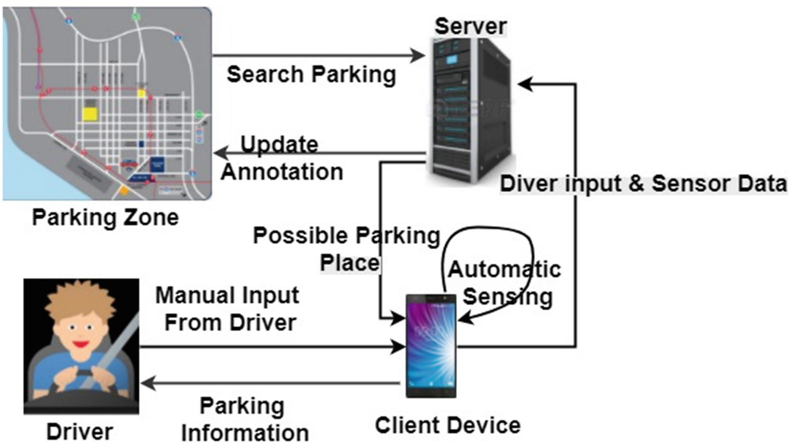

Fig. 4. Block diagram of smartphone-based SOPS

In a study by Salpietro et al. [21], the users' activities were identified automatically through the analysis of accelerometer and gyroscope data to determine the transition mode from car to walking, and vice-versa. To detect activities of users, driving-to-walking or walking-to-driving, sensors in smartphone and Bluetooth were used. Driver's actions such as walking, driving were classified using supervised machine learning. The solution has helped to solve the problem of installing external sensors in parking areas to track car occupancy. On the contrary, GPS, accelerometer, geospatial data, and Bluetooth data were used by Stenneth et al. [22] to automatically detect when and where a driver parked a car, or released the parking spot. A novel approach named Probabilistic Internal Navigation (ProbIN) [24] that used Bayesian Probabilistic framework was used to address the problem of noisy sensors reading. It was a novel statistical approach for mapping low-cost internal sensors to get the user's position for navigation. Lan and Shih [23] proposed a phone-based driver tracking system that studied the trajectory of the driver. They proposed a way to detect when a driver was about to leave a parking place. A waist-mounted and map-matching algorithm is used to get accurate prediction results. Another solution was presented by Biondi et al. [25] which gathered the user contextual information that was displayed as an approximated distribution of free parking spots using a map. A bluetooth low energy advertisement was used to detect passengers to reduce bias that might be introduced by multiple users in the same car. Nawaz et al. [30] introduced ParkSense, a robust signature matching approach based on bacon reception ratio and an approach based on the rate of change of Wi-Fi beacons to detect driving. In order to sense parking events, ParkSense leveraged the ubiquitous Wi-Fi beacons. It used Wi-Fi signature matching approach to detect driver's presence to the parked vehicle. PocketParker, a crowdsourcing system presented by Nandugudi et al. [26], detected driver's movement utilizing smartphone's GPS and accelerometer sensors. The system stored collected data in a centralized database and broadcast the information to the drivers using Wi-Fi and cellular network. Table 1 shows a summary of the existing smartphone embedded smart outdoor parking systems.

Table 1. Summary of different smartphone based SOPS

Study	Sensors	Storage	Accuracy
Stenneth et al. [22]	Accelerometer, Gyroscope and Bluetooth	Distributed	Transportation mode detection 92.5%, parking occupancy 100%
Nguyen et al. [24]	GPS, Accelerometer and Gyroscope	Centralized	87% for parking occupancy detection
Biondi et al. [25]	GPS and Bluetooth		–
Nandugudi et al. [26]	Accelerometer and GPS		Overall accuracy 92.5%
Nawaz et al. [30]	Wifi-beacon		Identify above 90% users return

We observe that mobile-based parking system uses two types of storages: distributed or centralized. Distributed storage stores data in devices that are not located in the same physical location. On the other hand, a central Database Management System (DBMS) manages all the distributed storages in a unified location. Distributed storage system can process all the requests to access data by balancing the load among several servers. To keep the data up to date in distributed storage system, it requires additional software. Therefore, this incurs additional cost and complexity. On the other hand, centralized database keeps all the data in a single place such as a server or mainframe computer.

Centralized database is easy to maintain since all the data resides in the same location. But the server of the centralized database becomes slow if there are multiple requests to the system.

In general, mobile phone-based system is suitable for outdoor parking. It is the most economical solution among the alternatives. Mobile-oriented outdoor parking system provides the best flexibility since the mobile phones can be carried everywhere. It has also helped to solve the problem of having complex infrastructure or expensive external sensors installation and maintenance. Mobile phone provides an economical smart parking solution by taking advantage of modern mobile phone's powerful sensors. Besides, the system is easy to use since the application is available on the phone. It also provides other features such as a booking system to allow users to reserve a parking slot in advanced.

Nevertheless, there are some disadvantages of using smartphone-based outdoor parking systems. To track location for the car parking systems, the user's location information is needed and this can lead to user privacy breach. Accelerometer and GPS are two important sensors for designing smartphone-based SOPS. Accelerometer is orientation and position dependent, and it needs complex training and processing to achieve good accuracy. Sometimes, the GPS sensor might miss the GPS signal in urban areas [28]. Again, some system takes manual input from the users which might be inflicted by false information created by free riders and selfish liars. In addition, there might be problems when a user books the parking a way too early while the other nearby drivers cannot book the parking place as it has already been blocked. Therefore, application developers need to consider many scenarios to solve or reduce these kinds of problem.

3 Discussions and Recommendation

This section discusses the different SOPS techniques and provides a comparison among these techniques. Table 2 shows the comparison of deployment flexibility, accuracy and cost of the SOPS techniques. We observe that vision-based technique is easy to deploy, and it requires less maintenance cost. However, the tracking systems might sometimes give false positive result due to occlusion effects and lighting conditions [33]. However, it incurs cost on the driver to purchase a smart phone. On the contrary, GPS-based systems are easy to deploy because it does not require infrastructure design and maintenance cost since there is no external sensor installed and parking detection is accurate [33]. Nonetheless, it only provides information of the parking area but not the exact vacant spot. WN-based SOPS approaches depend on additional sensors and the systems require complex infrastructure, which is difficult to deploy [29]. It becomes worse when the entire infrastructure need to be revamped. The accuracy of parking detection is very accurate [33]. Smartphone-based system, on the hand, provides easy deployment with no or very low installation and maintenance cost. But this techniques sometime delays to detect parking and user location privacy has to be disclosed [12].

Table 2. Comparisons different of outdoor parking techniques

Categories	Easy to deploy	Maintenance cost	Startup cost	Accuracy
Vision based	Yes	Moderate	High	False detection occurs
GPS based	Yes	No	Low	Accurate
Wireless based	No	Low	High	Accurate
Smartphone based	Yes	No	No	Delay occurs

From this study, it is clear that smartphone-based SOPS is the most economical solution as compared to the other methods. Although the system has some drawbacks such as sensor sensitivity, this can be resolved by using supervised machine learning techniques [32]. It is also possible to utilize fusion approach that combines data from multiple sensors to increase the accuracy of recognizing drivers' activity. Since mobile-based parking system does not require external hardwires installation and maintenance cost, it could be considered as one of the best options for outdoor parking service providers. Besides, the growth of mobile technology and the ease of mobile phone usability would also facilitate the development of mobile-based SOPS.

4 Conclusion

An efficient real-time outdoor parking system can eradicate the frustration of users for getting parking occupancy in outdoor places such as shopping malls, universities, hospitals. In this review, we present the latest deployments of outdoor parking systems using different approaches including vision-based, GPS-based, wireless-based and mobile-based. The main focus is drawn to the advantages, disadvantages, deployment, and cost of the various systems. Overall, there is a need to implement a cost-effective system to reduce drivers' hectic in finding parking spaces. An analytical comparison is presented and several issues are deliberated. The highlighted issues can be further explored for enhancement of the existing systems.

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