Smart Parking Tools Suitability for Open Parking Lots: A Review

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Abstract: Parking a vehicle in traffic dense environments is a common issue in many parts of the world which often leads to congestion and environmental pollution. Lack of guidance information to vacant parking spaces is one of the reasons for inefficient parking behaviour. Smart parking sensors and technologies facilitate guidance of drivers to free parking spaces thereby improving parking efficiency. Currently, no such sensors or technologies are in use for the common open parking lot. This paper reviews the literature on the usage of smart parking sensors, technologies, applications and evaluate their suitability to open parking lots. Suitability was made in terms of expenditure and reliability. Magnetometers, ultrasonic sensors and machine vision were few of the widely used sensors and technologies used in closed parking lots. However, this paper suggests a combination of machine vision, fuzzy logic or multi-agent systems suitable for open parking lots due to less expenditure and resistance to varied environmental conditions. No application provided real time parking occupancy information of open parking lots, which is a necessity to guide them along the shortest route to free space. To develop smart parking applications for open parking lots, further research is needed in the fields of deep learning.

1 INTRODUCTION

In densely populated areas as in cities, the availability of parking spaces is often less than the availability of vehicles which leads to a shortage of parking space (Chinrungrueng et al., 2007). A parking space is defined as a location designated for parking which can either be paved or unpaved. A parking lot is referred as a group of parking spaces and parking refers to a vehicle finding and occupying a vacant parking space.

Studies showed that in worldwide traffic dense environment, 30 to 50 percent of the drivers look for free parking space (Polak and Vythoulkas, 1993, Boltze and Puzicha, 1995, White, 2007, Gallivan, 2011). Based on previous studies drivers use between 3.5 and 14 minutes to find a parking space (Shoup, 2006a, Polycarpou et al., 2013). Examples of consequences are; frustration of drivers, accidents, lost business opportunities, congestion, and increased air pollution. According to (Shoup, 2006b), studies focus on areas where there is expected increase in traffic and scarcity of parking spaces. Congestion can be observed when traffic density is increased, which is observed during peak traffic periods (Geroliminis and Daganzo, 2008, Geroliminis and Sun, 2011). In terms of air pollution, acceleration and cruising of a vehicle lead to high amount of emissions compared to idle or deceleration. A daily average of 100 inefficient cruising's in a parking lot would generate 24 tons of CO_2 which is approximately equivalent to three times of CO_2 per capita in Sweden (Frey et al., 2012, Jan Minx, 2008).

In order to reduce parking related congestion and air pollution, public transportations such as bus, metro, etc., can be utilized. However, private vehicles are still used for convenience. One way to address the carbon emission issue is to replace all fuel consumption vehicles with electric ones. Since, the average age of a car in Europe or United States is approximately 11 years (U.S)(Statista, 2017, European Automobile Manufactures Association, 2017), it can be expected to take quite a long time before electric vehicles replace all fuel consumption vehicles. In spite of using electric vehicles, cruising of a vehicle to find a vacant parking space would still be time consuming leading to congestion. A solution to that problem might be driverless cars. Driverless vehicle is one of the upcoming technologies currently being developed. Few companies such as Google have already developed prototype vehicles which support driverless mode in specific conditions (Thierer and Hagemann, 2014). Vehicle to Vehicle (V2V) technology could be implemented on all

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vehicles in order to improve the safety of all driverless vehicles (Harding et al., 2014, Guler et al., 2014). An automated driverless vehicle would depend on a number of technologies such as GPS, sensors, V2V, etc. and it would take few decades to replace existing vehicles. Yet another, not that far-fetched, solution might be a decision support system that uses smart parking sensor and technologies to detect parking occupancy information which facilitate the drivers to make informed decision of where to go and park their car (Yang et al., 2003). Parking occupancy information can be gathered using sensors and technologies such as; ultrasonic sensors, magnetometers and multi-agent systems. Parking a vehicle with the use of assisted applications or technologies is known as smart parking. Smart parking applications are available online which facilitate in improving parking efficiency by providing navigational directions to a reserved empty parking space (Kotb et al., 2016).

There has already been considerable amount of research conducted to improve parking efficiency at closed parking lots which are paid parking lots and support reservation of parking spaces. There are applications available online to provide decision support through smart parking services in closed parking lots. A parking space can be reserved by paying it through mobile or web applications. Once the reservation is made, the vehicle can enter the closed parking lot and occupy a vacant or allocated parking space. When reservation is made using applications, the user would be given a reference code which can be used for authorization. However literature is very scarce with regard to another and very common type of parking lot, the open parking lots which does not support reservation, freely available for a limited amount of time and are commonly placed outdoors occupying large amount of space. Therefore, there still exists a research gap in order to improve parking efficiency at an open parking lot. It is assumed that the driver behaviour could be efficient if improved decision support to drivers are offered. The areal size of the often very large open parking lots could be reduced by improving parking efficiency along with reduced congestion and CO_2 emissions.

The aim of this paper is to review smart parking sensors, technologies and applications suitability at open parking lots. Challenges in an open parking lot are; freely available where reservation is not possible and they are subjected to environmental conditions when placed outdoors. Therefore, suitability of sensors and technologies was made by compatibility and expenditure parameters.

The remaining part of this paper is organised in the following way. Section 2, describes the methods used to conduct the review of existing smart parking sensors, technologies and applications. Section 3 describes and analyses smart parking sensors, technologies and applications while Section 4 discusses about their suitability in open parking lots. Finally, the paper is ended with conclusion in Section 5.

2 MATERIALS AND METHODS

In this paper, literature search was carried out to identify articles using online databases. Two search procedures have been performed. First search is to find the smart parking sensors, technologies and a second one with focus on smart parking applications. An initial search was made in Google scholar and based on the result in that search, a refined search have been made in databases such as; ACM, IEEE, Springer, Elsevier, Taylor & Francis, Google Books. Keywords such as; smart parking sensors, technologies, intelligent parking systems, wireless parking systems, online parking, parking efficiency, outdoor parking systems, etc., were used for literature search. The initial search and review of articles identified smart parking sensors and technologies, see Section 3. Studies referring to parking issues or development and testing of smart parking sensors, technologies were selected in the initial search. Further analysis of information collected from the articles identified the suitability of smart parking sensors, technologies for open parking lots. Since the paper focuses on sensors, technologies and interfaces which are used to collect and display real time parking occupancy information, frameworks or architecture of smart parking systems are not reviewed in this paper. Parking meters which are used for payments are placed either at a parking lot or beside parking spaces are not referred in this paper. From the literature search, previous literature reviews on sensors and technologies are presented in Table 1, since they cover the available sensors and technologies described in the literature. However, it should be mentioned that these reviews do not emphasize on parking issues related to open parking lots. Keywords such as; review of smart parking, summary of intelligent parking, efficient parking systems overview, etc. were used to identify review articles using mentioned online databases. Surveys or reviews referring to usage of smart parking sensors and technologies were selected.

Table 1: Literature reviews on smart parking sensors and technologies.

Smart Parking Tools	*(Mimbela and Klein, 2000)*	*(Idris et al., 2009a)*	*(Revathi and Dhulipala, 2012)*	*(Mahmud et al., 2013)*	*(Fraifer and Fernström, 2016)*	*(Hassoune et al., 2016)*	*(Enríquez et al., 2017)*
Infrared sensors	●	●	●			●	●
Ultrasonic sensors	●	●	●		●	●	●
Inductive loop detectors	●	●	●				
Parking guidance systems		●	●			●	
Radio frequency tags		●	●		●	●	
Magnetometer	●	●	●			●	●
Microwave radar	●	●					
GPS		●	●	●	●		
Machine vision	●	●	●	●	●	●	●
Vehicular Ad hoc networks (VANET)				●	●		
Multi-agent systems		●	●	●		●	
Neural network					●	●	
Fuzzy logic				●	●		

Online search engine such as Google and mobile application stores are used to find existing smart parking applications. Keywords such as parking applications, smart parking applications, mobile parking were used to identify applications. In mobile application store, keywords such as; parking, e-parking, smart parking, etc. were used. There are hundreds of parking applications available in mobile application store. However, in this paper parking applications which provide real time parking occupancy information and navigational directions to a reserved parking space are selected. All the referred applications support reservation which is possible only in closed parking lots.

3 SMART PARKING TOOLS

Smart parking tools consists of sensors, technologies and applications which are used to identify parking occupancy information and facilitate to improve parking efficiency. As shown in Table 1, (Revathi and Dhulipala, 2012, Mimbela and Klein, 2000, Hassoune et al., 2016) are reviews about various types of smart parking sensors, technologies along with their uses while (Fraifer and Fernström, 2016), identifies research gap in designing smart parking system for stakeholders. Furthermore, (Mahmud et al., 2013), reviews about intelligent parking technologies and their economic analysis and (Enríquez et al., 2017, Idris et al., 2009a) reviews the advantages and drawbacks of sensors and technologies. As shown in Table 1, machine vision using visual camera is referred by all the review articles. Sensors like ultrasonic and magnetometers are widely reviewed and tested which are used in various smart parking applications. Vehicular Ad hoc networks and fuzzy logic were not reviewed prior to 2013. Detailed description of each sensors and technologies can be found in this section along with emphasis on expenditure.

3.1 Smart Parking Sensors

There are various sensors which facilitate in detecting parking occupancy information and these are mentioned in the following sections. Sensors are one of the common tools which were widely tested in several previous literatures. Descriptions of these sensors are mentioned in the following sections.

3.1.1 Passive or Active Infrared Sensor

Passive sensors detect changes in energy and when a vehicle occupies a parking space, these sensors identify the change in energy and detects occupancy (Shaheen, 2005, Mouskos et al., 2007). Passive sensor observes a change in energy when a vehicle is placed or a person standing above the sensor. Based

on the amount of energy change, it can be used to isolate outliers. Active sensors would emit infrared energy and detect any object or vehicle by the amount of energy reflected. However, both passive and active infrared sensors are sensitive to environment and they would not be accurate when there is snow or rain. Passive infrared sensors should be placed under the ground or on the ceiling while active sensors are normally mounted above a parking spot. Both the sensors require high investment for procurement and maintenance. These sensors would be suitable for closed parking lots which are inside buildings and are not suitable for outdoor open parking lots.

3.1.2 Ultrasonic Sensor

These sensors would emit sound waves between 25 to 50 kHz and detect objects based on reflected energy. They are usually mounted on ceiling and are sensitive to environmental changes such as rain and snow (Kianpisheh et al., 2012a). Therefore, they are suitable for indoor parking lots rather than open parking lots. Based on the distance at which waves are reflected it can distinguish between a vehicle and a person. In order to get parking occupancy status these sensors should be placed on top of every parking space. These sensors would be available for low cost but installation and maintenance of multiple sensors and connecting them to a grid would be expensive in the long run. Wireless ultrasonic sensors are also used to gather parking occupancy information. They are connected using wireless sensor networks such as ZigBee protocol or other similar networks (Idris et al., 2009b). However, wireless sensors involves periodic maintenance costs. In another study, ultrasonic sensors are used on a drive-by vehicle and parking occupancy information is collected at regular periods (Mathur et al., 2010). Real time parking occupancy information cannot be attained using drive-by vehicle.

3.1.3 Inductive Loop Detectors

These detectors are installed using underground wiring system and they use principles of electromagnetism to detect the presence of a vehicle (Shaheen, 2005). They are commonly used at the entrance and exit to get the count of vehicles which can be used to know availability of parking spaces. These detectors are expensive to install and maintain (Mouskos et al., 2007) and they can be used in indoor and outdoor parking lots to get the count of available parking spaces. Accurate count of vehicles would be provided using these detectors and these are in use at multiple commercial parking lots.

3.1.4 Parking Guidance Systems

Parking guidance systems is another smart parking system which provides information about number of parking spaces available on display screens and these are usually placed near the parking lots as the driver can see and decide the parking space to occupy.(Waterson et al., 2001) (Idris et al., 2009b) Inductive loop detectors or visual camera can be used at the entrance and exit of a parking lot to know the count of the vehicles in a parking lot which would be displayed on the screens. However, they do not guide the driver to a particular parking space which is found empty. Therefore, there is every possibility that the driver would cruise for several minutes before finding an empty space to occupy. The driver can make a decision about the parking lot only after viewing the display screens (Kianpisheh et al., 2012b). Since sensors or visual cameras would be deployed only to get the count of vehicles the expenditure for installation and maintenance would be minimal making them suitable for open parking lots.

3.1.5 Radio-Frequency Identification (RFID)

Radio frequency tags are used to identify vehicle. Each vehicle will be given a radio frequency tag for identification. A transceiver and antenna would be installed at the entrance of a parking lot to identify the tag and allow the vehicle to occupy a parking lot (Rahman et al., 2009). These are suited for closed and indoor parking lots which are controlled. It is not suitable for an open parking lot as they are freely available. RFID is used to authorize movement of vehicles at a parking lot. However, it does not providing individual parking occupancy status nor facilitates the driver in finding a vacant parking space.

3.1.6 Magnetometer

These sensors detect the presence of vehicle by detecting the change in electromagnetic field. They need to be in close proximity to the vehicle, therefore, they are placed beneath the surface. They are not sensitive to the environment (Shaheen, 2005). These are suitable for both open and closed parking lots. There are wireless sensors with a battery life time of few years which can be used to detect real time parking occupancy information. The sensors should be placed under every parking space to know the occupancy of parking spaces. However, it is expensive to install and maintain these sensors on a large scale.

3.1.7 Microwave Radar

A microwave radar transmits microwave beam and based on the reflected signal it estimates the velocity of the moving target. However, it does not detect stationary objects. In order to eliminate this restriction, dual microwave Doppler radar can be used to detect both moving and stationary vehicles (Bao et al., 2017). These can be mounted or placed beneath the surface for vehicle detection. These radars are not sensitive to environment and can be used in open and closed parking lots. They should be placed in every parking space to detect parking occupancy status making them expensive to install and maintain these microwave radars on a large scale.

3.2 Smart Parking Technologies

Sensor technologies are tools which facilitate the driver in occupying a vacant parking space and descriptions of these technologies can be found in the following sections below.

3.2.1 Global Positioning System (GPS)

GPS based navigational directions are provided to the driver for occupying a vacant parking space. GPS will facilitate in finding the shortest/optimal route from the current location. However, GPS alone cannot gather occupancy information of parking spaces. In one study occupancy of parking spaces is estimated using historical occupancy information and navigational directions are provided using GPS to the estimated parking space (Pullola et al., 2007). The accuracy of the GPS with a single frequency receiver is less than or equal to 7.8 meters. If a dual frequency receiver is used, the accuracy is less than 0.71 meters. A normal parking space would be between 2.3 to 2.7 meters and most of the smartphones are provided with single frequency receiver which have higher error compared to dual frequency receivers. Dual frequency receivers are usually used for military products for greater accuracy. A GPS is also perceptible to errors when the signal is blocked due to tall towers, walls within a building or under the ground. Therefore, navigational directions using GPS will be prone to errors in a closed indoor parking lot. Usage of GPS is suited for outdoor open parking lots where there is less chance for signal blocking. Accuracy of the GPS signal is also dependent on availability of satellite.

3.2.2 Machine Vision

A visual camera can be used for license plate recognition or identifying parking lot occupancy using machine vision. The camera should be placed near the entrance of a closed parking lot for license plate recognition (LPR). Based on the number of vehicles entered and exited it can help to get the count of vacant parking spaces. However, occupancy status of parking spaces cannot be attained using this system. Video processing of parking lot using a camera is not ideal as it requires continuous transfer of large bandwidths. Therefore, a video should be broken to images at regular intervals and frame rates to facilitate continuous monitoring of the parking lot (Enríquez et al., 2017). For parking spaces occupancy detection, a camera can be installed overhead to a parking lot and relevant image detection algorithms can be used to segment vehicles and detect occupancy of parking space. A camera is suited for open parking lots as it can cover large number of parking spaces (Ichihashi et al., 2009). However, it is susceptible to limitations such as; occlusion and shadow effects, distortion and lightning change. These limitations can be removed with the use of 3-D scene information (Huang et al., 2013). Since limited number of cameras can cover large number of parking spaces the expenditure is considered minimal.

3.2.3 Vanet

This system uses wireless communication devices to provide services such as; smart parking and antitheft. Road side unites (RSUs) would be widely placed across parking lots and vehicles should be installed with on-board units (OBU). A Trusted authority will be responsible for registrations of OBU and RSUs. (Lu et al., 2010) Therefore, once a vehicle approaches the parking lot installed with RSUs navigational information to the vacant parking space will be provided to OBU. These devices are not sensitive to environment and are suitable for closed and open parking lots. However, installation and maintenance of RSUs in the parking lot would be expensive. In order to achieve accurate parking occupancy data and navigational information all the vehicles must install OBU. Parking occupancy data is prone to errors if there are vehicles without OBU are parked.

3.2.4 Multi-Agent Systems

These kind of systems makes use of multiple mediums such as sensors, mobile, algorithms, visual camera, etc. These systems are also capable of incorporating aspects such as user preference,

importance, etc., in finding a vacant parking space for the driver. Multi-agent systems are considered as foundation for automation of smart parking systems. A user can select a parking space using a mobile or web application and based on the user importance and preference, a parking space will be selected. The user will also receive navigational information to reach the parking space. Java tools such as JaCaMo and environment such as CArtAgo can be used in the architecture (Bilal et al., 2012). Machine vision systems or VANETs can be used instead of using sensors. Usage of multiple systems are supported in this architecture. These systems are suitable for both open and closed parking lots. The expenditure would be dependent on the usage of technology to identify occupancy status of parking spaces.

3.2.5 Neural Networks

Neural network is a data processing system which is inspired by brain nervous system. Neural networks have evolved over the years and various types of neural networks were developed such as; fuzzy, neural network, fluid neural network, feed forward and convolution neural network. Neural networks can be combined with machine vision to achieve automation. Neural networks were used in efficient recognition of license plates in real time videos (Rahman et al., 2003, Villegas et al., 2009). In one of the study, images from morning and night were taken separately to train the neural network and a two layered feed-forward network with hidden sigmoid is used to produce accurate results in detection of available parking spaces (Jermsurawong et al., 2012). Deep learning is a branch of machine learning which uses neural networks in object detection and classification. There is another evolving technology such as convolution neural networks which would take images as input and is more efficient in analysing images. In a recent study, convolution neural networks was used along with machine vision to capture parking occupancy information efficiently (Amato et al., 2017). This technology would function as an efficient tool in data processing while it is not involved in real time data capturing. Therefore, it is suitable for open and closed parking lots with minimal expenditure.

3.2.6 Fuzzy Logic

Fuzzy logic is an approach which incorporates multivalued logic in evaluating. Fuzzy logic can be used to develop forecasting models based on sample data. Similar to neural networks, fuzzy logic can also be used in multi-agent systems. According to a study, a sample of parking spaces availability information for 5 days using machine vision was taken to predict the availability of parking spaces in future dates using fuzzy logic (Chen et al., 2013). Fuzzy logic supports autonomy in providing information on the availability of parking spaces. The accuracy of forecast models would not be high without validating with real time data. Therefore, combination of fuzzy logic models with machine vision or sensor technologies would increase the accuracy of the overall system. These systems are suitable for both open and closed parking lots. The expenditure would be minimal if image processing is used along with fuzzy logic to estimate available parking spaces for the future as well as provide real time availability of parking spaces. Since this technology is not involved in the real time data capturing process, it can be used for closed and open parking lots with minimal expenditure.

Not all of the sensors and technologies are suitable for gathering real time occupancy information of open parking lots. Even though sensors are widely used to acquire parking occupancy information, they would be expensive to install and maintain on large number of parking spaces. Few sensors such as infrared and ultrasonic are sensitive to environment and are not suitable for outdoor open parking lots. Technologies such as; machine vision, multi-agents systems and fuzzy logic are suitable for open parking lots to acquire parking occupancy information and GPS can be used to provide navigational directions.

3.3 Smart Parking Applications

There are many free smart parking applications available in Google Play Store for Android and the Apple application store for iOS. Previously, reservation of parking space was done by calling to the service provider and now with the current usage of internet and smartphones, these services are provided online using mobile and web applications. These applications serve as decision support systems for the driver in occupying a vacant parking space. For instance, if the application shows a particular parking lot of choice to be full, the driver can search for nearby parking lots with available parking spaces or choose another destination. In this way smart parking applications serve as decision support systems in occupying available parking spaces. Table 2, shows smart parking applications available online provide parking occupancy and guidance information. All the applications are provided in limited cities of mentioned countries.

Table 2. Smart parking applications and their use of technologies and sensors.

Smart parking application	Country	Sensors/Technology used
Park.ME	Austria, Germany	Sensors
SmartParking	New Zealand	Sensors, RFID
ParkMe	Japan, US, UK, Germany, Brazil	Sensors
ParkAssist	US	M4 Smart sensors, LPR
SpotHero	US	Sensors
EasyPark	Canada	Sensors
PaybyPhone	France	Sensors
ParkMobile	US	Sensors
AppyParking	UK	Magnetometer
EasyPark Group	Sweden, Denmark, etc.	Transactional data and crowdsourcing
Parker	US	Sensors, Machine vision
ParkiFi	US	Magnetometer
Best Parking	US	Sensors
Parkopedia	US, Germany, Sweden, etc.	Predictive analytics, sensors
SFPark	US	Sensors
Open Spot	US	Crowdsourcing

All the applications mentioned in Table 2 provide smart parking services in closed parking lots which support reservation and all of them are available in mobile application stores. However, Open Spot is the only application which is currently unavailable and discontinued by Google. Navigational directions to the free available parking space are provided which improve the efficiency of parking behaviour. A percentage or number of available parking spaces are shown for selected parking lots. None of the applications give the driver a choice in selecting a particular parking space. Most of the applications use underground wireless sensors such as magnetometers to get real time parking occupancy information. Setup and maintenance cost of wireless sensors will be high and it is mandatory to replace all sensors again when the battery life is depleted. Since, a sensor needs to be placed in all the parking spaces, operational and maintenance costs of such sensors would be high. Crowd sourcing application are suited for open/closed parking lots and the expenditure is considered very minimal as no hardware installations or maintenance is required. However, the users need to update occupancy details of parking spaces every time they park the vehicle and the accuracy of the information will be dependent on the user updating the occupancy details and is prone to human errors. Applications such as; Parkopedia and EasyPark Group use historical data for predicting parking occupancy information. Algorithms like fuzzy logic, time series are used to predict parking occupancy information based on historical or sample data. These applications are operational in more number of cities and countries compared to other applications. All these applications provide an overview of parking occupancy which facilitates in decision making.

4 DISCUSSION

The review of existing smart parking applications show that most of these applications use sensors for parking occupancy detection in closed parking lots which would require considerable amount of expenditure for installation and maintenance. Few applications use predictive analytics or crowd sourcing which can also be used on open parking lots. The applications which used predictive analytics were operational in more number of cities and countries than the applications which used sensors for parking occupancy detection. The difference might be due to less expenditure in using predictive analytics than deploying sensors in all parking spaces. However, real time occupancy information of parking spaces cannot be acquired using predictive analytics and accuracy of parking occupancy information by crowdsourcing is not reliable. None of the applications provide real time parking occupancy information of open parking lots. Lack of economic returns can be one of the reasons for not providing real time occupancy information of open parking lots. Since there would not be any immediate economic gains with the use of smart parking tools at open parking lots it would be well suited to use a sensor or technology with minimal expenditure to make it financially viable.

According to previous literatures, several smart parking sensors and technologies were tested and reviewed. However, sensors or technologies were largely used for closed parking lots which support reservation. None of the technologies were used to improve efficiency of parking in open parking lots. Ultrasonic and infrared sensors are sensitive to

environmental conditions which might lead to inaccurate parking occupancy information. Sensors such as magnetometers and microwave radar are not sensitive to environmental conditions but are expensive to install and maintain at open parking lots. Therefore, sensors are not ideal for open parking lots as expenditure should be minimal. Technologies such as VANET are also expensive and can be ruled out for open parking lots. However, VANET can be suitable in the future when all the vehicles are connected using on-board and road side units. As expenditure plays an important role in the choice of technology, it is found that; machine vision, multi-agent systems, along with convolution neural network or fuzzy logic are suitable to provide parking occupancy information. Neural networks are used mostly for license plate recognition and there are limited studies which use convolution neural networks for parking occupancy detection. In deep learning, large datasets such as Alexnet are already available and additional data would facilitate in further improving image classification. Convolution neural networks and deep learning are contemporary technologies which can be used in parking occupancy detection of open parking lots.

The parking occupancy detection using machine vision will vary between closed and open parking lots as there can be varying light conditions in an open outdoor parking lot. As mentioned in Section 3.2, challenges faced by low lighting and shadow conditions can be addressed. Therefore, machine vision using visual camera is one of the feasible smart parking technology for acquiring real time parking occupancy information in open parking lots. Machine vision can be associated with convolution neural networks and deep learning for efficient image classification. Along with real time occupancy information, a short term prediction of occupancy can be acquired using algorithms like fuzzy logic and time series. Since, reservation is not possible in an open parking lot, a short term prediction would facilitate the driver in the decision making process of choosing a parking lot. The prediction of parking space availability can also be made based on the location of the driver and its distance to the desired parking lot or destination. An optimal route can be calculated from the location to destination based on the distance of the route using which estimated arrival time can be acquired. Therefore, parking space occupancy prediction based on estimated arrival time can be shown to the driver. In this way smart parking applications can serve as efficient decision support systems. Due to various types of parking lots, such as outdoor, multi-storey, basement or indoor, a combination of smart parking technologies can be used to improve the efficiency of parking behaviour with minimal expenditure.

5 CONCLUSIONS

This paper reviews smart parking tools suitability for open parking lots. All the existing smart parking technologies and applications are not suitable for open parking lots due to varying environmental conditions and high expenditure. As there are no immediate economic gains from providing smart parking services in an open parking lot, expenditure plays an important role in the choice of smart parking technologies. Parking guidance system can be used to get the count of available parking spaces while machine vision can be used to acquire real time parking occupancy information on open parking lots due to its minimal expenditure. However, there is no single ideal technology suitable for parking occupancy detection. Based on the type of parking lot and size, different combination of smart parking technologies can be used for efficient and financially viable parking occupancy detection. In order to further improve parking efficiency, navigational directions should be provided to a vacant parking space. Therefore, in order to address this challenge further research in the use of deep learning and multi-agent systems would help to provide real time parking occupancy information along with navigational directions to the available parking space in an open parking lot.

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