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A Systematic Review of Machine-vision-based Smart Parking Systems

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Abstract

The smart city concept development, particularly in smart parking systems, has not solved a problem in metropolitan or urban areas. In those areas, the population continues to rise, resulting in high demand for private vehicles and parking spaces. Finding a parking space is the most common issue a driver encounters, especially during peak hours. During peak hours, the difficulty arises as many people look around to find vacant parking spaces at once, which causes many negative impacts on cities and drivers themselves, such as pollution, traffic congestion, traffic accidents, waste of time and fuel, emotions, and so on. As a solution, a smart parking system exists to equip parking lots with many different sensors to automatically detect free parking spaces that would guide drivers to find the nearest parking space as efficiently as possible. An effective smart parking system can solve this problem and make better use of parking resources. However, many smart parking systems still use embedded sensors that are expensive for installation and inefficient. This paper presents a review of the existing approaches to the smart parking system. This paper focuses on machine-vision-based technology used for smart parking systems and highlights its main features, advantages, and disadvantages.

Keywords: Smart Parking System, Machine Vision, Image Processing, Parking Space Detection, Vehicle Detection, Video Processing

1. INTRODUCTION

Population growth and economic development have led to a rapid increase in the number of private vehicles. At the same time, parking spaces and road infrastructures are not developed at the same pace, resulting in a lack of parking spaces in most modern cities. Finding a parking space during big events or peak hours is a frustrating task and a challenge for drivers. It causes traffic congestion, wasted times and fuels, and increases the carbon emissions released to the environment, causing pollution and damage to the ecosystem.

Paidi *et al.* [1] conducted a study that shows that drivers needed 3.5 to 14 minutes to find a parking space, while Enrìquez *et al.* [2] indicated an average time of 20 minutes for drivers to search a parking space and this causes 30% of traffic jams. Ndayambaje *et al.* [3] noted that more than 30 percent of drivers are looking for a vacant parking space in dense traffic environments. In Indonesia, the population growth and favorable economic conditions gave rise to an increase in the number of vehicles up to 20% in 2012. This increase resulted in traffic jams and a lack of parking spaces in many densely populated cities in Indonesia [4]. Also, Enrìquez *et al.* [2] stated that 54 percent of the population lives in urban areas and is expected to grow to 66 percent by 2050. This means more difficulty in urban mobility and in finding parking spaces in metropolitan areas.

Many solutions were envisioned to tackle the congestions and emissions caused by the lack of parking lots in urban areas. One of the most effective solutions is implementing a smart parking system in parking lots using the latest parking sensors and technology to identify a vacant parking space and direct drivers to the empty lot. Paidi *et al.* [1] defined a parking space as a region designated for parking that can be either paved or unpaved, whereas a parking lot refers to many parking spaces, and parking refers to the location occupation of an empty parking space by a vehicle.

Many of the existing smart parking systems are not adequate or not smart enough because they do not have the functionality to guide the driver to the destination parking space and only provide information on the number of available parking lots. Many systems have limitations, such as the use of embedded sensors designed for indoor parking, magnetic and ultrasonic sensors that are expensive and limited to detecting one parking space. Using a machine-vision-based sensor with the associated image processing techniques from a camera can be effective as the camera can capture larger areas at once and can be used for other purposes, such as surveillance. Therefore, the integration of sensors and recent technologies would create a robust, useful, inexpensive, and efficient real-time smart parking system.

This paper presents a survey of smart parking systems that are based on machine vision technology and that use image processing methods for vehicles and space detection on parking lots. This paper aims to review the machine-vision-based smart parking sensors, the techniques used, and to highlight the drawbacks and advantages of each system to gain insights into the direction of current and future smart parking systems.

The remaining part of this paper is organized as follows. Section 2 describes the smart parking system, analyses the machine-vision-based systems and some of the algorithms used. Section 3 surveys existing machine-vision-based systems to highlight the various parameters representing the different machine-vision-based smart parking system solutions. This section also provides analysis and insight into the current and future direction of research in the area. Section 4 concludes the paper.

2. METHODS

To capture the most recent development and state of the art in the field of smart parking systems, latest scientific papers from various journals and conferences that are relevant to vision-based smart parking, smart parking systems using image processing, smart parking systems using CCTV, etc., were collected. As the paper focuses on vision-based smart parking systems, which mostly use image processing techniques to classify and detect vacant vehicle parking spaces, the classification of vacant parking spaces using sensor-based systems is not reviewed. The collected papers are summarized in Table 1 to give a highlight of the vision-based smart parking systems.

2.1. Smart Parking System

A smart parking system is a system that can manage parking difficulties in the city using several recent technologies and sensors [5]. These technologies may include wireless sensor networks, infrared, magnetometer, and camera. The smart parking system uses real-time data collection by sensor nodes located in the parking lots to acquire information about the vacant parking spaces in the parking area. This allows users to take advantage of the additional services, such as mobile applications integrated with sensor nodes, offered by such smart parking systems to provide real-time data of vacant parking spaces in a particular location. This real-time data helps users and drivers to find parking spaces and minimize congestions. Smart parking systems typically include smart payment systems, parking guidance and information system (PGIS), automatic parking, transit-based information system, and e-parking [6]. The PGIS used in [7] is known as a parking-lot-occupancy detection system. The module consists of sensors for detecting vehicles, either embedded or machine-vision-based.

Choeychuen [8] divided machine-vision-based systems that use image processing techniques into two approaches: approaches based on recognition and appearance. By studying vehicles' features and categorizing them from the input image region, the recognition-based approach to parking space detection will identify vehicles in the parking lot. This approach is precise but can be complicated as it involves a large number of datasets to be trained under various conditions to build the model classifier. On the other hand, the appearance-based approach calculates the vacant parking spaces from various appearance features, such as histogram density of edge orientation from an adaptive background model, masked area, or image subtraction. This approach requires fewer datasets during training.

Parking guidance information systems, which is one of the smart parking system's components, are further classified into three different categories [9]:

1) Counter-based systems. Such a system uses sensors to count the vehicles entering and leaving the parking area, for instance, by using induction loop counters. This system's limitation is that it does not guide the driver to the parking lot's exact vacant location.
2) Sensor-based systems. The sensors are installed on each parking space, such as ultrasonic sensors. The drawback of this system is that it is costly to install as it requires a large number of sensors on each parking space to cover the entire parking lot.
3) Image and video-based systems (vision-based). Such a system may be expensive because a large amount of data must be transmitted over a wireless network. However, this system can use the current CCTV cameras, which have a lower installation cost, and is a good option for outdoor parking lots. It is

possible to further classify image-based into two categories: the first is car-driven, in which an algorithm is used to detect vehicles as the object of interest. The second is space-driven, which focuses on the detection of empty spaces in the parking area. The most widely used space-driven algorithm is the background subtraction since the classifier can be made under different light conditions. However, this is not suitable for outdoor parking areas under specific climate conditions, such as foggy or rainy weather.

Researchers have attempted to combine car-driven and space-driven methods—such as support vector machines (SVM), edge detection, principal component analysis, optical flow, and convolutional neural networks—with various classifiers to find a single robust and highly accurate classifier,

A survey by Lin *et al.* [10] indicated that if drivers can have information on parking availability in real-time, they can adjust their travel schedule without wasting time driving around the city in vain. They also noted that an excellent smart parking system would help drivers find empty parking spaces effectively and efficiently through information and communication technologies. For cities, the benefits for deploying smart parking systems include reduction of the time for drivers to find parking space, reduction of environmental pollution, fuel consumption, traffic congestion through smart parking apps, increase in the number of people relying on public transportation, and more importantly increase in the city revenues from parking fees through smart parking systems.

2.2. Vision-based System

Many researchers have been more interested in using artificial intelligence based on images using artificial vision to solve the smart parking system. Enrìquez *et al.* [2] listed some of the problems of detecting parking spaces using a vision-based system:

1) Image quality; for object recognition tasks, images must be in good quality to be processed. The quality is affected by insufficient lightning at night and adverse weather conditions, such as rainy or foggy weather.
2) Occlusions; the captured images are sometimes obstructed by the surrounding objects, such as trees, buildings, and object shadows.
3) Classification problem; image-based classification systems have proliferated over the years and are maturing.

The same research [2] further highlighted some of the advantages of using a vision-based system over a sensor-based one:

1) Coverage; single captured image can cover dozens of parking spaces.
2) Cost; lower installation cost and maintenance cost compared to sensor-based.
3) Versatility; images obtained can be used for other purposes, such as surveillance systems.

2.3. Vision-based Algorithms

Detection of parking spaces using vision-based systems is also assisted by a series of vision algorithms. These algorithms are divided into various approaches to machine-vision as follows [2]:

1) Appearance-based approach; the parking space's current appearance is compared with the vacant space's original appearance. An example technique commonly used is tailor and fine-tuning.
2) Recognition-based approach; which focuses on object recognition through machine learning algorithms to detect and classify the vehicles occupying the parking space. This approach is complicated since a wide range of objects required to be recognized.
3) Three-dimensional image processing.
4) Combined technique; image processing is used to improve image quality, avoid light variations, and classify image content using a machine learning algorithm.
5) Monitoring technique; which depends on the parking lots that need to be processed. Two available types of monitoring are a) estimating the occupancy of the entire parking lot and b) checking the vehicle's presence in each parking lot.

2.2.1. Convolutional Neural Networks

Amato *et al.* [11] defined deep learning as an artificial intelligence branch that seeks to develop techniques that enable computers to learn the complex task of perception at the human level accuracy, such as seeing and hearing. It has the advantage of providing close to human-level accuracy in vehicle and pedestrian detection, image classification, speech recognition, object detection, natural language processing, and many more. They also maintained that one of many deep learning methods, convolutional neural network (CNN), is an effective method for vision tasks. CNN is a convolutional layer capable of modeling and distinguishes the spatial correlation between the neighboring pixels better and more effective than normal, fully connected layers. The final output of CNN is the classes where the network has been trained. However, the limitation of using CNN is that its training process is costly in computation and takes a lot of time. On the other hand, the prediction phase is fast and accurate if the network has been trained.

A smart parking system based on the CNN classifier has been implemented in [11]. A smart camera and two different datasets, PKLot and CNRPark, are used. PKLot dataset is used to train and test the parking lot occupancy detection, while CNRPark is used in two different locations with different points of view. The proposed system provides a distributed, effective, efficient, and scalable solution for real-time parking occupancy detection. As the system uses deep CNN, it is robust to disturbances, such as partial occlusions, and has a good generalization property. A low computation resource is needed for the classification phase, as it only uses Raspberry Pi modules equipped with a smart camera. The system uses a website to live view all the cameras deployed in the different parking places. After being tested in other locations and under different light conditions, the experiment result shows a very high accuracy even under partial occlusions. The test result also indicates that CNN has good generalization capabilities in predicting parking status tested on different datasets.

2.2.2. Other Machine Learning Algorithms

Bin *et al.* [12] introduced a smart parking system based on real-time image processing using a video camera as the sensor for parking space detection. The system's structure consists of three modules: image acquisition, image pre-processing, and image detection modules. The image acquisition collects the real-time images with a resolution no less than 640×480. Subsequently, the pre-processing module computes those images. It processes them using the detection algorithm, such as converting the images into grayscale. The detection module is where the final decision is made in real-time to determine the parking space occupancy status. This system is quite old but has an accuracy of 81%.

In [13], a parking space detection was proposed using an image processing technique with a brown-rounded image drawn at each parking lot. With the brown dots, each parking space can be identified easily. As a sensor, a video camera is used. The system is divided into five modules: initialization module, image acquisition module, image segmentation module, image enhancement module, and image detection module. The initialization module automatically detects the location of every parking lot from the image. The acquisition module captures and stores the images from a video camera; a high-definition camera is recommended and should not be obstructed by obstacles, such as shadows, trees, and buildings. The segmentation module separates the objects from the background using image subtraction, such as converting RGB images into grayscale and differentiate pixel value by thresholding the binary image. The next phase is enhancement, where it removes the noise by using a binary morphological function and removes the pixels from unrelated objects. Finally, the detection module determines the rounded brown image on each parking space and counts the total detected brown dots before it is displayed.

In [8], an automatic parking lot was used for parking space detection. The system uses a histogram of spatial features for masking parking lot and adaptive background morel for background subtraction of poor-quality images. A thresholding technique is used for fine-tuning due to the poor-quality images. The tuning method can improve the accuracy of the histogram for parking lot mapping. As the system uses automatic mapping, changing the camera's position and the parking layout will not affect the system. Besides, automatic mapping can learn the behavior of the parking area in unmanaged parking lots.

Almeida *et al.* [9] introduced a paper on parking space detection using textual descriptors. Two descriptors are used: a local binary pattern known as (LBP) and a local phase quantization known as (LPQ). Under varying weather conditions, including sunny, overcast, heavy, and light rain, an extensive database of 105,837 parking space images is captured. Since the light is not adequate to capture a good quality image, no night shots are captured. The resolution of images is no less than

1280×720 pixels. The database is divided equally into training and testing datasets. The test was made under different classifiers to compare the error rate, the classifiers, including LBP, LPQ, SVM, LPQ Gaussian window, and LPQ Gaussian derivative. The experimental result shows that both descriptors can achieve low error rates, and by combining different classifiers, the error rate can be reduced to 0.16%.

The work presented in [14] deals with a rounded image drawn at the parking lot that can produce parking-lot-occupancy status information. It has a similar method to the system proposed by [13] with more complex computation. The system comprises five modules: image identification for capturing empty parking area by locating the green dots in each space, image acquisition to acquire the image, image separation to differentiate the objects in an image, image development to reduce the noise by dilation and erosion, and lastly image determination to find the coordinates that initialize the car park space. The system finally determines the car's presence in the car parking lots by applying the point detection with a canny operator or edge detection.

A smart car parking system using CCTV nodes was developed by Fraifer and Fernström [15]. The system prototype is a low-cost and scalable smart parking management system that uses an embedded micro-web server to access and remotely manage devices and appliances using IP connectivity. The phases of implementation start from having the image’s perspective transform matrix. The algorithm then uses the prospective transformation matrix to extract frames from the streaming video. Using a contour approach (rectangular detection) that can distinguish the number of vehicles in the parking lot, the system will detect the empty parking spaces in the targeted parking lot. If the `findRect` method matches the detected shape to the parked vehicle's shape, it will detect the vehicle as a rectangle.

Kurniawan [16] introduced a guide to implementing many different internet-of-things projects, including a smart parking system. The system is implemented using Arduino and a Raspberry Pi smart camera sensor to detect a vacant parking space. The aim was to optimize the parking spaces as the number of vacant parking spaces will be known by the system. The method used was by differentiating between parking lot capacity as baseline background with the number of vehicles currently in the lot using background subtraction and an OpenCV library. It compares the frame depicting the parking lot with vehicles to the baseline background frame using a thresholding technique to get the vehicle's foreground mask. It then finally counts the number of vehicles detected to the availability of parking spaces.

A smart parking system based on video processing and analysis on a python program with real-time parking lot monitoring using a machine learning technique was built by Zacepins *et al.* [7]. The method used by the system was focused on video analysis and public video streaming. The system used five main classifier models: decision tree, logistic regression, random forest, linear support vector machine, and radial-basis function support vector machine. Consequently, for parking lot occupancy detection, five classifier models are contrasted. The outcome indicates that logistic regression performed better and predicted accurately. Logistic regression was then the classifier model selected for the use of real-time parking monitoring.

In [17], a smart parking-lot-management system algorithm was proposed. The algorithm can detect empty parking spaces from aerial images of parking lots, starting from processing the image and extracting occupancy information of spots and position. The system reports individual parking spaces, either occupied or not. The system accurately detects cars' presence in parking slots using two approaches: filled-edge image and dilated-edge image approaches. The filled-edge image performed better to determine the vacancy of the parking spot.

In [4], a smart parking system was developed by using the Haar cascade method. The Haar cascade algorithm detects vehicle objects and empty parking spaces in the parking area accessed from a mobile application. The system framework uses a Raspberry Pi camera. The system will then send the data through a Wi-Fi module on the Raspberry Pi minicomputer to a Firebase cloud platform. The result is displayed in real-time in the mobile application. The accuracy of the system depends on the occlusions from the shadows between two vehicles. The system also runs on different view angles of the camera. The result shows that the detection capability from different view angles is not affected in single-vehicle detection. In contrast, on multiple-vehicle detection, the accuracy is affected by the shadow between vehicles.

In [18], Loong *et al.* introduced a cost-effective smart parking system based on internet-of-things to monitor the parking lot and provide real-time parking lot status to the drivers. The system uses smart cameras and Raspberry Pi modules to obtain the parking space status. The experimental result achieved a high accuracy of 96.40%, which was conducted in an outdoor parking area consists of 20 parking lots with diverse weather conditions, such as a clear sky and a rainy day.

In [19], a real-world dataset containing videos from multiple parking spaces was used by Di Mauro *et al.* to maximize the use of parking spaces in urban areas. They investigated parking areas' parking occupancy status based on two scenarios: stall-based scenario on occupancy estimation and stall-free scenario on occupancy information. It assumes that parking stalls are numbered on the ground where the car is supposed to be parked in a stall-based scenario, whereas the stall-free scenario assumes that no parking stalls are marked in the parking space. The stall-based and stall-free approaches are then compared based on image classification semantic segmentation and image classification. The experimental result shows that if the geometry is known, an image classification method is preferred. Still, if the configuration is not known, then an image segmentation method the preferred method. The experiments also show that temporal smoothing is effective for improving the results based on object detection and image segmentation¸ but not preferred when using image classification.

Lastly, Trivedi *et al.* [20] developed real-time parking management for a small module using Hough transform. The goal was to detect and identify real-time parking space status. Two types of modules are proposed for car parking using a combination of color enhancement, edge detection, and the Hough transform method. The car park's two modules are oval: parallel parking with a different radius and parking angle of the same radius.

3. RESULT AND DISCUSSION

The review of the existing vision-based smart parking systems shows that detecting vacant parking spaces or vehicles depends on the quality of the images captured by the camera. Thus, it will be expensive if, for capturing the images, a high-quality camera that can capture good night-time images and reduce the error rates is installed. However, compared to sensor-based systems, the installation and maintenance cost for vision-based systems is still lower. Therefore, this system is highly recommended for future smart and reliable parking systems using artificial intelligence based on images using artificial vision.

Selecting a method and algorithm for a vision-based smart parking system is vital to acquire the best and efficient result. In recent years, many researchers are more interested in using Convolutional Neural Networks classifier. The reason behind this popularity is that CNN is more flexible and has a good generalization capability. The CNN module can be used in different parking areas using different datasets. As summarized in Table 1, the method implemented by [9] using SVM, LPQ, and LBP has achieved the lowest error rates compared to any other methods. However, the quality of the images needed is high to gain better accuracy. Many images are also required to train and test the datasets, which means the time to spend on creating the classifier will also be longer. In comparison, even though the CNN classifier used by [11] has a higher error rate than [9], the system can inhibit the noise caused by shadows, light, and partial occlusions the other methods cannot deal with. Thus, it is more advantageous to CNN for vacant parking space detection.

In comparison to sensor-based systems, Bin *et al.* [12] have highlighted some disadvantages of sensor-based smart parking systems, such as microwave detection, infrared detection, and ultrasonic detection. One of them is that the system is not adaptable to some climate changes, which means that it can only be used for indoor parking environment. Another disadvantage is that the system would require one sensor for each parking space, which is expensive for installation and maintenance for larger parking lots. However, the main advantage of using a sensor-based system is that the accuracy is very high, but it depends on the sensor used.

Table 1. Features of various vision-based smart parking systems

Ref.	Year	Algorithms / Models	Hardware Required	Type of Parking Area	Error Rate	Computational	Advantages	Disadvantages
[4]	2019	Haar Cascade, AdaBoost Algorithm	Smart Camera, Raspberry Pi, Cloud, IoT	Outdoor	20%	Low	In a single-car detection using Haar cascade, different view angles will not affect the detection capability. The car can be detected from any angle of view. The accuracy is 100% for single-car detection.	The system is not robust to occlusions such as car shadow. Additional hardware is required, such as the Raspberry module. In multiple-car detection, the accuracy is affected by the car and shadow, which results in detecting two cars as one object.
[7]	2018	Linear SVM, Logistic Regression, Radial Basis Function SVM, Random Forest, Decision Tree	Public Video Streaming Camera	Outdoor	10%	Medium	A universal system which can be found in all cases of car parking. Uses the existing camera, which is a cost-efficient method. All analysis and processing take less than 1 second; therefore, the system is reliable for real-time parking lot monitoring.	High-quality images of 1920x1080 pixels are needed. Computationally medium as it trains 21,000 images. Not robust for night-time detection. If the car is not parked in the considered lot, it would not be correctly detected by the system.
[8]	2013	Background Subtraction, Spatial Feature Histogram, Automatic Thresholding, Fine Tuning	Surveillance Camera	Indoor & Outdoor	-	Low	The performance of detected cars is improved by using automatic thresholding. The system can be used in a controlled environment and ideal weather conditions.	The system is not robust to occlusions. The system is affected by lighting change.
[9]	2013	SVM, LPQ, LBP, Normalization, Cross-validation	Microsoft LifeCam Camera	Outdoor	0.16%	High	A textual descriptor, such as LBP and LPQ, is a good alternative for parking space detection. A low error rate is achieved as the classifiers are combined. A good performance system.	Not robust for night-time detection. High-quality images are needed.

[11]	2016	CNN Classifiers (MLeNet & mAlexNet)	Smart Camera, Raspberry Pi	Indoor & Outdoor	1% to 18%	Medium	Robust against partial occlusions, different light conditions, and the presence of shadows. Good generalization capability as it robust to different parking lots testing. Inexpensive installation as low computation is needed for testing. The system can be used for other objects detection such as motorcycle parking space	Computationally expensive for the training phase. Performance of the system is not acceptable under nigh time, foggy or snowy.
[12]	2009	Thresholding, Edge Detection, Self-adaptive Algorithm	Video Camera	Indoor & Outdoor	19%	Low	Computationally low and inexpensive hardware needed. It has the capability of detecting in the indoor and outdoor parking area under only good light conditions.	The error rate is high. Not robust to different weather conditions as video camera gives an output of low-resolution images. Not robust to partial occlusions.
[13]	2012	Thresholding, Edge Detection, Binary Morphological Function, Dilation & Erosion	Video Camera	Outdoor	-	Low	Using brown dots as the target is simple, and no need to process the vehicle object. Very low computation is used as it only targeting the brown dots on each parking space.	The experiment is based on toys, so the accuracy is not detected. As the system wasn't tested in real-time, the weather factor is not determined.
[14]	2014	Canny Edge Detection, Erosion & Dilation, Template Matching, Morphological Process	Video Camera, Satellite Camera	Indoor & Outdoor	-	Low	Uses coordinate of each parking space, so less computation needed. An inexpensive method that can be used in different types of parking areas.	Not robust to varying weather conditions, which can be strengthened by high-quality image filtering such that the camera can distinguish the parking lots under any weather situation.
[15]	2017	Perspective Transformation, Smoothing, Noise Reduction, Thresholding, Contour Method	CCTV Camera, Server, IoT, Mobile App	Outdoor	-	Low	Using an existing CCTV node is a cost-efficient method. No need to change the infrastructures of the parking lot. Contour method is used to detect vacant parking space in parking lots by identifying the number of cars in the parking lot, which is a low computational method.	The system detects two cars if cars are parked along the line. Dark atmosphere due to climate and lighting will fail the system to operate as it needs artificial illumination. The video displayed on real-time streaming has some delay. The system is dependent on the speed of the Internet.

								CCTV resolution has to be high.
[17]	2018	Luminosity Method, Normalization, Noise Reduction, Otsu Thresholding, Canny Edge Detection, Sobel-Feldman Convolutions, Edge Tracking, Flood-fill operation	Aerial Camera, Wireless Sensor Network	Outdoor	-	Medium	The system accurately detected the presence of cars in parking slots within 2 seconds. The two approaches can be fused into one system to create better accuracy.	Replacement or installation of existing cameras or changing the camera's position would require the system's re-initialization. Poor quality images will increase the error rate. Medium computational since many operations are made in the system.
[18]	2019	Motion Tracking, Canny Edge Detection, Blob Tracking, Image Binarization, Gaussian Smoothing	Smart Camera, Raspberry Pi, IoT	Outdoor	3.6%	Low	A scalable and low-cost system that can be installed in a different parking lot. The system has been tested in outdoor parking spaces with diverse weather conditions, such as a clear sky and a rainy day, with an accuracy of 96.40%. Night-time detection can achieve the same accuracy with sufficient night illumination.	The accuracy of the method can be improved using a better camera and a faster processing unit.
[19]	2019	Temporal Smoothing, Semantic Segmentation	Full-HD Camera	Outdoor	-	Low	The system can be used in different parking area geometry and domain adaptation techniques.	11,066 images are collected in the testing and training dataset.
[20]	2020	Hough Transform, Edge Detection, Colour Enhancement	IP Webcam	-	-	Low	In controlled light conditions, the true-positive value is high, and the false-negative value is almost zero. With a fixed camera placement and without changes in light intensity, a 100% correct result was obtained.	The light change affects the experiment result. Real-time implementation is not made.

Table 1 highlights the existing vision-based smart parking systems reviewed in the previous section to summarize this section. The highlights are tabulated to emphasize features for a more straightforward comparison view. As shown in the table, not all existing vision-based systems are perfect and efficient. Therefore, it is essential to highlight each system's advantages and disadvantages to envision accurate, inexpensive, and efficient vision-based smart parking systems. Such systems will minimize the upcoming increasing number of traffic congestions in urban areas and reduce the impacts of congestions on the environment.

4. CONCLUSION

This paper has reviewed the different vision-based smart parking system methods to address vacant parking spaces' detection using a camera as the sensor. Conclusively, this paper has shown that vision-based smart parking systems are preferable over sensor-based smart parking systems. It will be the future of smart parking system with very high accuracy, reliability, scalability, and efficiency. Vision-based system algorithm is more flexible; we don't need to replace the sensor if we need to improve it. This will make the management of parking spaces more effective.

A survey was conducted by Polycarpou *et al.* [21] in 2013 involving 1,400 respondents in Greece to gather information on how quickly drivers can find a vacant parking space. The result shows that 37% spent more than 10 minutes, while another 63% spend less than 10 minutes to find an empty parking space. That means the smart parking system with less installation cost and extended liability is very recommended to solve this problem. This would benefit the local government and the drivers themselves.

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