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doi:10.15199/48.2021.09.27

An Enhancement in Accuracy of Vehicle Detection in Parking Areas Employing Haar-Like Features and AdaBoost Algorithm

Abstract. *With the increasing number of vehicles on the road, often it is difficult to find suitable parking spaces in metropolitan cities. It may cause wastage of time as well as traffic congestion if proper parking spaces haven't been preserved. An autonomous parking system can detect empty parking spaces and allow drivers to effectively park in empty parking spaces which require less time and less fuel. This paper has presented an intelligent vision-based approach that discovers vehicles and empty spaces autonomously. We have introduced Haar-like feature cascade classifier trained by a machine learning technique for the vehicle detection process. The proposed system has delivered promising results to the detection accuracy of the vehicles to allow parking places. The vehicle detection accuracy of the proposed system has been validated through simulation. Besides, the proposed approach has made available the optimum threshold value to acquire the best possible detection accuracy. The advantages of the proposed scheme are a) it saves time to get the vehicles parked; b) it provides to get rid of traffic congestion; c) as the driver gets the space immediately, so less energy is required with the proposed approach. Later, a brief comparison of performance metrics among various classifiers is provided.*

Streszczenie. *Przy rosnącej liczbie pojazdów poruszających się po drogach często trudno jest znaleźć odpowiednie miejsca parkingowe w metropoliach. Może to spowodować stratę czasu, a także zatory drogowe, jeśli nie zostaną zachowane odpowiednie miejsca parkingowe. Autonomiczny system parkowania może wykrywać puste miejsca parkingowe i umożliwiać kierowcom efektywne parkowanie na pustych miejscach, które wymagają mniej czasu i mniej paliwa. W artykule przedstawiono inteligentne podejście oparte na wizji, które autonomicznie wykrywa pojazdy i puste przestrzenie. Wprowadziliśmy kaskadowy klasyfikator cech podobny do Haara, wyszkolony techniką uczenia maszynowego dla procesu wykrywania pojazdów. Zaproponowany system przyniósł obiecujące wyniki w zakresie dokładności wykrywania pojazdów w celu umożliwienia parkowania. Dokładność wykrywania pojazdów proponowanego systemu została zweryfikowana poprzez symulację. Ponadto zaproponowane podejście umożliwiło uzyskanie optymalnej wartości progowej w celu uzyskania najlepszej możliwej dokładności wykrywania. Zaletami proponowanego schematu są: a) oszczędność czasu na zaparkowanie pojazdów; b) zapewnia pozbycie się zatorów komunikacyjnych; c) ponieważ kierowca natychmiast otrzymuje miejsce, więc przy proponowanym podejściu potrzeba mniej energii. Później przedstawiono krótkie porównanie metryk wydajności między różnymi klasyfikatorami.* (***Zwiększenie dokładności wykrywania pojazdów na parkingach dzięki funkcjom podobnym do algorytmu Haar i AdaBoost)***

Keywords: Autonomous parking, Computer vision, Digital image processing, Haar-cascade classifier, Parking space detection
Słowa kluczowe: wyszukiwanie miejsc parkingowych, algorytm Haar i AdaBoost

Introduction

Nowadays, the growing tendency in vehicle possession has increased the burden of city traffic and also it exacerbates the hassle of inadequate parking spaces. In recent days, most cars have managed to find parking spaces through the human workforce, and a few of them automated systems to control the parking location a trendy systematized approach. It is time-inefficient to discover the vacant parking space with the old-fashioned approaches and an additional expenditure of fuel on top of the cost [1]. An image processing based smart parking system has been developed for multi-story parking garages which eliminates long queues and traffic congestion for car drivers [2]. Maximum instances of the parking places continue to be untenanted; though, the full occupancy is low due to car parks' terrible administration. This is the unproductive practice of the parking place, which results in traffic roadblocks besides overcrowding close to the car parking spaces.

There are several techniques that present to organize car parking areas. A machine learning based approach is developed for automatic detection of vacant spaces where car boundaries are set and the approach deals with the non-rectangular and diverse resolution of images as input which trains the classifier by a single support vector machine (SVM) classifier [3].

Sensor-based techniques matter on bodily exposure sensors positioned upstairs or beneath a parking area. However, they are limited due to the significant capital charges of the massive quantity of bodily detectors obligatory to cover tremendous parking amenities [1]. Two types of sensors are incorporated for this purpose such as visual sensors and non-visual sensors. Sometimes, a photographic sensor is casted-off in conjunction with the magnetic sensors [4]. The magnetic sensors consume higher energy compared to photographic sensors. Photographic sensors are needed to authorize a magnetic sensor that benefits to observe car park tenancy. An additional blended sensor method engages distance and magnetic sensors, which remunerates for the little captivating footprint of positive automobiles [5]. This method has shown higher accuracy though it adds in an issue as a devoted sensor is a prerequisite for the treasury of an individually parking space. Thus, installation and maintenance cost is much higher with this approach. Even sensors' performances are largely affected by the natural state of affairs such as rain, temperature, and snow in parking areas. Usually, the supplementary frequent strategy is used to notice parking tenancy by the investigation sensors (e.g. cameras) that are already established in the car parking areas [6]. Another low-cost design has been introduced where wireless sensor nodes are placed at the crucial places of the car parks [7]. The wide variety of automobiles in the parking area can be decided to employ the distinction between inward and outward vehicles [7].

The image-based approaches for car parking plays an important role as the image-based strategies additionally incorporate unlike features but fewer organized data than sensor-based methods on top of counter-based approaches. It is viable to become aware of particular automobile features from image-based techniques. However, it is comparatively harder to do so through the usage of counter-based or sensor-based methods [8]. The vision predominantly founded parking area exposure strategies are identically convenient to install, less expensive, and the scheme can easily be managed according to the requirements as proposed in [9]. Furthermore, the facts received from images are ridiculous.

Still, the imperfections in the visualization approach need to be corrected based on the camera's role [7]. Moreover, another unsupervised vision technique has been proposed that has aimed at the decreased difficulty in totalling and requires fewer image frames per unit time [10]. In that paper, the authors described that the principal anxiety in image exposure is the shades caused by other automobiles in the parking areas [10]. A small-steadfastness internet digital camera is exploited to obtain images of the car parks that significantly diminish the expense. The images obtained are pre-processed, and then a pair of a region of interest (ROI) is utilized on each division of the car parks, which will increase the dependability of noticing vehicles [7]. Nowadays, there are many solutions considering the location of the parking areas. Images are segmented to parking spaces manually and then classified segments to understand the spaces either occupied or not. It is used as a high colour trajectory feature-based support vector machine (SVM) [11].

In this paper, we have employed an innovative framework by exploiting machine learning techniques along with taking advantage of Haar feature like cascade classifier to detect automatic parking space. This method has shown significant improvement of the accuracy and later, we provide a clear comparison among various classifiers which can have used for the same purpose to distinguish vehicles and vacant spaces in the parking areas. Moreover, we would like to focus on how the accuracy displays diversity along with a number of classifiers. The comparative analysis with this enhanced accuracy, the proposed approach offers less time to park the vehicle that influences the energy as well as fuel cost, i.e. overall producing the approach beneficial.

This paper is organized as follows: after the introduction, Section 2 describes the methodology for designing an autonomous intelligent scheme that is used to discover parking spaces. Section 3 illustrates the result and performance analysis of the proposed approach. Finally, the conclusions are comprised in later section.

Fig. 1. Elementary blocks of the proposed system

Research methodology

This paper is presented a new approach that classifies the parking area whether it is occupied by an automobile or vacant. The proposed system consists of four main modules. The Fig.1 shows the basic functional blocks of the proposed system. The initial step is to install a surveillance camera which is used to capture continuous images of the vehicles. This surveillance camera is directly connected to the server which is connected to either a local server or a cloud server. At the server unit, computer vision method is implemented exploiting Haar-like feature cascade classifier to identify vehicles and parking slots. If local server is used, then data will be sent to Firebase Realtime Database (FRD) after identification. If cloud-based server such as Google cloud platform is used, then data will be forwarded to FRD from this server after identification. Those data from the database can be retrieved or extracted anytime according to needs. All kinds of information like free spaces of the parking lot can be provided to the end-user through both web and mobile applications. Implementing our system architecture is also easier than other system architecture which is used in the paper [12] because proposed method is adorned with microservice architecture. The prime advantages of the microservice architecture are scalability and reliability which make them popular in use [13].

The proposed method has been simulated following few steps and these steps are illustrated in Fig. 2. Laplacian operator is used to detect the shape of the image of interest. The Laplacian operator is a 2nd order derivative mask used to locate edges in an image or a photo. The Laplacian operator didn't take out edges in any specific route compared to foreign operators that make Laplacian operator more popular. However, it takes out edges in both inner and outer edges [14].Though Laplacian is sensitive to noisy conditions however it take out edges of i) *Inward edges* and ii) *Outward edges*.

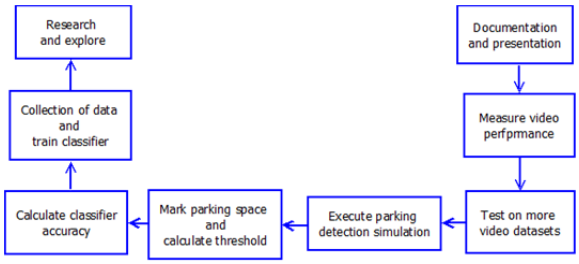

Fig. 2. Work flow diagram of parking space detection scheme

AdaBoost algorithm

The AdaBoost learning algorithm has become more popular in research for object recognition that can discover body degree by using a level on a cascade. Since 2001, the *adaBoost* algorithm has used machine learning techniques to discover a face detection classifier [15]. To distinguish the occupied and vacant spaces in the parking area, it is followed motion tracking throughout this research work. Motion tracking using upbringing subtraction proce-dures, delineations and geomorphological operations are being casted-off. Each sub-class has skimmed for specific standards on every step. Besides, a sub-class encom-passing fantastic body used to be used as a feedstuff for the next degree riddling with more precise conditions till acquiring a sub-class which was once prophesied as a car. On the contrary, a sub-class no longer can be able to contain tremendous objects that used to be marked as background and separated by using a sub-class comprising superb items as illustrated in [12]. The AdaBoost algorithm is to assemble a robust classifier and thus the algorithm sequentially uses some weedy classifiers that are mainly constructed on Haar-like feature extraction. The robust multilevel classifier trained in this paper is followed by three weedy classifiers, as presented in Fig. 3.

The Haar-like feature is a rectangular function offering a unique indication of an image. The Haar feature-like characteristic affords headlong multiplication relying on the number of pixels inside the rectangle area of interest and usually does not rely on the pixel rate of the image. In finding the object exposure value, the Haar feature-like function fee is used to be calculated the use of an essential image. The essential image ought to calculate values precisely and tremendously shortly by means of creating a new presentation of the image through the use of the importance of region formerly skimmed by way of specific Haar feature-like aspects. The fundamental equation that can be followed in this context the equation,

$$S(x,y) = i(x,y) + s(x,y-1) + s(x-1,y1) + s(x-1,y-1) \quad (1)$$

The cost of a necessary image was acquired by means of the sum cost of the previous index, began by way of the leftward topmost until the rightward bottom-most; moreover, an integral image ought to be premeditated as in (1).

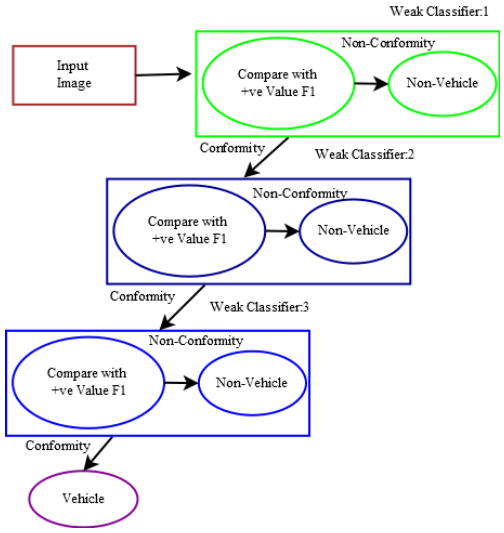

Fig. 3. Schematic of a strong classifier made of cascaded layers

The cost had been calculated via the usage of a necessary image of the object. The equation with the threshold value of particular facets has to be designed via the AdaBoost algorithm. The target is achieved to discover budding elements due to the fact of specific facets were pertinent to use for inimitable object detection. Besides, the AdaBoost algorithm associates practicable points called vulnerable classifiers to come to be robust classifiers.

Process of vehicle tracking and counting

Automobile tracking has used to reap the particular role of the vehicle entire the body to be associated with a list of preceding places of traced objects. However, new places or places not consisting of tracked object places were delivered as a two dimensional (x, y) location of a newfangled object. If the newfangled role were counted in the listing of earlier traced objects' sites, it would be used as a new function of a known entity. The universal system of vehicle tracking is offered with the aid of the design in Fig. 4.

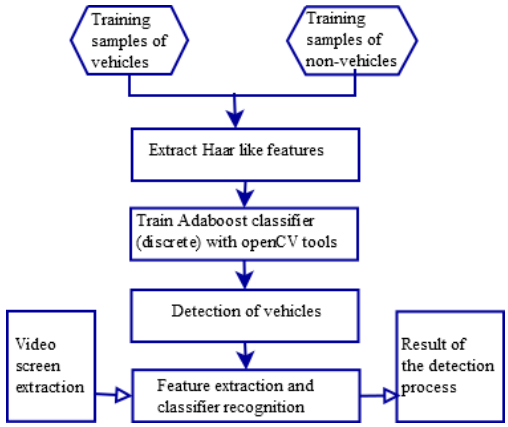

Fig.4. Block diagram of the vehicle tracking process

Each passing automobile object interior ROI is used to be tracked based totally on its role and would be associated with the listing of tracked object locations. For a new location which includes in the list of tracked objects, it was being brought as a newfangled object and should be calculated. If the new-fangled role used to be protected in the listing of locations of beforehand traced objects, its capability the role had already been calculated as the documented automobile.

Results and discussion

The experiment in this work is completed under an environment of Spyder IDE, Python-3.7 supported, incorporated with modules of recently released OpenCV 4.4.0.44, in a computing machine with a processor of Intel® Core i5 5200u, 2.20 GHz, and an internal RAM of 8GB.

Training and Testing

We followed here the *AdaBoost* learning algorithm as stated earlier. In this approach, a cascade function is trained from many positive and negative images as it is a machine learning-based method. Firstly, the algorithm desires many positive impressions of vehicles like cars and negative images except cars or vehicle-like objects to train the classifier. Later, we need to extract features from it. The cascade classifier contains a series of phases, where every step is an ensemble of weedy learners. The weedy learners are simple classifiers referred to as conclusion bases. Each phase is trained using an approach referred to as boosting. Boosting offers the capacity to instruct a highly correct classifier by using captivating a weighted average of the choices made by using the weedy learners.

For training the datasets, we have chosen 1500 images of the cars (positive image) and 1300 images of the non-car images or negative images such as natural scenery, human beings, and different types of scenes. Those images are grayscale processed flattened into a pixel arrangement of 128×128 resolution. The lasting images are used to test the appreciation of the indicator designed in this broadside. The accuracy of the classifier is enhanced further if we consider the larger datasets.

Simulation results

An efficacy program was used to compute the correctness of the classifier in sensing automobiles. The program applies to the classifier on a set of frames and computes the percentage of automobiles acknowledged in each frame. Later, the accuracy of correct detection is presented as a form of percentages. The results are as follows:

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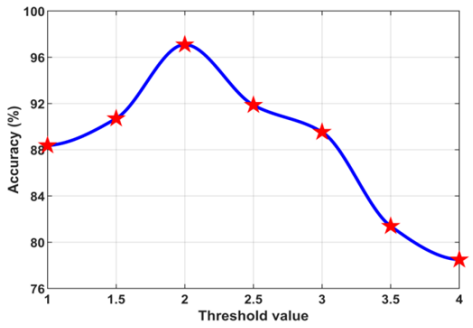

Fig. 5. System accuracy as a function of threshold value for specific test frame

It is drawn the accuracy as a function of the threshold value of an image which is illustrated in Fig. 5. From the Fig. 5, it is clearly noticed that the introduced scheme has shown higher accuracy at a certain threshold value. Here, at the threshold value *2.0* works far better than the other threshold values in this test frame. In addition, it is concluded from Fig. 5 that the optimum threshold value for the proposed approach is *2.0*. Finally, the proposed classifier has achieved an accuracy of *97.09%* along with the threshold value has set to 2. The positive and negative dataset used in this research work can be found in [16]

We have employed Haar-like features cascade classifier which is used to detect the occupied and vacant spaces in a parking area. Finally, the result of the proposed classifier is compared with the already implemented system such as *kNN* and SVM classifier. The comparison of

average detection rates of our proposed system and other techniques [13] are plotted in Fig. 6. The comparison is performed with the same datasets for all the classifier approaches. It is comprehended from the Fig. 6 that the proposed method provides the best possible detection accuracy among other methods.

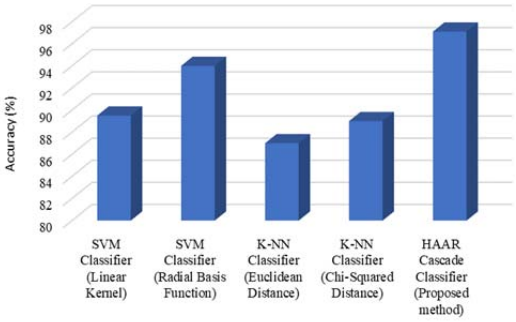

Fig. 6. Performance metrics of various classifiers used for automobile tenancy in the parking area

Conclusion

An autonomous and efficient parking system is offered in this research paper which is convenient to practice. From the surveillance data stream, the proposed approach is developed for real-time detection of opportunistic space in a parking area whether it is occupied by an automobile or left vacant. Besides, the Haar-like feature classifier does a decent job that is implemented based on convolution neural networks. The overall accuracy of the vehicle detection is greatly increased by employing this approach which is validated by the simulation result. Finally, the simulation result is compared with other existing classifiers in use. The comparison offers the proposed approach outperforms other existing SVM and HOG classifiers. This method suits well if the vehicle is recognizable from any visible point and is also adaptable for large or small parking spaces. It takes less time to park a vehicle for a driver while employing the proposed approach. So, incorporating less time in car parking is advantageous in such a way that it consumes less fuel or energy as well as contributes less traffic on the road. Thus, the design of the proposed approach is believed cost-efficient. The performance of the system depends on the image quality of the vehicles; therefore, if the image has no distinguishable feature (e.g. one vehicle is shaded over another vehicle) which puts a limit on the performance of the proposed method. Furthermore, the accuracy of the system is dependent on the laplacian threshold, motion tracking algorithm based on background subtraction, and most importantly, the strength of the classifier. The challenge faced was to determine motion in a small region of interest when there's a high possibility of noise. For example, the camera was placed near the stairs and the reflection of people walking down the stairs was being reflected in the input video provided by the camera. It becomes challenging to reduce the impact of such noises and detect a small amount of motion. In future research, this issue can be addressed and find a possible way to overcome the constraint. Thus, the approach will provide a more accurate result as well as give provision for commercial use.

Acknowledgment

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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