Road Traffic Anomaly Detection: A Survey

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Abstract. Lately the number of vehicles circulating on roads had been widely increased especially in the big cities, leading instantly to congestion and consequently the accidents rate increasement. In order to reduce traffic issues and enhance road safety, so many researchers focus their vision on this era problem trying to look for solutions by developing algorithms and embedded applications based on image processing and artificial intelligence, therefore we aim to automate the traditional detecting systems used to spot traffic violations such as: speeding detection; crossing a red light; driving on a prohibited lane, etc. this offenses considered among the principal factors of road accidents, for this main reason the built of those embedded systems play a very important role for traffic accident reduction through monitoring the road safety and automating the penalty detection. In this article, we are trying to study the most recent techniques based on computer vision to monitor and detect traffic offenses, lightning the strengths and weaknesses of these techniques, additionally we provide research a comparison and study basis to facilitate their future work also improve robust approaches to detect road violations.

Keywords: Detection of traffic violations · Crossing a red light · Speed detection

1 Introduction

In these recent years, traffic management has become one of the main issues concerning public health, especially with the increasement of vehicles, good traffic management requires real-time embedded systems that are able to replace human roles, installed in most principal roads especially those with traffic jam. These monitoring systems allow us to detect all types of code infringement. To take precautions and make all the road users drive quietly and safely [1].

This article presents a study of different systems based on image processing and artificial intelligence, additionally a state of art concerning automation of code violation detecting systems, we have summarized some recent works, each one solves one of traffic problems, either red signal detection [2–5], speeding detection [6–8], sudden change of direction [9] or driving on a prohibited lane [10].

We aim to provide researcher with a preliminary data basis about various existing techniques, different pre-processing, and techniques to minimize noise in frames which

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is a necessary step in most algorithms, the major step in all the proposed algorithms is the choice of technology used for detecting vehicles; additionally, we present the experimental results of each application to discuss the performance of each algorithm.

This work is organized as follow: Sect. 2 present a state of art about the different approaches based on image processing and artificial intelligence dedicated to detecting all types of traffic violations, Sect. 3 presents the results analysis of the different techniques discussed above, conclusion and future work are presented in Sect. 4.

2 Literature Review

In this section, we present an overview about the automated systems based on artificial intelligence and image processing dedicated for automatic detection of traffic violations. More precisely, speeding; crossing a red light; driving on a prohibited lane etc. These techniques require a high-resolution camera to facilitate the progress of different algorithms and get the best results, in addition to make the system apt in different lighting conditions (day and night). We have examined the powerful points of the techniques documented furthermore suggested different other research orientations in pursuance of improving the obtained results and the offered systems service. Most of these algorithms suggest adding new functionalities such as detect and recognize number of vehicles violating the Highway Code.

Akila et al. [9] presented an automated and real-time system for detecting traffic violations, more precisely detecting the vehicles that suddenly change their trajectory, to achieve this system, they have chosen the "Haar Cascade" detector because of its high precision and performances, additionally to employ it they have trained a classifier using images database which either contain vehicles or not. Subsequently this classifier checks all the image fractions to determine if there are one or more vehicles in it, furthermore, tracks every single vehicle using the previous detecting results (x and y coordinates, area, and width/height ratio), these values are inserted in a KalmanBoxTracker model while identifying each object separately, afterward the KalmanBoxTracker object is placed in list, this last contains all the information about tracked vehicle.

During the association phase each newly detected vehicle is added to the list while the others deemed obsolete are removed, and to detect vehicles road violations, they adopt for a new mechanism that calculate the trajectory angle of the vehicle, i.e., the angle between two lines connecting four points of the trajectory, considering that the trajectory makes a series of points pk, pk-1, pk-2 ……. With pk is the current position, then calculate the angle between the line pk and pk-2 with pk-2 and pk-4. The main raison for skipping a position is reducing the effects of noise and position errors, therefore while defining a threshold the violation is detected if the value found exceeds this threshold.

The system produces results with a large value of MOT = 0.90 (Multiple Object Tracking), towards result amelioration through increasing accuracy rate we should define the detection area to avoid tracking the discarded vehicles and therefore minimize the false negative rate.

Joel et al. [7] proposed a very fast traffic violation detecting system, to detect vehicles, they used the SSD model trained by the COCO dataset, and then define a line of interest regions i.e., the line where the vehicles are banned to cross when the light is red, afterwards inserting the image in the SSD model to generate a bounding box if there is a vehicle.

The coordinates of the latter used to determine if a vehicle goes by the line of interest, the condition of this line is defined by the condition of the red light i.e., by a timer, for example if a vehicle goes by the line while the red traffic light is on then this vehicle marked as a red-light offender.

Additionally, they proposed an algorithm to detect speeding vehicles based on OpenCV, which means calculating the Euclidean distance [11] between two successive frames. To find the current distance in meters we should multiply the resulted distance in pixels by the equation converting pixels to meters, therefore we divide the obtained result by the value of fps. The researchers conclude that the SSD model is excellent for detecting red light crossing with a rate of 100% and speeding with a rate of 92.1%.

Bordia et al. [5] presents a system dedicated to detects vehicles crossing the lines when the signal turns yellow or red, this system requires two cameras, one to detect the traffic light is placed in front of the light and the other to detect vehicles placed in front of traffic. Therefore, the development of this algorithm requires four main phases.

First phase, the detection of the traffic light contains two tasks: 1 detecting the position of the traffic light using TensorFlow object detection trained on (COCO dataset [12]), 2 color identification by Faster RCNN trained on Bosh database [13, 14]. The second phase is the detection of traffic line, to facilitate the calculation and eliminate all kind of noise, the algorithm starts with the identification of the interest region while taking just half of the image containing the stop line. Therefore, the image is cropped (zero, height/2) and (zero, width/2) and then converting each frame to grayscale to apply the Canny Edge algorithm.

Additionally, for vehicle detection the studies are based on the Mobile net SSD model and trained on the COCO dataset, to detect vehicles crossing the white security line they combined the results of the last two steps i.e., the intersection of the white line coordinates and the coordinates of the detected vehicles. Let's take the coordinates p (x1, y1), q (x2, y2) as the ends of the safety line and the coordinates d1, d2 as the car box diagonal, we decide a traffic violation if the triplet (p, q, d1) and (p, q, d2) have different orientations.

To summarize, concerning vehicle detection the SSD model according with the COCO database gives the best results, concerning the traffic lights detection, the faster RCNN gives an accuracy of 74.14% and it could be improved with more training, and for more system amelioration they have proposed adding the classification of various vehicles and reading car numbers.

In order to detect speeding vehicles, Neha et al. [6] have proposed an algorithm that goes through several stages, starting with the acquisition of the frames, then the pre-processing steps which have a role of minimizing the noise, This model consists of extracting the different ROIs, converting the image to grey level so as to reduce noise and computational complexity, therefore applying Gaussian Blurring to facilitate edge detection, and finally apply FastNlMeansDenoising, in order to simplify the analysis, we partitioned the frame by segmentation, next the classification is done using Haar Cascade while training a model to distinguish the positive images that contains the vehicles and the negative ones, afterwards the Haar Cascade becomes able to detect vehicles and draw a bounding box for each vehicle.

The last model of the proposed algorithm is responsible for speed calculating, therefore they used the VASCAR algorithm to estimate the speed of each vehicle, while knowing the displacement between two reference points on the trajectory, the principle of this algorithm is to start a timer when the vehicle passes the first point and doing the same thing for second point. We can conclude the time needed to move without breaking the road rules by subtracting the timer's values, therefore we can simply calculate the speed with the formula v = displacement/time, whilst comparing this result to a speed threshold we detect the vehicles that offences highway code. The authors concluded that their method compared to others is more efficient and eventually gives an accuracy of 0.928.

Pasit et al. [3] have presented a software technique to identifying traffic light colors, the proposed algorithm is very important because it represent the first step that launch the other traffic light violation step. First, define the region of interest to detect only the area containing the traffic light; afterwards, authors have proposed three methods to detect the red-light color. The first one consists in converting the images in grey level, doing a thresholding, then comparing the three colors with a predefined model to determine which color is on, the second is based on the conversion of RGB color images to HSV and compare the value of the hue to determine the color of the traffic light lit, and thirdly a step that makes a combination of the first two methods which means that the true color is when the results of the two methods are identical, and if it is red the violation detection routine automatically triggered, this technique detected the three color with an accuracy of 96%.

A one-way violation detection system by three-wheeled vehicles because they have a greater tendency to violate these rules is proposed by Helen et al. [10], to detect three-wheeled vehicles they used the pre-trained TensorFlow object detection model provided by the Zoo model, the next step is to follow this type of vehicle, by storing the centroid coordinates of each vehicle for the displacement calculation, and then if we notice that the direction of a vehicle is opposite to the direction of traffic, then we can conclude that this vehicle has violated the rules of one-way traffic. This method is cost-effective and easy to deploy and works well for one-way traffic areas.

In this study the authors Ruben et al. [8], presents a traffic violation detection system: traffic light violation and vehicle speed detection based on YOLOV3 as a detection algorithm [15], because of its detection speed and accuracy, This model allows us to classify moving objects, and therefore to classify vehicles, and then classified the other elements by the same model as the traffic lights, after detection of the vehicles we obtain the coordinates of the box and we calculate the intersection of these coordinates with the ROI which is the traffic signal line, the percentage of the intersection is the index that will show whether a car has violated the traffic law or not, and the speed is calculated using three principles: anchor calculation, pixel calculation and box area calculation. This system gives an accuracy of 89.24% for the detection of speed violations.

A complete application to detect vehicles in violation of the stop line is developed by Satadal et al. [2], to test the correct functioning of this application, the authors collected a real database by installing three cameras at an important intersection of the road, the cameras are synchronized with the traffic signals to take only the videos with the red light on. The videos are taken in different lighting conditions (day/night), to this end for the detection of the vehicles they used a method which adapts to the change of illumination, based on the adaptative background subtraction method. the algorithm is structured as follows: calculate the difference between the successive images, if the value is below than a predefined threshold, then the image is considered as background, and it is stored in the database as soon as a change is made to the database, then the average background image is generated by averaging the last five images. Then a new image is subtracted from the background image, in this image of subtraction the gray values of all pixels are added and compared to a threshold, to decide that there is a possibility of a vehicle intrusion. and to detect stop line violations, the authors have proposed a new technique: draw five lines hypothetically on the stop line, if all pixels along the lines are black, it is decided that there is no occlusion, and to decide that there is a violation of the stop line or red light, the vehicle must continuously obscure the stop line, which means that the longest average exceeds a given threshold, This technique successfully identifies vehicles in 92% of cases.

A region-based approach is proposed by Yanyue et al. [4], to detect that does not stop in front of the stop line, the authors define the detection zone by (the stop line until the front of the sidewalks) which is long enough to take a minimum number of frames to study the movement of the vehicles. and to detect moving vehicles, they proposed a method based on the background subtraction and also allows to distinguish the moving object from the shadow, This method relies on the difference between the hue frames based on the HSV color model to detect vehicles [16], by following the steps: transformation of the detection region from RGB to HSV, calculate the line-by-line average of the hue of the current image and the background, Do the subtraction by line for the average hue of the background frame to current frame. The authors defined two thresholds, The first one is used to judge the state of the line, if the result of the subtraction is greater than the threshold then we say that the detection region is incomplete, we count the incomplete and continuous lines, where SLmax1 is the maximum value, if the SLmax1 value is higher than the second predetermined threshold which is the maximum length of a continuous incomplete line, then the car is in the detection zone, This method is based on the initialization of the background during the red signal, and also to take image captures without moving objects quickly, They divided the detection area into three parts, and update each part separately. To update the background the authors, use Surendra's algorithm [17], in which we replace the background with the current frame for the region that does not contain a moving object, and to detect the movement of vehicles they proposed to set two thresholds, one is the Sstop threshold, and the other Srun. They assume that fw is the total pixel rows between the two frames of vehicle forward, If fw is less than Sstop then the vehicle is stopped, i.e. there is no violation, if fw is greater than Srun then the vehicle does not stop which means there is a violation, The algorithm proposed in this article detects vehicles efficiently and can eliminate the disturbances caused by shadow and illumination, and the weak points of these algorithms are, it does not address the problem of hidden vehicles, and also the quality of the video affects the veracity of the detection.

3 Results Analysis

The Table (1) evaluates the techniques described in the previous section:

Table 1. Representative work based on type of violation

Ref	Type of violation	Specific technique	Detected object	Method	Assessment
[2]	Stop line violation	Adaptative background subtraction method	Vehicle	Image processing	**Pros:** Identifies vehicles in 92% of cases **Cons**: a configurable solution, a threshold must be set
[3]	Red light violation	Compare the RGB and HSV color of traffic light to a threshold	Traffic light colors	Image processing	**Pros:** This technique is simple for implementation and give an accuracy of 96% **Cons**: sensitive to light changes
[4]	Stop line violation	Frame difference in hue based on HSV color of image	Vehicle	Image processing	**Pros:** detects vehicles efficiently **Cons**: it does not address the problem of hidden vehicles, and the quality of the video affects the veracity of the detection
[5]	Red light violation	TensorFlow object detection COCO dataset	Traffic light	Supervised learning	**Pros:** Good result of detection and classification **Cons:** Detect traffic light in all condition (angle of vision and lighting) need for data augmentation

(*continued*)

Table 1. (*continued*)

Ref	Type of violation	Specific technique	Detected object	Method	Assessment
[5]	Red light violation	Faster RCNN Bosh dataset	Traffic light colors	Supervised learning	**Pros:** gives an accuracy rate of 74.14% which is sufficient to validate the proper functioning of the violation detection algorithm **Cons**: requires more training of the model, and it is slower compared to the SSD algorithm
[5]	Red light violation	Mobile net SSD model	Vehicle	Supervised learning	**Pros**: SSD model suitable for detecting red light violation **Cons**: A large training dataset is required for high accuracy
[6]	Over speed detection	Haar Cascade	Vehicle	Supervised learning	**Pros:** image pre-processing + Haar cascade + VASCAR: the combination of the three treatments gives an accuracy of 0.928 for speed detection **Cons**: They tend to follow false positive vehicles

(*continued*)

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Ref	Type of violation	Specific technique	Detected object	Method	Assessment
[7]	Red light violation	SSD model COCO Dataset	Vehicle	Supervised learning	**Pros**: SSD model is excellent for detecting red light crossing with a rate of 100%, very fast **Cons**: A large training dataset is required for high accuracy
[7]	Over speed detection	SSD model COCO dataset	Vehicle	Supervised learning	**Pros:** SSD model suitable for detecting over speed and give a rate of 92.1%, very fast **Cons**: A large training dataset is required for high accuracy
[8]	Traffic light violation	YOLOV3	Vehicle	Supervised learning	**Pros:** This algorithm based on YOLOV3 give an accuracy of 89.24% for the detection of speed violations, speed detection **Cons**: does not detect small objects correctly
[9]	Sudden change of trajectory	Haar Cascade	Vehicle	Supervised learning	**Pros**: provides high accuracy for the MOT which means that the algorithm will work very well with violation detection **Cons**: They tend to follow false positive vehicles, especially the far ones

(*continued*)

Table 1. (*continued*)

Ref	Type of violation	Specific technique	Detected object	Method	Assessment
[10]	A one-way violation detection	TensorFlow object detection model	Three-wheeled vehicles	Supervised learning	**Pros:** This method is cost-effective and easy to deploy **Cons**: this method works only for one-way traffic areas

All the methods we have studied give good results for the detection of violations in the roads, based on the disadvantages of the used methods we can conclude that most of the algorithms based on deep learning (supervised), require an increase of the training database, and for the other algorithms which are based on background subtraction it is necessary to always take into consideration the change of lighting, the shadow detection and the intersection of objects.

4 Conclusion and Future Work

In this research paper, we have presented an analysis study of different techniques dedicated to resolve traffic violation issues based on image processing and different artificial intelligence models. To automatically detect the road violations, we introduced the most recent systems apt to detect all types of traffic offences, through combining the best-proposed solutions that gives the most efficient results. This paper aims to provide researchers with the preliminary knowledge needed to develop robust approaches. And therefore, ameliorate different features or build new algorithms with innovative ideas, additionally improve both the accuracy and the computation time. The Future work consists of developing some ameliorated approaches based on artificial intelligence algorithms to detect vehicles that cross the stop signs further the duplication of vehicles in a banned place taking into consideration all real lighting conditions.

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