Real-Time Traffic Rules Infringing Determination Over the Video Stream: Wrong Way and Clearway Violation Detection

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***Abstract*— Video processing techniques are used in research areas about traffic for many purposes such as measuring traffic density, crash detection, vehicle classification and counting. To control the traffic flow and create a safer environment, vehicle detection, tracking, security lane and wrong way violation detection is achieved with the developed system. As known, security lane violation causes units from security, health or fire departments to not be able to use those lanes when needed. Also, wrong way violation is one of the main causes of car crashes. These types of violations directly or indirectly cause serious numbers of loss of life and property. In order to prevent such problems, it is very important to detect the infringers early. In this paper, the wrong way and clearway violation detection over the video stream in real-time is achieved.**

Keywords*— *Image Processing, Vehicle Detection, Vehicle Tracking, Security Lane Violation, Wrong Way Violation.

I. INTRODUCTION

With the ever increasing population of people and vehicles, traffic accidents increase every day. Traffic should be controlled fast and in time to prevent these type of situations. However, the size of the data can make it harder to control traffic. For this reason, detecting lane and wrong way violations from cameras would make traffic control easier. In this study, a software-based system is proposed that will minimize human errors and ensure that the people who perform the audit can make accurate and quick decisions.

In the literature, there are many studies regarding traffic rules violation. Detection of speed violations is usually done by radar and sensors. They may be portable, but they are expensive and also require frequent maintenance. Alonso et al. [1] performed lane change detection of moving vehicles using the optical flow algorithm. They compared the results with the ground truth, which they obtained with the lidar. Yalcin et al. [2], proposed solutions for road boundary detection and obstacle detection, in order to allow autonomous vehicles to find their way. Light Detection and Ranging (LIDAR) which is the most popular technique for these problems. Çelik ve Kusetoğulları [3] proposed a solar-powered speed camera system to detect and report moving vehicles that violate the speed limit. The maximum error in the speed measurement is 1.5 km / s as the average speed measured in the test area. However, when the amount of shadow in the processed video sequence increases, the system fails. Sridharamurthy et al. [4] proposed a traffic violation detection technique using vehicle ad hoc networks to detect speed violation and driver behavior. They used a sensor device, a digital map and a GPS-based system for an area of 1000 m × 1000 m, and they split a network into several clusters, each with an infrastructure node (base station). The engine node creates a contact point for all vehicles in that area. When the driver performs a speed violation, the engine node sends a warning message to the control center, which includes the identity, the breach type and the violation to the infrastructure.

In literature there are several vehicle detection methods. Matthews et al.[5] proposed a way to separate vehicles and roads. They used vehicles' region of interests as dataset for classification and then used Principal Component Analysis (PCA) method to reduce the size of the dataset. To classify the systems they achieved 90% accuracy with multi layer perceptrons. Goerick et al.[6] used Local Orientation Coding (LOC) to extract edge information and neural networks for vehicle detection. Papageorgiou et al.[7] proposed an object detection scheme using waves and SVMs. Sun Z. et al[8] proposed using Gabor filters for vehicle attribute extraction and SVM for vehicle detection. Şentaş et al. [9] used two different methods for vehicle detection and classification, and evaluated the performance of the methods. The first one is the Convolutional Neural Network (CNN), in the second method they use, first they extracted the features of the vehicles with Histogram of Oriented Gradients (HOG) algorithm and then classified them with Support Vector Machine (SVM).

Wrong way violations often result in deaths of innocent drivers. A lot of work in literature are aimed to solution of this problem. Monteiro et al.[10] proposed detection of people driving on the wrong way using optical flow. Proposed solution consists of 3 basic steps: learning, detection and verification. In the first step flow of vehicle motion is learned with mixture of Gaussians ve modeled. Second step (detection and temporally verification) uses said model to detect vehicles in the wrong way. In the third and the last step, before the alarm goes off an approach based of appearance is used to detect the vehicle. Haendeler et al.[11] proposed a Passive Vehicle Detection (PVD) technology based on radio sensors in the side of the road which can detect direction of the vehicle. Detection system consists of six radio modules integrated into existing radiators. The paper focuses on functional verification and verification with area testing. In their work, Jain and Tiwari[12] proposed a method of detecting wrong way violators by following the drivers from air with based on optical flow.

In the field of security lane detection instead of detecting vehicles which violate security lane with a camera, studies focused on assisting drivers with advanced driver assistance systems by lane detection and tracking using an on-vehicle camera. Zhou et al.[13] proposed a lane detection system with geometrical models and Gabor filters. Lanes' geometric model has four parameters which are starting position, lane direction, lane width and lane curvature. Algorithm consists of three steps. In the first step estimation of parameters of the lane detecting camera on the vehicle using 2D calibration method[14] is aimed. In the second step, estimation of the first three parameters, starting position, lane width and lane direction using dominant orientation estimation[15] and local Hough transform is aimed. After that construction of lane candidates is applied for last lane model pairing; in the third step model pairing is applied. Proposed lane module pairing algorithm is applied for the best equipped lane model. In this project, driver assistance is aimed by detecting and tracking lanes inside the vehicle. Detection of the vehicles in the traffic is not accomplished since detecting traffic violation is not aimed. Yinghua He et al.[16] In their paper titled "Color-based Road Detection in Urban Traffic Scenes", they proposed road area detection algorithm based on color images. Their work consists two steps: initially boundaries of the lane were estimated by image intensity, then the area of the lane was determined based on the full-color image. In the first step an edge image of the scene analyzed the color components of the road surfaces to obtain candidates for the left and right road edges, and to confine the area to be used to calculate the mean and variance of the Gaussian distribution to be used later. In the second step, the road area has been effectively extracted and strengthened the boundaries appropriately suited for road extraction. As a result this work was proposed for the development of intelligent/autonomous vehicles but was not targeted on traffic violations. In this study, only one vehicle was allowed to follow the lanes and the statuses/states of the other vehicles weren't examined. Cheng et al. [17] have proposed a lane detection method which aimed at managing moving vehicles. Firstly, lane signs extracted based on color information and lane sign colors extraction is designed to be unaffected by the lighting changes and the proportion of area used by vehicles on the road. Afterwards, extracted lane signs were used to distinguish size, shape and motion information from real lane signs in vehicles of the same color as the lane markers.

Within the confines of this research, the following works were done: vehicle tracking, safety lane, and reverse direction violation were detected via video stream from the camera. In contrast to similar studies, the boundaries of safety lanes were applied to determine the violation of the safety lanes, initial and final coordinates given as an input. Afterwards, the possible violation of safety lane by the vehicle will be determined by feeding the linear equation of the two known points with the center coordinates of tracking vehicles. In the process of reverse direction determination, the violation will be detected taking into account the difference between y-axis at the center coordinates of vehicles.

The remaining part of this work has been organized as follows. Methods used for vehicle detection, vehicle tracking, Wrong Way and Clearway Violation Detection has been explained in Section 2 and Section 3 discusses the results obtained from this work Section 2.

II. WRONG WAY AND CLEARWAY VIOLATION DETECTION

Vehicle detection and tracking has to be done first in order to detect security lane or wrong way violation. The flow diagram in Figure 1, will be used to implement detection of violations.

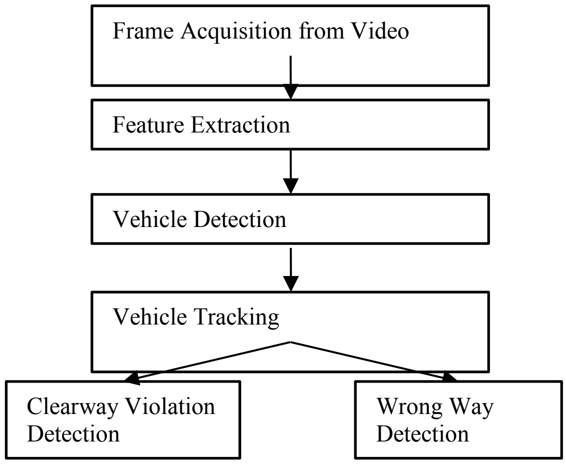

Figure 1. Violation Detection Flow Diagram

A. Feature Extraction, Vehicle Detection and Tracking

Kul et al. [18] examined the real-time performance and foreground extraction algorithms (BGS Library) of the BGSLibrary algorithms in data sets known as Background Models Challenge (BMC) and ChangeDetection and evaluated their performance in order to facilitate traffic surveillance. The background subtraction technique has traditionally been applied to the perception of objects. However, when applied to a surveillance system that captures the outdoor scene, the background subtraction technique perceives not only objects but also too much noise because it shows great sensitivity to minor changes such as lighting changes. Kul et al. In another study of [19], vehicle detection and classification of the vehicles according to their types were carried out. Vehicles are divided into small, medium and large classes according to their sizes and they have been sending data in real time to subscribers with the publish/subscribe model. To detect vehicles, Support Vector Machines (SVM) are used. To teach said SVM's Histogram of Oriented Gradients (HOG) features are extracted. Purpose of the HOG algorithm is to represent an image groups of local histograms. These histograms consist of orientation and magnitude of gradients in those areas.

In order to retrieve the data set, In Kocaeli, the video stream with the resolution of 1920x1080 has been shot in the traffic. A total of 4849 images including positive and negative images were obtained from the captured videos. Of the total images, 1473 are positive images and 3376 are negative images. Positive images consist of 784 cars, 164 buses, 77 minibuses, 200 minivans and 137 trucks. Positive images refer to vehicles in the image, while negative images refer to non-vehicle images in the image.

To track vehicles, from OpenCV library [20] Boosting[21], Goturn[22], KCF[23], MedianFLow[24] and TLD[25] are tested. Medianflow is observed to be the fastest. For this reason, MedianFlow algorithm is used.

B. Clearway Violation Detection

To detect security lane violation first the lane on the road should be identified. Two points in the lane are asked from used, then a line is drawn to the screen defining this lane. Vehicles crossing this line is assumed to violate security lane.

Operations done here are explained in detail in the consequent chapters.

As known, in Turkey traffic flows from right and security lane is the rightmost lane but to the camera it is the leftmost lane on the video. At the beginning, coordinations of two points in the security lane are asked from the used.

Suppose Ct (a,b) and Ct+1 (c,d) are given points shown in Fig. 2. Slop of the line defined by these two points are calculated in Equation 1.

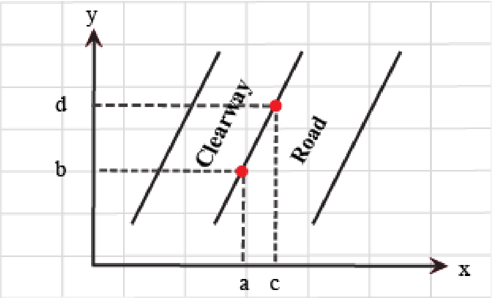

Figure 2. Clearway Strip Line

$$m = (d - b) / (c - a) \quad (1)$$

In the Equation 2, function of the line defined by a slope and two points are calculated.

$$m = (y - y_i) / (x - x_i) \quad (2)$$

$$y = mx + k \quad (3)$$

Center point of the bounding box of the detected vehicles are fed to this equation. Equation returning a result less than or equal to zero means the vehicle is on the left side of the line and vice versa. Vehicles which return a value less than or equal to 0 are assumed to violate the security lane.

C. *Wrong Way Violation Detection*

Wrong way violations are detected using the vertical difference of the bounding box around the cars. To detect vehicles driving on the wrong way, videos captured in Kocaeli province are used. Vehicles are detected again using SVM's. After vehicle detection, center points of the bounding box between consequtive frames are compared.

Suppose vehicle's coordinates in the n'th frame is Cn (a,b) and Cn-1 (c,d) in the (n-1) th frame. If we assume traffic is flowing to the cameras direction if d is less then b then the car is assumed to violate wrong way.

III. Results and Conclusion

To see training results and detect violations, 50 FPS 1080p footage is taken in the Kocaeli province. Detected vehicles are drawn with a bounding box around them, also classification result can be seen in the bottom left corner of said bounding box in the Figure 3.

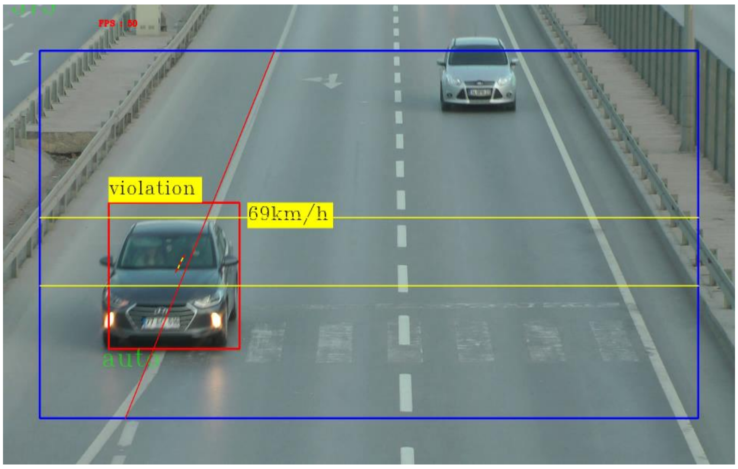

Figure 3. Violation Detection Flow Diagram

As seen in the Figure 4, system detects violation as soon as the vehicle crosses the lane.

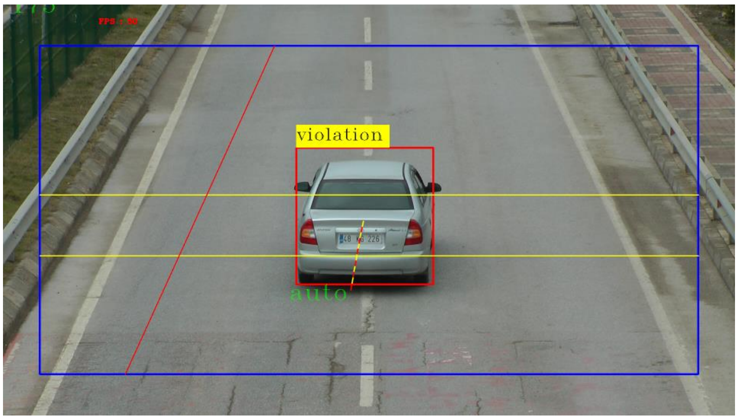

Figure 4. Violation Detection Flow Diagram

As seen in the Figure 3, previous positions of the vehicles are represented by red and yellow lines. If a vehicle drives on the wrong way, the violation is detected by the system. As a result, detection of security lane and wrong way violations are done successfully as the project accomplishes its goal.

Unlike other studies in the literature, violation detection processes have been performed based on real-time image processing techniques. Since background subtraction techniques are not used in vehicle detection processes, camera shake or movement does not cause probing. Our work continues to provide better results in severe weather conditions (fog, snow storm, etc.). In addition, it is planned to develop a publish/subscribe distributed system model in which users can track infringements only in the type that they only want.

Acknowledgment *(Heading 5)*

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