A Study on Real Time Lane Change Assistant Method with Side-Mirror Cameras

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***Abstract*—Vehicle detection in real-time from rear-side of a host vehicle is one of important problems in Lane Change Assistance. In this paper, we propose a vision system for real-time vehicle and lane detection and tracking using two cameras, which are equipped under the wing mirror both left and right side. From the input images, EDLines algorithm is used for line segment detection in real-time. According to the achieved data, lane detection is developed by analyzing angles of the line segments, and area between two lanes on the same side of vehicle is defined. In the vehicle detection, based on the brightness and darkness between vehicle and road, vehicle is detected in real-time using the simple algorithm. Finally, kalman filter is used in vehicle tracking for vehicle information such as distance or speed.**

***Index Terms*—lane detection, vanishing point detection, vehicle detection, vehicle tracking**

I. Introduction

Until now, vision sensor has been widely used for lane and vehicle detection system because it resembles the human visual perception system and provides rich information for patter recognition techniques. Furthermore, vision sensor is suitable for a low-cost, low power solution. However, the use of vision system for smart vehicle is challenging in real traffic and environments, because of camera movements, the variable illumination conditions, and real-time satisfaction. Many researchers have studied and proposed the different strategies to detect and track vehicle and lane, but most of works have done separately.

In the lane detection, we can approach on two features. The first based on boundary detection consists of three approaches: Edge detection [1], [2], vanishing point detection [3], [4], and Hough transform [5]. Edge feature and Hough transform are relied on the difference of brightness between road and road boundary, or between lane markings and road. And lane markings are detected by clear edges or by straight lines. Various articles assume that the lane markings converge at the vanishing point in image. Therefore, they firstly detect the vanishing point, then lane or road based on the vanishing point. The second one relies on the region features, which include texture features [6], color features [7], [8], and intensity invariant features [9]. Texture-based road detection methods focus on identification of textural differences between road and on road regions to segregate. In addition, color based features approach on the difference of color between the road surface and the outside area of road. Road detection is studied on the shadows and illuminant invariant image.

Vehicle detection and tracking have been widely researched in recent years. Two common knowledge-based and region-based methods are proposed. The knowledge-based methods employ a priori knowledge to hypothesize vehicle location in an image. These approaches normally use information about symmetry [10], color [11], shadow [12], geometrical feature [13] (corners, horizontal/vertical edges), texture [14], and vehicle lights [15]. The region-based methods are to model the appearance of the vehicle by one kind of features: principle component analysis [16], Gabor wavelet [17], or Haar-like feature [18]. These methods use machine learning to classify the region into categories of vehicle or non-vehicle. Although these methods are

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powerful and robust in vehicle detection, they are time consuming.

In this paper, we introduce an integrating approach in lane detection and vehicle detection-tracking for the lane change assistance. Firstly, lane was detected by using a vanishing point and detected lines. Then, we used a simple algorithm only to detect vehicles on the detected lanes. After that, Kalman filter was used for vehicle tracking. This paper is organized as follows. Section 2 introduces the integration approach. Section 3 describes steps for the lane detection. The method of vehicle detection and tracking is shown in section 4. Section 5 presents the experimental results. Finally, section 6 is our conclusion.

II. Overall System

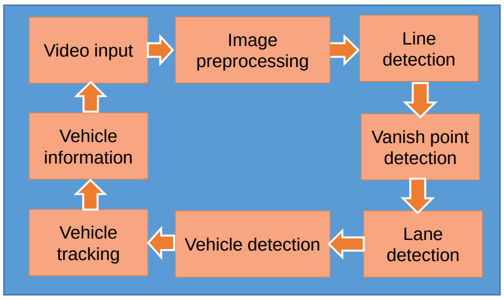

Figure 1. Vehicle tracking system

The system for rear-side vehicle detection is configured as Fig. 1. The vision system is installed under the right and left wing mirrors. The cameras view the backward of a vehicle and have 1/3” CCD image sensors with resolution of 640 x 480 pixels. The cameras are directed at a 7^o pitch angle and 20^o yaw angle. The image inputs are used for all processes. The detection and tracking system consists of the following main modules:

- Images preprocessing: Acquired color images from cameras are converted to intensity level image, and then some image preprocessing algorithms are applied to reduce noise and enhance the quality of image.
- Line detection: The key point of this part is to detect lines in real-time through EDLines algorithm [19].
- Vanishing point detection: We classified the detected lines into two groups: an irrelevant lines and relevant lines. The irrelevant lines include the vertical lines, horizontal lines, and noise lines. After the irrelevant lines are found out, they will be removed. The vanishing point is intersection of the relevant lines.
- Lane detection: Lane markings lie parallel to each other. Consequently, with image of camera, these lane markings converge on the vanishing point. After the vanishing point is detected, the lane is defined by analyzing the angles of the relevant lines.
- Vehicle detection: In this module, vehicle is detected through the difference of brightness between vehicle and road.
- Vehicle tracking: In this paper, this paper, Kalman filter is applied to update and estimate the vehicle information.

III. Lane Detection

A. Line Analysis

The first step of the method is to discover the line segments from the image inputs. For line detection, Hough Transform (HT) has been widely used in the literature, however it is computationally intensive. Line Segment detector (LSD) is fast to detect line, but it is not enough for the complex application. Therefore, EDLines is employed in this paper. For each image, EDlines algorithm only spends from 10ms to 15ms for the line detection; it is much faster than the other algorithms such as Line Segment Detector (LSD) without the need for any further processing. Figure 3b shows the line segment detected by EDLines algorithm from original image.

When EDLines is used for line detection, the running times of EDLines increases order of image size. Images with 1200x900 of size spend about 60ms for line detection, but images with 640x480 of size only spend about 10-15ms for processing time. In the case that the cameras with the high resolution is used, the received image will be resized to 640x480 form. The obtained line is good enough for lane detection shown in Fig. 2

a. 1024x650 of size b. 640x480 of size

Figure 2. EDLines algorithm with two sizes of image

The next problem is to remove the irrelevant lines. The relevant lines are group of the lane markings, the irrelevant lines are the remaining lines including the vertical lines, horizontal lines, etc. As Fig. 3c shows that the vertical lines are defined as the green lines and the horizontal lines are marked by the red lines. These lines are removed as shown in Fig. 3d. The remaining lines of the irrelevant lines are deleted based on their angles.

To remove the remaining lines of the irrelevant lines, we define angle range for the two rear-sides of the host vehicle. As in Fig. 4b, the angle range is from 20 degree to 85 degree for rear-left side and the angle range in Fig. 4c is for rear-right side. With the detected lines in rear-left side, the angles between the detected lines and the vertical axis are calculated as Fig. 4a. The lines are valid if their angles belong in 20 to 85 degree and the lines are deleted if their angle lies out of the angle range. This step eliminates majority of the lines, and greatly reduces the processing time for the following steps. After the elimination of the irrelevant lines, we achieved a result as Fig. 4a; the remaining lines are used for the vanishing point detection.

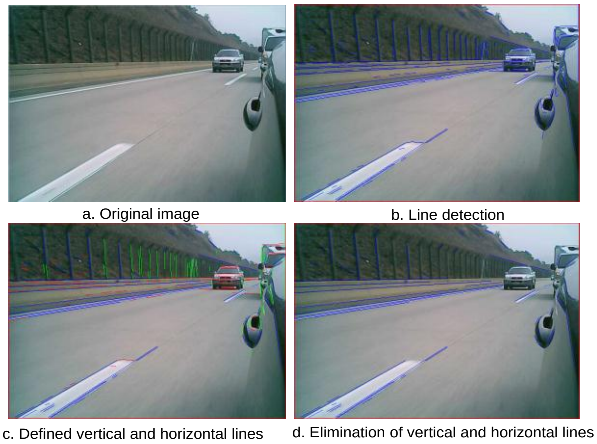

Figure 3. Line analysis

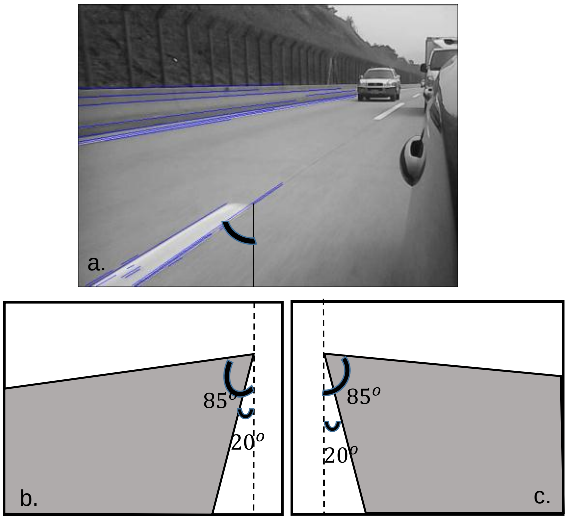

Figure 4. a - Selected lines; Range of angle based line elimination on the right (b) and left (c) of the host vehicle

B. *Vanishing Point Detection and Lane Detection*

The purpose of this step is to define the left-side lane area or right-side lane area of the host vehicle. These areas are established by two lanes and vanishing point. According to the remaining lines, we must analyze them to define two lanes and vanishing point. Another problem is to reduce the computational time in this step.

For this problem, we utilized the assumption that the lane markings converge at the vanishing point. The remaining lines belong to lane markings or road boundaries. The point where these lines converge can be defined as the vanishing point. From Fig. 4a, we group the remaining lines into two clusters. The first cluster consists of the detected lines on the closest lane marking and their noise and the second cluster consists of the detected lines on another lane marking on the road boundary and their noise. Two clusters are defined based on the angle values between the detected lines and the vertical axis (Fig. 4a). We determined 10^o of angle difference as the classification condition, which means that any two lines with more than 10^o of angle difference cannot be clustered together. The result of clustering is shown in Fig. 5, the red lines are the first cluster and the closest to the host vehicle. The blue lines belong to another cluster; they include the detected line on the farer lane marking and on the road boundary.

Figure 5. Two clusters for the vanishing point and lane detection

The vanishing point is an intersection among the lane markings. This task detects the vanishing point based on the two classified clusters. Therefore, all lines on each cluster are extended as Fig. 6a. For each line of the first cluster, we found the intersection points with all lines of another cluster. By all of the intersection points between two clusters, the vanishing point is the point where the majority of the lines converge. In Fig. 6b, we present the test image in which the vanishing point is clearly visible with a red point.

The next work is to detect the lane marking from the vanishing point and two clusters. Fig. 6b shows the vanishing point and the extended lines, but there are many extended lines which do not go through the vanishing point - the noise lines. For this reason, we have to remove the noise lines. From the vanishing point, we calculated the distance between the vanishing point and the extended lines of the two clusters. We also determined a 10 pixel value of distance as the checking condition, which means that any lines with the calculated distance exceeding 10 will be removed. Finally, after removing the noise lines, we got the result like Fig. 6c.

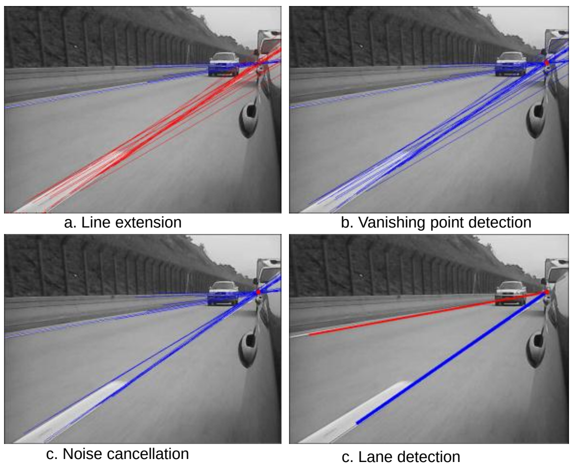

Figure 6. Lane detection

In order to detect lane marking, we rely on the lines on the lane marking or on the road boundary of two clusters as Fig. 6c. The first cluster includes the lines on the lane marking which is closest to the host vehicle. We calculated all angles between these lines and vertical axis.

Then, we defined the minimum value of all angles, the first lane marking is determined as line has the minimum angle (the blue line in Fig. 6d). Another cluster consists of the lines on another lane marking and on the road boundary. Similarly, we calculated all angles between these lines and vertical axis. After that, we specified the minimum value of all angles, the second lane marking is defined as line has the minimum angle (the red line in Fig. 6d).

IV. VEHICLE DETECTION AND TRACKING

A. Vehicle Detection

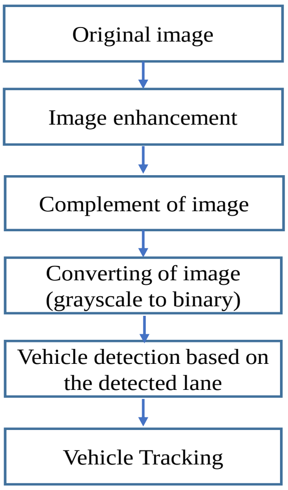

Figure 7. Algorithm for vehicle detection and tracking

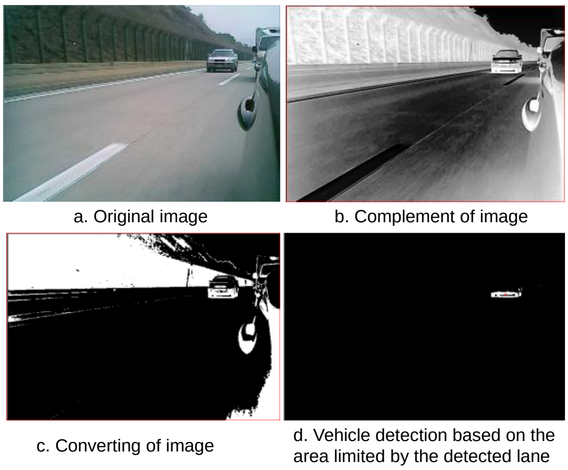

Figure 8. Image processing for vehicle detection

Vehicle detection in real-time is the most important problem in this paper. Hence, the simple method is proposed in Fig. 7, which is based on the difference of brightness between the road surface and car, or between the road surface and shadow of vehicle. In order to approach this feature, the original images are processed to enhance the quality of image, then the complement of image are applied as Fig. 8b. Then, we convert the received images from grayscale to binary in Fig. 8c. From Fig. 8c, we can see the difference between the vehicle and the road surface. Finally, through the combination between Fig. 8c and the detected lane, vehicle is detected like Fig. 8d.

Noise filter is also the important problem in image processing. In lane and vehicle detection, noise consist of cross-lines, white/yellow lines, direction indicating lines on the road and objects which is not on the road. Noise directly affects the accuracy of the algorithm, it leads to the unstable system. In this paper, we mention two cases of noise on the highway. Noise in Fig. 9a is white line, noise in Fig. 10a includes letters and direction indicating line.

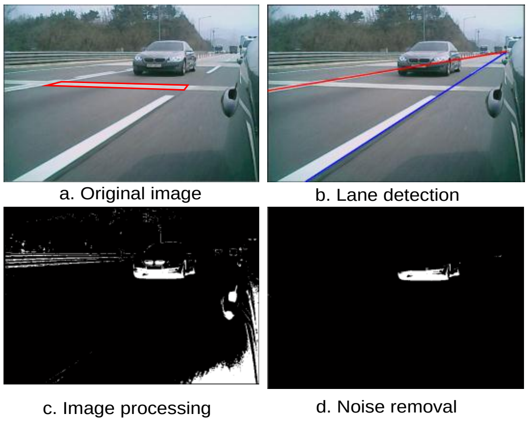

Figure 9. Noise removal in case 1

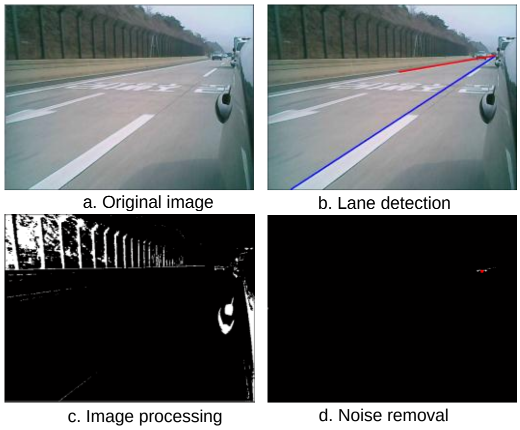

Figure 10. Noise removal in case 2

With the proposed method, firstly lane is detected on the left and right of the host vehicle. Fig. 9b and Fig. 10b shows the detected lane between the red line and blue line. After lane detection, we only need to detect vehicles on the detected lanes. It means that this step also removed the objects belong to outside of the road.

At the step 2 and 3 of image processing, noise consists of the white/yellow lines, the direction indicating lines are eliminated as shown in Fig. 9c and Fig. 10c. Finally after noise removal, vehicle is easily detected as in Fig. 9d and Fig. 10d.

B. Vehicle Tracking

We perform tracking to smooth vehicle detection in movement process, to interpolate position tuning short time in which detection has failed, and to predict the next position of targets in the future. Also, we used the

Kalman filter, which is known as linear quadratic estimation; it updates and estimates information from previous data to be stored in memory.

Kalman filter was used to track the two parameters of the detected vehicle (x coordinate and y coordinate on images) and a state vector $\hat{x}$ contains these parameters. Firstly, we calculate time update (or prediction value) of the state vector $\hat{x}^-$ and state error covariance matrix P^- at time k

$$\hat{x}^- = A\hat{x}_{k-1} \tag{1}$$

$$P_k^- = AP_{k-1}A^T + Q \tag{2}$$

where A is the state transition matrix and Q is the process noise covariance matrix. These prediction values are combined with the system measurements z to correct and update the corresponding trackers. The Kalman gain K is computed by

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \tag{3}$$

where H is the matrix that relates the true state space with the measurement space and R is the measurement noise covariance matrix. This Kalman gain is then used to correct the previous prediction of state and error covariance

$$\hat{x} = \hat{x}^- + K_k(z_k - H\hat{x}^-) \tag{4}$$

$$P_k = (I - K_k H)P_k^- \tag{5}$$

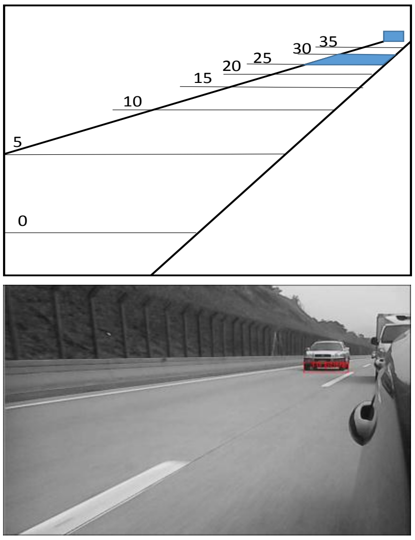

Figure 11. Model for defining the distance of the detected vehicle

In order to determine the distance between the host vehicle and the detected vehicle, we built a model between the position of the detected vehicle on images after tracking and its distance to the host vehicle, shown in Fig. 11. From the fixed distances in Fig. 11, we calculated their y coordinate on image. The relationship between distance and y coordinate is built by

$$y = 2*10^{12} * x^{-5.01} \tag{6}$$

where y is the distance between the detected vehicle and the host vehicle and x is y coordinate of the detected vehicle on images.

V. Experiments and Discussion

A. Test for Various Weather Conditions

Before the experiments are carried out, we tested the line detection algorithm and vehicle detection algorithm with various weather conditions such as rainy, foggy, and inside of tunnel. Firstly, the EDLines algorithm was used for testing in three cases of weather condition like Fig. 12. From the received line segment, the lane will be detected by using the lane analysis algorithms.

Figure 12. EDLines algorithm with the various weather conditions

Figure 13. Vehicle detection algorithm with the various weather conditions

The vehicle detection algorithm is also tested in the three cases (rainy, foggy and inside of tunnel). From the received results like Fig. 13, based on the detected lane, vehicle can be detected

B. Experiments

The highway driving conditions were used in this study to detect and track the rear side vehicle. The test vehicle equipped with a vehicle detection system was driven on the second lane of highway. The main goal of the experiments is to detect and track vehicles on the first lane of the high way (rear left side of the host vehicle) and on the third lane of high way (rear right side of the host vehicle). Therefore, in this paper, we considered four cases. Three cases detect on the rear right side of the host vehicle and the rest detects on the rear left side.

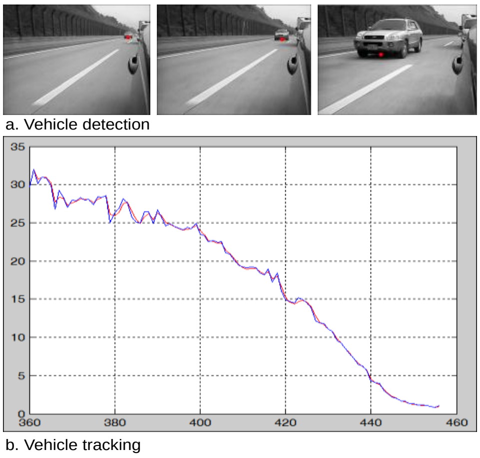

Figure 14. Model for defining the distance ò the detected vehicle

Scene 1 detects vehicles in normal state, which means that the needed vehicle is moving on the third lane and there are not any vehicle on the remaining lane. In this case, if there are two vehicles on third lane, we only need to detect and track the nearest vehicle. The result of detection is shown in Fig. 14. Fig. 14b shows the result of tracking by using the Kalman filter. The blue line is distance between the detected vehicle and the host vehicle by using detection algorithm and the red line is the result of using the Kalman filter.

Figure 15. Lane detection in scene 2

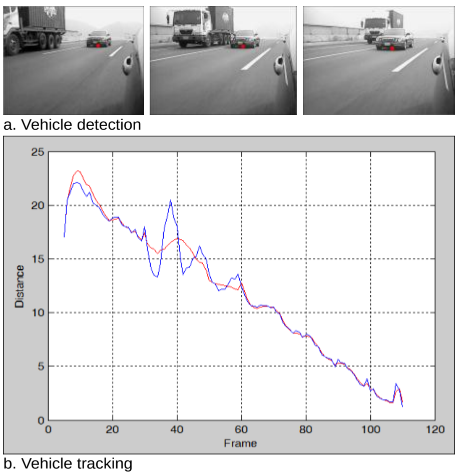

Figure 16. Results for vehicle detection and tracking in scene 2

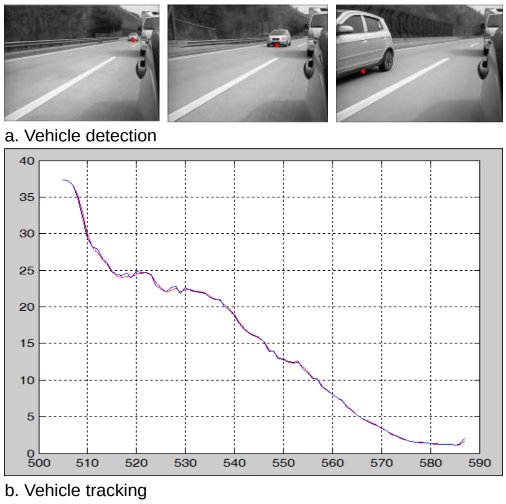

Figure 17. Results for vehicle detection and tracking in scene 3

Scene 2 is a special case when there are some vehicles - one is on the second lane and the other is on the third lane. We need to detect the vehicle on the second lane for lane change assistance. This case with vehicle in the third lane is considered as noise. By using the proposed method, the second lane was defined as in Fig. 15, after that the vehicle on the third lane was detected and tracked as in Fig. 16. Kalman filter was used for tracking the distance. Scene 3 is also especial case when there is a vehicle on the second lane and camera can see this vehicle. However, this vehicle was not detected and results of the detected vehicle are presented in Fig. 17.

VI. Conclusion

The real-time vehicle detection and tracking based on lane detection are proposed in this paper. The proposed algorithm shows good performance of detecting a target as well as estimating the relative distance. This result supports well for Lane Change Assistance or warns the driver because the system not only detects vehicles but also defines lane on the two rear-side of the host vehicle. In the lane detection, EDLines was used to detect lines very quickly. Besides, the method was also used the simple algorithm in vehicle detection to reduce the computational intensive to satisfy the real-time. From the tracking information, it confirmed that the vehicle detection and relative distance are carried out smoothly by using Kalman filter and a rear-side vehicle can be detected up to about 35 meters.

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