Road Triangle Detection for Non-Road Area Elimination Using Lane Detection and Image Multiplication

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***Abstract*—The background has become the key issue in maintaining the accuracy of final analysis for object detection in the development of an image processing algorithm. Therefore, this paper focuses on intelligent transport system (ITS), in which some of the background characteristics such as trees, road divider, and buildings interfere in the detection system algorithm. Therefore, this paper presents an algorithm that can remove the unwanted background, outside the road area boundaries for dynamic video footage. Using the onboard camera to capture the road traffic, the background is always moving in motion together with the foreground; therefore, a region of interest that focuses only on the road region needs to be established. The algorithm consists of three main components: lane detection, vanishing point and image multiplication. From the three components, other methods are applied, namely Hough transform, line intersection, image masking and image multiplication, which are combined together to create the background subtraction system. In the final analysis, the test results under various road conditions show a good detection rate and background removal.**

***Index Terms*—Background Removal; Image Processing; Lane Detection; Road Triangle; Vanishing Point.**

I. INTRODUCTION

Studies involving intelligent transport system (ITS) can focus on many categories. Some of the parts are based on image computational processing, such as vehicle detection, road lane marks detection, and road obstacle detection. For improvement, each part has its own sub-parts in order to get the best result in the final analysis. Modern ITS is expected to exploit the use of multiple sensors fusion to improve the reliability and safety of transport system. In this paper, we focus on the road lane mark detection and the background removal outside of the road lane boundaries using computer vision method.

In vehicle detection, the accuracy of detection often has some issues with the background of a scene, which can be identified as noises to the algorithm. This always happens, especially to the algorithm that works with a dynamic background. Dynamic background refers to the background of the video, which is in motion with the foreground. Research on the dynamic background has existed since researchers, such as Chong, Chen [1] use the onboard camera to record and monitor the road traffic scenes. The moving background is interfering the vehicle detection algorithm due to the fact that the motion of the foreground and the background are identical. The moving background that needs to be removed is along the side of the road, which are the outer road boundaries. The common objects that can be seen in the background are such as trees, road divider, and pedestrian path.

There are many studies related to segmentation of the boundaries between road area and outside or non-road area. For example, there are approaches based on the camera position, in which most cameras are fixed on the road as an instance like a surveillance camera. For that purpose, the background captured in the camera is almost static. This approach basically uses a background subtraction method based on the difference of motion of the target object and the almost static background [2-7].

The segmentation between the foreground and background has the ability to improve the accuracy of vehicle detection. There are researches that differentiate the background using its motion characteristic. The flow of the motion spreads out gradually at the side of the image and the velocity will increase as the scene moves closer. This information is used to classify the background and the region of interest as well as the foreground (Jazayeri, Cai, Zheng, & Tuceryan, 2011).

The vehicular autonomous system is really important in autonomous vehicle guidance to avoid collision with another vehicle, or road obstacle by providing a warning to the driver, in case of danger. It uses vehicular onboard units that detect the surrounding vehicles motion status to update the driver [8]. In the studies of dynamic background removal by [2], they use the detail of basic sequences method which has the capability of basic sequence method ground by making it classified into an uninteresting movement; thus, not including it in the detection process. Moreover, [9] introduces an adaptive background update to differentiate the motion property of the dynamic background on road scenes, where it uses the lighting change of the scene and the moving pixel properties.

On the other hand, the significant method used in most of lane detection is the Hough transform [10-13]. The Hough transform operator detects straight lines and curves. It is the most reliable method to detect straight lines by counting each unique equation for every possible lines that can be detected from each point in the image [11].

To develop a boundary between the road and the non-road area, there are many available methods that can be employed. Image processing techniques are such as image pre-processing, line detection, image masking and image multiplication, which can be implemented for the purpose of background elimination and image segmentation. Road area extraction to segment the road and the outer road has been utilized in many researches. Li *et al.* combine the structure information and classification of texture from the road scene with super pixel scene segmentation [14]. The study from [15] said that the color of lane marks are usually painted in white and yellow, and some are usually painted in a high contrast compared to the road surface color. Using that color information, they enhance the lane character of the road surface by increasing the lane-mark intensity values using Equation (1).

$$I = R + G - B \quad (1)$$

The vanishing point is usually located in the middle of the image and the road region is below that point. Therefore, detection is one of the important parts in determining the road area region. This distinguishes between the road and the non-road, which is the focus of research in finding straight lines in the road image and extracting road region for vanishing point support. The road region is segmented based on the vertical lines. There are approximations of vertical lines that represent both sides of the road, such as buildings, trees, fences and other vertical object. Further, this segmentation is based on the envelope of vertical lines, while the vanishing point is based on the selection of straight lines suitable for a candidate and then calculated using mean shift clustering. In paper [3], the method divides the image plane into the interior region (IR) and exterior region (ER) to represent the image region. Three vanishing points are detected sequentially using the 1D histogram. This method, however, requires much more computational time, thus, making it longer to process.

The proposed method has the ability to be combined with additional sensors to improve its reliability. Computer vision is an important step to visualize the rate of detection, accuracy and others for performance analysis. Decision fusion method proposed by [16, 17] can be approached for the combination of sensors with a camera to improve the reliability of detection using the sensor, such as radar system.

In this paper, the lane detection based on a simple algorithm using Hough transform is applied. In this research, we assume that the road is flat; thus, the road lane is straight, and there is a triangle coming out in the output of the road [1]. Therefore, to find the vanishing point of the road triangle, lane detection is used to detect lane mark on the road. Using a simple mathematic formula, the intersection point between the lane detected on the left side and right side road mark is used as the vanishing point of the road triangle. The next section demonstrates the system that uses our proposed algorithm for the final analysis on the ROI for the road so that all unwanted dynamic backgrounds outside the road boundary can be removed. The proposed method is low in computational time and effective in removing the background. These are proven by the final experimental result using multiple video footage conditions presented to substantiate the effectiveness of the proposed method.

II. ALGORITHM DEVELOPMENT

The overall flow of the background elimination system can be viewed from the flow chart in Figure 1.

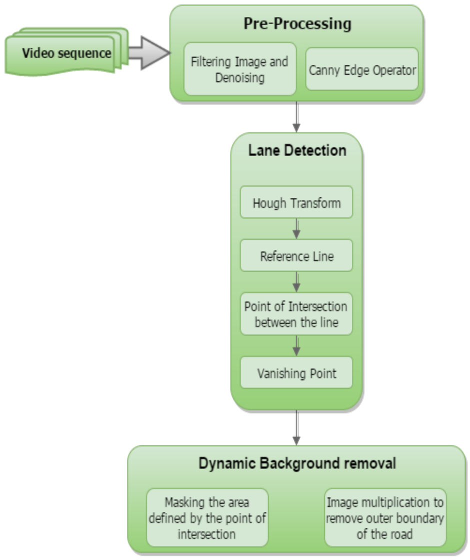


Figure 1: The overall flow of the system

The system starts by reading the input image frame sequence of the road video. Next, the system reads the image of pre-processing operations, which is the enhancement in the road lane feature that we need to detect from the image frame. The enhancement is carried out by image smoothing techniques for noise filtering. Meanwhile, the Canny operator is utilized for the edge extraction. For the lane detection, Hough transform is used to detect the most left most and right of the lane. Further, a reference line is drawn into the image frame. Three intersection points between the line are determined using a point of intersection between the two lines where one is A and another line is B, as described in Equation (2).

$$A \cap B \quad (2)$$

The center point is known as the vanishing point, which is the end of the road. Lastly, after determining the road area through the lane detection, the outer boundary of the road or the dynamic background of the road is removed using image masking and image multiplication. The details of the process are explained based on the highlighted parts.

A. Image Pre-processing

Image pre-processing is an important operation in improving the image, and it enhances the important feature, which is the road lanes mark that is needed in each of the image frames. The region of interest (ROI) is set by selectively pick the needed number of rows to be processed. At this point, the image frames are processed in the lower area where the road lanes lie. Next, the image frame is converted to greyscale format since the luminance is important in distinguishing visual features. The color image information does not help in identifying important edges in the image and the complexity of the codes takes as much as three times longer for processing time in each pixel. Hence, the conversion is important in this process. Further, the thresholding can be done by saturating the values of the image pixel to be between 0 (black) and 1 (whites) in order to convert the greyscale image into a binary image.

In this research, the video frame sequences contain both background and foreground in motion as the camera is onboard in the car. It is difficult to distinguish road and non-road area using motion techniques. Therefore, the first step in removing the noise in the image frames is applying blurring techniques in the frame. In this research, Gaussian smoothing is used as the Blurring techniques as they are able to smooth the image by removing unwanted features and small noises from the image before applying the edge detection operator. Figure 2 and Figure 3 show the images before and after applying blurring techniques. Notice that the left road divider disappears after the blurring is applied. This is a crucial image improvement because the road divider interferes with the line detection operations.

Figure 2: Before blurring techniques.

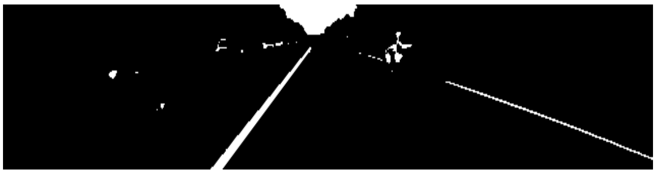


Figure 3: After blurring techniques.

After using the blurring techniques, the next important step is to implement median filtering to remove the noise in the video frame. The median filter is a nonlinear method that removes noise from an image, commonly used in many researches. The advantage of using this filter in the lane detection at this point of time is that it preserves the edges while the noise is removed [18]; thus, it is an effective operator in the system that functions to detect the edges, while keeping its important features in the next step.

In prominent studies of lines detection, the canny edge operator is widely used in enhancing the road lane features and boundaries [19-22]. This operator satisfies the edge line criteria needed by Hough transform for lane detection. Moreover, it has a low error rate of detection, which has an accurate edge detection from the image frame. The edge extraction is shown in Figure 4.

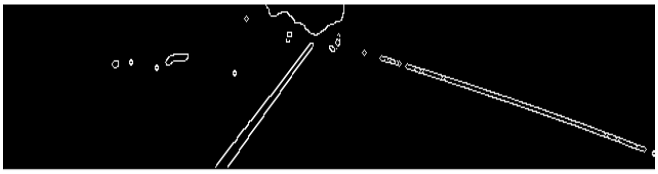


Figure 4: Canny Edge operator

B. Lane Detection

The Hough transform is applied in detecting two sets of solid lanes (left and right). The transformation can extract the features used in estimating lane parameters [23]. Hough transform uses a parametric for representation of a line to detect the lines in an image and is calculated using Equation (3).

$$\rho = x * \cos(\theta) + y * \sin(\theta) \quad (3)$$

The variable ρ is the distance between the origin and the line along its vector perpendicular to the line, while θ is the angle between the x-axis and the vector. Thus, Hough Transform can generate a parameter space matrix that corresponds to ρ and θ value in rows and columns respectively [24].

Figure 5 shows the detected lane and lanes that are marked using a colored line: The left lane is in the green line, while the right lane is on the blue line. These two lanes are the solid white lanes that are near to the non-road area at the left and right side.

Figure 5: Left and right lane detection using Hough transform.

Both the green and blue line marker follow the lane detected across the image frames. Since the road is flat, the lines that follow the road lanes mark is intersected at the peak of the image. The point of intersection at the road end is pointed at the vanishing point.

Both of the lines are linear with slope due to the straight lines are angled away from the horizontal shown in Equation (4) with two parameters slope (m) and y-intercept (b) as its uniqueness. The intersection point is then obtained by using this equation.

$$y = mx + b \quad (4)$$

The point of intersection is the intersection between two lines that overlap each other at the end of the road. Thus, the coordinate for the intersection is obtained and marked using the red circle as shown in Figure 6.

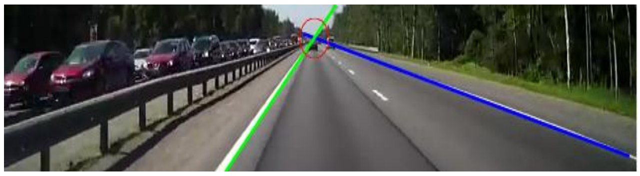


Figure 6: Point of intersection in red circles.

A horizontal reference line is drawn in Figure 7 in order to find the intersection with the two lines at the left and right. Both of the lines intersect with the reference lines, resulting in a total of three points of intersection. These three points look like a triangle as shown in Figure 7 and this triangle area is defined as the Region of Interest (ROI). The ROI is to be used as the focused region for vehicle detection algorithm.

Figure 7: Point of intersection with reference line.

C. Image Masking and Multiplication

The three coordinates which are obtained from the intersection are used to create binary masking. This marking is used to highlight the ROI inside the triangle so that the unwanted region can be removed. The triangle mask is set to ‘1’ and the outside is ‘0’ in order to allow image multiplication techniques to be applied to the image with the mask created, as shown in Figure 8. Since the outside of the road triangle is set to ‘0’ value, all the objects in that region are completely removed in the final result.

Figure 8: Road triangle masking

III. RESULTS AND DISCUSSION

To evaluate and test the performance of the proposed algorithm, the video footage taken from multiple road conditions online under normal driving conditions are used. These video footages have similar characteristics as those that taken using normal on–board dash camera installed on cars.

Figure 9 shows the image of the output result analysis when image multiplication operation is carried out between the image mask and the original image. The outside boundary of the road triangle is defined as the background that is targeted to be removed.

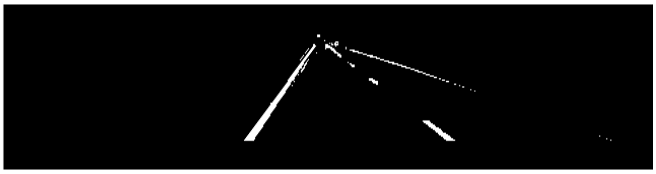


Figure 9: Image multiplication result

Figure 10 shows the results when the Sobel operator is applied inside the region of interest (ROI) to highlight the road features for a better observation. Sobel operator will be used in the studies for vehicle detection to find the gradient feature. Local feature in the shadow of the vehicle is used in the detection of the vehicle. Since the shadow is spatially continuous, a gradient mask can be used in detecting the shadow line [1]. The removal of the dynamic background can help in improving the accuracy of the vehicle detection from the direct focus of processing inside the Region of Interest done by the proposed algorithm.

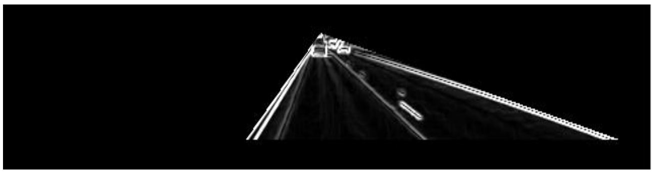


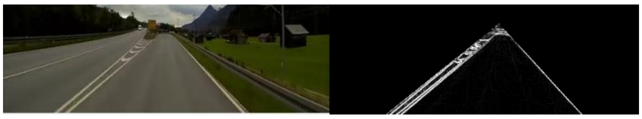
Figure 10: Sobel Operator applied to the region of interest.

The sample of four different types of video are used. Figure 11 shows four original image frame of the video before applying the algorithm. Each video has a different type of road conditions and characteristics.

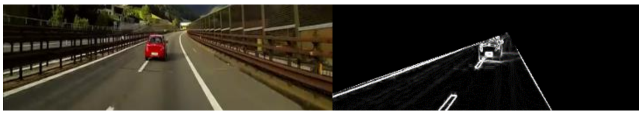
In Figure 11 (a), the road condition is at the countryside. The interference was the grass along the side of the road and the road is a single lane. Figure 11 (b), is a two-way lane with each way has one lane area. There are bushes and trees along the sides of the road that are considered the major interference in the lane detection. In Figure 11 (c), the movement of the vehicle with recording camera is exiting the main road and a triangular tract of land on the division of the main road is present. Lastly, the fourth road condition in Figure 11 (d) has a high constant divider that can replicate the lane detection features.

(a)

(b)



(c)



(d)

Figure 11: Results using four different road conditions.

A total of 2366 image frames sequence are used to test the performance of the developed algorithm. The sequence is a combination of four video footage that has been tested with the proposed algorithm. Figure 11 shows the result of the performance of this algorithm next to its original image. Out of 2366 image sequence from the multiple road conditions, the obtained successful rate is 82.59%. this means that the detection failure is 17.41% in the images sequence, which is due to bad conditions that affect the lane detection accuracy. The bad conditions such as the invisible lane marking, the presence of triangular tract on road lanes and the changes of lighting when a vehicle is driven under the bridge and road fly over.

The performance of removing the unwanted region image results depends entirely on the lane detection. The accuracy of lane detection is crucial for image masking and multiplication to take place. Therefore, it is important that the lane detection can track the left and right road lane consistently.

IV. CONCLUSION

In this paper, we describe and implement a new algorithm for dynamic background removal on road scenes. The road scenes are recorded using the onboard camera installed inside a moving car. The method combines lane detection, vanishing point and image subtraction. Each component depends on each other and if one does not work, the whole system will fail to remove the background. The method succeeds in background removal in the final analysis until such time a few improvements for future work can be made. During the lane detection, when a vehicle is moving beside the onboard camera, it covers the lane mark of the roads. Hough transform can still track the loss of the lane marks by assuming the lane still exists by counting the number of loss frame. If the lost track is more than the defined number of frames, then it will stop tracking. However, the lane track cuts the vehicle during the tracking assumption; thus, when masking is applied and the image multiplication is executed, part of the vehicle is lost. For that reason, an improvement needs to be done, especially in the lane detection part. Moreover, vehicle detection can be implemented without any effects from the background component, which can be achieved using edge detection using a Sobel operator and a bounding box detector.

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