

# Lane Marking Detection in Various Lighting Conditions using Robust Feature Extraction

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## ABSTRACT

Robustly extracting the features of lane markings under different lighting and weather conditions such as shadows, glows, sunset and night is the a key technology of the lane departure warning system (LDWS). In this paper, we propose a robust lane marking feature extraction method. By using the characteristics of the lane marking to detect candidate areas. The final lane marking features are extracted by first finding the center points of the lane marking in the candidate area then these center point pixels are labeled according to the intensity similarity along the direction of the vanishing point. The performance of the proposed method is evaluated by experiment at results using real world lane data.

## Keywords

LDWS (Lane Departure Warning System), Lane Marking Feature Extraction, Lane Detection, Image Processing, Computer Vision

## 1. Introduction

Recent automotive industry mainly concerns about the safety and convenience of the driver and much research work on systems such as ITS (Intelligent Transport System) and ADAS (Advanced Driver Assist System) have been conducted. One of the main key technologies of ITS and ADAS is the LDWS (Lane Departure Warning System), a system which detects information of the current driving lane and warns the driver when the vehicle begins to move out of its lane. This system has become more famous and many studies are underway as it is designed to minimize accidents caused by the unconsciousness of driver.

The Lane Marking Feature Extraction used in LDWS system is based on conventional methods such as color model method [Sun06a], [Lee09a], edge information method [Lin10a], [Macek04a], B-Snake method [Wang04a], stereo method [Yaylor96a], [Hattori00a], and perspective transformation method [Aly08a].

In the color model method; the lane marking is first detected by converting the RGB image into the HSI (hue, saturation, intensity) color model and then binarizing it by using saturation and intensity values. The Lane marking is detected well in good environment conditions but, the detection rate

becomes very low and poor in low light situations such as sunset or dawn and even when shadow is mixed.

In the edge information method, Canny or Sobel filters are used to detect the lane edges. The line is then extracted by identifying the straight line components using the Hough space. Unlike the color model method, this method manages to detect the line in different lighting conditions such as sunset or cloudy environments without being affected by the color temperature. But the extraction of the lane marking becomes more difficult if edges other than straight line components are detected.

In this paper, we generate an accumulative intensity difference image of the lane marking and road areas by using the characteristics of the lane marking. Then we obtain the center point candidate image of the lane marking by using the distribution kernel of the accumulative image and label the pixels of the image in the direction of the vanishing point. The current driving lane is then detected by the Hough transformation of the lane marking feature extraction image.

Section 2 of the paper describes the lane feature extraction process, Section 3 describes the procedure used to detect the lane marking using feature points, Sections 4 evaluate the recognition rate of the

proposed method through experiment results and Section 6 depicts conclusion.

## 2. Lane Marking Feature Extraction

In our paper, we have made three assumptions for robust lane marking feature extraction in different lighting conditions. Three assumptions are as follows.

- First, the lane marking has a constant width.
- Second, the intensity value of the lane marking area is higher than the intensity value of the road area.
- Third, the driving direction and the lane marking are parallel.

As above mentioned assumptions are invariant to light conditions; they are used to detect the candidate region of the line in LDA (Line Difference Accumulation). The center points of the candidate area are then detected in the process of LCC (Line Center Candidate) and the lane marking is detected in the LCC-R (Line Center Candidate-Refinement) process by removing the components except the detected center points. Fig. 2 shows the proposed lane marking detection procedure.

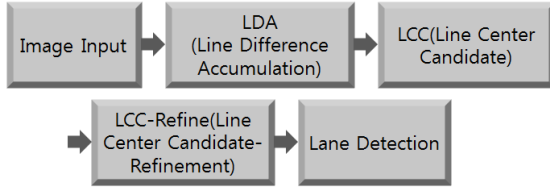


Figure 1. Flow diagram of the proposed algorithm

### 2.1 Line Difference Accumulation(LDA)

An input image is first converted into a gray image. The intensity difference of image  $I(x, y)$  and  $I(x \pm d, y)$  is calculated using Equation (1) where  $I(x, y)$  is pixel intensity and  $d$  is an offset value of  $x$ .

$$\text{Val}(x, y) = 2 \times I(x, y) - I(x + d, y) - I(x - d, y) \quad (1)$$

After generating  $D(x, y)$  according to Equation(2); Equation (3) is used to create  $H(x, y)$  LDA image by increasing the value of  $d$  from  $d_{min}$  to  $d_{max}$ .

$$D(x, y) = \begin{cases} 0 & \text{if } (I(x, y) < I(x + d, y) \text{ or } I(x, y) < I(x - d, y)) \\ \text{Val}(x, y) & \text{otherwise} \end{cases} \quad (2)$$

$$H(x, y) = \sum_{d=d_{min}}^{d_{max}} D(x + d, y) + \sum_{d=d_{min}}^{d_{max}} D(x - d, y) \quad (3)$$

$$\begin{aligned} d_{min} &= \mu \times (y - V_y) \\ d_{max} &= \mu \times (y - V_y) + 3 \end{aligned} \quad (4)$$

In Equation (4),  $y$  is the  $y$ -axis coordinate used to calculate  $d$  and  $V_y$  is the  $y$ -axis coordinate of the vanishing point. Even though the width of the lane marking is said to be same; the width of the lane marking in image is proportional to the  $y$ -axis and as a result;  $d$  is changed according to the  $y$ -axis as it is expressed in Equation (4).  $\mu$  is a weight factor of the lane marking width, and it is determined by camera calibration.

The intensity value of the road area in the gray level image is low and the intensity value of the lane marking is high. As the intensity difference between these two values is high; it allows us to acquire a potential candidate region. In the detected  $H(x, y)$  image, one pixel can be a strong candidate of the lane marking if the intensity difference between the pixel and another pixel apart from  $d$  distance is high.

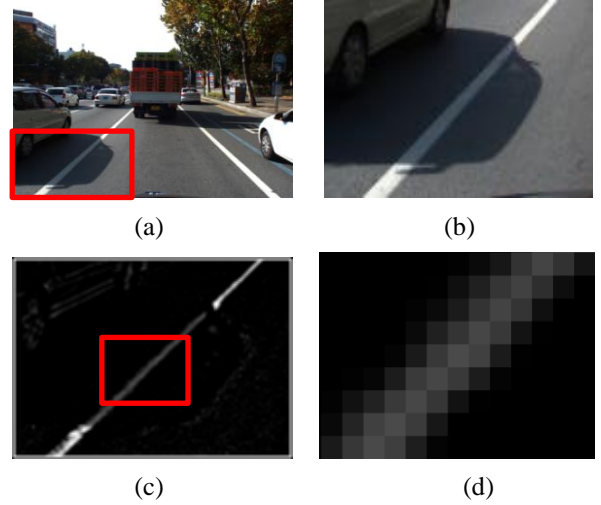


Figure 2. Result of LDA image. (a) input image. (b) cropped input image of the red box. (c) LDA image. (d) cropped LDA image of the red box.

Detected lane marking candidate area is shown in Figure.2 and the center point appears to have the highest intensity. As it contains the highest intensity, strong candidates can be detected without any difficulties even sunset or shadow areas contain lower intensity.

## 2.2 Line Center Candidate(LCC)

In this section we find the center of the candidate area using the LDA (Line Difference Accumulation) image which we have detected in the previous section. An LDA image pixel gets a higher intensity value as it becomes the center point of the lane marking and it gradually decreases toward the outskirts of the lane marking. The kernel which has a distribution function of  $f(x) = 5 / (5 + x^2)$  (equation (5)) inside the search range is correlated and the largest pixel of the result is assigned as the center of the line.

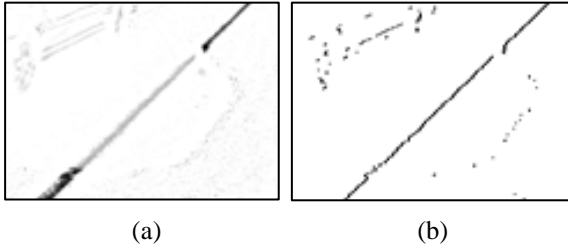


Figure 3. Result of LCC image. (intensity of the image was reversed) (a) LDA image. (b) LCC image..

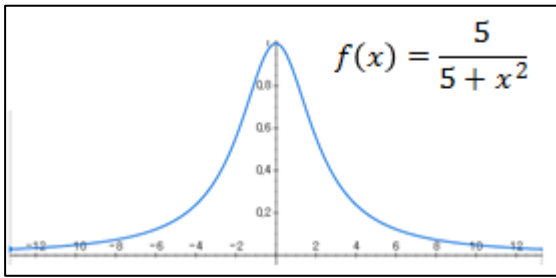


Figure 4. Distribution function,  $f(x) = 5 / (5 + x^2)$

$$C(x,y) = \underset{i \in [-SearchRange, SearchRange]}{\operatorname{argmax}} \left( \sum_{j=-KernelSize}^{KernelSize} \left( \frac{5}{5+j^2} \right) * H(x+i+j, y) \right) \quad (5)$$

$$SearchRange = \alpha \times (y - V_y) + 3 \quad (6)$$

$$KernelSize = \beta \times (y - V_y) + 2 \quad (7)$$

$\alpha$  and  $\beta$  are arbitrary constants which are determined through experimentation. KernelSize determines the size of the distribution kernel whereas SearchRange determines the search range. We set the size of the kernel and the SearchRange to be proportional to the y-axis as the pixel width of the lane marking is proportional to the y-axis. According to Equation(5), the maximum value point of the distribution kernel in the search range is assigned as the lane center

candidate. Figure.3 shows the results of the Line Center Candidate.

## 2-3. Line Center Candidate Refinement (LCC-R)

The noise of the LCC image obtained in the previous section can be detected as a candidate region of the center of the lane marking.

In this section, we remove the noise of the candidate region by applying the *connected component labeling* (Figure5.) along the vanishing point direction starting from the bottom of the y-axis. In this process, if the number of connected pixels is less than five; connected area is not considered as a lane marking candidate and will be removed. Figure5 shows the labeling process. Figure.6 shows the Line Center Candidate Refinement results.

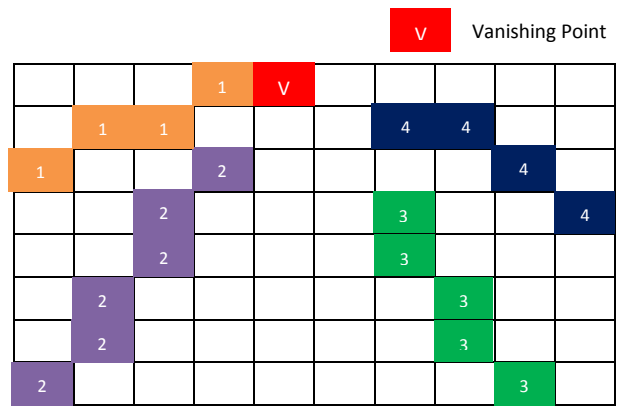


Figure 5. LCC-R image labeling process

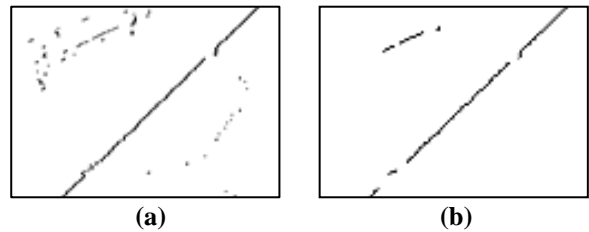
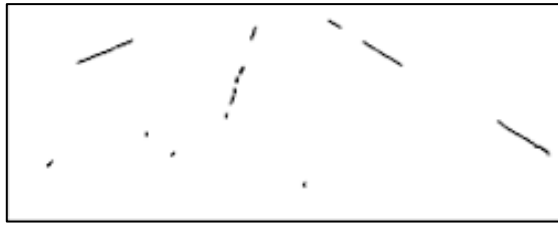


Figure 6. Result of LCC-R image.  
(a) LCC image. (b) LCC-R image..

## 3. Lane Marking Detection

In this section, we detect the lane marking by using the LCC-R image which we obtained in the previous section.

In order to detect the lane marking, we apply the Hough transform [Yu97a] to the LCC-R image. The two Hough lines which have the highest intensity value of the LDA image in the vanishing point direction are determined as the last lane markings. Figure.7 shows the results of the final lane marking detection.



(a)



(b)

**Figure 7. Results of lane marking detection.**  
**(a) LCC-R image (b) lane marking detection image**

#### 4. Experiment

After mounting the Pointgrey's Grasshopper2 and a lens with focal length of 8mm in the car, we performed the experiment by obtaining image at 30 fps in a 640 × 480 resolution in a PC running Windows7 containing an Intel Corei5-3470 3.20GHz with a 8GB RAM.

If the Hough line is presented on the lane marking, it is assigned to the Success column. If a Hough line does not exist or presented on a non lane marking position; it is assigned to the Fail column. Figure 8 shows the results of lane feature extraction done in various lighting conditions.

	Total frame	Success (frame)	Fail (frame)	Recognition rate (%)
Daylight	1500	1493	7	99.53%
Sunset	1200	1184	16	98.66%
Shadow	800	756	44	94.50%
Night	1200	1189	11	99.08%
complex	1000	946	54	94.60%
Total recognition rate				96.27%

**Table 1. Recognition in various environments**

A higher overall recognition rate of 96.27% was obtained when we performed the experiment in complex environment conditions such as daylight, sunset, shadow and night.

Incorrect recognition occurs when guardrails or sidewalks are detected as they have the similar characteristics as the road lane marking.

If the paint of the line is tattered, it can be detected as noise and will be removed.

In cases of misrecognition; shadows of road side trees, buildings can be detected as the road line when the sunlight is projected parallel to the road in the same angle.

#### 5. Conclusion

A robust lane marking feature extraction method in various light conditions was proposed. In this proposed method, the LDA (Line Difference Accumulation) image was obtained by using the independent characteristics of illumination and the LCC (Line Center Candidate) image was obtained by using the intensity distribution characteristics of the lane marking which was obtained by LDA. After removing the noise from the LCC image; the strong lane marking which was invariant to different environment conditions was obtained by detecting the LCC-R image. The processing speed also can be used for real-time detection at 22.31fps as the experimental results from a variety of lighting conditions gave a very high average recognition rate of 97.94%.

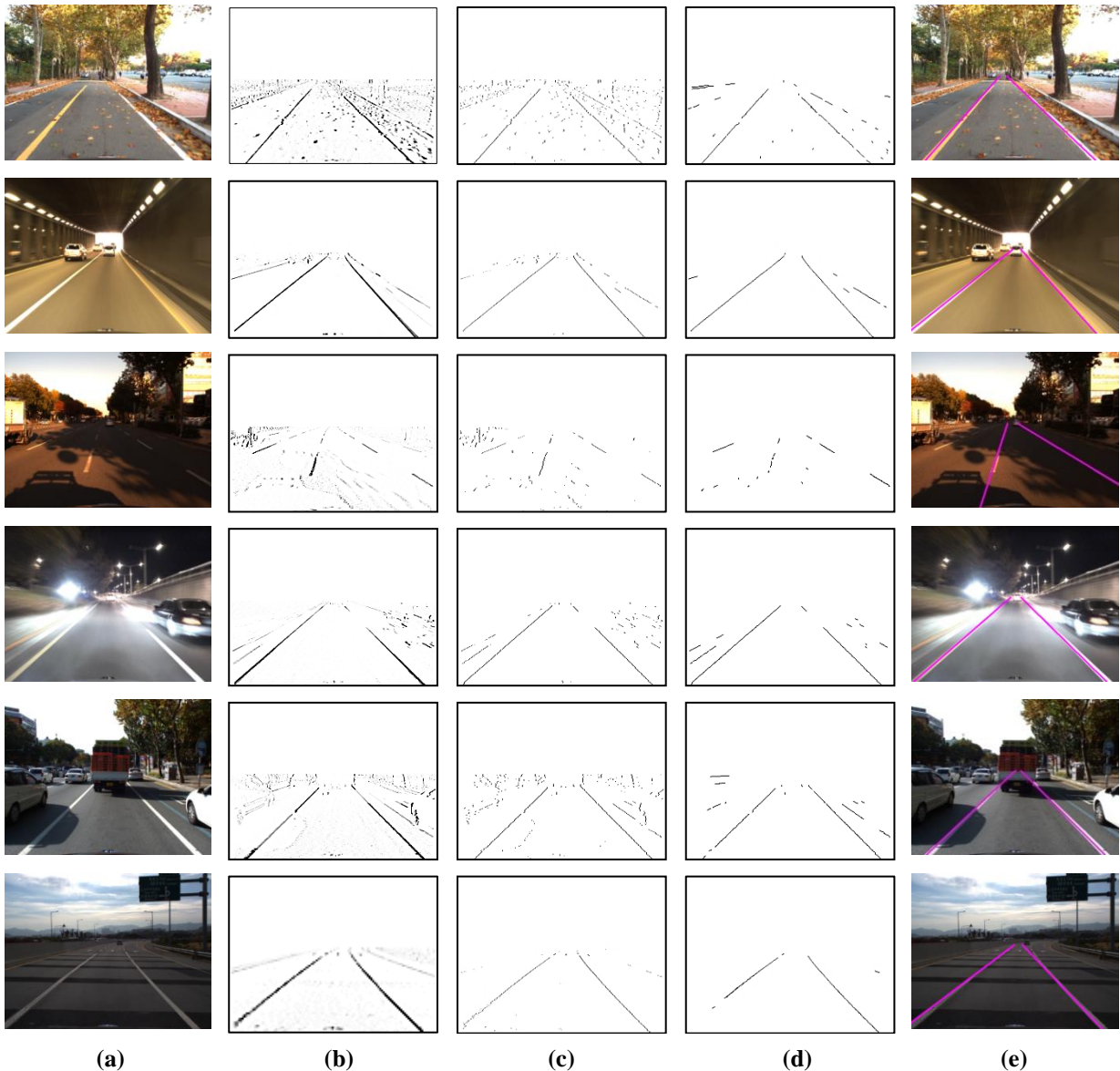
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**Figure 8. Result of lane feature extraction by various lighting conditions.**  
 (a)input image (b)LDA image (c) LCC image (d)LCC-Refine image (e)lane marking detection image