Lane Detection Using Characteristic of Hough Transform and Steerable Filter

Dae-Ryoung Moon  
Inha University  
Younghya-dong, Nam-gu, Incheon, Korea  
mys1756@gmail.com

Yo-Sung Ho  
Gwangju Institute of Science and Technology (GIST)  
123 Choemangwagi-ro, Buk-gu, Gwangju 500-712 Korea  
Hoyo@gist.ac.kr

Abstract—In this paper, we propose a method of lane detection using Hough transform and a steerable filter. Lane detection has to be preceded to drive intelligent vehicle that makes stability higher. So, we commonly use Hough transform to perform lane detection. However, it is hard to detect lanes because Hough transform detects all lines existed in the image. Also, it is just one of those common things to recognize wrong lines depending on the change of the lighting or the weather. To improve this, we set up the region of interest (ROI) and use Sobel filter to acquire vertical lines. Then, we can get a binary-coded image by using Otsu method and detect lines using Hough transform and the steerable filter. As a result, we can get a correct image regardless of the various road conditions.

Keywords—Hough Transform; Steerable Filter; Lane Detection; Otsu;

I. INTRODUCTION

As the number of the vehicles increases in these days, the traffic and the number of the car accident is also increasing. Therefore, many people is recognizing the need of safety in the roads. Accordingly, Technologies of the intelligent vehicle which is focused on the stability have been developed to decrease the car accident and the traffic [1]. Above all, lane recognition is one of the core elements of the intelligent vehicle. Generally, the lane has a highly various and complex shape, so we need to recognize it accurately [2]. Another difficult point of lane detection is to detect the path efficiently in the diverse situations. For example, the color of the lane can be changed owing to shadow and the camera can recognize wrong lanes because of the light. For this reason, there are many algorithms to detect the lanes and a lot of people is studying the method of lane detection. Usually, many algorithms include Hough transform to detect lanes. That is because it can detect lines easily. However, Hough transform cannot detect lanes well. It also detects all lines of the tree, wall, vehicles we do not have to detect. For the better condition, we extract lanes by using the characteristic of Hough transform and the steerable filter. By using the steerable filter, we will see a correct result more than the result only using Hough transform.

II. PRE-PROCESSING

When we apply lane detection, noise can be formed on the image camera by various circumstances. The circumstance can be a light, shadow, weather and something like that. If so, because the result of lane detection can detract credibility, we have to go through something before using Hough transform [2]. So, we need pre-processing to revise the result additionally.

A. ROI Set-up

If we check the image of camera in a vehicle, we can notice unnecessary backgrounds commonly. To detect lanes efficiently, we need set-up region of interest (ROI). We set-up ROI to get the two-thirds of the image. The result is Fig. 1 (d). When we compare with Fig.1 (c), we obtain a correct result.

![Original image](image1)

![Image after ROI set-up](image2)

![Result before ROI set-up](image3)

![Result after ROI set-up](image4)

Fig. 1 ROI implementation result

B. Median Filter

Median filter is an effective filter for impulse noise like salt and pepper. A basic idea behind the filter is to get a middle value from sorted values. The process is as follows. At first, a mask is applied on center of coordinate (x, y) of the image. If the mask size is m x n, the center of coordinate is \( \left( \frac{m+1}{2}, \frac{n+1}{2} \right) \). Values of the applied mask region are aligned and, a middle value of it is entered to coordinate of the transformed image \( g(x, y) \). Equation (1), (2) is expressions of median filter. In Eq. (1), Values are a coordinate set of the mask region. In Eq. (2), \( s_{xy} \) is a coordinate set of inside that apply m x n mask of (x, y) center [2]. In other words, \( s_{xy} \) is the applied set of the values.

\[
\text{Values} = \sum_{m=1}^{m} \sum_{n=1}^{n} a(m, n) \times f(x - \frac{m+1}{2}, y - \frac{n+1}{2})
\]

\[
g(x, y) = s_{xy}(\frac{m+1}{2}, \frac{n+1}{2})
\]
C. Sobel Filter

Sobel Filter consists of two equations. Eq. (3) is the equation extracting vertical edge elements, Eq. (2) is
the equation extracting horizontal edge elements [3]. From among these, we use vertical Sobel filter and, we remove horizontal
lines, extract elements which can be vehicle lines.

\[
g_h = [l(i - 1, j + 1) + 2l(i, j + 1) + l(i + 1, j + 1)] - [l(i - 1, j - 1) + 2l(i, j - 1) + l(i + 1, j - 1)] \tag{3}
\]

\[
g_v = [l(i + 1, j) + 2l(i + 1, j) + l(i + 1, j)] - [l(i - 1, j) + 2l(i - 1, j) + l(i - 1, j)] \tag{4}
\]

III. LANE DETECTION

In these days, there are so many methods about lane detection. Lanes can be detected by using colour information or,
getting straight lines by using Hough transform or getting angle information by using the Steerable filter. Also, lanes can
be detected by using Calman filter and, by using random sample consensus (RANSAC) algorithm or something like that. From
among these, we detect all lines in the image to use Hough transform and extract a line that matches specific angle by using
the steerable filter.

A. Hough Transform

Hough Transform has a characteristic that can search boundary lines of the object although we do not have a perfect
knowledge about the position of the object. Moreover, we can find a line from some dots of the line. We can express a straight
line as Eq. (7). On the other hand, we can show the straight line as Eq. (8) in a, b parameter space. As mentioned earlier, we can
see finding a line from some dots of the line in Fig. 4. The left image is matching Eq. (7) and the right image is matching Eq.
(8). The some dots of the left image can be expressed \((x_1,y_1),(x_2,y_2),(x_3,y_3)\), and something like that. In Eq. (8), these
dots are transformed to a equation and, slope m and y-intercept
is transformed to a dot.

\[
y = mx + n \tag{7}
\]

\[
n = x_1m + y_1 \tag{8}
\]

However, it is difficult to process if slope approaches to infinite. To overcome this problem, Eq. (7) changes as Eq. (9). Straight lines are expressed as a set of pixels existing on a same
line in Hough transform algorithm. The \((\rho,\theta)\) value extracted from each pixel of the image gathers on the accumulating table,
we can extract a straight line by doing inverse transformation \((\rho_0,\theta_0)\) [5]. Figure 6 is the original image and result using
Hough transform. There are many lines like trees, wall, outside lanes besides a lane that we want to get. Straight lines can
be made by using Hough transform although the image do not have many components of lines or lanes are covered by vehicles
because of the characteristic of Hough transform. So, we need to remove horizontal lines additionally by using a steerable filter.

\[
\rho = x\cos\theta + y\sin\theta \tag{9}
\]
B. Steerable Filter

A steerable Filter consists of linear summation of filters having reference direction and have random directivity. A form of Gaussian function is mainly used as filter [6]. The equation is (10). If we differentiate this filter vertically and horizontally, we can express as Eq. (11), (12). And then, if we do linear summation with Eq. (11) and Eq. (12), we can change as Eq. (13). Figure 7 is a result using Steerable filter on Hough transform result. Only two lanes around the camera are detected by using angle information of the image. The angle $\theta$ is measured from the left vertical side of the image. Generally, the more line close to the camera, the more angle of left line is low and the more angle of right line is high. Thus, to detect the left lane, we have to set angle low and to detect the right lane, we have to set angle high. Also, because most of the horizontal lines have around 90°, we have to avoid setting angle 90°. So, we set the angle to about 60° and the result is Fig. 7.

\[ G(x, y) = e^{-(x^2+y^2)} \]  
\[ G_1^x = \frac{x}{\sqrt{2}} e^{-(x^2+y^2)} = -2xe^{-(x^2+y^2)} \]  
\[ G_1^y = \frac{y}{\sqrt{2}} e^{-(x^2+y^2)} = -2ye^{-(x^2+y^2)} \]  
\[ G_1^\theta = \cos(\theta) \cdot G_1^x + \sin(\theta) \cdot G_1^y \]  \[ (10) \]  \[ (11) \]  \[ (12) \]  \[ (13) \]

IV. EXPERIMENTAL RESULTS

Experiments are implemented on acquiring images in various situations of expressway. Experimental situations are normal situation, shadow, dark condition like a tunnel, entry of other vehicle, something like that. Measured lines are yellow and white lines, detect only two lines around the vehicle. In Fig. 8 (b), although another vehicle enters on lanes and cover a part of the lane, the camera detects the line because of the characteristic of Hough transform. In Fig. 8 (c), camera detect white tunnel lanes. It means the camera also can detect lanes at night. Lastly, the camera detects lanes covered by shadow in Fig. 8 (d), that is because Sobel filter detects the edge of lanes and Hough transform draws blue lines. Although Sobel filter cannot detect the edge of lanes covered by shadow, the camera detect the other edge of lanes and recognize lines of the lane. Setting conditions, we can get a high recognition rate, however, we can get a low recognition rate special condition like city where has many buildings and highly complex roads.

(a) Normal condition  
(b) Entry of other vehicle  
(c) Tunnel  
(d) Shadow  

Fig. 8 Result in various road conditions

V. CONCLUSION

In this paper, we proposed lane detection method using Hough transform and the steerable filter. In detail, we employee the pre-processing to detect lines. First, we set up ROI to eliminate unnecessary backgrounds and used median filter to remove small noise without image spreading. After that, we used Sobel filter to get straight lines. Then, the image was changed to binary image to detect lines easily. Next, we extracted all of straight lines by using Hough transform and acquired two lanes around vehicle by using steerable filter. Finally, we confirmed lane detection in the various expressway conditions. However, we found that the low recognition rate in the case of complex road conditions and a city where has many buildings.

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REFERENCE