Automatic control of an Electric Vehicle using visual information

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Abstract

The aim of this research is to realize automatic control of an Electric Vehicle (EV), which the line ahead of the EV is detected by CCD camera and EV is made to follow the line. In this paper, image processing for line detection and calculation of a steering angle is described. For the method of line detection, edge detection forms the grayscale image. Then, both edges of the line are extracted using Hough transformation.

1. Introduction

In recent years, serious traffic problems, such as traffic accident and traffic congestion, have been encountered by the automotive society. Then, research of ITS (Intelligent Transport Systems) is made to improve and solve the traffic problems. Because of that, the research on automatic operation of a car manage attracts attention. Driver operation support and automatic operation can prevent the accident by artificial control.

Automatic control of a small recognition vehicle has been studied in this laboratory [1][2]. Research of the next stage of automatic operation of a car, the aim of this research is to realize automatic control of an Electric Vehicle (EV), which the line ahead of the EV is detected by CCD camera and EV is made to follow the line.

In this research, image processing for line detection and the compensation for deriving a steering angle is stated.

In this paper, by using EV system composition, image processing for line detection, the EV experiment is described.

2. Overview of the EV

The composition of the EV used in this research is explained. The EV use for our experiment "MINI-SWAY" and is produced by DAIHATSU Company. The "MINI-SWAY" shown in figure 1 is 1,010[mm] of overall width, 2,395[mm] of overall length, and 1,490[mm] of overall height. In order to control from the computer, the EV was improved with accelerator brake and handle by DENKEN. The stepping motor (CSK543AP-TG20, CSK564AP -TG20) are used for an accelerator and a brake. AC servo motor (SGM-01B314) is used for the Steering. The CCD camera is attached to on the top the EV. In order to control the

Fig.1 Electric Vehicle

EV, there are two computers located in the EV body particularly in the trunk. The computer for image processing is equipped with the capture card (FDM-PCI) and a video frame received form the camera capture card has size of 640×480 pixels which 640 pixels represent the height of the image and 480 pixels represent the width of the image respectively are in RGB format. The computer for driving is equipped with the motor controller board and each motor operation using the data from computer for image processing.

3. Image processing for line recognition

In order for EV to carry out an autonomous travel, the position of EV on the road is recognized and it is required to carry out steering operation using the information. Then, the purpose of the computer for image processing is the target line which it is marked on the road is recognized. Next, the steering is operated based on the recognized line.

3.1 The recognition method

Line recognition was performed using hue and saturation of a HLS table color system. However, the method was not stabilized when disturbance occurred such as light, and has not being able to recognize the target line. In order to be stabilized and to perform line recognition, processing using the edge produced of both edges of the line is performed.

3.2 Reduction of the image and Grayscale image

The input image from the camera is 640×480 pixels. Therefore, an input image is reduced in order to shorten

processing time. The input image is scanned at intervals of 2 pixels, and it reduces to 320× 240 pixels. Next, in order to perform edge processing, reduced image is converted to a grayscale image as equation (1).

$$Grayscale\_image = (222 \cdot r + 707 \cdot g + 71 \cdot b)/1000 \quad (1)$$

3.3 Edge detection

The white line on a road produces the edges which clarify the edges of the line. The Sobel filter of the transverse direction of primary differentiation is used for edge detection. Using this method, both edges of line can be

Fig.2 Edge detection result

emphasized and the edge produced in the road is reduced. The detected edge using the Sobel filter is shown in figure 2.

3.4 Straight line detection

Not only the edge produced to the both edges of the line but the other edge, such as edge produced on the road surface, is remained in the image which had edge detected. In order to extract only the edge produced to both edges of the line, straight line is extracted using Hough

Fig.3 The straight line extraction result using Hough transformation

transformation. Two straight lines are extracted. Conversion in polar coordinates can be obtained using equation (2). Reverse conversion in rectangular coordinates can be obtained using equation (3).

$$\rho = xi\cos\theta + yi\sin\theta \quad (2)$$

$$y = -\frac{\cos\theta}{\sin\theta} \cdot x + \frac{\rho}{\sin\theta}, x = -\frac{\sin\theta}{\cos\theta} \cdot x + \frac{\rho}{\cos\theta} \quad (3)$$

When the target line is straight, the both edges of the straight line can be extracted using Hough transformation. However, when the target line has curved, two obtained straight lines using Hough transformation may miss the target. Such a problem is solved by regional division. The straight line extraction result using Hough transformation is shown in figure 3.
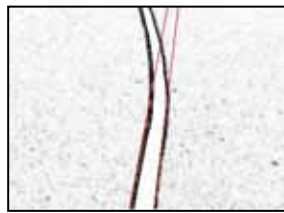
3.5 Code area

When extracting the center of gravity coordinates of a line, code area is limited and processed.

The code area in width is made within of 60~89 pixels and 120~149 pixels. The code area in depth depends on center of gravity coordinates in the previous one. For example, when the center of gravity coordinates (x,y) are acquired, next code area in width is immovable and next code area in depth is taken as the range of x-50 and x+50 pixels. This is because the target line is continuity and it does not have a sudden curve. The center of gravity coordinates of a line can be searched by using this method. Moreover, even if strong edge other than a line exists on the road, only the edge of both edges of the line can be extracted. In each code areas, a target line can be regarded as a straight line, when Hough transformation is performed, the straight line of both edges can be obtained correctly.

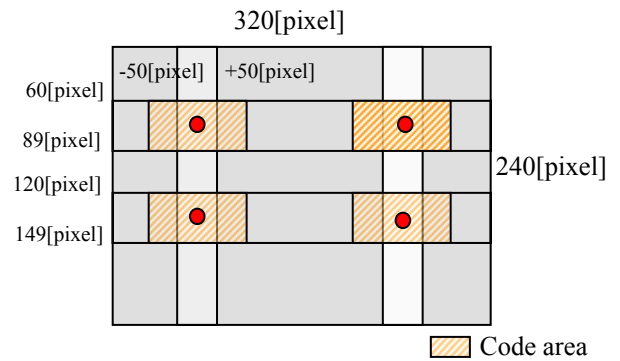The same method is used even when there is a target line. The code area is shown in figure 4.

Fig.4 Code area

3.6 Experimental result for the center of gravity coordinates

The extraction result for center of gravity coordinates in case of one target line and two target lines is shown in figure 5 and 6. The center of gravity coordinates can also be acquired by one target line, or two target lines.
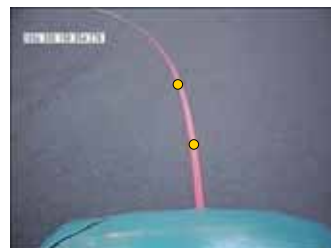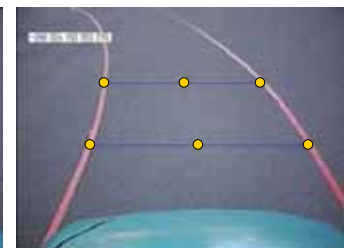

Fig.5 The extraction result for one target line

Fig.6 The extraction result for two target line

4. Robust design

Image data tends to be influenced by disturbance. In the steering operation using image data, wrong image processing will cause big accidents. Moreover, since the code area of the inputted image is divided and the target line is extracted. If it fails, it cannot return to the reference code area. Then, the image processing is made robust to disturbance.

4.1 Evaluation algorithm

The center of gravity coordinates for a code area is considered. The Center of gravity coordinates change because the EV moves. Therefore, the next center of gravity coordinates can be expected from the old center of gravity coordinates. In order to calculate a quadratic approximation curve, least-squares method is used. It is based on the old center of gravity coordinates which has being acquired correctly. And, the following center of gravity coordinates are evaluated. The evaluation method configures a certain fixed deviation from the center of gravity coordinates expected.

The x-coordinate (x_i) of the center of gravity coordinates acquired from image data is called actual measurement. And, (x_{i_Pre}) from the x-coordinate of the old the center of gravity coordinates is called predictive value. When the actual measurement (x_i, t_i) in Time t is obtained, the predictive value (x_{i_pre}, t_{i_Pre}) is calculated on the basis of actual measurement (x_{i-1}, t_{i-1})~(x_{i-5}, t_{i-5}), and the actual measurement (x_i, t_i) is evaluated. If the acquired coordinates are successful, a quadratic approximation curve is updated, and next the center of gravity coordinates acquired are evaluated. When the actual measurement (x_{i+1}, t_{i+1}) in Time t+1 is obtained, the predictive value (x_{i_pre}, t_{i_Pre}) is calculated on the basis of actual measurement (x_i, t_i)~(x_{i-4}, t_{i-4}), and the actual measurement (x_{i+1}, t_{i+1}) is evaluated. If the acquired coordinates are successful, a quadratic approximation curve is updated. The width of an evaluation value is set as 25 pixels~25 pixels and center of gravity coordinates are evaluated. If the acquired coordinates are s fails, a steering angle is calculated from the predictive value. Thus, the evaluation is repeated.

4.2 Return algorithm

A code area is returned using the evaluation method which described the point. If the acquired center of gravity coordinates are over the width of evaluation, center of gravity coordinates may be recognized incorrectly by disturbance. When the next code area is set up from the center of gravity coordinates, the true center of gravity coordinates are no longer acquired. Then, if the acquired center of gravity coordinates exceed the width of evaluation, the next code area is decided from the predictive value. And the code area is set up with ±65 pixels from the prediction value. The algorithm of the return to the code area is shown in figure 7.
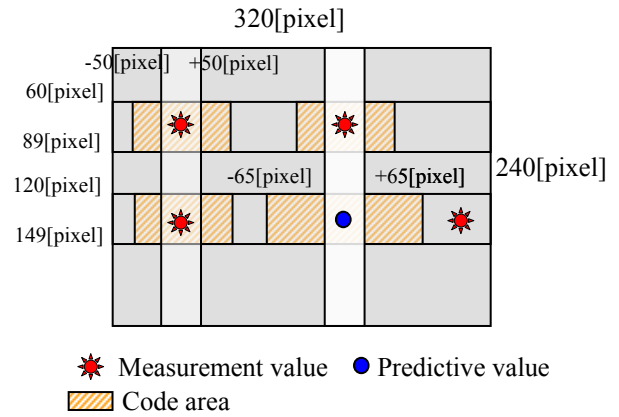

Fig.7 Code area of return algorithm

5. Steering control
5.1 Steering angle

In order to determine a steering angle from image data, the principle of "Method of the move target point following" [4] is used. Coordinates (x_1, y_1) are made into the target point of the EV among the center of gravity coordinates (x_1, y_1) and (x_2, y_2) acquired from the image. At this time, the steering angle δ of the EV is calculated on the basis of the position (x_1, y_1) and the target direction θ of the EV in the position from the move coordinate system.

$$\delta = \arctan 2l(3 \times y_1 - x_1 \times \tan\theta) / x_1^2 \qquad (4)$$

It changes into a move coordinate system from the acquired coordinates.

$$X\_real\_coordinate[mm]$$
$$= \frac{-10.32 \times y_1 + 5733}{640} \times x\_pixel\_length \qquad (5)$$

$$Y\_real\_coordinate[mm]$$
$$= 16.5 \times y\_pixel\_length \qquad (6)$$

$$x\_pixel\_length[pixel] = |x_1 - 319| \qquad (7)$$

$$y\_pixel\_length[pixel] = |479 - y_1| \qquad (8)$$

$$l = 1500[mm] \quad \text{Wheel base} \qquad (9)$$

A steering angle is calculated as the equation (4), and a pulse required for a steering angle is also calculated. The equation (10) changed into a pulse is from experiment data.

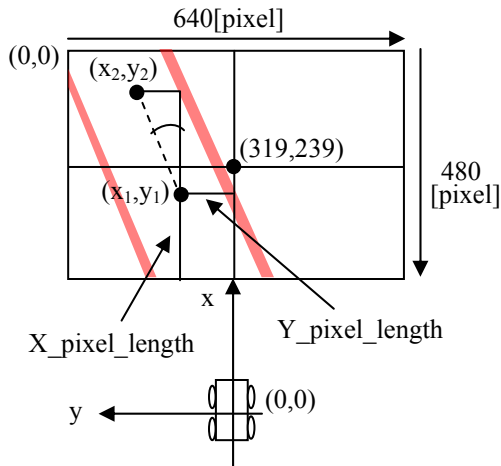$$Pulse = 3360.3 \times steering\_angle(\delta) \text{ [deg]} \quad (10)$$

Fig.8 Relation between the EV and the target point

5.2 Steering operation

AC servomotor used for the handle is operated for continuation. And, the rotation direction is determined from the target pulse which is being received from the image data. For example, when the servomotor is carrying out the right rotation, If the target pulse transmitted from the PC for image processing is larger than the present pulse, the rotation direction of the servomotor is maintained, if the target pulse transmitted from the PC for image processing is smaller than the present pulse, the rotation direction of the servomotor is reversed.

6. Run experiment of EV

6.1 Experiment method

The experiment use recognition and steering operation of a target line. In an experiment, A target line is arranged to position forward right of vehicles, the EV is controlled automatically to follow the target line. However, the experiment performed the operation of the accelerator and the brake, and the speed is fixed at low speed. The EV and a target line are shown in figure 7.

Fig.9 EV and a target line

6.2 Experimental result

As for an initial position, the target line is located at 750 [mm] from the center of the EV. The EV is driven in a zigzag from the start to about 45[s]. The result shows the deviation from the center of the EV is about 50~100[mm]. The line width was 100 [mm], EV is able to run on the line. Even if a target line is in the both ends of a road, the same result can be obtained.
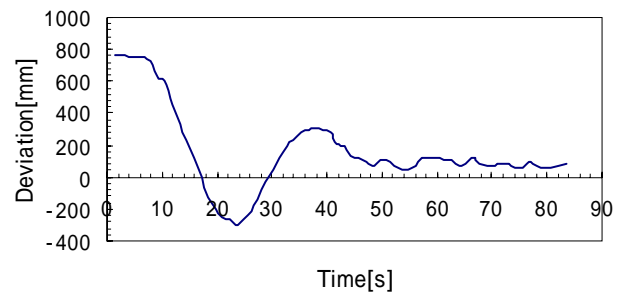

Fig.10 The deviation from the center of the EV

7. Conclusion

The stable the target point can found by replacing the line recognition using color information with the line edge.

In cruise Control, a target line is arranged in the center of a road. Although the deviation from the center of the EV was not 0[mm], it was able to run on the line. But then, the EV is driven in a zigzag until it converges, the cruise control of the EV has been improved.

References

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