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A Lane Following Mobile Robot Navigation System Using Mono Camera

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A Lane Following Mobile Robot Navigation System Using Mono Camera

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Abstract. In this paper, we develop a lane following mobile robot using mono camera. By using camera, robot can recognize its left and right side lane, and maintain the center line of robot track. We use Hough Transform for detecting lane, and PID controller for control direction of mobile robot. The validity of our robot system is performed in a real world robot track environment which is built up in our laboratory.

1. Introduction

In order to provide convenience and welfare, robotics technology has been studied in many difference fields, and especially, many researchers are focused on self-driving of mobile robot navigation [1].

To achieve autonomous navigation of mobile robot, perception of surroundings, driving path planning and robot control algorithm are key features. Many robotics technology include home service robot, AGV and autonomous vehicle are based on mobile robot navigation.

Recently, as robot hardware and robotics technology have been improved, there are many researches about robot perception and recognition systems. For example, using mono camera, a kind of CCD image sensor, lane detection and obstacles detection algorithms are proposed in [2].

While lane detection and obstacles recognition using mono camera in real robot systems, it is hard to compute the distance between robot and obstacles or lane. To overcome this drawback, lidar and camera fusion system has proposed. Finally, PID controller is applied to control mobile robot

In this paper, we propose a sensor fusion system using lidar and camera and its application to robot self-driving system. Using Hough transform, we can detect the lane information in mono camera data and lidar will provide the distance between robot and obstacles. The remaining part of this paper is as follow. We explain lidar/camera recognition algorithm in chapter 2 and experimental setup and results are remarked in chapter 4. The conclusion and future works are in chapter 5.

2. Mobile Robot of Navigation System

In this chapter, we propose lane and obstacle detection system using lidar and camera. The whole system of proposed system is remarked in figure 1.

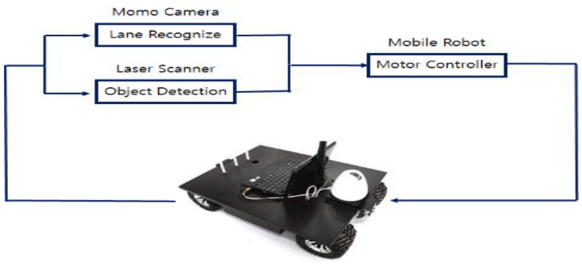

Figure 1. Robot Perception System

2.1. A Lane Recognition System of Mobile Robot

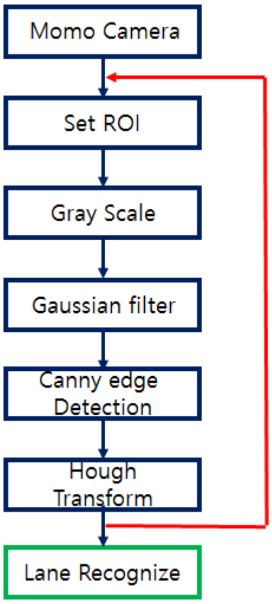

Figure 2. Lane recognition system

In this subchapter, we introduce a lane detection system using mono camera. The proposed lane detection algorithm is in figure 2. First, for reducing computation complexity, we extract region of interest(ROI) in image data and remove useless data. As converting color image to gray scale image, we accomplish more efficiency in terms of computation, and Gaussian filter is applied for remove noise in image data. And in order to find edge data, we apply canny edge detection method, and hough transform is used for lane recognition..

2.1.1 Gaussian Filter. In this paper, we applied Gaussian filter for pre-processing. Gaussian filter can remove high frequency noise in image and it can make the lane detection accuracy[3]. The 2-dimension Gaussian filter equation is as follow.

$$g(x,y) = \frac{1}{2\pi e^2} e^{\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

2.1.2 Canny Edge Detection. Canny edge detector is based on Gaussian blur and sobel masking method[4] Sobel edge masking is a kind of 1st order derivation operator, it can detect edge of every direction and normalization of every pixel data[5]. The detail of Sobel edge detector is as follow in eq. (2)

$$\bigtriangledown G(y,x)=(\frac{\partial G}{\partial},\frac{\partial G}{\partial x})=(d_x,d_y)=(G(y+1),x \quad G(y \quad 1,x),G(y,x+1) \quad G(y,x \quad 1)) \tag{2}$$

The gradient of 2-dimensional image is partial derivative of x direction and y direction.

$$S(y,x)=magnitude(\bigtriangledown G)=\sqrt{{d_y}^2+{d_x}^2} \tag{3}$$

$$D(y,x)=tan \;^1(\frac{d_y}{d_x}) \tag{4}$$

The pixel of edge which is detected by sobel masking can be defined by geometric mean of longitudinal and lateral gradient, S(y,x) is magnitude of edge, and D(y,x) is direction of gradient.

2.1.3 Hough Transforms. In this paper, hough transform [6] has been applied to detection lane Random points on (x,y) co-ordinate(Cartesian coordinate) can be represented in curved line on (r,θ) coordinate (polar coordinate) and if these curved line make a cross point, Random points on (x,y) co-ordinate can be regarded as points in a same line like figure (3) So we can get one line like eq.(5) to transform (x,y) co-ordinate to (r,θ) coordinate

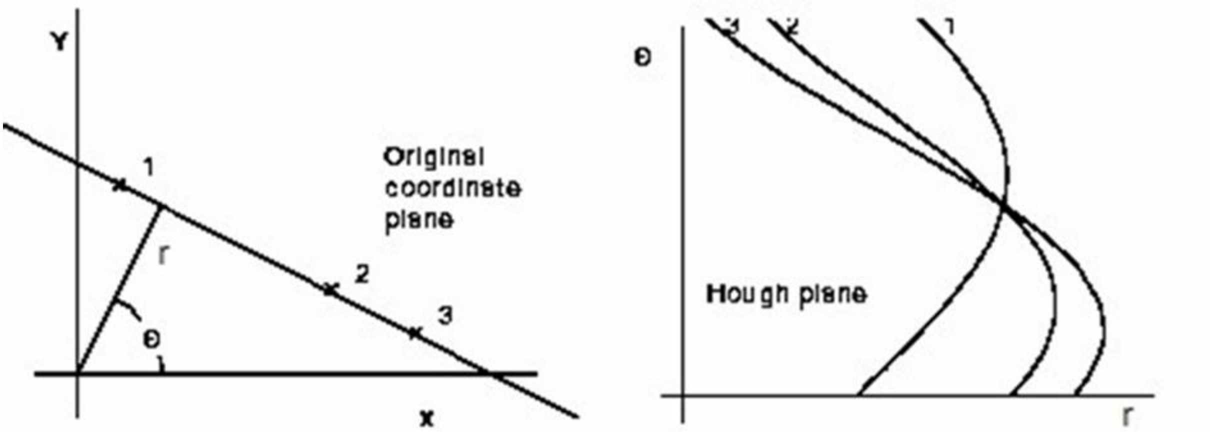

Figure 3. Hough transform

$$r=x \quad cos\theta+y \quad sin\theta \tag{5}$$

2.2. Obstacle Detection System of Mobile Robot

Lidar (a.k.a Laser scanner) transmit light to obstacle and it calculate the distance between sensor to obstacle using light velocity and time of flight. Eq.(6) is distance computing equation.

$$R=\frac{T}{2}C \tag{6}$$

R is distance to obstacles, T is time of flight, C is velocity of light

2.3. A Control System of Mobile Robot

The control system of mobile robot is as follow.

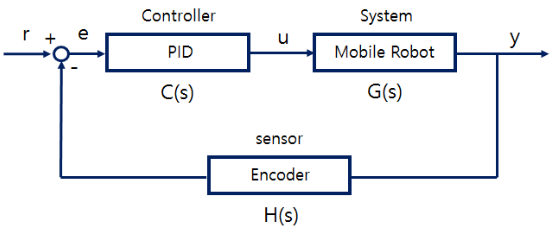

Figure 4. Control system

The robot dynamic system is as follow

$$\tau = K_t i_a = J_a \frac{d^2\theta}{dt} + B\frac{d\theta}{dt} \tag{7}$$

In eq. (7), τ is motor torque, K is torque constant, J is inertial mass of motor, B is friction coefficient of motor, θ is turning angle of motor.

$$F = \frac{T_M \quad G_r}{R_W} \tag{8}$$

In eq.(8), F is force via robot motor, G_r is gear ratio of motor and wheel, R_w is radius of robot wheel.

$$F = m\frac{dv}{dt} + bv \tag{9}$$

In eq.(9), m is robot mass, b is friction coefficient of mobile robot and V is velocity.
Finally, PID controller is represented like eq.(10).

$$u(t) = k_p e(t) + k_i \int_0^t e(\tau)d\tau + k_d \frac{de(t)}{dt} \tag{10}$$

3. Experiment and Result

3.1. Lane Recognition System

In this chapter, we show the real world experiment about our proposed method. The detail of robot in this experiment is below Figure 5 and Table 1.

Figure 5. Mobile robot platform

Table 1. Specification of the Mobile Robot

Category	Specification
Main controller	ATmega128
Communication	RS232c
Motor	2 DC motor, Servo motor
Size	650mm (length) Ⅹ 470mm (width) Ⅹ 158mm (height)
Weight	8Kg


Figure 6. Original image **Figure 7.** ROI image.

Figure 6 is original image of robot camera and figure 7 is ROI.


Figure 8. Gray image **Figure 9.** .Filtering image

Figure 8 is gray scale image and Gaussian filtering results is shown in figure 9. By using Gaussian filter, we can remove high frequency noise and detect lane edge more accurately.


Figure 10. Edge detection image **Figure 11.** .Hough transform image

In figure 10, the result of canny edge detector is shown and based on these edges, hough transform recognize lane. Figure 11 is hough transform result. We can verify the validity of hough transform in real world system.

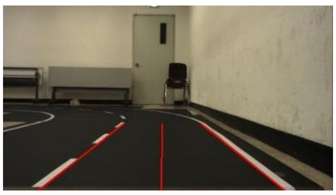

Figure 12. Lane recognition

Finally, we can make reference control line using mean of right, left side lane in figure 12.

3.2. Obstacle Detection System

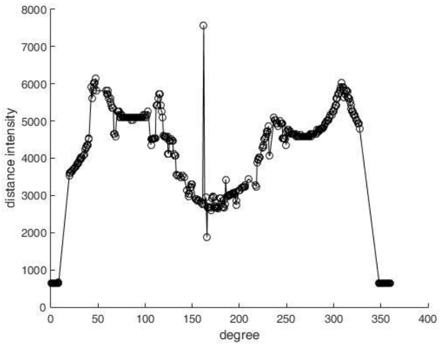

Figure 13. Laser scanner graph

Figure 13 is lidar data. As you can see in figure 13, the signal intensities in 0~10 degree and 350~360 degree are small compared to other angle. This means there are some obstacles intensities in 0~10 degree and 350~360 degree position.

4. Conclusion

In this paper, we proposed an perception system for autonomous robot navigation system using mono camera and single lidar sensor. Mono camera can detect lane information with hough transform and lidar sensor can recognize obstacles information based on TOF information. By using two sensors, we can design the robot controller for following lane track. Future works will be focused on more dynamic environement.

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