Advanced Lane Detecting Algorithm for Unmanned Vehicle

Hee-Chang Moon*, Woon-Sung Lee** and Jung-Ha Kim***

*Graduate School of Automotive Engineering, Kookmin University, 861-1, Chungnung dong, Sungbuk ku, Seoul 136-702, Korea (Tel : +82-2-916-0991; Fax : +82-2-916-0991; E-mail : moonhc2@hanmail.net)

**Graduate School of Automotive Engineering, Kookmin University, 861-1, Chungnung dong, Sungbuk ku, Seoul 136-702, Korea (Tel : +82-2-910-4712; Fax : +82-2-916-0991; E-mail : wslee@kookmin.ac.kr)

***Graduate School of Automotive Engineering, Kookmin University, 861-1, Chungnung dong, Sungbuk ku, Seoul 136-702, Korea (Tel : +82-2-916-4715; Fax : +82-2-916-0991; E-mail : jhkim@kookmin.ac.kr)

Abstract: The goal of this research is developing advanced lane detecting algorithm for unmanned vehicle. Previous lane detecting method to bring on error become of the lane loss and noise. Therefore, new algorithm developed to get exact information of lane. This algorithm can be used to AGV(Autonomous Guide Vehicle) and LSWS(Lane Departure Warning System), ACC(Adapted Cruise Control). We used 1/10 scale RC car to embody developed algorithm. A CCD camera is installed on top of vehicle. Images are transmitted to a main computer though wireless video transmitter. A main computer finds information of lane in road image. And it calculates control value of vehicle and transmit these to vehicle. This algorithm can detect in input image marked by 256 gray levels to get exact information of lane. To find the driving direction of vehicle, it search line equation by curve fitting of detected pixel. Finally, author used median filtering method to removal of noise and used characteristic part of road image for advanced of processing time.

Keywords: Lane Detection, Unmanned Vehicle, Image Processing, Sensor

1. INTRODUCTION

This paper describes a system design of a miniaturized unmanned vehicle system and lane detecting method using CCD camera. Modern society had accomplished much development by development of machine. Development of craft among it did industry to develop more. However, the development of vehicle make vehicle to become complex. So driver is fatigued with long time drive. And this weariness causes to accident. So many research institution and academic world study electronic device for the vehicle. These devices help the driver to drive easily. Till now we developed real scale unmanned vehicle but it has some problems such as unknown system, test environment and safety. So we decide to design miniaturized unmanned vehicle that has same algorithm and similar system. This miniaturized vehicle has vehicle control, sensor, vision and communication systems. In this paper, we will explain system configuration, vehicle control method and communication method with control computer and deal with advance lane detecting method.

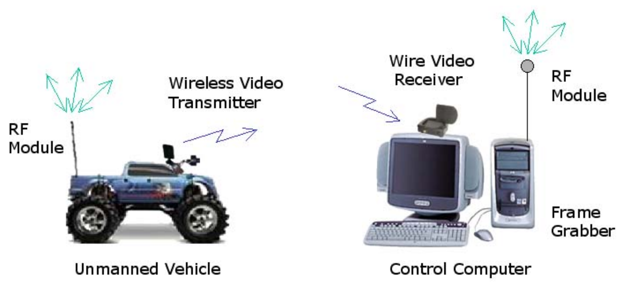

Fig. 1 System concept of unmanned vehicle

2. SYSTEM CONFIGURATION

This system can drive itself for detecting lane and obstacle on the road. It has four subsystems as control, sensor, vision and communication systems. Control system and sensor system have own microprocessor, and operate itself. The microprocessor of sensor system can transmit sensor value to control system on the vehicle. And main processor of control system can communicate with control computer and transmit and receive driving condition of vehicle and vehicle control value. Vision system is used to road lane detection, and communication system is used to receive and send from road and vehicle data. Now we would like to explain structure of each system and control method.

2.1 Vehicle control part

For vehicle control, we must control longitudinal and lateral of vehicle. Fig. 2 shows vehicle control diagram.

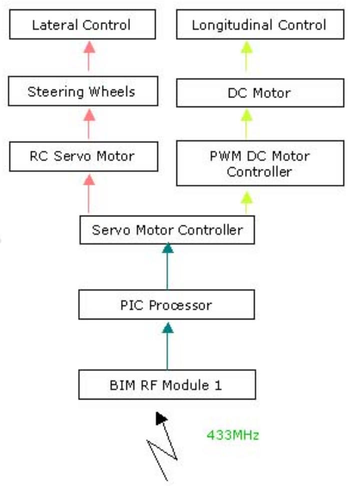

Fig. 2 Vehicle control part diagram

2.1.1 Longitudinal control method

Longitudinal control of the vehicle is operated by two DC motors which is mounted on the vehicle. We used a high voltage current PWM motor driver using FFT. Because general motor driver has a weak power and don't endure heat and weight. We used a closed loop system, which is designed by software. Fig. 3 is shown the control method of vehicle velocity. For feedback, we used photo interrupter. It can check rotations of wheel. Current velocity is calculated on PIC processor with the rotation number of wheel. Micro processor compares current velocity with wanted velocity and then decides PWM value.

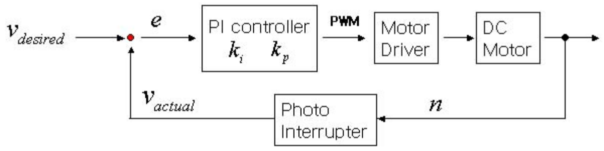

Fig. 3 Longitudinal control method

2.1.2 Lateral Control

We used RC servo motor and open loop control system for vehicle lateral control. Because RC servo motor has good response against control value. As the result of lane detection, we know four lane positions. Fig. 4 is result of lane detecting process. We can decide direction θ of the vehicle using lane position data p1, p2, p3, p4.

$$d = \left| \frac{x_4 - x_3}{2} - \frac{x_2 - x_1}{2} \right|, \quad h = 100 \text{ (constant)}$$

$$\theta = \tan \frac{h}{d} \qquad (1)$$

Steering angle range is ±30 degrees. Control value of RC servo motor is decided by using equation (2).

$$p_s(n) = 1.417\theta(n) + 127.53 \qquad (2)$$

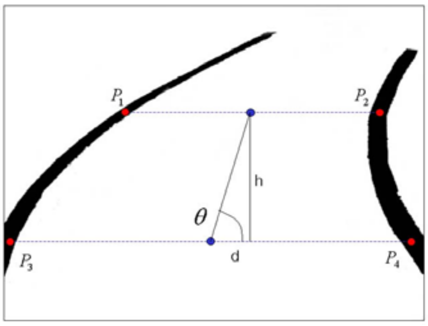

Fig. 4 Extract point of right and left lane

2.2 Vision System

General vision system has CCD camera, frame grabber and computer. But the vision system used miniaturized unmanned vehicle has more equipments such as wireless video RF modules. Fig. 5 is a vision system configuration and present signal flow.

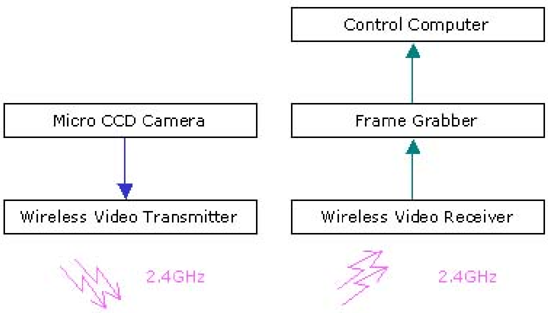

Fig. 5 Vision system functional diagram

This system can divide 2 parts as video source and video process part. The video source part is composed of micro CCD camera and wireless video transmitter and the video process part is composed of wireless video receiver, frame grabber and computer. For fast image processing, we used IMAQ vision frame grabber that made by National Instrument. It has ability of process 30 frame per second and offer easy development environment.

2.3 Communication System

The communication system of the vehicle is composed of data communication and video communication. Usually data communication method is serial and parallel communication method using wires. Because the system was divided 2 parts, so we used wireless communication method. Fig. 6 explains a communication system configuration and each control signal transmit and receive process. For real time communication, we used four RF data modules made radio matrix. 2 RF modules were assigned for data transmission and 2 RF modules were assigned for data receiving.

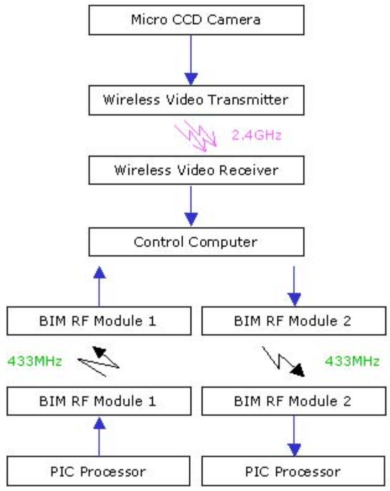

Fig. 6 Communication system of the vehicle

2.3.1 Data RF Communication

We must use packet for smooth data sending and receiving. Fig.7 and Fig. 8 are data packets for data communication between vehicle and control computer.

Preamble "0xff"	Start byte "SD"	Data1 N	Data2 S1	Data3 S2	Data4 S3	Data5 S4

Fig. 7 Transmit data packet in the vehicle

Preamble "0xff"	Start byte "CD"	Data1 PWM1	Data2 PWM2

Fig. 8 Receive data packet in the vehicle

Especially, preamble is added on the data packet in wireless communication to prevent data lose.

2.3.2 Video RF Module

In this system, video RF module is very important because the vehicle extract lane on the road from video. If there is no video input, the vehicle cannot drive as it should. Therefore video source must enter without fail from CCD camera. We used video RF module that have high frequency bandwidth. In Fig. 5, we also see the vision system configuration.

3. LANE DETECTING ALGORITHM

Previous lane detecting method is possible to detect a continuous lane on the road. But the real lane on the road is not continuous. For stabilized driving, the compensation method of discontinuity lane is necessary. This algorithm is consists of 4 parts.

3.1 Introduction algorithm

This algorithm is consist of 4 parts such as image input, preprocessing, lane detecting and calculate control value. Fig.9 shows flow chart of lane detecting algorithm. Image from CCD camera on the vehicle is transmitted to control computer. Then the image process several steps to remove noise and make clear lane. And then the algorithm is searching lane on the fixed area. We can obtain lane position data. Using these data, we can make two second order equations about a pair of lane on the image.

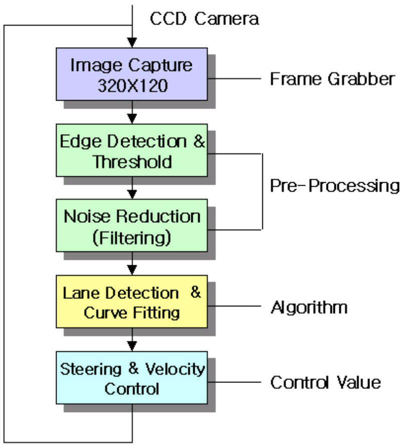

Fig. 9 Lane detecting algorithm

3.2 Searching range

For fast image processing, we are interested in a part of image. Because searching time is increase in whole area. So we make 300*40 pixels searching range. Fig. 10 shows image size and searching range.

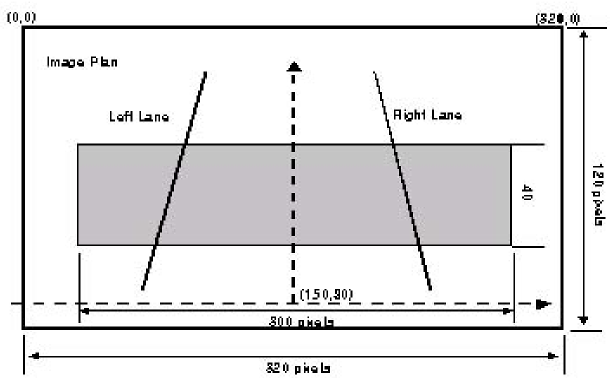

Fig. 10 Searching range on the image

3.3 Preprocessing of image

Preprocessing is performed for removing noise and making image clearly. And it includes edge detection.

For remove noise, we use thresholding method and filters such as median. Equalizing filter that is used to remove noise doesn't keep edge but median filter can maintain edge. Fig. 11 shows example about result of filtering.

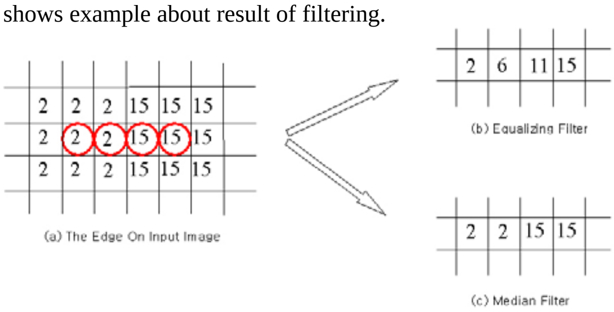

Fig. 11 Result of filtering

3.4 Detecting lane

After preprocessing step, the algorithm is starting to search lane positions on searching range. These data include loss of lane and error. So we used least squares regression for compensating errors. Using this, we can make two linear equations about a pair of lane.

Equation (3) is present summation of error square. n is number of set.

$$S_r = \sum_{i=1}^{n} (y_i - a_0 - a_1 x_i)^2 \tag{3}$$

Equation (4) shows partial differentiation about each coefficient of a_0 and a_1

$$\begin{aligned} \frac{\partial S_r}{\partial a_0} &= -2\sum_{i=1}^{n}(y_i - a_0 - a_1 x_i) \\ \frac{\partial S_r}{\partial a_1} &= -2\sum_{i=1}^{n} x_i (y_i - a_0 - a_1 x_i) \end{aligned} \tag{4}$$

In here, differential value must be zero for making S_r to minimize. Equation (5) shows quadratic simultaneous equation from equation (4).

$$\begin{aligned} (n)a_0 + \left(\sum_{i=1}^{n} x_i\right) a_1 &= \sum_{i=1}^{n} y_i \\ \left(\sum_{i=1}^{n} x_i\right) a_0 + \left(\sum_{i=1}^{n} x_i^{\,2}\right) a_1 &= \sum_{i=1}^{n} x_i y_i \end{aligned} \tag{5}$$

We can obtain coefficient value of a_0 and a_1 from solving equation (6).

$$\begin{aligned} a_1 &= \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^{\,2} - \left(\sum_{i=1}^{n} x_i\right)^2} \\ a_0 &= \bar{y} - a_1 \bar{x} \end{aligned} \tag{6}$$

4. TEST AND RESULT

We make two kinds of experimental on vehicle driving. One is using previous algorithm and the other is using advance algorithm. For the test, we make a pair of lane has systematic gap so this lane is non continuous lane.

Fig. 12 shows result of lane detecting using advanced lane detecting algorithm. Blue line is present left lane positions and red line is present right lane position. In spite of the lane is not continuous, the detected lane is continuous.

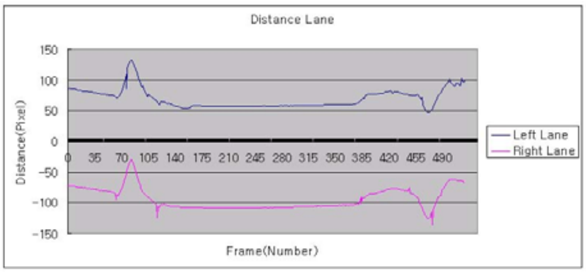

Fig. 12 Lane positions using compensation method

Fig. 13 shows steering servo motor's angle. As the result, steering servo has good response and accurate position at any point. It means unmanned vehicle driving is stable.

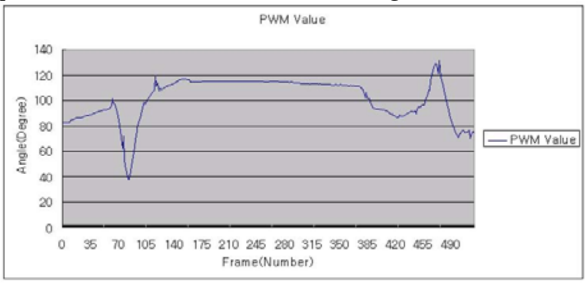

Fig. 13 Servo motor's angle using compensation method

Fig. 14 is a result of lane detecting using previous algorithm. At a gap, lane position values rapidly changed because this algorithm doesn't compensation method.

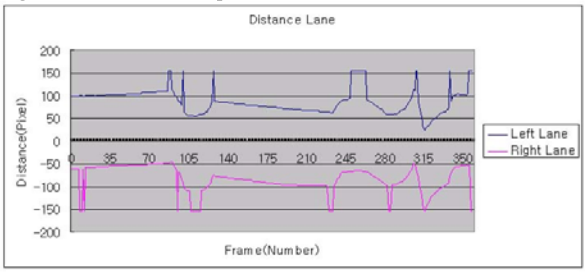

Fig. 14 Lane positions using previous algorithm

Fig. 15 is a steering servo's angle plot. As the result, the steering servo motor didn't keep accurate position. It means the unmanned vehicle driving is uncertain.

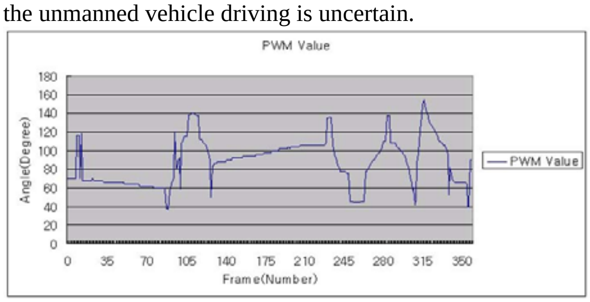

Fig. 15 Servo motor's angle using previous algorithm

5. CONCULUTION

This paper is mainly dealt with advanced lane detecting method for unmanned vehicle driving. Unmanned vehicle is composed of pic micro controller, smc(servo motor controller), RF modules and CCD camera. The lane detecting algorithm is very important because the vehicle is following lanes. In this paper, we present a lane detecting method. This method is better than our previous algorithm. But this algorithm's weak point is a time. Frame processing time is required 200~300ms. So this algorithm can process 4~5 frame per second. We must make effort to reduce image processing time per frame. We must improve wireless communication method to change communication equipment and algorithm.

6. ACKNOWLEDGMENTS

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REFERENCES

[1] J. W. Lee, "An Application of Computer Vision and Laser Radar to a Collision Warning System," *Transactions of the Korea Society of Automotive Engineers (KSAE)*, Vol. 7, No. 5, pp. 258-267, 1999.

[2] H. C. Moon, W. S. Lee, J. H. Kim, "Unmanned Vehicle System Design using 1/10 Scale Vehicle," *Proceeding of the Korea Society of Automotive Engineers (KSAE)*, Vol. 2, pp. 1081-1086, 2003.

[3] S. G. Kim, H. C. Moon, C. M. Kim, J. H. Kim, " Steering Control of Autonomous Vehicle by the Vision System," *Proceeding of ICCAS 2001*, pp. 615-618, 2001.

[4] G. D. Lee, S. W. Kim, "Advanced Vehicle Control Systems of the Intelligent Transport," *ICASE*, Vol. 6, No. 4, pp. 10-19, 2000.

[5] S. M. Cho, K. S. Lee, K. S. Huh, "Vehicle-to-Vehicle Distance Control using a Vehicle Trajectory Prediction Method," *Transactions of the Korea Society of Automotive Engineers (KSAE)*, Vol. 10, No. 3, pp. 123-129, 2002.

[6] Y. Sung Hoon, K. Myung Soo, M. Hyun Jin, L. Sang Ho, L. Suk, "Driving Information System with Real-Time Road Image," *Proceeding of KACC*, pp. 1241-1244, 1998.

[7] Steven C. Chapra, Raymond P. Candle, Numerical Methods for Engineers, McGRAW-Hill, 1999.

[8] C. M. Kim, H. C. Moon, S. G. Kim, and J. H. Kim, "Obstacle Avoidance and Lane Recognition for the Directional Control of Unmanned Vehicle," *Proceeding of ICCAS2002*, pp. 92-95, 2002.

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