Practical Study about Obstacle Detecting and Collision Avoidance Algorithm for Unmanned Vehicle

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Abstract: In this research, we will devise an obstacle avoidance algorithm for a previously unmanned vehicle. Whole systems consist mainly of the vehicle system and the control system. The two systems are separated; this system can communicate with the vehicle system and the control system through wireless RF (Radio Frequency) modules. These modules use wireless communication. And the vehicle system is operated on PIC Micro Controller. Obstacle avoidance method for unmanned vehicle is based on the Virtual Force Field (VFF) method. An obstacle exerts repulsive forces and the lane center point applies an attractive force to the unmanned vehicle. A resultant force vector, comprising of the sum of a target directed attractive force and repulsive forces from an obstacle, is calculated for a given unmanned vehicle position. With resultant force acting on the unmanned vehicle, the vehicle's new driving direction is calculated, the vehicle makes steering adjustments, and this algorithm is repeated.

Keywords: Unmanned Vehicle, Obstacle Detection, Obstacle Avoidance, Ultrasonic Sensor, Certainty Value, Virtual Force Field Method

1. INTRODUCTION

According to increase in a number of vehicles, it led to many problems which are environment problems, traffic jams and car accidents. To solve these problems, we introduced in a concept of the oncoming intelligent vehicle which is emphasized the vehicle's safety in order to guarantee safety of a traveling vehicle. Also efficient constructions of the transportation system affect growth of economy and efficient use of the road. We have tried to adapt obstacle avoidance to this research based on the Virtual Force Field (VFF) method. The VFF method is especially suited to the accommodation of inaccurate sensor data (such as that produced by ultrasonic sensors) and sensor fusion, and allows the unmanned vehicle to drive quickly without stopping for obstacles. And we are going to make an effort to maximize vehicle's safety by using diverse sensors.

Especially the objective of this paper is obstacle detection and collision avoidance while an unmanned vehicle using ultrasonic sensors is moving.

2. SYSTEM CONFIGURATIONS

Whole system consists of vehicle system, vision system, control system, and communication system. The vehicle system has microprocessor, and it is operated by PIC16F877. The vision system is used to detect road lane, and the communication system is used to receive and transmit road and vehicle data. The control system calculates receiving data from wireless video receiver.

Now we would like to explain structures and features of each system and mainly explain obstacle avoidance algorithm.

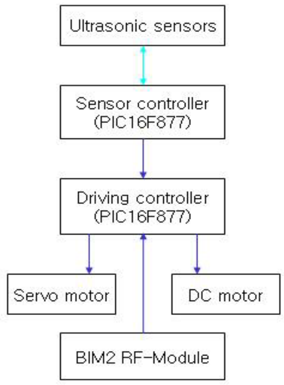

Fig.1 The system configuration of vehicle

2.1 Vehicle system

In this research we use miniaturized RC car which was made by TAMIYA co., called TXT-1 in order to construct system as safely as possible. Fig. 2 shows an unmanned vehicle, which is used in this research.

Fig. 2 The picture of unmanned vehicle

Longitudinal control of the vehicle is operated by two DC (Direct Current) motors mounted on the vehicle. As lateral control of the vehicle, we designed open-loop control system using RC servo motor because RC servo motor has good response against control value. Both DC motors and RC (Radio Control) servo motor are operated by microcontroller PIC16F877 and SMC (Servo Motor Controller). We used ultrasonic sensors to detect obstacles and to avoid collision. This sensor is also operated by PIC16F877.

2.2 Vision system

Vision system handles images which are received from camera. Vision system consists of CCD camera, frame grabber and computer. After the computer analyzes road image from CCD camera, it calculates the location and curvature of the lane. And then it controls whether the vehicle tracks the lane.

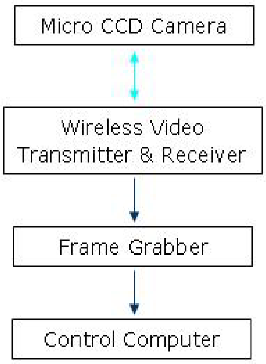

Fig. 3 Configuration of vision system

2.3 Control system

Because the control computer processes many data, we use Pentium 4 PC. This control computer receives vehicle data from RF module and analyzes present condition of vehicle. And it calculates direction of vehicle after separating lane from an image that is received from wireless video receiver. Then it sends control values of vehicle by using RF module. We are programming by using Visual Basic 6.0 of Microsoft co. and Measurement Studio of National Instrument co. So users may easily indicate information of vehicle.

2.4 Communication system

The communication system used in the vehicle is data communication and video communication. Usually, communication methods widely are classified in the serial and parallel communication using wires. But, in this research, we used wireless communication method.

For real time communication, we used four RF modules made by Radio matrix. Two RF modules were assigned for transmission and other two RF modules were assigned for reception.

2.5 Collision Avoidance Algorithm

2.5.1 Ultrasonic sensor specification

Ultrasonic waves have large attenuations in the air and are comparatively available for short measurement arranges within 10m. So, ultrasonic waves can sense a wide field. Ultrasonic sensors using in this research can receive or transmit ultrasonic waves without additional circuits. We use ultrasonic sensors, which have measurement ranges of 3m and the central axis's radius of 15°. Table 1 shows specifications of the ultrasonic sensors. Fig.4 shows measurement ranges of the ultrasonic sensor and Fig.5 shows the unmanned vehicle mounted ultrasonic sensors.

Table 1 Specifications of an ultrasonic sensor

Voltage	5V
Current	30mA, 50mA Max
Frequency	40KHz
Max Range	3m
Min Range	3cm
Sensitivity	Detect a 3cm diameter stick at>2m
Echo Pulse	Positive TTL level signal, width proportional to range
Size	1.75" w × 0.625" h × 0.5" d

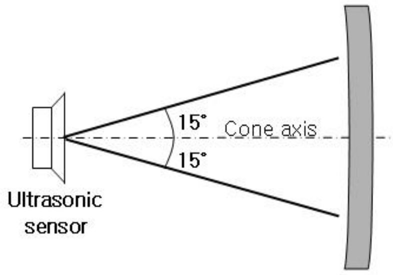

Fig. 4 The measurement range of the ultrasonic sensor

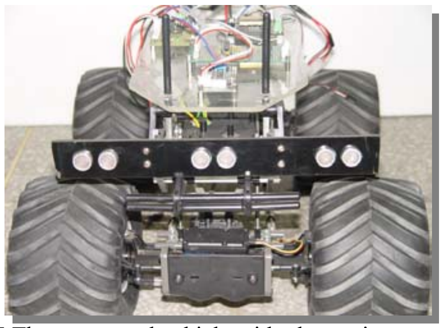

Fig. 5 The unmanned vehicle with ultrasonic sensors on

2.5.2 Basic Concept

We attached three ultrasonic sensors to the front of vehicle in order to detect obstacles while an unmanned vehicle is in motion. These ultrasonic sensors are operated by PIC16F877, and a PIC controls two ultrasonic sensors. Ultrasonic wave moves approximately 340m per 1 second, therefore a formula of calculating the distance is as follows.

$$l = \frac{(343.3 + 0.61T)t}{2} \quad (1)$$

Where, l is distance between an ultrasonic sensor and an object, T is temperature of the environment and t is reflection time between an ultrasonic sensor and an object.

We can calculate the distance between the vehicle and the obstacle by dividing the distance into 2. Consequently, the obstacle avoidance algorithm by three ultrasonic sensors is as follows.

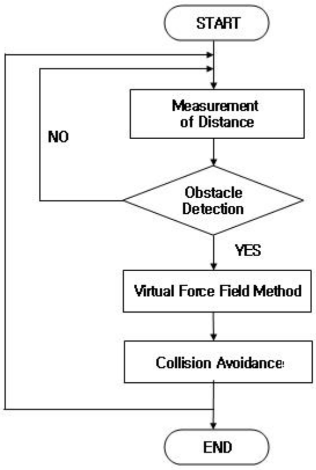

Fig. 6 The algorithm flowchart of collision avoidance

2.5.3 Certainty Values

We are going to express the probability existing obstacles as relative values from ultrasonic sensors in front of unmanned vehicle. To apply certainty value idea to the obstacle avoidance algorithm, we set up a square region of the histogram grid. We call this the active window, and cells that are covered by the active window are called active cells. Because ultrasonic sensors are laid in front of the vehicle in this research, the active window covers an area of 5*30 cells in the histogram grid. Three ultrasonic sensors are operated in accordance with fixed procedures. If obstacles are detected by ultrasonic sensors, a certainty value (CV) that is located on the acoustic axis of the sensor increases by 1. Here a certainty value (CV) is probability that obstacles are in the histogram.

Fig. 7 shows the certainty value and the probability distribution that is obtained by continuous and rapid sampling of the ultrasonic sensors while the vehicle is moving.

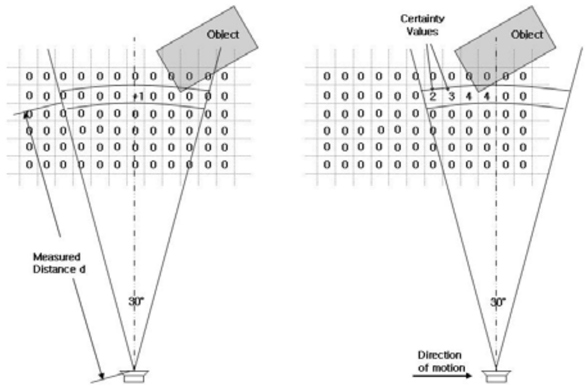

Fig. 7 Histogram grid for obstacle representation of an ultrasonic sensor

2.5.4 Virtual Force Field Method

In order to apply the virtual force field idea, each obstacle generates virtual repulsive forces by using the distance information between an ultrasonic sensors and an obstacle. And the unmanned vehicle generates an attractive force by using the center of lane and the given position of unmanned vehicle. We have to calculate resultant force, R from repulsive forces and an attractive force. However, this method requires great calculation time and memory space. We assume the under two parts in this paper. First, because the unmanned vehicle moves along the lane from a vision sensor the motion of unmanned vehicle is not large. Therefore if the certainty value equals one, we regard it as the obstacle. Second, repulsive forces are in inverse proportion to the square of distance.

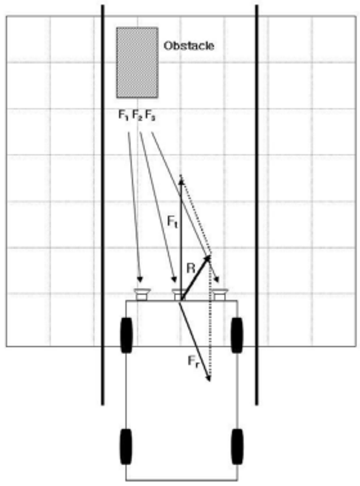

Fig. 8 The concept of virtual force field method

$$\mathbf{F_r} = \sum_i \mathbf{F}_i \qquad (2)$$

Each individual repulsive force is defined by

$$\mathbf{F}_i = \frac{F_{cr} C_{i,j}}{d^2} \left[\frac{x_i - x_0}{d} \hat{x} + \frac{y_i - y_0}{d} \hat{y} \right] \qquad (3)$$

Where, F_{cr} is repelling Force, d is distance between active cell (i,j) and the unmanned vehicle, $C_{i,j}$ is certainty value of active cell(i, j), x_0, y_0 are present coordinates of the unmanned vehicle, and x_i, y_i are coordinate of active cell(i,j).

The position of center in front of the vehicle is the origin of absolute coordinate. The position prescribes the magnitude and direction of the attractive vector.

$$\mathbf{F}_t = F_t(\Delta x \hat{x} + \Delta y \hat{y}) \qquad (4)$$

Where F_t is the magnitude of force and Δx, Δy are motion deflection in x and y direction. Therefore, $\mathbf{F}_t$ is added vectorially to $\mathbf{F}_r$, producing the resultant force vector $\mathbf{R}$.

$$\mathbf{R} = \mathbf{F}_t + \mathbf{F}_r \qquad (5)$$

The direction of resultant force of $\mathbf{R}$ is $\theta = \mathbf{R}/|\mathbf{R}|$. The unmanned vehicle generates steering angles by $\delta = 90 - \theta$ and can avoid obstacles.

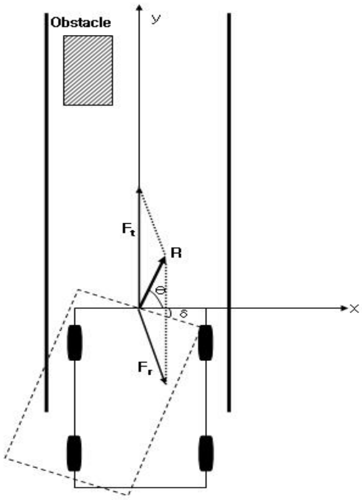

Fig. 9 Obstacle avoidance by generating steering angles

3. EXPERIMENTS

Experiments of the miniaturized unmanned vehicle divide into vehicle test, ultrasonic sensor test and communication test. Microprocessor on the vehicle is PIC16F84 and PIC16F877 comes from Microchip co. and programming in the C language by using CCS-C compiler.

3.1 Vehicle Driving Test

Vehicle test is driving along the lane on the road. The obtained information from vision sensor is used to control the vehicle velocity and steering. Fig. 10 shows road lane data using wireless communication.

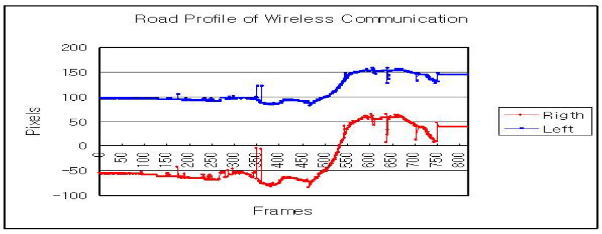

Fig.10 Road lane data using wireless communication

As you see the Fig.10, using wireless RF module caused the noises. Because the unmanned vehicle momentarily didn't recognize the lane, road lane data is heavily fluctuating in Fig.10.

3.2 Communication Test

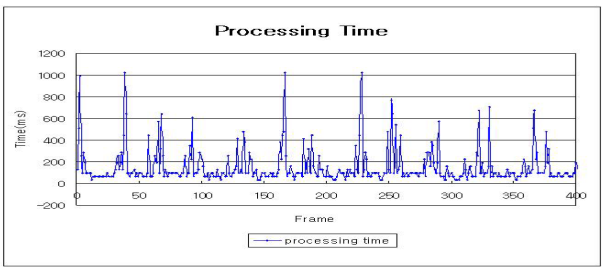

Fig. 11 Time of processing

We checked processing time of a frame using wireless RF modules. Fig.11 shows the time of processing a frame. We obtained similar tendency like vehicle driving test result. The processing time of a frame is about 144ms and the processing frame of one second is 7 frames.

3.3 Ultrasonic Sensor Test

Ultrasonic sensor test has not yet completed. We are testing for the basic characteristic of ultrasonic sensor. And we are going to make an experiment on ultrasonic sensor for all cases of obstacle's position.

4. CONCLUSIONS

The unmanned vehicle consists of the vehicle system and the control system. We used RF communication modules to communicate these two systems. In the result, it needs to reduce the processing time. Also, we devise the obstacle detection and collision avoidance algorithm. If the unmanned vehicle detects obstacle from ultrasonic sensors during the traveling, the unmanned vehicle can avoid obstacles in accordance with the collision avoidance algorithm. And we are going to test ultrasonic sensors to apply to the Virtual Force Field (VFF) method for all cases of obstacle's position.

ACKNOWLEDGMENTS

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REFERENCES

[1] Tumbo S. D. and M. Salyani J. D. "Laser, Ultrasonic and Manual Measurement of Canopy Volumes of Citrus Trees," *American Society of Agricultural Engineers* (*ASAE*), Paper No. 01-011068.

[2] H. C. Moon, "Design of the Unmanned Vehicle System by using Vision System," Master's Thesis, Graduate School of Automotive Engineering, Kookmin University, Seoul, Korea, 2002.

[3] J. Borenstein and Y. Koren, "Tele-autonomous Guidance for Mobile Robots," *IEEE Trans. on System, Man, and Cybernetics,* Vol. 20, No. 6, pp. 1437-1443, 1990.

[4] J. Borenstein, and Y. Koren, "The Vector Field Histogram-Fast Obstacle Avoidance for Mobile Robots," *IEEE Journal of Robotics and Automation,* Vol. 7, No. 3, pp. 278-288, 1991.

[5] S. G. Kim, H. C. Moon, C. M. Kim, and J. H. Kim, "Steering Control of Autonomous Vehicle by the Vision System," *Proceeding of ICCAS2001*, pp. 615-618, 2001.

[6] M. S. Kim, "The System Modeling for Unmanned Vehicle & Autonomous Driving Technique by Ultrasonic Sensors," Master's Thesis, Graduate School of Automotive Engineering, Kookmin University, Seoul, Korea, 2001.

[7] 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.