Smooth Automatic Vehicle Stopping Control System for Unexpected Obstacles

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***Abstract*— Various studies have been conducted regarding vehicles and obstacle avoidance, but very few studies deal with the avoidance of obstacles that suddenly and unexpectedly appear during vehicle operation. We conduct automatic stopping control of the vehicle using a fuzzy control system when the vehicle stop suddenly. The propose system conducts stopping control of the vehicle depending on the distance to the obstacle. The simulation experiments and actual experiments using a mobile robot on behalf of a vehicle were conducted regarding the proposal.**

Keywords—unexpected obstacles; obstacle avoidance; speed control; distance; fuzzy control

I. Introduction

Due to the increasing numbers of traffic accidents and elderly drivers in recent years, it has become necessary to manufacture safer vehicles. To this end, studies on Intelligent Transport Systems are being conducted [1][2][3][4][5][6].The cause of roughly 60% of traffic accidents is the driver's late response to a dangerous situation or errors in judgment. The spread of Advanced Safety Vehicles equipped with features to assist the driver's recognition, judgment, and vehicle operation is expected to help reduce the incidence of traffic accidents. Notably, the evasion of obstacles that appear unexpectedly is an important issue in vehicle traffic safety. Automatic braking systems for obstacle avoidance have been developed and are considered adequate to safely stop a vehicle. However, because the effectiveness of the systems is given priority, less consideration has been given to the problem of whether passengers experience discomfort when the braking system is activated [7]. Various studies have been conducted regarding vehicles and obstacle avoidance [8][9][10][11][12], but very few studies deal with the avoidance of obstacles that suddenly and unexpectedly appear during vehicle operation [13]. The avoidance of such obstacles in front of the vehicle is possibly applicable in real-world traffic situations.

In this study, a mobile robot was used in place of a vehicle and a system is proposed that will execute either a sudden stop or a speed reduction through speed control, depending on the distance to the obstacle. Speed control of the mobile robot was implemented using a fuzzy control system.

The fuzzy control system was controlled by inference rules written in an IF-THEN format. Conventional methods are able to handle only clearly defined values, but a fuzzy control system can make fine-grained deductions because it can handle ambiguous expressions. The modeling of human empirical knowledge is important to the handling of ambiguity [14]. This study examined speed control according to the distance to an obstacle. The stopping controls of the mobile robot were operated in this study using a fuzzy control system in order to replicate the real-time reaction ability of a human in the avoidance of an obstacle.

The obstacle recognition is conducted by processing an images acquired from a camera mounted on the robot. This processing is implemented using an image recognition IMAPCAR2 (Integrated Memory Array Processor for CAR2) parallel processor.

This paper consists of four main sections to introduce the entire project. Section 2 presets the structure of the main system which includes obstacle detection part and control part. The automatic control following Fuzzy logic is presented in section3. Finally, section 4 concludes paper and introduce some future works.

II. SYSTEM CONFIGURATION

Figure 1 shows the configuration of the main system which consists of obstacle recognition unit and smooth automatic stop control unit used in this study. This study deals mainly with automatic stop control unit.

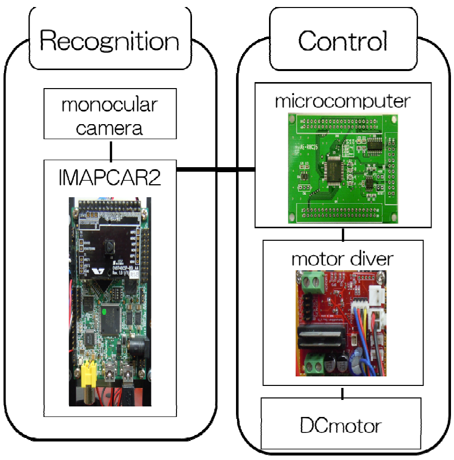

Fig.1.System configuration

The distance measurement unit contains an IMAPCAR2 image recognition parallel processor (Renesas Electronics Corp.,). This high-speed parallel processor is capable of performing 170 billion calculations per second, and is used for recognizing obstacles that appear suddenly and measuring the distance to those obstacles. The control unit implements the smooth automatic stop control of the vehicle optimized for the measured distance [13]. The implementation of the control unit mainly includes microcomputer and motor controller. The microcontroller is to calculate the control variable.

III. AUTOMATIC STOP CONTROL

A. *Fuzzy Control*

Here, the automatic stop control of the vehicle is implemented based on fuzzy control. The control variable in the fuzzy control is calculated based on the following rule definitions (NB: distance to obstacle is smaller; MD: distance to obstacle is medium; PB: distance to obstacle is big). The defined rules regarding to control variable determination are as below, the left part and right parts of a rule are called as antecedant part and consequent part respectively.

Control Rule 1. IF x is NB, THEN y is NB

Control Rule 2. IF x is MD, THEN y is MD

Control Rule 3. IF x is PB, THEN y is PB

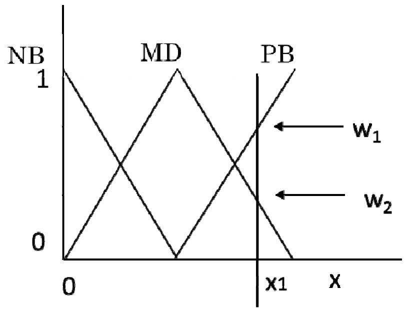

Fig.2.Fuzzy set

Here, x is the state variable and y is the control variable. NB and PB of the control variable correspond to concrete values (e.g., PB=10). As Figure 2 shows, when x=x1, control rules 2 and 3 are used because x is crossed by MD and PB. In this case, we obtain the degree of w_1 and w_2 from the fuzzy set, following antecedent part. Figure 3 and 4 illustrates the grade function of the consequent part. As Fig. 3 and 4 illustrates, grades $w_1$and w_2 are reflected to grade function of consequent part following the above rules. The trapezoidal shapes according the reflected w_1 and w_2, are used to decide the control variable. Figure 5 illustrates the control variable calculation, AND operation of above mentioned two trapezoidal shapes is conducted. The gravity point of final shape which illustrated in Fig. 5, is calculated following the equation 1. This values is used as control variable.

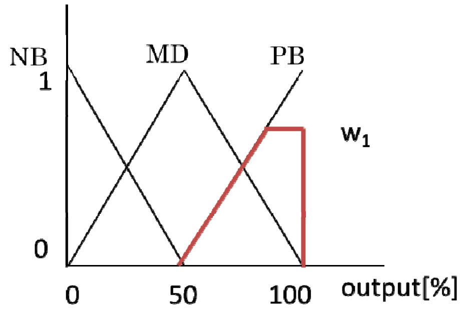

Fig.3. Comparison between w1 and PB

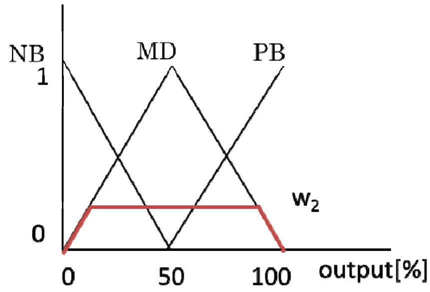

Fig.4. Comparison between w2 and MD

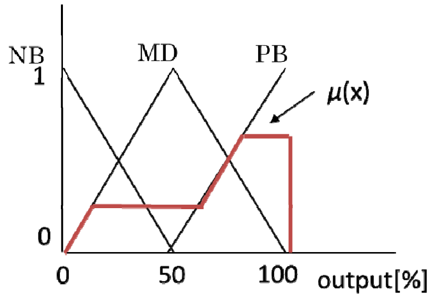

Fig.5. Final shape

$$y = \frac{\int x \times \mu(x)}{\int \mu(x)} dx \quad (1)$$

$\mu(x)$: Synthesized fuzzy sets

IV. EXPERIMENTS

We conduct a simulation experiment and actual experiment using moving robot. In each experiment, output to the motor following the distance to the vehicle is determined using the proposed fuzzy control method. The stream of determining the output for motor driver is illustrated in fig. 6.

A. *Simulation results*

Figure 7 shows the results of a simulation and describes the output given for the distance value, which is then used in the speed control system. This simulation is conducted varying the distance between 0 and 300cm.

From this, we can see that at a distance of ≤ 80 *cm* between the mobile robot and the obstacle, the output is 0 and the robot stops. At a distance of ≥ 240 *cm* the output is 100 and the speed remains constant. At distances between 80 and 240 *cm* the output changes to values between 0 and 100 according to the distance.

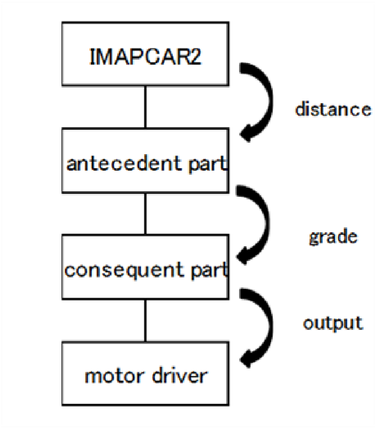

Fig.6. Speed control flow

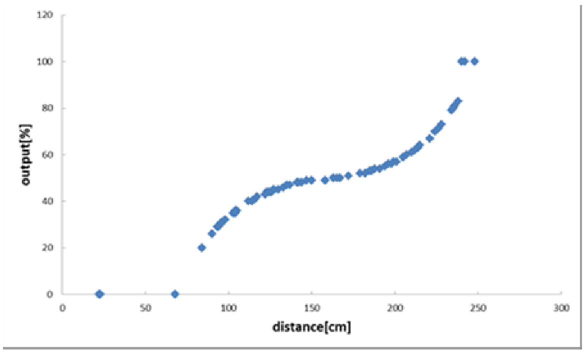

Fig.7. Distance output

B. *Actual exprimets using a mobile robot.*

We install the main system illustrated in Fig. 1 including obstacle recognition unit and smooth automatic stop control unit on a mobile robot and experiments were conducted moving the robot. Here, obstacle detection is conducted processing the images from the camera, following a method in the literature [13]. We could observe that the smooth stopping of the robot regarding to the distance to obstacle is possible with the new proposal.

V. CONCLUSION

In this study, we constructed a system to control the stopping according to the distance between the vehicle and an obstacle that suddenly appears in front of it. We then conducted a simulation and actual experiments, and identified the speed output according to that distance. In a future study, we will further investigate the proposed method for calculation of control values using actual vehicles and obstacles.

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