A study on autonomous steering and Cruise speed control using Fuzzy Algorithm

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Abstract: This paper contains studies which are Cruise speed control which is made by PID algorithm and automated steering system for avoiding the obstacle coming from the front which is using Fuzzy algorithm. This mobile car uses DC motor whose speed is detected by encoder. Ultrasonic Waves Sensor established in the front detects the obstacle and the curve. And the sensor established in the side detects the distance of the space of the road. If the sensor detects the obstacle or the curve, the car is controlled by using Fuzzy algorithm. The Fuzzy algorithm calculates the speed and steering angle by using the value which is obtained from sensor.

Keywords: Fuzzy, autonomous steering, PID, Cruise Speed Control

1. INTRODUCTION

These days many fields are made to autonomous system. But most of the autonomous system field is still limited to instruct field. The technology can make those fields spread to our lives. Especially, the vehicle field's autonomous study is done by many company, student and so on.. These autonomous vehicle can make human's life comfortable and the car accident is reduced and the traffic jam is reduced, too. This paper contains studies which are Cruise speed control which is made by PID algorithm and automated steering system for avoiding the obstacle coming from the front which is using Fuzzy algorithm. This mobile car uses DC motor whose speed is detected by encoder. Ultrasonic Waves Sensor established in the front detects the obstacle and the curve. And the sensor established in the side detects the distance of the space of the road. If the sensor detects the obstacle or the curve, the car is controlled by using Fuzzy algorithm. The Fuzzy algorithm calculates the speed and steering angle by using the value which is obtained from sensor. All system is controlled by 8 bit micro-processor (Atmega 128). The experience is helpful to develop the autonomous controlled car.

2. PID Algorithm

The transfer function of the PID controller looks like the following:

$$K_p + \frac{K_I}{s} + K_D s = \frac{K_D s^2 + K_p s + K_I}{s}, \quad (1)$$

- Kp = Proportional gain
- KI = Integral gain
- Kd = Derivative gain

First, let's take a look at how the PID controller works in a closed-loop system using the schematic shown above. The variable (e) represents the tracking error, the difference between the desired input value (R) and the actual output (Y). This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The signal (u) just past the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error.

$$u = K_p e + K_I \int e dt + K_D \frac{de}{dt}, \quad (2)$$

This signal (u) will be sent to the plant, and the new output (Y) will be obtained. This new output (Y) will be sent back to the sensor again to find the new error signal (e). The controller takes this new error signal and computes its derivative and its integral again. This process goes on and on.

2. 1 The characteristics of P, I, and D controllers

A proportional controller (Kp) will have the effect of reducing the rise time and will reduce ,but never eliminate, the steady-state error. An integral control (Ki) will have the effect of eliminating the steady-state error, but it may make the transient response worse. A derivative control (Kd) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response. Effects of each of controllers Kp, Kd, and Ki on a closed-loop system are summarized in the table shown below.

Table1. Features of PID controller's gain

CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	Small Change

Note that these correlations may not be exactly accurate, because Kp, Ki, and Kd are dependent of each other. In fact, changing one of these variables can change the effect of the other two. For this reason, the table should only be used as a reference when you are determining the values for Ki, Kp and Kd.

3. Fuzzy Algorithm

Fuzzy logic is a superset of conventional(Boolean) logic that has been extended to handle the concept of partial truth- truth values between "completely true" and "completely false". As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The importance of fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature. The essential characteristics of fuzzy logic as founded by Zader Lotfi are as follows.

- In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning.
- In fuzzy logic everything is a matter of degree.
- Any logical system can be fuzzified
- In fuzzy logic, knowledge is interpreted as a collection of elastic or, equivalently , fuzzy constraint on a collection of variables
- Inference is viewed as a process of propagation of elastic constraints.

The third statement hence, define Boolean logic as a subset of Fuzzy logic.

3.1 Fuzzy Control

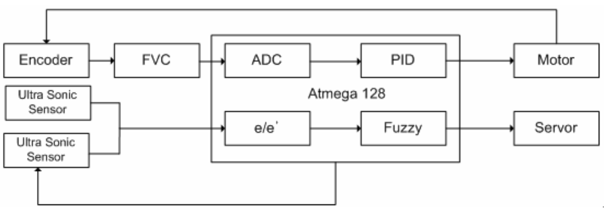
Fuzzy control, which directly uses fuzzy rules is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani in the late 70s, three steps are taken to create a fuzzy controlled machine:

1) Fuzzification(Using membership functions to graphically describe a situation)

2)Rule evaluation(Application of fuzzy rules)

3) Defuzzification(Obtaining the crisp or actual results)

4. System of the car.



The fig1 describes the system of the car.

The system is divided two parts. The one is motor control part. And the other is the Steering control part.

4.1 Motor Control Part

The motor is controlled by Atmega 128. The motor's speed is detected by encoder module. The encoder is made of the photo-interrupter. The encoder module is made by the encoder, FVC(frequent to voltage converter) and ADC. The encoder creates the pulses. The pulse is the input of the FVC. The FVC makes the voltages which is the input of ADC. Fig2 is the circuit of the FVC.

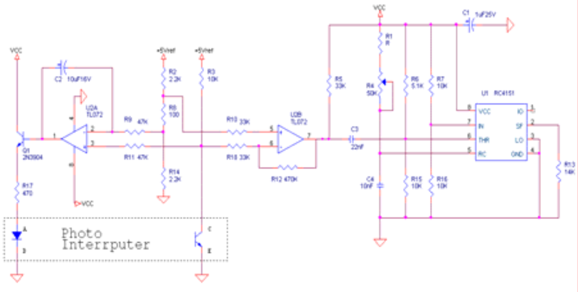


Fig2. The circuit of the FVC.

The value of the ADC is the feedback value of the PID Controller. The CPU runs the ADC procedure. The value is 10bit.

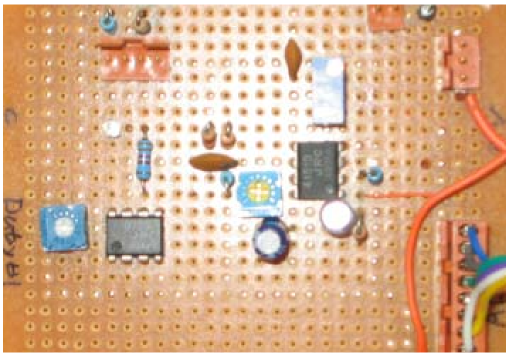


Fig3. The FVC module

4.2 The Steering Control Part.

The steering is run by Fuzzy Controller. The Fuzzy controller is made by two ultra sonic modules. Fig3 is the Circuit of the Ultra Sonic Sensor module.

Table2. The module's Features

Voltage	5v
Frequency	40KHz
Maximum Range	3 m
Minimum Range	3 cm
Sensitivity	Detect a 3cm diameter stick at > 2 m
Input Trigger	10uS Min. TTL level pulse
Echo Pulse	width proportional to range.
Weight	0.4 oz.
Size	1.75" w x 0.625" h x 0.5" d

If the trigger pulse inputs to module from the CPU, the module shout the sonic burst from the module. The echo pulse's width is the source to calculate the distance from module to the object. The formula is that

$$D = T \times 340 / 2, \qquad (3)$$

D : distance from module to object

T : pulse width (if there is no object, the width is 36 ms)

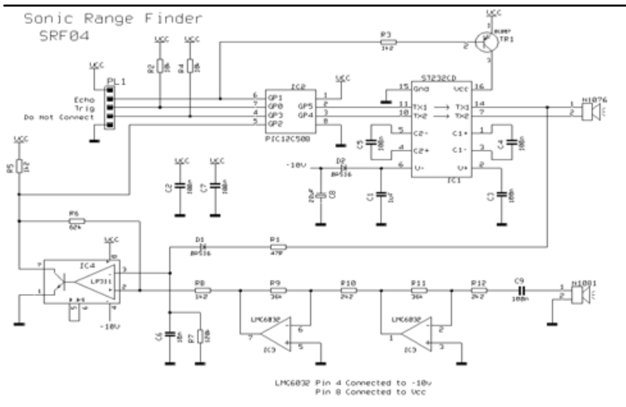


Fig 3. The circuit of the Module

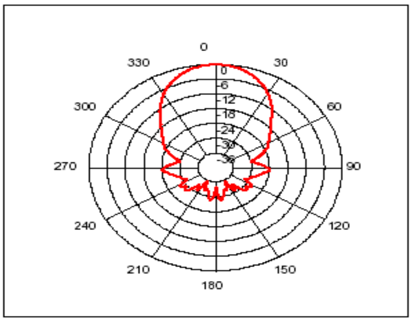


Fig4. The beam pattern and beam width

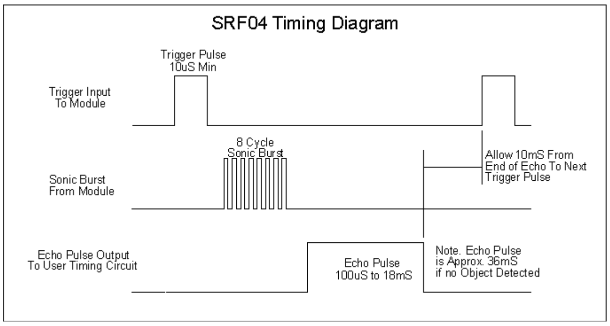


Fig5. The module operating system

5. The Cruise Control using PID Algorithm

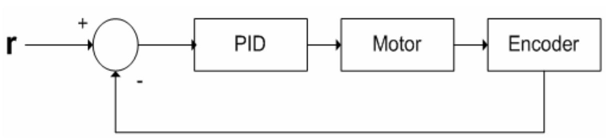


Fig6. The block of PID controller

The PID controller which we use is discrete PID controller. And the feedback value and the reference value is the value of the ADC. The input analogue value is voltage and the output one is binary which range is 10bit. At first the CPU calculate the ADC and we multiply proper constant to make input value to the motor driver. The discrete PID controller formula is

U = Kp*(E(t) – E(t-1)) + Ki*E(t) + Kd*(E(t)- (2*E(t-1) + E(t-2), (4)

- Kp = Proportional gain
- KI = Integral gain
- Kd = Derivative gain

To get the proper controller's gains, we changed the gain several times. Finally we can find the most proper gain which can do cruise control well. The below shows the controller's gain which is used in this paper.

- Kp = 0.15
- Ki = 0.005
- Kd = 0.001

There are some figures which describes the signals of the output. The signal of the graph is voltage which is output of the FVC. The voltage is propation to the speed.

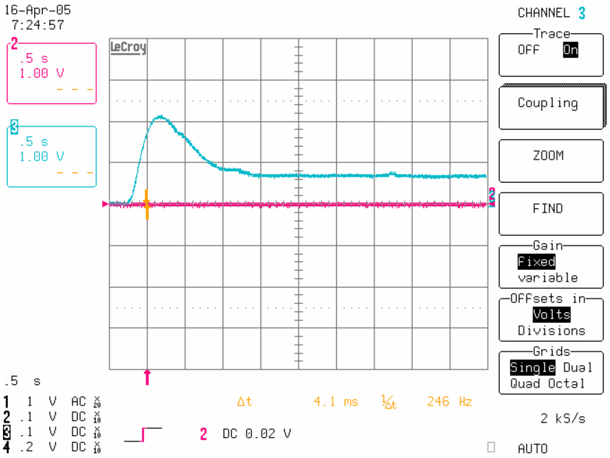


Fig7. The output of the FVC.

The Fig7 is the state of the start. At first the car's speed is zero so the output voltage is zero, too. If the car starts, the voltage try to keep track with reference value.

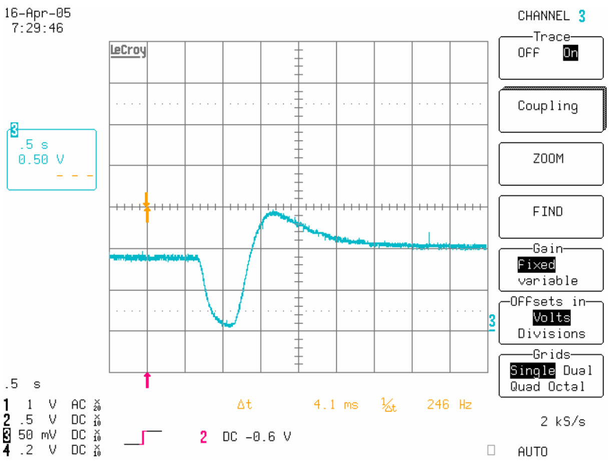


Fig8. The output of the FVC

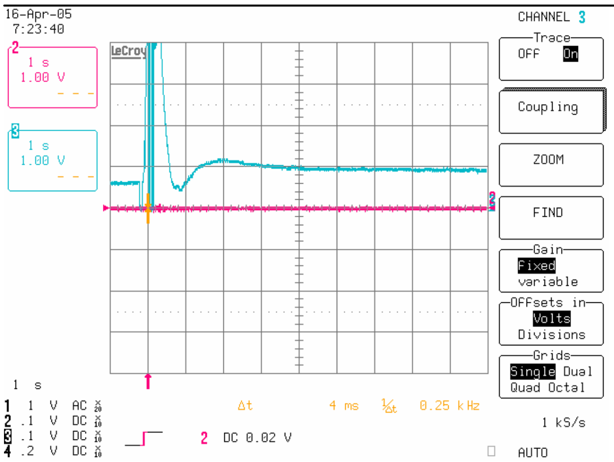


Fig9. The output of the FVC

The Fig8 is the output of the FVC. When the car meets an upward road while the car is driving cruise, the car's speed is down then the controller try to return to the reference speed.

6. Steering controller using Fuzzy

Table3. Fuzzy control rules

e \ ce	NB	NS	ZO	PS	PB
NB	NB	NB	NM	NS	ZO
NS	NB	NM	NS	ZO	PS
ZO	NM	NS	ZO	PS	PM
PS	NS	ZO	PS	PM	PB
PB	ZO	PS	PM	PB	PB

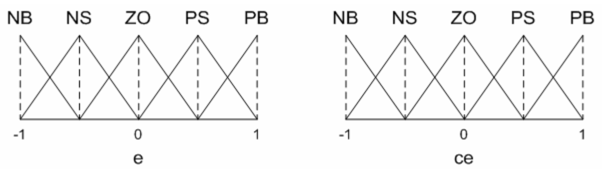


Fig10. The Fuzzy set and Defuzzification.

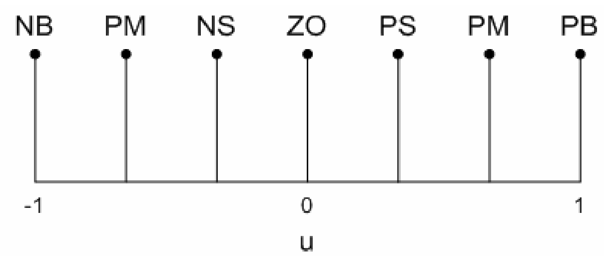


Fig11. Membership function for fuzzy controller

In this paper, we use Fuzzy controller which we can design easily and include the experiments of experts. The table1 shows the Fuzzy rules to control steering controller. And the fig shows the Fuzzy set of the controller. We get the results throught the MAX-MIN operator. And single-tone method is used to get the control signal. In the table e means the difference of the left sensor's value and the right sensor's value.

$$e = \text{right sensor} - \text{left sensor}, \quad (5)$$

If the e is positive, the car is close to the left side. And if the e is negative, the car is close to the right side. The change of error shows the direction of the car. If the change of the error is negative, the direction of the car is left. If the change of the error is positive, the direction of the car is right.

7. Conclusion

In this paper, we make an experiment several times. The car can do speed control and steering control by itself. The car maintains his speed while it drives. If it finds the object or corner, it can avoid the object and turn the corner by itself. It maintain the its speed very well. But during the steering and turning the corner, it rocks from side to side. Fuzzy controller tries to make equal left distance and right distance from the wall to the sensor modules. It is problem to solve. If we use the location deduction algorithm using Fuzzy, we think that the problem will be solved. We know the potential of the development the autonomous controlled car. This paper has only cruise control and steering. In the future, we develop this car so much. We'll add the CCD camera, RF module, and more sensors. So the car can steer more smoothly and monitor the car's state in real time by wireless communication.

Reference

[1] Lefteri H.Tsoukalas and Robet E. Uhrig "Fuzzy and Neural Approaches in Engineering"

[2] Richard Valentine "Motor Control Electronics Handbook"

[3] J. G. Ziegler and N. B. Nichols, "Optimum settings for automatic controllers", Trans. ASME, vol. 64, pp. 759-768, 1942.

[4] Benjamin. C. Kuo, " Automatic Control System", Prentice Hall, Seventh Edition, pp. 470-794, 1995

[5] Norman S. Nise, "Control System Engineering", Secong Edition, pp.295-676, 1996.

[6] K.Ogata, Modern Control Engineering, 2nd edition, Prentice Hall, 1990.

[7] R. C. Dorf and D. R. Miller, "A method for enhanced PID controller design", Journal of Robotics and Automation, Vol. 6, pp. 1991.

[8] 3. P. N. Paraskevopoulos, "On the design of PID output feedback controllers for linear multi-variable systems", IEEE Trans. on Industrial Electronics and Control Instrumentation, vol. IECI-27, pp. 16-18, Feb, 1980.

[9] R. C. Dorf and R. H. Bishop, Modern Control Systems, 7th edition, Addison Wesley, 1995.

[10] T. Iwasaki and A. Morita, "Fuzzy auto- tuning for PID controller with model classification." in Proc. NAFIPS '90 Toronto, Canada, June 6-8, 1990, pp. 90-93.

[11] J. H. Kim, J. H. Park, and S. W. Lee, "Control of Systems with Deadzones usings PD Controllers with Fuzzy Precompensation", proc, of the IEEE Conf. Intelligent Control, pp.451-456 1993 August.