A Design of Intelligent Automobile Cruise Control System with Laser Rangefinders

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Abstract — In order to realize the automation of space control of automobile, an intelligent control system was designed, which consists of a laser rangefinders, a speed sensor, a digital controller and a performing motor. The laser rangefinders were developed for the system. The digital controller adopted PIC16F877 SCM, and a step motor was utilized for the performing. Using fuzzy logic theory, an intelligent control scheme was developed to realize the automation of space control according to the error for space and speed in the automobile cruise control system. The method needn't build the accurate mathematic model of object, but according to the artificial experience or state to build the control rule. It avoids the object's uncertainty, noise, infection of nonlinearity and variable time. The experimental results show that anticipative aims are achieved on the prototype machine.

Index Terms —laser rangefinders, automobile cruise control system, fuzzy control

I. Introduction

With the development of automobile industry and science – technology, the requirements have become strong for reducing fatigue of drivers, fuel consumption and environmental pollution, improving comfort and safety. In the process of the automobile driving, some massive uncertain factors affect the control decision. The fuzzy control and neural network technology needn't establish an accurate mathematical model. It just bases on the artificial experience and intelligence decision to complete controlling.

Therefore, it avoids the object's uncertainty, yawp, infection of nonlinearity and variable time. For reaching automobile electronic cruise control system was designed using intelligent control algorithm and according to the deviation of space of vehicle driving between target and real to adjust control parameter.

II. Structure of System

The new automobile cruise control system consists of a laser rangefinder, a velocity sensor, a digital controller and a performing machine unit. The system structure is shown in Fig.1. Laser rangefinder completed detection of vehicle space, velocity sensor completed detection of speed, control unit completed comprehensive treatment to signal and performing machine completed driving. The electronics digital controller is the core of the cruises control system, which function is to receive space signals from laser rangefinder, and preset signals of vehicle space and signals of electronic switch, and obtain output control signal to drive performance machine by converting and computing.

Firstly, driver gives desired speed signal, namely setting speed according to the requirements. Then the system will automatically control based on the specified speed and practical speed. When the testing practical speed is higher or lower than the specified speed, the controller ECU will obtain the variance between the specified signal and the feedback signal, i.e. error signal. Testing speed compared with desired speed of the variable under control which is fed in manually. The error signal become throttle control signal after amplification and processing, then it was sent it to throttle controller to drive the throttle, and adjusting the extent of the engine throttle to correct the error between instruction and feedback signal of practical speed, so the speed can quickly recover the level set by the driver and keep a steady speed. Tracing driving control locks the target vehicle, which drivers want to track to keep a space. When the space with target vehicle increases, then speed of the tracing vehicle will increase. On the contrary, the space with target vehicle decreases, the speed of the tracing vehicle will decrease.

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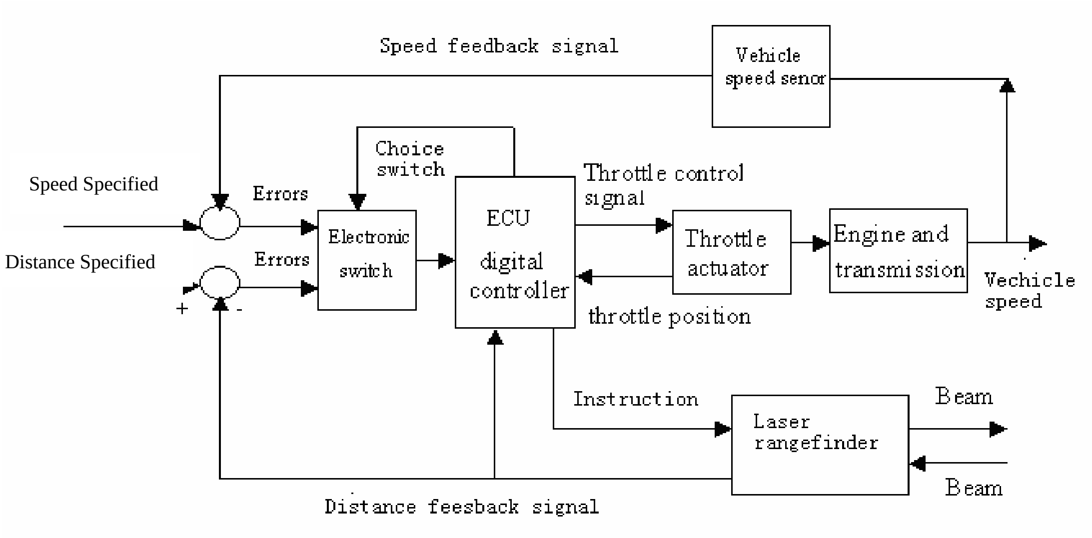

Fig.1.Principle diagram of vehicle electronic cruise control system

III. Design of Laser Rangefinders

To fulfill the request of the vehicles electron cruise system, a laser rangefinders was developed. The laser beam diameter can reach to above 15 meters in the place of 500 meters away, so it can satisfy the request of unidirectional width of highway. The system has many advantages, such as simple structure and low cost. It becomes reality that uses on vehicles. The laser range finder is made of laser a semiconductor, which has small volume and light weight, and consumes a little electric energy. The output power in pulse is only several dozen watts; the emission frequency of laser is high very much. Configuring proper circuits and selecting proper algorithms, it can be used for measuring of fixed target and motion target on ground. The block diagram of special laser range finder is shown in Fig.2.

The type of laser ranging is pulse. When the controller give off ranging pulse to emission control circuit, laser rangefinders starts timing at the same time, the emission control circuit drives laser diode and emits ranging laser beam. If the beam meets target and reflects back, the laser receiver system receives beam pulse and transfers signal to the MCU to stop timing. The space can be obtained by MCU calculating.

Main characteristic parameter:
Least measuring range: 14m, measuring.
Space for human: 200m.
Measuring space for automobile: >500m.
Space error: $\pm$ 2 m.
Repetition frequency: >10times/s.
Communication interface: RS232.
Power source: 9v,

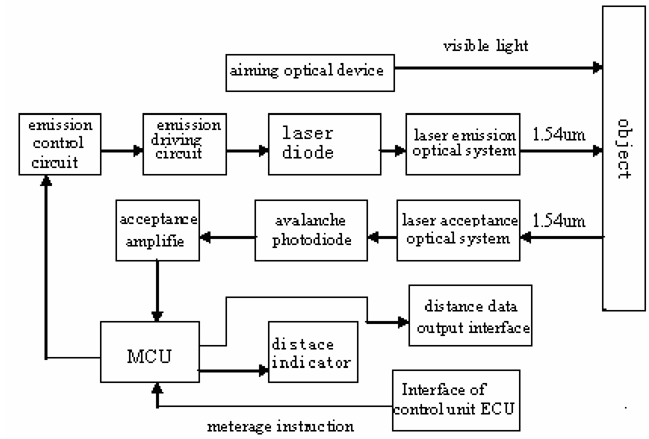

Fig.2.Structrue of laser rangefinder

Working mode: standard, run, interfere (>150m), REFL communication mode: SRS232C serial synchronism. Baud rate: 9600 bps.

IV. Hardware Design of Control System

The hardware structure diagram of electronic cruise control system is shown in Fig.3. The controller ECU adopted PIC16F877 MCU in the control system. Controller PIC16F877 MCU programming performs all data processing according to setting space by driver and practical space of the vehicle, and produces output signals to the step motor for changing throttle opening. In order to the safety, the braking switch is connected with throttle actuator, treading pedal and stop control program of MCU. Power of throttle actuator is switched off at the same time to ensure the throttle closed completely. Laser range finder and interface circuit adopted RS232C, electricity level converter adopted MAX232. MCU gives laser rangefinder two pulses continuously and starts timing. While MCU gives a stop pulse, the laser rangefinder stops working so as to save energy. If given a pulse again, the laser rangefinder restarts.

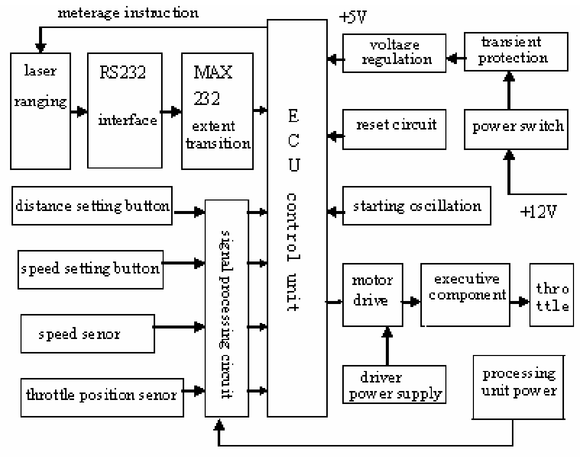

Fig.3. Structure of electronic cruise system

Vehicle speed sensor is installed on the master transmission spindle; ECU counts the pulses of speed sensor and timing simultaneously so as to obtain an instantaneous rotating speed. The main component of the position sensor, which installed on the throttle, is a line potentiometer. Its variable resistance pointer is connected to the line on throttle, while pulling the line on throttle, the pointer will move simultaneously. As a result, the resistance of the potentiometer changed, voltage of A/D convertor on ECU was obtained, and then the position of throttle was calculated.

This system adopts the signal processing circuit, which can set the desired value of space. Drivers can keep the desired space with the preceding vehicle by pushing down the button, which is used for setting space. When the driver pushes up the button, the value of space is desired by the cruise system. Also, it can set the desired speed through the same operation. When the driver pushes up the button, vehicles drive at the speed that the cruise wants to keep.

An electronic actuator consisted of a step motor, safety electromagnetic clutch and apposition sensor was utilized. The motor can rotate with control arm of executive elements together so that the throttle opening was changed by controlling cable of control arm. For limiting the angle of the control arm, the motor circuit equipped with a positive stop switch. Between motor and control arm equipped with one safety clutch. When cruise system is working, the safety electromagnetic clutch is connected. So the motor’s rotation can change the throttle’s opening. If any part of the actuator or ranging laser radar in the process of cruise system controlling is wrong, the safety clutch will separate immediately.

The step motor can transform digital signal into a quantitative of angle shift, which is given off by ECU. Inputting every pulse, the motor will drive throttle to rotate a little angle so as to ensure the accuracy of the throttle’s opening and closing. The step motor’s rotating angle is the throttle’s rotating angle, which is proportional to the pulse. The direction of throttle swiveling is the direction of the step motor, which is determined by the phase sequence of distributing pulse.

Electronic actuator equipped with a position sensor, which is a slip potentiometer of variable resistor. It was used for monitoring the rotation position of the actuator’s control arm. The output signals were transmitted into the ECU.

V. DESIGN OF CONTROL STRATEGY AND ALGORITHM

Due to the complexity of control process, the vehicle space intelligent controller adopts fuzzy control strategy. The block diagram of control strategy is shown in Fig.4. Fuzzy control system needn’t establish the accurate mathematical model. It just utilizes the artificial experience, applied knowledge language and logic relationship to process analytical model, and uses previous control rules and reasoning to realize control based on the artificial experience or statistical way. According to the space between the front-and-back driving vehicles and the speed difference (variable rate of space) carry out fuzzifying, fuzzy reasoning and fuzzy decision, and then obtained the control quantity. There are two working ways, one is speed mode, the other is tracking mode.

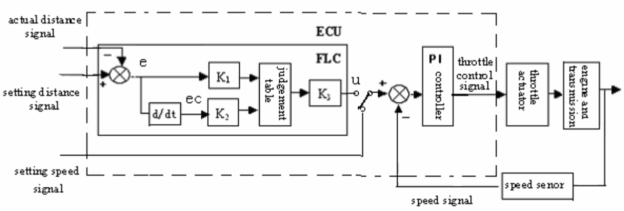

Fig. 4. Block diagram of control system

When the system is working on tracking mode, the controller ECU uses fuzzy controlling algorithm, namely using fuzzy control system with two inputs. The input signals of the fuzzy control system are the error of giving space signal, feedback space signal and variable rate of the error. The input signals were transferred into fuzzy quantities by fuzzifying. Then, control variable of the adjustment throttle opening was obtained by fuzzy reasoning and fuzzy decision according to fuzzy

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knowledge base. Variable of System and Membership Function

The input of the fuzzy control system is the error between the set specified signal and the feedback signal and the error variety variable ratio rate (the precision). Output u of fuzzy controller is the throttle opening; inputs are difference of the vehicles' space e and its change rate ec. The fuzzy variables are U, E, and EC. k_1, k_2 are scaling factor, k_3 is proportion factor. Assume the change range of input is {*a*, *b*}, the scaling change range of output is {*p*, *q*}, the range of integer universe is {-*n*, *n*}, then the calculation formula of the scaling factors and proportion is:

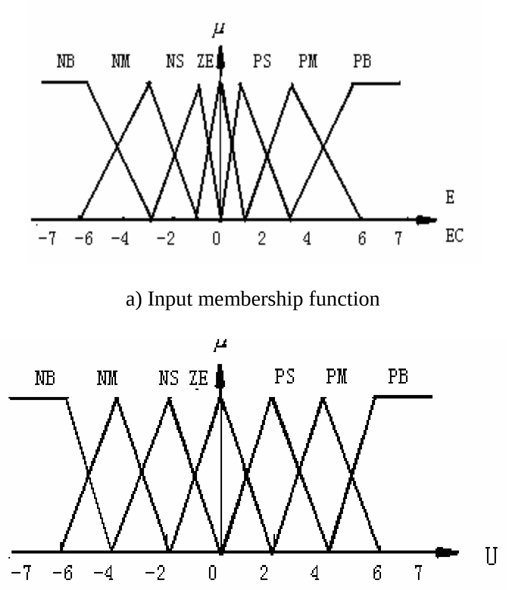
$$\begin{cases} k_1 = 2n/(b-a) \\ k_3 = (p-q)/2n \end{cases} \quad (1)$$

The language value of fuzzy variable e, ec and u could be divided as 7 archives: the minus most, the minus more, the minus small, the zero, the positive small, the positive more, the positive most, which can be expressed by the signs: NB, NM, NS, ZE, PS, PM, PB. The rough fuzzy controller's input and the control variable's universe could be divided as 15 grades (-7, -6, -5, -4, -3, -2, -1, 0, 7, 6, 5, 4, 3, 2, 1).Then we can calculate the integer universe's value E, EC and U, which are mapped. According to their membership functions, the fuzzy variable could be fuzzed.

In fact, the process of accurately variable fuzzification is transformation integer universe and obtains subordinate degree according to the membership function. As the speed and space are very large, the drivers are more sensitive to the low change. Considering the ECU convenient operation, selecting heterogeneous triangle function as membership function of the input variable, due to the error of speed and space are smaller, the sensitivity of the system is high, but the output control variable adopted uniformity triangle function.

A. Control rules and Fuzzy Reasoning

Base on the manual strategy, the fuzzy control rules of controller is established according to experience of men and manual language. It is accumulation of artificial experiences. The fuzzy control rule of this the fuzzy controller is base on the followed principle. When the value of space error is negative and very large (NB), increment of throttle opening is positive and very large (PB), error will be eliminated with the largest speed. When the value of space error is negative and middle



a) Input membership function

b) Output membership function

Fig 5. Membership function of variables

degree (NM), the throttle opening increment is positive medium (PM), the error will be eliminated with medium speed. When value of the space error is negative small (NS) or zero (ZE), it must consider the rate of change (EC) to prevent overshooting. When EC is positive, it shows that error is trend to decrease, control increment should be taken smaller; when EC is negative, it shows that the error is trend to increase, control increment should increase. When the space error is positive, control increment should increase for increasing increment of throttle opening, so that vehicle is running with lower speed for keeping a constant of space.

Fuzzy control rules table as Table 1 expressed 49 control rules, fuzzy relationship matrix R can be obtained by the control rules. As fuzzy matrix and fuzzy relationship of the input and output are known, so results of the fuzzy reasoning can be obtained based on matrix operations and synthesis operations.

TABLE I

FUZZY CONTROL RULES

U				EC				
		PB	PM	PS	ZE	NS	NM	NB
E	PB	NB	NB	NM	NM	NS	NS	PM
	PM	NB	NM	NS	NS	NS	ZE	PM
	PS	NB	NM	NS	NS	ZE	PS	PB
	ZE	NB	NS	NS	ZE	PS	PS	PB
	NS	NB	NS	ZE	PS	PS	PM	PB
	NM	NM	ZE	PS	PS	PS	PM	PB
	NB	NM	PS	PS	PM	PM	PB	PB

Assume rule items are K, form of control rules is IF A_i AND B_j, THEN C_{ij}, then

$$\begin{aligned} R_1 &= A_1 \times B_1 \times C_{11} \\ R_2 &= A_2 \times B_2 \times C_{12} \\ &\cdots\cdots \\ R_k &= A_m \times B_n \times C_{mn} \end{aligned} \qquad (2)$$

The total relation of fuzzy controller:

$$R = \bigcup_{i=1}^{k} R \qquad (3)$$

Assume the input matrixes are A and B, then output matrix:

$$C = (A \times B) \circ R \qquad (4)$$

Choosing Mamdani reasoning algorithm, namely, AND operator use minimal operation, OR use maximal operator, fuzzy implication use minimal operation, fuzzy rules use synthesis methods of maximal operation to calculate results. The center of gravity, namely weighted average was used to realize fuzzy decision for obtaining output of fuzzy controller. Assume the language variable's universe factors of the output control quantity U are u_1, u_2, …, u_n and $\mu_c(i)$ is the jurisdiction of the output factors, then the fuzzy control quantity is :

$$U = \frac{\sum_{i}^{n} \mu_c(i) \times u_i}{\sum_{i}^{n} u_c(i)} \qquad (5)$$

Accurately control variable:

$$u = k_3 \bullet U \qquad (6)$$

B. Using Fuzzy Neural Nnetwork to Achieve Fuzzy Controller's Assistant Design

By the combination of fuzzy combine with neural network, we it can deal with fuzzy information with its study and auto-recognizing mode, namely we can deal with fuzzy rules' auto-create and its membership function's creation. It is more complex that using neural network to make controller. Using the present computers to simulate the neural network and to achieve on-line study and the quick control is difficult, while However, it is capable to achieve study and assistant design[3]. The design of the fuzzy controller is that using a fuzzy neural network instead of the fuzzy controller, and its essence is that using function to describe fuzzy mapping, and in the form using the mechanism which the neural network work on the knowledge to achieve the memory of the control rules group and to achieve input and output mapping of the system. The fuzzy neural network confirms the connection coefficient and switch value among the nerve units according to the information in the table and the output example.

VI. Application Effect

To verify the effectiveness of establishment intelligent control strategy, experiments that a car installing the system ran on the highway were carried out. The response curve of the system is plotted in Fig.7. After starting space control model, the car tracks on desired space in a few minutes. When the gradient of road changed, the car can quickly recover tracking by adjustment action of system. The results show that the performance of the system achieves the requirements designed.

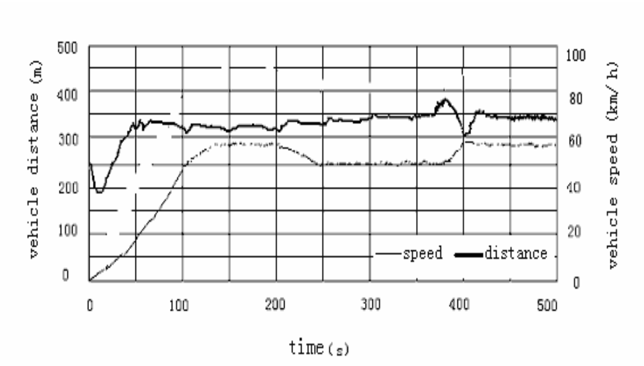


Fig.6. Response speciality curve of system

VII. Conclusion

An intelligent control system was introduced. As the laser rangefinder was developed to detect target, the electronics digital controller base on SCM and control strategy base on fuzzy logic and NN was designed in the system so that it can satisfy the request of the automobile electron cruise system. The cost and complicacy of the system reduces at the same time. New space control function of the system increased. Experiments show that the system is feasibility feasible. It supplies an efficient way to develop a new automobile cruise control system.

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