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Research Article

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Research on Coordinated Control Strategy of Engine Speed Based on Fuzzy Control

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Abstract The improvement of automobile shift quality requires coordinated control of the engine, clutch, and transmission. To control the engine speed when the automobile shifts to the target speed value required by the transmission, active control of engine transmission is an effective method.. The research proposes a coordinated control strategy based on fuzzy controller. By establishing a reasonable fuzzy controller and using fuzzy control rules to control the engine speed during gear shifting to achieve a smooth shift and reduce shift shocks. And build the MATLAB/Simulink model, use the square wave input signal to simulate the jump input signal, and realize the simulation of the control system. Simulation results show that the system can better achieve active adjustment synchronization, effectively reduce the speed difference during the shift process, and thus improve the shift quality.

Keywords Fuzzy Control; Coordinated Control; Speed Difference; Speed Regulation

1. Introduction

At present, with the development of vehicle bus protocol functions, active engine control has become one of the ways to effectively improve shift quality. In the process of interventional coordinated control of engine speed, fuzzy control is based on expert language or operating experience to determine the control rules, which is applicable to the changing characteristics without fixed control laws. Therefore, fuzzy control can be used to actively adjust the engine speed.

In this paper, based on the research of the coordinated control of the line-controlled automatic transmission, the speed difference n of the actual output speed n1 of the engine output shaft and the target speed n0 and the change amount *nc* of the speed difference are used as the input, and the air-fuel ratio *af* is the control amount. The conditions and operations of the control speed are expressed by fuzzy sets, and an appropriate fuzzy rule base can be formulated to adjust the engine speed in real time during gear shifts to achieve precise control of the engine speed and achieve the desired speed value, that is, the target, in real time. Speed value [1]. The simulation results show that this system can effectively reduce the speed difference of the shift, so as to achieve the purpose of improving the shift quality.

2. Coordinated Control Strategy of Fuzzy Controller

The improvement of shift quality requires coordination among the engine, clutch and transmission. The coordinated control strategy based on fuzzy controller studied in this paper, by controlling the speed of the engine, when the speed of the transmission input shaft needs to be reduced when changing from low gear to high gear, the method of adjusting the engine to actively reduce the speed is used to adjust the speed of the transmission input shaft. The speed reaches the speed required by its output shaft; when the gear is shifted from high gear to low gear, the speed of the transmission input shaft needs to be increased to adjust the engine to actively increase the speed so that the speed of the transmission input shaft reaches the speed required by the transmission output shaft. Actively adjust synchronization to achieve smooth gear changes and reduce gear shift shocks.

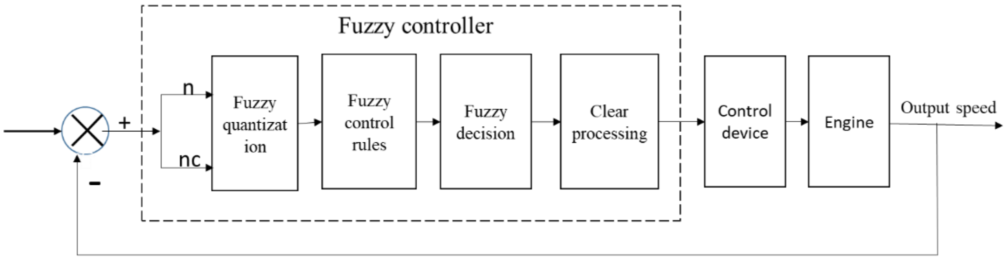

Figure 1: The schematic diagram of motor speed fuzzy control

The core of the fuzzy control is the fuzzy controller. The schematic diagram of the engine speed fuzzy control is shown in figure 1. The control system takes the speed difference n and the rate of change nc of the speed difference between the actual output speed n1 of the motor output shaft and the target speed n0 as the system input. The quantity is converted into a fuzzy quantity after fuzzy quantization, and fuzzy decisions are made through fuzzy control rules, and then converted into an accurate quantity through clear processing, and then the digital value of the accelerator pedal is converted into an analog signal through the D/A conversion module, and the MCU passes the conversion The pedal signal of β times controls the motor speed to approach the target speed.

In the process of coordinated control, the communication between the engine control unit NU and the remote control automatic transmission control unit TCU is achieved through the CAN bus [2]. During the shift process, the engine control unit NU can accurately respond to the target speed and target torque command requirements proposed by the TCU controller in real time, that is, the shift control module in the TCU control unit outputs the shift When the engine control unit NU receives this signal, the engine control unit NU acts on its speed/torque control module to output the corresponding output speed torque.

3. Design of engine speed fuzzy controller

3.1. Membership function and the choice of theorem

In this fuzzy controller, there are five fuzzy sets for the speed difference, and the fuzzy subset of the input variable speed difference *n* is represented by {NB, NS, P0, PS, PB}, and its domain is [-1500,1500], The membership function is shown in figure 2; the fuzzy subset of the input variable speed difference change rate *nc* is represented by {NB, NM, NS, P0, PS, B}, and its theoretical domain range is [-80,80], which exceeds This range is processed according to the boundary, and the membership function is shown in figure 3; the output air-fuel ratio *af* has four fuzzy subsets, which are expressed by {SL, L, M, H}, respectively, and their domain is [12,18], the membership function is shown in figure 4.

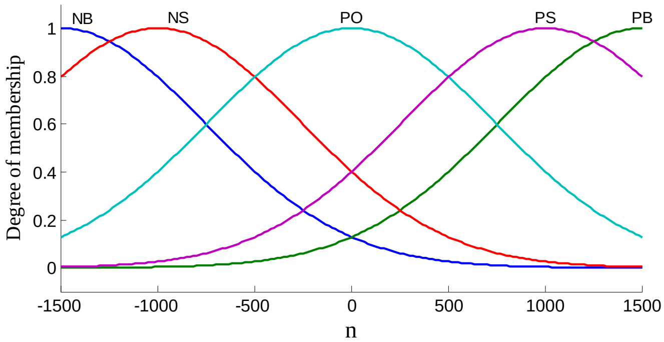

Figure 2: Fuzzy distribution of the speed difference n

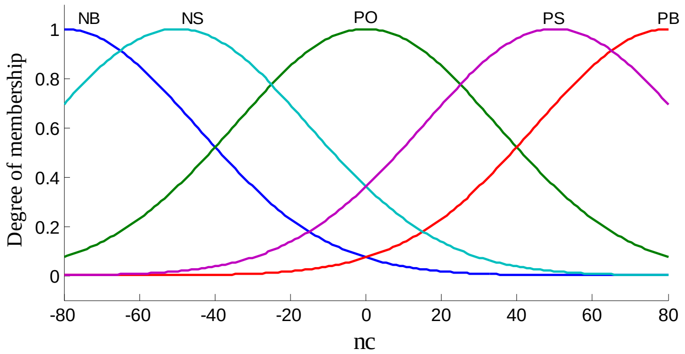

Figure 3: Fuzzy distribution of the change in the rotational speed difference nc

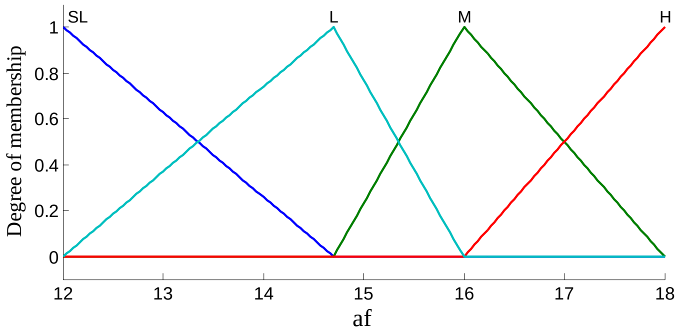

Figure 4: Fuzzy distribution of air-fuel ratio af

3.2. Formulate fuzzy control rule base

In this fuzzy controller, there are five fuzzy sets for the dual input speed difference and the speed difference respectively, and the output air-fuel ratio has 4 fuzzy sets, then the total fuzzy inference rules are 25. The principle of formulating fuzzy rules is that, according to the variation range of the input speed difference and the speed difference variable, it corresponds to the size of the output air-fuel ratio [4]. For example, if the speed difference E is negative, and the smaller, the actual speed needs to be increased, that is, the air-fuel ratio decreases; if the change amount N of the speed difference is positive, and the larger, the adjustment needs to increase the air-fuel ratio. Amplitude. Based on the above analysis, fuzzy control rules can be obtained, as shown in table 1.

Table 1: Fuzzy inference rules table of fuzzy coordination control

NE	NB	NS	P0	PS	PB
NB	SL	L	L	M	M
NS	SL	L	M	M	M
P0	L	L	M	M	H
PS	L	M	M	H	H
PB	L	M	M	H	H

3.3. Fuzzy Reasoning and Clarification

Fuzzy inference generally adopts Mamdani's method. For each control rule, the minimum value of the input variable membership is the membership of the antecedent of the control rule. The inference result is obtained by the minimum calculation of the membership function of the antecedent rule and the posterior function of the rule. , And the final fuzzy inference result requires the maximum calculation processing of the above inference results. The result is a fuzzy set, which is the sum of the conclusions of multiple fuzzy control rules, but the membership functions of fuzzy sets are mostly segmented and irregular The fuzzy control system requires that the final output to the actuator is an accurate quantity. This fuzzy quantity cannot directly control the change of the motor voltage, so it needs to be clarified, and they are equivalent to a clear value mapped to a Representative values. The process of clarification is based on the principle of "reasonable, convenient calculation and continuity". Common methods include area center method, area average method and maximum membership method [5]. The area control method uses area center method and its expression The formula is:

$$X_{avr} = \frac{\sum_{i=1}^{n} x_i u_U(x_i)}{\sum_{i=1}^{n} u_U(x_i)} \tag{1}$$

In the Mamdani-type fuzzy inference logic algorithm, "And Method" takes "Min", "Or Method" takes "Max", "Implication" takes "Min", "Aggregation" takes "Max", "Defuzzification" takes "Centroid" ", the editing interface of the Mamdani fuzzy inference system is shown in figure 5. After the area center method is used to clarify the processing, a fuzzy rule mapping relationship between input and output is obtained, as shown in figure 6.

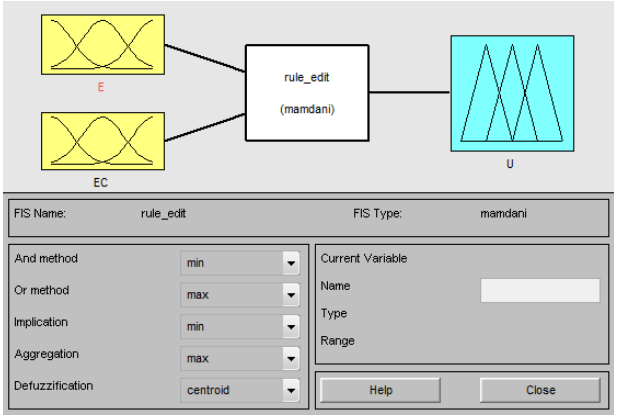

Figure 5: Mamdani Fuzzy inference system

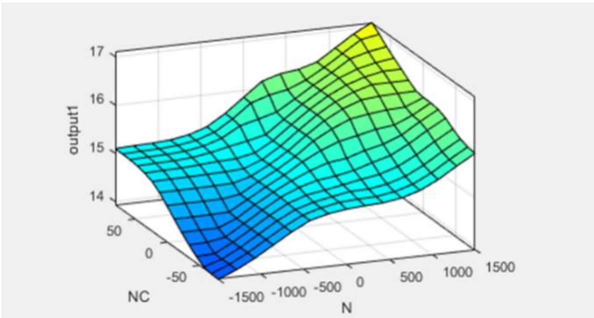

Figure 6 : Fuzzy rule map of input and output

Based on the PID algorithm, n and *nc* are used as input, and parameter adjustment is performed by querying the fuzzy rule table for fuzzy reasoning [6]. In the above map, the overall relationship between output and input can be observed. As shown in the Figure, the area shown is within the range of the set rule, and the surface is not abrupt and relatively smooth. Therefore, the design of the above fuzzy controller is reasonable.

4. Simulation experiment of fuzzy coordinated control system

4.1. Fuzzy Control Simulation Model Establishment

The simulation model of the fuzzy control is built in Matlab/Simulink. Among the built models, there are Fuzzy Logic Controller1, Sum, Mux, Gain, Scope, Constant, Signal Generator, Dirivative and other modules [7]. The Simulink model built is shown in figure 7.

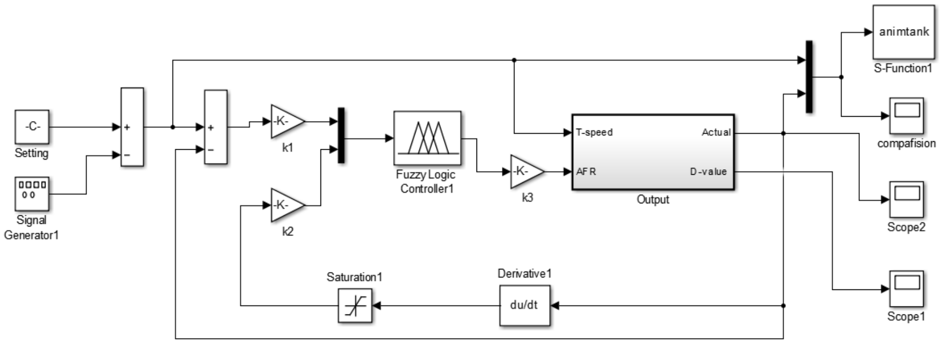

Figure 7: Simulation model of fuzzy coordinated control

4.2. Simulation and Analysis

The simulation of the control system refers to observing the changes before and after its output based on the input signal to the system, so as to analyze and understand the various characteristics of the system [8]. When simulating the fuzzy control system established in this paper, the square wave is selected as the input signal, and the changes of the upper and lower edges of the square wave are used to simulate the sudden change process of the input speed to detect the following performance of the system. That is, the step target speed input signal is simulated with a square wave signal, and the system follows it. If the system can better follow the change of the square wave, any change in the input speed can show good adaptability. The simulation results obtained are shown in figure 8.

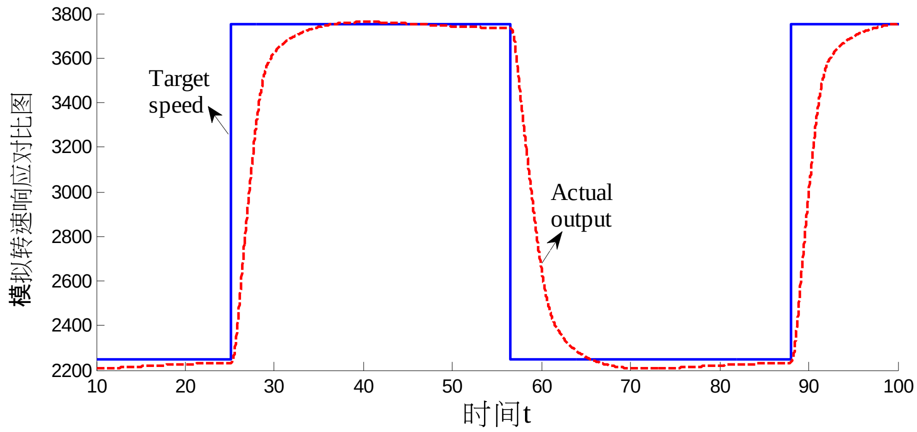

Figure 8: Tracking diagram of simulation results

It can be seen from the simulation chart that the simulated actual speed output by the simulation system can better follow the change of the set target speed, it can be explained that the simulation system can relatively effectively reduce the speed difference during the shift process and improve the response time, Therefore, the shift quality of the motor speed is improved.

5. Conclusion

This paper mainly introduces the application of fuzzy control algorithm in the coordinated control system of engine speed. Based on the principle of coordinated control between the engine control unit NU and the automatic transmission control unit TCU, a fuzzy control algorithm is used to achieve precise control of the engine speed in real time approaching the target speed value required by the transmission. The system is applied to the control of the engine's movement when the vehicle shifts. It can adjust the control parameters as the output parameters of the controlled object change, and realize self-tuning to adapt to various environments and conditions. The simulation results show that the system can relatively effectively reduce the speed difference in the shift process, so as to achieve the purpose of improving the shift quality.

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