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Idle Speed Control of Gasoline Engine Based on Fuzzy Neural Network

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Abstract: Fuzzy neural network is an intelligent method based on state feedback. In the process of learning and recognition, it has a very high fault tolerance rate and can help people quickly and accurately find the information they need. The engine idle speed and fuel combustion process are measured by using the fuzzy neural network control method. Therefore, in order to improve the idle speed control ability of gasoline engine, this paper studies the application of fuzzy neural network in its control system. This paper mainly uses the experimental method to compare and analyze the fuel economy based on multi-mode through the variables of vehicle idle parking in different periods. The experimental results show that the fuel economy of the start stop system in peak hours is increased by 20.38% on average. The idle start stop control strategy based on multi-mode information can effectively improve the fuel economy of the start stop system.

1. Introduction

With the continuous development of the automobile industry and higher and higher technology, the requirements for engines are more stringent. At present, traditional PID control is mostly used. Due to its limitations and hysteresis characteristics in the internal structure of the human body, it is difficult to avoid some problems. Fuzzy neural network model is to transform a complex process into a parameter control system by studying the state, and then realizing the dynamic response under the regulation of the system. This method can effectively solve the problems in traditional control theory.

There are many theoretical achievements based on the research of fuzzy neural network and the research of gasoline engine idle speed control method. For example, some scholars said that in view of the specific situation of traffic congestion and low road level in China, the idle speed control of the engine has become the main part of the control [1-2]. Some scholars have also proposed the method of using RBF neural network to control the idle speed of gasoline engine [3-4]. In addition, some scholars put forward a fuzzy radial basis function (RBF) neural network control scheme

formed by fuzzy FCM model according to the weight according to the idle speed control requirements of the automobile engine [5-6]. From these studies, we can see that the idle speed control of gasoline engines requires the use of existing scientific and technological forces to improve the control ability. So it is necessary to combine the research of fuzzy neural network in this paper.

This paper first studies the idle start stop system, and discusses its technology and application. Secondly, the composition of idle speed control system of automobile engine is analyzed. Then the fuzzy neural network control and its process are described in detail. Finally, through the simulation experiment, the data are calculated and sorted out, and relevant conclusions are drawn.

2. Idle Speed Control of Gasoline Engine Based on Fuzzy Neural Network

2.1. Idle Start Stop System

Idle speed start stop technology can automatically stop the engine at idle speed, quickly complete starting when power is needed, and restore the vehicle running state. The whole control process is automatically completed by the system, and will not interfere with the driver's driving habits. In view of the prevailing congestion situation in major cities, it shows a huge potential for oil saving and emission reduction. Idle start stop technology can be applied to both manual transmission vehicles and automatic transmission vehicles [7-8].

In the case of traffic congestion, the idle start stop function is enabled. When a traffic accident occurs at a red light intersection or in front of it, the manual transmission vehicle control center equipped with the idle start stop system needs to stop temporarily. The manual transmission vehicle control center receives the driver's operating instructions according to each sensor, analyzes and judges the driver's driving intention, and quickly stops or starts the control. If the driver has the intention to stop the vehicle and the vehicle status meets the idle shutdown conditions, the system will control the engine to stop. When the road is ready for traffic and the driver has the intention to start, the system controls the starter to quickly start the engine and restore the vehicle running state [9-10].

Compared with the manual transmission model, the automatic transmission model has a simple operation process, but it is difficult for the whole system to identify the driver's operation intention. It needs to be identified by the vehicle speed, accelerator pedal status and other signals. When the vehicle is running on a congested road, it needs to stop temporarily when encountering a red light intersection or a traffic accident ahead. Under the condition that the vehicle status meets the idle shutdown condition, the engine will be automatically controlled to cut off fuel. When the signal light turns green, it is necessary to start the vehicle. The driver releases the brake pedal and steps down the accelerator pedal at the same time. When the vehicle status meets the idle starting conditions, the system will automatically control the starter and quickly start the engine to restore the vehicle to running status [11-12].

The direct start stop technology of auxiliary starting motor mainly includes intelligent start stop technology and integrated generator technology. The intelligent start stop technology replaces the traditional starter motor with an enhanced starter motor and the battery with a new AGM battery to meet the working environment of frequent start stop and achieve the requirements of long life and high durability. The idle start stop system using integrated generator technology is mainly BSG technology. The engine transmits power with BSG motor through belt, and the original starter structure is saved in the system. When the car stops temporarily at a red light, the system will stop fuel injection by controlling the engine fuel injection device to complete the engine shutdown.

When the traffic conditions are met, the system controls the BSG motor to drive the engine to finish starting. The original starter is saved in the system to prevent difficulty in starting the engine at low temperature. Normally, the BSG start stop system has the function of braking energy recovery at the same time. Under this working mode, the BSG motor operates in the generator mode and charges the battery through the inverter, so it can achieve better energy conservation and emission reduction effects. In cylinder direct injection instantaneous reversal technology uses the cylinder direct injection engine to replace the starter. By developing the corresponding control logic to accurately control the fuel injection and ignition of the engine, the start stop control of the engine can be achieved. Therefore, the idle start stop system needs to accurately control the piston position, accurately inject fuel for ignition, and ensure high gas sealing performance of each cylinder when the engine is stopped [13-14].

2.2. Composition of Automobile Engine Idle Speed Control System

The electronic control system of automobile engine mainly includes the following subsystems, which are composed of gas supply, fuel supply, ignition and electronic control system. The main task of the air supply system is to measure and control the amount of air required by the engine during gasoline combustion. The air supply system is mainly composed of throttle body, air filter, air valve, air pressure sensor, regulator box and other components. It is the work of the fuel supply system to inject atomized gasoline into each cylinder of the engine and mix it with air to form a combustible mixture. The fuel supply system is composed of pressure regulator components, gasoline pipe components, gasoline pump components, fuel injectors and other components. The electronic control unit feeds back the current working state to the electronic control unit in the form of electrical signal [15-16].

Air intake, fuel injection and ignition control are all control variables of automobile engine idle speed control. The main content of fuel injection control is to control the fuel injection quantity of the fuel control device so that the fuel and air can be mixed in a certain proportion to form a combustible mixture. In the engine, the ignition control system is responsible for igniting the fuel mixture in the cylinder, and the ignition time will directly affect the combustion of the fuel mixture. From the perspective of engine intake control structure, the intake control of the engine can be divided into direct throttle control strategy and bypass air control strategy [17-18].

2.3. Fuzzy Neural Network Control

Neural networks can acquire new knowledge through learning, which is the reason why they are intelligent. Therefore, how to determine the learning rules of neural networks is very important for building neural networks. The basic principle of neural network control is as follows:

Let the input v of the controlled object and the system output m satisfy the following nonlinear functional relationship:

$$\mathrm{m} = f(v) \quad (1)$$

Determine the optimal control input v, so that the actual output of the system is m_{α}. In this system, let the function relationship be:

$$\mathrm{v} = \mathrm{g}(m_{\alpha}) \quad (2)$$

Because the controlled object to be controlled by neural network is generally complex and uncertain, it is difficult to establish nonlinear functions $\mathrm{f}(\cdot)$.

The core of fuzzy reasoning is knowledge base, which is composed of IF-THEN rules. The general structure of fuzzy reasoning system includes six main parts: input, fuzzification, knowledge base, reasoning unit, defuzzification and output. The control rules and internal parameters of fuzzy control can be dynamically or automatically adjusted in the process of self-learning to optimize the control effect of the system. The core of PID controller design in industrial application is to determine the three parameters of PID. In the work, it can greatly optimize the control system according to the dynamic operation of the system.

3. Idle Speed Control Simulation Experiment

3.1. Linearized Model Simulation

Linearization process of the model is to select a reference working point when the engine is idling. Since this working point is a nonlinear model, the original model is compared with the linearized model to check whether the linearization is accurate. The simplified structure of the engine idle speed control system is shown in Figure 1:

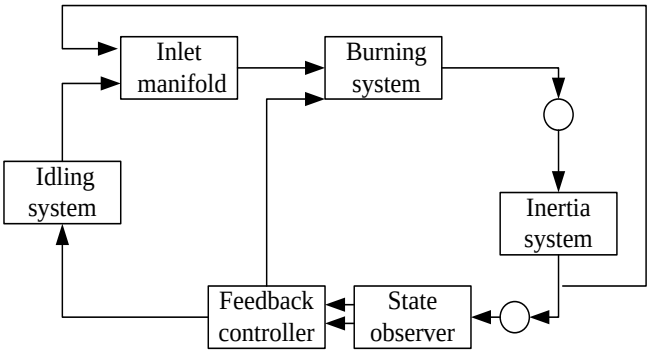

Figure 1. Engine idle control system

In order to obtain better verification effect, the verification strategy adopted in this simulation is as follows: First, let the original nonlinear model and the linearized model run under the reference working point conditions of open loop conditions, and then interfere with the two models at the same time. According to the results obtained, compare and analyze whether the two models have similarity.

Intake manifold, combustion system, inertial system, state observer, feedback controller, idle speed system

3.2. Specific Environment Settings for Simulation Experiment

The object of this simulation is an engine model with four cylinders and ignition by electric spark. During the simulation, the simulation is realized in Matlab software. The simulation environment is set as follows: ambient temperature 292K, ambient pressure 98 kPa, engine has been started and running for a period of time, and engine idle speed 805 r/m. During simulation, the control input is obtained by feedback, and the throttle opening can be obtained based on the relationship between intake air volume and throttle angle.

3.3. Idle Start Stop Control Strategy

Comprehensively consider the information of driving video images, short-term driving conditions, interval driving conditions and other modes, predict the length of idle parking time, determine whether the idle conditions are invalid idle, and control the engine start and stop. In the start stop control system based on multi-mode information, if the driving video image exists and the countdown recognition is recognized, it has the absolute right to determine the idle time prediction. Because the signal lamp countdown number can accurately determine the idle stop time when the vehicle starts and stops due to the signal lamp. When there is no countdown data or the countdown data can not be identified, the weight adaptive method based on the similarity of working conditions will be used to predict the idle shutdown time. In the experiment of this paper, the fuel economy of start stop system for gasoline engine idle speed prediction in different periods and the fuel economy of start stop system with multi-mode information are analyzed.

4. Fuel Economy Analysis

4.1. Fuel Economy Analysis of Start Stop System Based on Idle Speed Prediction

The fuel consumption of idle start stop system is analyzed under actual urban road driving conditions. The fuel economy of the traditional start stop system and the start stop system based on idle condition prediction in peak and flat periods is shown in Table 1. TS in the table represents the number of traditional invalid idle stops, IS represents the number of invalid idle stops with traffic control signals, TE represents the traditional fuel consumption, IE represents the fuel consumption of the start stop system with traffic control signals, P represents the proportion of reducing invalid idle, and IP represents the proportion of improving the fuel economy of the improved start stop system.

Table 1. Analysis of fuel economy in peak period

	TS	IS	TE	IE	P(%)	IP(%)
2.68	20	3	144.77	120.13	85	17.01
2.74	19	1	159.25	125.44	95.73	21.22
2.27	16	1	126.25	97.13	93.75	23.04
2.53	18	2	157.76	125.76	88.99	20.25

As shown in Figure 2, the fuel economy of the proposed start stop system based on idle condition prediction has been improved in both peak and off peak periods, and the improvement effect is better and more obvious in peak periods. The improvement of the accuracy of idle condition prediction will help to further improve the fuel economy of the start stop system based on idle condition prediction.

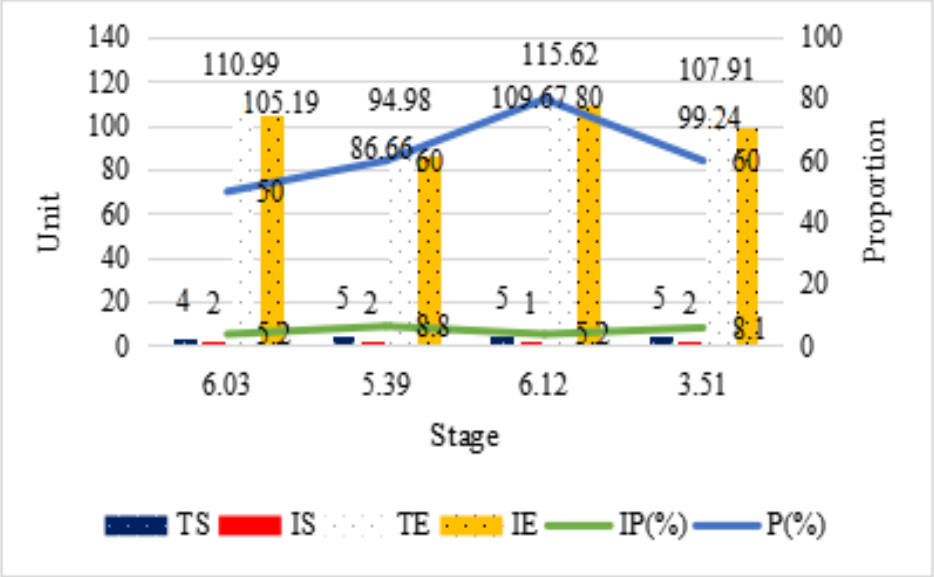

Figure 2. Fuel economy analysis of start-off system in flat peak period

4.2 Fuel Economy Analysis of Start Stop System Based on Multi-Mode Information

The fuel economy of the traditional start stop system is compared with that of the start stop system based on multi-mode information in peak hours, as shown in Table 2. The proposed idle start stop control based on multi-mode information has better fuel economy than the traditional start stop system, and can effectively reduce invalid idle start stop in both peak and off peak periods. During peak hours, the fuel economy has been improved by more than 20%, which can reduce more than 80% of invalid idle start and stop.

Table 2. Fuel economy analysis of start-stop system based on multi-mode information in peak period

	TS	IS	TE	IE	P(%)	IP(%)
2.68	20	2	144.77	115.04	90	20.54
2.74	19	1	159.25	119.73	95.73	24.81
2.27	16	2	126.25	95.35	87.5	24.48
2.53	18	1	157.76	121.81	95.56	22.79

As shown in Figure 3, the improvement effect of fuel economy during the peak period is affected by the periodic changes of the signal light, showing a certain volatility. The fuel economy during the peak period has increased by 6.41%~11.8%, which can reduce 60%~80% of the invalid idle start and stop. By adding the judgment of signal light information, the proposed start stop system based on multi-mode information has better improvement effect than single mode information.

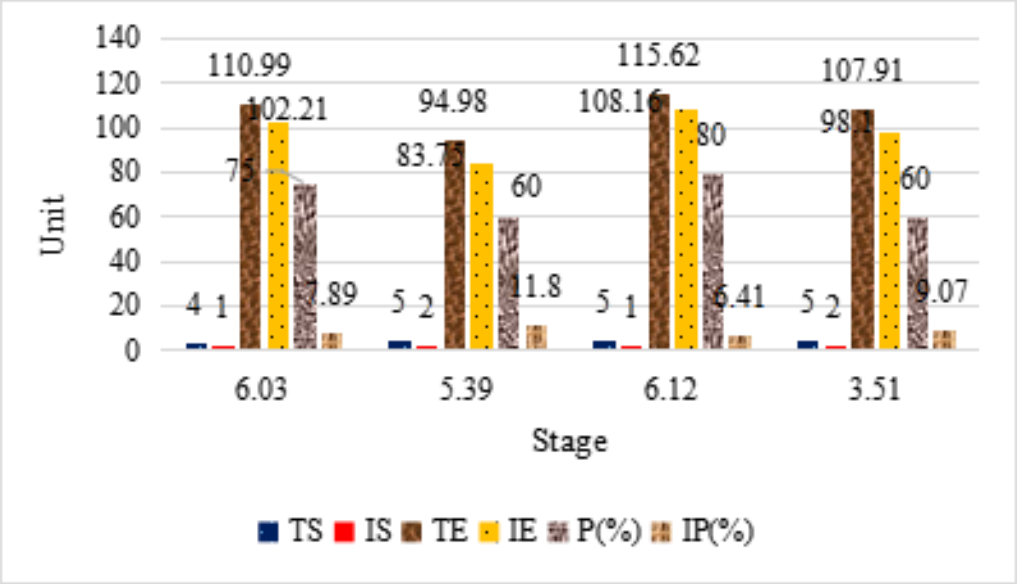

Figure 3. Fuel Economy Analysis of Start-Stop System Based on Multi-mode Information in Flat Peak Period

5. Conclusion

Fuzzy neural network (FNN) is a nonlinear topological structure modeled on the structure of biological brain. Fuzzy neural network has the ability of multi input control system, and can fuse many types of systems together. When selecting a control strategy, you can use multiple output variables. In this paper, an improved fuzzy pattern recognition method is proposed, which is suitable for automobile idle speed regulation function. The performance and reliability of automobile engine idle speed control is an important factor that determines its wide application in modern society. It is closely related to engine power, fuel economy and emissions. So this paper thinks that the fuzzy neural network can react accurately and timely in the starting and stopping of gasoline engine at idle speed.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Abdollah Amirkhani, Masoud Shirzadeh, Mahdi Molaie:An Indirect Type-2 Fuzzy Neural

Network Optimized by the Grasshopper Algorithm for Vehicle ABS Controller. IEEE Access 10: 58736-58751 (2021).

[2] David Chunhu Li, Michael Yu-Ching Lin, Li-Der Chou: Macroscopic Big Data Analysis and Prediction of Driving Behavior With an Adaptive Fuzzy Recurrent Neural Network on the Internet of Vehicles. IEEE Access 10: 47881-47895 (2021).

[3] Sunisa Luemsai, Thongchai Botmart: Improved Extended Dissipativity Results for T-S Fuzzy Generalized Neural Networks With Mixed Interval Time-Varying Delays. IEEE Access 10: 2480-2496 (2021). https://doi.org/10.1109/ACCESS.2021.3139633

[4] Ankit Kumar, Vijay K. Yadav, Subir Das, Rajeev: Global Exponential Stability of Takagi-Sugeno Fuzzy Cohen-Grossberg Neural Network With Time-Varying Delays. IEEE Control. Syst. Lett. 6: 325-330 (2021). https://doi.org/10.1109/LCSYS.2021.3073962

[5] Sarthika Dutt, Neelu Jyothi Ahuja, Manoj Kumar: An Intelligent Tutoring System Architecture Based on Fuzzy Neural Network (FNN) for Special Education of Learning Disabled Learners. Educ. Inf. Technol. 27(2): 2613-2633 (2021). https://doi.org/10.1007/s10639-021-10713-x

[6] P. Sathish, N. M. Elango: Gaussian Hybrid Fuzzy Clustering and Radial Basis Neural Network for Automatic Brain Tumor Classification in MRI Images. Evol. Intell. 15(2): 1359-1377 (2021). https://doi.org/10.1007/s12065-020-00433-5

[7] Paul T. Sheeba, Sankaranarayanan Murugan: Fuzzy Dragon Deep Belief Neural Network for Activity Recognition Using Hierarchical Skeleton Features. Evol. Intell. 15(2): 907-924 (2021). https://doi.org/10.1007/s12065-019-00245-2

[8] Iman Shafieenejad, Elham Dehghan Rouzi, Jamshid Sardari, Mohammad Siami Araghi, Amirhosein Esmaeili, Shervin Zahedi: Fuzzy Logic, Neural-Fuzzy Network and Honey Bees Algorithm to Develop the Swarm Motion of Aerial Robots. Evol. Syst. 13(2): 319-330 (2021). https://doi.org/10.1007/s12530-021-09391-4

[9] Nebojsa Bacanin, Timea Bezdan, Fadi M. Al-Turjman, Tarik A. Rashid: Artificial Flora Optimization Algorithm with Genetically Guided Operators for Feature Selection and Neural Network Training. Int. J. Fuzzy Syst. 24(5): 2538-2559 (2021). https://doi.org/10.1007/s40815-021-01191-x

[10] Arijit Sarkar, Rekha Guchhait, Biswajit Sarkar: Application of the Artificial Neural Network with Multithreading Within an Inventory Model Under Uncertainty and Inflation. Int. J. Fuzzy Syst. 24(5): 2318-2332 (2021).

[11] Dima Taha, Ahmad AlZu'bi, Abdelrahman Abuarqoub, Mohammad Hammoudeh, Mohamed Elhoseny: Automated Colorectal Polyp Classification Using Deep Neural Networks with Colonoscopy Images. Int. J. Fuzzy Syst. 24(5): 2525-2537 (2021). https://doi.org/10.1007/s40815-021-01182-y

[12] Jay Kant Pratap Singh Yadav, Zainul Abdin Jaffery, Laxman Singh: Optimization of Hopfield Neural Network for Improved Pattern Recall and Storage Using Lyapunov Energy Function and Hamming Distance: MC-HNN. Int. J. Fuzzy Syst. Appl. 11(2): 1-25 (2021). https://doi.org/10.4018/IJFSA.296592

[13] Arobinda Dash, Utkal Ranjan Muduli, Surya Prakash, Khalifa Al Hosani, Sandhya Rani Gongada, Ranjan Kumar Behera: Modified Proportionate Affine Projection Algorithm Based Adaptive DSTATCOM Control With Increased Convergence Speed. IEEE Access 10: 43081-43092 (2021).

[14] Limin Hou, Jianhua Ma, Wei Wang: Sliding Mode Predictive Current Control of Permanent Magnet Synchronous Motor With Cascaded Variable Rate Sliding Mode Speed Controller. IEEE Access 10: 33992-34002 (2021).

[15] Frederic Jacquelin, Jungyun Bae, Bo Chen, Darrell Robinette, Pruthwiraj Santhosh, Joshua Orlando, Daniel Knopp: Connected and Autonomous Vehicle Cohort Speed Control Optimization via Neuroevolution. IEEE Access 10: 97794-97801 (2021).

[16] Abdul Khalique Junejo, Wei Xu, Ashfaque Ahmed Hashmani, Fayez F. M. El-Sousy, Habib Ur Rahman Habib, Yirong Tang, Muhammad Shahab, Muhammad Usman Keerio, Moustafa Magdi Ismail: Novel Fast Terminal Reaching Law Based Composite Speed Control of PMSM Drive System. IEEE Access 10: 82202-82213 (2021).

[17] Sethembiso Nonjabulo Langazane, Akshay Kumar Saha: Effects of Particle Swarm Optimization and Genetic Algorithm Control Parameters on Overcurrent Relay Selectivity and Speed. IEEE Access 10: 4550-4567 (2021).

[18] Nga Thi-Thuy Vu, Ha Duc Nguyen, Anh Tuan Nguyen: Reinforcement Learning-Based Adaptive Optimal Fuzzy MPPT Control for Variable Speed Wind Turbine. IEEE Access 10: 95771-95780 (2021).