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A Gear Decision of Hybrid Electric Truck Based on Neural Network

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Abstract: The basic shifting law of hybrid electric vehicles is formulated in a static environment and cannot adapt to the complex and changeable vehicle operating environment. Therefore, its gear decision must comprehensively consider the driver's driving intention, road conditions and vehicle operation parameters, etc. It can effectively solve the unnecessary shifting phenomenon and the cyclic shifting problem of the vehicle under complex road surface, and can improve the dynamic performance and economy of the vehicle. The purpose of this paper is to analyze the gear position decision of hybrid electric truck based on neural network. In the experiment, the main parameters of the hybrid truck are determined, and the gear prediction algorithm is used. Experiments are carried out in two aspects: the solution of the optimal dynamic shift curve of the hybrid truck and the example simulation and analysis of gear decision based on neural network.

1. Introduction

At present, there are many classification algorithms, including neural networks, support vector machines, decision trees, etc., and neural networks are widely used because of the following advantages. The neural network is used to control the automatic shifting of hybrid electric vehicles, mainly to make the shifting laws stored in the automatic transmission control system include the driver's rich experience and other expert knowledge, so that more factors and factors can be considered when shifting decisions. indicators, so that the selected gear is similar to the human manipulation process to the greatest extent [1]. The learning ability of this kind of controller can adopt the learning control method for the unclear object, so that the deviation between the output result of the object and the given target value can meet the specified requirements. Using the neural network to establish a gear decision model, it is not necessary to analyze the interior of the automatic transmission or the shifting process. It only needs to use the measured vehicle state parameters and gear values during the driving process as input and output data. After training, a neural network model whose input and output characteristics are equivalent to the actual shifting process can be obtained, which has broad application prospects for the study of complex high-order nonlinear automobile shifting decisions with multiple disturbance sources.

With the continuous progress of the automobile industry, the sales of automobiles around the world are increasing day by day, which has also brought about the increasing shortage of energy and the continuous deterioration of the environment.Hayslett S studied the automobile as a typical example of a technological process. Vehicle energy sources (ie gasoline, electric or even hybrid) were first discussed a century ago when more than 30% of vehicles were running on electricity. Later, the pioneers praised the electric cars. The internal combustion engine has dominated the debate for a long time, creating a way to mass-produce more affordable gasoline cars. Because current combustion engines alone cannot meet the stringent regulations around the world, the industry is moving quickly to implement more energy technology options. Of these, the most promising is the 48V reduction system, as it offers an effective solution that immediately reduces emissions [2]. In this paper, Goerges D proposes an online switching and power distribution strategy for parallel electric vehicles to increase fuel efficiency. Motion control is implemented by a neural network. The training of the neural network is done using the data obtained from the power planning for different driving cycles. The simulation results show that the conversion patterns and fuel consumption obtained from the neural network and dynamic programming are similar, emphasizing the optimal conversion control of the hybrid electric vehicle based on the neural network. Furthermore, power ratio control is achieved through action-dependent heuristic dynamic programming. Heuristic dynamic programming does not require a system model and allows learning. Therefore, power distribution control is robust to uncertainties and disturbances, and adapts to various driving conditions and driving behaviors. The combination of variable control based on neural network and power planning based on power distribution control results in an automatic power control process with real-time applications possible [3].Hybrid electric vehicles take into account the advantages of traditional vehicles and pure electric vehicles, and can achieve the purpose of energy saving and emission reduction. It is a research hotspot in the field of new energy vehicles today.

This paper studies the improvement status of hybrid electric vehicles at home and abroad; the research on gear decision of hybrid electric truck, including its improvement history and the analysis of gear decision system; and the application of neural network in gear decision. In the experiment, the main parameters of the hybrid truck are determined, and the gear prediction algorithm is used. Experiments are carried out in two aspects: the solution of the optimal dynamic shift curve of the hybrid truck and the example simulation and analysis of gear decision based on neural network.

2. Research on the Decision Analysis of Gear Decision of Hybrid Electric Truck Based on Neural Network

2.1. Improvement Status of Hybrid Electric Vehicles at Home and Abroad

In the early days of the improvement of the hybrid vehicle, the engineer's idea was simply because it was a "gasoline hybrid powertrain", which could charge the electric motor through the gasoline engine, and such a simple idea With the rapid improvement of the automotive industry, the hybrid vehicle The related technology of the electric vehicle has also begun to jump by leaps and bounds, and various optimization control strategies for this system have been proposed to make the hybrid electric vehicle perform better than the traditional vehicle in all aspects, and mass production has begun. The current configuration of hybrid electric vehicles is from Structurally, it is mainly divided into 3 types; series type, parallel type and hybrid type combining the characteristics between the two [4, 5].

In recent years, the competition in the automobile industry has been fierce. Manufacturers in various countries have launched their own hybrid models. In this regard, China is no exception. The government has made a lot of subsidies for new energy vehicles, especially for hybrid buses this year. subsidy. Foreign countries have increased subsidies for new energy sources. The most representative of them is the Toyota Prius, which has a deep technical accumulation in the research and improvement of hybrid power systems. It provides a great solution for solving the fuel consumption problem of traditional cars without changing the number of gas stations and the driving habits of users. Good solution. The superior fuel consumption rate of HEVs also fully verifies the feasibility of adopting the HEV one solution to solve the problem of fuel consumption. The technology research and improvement of hybrid vehicles in China is relatively backward compared with foreign countries. However, with the gradual exhaustion of chemical energy such as coal and petroleum, the government gradually realizes the necessity of developing new energy. As a result, the government department has set up research and improvement topics for new energy vehicles; the 863 plan has increased subsidies for the new energy field [6, 7]. During the Eleventh Five-Year Plan period, the R&D process of its industrialization has been continuously accelerated. At the same time, domestic automakers have also stepped up their research and improvement efforts on new energy vehicles.

2.2. Research on Gear Decision of Hybrid Electric Truck

(1) Improvement history

Gear decision technology has its own improvement track since its initial research and improvement. With the continuous improvement and innovation of technology, related gear decision technology has also developed rapidly [8, 9], which can be divided into four stages, as shown in Table 1:

Table 1. Improvement process of gear shift decision strategy

Stage	Time quantum	Feature
Preliminary stage	Before 1938	The simplest, according to the engine speed or speed of a single parameter shift
Fluid control stage	The 1938s-early 1970s	The hydraulic oil path is used to indicate the shift decision logic, as the two-parameter shift rule
Electronic control stage	70s-late 80s	Through the large-scale digital integrated circuit decision gear, with the two-parameter shift rules
Intelligent stage	Early'90s--present	Intelligent control theory and technology are widely used to realize intelligent and adaptive gear decision-making on the basis of human and vehicle environment identification

(2) Analysis of gear decision system

His gear decision of the hybrid truck studied in this paper is based on good road conditions and does not consider the influence of special environment and special driver's intention. Under the intention, the vehicle is prone to unnecessary shifting phenomena [10, 11]. The following methods are usually used to avoid this phenomenon:

1. Increase the downshift delay. Due to the inertia of the vehicle, the opening of the fuel port and the speed of the vehicle do not change correspondingly. By increasing the downshift delay, the vehicle speed can correspond to the change of the opening of the fuel port as much as possible. The corrections have the effect of degrading performance.

2. Increase the hold floor on the selector. For example, when the driver encounters a turning condition, at this time, in order to prevent the vehicle from downshifting and then upshifting, he can

switch to the hold gear. In this way, when the vehicle enters the curve, the gear is maintained to prevent downshifting, and the phenomenon of re-upshifting when the vehicle exits the curve can be avoided [12].

3. Add various function keys and switches. When the vehicle encounters different road conditions, it selects different modes to operate, such as snow mode, so as to realize the corresponding gear decision.

The above methods can reduce the unnecessary shifting of the vehicle in some aspects, but they are too dependent on the driver's operation, which is not intelligent, and is relatively complicated for those who are not familiar with driving alone. Since the vehicle is in a person-vehicle-road closed-loop system, the influence of different driving intentions and road environment on gear decision must be considered, and finally a comprehensive intelligent gear decision is made [13-14].

2.3. The Application of Neural Network in Gear Decision

People's higher pursuit of vehicle performance makes it difficult to determine the optimal shift point that adapts to the driving intention and the needs of the driving environment under special operating conditions [15, 16]. Since the optimal gear is the result of the superposition of factors such as the driver's intention, road conditions, engine, and motor operating conditions, these factors are strongly correlated within a certain time domain. The problem is a problem of solving the nonlinear mapping classification between the car state parameters and the optimal gear value.

Neural network is a multi-layer feedforward neural network trained according to error back propagation, which can learn and store a large number of nonlinear mapping relationships between input and output. It is the most widely used type of neural network model at present. Based on this, this paper uses neural network to design an adaptive gear decision model [17, 18]. Based on the learning of the driving sample data of the driver's experience and driving conditions, and the training results are stored at the same time, the neural network controller can accurately determine the most suitable gear through association and memory according to various states of the vehicle., to adapt to people-vehicle-road needs [19].

3. Investigation and Research on Gear Decision of Hybrid Electric Truck Based on Neural Network

3.1. Main Parameters of Hybrid Electric Truck

The main parameters of the hybrid truck are shown in Table 2:

Table 2. Main parameters of vehicle

Parameter name / unit	Parameter value	Parameter name / unit	Parameter value
Complete vehicle mass	1413	Level 1 transmission ratio	3.652
Windward area	2.5	Level 2 transmission ratio	2.51
Drag coefficient	0.41	Level 3 transmission ratio	1.352
Air density	1.324	Level 4 transmission ratio	1.210
Tire radius	0.354	Level 5 transmission ratio	0.95
coefficient of rolling resistance	0.024	Level 6 transmission ratio	0.91
Transmission total efficiency	0.99	Cell voltage	380
Gravity Acceleration	10.01	Battery charge and discharge internal resistance	0.43
Main deceleration ratio	6.2	Battery Cullen Efficiency	0.9

3.2. Gear Prediction Algorithm

The approximation accuracy of the network model can be evaluated by checking the absolute error between the predicted gear and the test sample gear and calculating the mean absolute error. In the formula, R is the absolute error; P is the average absolute error; N is the number of samples; Y is the sample gear; $\hat{Y}$ is the BP neural network prediction gear, and its expression is:

$$R = \left|Y - \hat{Y}\right| \tag{1}$$

$$P = \frac{1}{N}\sum_{1}^{N}\left|Y - \hat{Y}\right| \tag{2}$$

4. Analysis and Research on Gear Decision of Hybrid Electric Truck Based on Neural Network

4.1. Solution of Optimal Dynamic Shift Curve for Hybrid Electric Truck

The optimal dynamic shift curve solution only needs to pay attention to whether the required driving torque of the truck can be provided by the hybrid system, that is, whether the combined torque meets the required torque, and the power source distribution and vehicle working mode have no effect on the dynamic shift curve solution. The fuel economy of the whole vehicle will be affected by the working point position of the engine and the motor, and the economical shift curve needs to be solved by mode. Since hybrid trucks generally work at just starting or at low speed, the gear position can be kept in the first gear at this time, and there is no need to shift mode solves the shift curve. The optimal dynamic shifting law is solved, and the obtained curve is shown in Table 3 and Figure 1:

Table 3. Hybrid van-up gear data

Gear	Throttle opening	Speed of a motor vehicle
1 to 2 block	58	20
2 to 3 block	35	30
3 to 4 block	42	40
5 to 6 block	49	50

After the upshift curve of the hybrid truck is obtained, the downshift curve is obtained by selecting a reasonable downshift speed difference according to the equal-delay shift delay criterion. As a rule of thumb, the downshift speed is generally 20/kmh lower than the corresponding upshift speed. The downshift speed difference is 10/kmh. The introduction of the downshift speed difference can improve the unstable shifting phenomenon when the vehicle is driving at low speed, which is beneficial to the improvement of driving comfort.

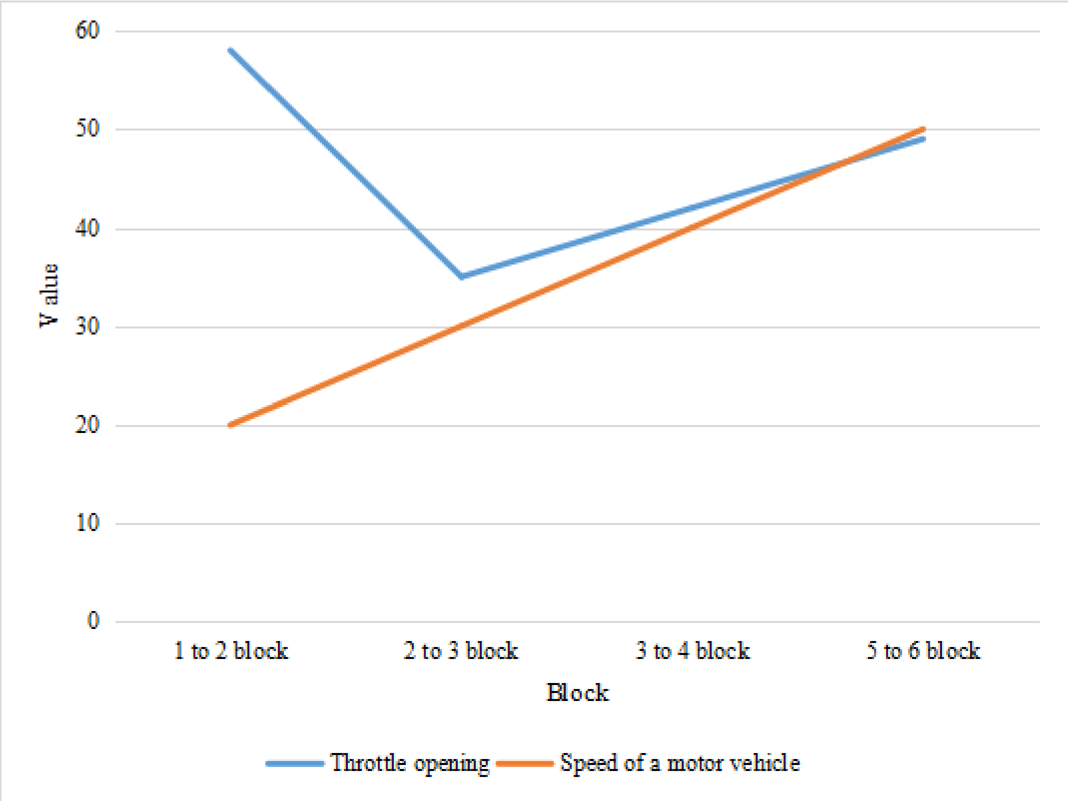

Figure 1. The shift schedule of hybrid electric vehicle

4.2. Simulation and Analysis of an Example of Gear Decision-Making Based on Neural Network

In order to verify the effectiveness of the proposed neural network model in gear decision-making under special working conditions, the sample data containing driving intention and driving environment information will be learned under the condition of rapid acceleration, and an offline model will be established. The simulation verifies the accuracy of the neural network model established for each working condition in the prediction of the gear position of the hybrid truck. In order to determine the optimal value of the number of hidden layer neurons suitable for the neural network under the condition of rapid acceleration, the number of hidden layer nodes in this experiment is gradually increased according to the initial value of 3, until a satisfactory training effect is achieved. When the number of neurons in the hidden layer is 3~7, the mean square error and the number of training steps obtained by the three-layer BP network training are shown in Table 4 and Figure 2:

Table 4. The relationship between the number of hidden layer and the training error of BP network

Number of neurons in the hidden layer	Training error	Training steps
3	0.0018213	75
4	0.0022542	145
5	0.0019524	455
6	0.0025418	225
7	0.0041578	198

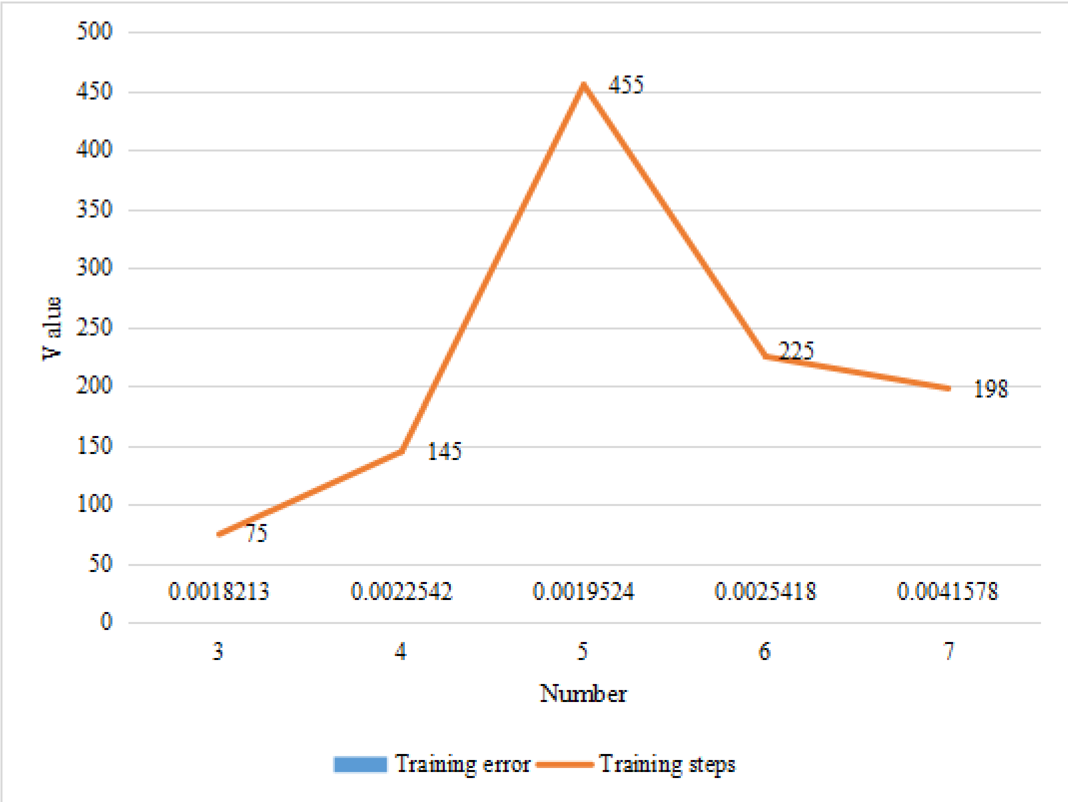

Figure 2. Comparing the training error with the step number data

The main purpose is to carry out the simulation analysis of gear prediction based on the neural network model established in the rapid acceleration condition. It can be seen from the simulation results that the neural network model designed in this paper can predict the gear position of the car according to the driving state of the car by learning the driving samples containing the driver and environmental information, which effectively solves the problem that it is difficult to determine the adaptation according to the needs of the car. The problem of driving intention and the optimal shift point of the driving environment; and establishing different network structures based on different working conditions, effectively reduces the learning and training time, and improves the prediction accuracy of the neural network.

5. Conclusion

Hybrid electric vehicle has become a research hotspot of major automobile manufacturers, and it is also the best new energy vehicle in current industrialization. A hybrid vehicle equipped with an automatic transmission system can automatically shift within a certain speed range according to road conditions, etc. At present, the automatic transmission technology of various automobile manufacturers has been matured and industrialized. The improvement of a new type of intelligent transmission system will be one of the improvement directions of the entire automobile industry. The gear decision system is one of the key parts of the automatic transmission system, and it is of great significance to conduct related research on it. Due to the limited research time of the paper and the high complexity of hybrid vehicles, the author believes that further research can be done from the following aspects: other driving styles and driving intentions in the human-vehicle-road system, as well as the smart driving environment Considering that when the vehicle is in a corner, there are emergency corners and general corners, and the corresponding gear decisions are different.

Moreover, the driving style of each driver is also different, and the driving style of different drivers can be identified.

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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.

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