Research on Control Strategy of Intelligent Vehicle Autonomous Learning Based on Neural Network Algorithm

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**Abstract.** With the development of the automobile industry and the intelligent automobile, people's demand for the comfort of the car is improved, so the comfort of the smart car needs to be reasonably controlled. In this paper, the intelligent control method based on neural network algorithm is used to control the influence parameters of damping force of shock absorber. Memory architecture is established to store memory, genetic algorithm is utilized to optimize and judge which endows the car with the ability of autonomous learning. The theoretical study shows that the judgment ability and accuracy of comfort adjustment can be improved effectively by the optimization of genetic algorithm combined with neural network.

**Introduction**

With the development of the global automobile industry, the demand for the automobile is increasing, and the requirement for operation stability and comfort of the vehicle suspension is also raising. The requirements for the operation stability and comfort of the vehicle suspension are also applicable to the smart car. IEEE control systems association believes that intelligent control must have a simulation capacity of human learning and adaptive \[1\]. Neural network and genetic algorithm are widely used in the intelligent control system. American neural network scientist Hecht Nielson gives a definition to neural network as following: A neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes. The neural network has unique abilities in the intelligent control of the parameters, structure and environment of self-adaptation, self-organization, self-learning. Genetic algorithm is a kind of non-deterministic natural stochastic optimization tool. As a kind of global optimization method with high efficiency, parallel and random search abilities, it is a powerful tool to solve some problems. It can be mixed with other technologies for intelligent control of the parameters, structure or the environment of the optimal control. The combination of neural network and genetic algorithm can be a method of scientific search operation. According to the advantages of neural network, the global scholars have made deep researches on the neural network modeling technology of shock absorber. Sincebaugh et al. \[2\] study the neural network model of the nonlinear characteristics of the military vehicle hydraulic shock absorber by using non-parametric modeling. Chang and Roschke \[3\] use neural network to simulate the response of dampers, the non-parametric modeling is also used. Dong pan et al. \[4\] build the modeling of vibration damper based on neural network, and the built model is trained and tested. The results show that the vibration damper has a good simulation and prediction ability of damping force-velocity. With the increase of the number of learning, the accuracy of the model can be improved. Eski \[5\] designs a robust control system based on neural network for the control of vehicle suspension, establish 7 degree of freedom model of automobile and compared the suspension with the PID controller. The simulation results show that the neural network algorithm has good performance of anti-road disturbance. Guo, D et al. \[6\] propose an indirect adaptive control method for neural networks, both the system simulation and the suspension test show that the indirect
adaptive control of the neural network can enhance the control effect. N Al-Holou et al. [7] propose a robust intelligent nonlinear controller for active suspension systems based on a comprehensive and realistic nonlinear model, and a sliding mode neural network inference fuzzy logic controller is designed. The simulation results prove that controller exceeds existing conventional controllers in the aspects of body acceleration, suspension deflection, and tire deflection. Hui, W et al. [8] presents an adaptive control strategy based on neural network, which aims at the time variant and nonlinear complex system as semi active air suspension. The results of simulation analysis and bench test show that the vibration amplitude of the vehicle body can be reduced by about 30%. Chuanyin, T et al. [9] use a control strategy based on the combination of genetic algorithm and neural network to design a controller for vibration damper. The problem is that after the acceleration of the body and the suspension of the dynamic travel have been improved, the dynamic load of the wheel has deteriorated.

In this paper, an artificial intelligence learning method based on the combination of neural network and genetic algorithm is proposed. The influence parameters of damping force of shock absorber are changed on the basis of previous attempts; memory data is built by using neural networks, a few parameters memories are stored in the process of automobile test. The neural network and genetic algorithm are combined which provides a method for the instantaneous judgment of the comfort adjustment. Whether each instantaneous judgment is reasonable or not is judged. If it is reasonable, it can be deposited in the memory data which is treated as a new memory to provide a basis for the subsequent instantaneous judgment.

**Parameters Affecting the Comfort of the Car**

The comfort means that a comfortable riding environment and convenient operation conditions which should be provide by the car. Comfort should include ride comfort, air conditioning properties (temperature, humidity, etc.), interior noise, riding environment (active space, the width of door and channel, internal facilities, etc.) and the operating performance of the driver.

Automobile suspension is an elastic connection between the vehicle body and the wheels. The function of automobile suspension is to ease and restrain the vibration and attack caused by the uneven road surface which can ensure that the members and shipped goods are in good condition. By adjusting the damping force of the damper on the suspension, the frequency and vibration acceleration of car can be adjusted, then the comfort can be changed. Factors selected by this paper include: speed, road roughness, the angle between road surface and horizontal direction, sprung mass, etc.

Under different road conditions, speed, road roughness, the angle between road surface and horizontal direction and sprung mass are able to influence the adjustment of damping force made by shock absorber so that the comfort can be influenced. Comfort is represented by the frequency of body vibration (The frequency of the body's upper and lower movements when the body is used to walk should be designed to be the natural frequency of vehicle body vibration, its frequency is about 60 to 80 times per minute (1Hz to 1.6Hz)). In this paper, vehicle body vibration frequency of 1.3Hz is set as optimal comfort.

**The Establishment of a Memory Architecture**

Artificial neural network has a certain adaptive ability and autonomous learning ability. Neural network algorithm simulates the neurons which store the memory by distributing the memory information on the network layers. Information processing is mainly based on the cooperative processing between distributed layers. The study of artificial neural network mainly includes supervised learning and unsupervised learning: The former classifies and models in a given range; and the latter has a certain learning ability, it can discover potential rules of the external system and learn it.

The input layer of λ1 is assumed that it contains the number of σ1 of neurons (parameters) and the output layer of λ2 contains the number of σ2 of neurons, where the layer number of hidden layer is ρ,
The N-th hidden layer is expressed as \( \rho(N) \) and each neuron of this hidden layer is expressed as \( \rho(Na) \), a \((1,2\ldots n(N))\). The distribution of neurons of neural network layers is shown in Fig. 1. The measured influence parameters of damping force of shock absorber are imported into network layers, it means that the influence parameters of damping force of shock absorber are classified according to the properties of parameters firstly, the parameters which have the same properties are distributed into the same network layer, these parameters which own the same properties can be stored as neurons. The memory architecture can be built in the way stated above.

![Network layer diagram](image)

**Figure 1.** The distribution of neurons of neural network layers.

Each neuron has single output attribute in the direction of the input information. One neuron has a connection weight to a neuron of next network layer. For a neuron, its input can be expressed as:

\[
\sum_{p=0}^{m-1} \omega_p \mu_p.
\]  

(1)

Its output can be expressed as:

\[
y = f(\sum_{p=0}^{m-1} \omega_p \mu_p - \theta).
\]  

(2)

\(w_p\) is the connection weight between the p-th neuron of the i-th network layer and the target neuron, \(\mu_p\) is the input of the p-th neuron of the i-th network layer of the target neuron, \(\theta\) is the internal threshold and \(f\) function is the activation function.

The output can be expressed as following:

\[
\begin{cases}
   y = 1, \text{if } \sum_{p=0}^{m-1} \omega_p \mu_p \geq \theta \\
   y = -1, \text{if } \sum_{p=0}^{m-1} \omega_p \mu_p < \theta
\end{cases}
\]  

(3)

The processing procedure is shown in Fig. 2:

![Processing procedure diagram](image)

**Figure 2.** The processing procedure of input of the target neuron.

According to the input and output models stated above, the method of memory store can be obtained which also means that the connection situation among neurons can be expressed with models. Assuming that one of the parameters of the upper network layer are connected with some network parameters of the next layer, the output signals among them are expressed as 1; otherwise,
the signals are expressed as -1. Different types of influence parameters of damping force of shock absorber can be stored in different network layers.

The Application of Genetic Algorithm

The genetic algorithm can be applied in this paper. The influence parameters of damping force of shock absorber are produced when the vehicle is running, which are distributed in different neural network layers. As for each neural network layer, each type of parameters corresponds to a network layer, and different parameters of one type correspond to different neurons. The influence parameters of damping force of shock absorber need to be compared with the original parameters of each neural network layer one by one. The main steps of implementation are as following:

1. The network layer of the influence parameters of damping force of shock absorber should be determined, and these parameters are hypothesized as \( \chi_1, \chi_2, \ldots, \chi_n \). When determining the network layer for parameters, the input layer and output layer should be confirmed firstly. Assuming that the parameters \( \lambda_1 \) and \( \lambda_2 \) correspond to the input layer and output layer, respectively. The influence parameters of damping force of shock absorber of the input layer can be determined after the \( \chi_1, \chi_2, \chi_3 \) being mapped to \( \lambda_1 \) one by one. If there is a parameter belongs to one of \( \chi_1, \chi_2, \chi_3 \) which is the same type of parameter as \( \lambda_1 \), then the mapping process will be stopped. Otherwise, the process will be continued. The output layer is processed by the same way.

2. After the input layer and the output layer being determined, the parameters \( \chi_a, \chi_b \) are hypothesized as the parameters which have the same type with \( \lambda_1, \lambda_2 \) respectively (Hypothesis: \( a < b \)), so the network layer of the rest parameters \( \chi_1, \chi_2, \ldots, \chi_{a-1}, \chi_{a+1}, \chi_{b-1}, \chi_{b+1}, \ldots, \chi_n \) need to be confirmed. Using the mapping method above in step (1), the network layer distribution of the parameter of \( \chi \) can be ensured. If \( \chi \) is not belong to any original network layer, the parameter of \( \chi \) will be processed as a new hidden layer which will be recorded in the neural network memory after the completion of following steps.

3. The genetic algorithm is mainly used in the optimal selection after mapping and contrast. \( (\mu_1, \mu_2, \ldots, \mu_m) \) are hypothesized as the actual parameters of the network layer of \( \chi \), and it represents the concrete number. After the network layer of \( \chi \) being determined, \( \chi \) needs to be mapped with \( (\mu_1, \mu_2, \ldots, \mu_m) \), one by one. This process can be expressed as the selection of genetic algorithm which means that \( \chi \) is paired with \( (\mu_1, \mu_2, \ldots, \mu_m) \) respectively. The contrast result after the pairing can be regarded as crossover operation. The similarities of \( \chi \) and \( \mu_1, \mu_2, \ldots, \mu_m \) are needed to be compared. If \( \chi = (f_1(\mu_1), f_2(\mu_2), \ldots, f_k(\mu_k)) \) and \( \mu \) are regarded as similar, \( \mu_p \) \( (\mu, \mu_2, \ldots, \mu_m) \) and \( p \) is the grade of a parameter. \( f_1(\mu), f_2(\mu) \) are the contrast functions which used in the contrast of \( \chi \) and \( \mu \). If \( \chi \) is not belong to any original network layer, this step will be skipped.

4. According to the step (3), after the influence parameters of damping force of shock absorber \( (\chi_1, \chi_2, \ldots, \chi_n) \) belonging to the network layers they belong, these parameters are mapped with existing parameters which are in the original network layers one by one, respectively. If there is at least one parameter of \( (\chi_1, \chi_2, \ldots, \chi_n) \) belongs to an original network layer, but it does not meet the condition: \( \chi = (f_1(\mu_1), f_2(\mu_2), \ldots, f_k(\mu_k)) \), the new action of \( (\chi_1, \chi_2, \ldots, \chi_n) \) cannot be judged by extracting similar information from the original memory. Here, there is a rule followed by this paper: if \( \chi = (f_3(\mu_3), f_4(\mu_4), f_1(\mu_1), f_2(\mu_2)) \) and \( \mu_p \) is the similar parameter. If \( \chi = (f_3(\mu_3), f_4(\mu_4), f_1(\mu_1), f_2(\mu_2)) \) and \( \mu_p \) is the similar parameter and \( p \) is uncertain quantity. The search process will be continued until \( \chi = (f_3(\mu_3), f_4(\mu_4), f_1(\mu_1), f_2(\mu_2)) \) is found, after that, this step can be stopped.

5. If any \( \chi \) in \( (\chi_1, \chi_2, \ldots, \chi_n) \) all satisfy the condition that \( \chi = (f_{x-1}(\mu_i), f_x(\mu_i)) \), where \( i \) represents the network layer and \( p \) represents the grade of a parameter, so \( \mu_{ip} \) and \( \chi \) are regarded as similar in the same network layer. Similarly, there is an original parameter which can be found in each network layer for \( \chi \). According to the original memory route of \( (\mu_{ip1, \mu_{ip2}, \ldots, \mu_{ipm}}) \), the action of the influence parameters of damping force of shock absorber which include \( (\mu_{ip1, \mu_{ip2}, \ldots, \mu_{ipm}}) \) can be executed, and this
action is the same as the action of \((\mu_1 p_1, \mu_2 p_2 \ldots \mu_k p_n)\). Where \(p_1, p_2 \ldots p_n\) are the similar parameters of each network layer and \(k\) is representing the total number of network layers.

(6) After the action being completed, if the effect which is produced by the action is in line with the standard, the memory of the influence parameters of damping force of shock absorber of \((\chi_1, \chi_2 \ldots \chi_n)\) can be treated as effective memory which is able to be recorded in the neural network. This action of \((\chi_1, \chi_2 \ldots \chi_n)\) is the same as the action of \((\mu_1 p_1, \mu_2 p_2 \ldots \mu_k p_n)\). If the effect which is produced by the action is not in line with the standard, this memory will be recorded to another neural network. If the vehicle body vibration frequency falls in 1.0Hz-1.6Hz, the action is reasonable; otherwise, the action is not reasonable.

The mapping process is shown in Fig.3.

![Mapping Network Diagram](image)

Figure 3. The schematic diagram of the mapping process.

**Growth in Memory Data**

Speed, road roughness, the angle between road surface and horizontal direction and sprung mass are expressed as \(v, q, r\) and \(m\). \((v_1-v_2), (q_1-q_2), (r_1-r_2), (m_1-m_2)\) can guarantee the indicators except comfort are within the normal range. Adjusting the parameters which makes \(v = (v_1, v_2), q = (q_1, q_2), r = (r_1, r_2), m = (m_1, m_2)\), then a group of damping force adjustment data can be obtained. As is stated above, the micro-computer in the car assesses the effect of execution of action after the action being done. The vibration frequency of the vehicle body is obtained by the sensor, and the 1.3Hz is compared with the frequency gained. If it is between 1Hz and 1.6Hz, it meets or exceeds expectations, the memory can be recorded in the neural network as new memory. It means that the action is reasonable and it can be saved as new memory. "Data growth" means the growth of memory data, and this memory will be the reference for the judgment of later action.

In the application of the genetic algorithm, if there are one or more actual parameters of \((\chi_1, \chi_2 \ldots \chi_n)\) which are not corresponding to any existing network layer, the new network layer is necessary to be built. Before a new memory is built, the action should be executed even though one or more actual parameters are not corresponding to any existing network layer. At this time, the action can be set as: the parameter of \(\chi\) which is not corresponding to any existing network layer is removed, and other parameters will be corresponding to the original parameters of network layers according to the method stated above. The action of \((\chi_1, \chi_2 \ldots \chi_n)\) is consistent with the action of original parameters of network layers. There is a problem that the parameter of \(\chi\) which is not corresponding to any existing network layer is not in the original memory data, so the rationality of the action need to be judged after the action has been executed. If the action is in line with the standard after it has been executed, it can be collected in the memory data. If the action is not in line with the standard after it has been executed, then it should be deposited into another memory data.
There is a continuous problem of action: A action can be produced in a moment, so it is set that there is only one instantaneous action produced in the time of $\lambda$, and a complete adjustment process need to be combined with many instantaneous actions. After the whole adjustment process has been done reasonably, all instantaneous actions are analyzed and processed, and the instantaneous actions which are irrational will be eliminated and other instantaneous actions will be stored in the memory data.

Summary
In this paper, the neural network algorithm and genetic algorithm are introduced firstly. Then the researches of scholars on the intelligent suspension are elaborated. In order to improve the comfort of the smart car, a new intelligent control scheme of suspension is proposed. Autonomic learning function of neural network algorithm is used. After the genetic algorithm is utilized to optimize, the action of vehicle can be judged and then the memory data can be increased. The analysis shows that good comfort can be provided by using neural network algorithm to control the vibration of the shock absorber after repeated study.

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References