

Retraction

Retracted: Finite Element Structure Analysis of Automobile Suspension Control Arm Based on Neural Network Control

Security and Communication Networks

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Li, "Finite Element Structure Analysis of Automobile Suspension Control Arm Based on Neural Network Control," *Security and Communication Networks*, vol. 2021, Article ID 9978701, 11 pages, 2021.

Research Article

Finite Element Structure Analysis of Automobile Suspension Control Arm Based on Neural Network Control

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The control arm is an important transmission and guidance device in the Macpherson suspension system, which has an important impact on the ride comfort, operation stability, and safety of the vehicle, so it is necessary to study the structural performance of the control arm. In this paper, based on neural network control model, finite element analysis, and fatigue analysis theory, the strength, stiffness, and dynamic and fatigue performance of the control arm are studied and analyzed. Taking the ground contact force of the tire as the input condition, the static analysis of the front suspension is carried out, and the boundary condition of the load of the control arm is extracted. The finite element strength of the control arm is calculated in the OptiStruct solver under the conditions of uneven road, braking, and turning. At the same time, the longitudinal stiffness and lateral stiffness of the control arm are analyzed. The simulation results show that the control arm has better strength and stiffness performance.

1. Introduction

The simulation results show that the control arm has better strength and stiffness performance. It plays an important role in transmitting all the forces and torques between the frame and the wheels, mitigating the impact of the road surface, attenuating the vibration, and so on. In addition, it has an important impact on the performance of the vehicle, especially the ride comfort and handling stability [1]. Therefore, it has become the focus and key of chassis platform development. With the increase in the vehicle speed, the ride comfort, handling stability, safety, and economy become more and more important. This puts forward more strict requirements for the suspension design objectively. It should ensure that the suspension has proper frequency characteristics, good kinematics, and elastic kinematics (K & C) characteristics, sufficient strength, and service life of suspension parts. The weight is as small as possible. However, considering the complexity of the structure of suspension system, the load boundary conditions of most parts are difficult to be obtained by manual calculation or experiment. It is difficult to check its strength by traditional methods such as mechanics of

materials and elasticity [2]. Therefore, the design and improvement methods based on physical prototypes have been difficult to adapt to the increasingly stringent design requirements. There is an urgent need to find a more effective solution.

With the rapid development of computer software and hardware technology, finite element method has been widely used in the analysis and design of engineering structures. Due to the development of modern materials science, modern physics, test technology, and analytical means, modern mechanics are facing new profound changes and developing towards a broader field of foundation and application. The mechanical properties of materials including constitutive relation and nonlinear mechanical behavior of large deformation are studied in the combination of microscopic and microcosmic. Some complex computing problems are based on serial computer. And the increase of computing speed depends on two factors: hardware and algorithm. The improvement of hardware speed can improve the computing speed to a certain extent, but it cannot solve the problem fundamentally. In general, the improvement of the algorithm is at the cost of reducing the accuracy. At present, some large-scale complex computing

can be carried out on giant parallel computer by parallel computing method [3]. It is generally believed and proved by practice that the multidimension of parallel processing overcomes the disadvantage of one-dimensional serial processing and is more in line with the objective reality of multidimension. However, like traditional serial computers, parallel computers have the following problems: they do not solve the problem of separation of instruction flow and data stream. The speed of running depends on the establishment of the algorithm. The number of processors, the speed of the processor, and the real-time processing of complex problems are extremely difficult to separate software and hardware, and the programming complexity cannot solve the bottleneck problem between high speed host and low speed I/O interface. In addition, there are some other problems, such as the low level of intelligence, lack of reasoning, understanding, association, self-learning, self-organization, and self-adaptation [4].

Control arm, as one of the automobile suspension systems, is extremely important to the security and functional components and the parameters of the design requirement and is extremely strict control arm of automobile driving safety, and handling comfort plays an important role. Regarding the above requirements, the control arm strength of their physical parameters including stiffness and the need for precise design and optimization of control arm through physical connection mechanism are connected to the car body, wheel side through ball hinge connected to hub, frame side through ball joint connected with rubber bushing, and frame design and performance parameters on the analysis of the control arm. On the basis of ball joint and sleeve to control arm, it should also consider the influence of related parameters of application conditions in the lightweight design of the control arm in the process of model building, and it does not take into account the connection on the control arm ball joint and sleeve, but with the junction surface as the analysis, the design does not reflect the actual increase in payload, and it can provide better driving quality. Research has shown that the influence of rubber bushing parameters on suspension is not the same in the same dimension. The axial stiffness and torsional stiffness of rubber bushing have no significant influence on suspension performance, while the radial stiffness of rubber bushing has a greater influence on suspension performance.

Neural network is a large-scale complex nonlinear dynamic system with highly parallel distributed processing and collective computing capability. The combination of information storage and processing reflects the characteristics of the human brain. With the in-depth study of neural network computers, it will be possible to solve the problems existing in serial and parallel computers. The application of neural network has penetrated into various fields, and in intelligent control, pattern recognition, and computer vision, self-neural network is a large-scale complex nonlinear dynamic system, with a high degree of parallel distributed processing and collective computing capabilities. The combination of information storage and processing reflects the characteristics of the human brain [5]. With the in-depth study of neural network computers, it will be possible to solve the

problems existing in serial and parallel computers. The application of neural network has penetrated into various fields and has been applied in intelligent control, pattern recognition, computer vision, adaptive filtering and signal processing, nonlinear optimization, and continuous speech recognition. Encouraging progress has been made in areas such as knowledge processing and sensing technology. Neural network can be mapped to dynamic circuit, and the process of solving the problem is the dynamic stability of the circuit. Therefore, the solution of the problem can be obtained in the order of magnitude of the circuit.

In order to improve the reliability and stability of automobile suspension system, the important components of automobile suspension control arm were studied. According to the characteristics of the shape of the control arm of complex suspension, the reverse engineering technology was used to build the reverse model. At the same time, the control arm of the automobile suspension is analyzed under the load condition to ensure the safety of the control arm of the automobile suspension in the process of driving.

The main contributions in this paper are as follows: based on neural network control model, finite element analysis, and fatigue analysis theory, the strength, stiffness, and dynamic and fatigue performance of the control arm are studied and analyzed. The finite element strength of the control arm is calculated in the optimal structure solver under the conditions of uneven road, braking, and turning.

The rest of this paper is organized as follows. Section 2 discusses Neural Network Control theory, and Finite element structure of car suspension control arm is induced in Section 3. Section 4 shows simulation results analysis and discussion, and Section 5 concludes the paper with summary and future research directions.

2. Neural Network Control Theory

2.1. Artificial Neural Networks. Artificial neural network (ANN) is a nonlinear processing system formed by the interrelation of a large number of processing units [6]. Artificial neural network is a data model established by simulating the neurons of animals. The data model uses a structure similar to the synaptic connection of the brain to process information. It is based on the research of modern neural network. The neural model is as shown in Figure 1. We use the artificial neural network to analyze the damage changes of the suspension. By taking the attributes of different finite elements as parameter inputs and continuously training and iterating through the neural network, the final regression results can be obtained to judge the changes of the finite elements before and after input and output, and then to judge the corresponding changes in the payment request.

The main characteristics of artificial neural network are as follows:

- (i) Nonlinear relationship: the neural network uses the relationship between the weights to establish a certain relationship between the input layer and the output layer, which is a nonlinear relationship, which is also a kind of implicit functional relationship.

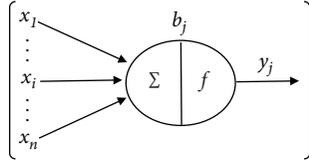


FIGURE 1: Neuron model.

- (ii) Nonlocalization: neural networks are usually made up of multiple neurons that are closely related and interact with each other [7].
- (iii) Extremely qualitative: neural network can carry out adaptive self-learning ability. It processes information with a variety of changes that can be described through an iterative process.
- (iv) Nonconvexity: this property of neural networks leads to diversity in the evolution of systems. In general, the evolution direction of a system is determined by its state function, which has multiple extremum, so the system will have more stable equilibrium states.
- (v) Neural network can be used for classification, prediction, clustering, and so on. It is widely used in our social practice.

The architecture of the convolutional neural network model is shown in Figure 2.

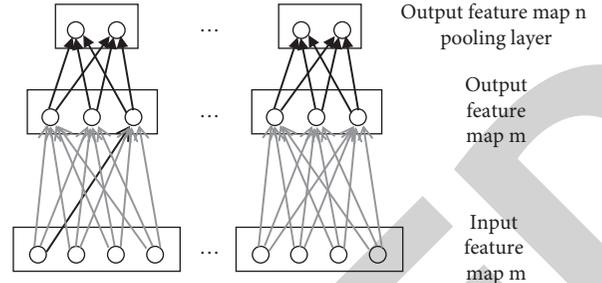


FIGURE 2: Convolution layer and pooling layer structure.

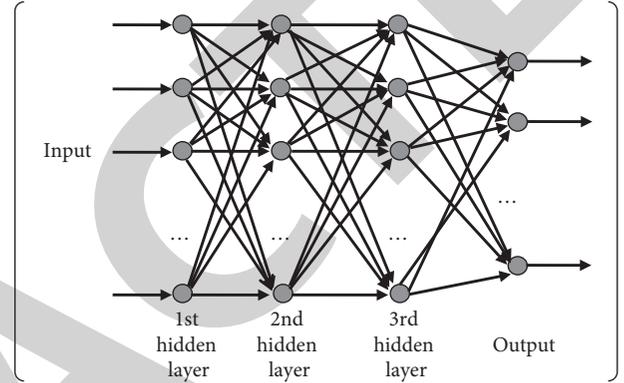


FIGURE 3: Multilayer perceptron structure.

2.2. Nonlinear Combinatorial Forecasting Model. The combined forecasting method is a prediction of two or more different forecasting methods for the same problem. It can be a combination of several quantitative methods and several qualitative methods, but in practice it is the combination of qualitative and quantitative methods. The main purpose of the combination is to make comprehensive use of the information provided by various methods and to improve the prediction accuracy as much as possible (in order to make comprehensive use of the information provided by the various methods, to improve the prediction accuracy, and to make more use of the combination of qualitative and quantitative methods) [8]. Combination prediction can be divided into equal weight combination and nonequal weight combination. It uses the prediction input of each single prediction model as the analog input layer of neural network training and combines the prediction results as the output. The formula (1) is a nonlinear combination prediction method:

$$y = f(x_1, x_2, \dots, x_i, \dots, x_n), \quad (1)$$

where y is the output of the neural network combiner, that is, the predictive value of the combinatorial prediction model. The neural network control model of multilayer perceptron is shown in Figure 3.

2.3. Neural Network Learning Algorithm. Input layer node: the input layer node is obtained by reducing the selection index by principal component analysis. In the neural

network model prediction, the input layer variables often represent different physical meanings, so their dimensions are often different. We can change them to the same dimension by the normalization method [9]. The commonly used normalized formula is as shown in

$$\bar{x}_i = \frac{(x_i - x_{\min})}{(x_{\max} - x_{\min})}. \quad (2)$$

Hidden layer nodes: the number of hidden layer nodes is closely related to the number of input layer nodes and the number of output layer nodes, but there is no extremely mature method to determine hidden layer nodes. A formula commonly used is

$$m = \sqrt{n + l} + a. \quad (3)$$

In the upper expression, n is the number of nodes of the input layer, m is the number of nodes of the hidden layer, l is the number of nodes of the output layer, and a is a constant.

$$1 \leq a \leq 10. \quad (4)$$

Training process: the neural network adopts the driving quantity item, the BP algorithm that dynamically changes the learning rate, adjusts the weights from the input layer to the hidden layer and the hidden layer to the output layer, and adjusts each training. If the error is reduced twice in a row, the learning rate will be increased properly; otherwise, the learning rate will be reduced accordingly. Generally, the adaptive learning rate is automatically adjusted by (3) and (4). And it is adopted (4) to adjust the adaptive learning rate automatically, and then it adopts momentum term to reverse

correct the weights of the input layer to the hidden layer and the hidden layer to the output layer.

$$\eta(k+1) = \begin{cases} 1.05\eta(k), & e(k+1) < e(k), \\ 0.75\eta(k), & e(k+1) > 1.04e(k), \\ \eta(k), & \text{others.} \end{cases} \quad (5)$$

In the formula: the learning rate for step k is $\eta(k)$, and $e(k)$ is the error of step k .

The hidden weight adjustment can be expressed as follows,

$$V_p(k+1) = V_p(k) + \eta_p(k)\delta_i h_p + a_p(k)[V_p(k) - V_p(k-1)]. \quad (6)$$

The input layer weight can be expressed as follows:

$$W_p(k+1) = W_p(k) + \eta_p(k)\delta_i h_p + a_p(k)[W_p(k) - W_p(k-1)]. \quad (7)$$

The formula a_p is a momentum factor.

3. Finite Element Structure of Car Suspension Control Arm

3.1. Introduction to Multibody System Dynamics

3.1.1. Development of Multibody System Dynamics. For complex mechanical systems such as car suspension, the motion of many components is nonlinear with large displacement. When constructing dynamic equations, they face complex and arduous algebraic and calculus operations due to the nonlinearity and complexity of the equations. It is extremely difficult to solve the problem. Multibody system dynamics developed on the basis of classical mechanics provides a powerful tool for solving this problem [10].

Multibody system dynamics are promoted by the development of modern science and technology, which is represented by space machines, aircraft, and robots, and are related to motion biomechanics, spacecraft control, robotics, and robotics. For demonstration, a case study was conducted, and it demonstrated that, with the increase of effective series stiffness, the hydraulic yaw damper could dissipate the lateral vibration energy of the front bogie significantly. Mechanical dynamics and other fields are closely related and play an important role in the discipline. A mechanical system that is usually connected by a plurality of objects through a pair of motion to perform the desired action is called a multibody system. If every object in the system is regarded as a rigid body with invariant shape, the system is called a multirigid-body system. And if there are some objects in the system, which must be considered and deformed, it is called a multiflexible body system.

3.1.2. Contents of Multibody System Dynamics. Multibody system dynamics includes multirigid-body system dynamics and multiflexible system dynamics. The research object of multirigid system dynamics is a system composed of arbitrary finite rigid bodies, which are

connected by some form of constraint. These constraints can be ideal holonomic constraints, nonholonomic constraints, stationary constraints, or unsteady constraints. To study the dynamics of this kind of systems, we need to establish the nonlinear equations of motion, the expression of energy, the expression of dynamics, and the relation of some other quantities. Multirigid-body system dynamics mainly solve the problem of multirigid-body system dynamics, and each component can have relatively large motion.

3.1.3. Rigid-Flexible Coupling Analysis. Generally speaking, the rigid-flexible coupling analysis is mainly based on modal synthesis hypothesis. Finite element analysis provides structural modal matrix, modal stress, and other information for multibody system simulation. The above information is included in the neutral interface file and input into the simulation environment of the mechanical system, so as to establish the virtual prototype of the research object. By simulation analysis, not only the large-scale translation and rotation of the multibody dynamics system, but also the small scale deformation of the flexible body parts in the motion process can be obtained, and the interaction between the two motions can also be obtained: the effect of flexible body deformation on large-scale motion (including system vibration characteristics) and the reaction of large-scale motion on elastic deformation. At the same time, the system simulation can provide the movement law and modal coordinate of any part of the mechanism for the finite element analysis, so as to provide the accurate boundary condition and load condition for the finite element analysis [11]. The data exchange relationship between finite element analysis (FEA) and multibody system simulation (MBS) can be described in Figure 4. Based on rigid-flexible coupling analysis method, researchers analyze the mechanics characteristic of upper arm and get the deformation of end measuring point, maximum stress position, and stress curve, when spot-welding robot is moving under loads [12]. The analysis method is intuitional and accurate and can increase the accuracy of dynamic response analysis of parts under the dynamic loads. The simulation results are considered an extremely important theoretical basis for structure design and optimization of the spot-welding robot [13].

3.2. Introduction to ADAMS Software. ADAMS software is a famous virtual prototype analysis software developed by MDI Company in USA. It is one of the most authoritative software about mechanical system dynamics and kinematics in the world. It was originally compiled by Chace of Michigan University. ADAMS has been widely used in automotive, aerospace, and other fields [14]. ADAMS software is based on the theory of multirigid-body system dynamics. The ADAMS software uses interactive graphics environment, part library, constraint library, and force library to set up the parameterized model of mechanical system. Its solver adopts Lagrangian method in the dynamics theory of multirigid-body system to establish the dynamic equation of the system [15]. The static, kinematic, and dynamic analyses of the virtual mechanical system are carried

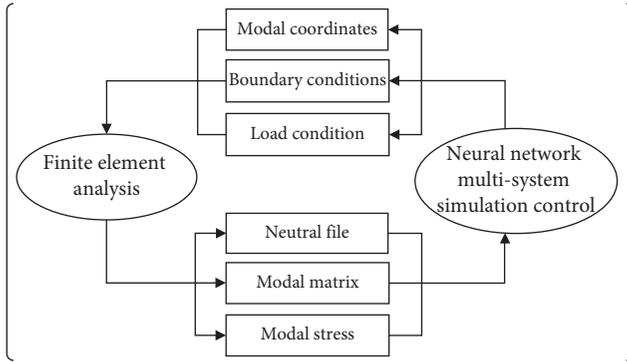


FIGURE 4: Data Exchange between Finite element and Neural Network Multibody system Simulation.

out, and the displacement, velocity, acceleration, and reaction force can be outputted [4]. ADAMS simulation can be used to predict the dynamic performance, motion range, collision detection, peak load, and input load of finite element calculation of mechanical system. Users only need skilled use of interface and can easily complete customized tasks [16]. ADAMS software has become one of the main tools for scientific research, product development, and design in enterprises, research institutes, and related universities [17].

ADAMS uses the Lagrangian equation method, which is widely used in the dynamics theory of multirigid-body system in the world to establish the dynamic equation of the system. The Cartesian coordinates of the center of mass of the rigid body and the Euler angle or generalized Euler angle reflecting the displacement of the rigid body are taken as the generalized coordinates [18].

$$\begin{aligned} q_i &= [x, y, z, \Psi, \theta, \varphi]^T, \\ q &= [q_1^T, q_2^T, \dots, q_n^T]^T. \end{aligned} \quad (8)$$

The system dynamics equations used by ADAMS are as follows:

$$\frac{d}{dt} \left(\frac{\partial T}{\partial \dot{q}} \right)^T - \left(\frac{\partial T}{\partial q} \right) + \varphi_q^T \rho + \theta^T \mu = Q. \quad (9)$$

The holonomic constraint equation is expressed as follows:

$$\varphi(q, t) = 0. \quad (10)$$

The nonholonomic constraint equation is expressed as follows:

$$\theta(q, \dot{q}, t) = 0. \quad (11)$$

3.3. Finite Element Model of Control Arm

3.3.1. Basic Idea of Finite Element Method. The structural analysis of a mechanical part is actually a mathematical problem for solving an infinite number of degrees of

freedom continuum, for which it is extremely difficult to obtain an analytical solution. The emergence of finite element method provides an effective tool for solving the problem [19]. The basic idea of the finite element method is to discretize a continuous solution region into a finite set of elements that are connected to each other in a certain way [6]. That is to say, a finite element set is used to replace the contiguous solution region with the same geometric shape or approximately the same geometry. Because the elements can be combined in different ways, and the elements themselves can be described by different shapes, it can be used to simulate the continuum with extremely complex geometric shapes [20]. The process may be organized in five steps: (1) create an initial FE model of the structure; (2) identify the experimental modal parameters; (3) update the initial FE model based on the experimental modal parameters; (4) repeat steps (2) and (3) again after the deterioration has happened; and (5) use the updated parameters as an indicator of the deterioration. As a numerical method, finite element method (FEM) is characterized by the assumption of approximate function in the element to describe the field function in the solution domain in a piecewise manner [21, 22]. In this way, the continuous and unknown field functions (infinite degrees of freedom) in the domain are transformed into the field functions of the new unknown variables (i.e., degrees of freedom) of finite elements and nodes. If the element scale tends to be infinitesimal, then the discrete unknown field function with finite degrees of freedom will be transformed into the continuous unknown field function with infinite degrees of freedom, and the approximate solution will converge to the exact solution.

3.3.2. Basic Flow of Finite Element Strength Analysis. The basic process of finite element strength analysis can be summarized into the following steps:

- (1) Structure discretization: Structure discretization is that the structure to be analyzed is divided into a finite number of units, and set nodes at the specified point of the unit body, so that the relevant parameters of the adjacent elements have a certain continuity and constitute the assembly of the elements [10].
- (2) Select displacement mode: Linear finite element method is an approximate numerical method based on the principle of minimum potential energy. Displacement is regarded as the basic unknown quantity. In order to express the displacement, strain, and stress of the element by the nodal displacement, the displacement is assumed to be a simple function of the node coordinate when analyzing the continuum problem. This function is called the shape function of the displacement mode. The relationship between the node displacement of the element and the displacement of any point in the element can be expressed as follows:

$$u_e = N \cdot u. \quad (12)$$

Among them, the element displacement array u is the element node displacement array, and N is the shape function matrix.

- (3) Determine the mechanical properties of the unit: Firstly, by using geometric equation, the relationship between node displacement and element strain is derived from formula (12):

$$\varepsilon = B \cdot u. \quad (13)$$

The strain matrix B for any point in the element is the element strain matrix.

Secondly, by using constitutive equation, the relationship between node displacement and element stress is derived from formula (13).

$$\sigma = D \cdot B \cdot u = S \cdot u, \quad (14)$$

where D is the elastic matrix, and S is the element stress matrix.

Thirdly, by using the variational principle, the relationship between the node force and the node displacement acting on the element is established, that is, the balance equation of the element as follows:

$$K_e \cdot u = F_e, \quad (15)$$

where K is the integral stiffness matrix of the structure, U is the integral displacement array of the structure, and F is the integral load array of the structure.

- (4) Solving nodal displacement and element stress: Equilibrium equation (15) is set up, and the displacement matrix of the node is obtained after the constraint treatment. Furthermore, the stress of each element can be obtained by using formula (14) and the calculated node displacement. According to the needs of the project, the above calculation results are sorted out and postprocessed to obtain different analytical results.

3.3.3. Basic Flow of Finite Element Modal Analysis.

Modal analysis can be divided into numerical modal analysis and experimental modal analysis. Compared with the experimental modal analysis method, numerical modal analysis can predict the modal parameters of the structure in the early stage of product design and avoid the design defects as soon as possible. The numerical modal analysis is based on the finite element model of the structure, and its basic analysis flow can be summarized as the following steps.

The equations of motion of the elements are established by the element characteristic matrix as follows:

$$M_e \cdot \ddot{u} + C_e \cdot \dot{u} + K_e \cdot u = F_e. \quad (16)$$

The set of element characteristic matrix is regarded as the integral characteristic matrix of structure, and then the equation of motion of the structure is obtained:

$$M \cdot \ddot{U} + C \cdot \dot{U} + K \cdot U = F. \quad (17)$$

Natural frequency and modal mode are the most important set of structural modal parameters. The purpose of solving them is to predict the resonance frequency and harmful modes of the structure, which can also provide the basis for dynamic response analysis. Because the natural frequency is independent of the load, and the damping has little effect on the natural frequency and mode, the undamped free vibration equation of the structure is obtained.

$$M \cdot \ddot{U} + K \cdot U = 0. \quad (18)$$

The free vibration can be decomposed into the superposition of a series of simple harmonic vibrations, and the upper formula can be transformed into the following expression.

$$(K - \omega^2 M) \cdot \phi = 0. \quad (19)$$

4. Simulations

4.1. Simulation Parameter Configuration. The choice of element type is directly related to the calculation and analysis of finite element model. The finite element model is used to simulate the control arm under the actual working conditions, and the selection of appropriate elements directly affects the mechanical characteristics, load, and boundary conditions of the control arm structure. Because the length and width of the upper and lower plates are far larger than the thickness of the sheet metal parts, it should be divided into shell elements and other parts of the selection unit to divide. The precision of rectangular shell element is high, but the shape of upper and lower plate is extremely complex, so it is difficult to realize that all the elements are rectangular shell element when meshing. Therefore, the rectangular and triangular mixed shell elements are used to divide the upper and lower plates. The front point of the control arm is divided into hexahedron mesh, and the other parts are irregular in structure, and the tetrahedron element is used to divide the control arm. As in Figure 5, this paper uses a four-layer neural network control method, and the specific neural network control model is shown in Figure 5.

Mesh quality is an extremely important factor to ensure the accuracy of the finite element solution. When the mesh quality is poor, the accuracy of the solution will be significantly reduced, and the model may not converge or even stop the calculation. Therefore, checking the quality of the mesh is an indispensable step before the finite element calculation. The grid quality checking function is set up in HyperMesh to satisfy the smooth operation of RADIOSS solver. The 2D mesh quality requirements are as shown in Table 1.

The whole grid cell model of each part of the control arm is shown in Figure 6.

The quality of the upper and lower plate and shell units of the control arm are seen in Table 3.

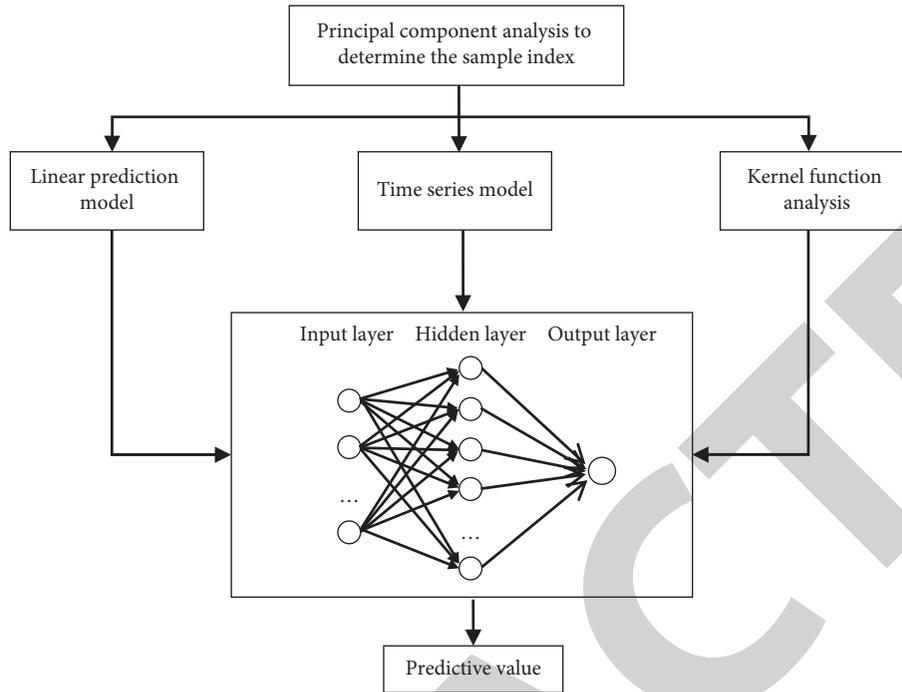


FIGURE 5: Four-layer model of BP neural network.

TABLE 1: 2D grid quality requirements.

Element attribute feature	Quality requirement
Jacques	≥ 0.7
Aspect ratio	≤ 5
Warpage	≤ 5
Distortion	≤ 60
Quadrilateral minimum angle	≥ 45
Quadrilateral maximum angle	≤ 135
Triangle minimum angle	≥ 15
Maximum angle of the triangle	≤ 105
The proportion of the number of triangular elements	$\leq 15\%$

3D mesh quality requirements are seen in Table 2.

TABLE 2: 3D grid quality requirements.

Element attribute feature	Quality requirement
Warpage	≤ 5
Aspect ratio	≤ 5
Distortion	≤ 60
Body distortion	≤ 0.6
Body aspect ratio	≤ 5
Jacques	≥ 0.7
Quadrilateral maximum angle	≤ 135
Quadrilateral minimum angle	≥ 45
Maximum angle of the triangle	≤ 120
Triangle minimum angle	≥ 20
Tetrahedron collapse ratio	≥ 0.5

4.2. Analysis of Results. The vehicle is mainly used for short distance walking of the city, and the road surface is mainly asphalt cement road with better pavement. The designed maximum speed is 80 km/h, and the commonly used speed is 60 km/h. According to the national standard GB/T4970-

1996, “Random input driving test method for vehicle ride comfort,” the simulation road surface is selected to meet the requirements of GB7031, and the commonly used speed is 60 km/h. The simulation of the vehicle ride comfort based on the four-column test bench is carried out on the virtual

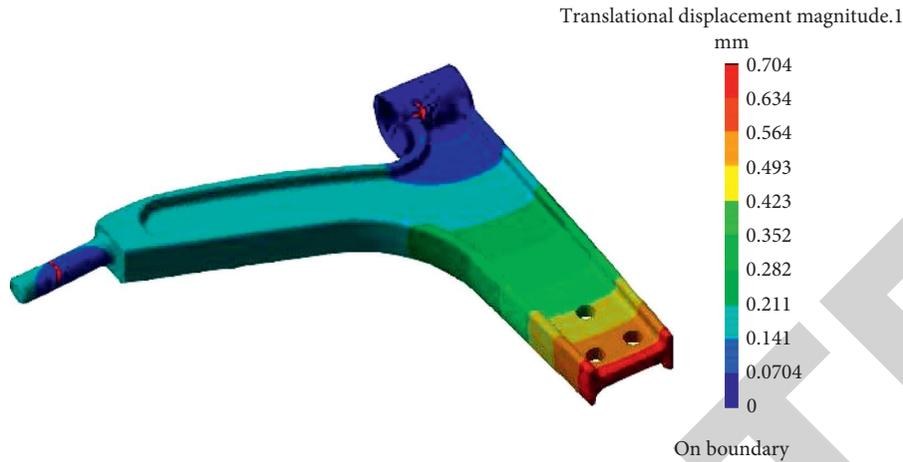


FIGURE 6: Grid drawing of vehicle suspension control arm.

TABLE 3: Upper and lower plate 2D unit quality.

Unit quality standard	Number of units that do not conform to the standard	Nonstandard cell ratio (%)	Worst value	Standards compliant
Jacobi	69	1	0.6	≥ 0.7
Aspect ratio	0	0	3.07	≤ 5
Warpage	60	1	9.99	≤ 5
Distortion	0	0	34.34	≤ 60
Quadrilateral minimum angle	0	0	46.28	≥ 45
Quadrilateral maximum angle	0	0	129.92	≤ 135
Triangle minimum angle	0	0	32.26	≥ 15

prototype model of the whole vehicle. In the ADAMS/Car Ride module, the road surface file generator (Road-ProfileGeneration) is used to build the B class random road surface. Because the Ge zeroing simulation cannot be calculated, $G_s = 25.27$, $G_a = 0$, $G_e = 0.0000001$ are set up.

The simulation time is 60 s, the frequency limit is 100 Hz, and the number of simulation steps is 6 000. The load time history data of the control arm are extracted. It shows the degree of volatility history of the ball pin at the outer end of the control arm obtained from the 60 km/h vehicle simulation in Figure 7.

According to the calculation results, the overall fatigue life of the control arm is extremely good and can reach the $10e20$ secondary cycle. However, the fatigue life in the partial stress concentration region is not that high, which is lower than the number of $10e6$ cycles, such as the back bushing joint, the front bushing joint, the reinforcement arm joint, and the outer end joint. These areas are prone to fatigue failure due to the large structural changes and obvious stress concentration. Service life of the control arm of the car suspension is given in Figure 8. We can see that the proposed algorithm can have the longest lifetime. This is because that the proposed algorithm can cope with more difficult situations with adopting the neural network control method.

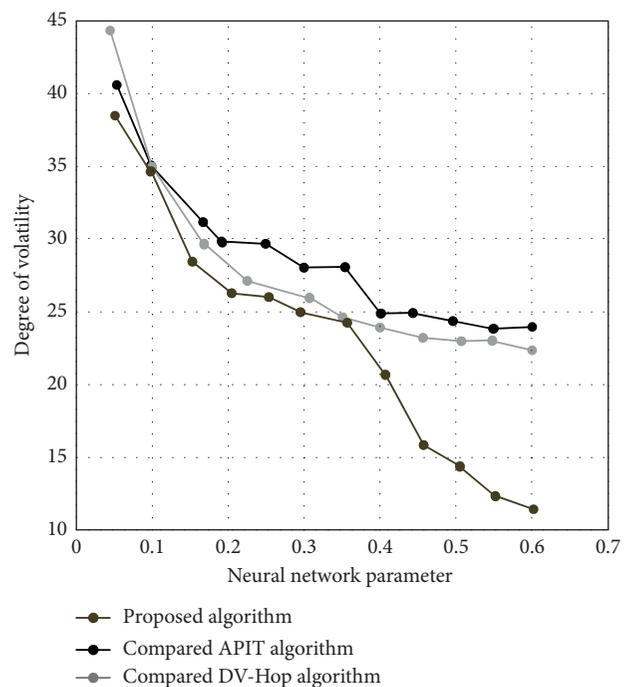


FIGURE 7: Vehicle stability analysis.

The result of fatigue simulation is the number of cycles, and it is necessary to convert the number of cycles into mileage. According to the national standard, the speed of the calculation is 60 km/h, the time represented by each cycle number is 60 s (the input time of Gen 11 road spectrum), and the shortest cycle number of the control arm is 41680 times of the fatigue life of unit 180748. The equivalent road mileage can be expressed as follows: 41680 Km, the minimum fatigue life of the control arm is 41680 km, which meets the reliability test requirements of the general automobile of 3000 km.

The fatigue simulation local cycle number of the control arm is lower than the 10e6 cycle number, but the minimum driving mileage is 41680 km, which meets the reliability test requirements of the general automobile. The fatigue life of the control arm can be further improved by optimizing the structure of the control arm to reduce the stress concentration of the control arm, taking the measures of surface strengthening, surface treatment with higher precision, and selecting materials with better fatigue performance. Comparative analysis of quality before and after optimization is given in Table 4.

The minimum mass of the control arm is the objective function, the thickness of the upper and lower plates is the design variable, and the stress intensity of the upper and lower plates is less than 340 MPa as the constraint condition to optimize the size. After optimization, the safety factor is more than 1.4 except the braking condition, and the safety factor is still above 2 in the other conditions. Under the condition of not changing the structure of the control arm, the research and design of the available dimension optimization can quickly reduce the quality and guide the development and design of the control arm.

In the last three years, many methods are proposed to handle the related problem; here, we introduced three outstanding methods, that is, APIT [23], DV-Hop [24], and CNNA [25], which can be used to solve the related works taking different kinds of network structures. APIT is a graph-based network that builds connections between different risk nodes. And DV-Hop uses a specific loss structure to keep the similarity of real and predicted crafts design. CNNA is the basic model that needs more computation consumption to obtain the desiring performances. However, these methods have their disadvantages, respectively, as follows. GNNA is too slow, RNNA is so complicated, and CNNA also needs more spaces.

In this paper, we utilize the entropy loss function to build the model for our research problems. It can be defined as follows: $loss(x, y) = \sum_{i=1}^n -p_i \log(1 - p_i)$. where x and y are represented as the real arts and crafts' score and difficulty and y means the predicted score and difficult of our proposal. P_i means the probability of them when they are similar. The bigger the value of the loss, the worse the performance of our proposal. And our proposal is used to train a model that fits the real and predicted arts and crafts, so that the machine can assist the arts and crafts designed. However, we may pay attention to our models to make them avoid overfitting.

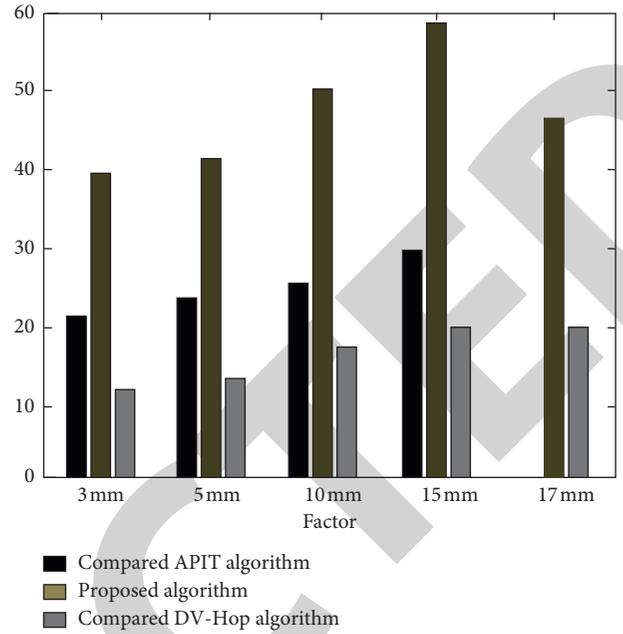


FIGURE 8: Service life of the control arm of the car suspension.

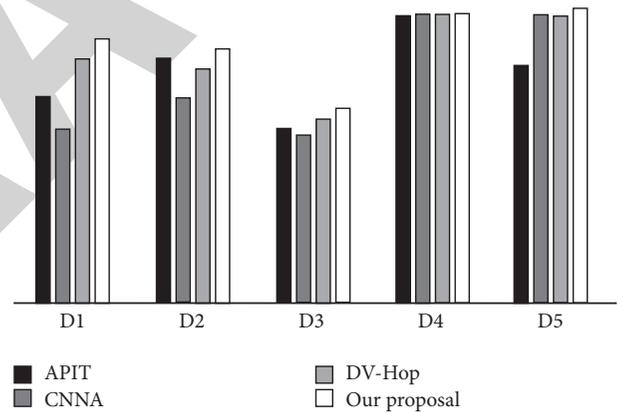


FIGURE 9: The F1-score of the control arm of the car suspension.

And compared with the three methods, our proposal can deal with the problems easily, and we also need a smaller computation space to build our model. However, our model may obtain a relative lower accuracy than others sometimes, which may lead to the instability of the prediction.

In order to investigate the effectiveness of our proposal and other methods, here, we take F1-score into account to assess the experiment results, which can be defined as follows: $f1 - score = 2 * precise * recall / (precise + recall)$, $precise = (TP / (TP + FP))$, $recall = (TP / (TP + FN))$.

The results can be shown in Figure 9. As shown in Figure 9, the white bar represents our proposal, and on all datasets, we can see that our proposal is better than others except D4, in which all methods obtain the same results. It is indicated that our proposal can perform well than the other three methods.

TABLE 4: Comparative analysis of quality before and after optimization.

	Preoptimization quality (kg)	Optimized quality (kg)	Reduce quality (kg)	Percentage (%)
On board	2.703	1.923	0.78	28.86
Lower plate	1.615	1.293	0.322	19.94

5. Conclusion

Neural network is a large-scale nonlinear complex dynamic system. Its nonlinearity is mainly reflected in the nonlinearity of the transfer function of neurons and the connection of a large number of nonlinear neurons, while the nonlinearity of mechanical behavior or mechanical calculation is mainly reflected in the constitutive relations of materials. In this paper, the vehicle suspension control arm based on neural network control is adopted, and its performance is analyzed by finite element structure analysis method. The experimental results show that the proposed neural network-based suspension control arm can greatly improve the stability of the vehicle, and in the reliability test, it has a better performance. Therefore, the neural network-based vehicle suspension control arm can be applied to the real bicycle suspension system in the future to improve the stability and reliability of the vehicle suspension system. However, when I give a large coefficient of the sign function, the convergence speed can be accelerated, but at the same time, due to the discontinuity of the sign function, the control input of the system will quickly switch back and forth, resulting in a large disturbance. Therefore, my torque input will have a large disturbance. The subsequent improvement is to use fuzzy control to adjust the gain coefficient of the symbol function, so that when the system is far away from the equilibrium point, it can ensure a large gain coefficient so as to approach quickly, while when it is close to the sliding mode surface, the gain coefficient will decrease, so as to reduce the jitter near the sliding mode surface.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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