# Parking Maps Based on Momentum BP Neural Network Modeling and Prediction of 3S

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**Abstract.** In order to quickly and accurately determine the location and extent of the instability of complex steel structures, the method has been proposed which is to build a full model based ANSYS finite element analysis software and mapping model based add momentum BP neural network to achieve predictive. The structure is modeled by finite element analysis software, and through which could get the full model structure. The von-mises stress and structure of different layers of maximum deformation has been regarded as the training samples. The nonlinear relations could be got by neural network. Ultimately generalization mapping model could be got. The examples show that the data obtained by artificial neural network to predict with high accuracy, compared with the full-model, the error is only 5.28% maximum, the average error is 3%, which proved the feasibility of the method and laid the foundation for the subsequent optimization.

## Introduction

Most of the complex structures statically indeterminate structure, the calculation method is to build flat model usually, the calculation process of this method is complex and there is a lot simplification. For example, most of the connecting rod between the parking garage is rigid junction, however, the main force of each rod in actual calculation is axial force, so the rods are simplified to hinge junction usually, such simplification have smaller error, in most cases it is allowed, but in the process of establishing the whole model of the three-dimensional garage add uniform wind load, so each rod is bending member actually，there is a great error between plane model and full model. In the process of full model established by ANSYS which is consider section bar, unit type, material and other factors, in the process of applying load which is consider the wind load, seismic load and weight, these factors have be simplified in the process of plane model calculation, so the whole model has higher precision and more realistic deformation. But to the beginners it is difficult to establish a full model by finite element software, even a proficient user needs a few days to create a complete analysis command. How to predict the stress and deformation in the engineering application quickly is not only expectation, but also problematic. Through actual calculation in this paper, the nonlinear relationship between the stress and strain on different floors of the garage has been discovered. The neural network has a high degree of fault tolerance, redundancy and non-linear mapping. A scientific and rational mapping model has been established through the training of sample. Eventually the hidden map has been found.

Figure 1. The model of packing system

BP neural network provides a practical approach to solve highly nonlinear problem. Many scholars attempt it from different angles, such as the method which uses the simple model to predict full model[1]. That need to build a standard BP neural network model. Although this approach eliminates the need for space model, but the calculation of the simple model is complex. And it is different to simplify the structure of each person, so the results will be certainly different, the workload has not been reduced. For another example, some scholars have proposed building structural damage recognition factor by testing the frequency [7], then predict it by the BP neural network. This approach has skipped to build the simple model, the accuracy is also acceptable, but this method needs to construct the model to calculate the frequency changing ratio at different locations, which does not eliminate the full model building. In view of this, In this paper ,the author proposes to obtain different layers maximum von-mises stress and maximum deformation of different conditions by establish spatial finite element model directly, the input layer of neural network is the number of layers, the output layer is von-mises and deformation. Select the appropriate number of hidden layer by comparing the experimental error, according which to build the neural network model. Finally test the feasibility of the proposed method through comparing the momentum BP neural network and BP neural network.

## Full model

Select PCSQ22D-QH11A type parking garage as an object of study, the total height of the garage is 26.2m. The total width is 6.9m, which could park 22 cars at most. The material of rod is Q235, the material characteristics: $\rho = 7830\text{kg/m}^3, E = 206\text{GPa}, \mu = 0.3$.

Because of the nonlinearity of high-rise steel structures, beam188 structural unit has been used to build the finite element model. The unit which is suitable for large angle rotation, linear and nonlinear large-strain problem. There are three forms of the garage section, columns, beams and diagonal bracing. The beam element has been selected to build the model, which through dotted line connection. In order to ensure the convenience of cross section model selection, the software modules sections have been chosen to define the section of the line. In order to obtain samples neural network training data, you need to change the model layer repeatedly. So in the process of preparing APDL command all use parameterized loop, such as“*do *enddo”.

In the process of applying load, wind load applied in the partial load state side which could make the maximum deformation occur of the garage. Uniform load has been imposed on all nodes on the side via the “*get” function. As support vehicle plate contact with the garage structure on four wheels, so simplify the load of the structure evenly distributed on four nodes.

After completing the above finite element model, the maximum von-mises load stresses and deformation of different layers could be got, as showed in table 1.

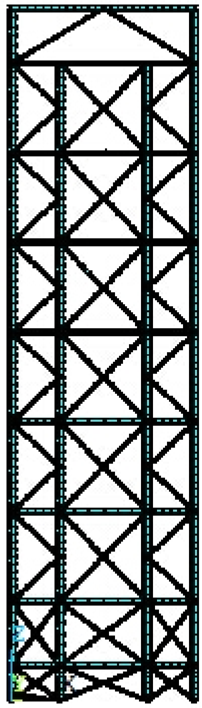

Figure 2 The finite element model of packing system

Table 1 the stress and deformation of different layers of different load

| Layer | Fully load | | Partial load | | Empty load | |
|---|---|---|---|---|---|---|
| | Von-mises stress | Maximum displacement | Von-mises stress | Maximum displacement | Von-mises stress | Maximum displacement |
| 4 | 7.39 | 2.199 | 7.42 | 2.455 | 7.42 | 2.208 |
| 5 | 7.99 | 2.617 | 8.3 | 3.143 | 8.17 | 2.636 |
| 6 | 10.2 | 3.228 | 10.8 | 4.112 | 9.1 | 3.255 |
| 7 | 12.9 | 4.078 | 13.6 | 5.454 | 10.3 | 4.118 |
| 8 | 15.9 | 5.251 | 16.8 | 7.272 | 12.6 | 5.308 |
| 9 | 19.3 | 6.85 | 20.2 | 9.687 | 15.2 | 6.925 |
| 10 | 23 | 8.996 | 24.1 | 12.842 | 18.1 | 9.09 |
| 11 | 27.1 | 11.831 | 28.3 | 17.147 | 21.4 | 11.946 |
| 12 | 31.6 | 15.521 | 32.9 | 22.665 | 25.1 | 15.657 |
| 13 | 36.5 | 20.339 | 38 | 29.557 | 29.2 | 20.503 |
| 14 | 41.3 | 26.211 | 42.9 | 37.562 | 33.1 | 26.396 |
| 15 | 47.1 | 34.048 | 48.8 | 47.837 | 38 | 34.256 |

**Mapping model**

BP neural network is widely used because it has powerful nonlinear mapping ability, high degree of fault tolerance and adaptive generalization ability. But its limitations are evident, Standard parameters of BP neural network is:

$$\Delta w_{ij}(n) = -\beta \frac{\partial E}{\partial w_{ij}} \quad (1)$$

Which can be obtained from the formula, when the partial derivative of the Error plane becomes small the weight adjustment range is correspondingly small, convergence rate become lower. When the partial derivative value growth, the weight adjustment range growth, which leads the adjustment weight becomes large and overshoot the smallest point, weights adjusting routes become jagged, so it's become difficult to converge to the minimum point. So the training time is become longer. The standard parameters of BP neural network who added momentum term is:

$$\Delta w_{ij}(n) = -\beta \frac{\partial E}{\partial w_{ij}} + \eta(n)\Delta w_{ij}(n-1) \quad (2)$$

What can be obtained from the formula is the adding momentum term equal to damping term, which continue change in the learning process, that could make the value adjustments move in the same direction, even in different directions, the oscillation tendency also can be reduced. The convergence can be accelerated.

**Determine the input and output layer nodes**

On the selection of input and output nodes, in order to increase efficiency and skip the simple model and the model build process. On the selection of input nodes must be easy to obtain and avoid complicated, which is also having a great influence on the garage. So the garage floors have been selected as the output node. On the selection of output nodes which should be able to predict the strength, stiffness and stableness of the garage. So choose the respective maximum von-mises stress and maximum deformation of six nodes in different conditions.

**Determine the hidden layer**

A model could approximate any function if there are a sufficient number of hidden layer nodes in theory. But too much hidden layer may lead to wasting a long time, too little may cause some defects such as non-convergence. The normal method to establishment the hidden layer is using the common empirical formula:

$$x = \sqrt{mn} \quad (3)$$

In the equation, m is the output layer node, n is the input layer node. In order to convergence

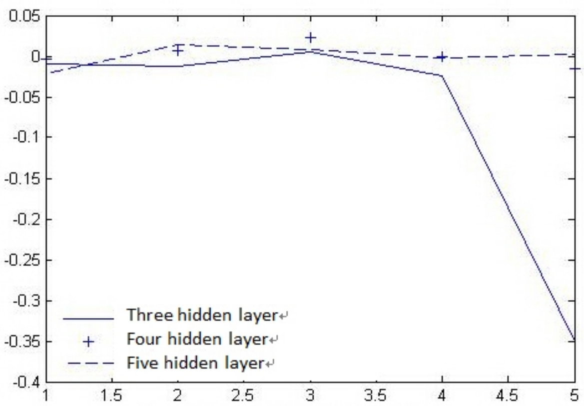


Figure 3 Comparison of different hidden layer output error

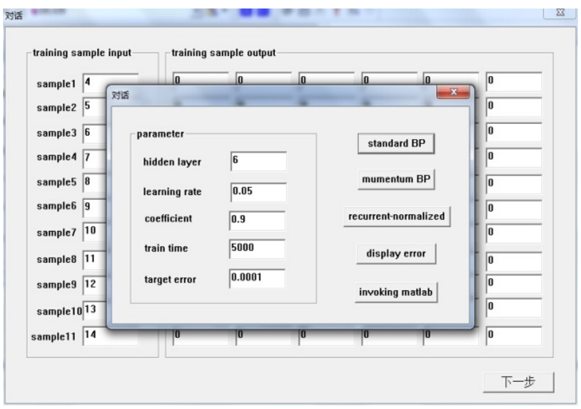


Figure 4 Neural network program

accurately. The different hidden layer has been selected to train and compare, as showed in figure 3,4 and 5 layer can achieve a higher degree of convergence in the same sample, so 4 layer is selected to ensure accurate and reduce the training time.

The neural network has been trained according to 12 sets of data which is getting from the finite element model. The 0.0001 target error has been reached by 1801 times training. The predicted value needs to be recurrent-normalized. The obtained data are shown in table 2.

Table 2 The prediction values and error of neural network

| Layer | Fully load | | | | Partial load | | | | Empty load | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Prediction of Von-mises stress | Error | Prediction of Maximum displacement | Error | Prediction of Von-mises stress | Error | Prediction of Maximum displacement | Error | Prediction of Von-mises stress | Error | Prediction of Maximum displacement | Error |
| 4 | 7.47 | 1.15 | 2.21 | 0.61 | 7.56 | 2.01 | 2.53 | 3.21 | 7.59 | 2.35 | 2.24 | 1.57 |
| 5 | 7.89 | 1.19 | 2.56 | 1.92 | 8.14 | 1.91 | 2.99 | 4.83 | 7.85 | 3.83 | 2.59 | 1.73 |
| 6 | 10.07 | 1.21 | 3.12 | 3.22 | 10.61 | 1.69 | 4.09 | 0.39 | 8.92 | 1.95 | 3.14 | 3.46 |
| 7 | 13.17 | 2.15 | 4.10 | 0.55 | 14.15 | 4.08 | 5.67 | 4.09 | 10.47 | 1.69 | 4.23 | 2.75 |
| 8 | 15.38 | 3.25 | 5.07 | 3.39 | 16.19 | 3.63 | 6.94 | 4.48 | 12.06 | 4.22 | 5.11 | 3.62 |
| 9 | 19.30 | 0.03 | 7.05 | 2.93 | 20.26 | 0.33 | 9.74 | 0.64 | 15.01 | 1.21 | 6.93 | 0.02 |
| 10 | 23.61 | 2.67 | 9.48 | 5.38 | 24.69 | 2.48 | 12.55 | 2.21 | 18.61 | 2.83 | 9.54 | 4.99 |
| 11 | 26.506 | 2.18 | 11.55 | 2.34 | 27.68 | 2.19 | 16.51 | 3.70 | 21.01 | 1.82 | 11.54 | 3.33 |
| 12 | 31.68 | 0.27 | 16.02 | 3.28 | 33.02 | 0.38 | 22.68 | 0.07 | 25.17 | 0.28 | 15.68 | 0.21 |
| 13 | 36.52 | 0.08 | 19.97 | 1.80 | 38.00 | 0.02 | 29.61 | 0.19 | 29.18 | 0.04 | 20.50 | 0.03 |
| 14 | 41.31 | 0.04 | 26.22 | 0.04 | 42.91 | 0.03 | 37.57 | 0.02 | 33.13 | 0.10 | 26.42 | 0.09 |
| 15 | 46.95 | 0.31 | 33.94 | 0.31 | 48.64 | 0.31 | 47.62 | 0.44 | 37.83 | 0.44 | 34.06 | 0.55 |

As shown, the prediction error range from a minimum of 0.04% to a maximum of 5.28%.Which is coinciding with the real data get from the full model. The feasibility and practicability of this prediction method has been proved.

**Error contrast**

According to the above data, the results, training time and training times of the momentum-BP neural network and the standard BP neural network has been compared, as figures 5 and 6 shown.

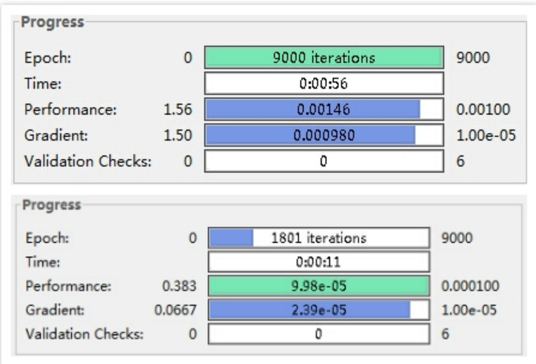


Figure 5 Standard BP/ Momentum BP training time and accuracy

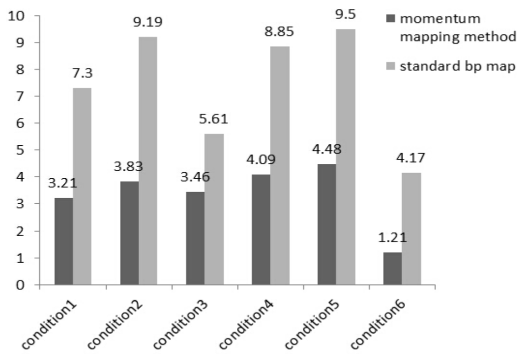


Figure 6 Standard BP/ Momentum BP error comparison

In figure 5, the standard BP neural network has not reached the target of 0.001 accuracy error in 9000 times training. While the momentum-BP neural network has reached 0.0001 accuracy error after 1801 times training. The momentum-BP neural network not only saves time, but also reduces the error greatly. Which can be seen in figure 6 also, First six standard BP neural network errors are always hovering around 4.37% to 9.5%. although stable, but high relative error. By comparison, momentum-BP neural network stable between 1.21% to 5.61%. The relative error is small, which validate the feasibility of this method further.

**Conclusion**

This paper presents a method which is based on momentum-BP neural network to forecast 3S of garage. The layer structure has been selected as the input layer node. The respective maximum von-mises stress and maximum deformation of six nodes in different conditions has been selected as the output layer node. The fast prediction of 3S of the garage has been realized through the training of artificial neural networks. Which not only skips the complicated calculation of the simple model, but also eliminate the need for the full model. The prediction accuracy achieves 3%, and the actual test was 5.28%. Which meets the actual demand and prove the feasibility of this approach.

## References


[1] XU Gening. Mechanical parking system operational design and implementation of structural[M]. Mechanical industry press of china, 2012.

[2] GONG Shuguang, XIE Guilan, HUANG Yunqing. ANSYS parametric programming and Command Peference[M]. Mechanical industry press of china, 2014.

[3] ZHANG Defeng. MATLAB neural network design [M]. Mechanical industry press of china, 2009.

[4] MA Rui. Artificial neural networks [M]. Mechanical industry press of china, 2010.

[5] REN Yujie. Numerical analysis and MATLAB realization [M]. Higher education press of china, 2007.

[6] XU Gening, GAO Youshan. Modeling and optimization of complex structure mapping method based on neural network [J]. Hoisting and conveying machinery, 2005(5).

[7] HAN Dongying, SHI Peiming. Steel structural damage identification based on derrick frequency and BP neural network [J]. Chinese Safety Science Journal, 2012(8).