Folding Reticulated Shell Structure Wind Pressure Coefficient Prediction Research based on RBF Neural Network

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Abstract. In order to make up for the wind tunnel test equipment of folding reticulated shells restrictions which lead to wind pressure data measured on the surface of structure has a low density. This passage based on the basic principle of RBF neural network, using the programming software MATLAB to predict the wind pressure coefficient under three kinds of condition on the folding reticulated shell when the wind speed 20 m/s and wind direction angle is 0 °, 45 ° and 90 °, respectively. The forecast results are compared with wind tunnel tests, and it was shown a good agreement with the test studies. Results show that using the RBF neural network method to predict the wind pressure on the surface of a structure is feasible. Based on the limited wind tunnel test , neural network method is applied to forecast the unknown point of wind pressure coefficient, improve and rich the wind tunnel test data, and provide an effective method for folding reticulated shell structure wind load forecast and analysis.

Introduction

Camping housing structure is a lightweight structure which birth and development in recent years, the folding reticulated shell structure is one of the main forms in camping housing structure system. Camping folding reticulated shell structure which was developed by an engineering institute as shown in figure 1, is a kind of light activity building structure. It use lightweight aluminium alloy folding truss arch as skeleton and canvas for wrapping material. Because the folding reticulated shell is light mass, soft and no foundation, the wind load is one of the control loads in structure design. And according to Chinese architectural structure load standards (GB50009-2012) [1] is unable to provide the shape coefficients of the similar structure to reference.

References [2] and [3] study on the structure under wind load by using a series of theoretical and experimental research and discussion, which has made a lot of progress. In order to get enough data to describe completely structure wind load characteristics in wind tunnel test, usually need to be layout enough pressure tap on the structure's surface, but on the one hand, because the quantity of scanning valve module and the limitation of the acquisition channel make the wind tunnel test synchronous measurement points are often relatively limited, on the other hand because the pressure equipment has certain channels interval at point by point scanning, layout too much pressure tap will lead to the time of single scan all pressure points is too long, which can't meet the "approximation with pacing pressure" hypothesis. Based on these above reasons some complex structure surface wind pressure data insufficient, commonly used method is artificial neural network technology in order to better indicate distribution information of wind pressure field. References [4] studied wind pressure distribution characteristics on the large span flat roof structure by using BP neural network and fuzzy neural network. References [5] predicted the average wind pressure coefficient and fluctuating wind pressure power spectrum on large span flat roof by using neural network method. References [6] using neural network method to predict the wind-induced pressure on large-span stadium roof. References [7] using neural network method to predict average wind pressure coefficient and the fluctuating wind pressure coefficient on low slope roof building. References [8] using neural network method to study the wind characteristics of urban wind environment. And using neural network method to study wind pressure distribution characteristics on complex structure camping folding reticulated shell has not seen.

In this paper, using RBF neural network technology to study folding reticulated shell when the wind speed of 20 m/s and wind direction angle of 0 °, 45 °, 90 ° under three conditions to predict wind pressure coefficient. Combining with wind tunnel test of camping fold reticulated shells structure and the predict wind pressure coefficient compared with measured data to verify the validity of the forecast results. By combining wind tunnel test technique with neural network method, using continuous treatment to discretization data, provide theoretical basis to the structure wind resistance refinement analysis and design.

The basic principle of RBF neural network

RBF neural network belongs to the multi-layer forward neural network, which is usually made of two neurons layer, hidden layer and output layer, as shown in figure 2. Input layer is composed of signal source node, the input layer nodes only pass the input signal to the hidden layer. The number of hidden layer unit depends on the need of problems which we want to describe, and the output layer respond to the input influence. Hidden layer nodes are composed of radial effect function such as Gaussian function, while the output layer nodes are usually simple linear function. Transformation function of hidden units is RBF, which is a kind of local distribution, the center of radial symmetry attenuation, nonnegative nonlinear function. When use BP neural network for function approximation, it has intrinsic defects such as low convergence and local minimum because the negative gradient method is adopted in weight adjusting. While no matter in approximation, classification ability and learning speed and so on, RBF neural network is more superior to BP neural network [9]. Compared to the BP neural network, RBF neural network need more neurons, but its training speed is faster than before. When the number of samples input too many, the effect of RBF neural network is better. RBF network is a kind of local approximation networks, it has been proved that it can approximate any continuous function with arbitrary precision.

In the RBF network learning process, the number of training sample is N, then the total error function for system to all training sample is:

$$J = \sum_{p=1}^{N} J_p = \frac{1}{2}\sum_{p=1}^{N}\sum_{k=1}^{L}(t_k^p - y_k^p)^2 = \frac{1}{2}\sum_{p=1}^{N}\sum_{k=1}^{L} e_k^2 \tag{1}$$

Among them, N is model sample logarithm; L is the number of network output node; t_k^p shows that under effect of sample p the expected output of neuron k; y_k^p shows that under effect of sample p the real output of neuron k.

Figure.1 Folding reticulated shell tent appearance figure

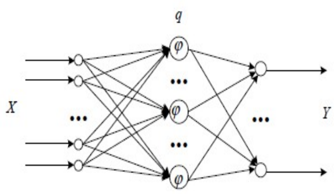

Figure.2 RBF network structure

Learning algorithm of RBF network is divided into two stages: the first stage is an unsupervised learning algorithm, which is a determination stage of hidden layer radial basis function center. Clustering all the input samples to get central vector and generalized constant of the Gaussian kernel function in each node of hidden layer. The second stage is supervised learning, which is a learning and adjustment stage of radial basis function weight. According to the sample, using the least square method to calculate weights w_{ki} of hidden layer and output layer

Methods application

Wind tunnel tests. References [3] perform camping folding reticulated shell structure wind tunnel test in Northwestern Polytechnical University aerofoil research center NF-3 low speed wind tunnel three-yuan test section. The wind tunnel is a 80 m long, the direct closing type wind tunnel all made of steel, the cross section of three-yuan test section is corner cut rectangular, which is 12 m long, 3.5 m wide, 2.5 m high, corner cut is 0.6 m, steady wind speed is 10 ~ 90 m/s, turbulence intensity 0.08%. From 0 ° ~ 180 ° every 15 ° test a set of data, and achieved pressure test about 10 m/s, 20 m/s and 40 m/s three kinds of wind speed, 13 wind directions, 39 working conditions in A wind field environment.

Figure.3 Folding reticulated shell model wind tunnel test

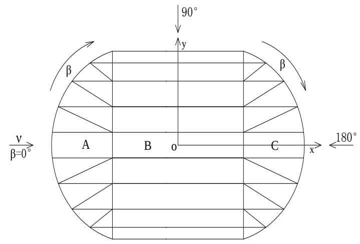

Figure.4 Wind direction and structure division

Camping folding reticulated shell pressure model composed of 20 cm thick board processing, as shown in figure 3, the model scale ratio is 1:15, the test wind direction and structure division as shown in figure 4. In wind tunnel test section model's blocking probability meet the requirements of less than 3%, due to the small size of model. According to the symmetry of model, along transverse symmetry plane, selecting half of the model layout 194 pressure points. In the subject of model along x axis was divided into five sections, each section layout 25 pressure hole in except the edge, on the end door of the model along y axis divided into 14 sections, in accordance with each section longitudinal length distribution layout different number 4 ~ 8 pressure points.

Network training and prediction. Transferring nearby function creates a radial basis neural network in Matlab, namely, RBF neural network model:

Net nearby (*p*, *t*, goal, spread)

Among them, p is representative training sample selected from 194 data of test results, t is the corresponding output sample vector, goal is network error target 0.000001, spread is RBF neural layer spreading constant of 1.0.

Predicting the average wind pressure coefficient for folding reticulated shell when the wind speed of 20 m/s and wind direction of 0 °, 45 ° and 90 ° three conditions, RBF neural network to the training sample simulation and the desired output almost overlap, it shows that RBF neural network training was very successful. RBF network simulate test sample of three conditions, from the point of view of simulation results, most of the predicted results and the test results can match better, the network has good generalization ability, but there are still some individual data errors is big, and the training results and simulation results of overall network can meet the requirements of engineering precision.

Average wind pressure coefficient contour map can be intuitively indicate spatial non-uniformity of wind pressure on the surface of building, can be qualitatively analysis wind pressure distribution on the surface of building. In order to analysis the data of wind tunnel experimental and the predicted results of the neural network, draw wind pressure coefficient distribution of camping folding reticulated shell structure under wind speed of 20 m/s wind direction of 0 °, 45 °, 90 °, respectively , as shown in figure 5, 6, 7.

Using neural network to predict the distribution of average wind pressure coefficient under each wind direction, with wind speed of 20 m/s, and the results compared with wind tunnel test results are almost the same, the position of positive and negative pressure is consistent, only slight differences in values. It shows that neural network prediction can effectively describe wind pressure distribution on the surface of building. Extreme negative value occurred in juncture area with A and B zone under 0 ° wind direction, which is zonal distribution. There are negative pressure zone concentrated in the juncture area of B zone. Negative pressure region constantly shifting with the change of wind direction, extreme negative pressure area gradually focused on the roof ridge. The maximum negative pressure value occurred when the wind direction is 45 °, which has the largest gradient change and is the most unfavorable wind direction Angle. Wind pressure is more easily formed negative pressure zonal distribution in juncture area and roof ridge area at each wind direction, where the gradient is larger. Concentrated wind is more easily formed in the place of the shape which has larger changes and is the adverse area of wind-resistant design, which can cause structural wind-induced damage. It indicates that neural network method can qualitatively reflect the distribution characteristics of wind pressure coefficient and approximate the test results of wind pressure distribution on the structure surface very well under different wind directions, and can well predict the wind load characteristics of wind sensitive parts on the structure, which has a good stability and is very suitable for nonlinear inference and prediction in structure wind engineering.

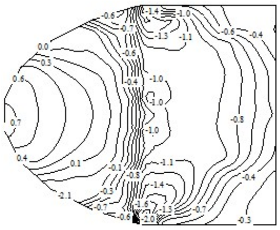

Figure.5 (a) The wind tunnel test of wind pressure distribution under 0 ° wind direction.

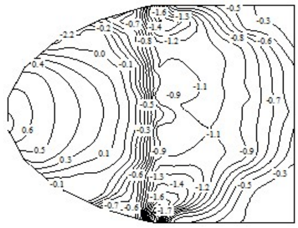

Figure.5 (b) The neural network of wind pressure distribution under 0 ° wind direction.

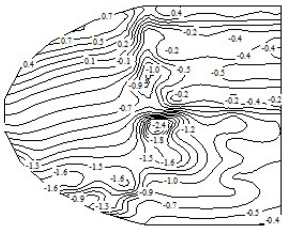

Figure.6 (a) The wind tunnel test of wind pressure distribution under 45 ° wind direction.

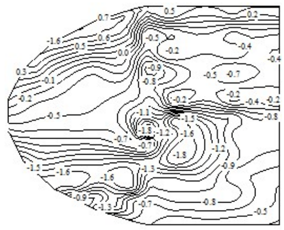

Figure.6 (b) The neural network of wind pressure distribution under 45 ° wind direction.

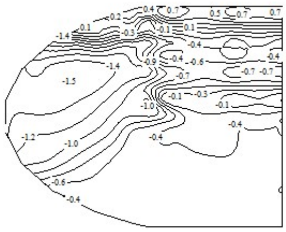

Figure.7 (a) The wind tunnel test of wind pressure distribution under 90 ° wind direction.

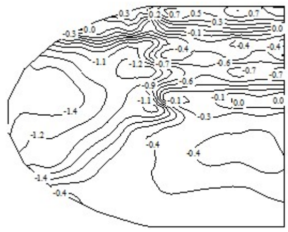

Figure.7 (b) the neural network of wind

Result

We can draw the following conclusion by using RBF neural network to predict the wind pressure coefficient of folding reticulated shell:

The RBF neural network has a good simulation effect on the training sample, which can be in superposition completely on expect output. There is greater error than the training error when simulates the test samples, this indicate that the training model of network need to be further improved.

Using the method of combining RBF neural network with the wind tunnel test is a good way to approach and forecast wind pressure coefficient of camping folding reticulated shell structure under different wind direction, the differences between predicted wind pressure data and experimental data are small. It indicates that RBF neural network method is applied to simulate the characteristics of structure wind pressure distribution, which provide necessary basis for refinement analysis and design on structure wind resistance.

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