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PREDICTION OF UNEVEN DISTRIBUTION OF SNOW LOAD BASED ON GENERALIZED REGRESSION NEURAL NETWORK

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At present, there are mainly three research ways on the distribution of snow load: field measurement, experimental simulation, and numerical simulation. They all need expensive equipment, specimen model used only once, and slight defective simulation software. Artificial Neural Networks (ANNs) are relying on a large number of input functions to estimate unknown or known occurrences. This paper attempts to apply ANNs to predict the uneven distribution of snow loads. First, the snow load database is collected and set up, including all the data from field measurement and experimental simulation. Second, part of the data from the 1m^3 model is used as a training set to train Backpropagation Neural Networks (BPNN) and Generalized Regression Neural Networks (GRNN). The parameters of the two neural networks are determined (such as the smoothing factor in the GRNN) and the rest of the data is used to examine the model; the prediction and measurement results of the two models are compared. Finally, based on different wind direction angles and wind speed, a GRNN model is established to predict the uneven snow load distribution. Through comparative analysis, GRNN is more suitable for predicting the uneven distribution of snow loads, especially in predicting snow thickness. In particular, the prediction effect of the model on the snow load distribution trend is good, and the prediction ability of the neural network model is displayed.

Keywords: Snow height, Backpropagation neural network, Smoothing factor.

1 INTRODUCTION

A neural network is an active and marginal interdisciplinary subject. It is of great theoretical significance to study its background and development process. The prediction problem has been studied and concerned by many domestic and foreign scholars for many years (Fu 2010). Artificial Neural Network (ANN) is a mathematical model that applies information processing similar to the structure of synaptic connections in the brain. It is also often referred to as Neural Networks (NN) or quasi-neural Networks directly in engineering and academia (Li *et al.* 2016). Since the beginning of the 21st century, great progress has been made in the research of ANNs, and research on various aspects of neural networks is increasing. Su *et al.* (2016), in order to expand the application range of typical roof wind tunnel test data, established a wind load prediction model for the long-span spherical roof, which was based on a generalized regression neural network and combined with a typical spherical roof series wind tunnel test.

Nowadays, there are more and more structural damage and collapse accidents caused by snowstorms, causing huge economic losses and casualties. The uneven distribution of snow load, especially for today's more and more buildings with large span, thin shell, and roof as special forms, has a greater impact on structural safety. At present, there are three research methods of snow load: field observation, numerical simulation, and wind tunnel test. Zhou and Gui (2008) summarized and analyzed the research status of these three methods. Li *et al.* (2016) conducted a practical measurement study on snow load on the surface of typical low-rise structures, such as flat roof, arched roof, high and low span roof, and double span and double slope roof. Liu *et al.* (2018) and Zhang *et al.* (2018) measured the distribution of snow around the buildings. Field observation research is indispensable, but field observation also has its disadvantages: heavy workload, high requirements, high cost, and many error-influencing factors. Wang *et al.* (2016) used the fine quartz sand particles to simulate wind-blown snow for a wind tunnel test in order to predict the snow load distribution of roofing. In terms of numerical simulation, the use of CFD technology to analyze wind-induced snow drift has begun to be widely carried out. Xiao (2017) used numerical simulation (CFD) combined with FAE method to study the snow distribution coefficient of the large-span roof structure surface.

In this paper, two neural network models are established, and the prediction results of the two neural networks are compared and analyzed, and the more accurate neural network model is selected.

2 EXPERIMENT

In order to increase the accuracy of the neural network model prediction results and reduce errors, a large amount of data must be provided for the training model, and only high-quality data can guarantee the efficiency, accuracy and other performance of the model. Therefore, before the model is built, a large number of snow load experiments are needed to collect experimental data.

The experimental equipment in this paper includes snowmaker, snow screening machine, 3×2 fan matrix, 4m×3m flat thin wood board, and various wooden models, as shown in Figures 1-4. Among them, the snow screening frequency of the snow screening machine can be adjusted. This experiment considers that as long as the snowfall is sufficient, the snow height can be easily measured, preventing the snow from being too small and the error too large. Snow height is also not one of the experimental variables, so it is fixed to 20Hz. The 3×2 fan matrix can change the wind speed by adjusting the fan frequency, and its wind direction is fixed. In addition, the experimental measuring tools include anemometers, thermometers, hygrometers, and rulers, among others.

For the experiment of uneven distribution of snow load under different wind speeds, this paper adopts changing fan frequency to realize the control of wind speed, so as to achieve accurate control and multi-gradient change of wind speed. Meanwhile, the experiment speed is fast, the efficiency is high, and the accuracy is good. The 1m^3 cube model was placed in the center of the pad, and the pad was taken as the carrier of snow distribution. When the fan frequency was 15Hz, 20Hz, 25Hz, and 30Hz respectively, the snow cover height on the washer 20 minutes after snow fall was measured and the experimental results were recorded.

Since the pad is 4m long and 3m wide, the pad is separated by 5cm in the length and width directions, and the snow height is measured along the length direction and the width direction respectively, so as to ensure sufficient data can be collected. When establishing a coordinate system for data, the width direction of the pad is taken as the x-axis, the length direction is taken as the y-axis, and the origin is set at the center of the pad.

Figure 1. Snowmaker.

Figure 2. 3×2 Fan matrix.

Figure 3. Snow screening machine.

Figure 4. 1m^3 Cube model.

3 PREDICTIVE SIMULATION ANALYSIS OF 1M^3 CUBE MODEL

The structure of the BP neural network model is relatively simple, consisting of one input layer, several hidden layers, and one output layer. The structure of the BP neural network model in this paper is shown in Figure 5. GRNN is composed of four layers in structure, namely input layer, mode layer, summation layer, and output layer. A typical GRNN structure is shown in Figure 6.

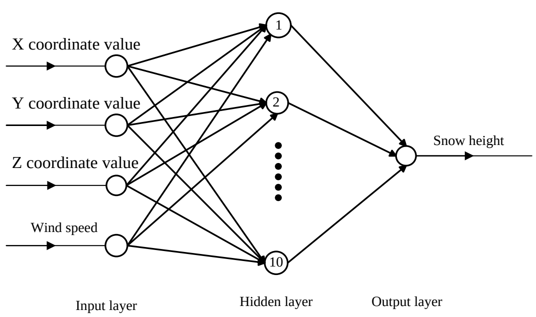


Figure 5. BPNN model.

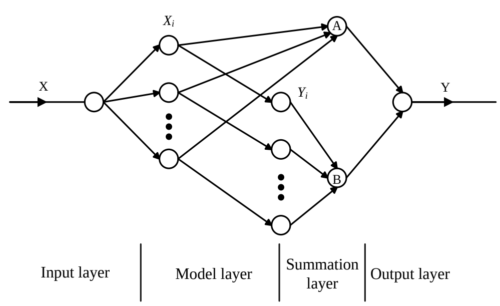


Figure 6. Typical GRNN model.

3.1 Prediction Results with Different Wind Speed

Wind speed is one of the most important factors affecting the uneven distribution of snow load. Therefore, firstly establish a snow load model with only wind speed influence and try to establish a neural network model that can predict the snow load distribution under different wind speeds. Based on the collected snow load experimental data, the snow load distribution prediction model of 1m^3 cube model can be established. Three of the data sets and results corresponding to the four wind speeds are selected as the training sets, and the other one is used as the detection set.

Considering the distribution of snow cover, the overall distribution trend, the peak and minimum values of snow cover height, and the average value of snow cover height are all important indicators. Therefore, for the evaluation of the prediction results, this paper adopts the overall distribution trend of snow cover, the peak (maximum) of snow cover height, the minimum and average value of snow cover height, as well as the correlation coefficient R between the predicted results and the measured results by comparing the predicted results with the experimental results. The expression is shown in Eq. (1).

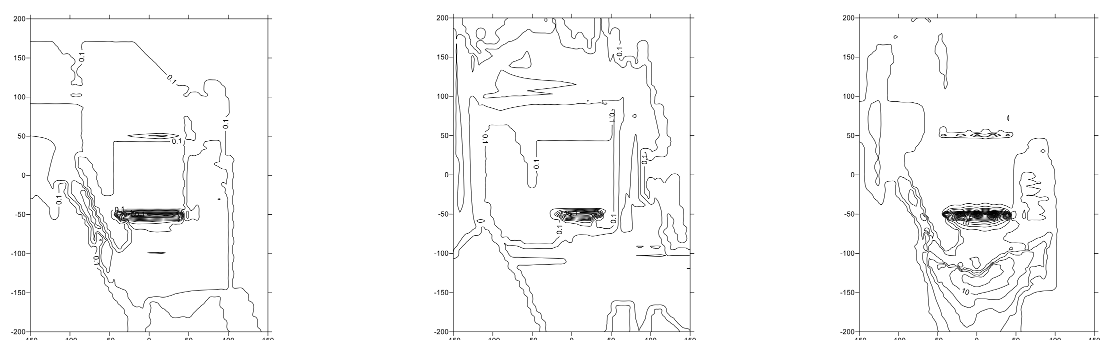
$$R = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot (y_i - \bar{y})^2}} \tag{1}$$

Among them, x_i is the predicted value, y_i is the measured value, n is the sample capacity, $\bar{x}$, $\bar{y}$ are the average of the predicted value and the measured value respectively.

The totals of collected data points of the training set and the predicted output are both 4941. For comparison, the data processing results of the snow load distribution experimental data and the prediction results of the neural network model under different wind speed conditions are shown in Table 1. The snow distribution trend is represented by the contour map drawn by the surfer software; the results are shown in Figure 7.

Table 1. Comparison between neural network model prediction results and measured results (1.5m/s).

		The average value of snow height $\bar{h}$ (mm)	The peak values of snow height h_{max} (mm)	The minimum values of snow height h_{min} (mm)	correlation coefficient R
Measured results		2.42	62.00	0.00	--
Prediction results	BP	2.00	50.21	0.91	0.76
	GRNN	3.60	48.00	0.00	0.78



(a) Measured results. (b) Prediction results of BPNN. (c) Prediction results of GRNN.

Figure 7. 1m^3 model snow distribution trend contour comparison (1.5m/s).

In addition, the cross section where the position where the snow peak appears is found, and the abscissa uses the ratio of the Y coordinate of the measuring point to the span L of the model, and the ordinate uses the ratio of the snow height h of the measuring point to the maximum value h_{max} of the snow depth of the ground area, draw a two-dimensional coordinate map to compare the degree of fitting of the predicted results with the measured results; the results are shown in Figure 8.

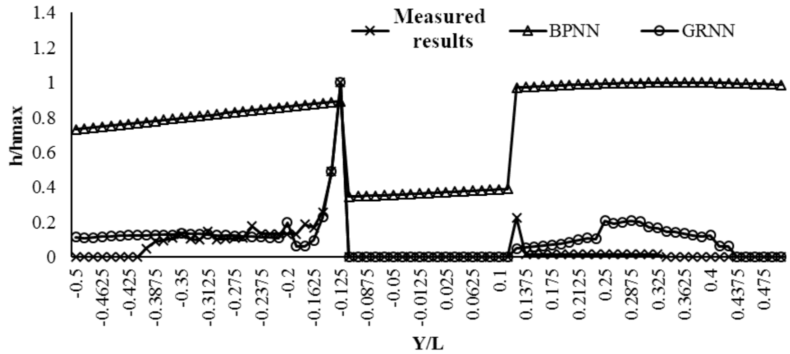


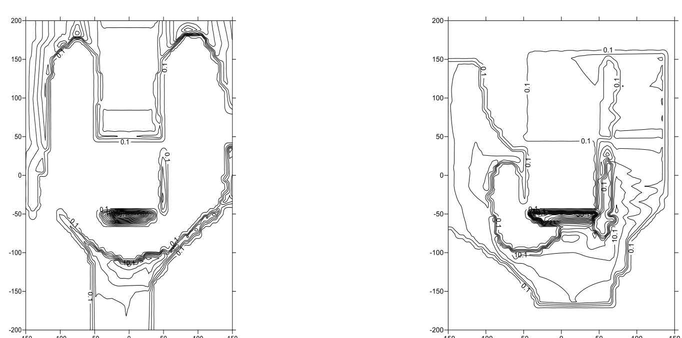
Figure 8. The degree of fitting of the $1m^3$ model prediction results to the measured results (1.5m/s).

3.2 Predictive Analysis of Different Wind Direction Angles Under the Same Wind Speed

The previous predictions of wind speed affecting the uneven distribution of snow load are obtained. Through comparative analysis, it can be seen that GRNN has a better effect on the prediction of snow load distribution. The wind direction angle is also one of the important factors affecting snow load distribution. Therefore, considering the experimental data, a GRNN model for predicting the snow load distribution under different wind direction angles of the same wind speed is established. For the experiment of $1m^3$ cube model, the wind speed is 2m/s, and the wind direction angle has four values, 0°, 15°, 30°, and 45°. Three of the data sets and results corresponding to the four wind direction angles are selected as the training set, and the other one is used as the detection set. Similar to the wind speed prediction model, in this model, the results are shown in Table 2, Figure 9, and Figure 10.

Table 2. Comparison between neural network model prediction results and measured results (0°).

	The average value of snow height $\bar{h}$ (mm)	The peak values of snow height h_{max} (mm)	The minimum values of snow height h_{min} (mm)	The correlation coefficient R
Measured results	1.88	38.00	0.00	--
Prediction results	2.49	34.10	0.00	0.80



(a) Measured results. (b) Prediction results.

Figure 9. $1m^3$ model snow distribution trend contour comparison (0°).

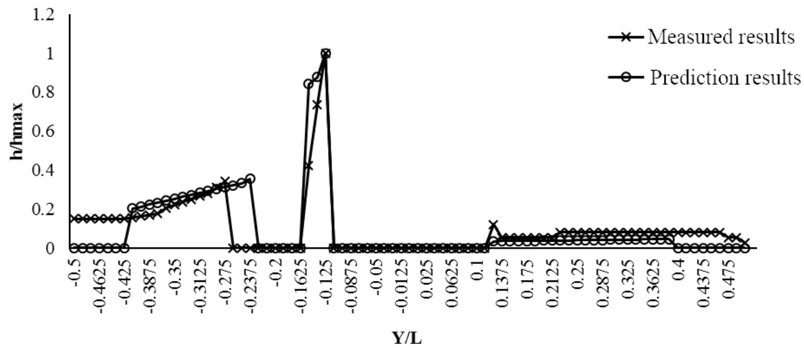


Figure 10. The degree of fitting of the $1m^3$ model prediction results to the measured results (0°).

4 CONCLUSIONS

In this paper, the neural network is used to predict the uneven distribution of snow load. The conclusions can be drawn as follows:

(1) It can be found that it has a good result in predicting the distribution trend of snow load, especially in the prediction of the position where the peak appears. Although there are some errors in the specific values, the errors are also within a certain range and have certain reference value;
(2) Different neural networks have different accuracy for predicting the results. Compared with BPNN, GRNN has better prediction result;
(3) In the case of predicting the same wind speed with different wind direction angles, the generalized regression neural network has a correlation coefficient of 0.80, indicating a high correlation.

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