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Research on Noise Mode Prediction of Air Conditioner Based on Training Neural Network Method

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***Keywords*— Air conditioning, Air-conditioning noise, neural networks**

Abstract*— *This research establishes forecasting models for air-conditioning noise through training-type neural networks, which can improve the accuracy of the forecast, reduce costs and time, optimize system design and improvement, improve user experience and reduce environmental impact. This study uses Matlab to build training neural networks and uses the Levenberg-Marquardt. The results showed that the neural networks built by the training methods and the data and model combination were excellent. Therefore, the neural network to establish the model for the forecast of air conditioning noise has a significant effect for future air conditioner companies in the research and improvement of the noise.

I. INTRODUCTION

Air-conditioning has become an indispensable part of modern society in recent years, with the continuous development of science and technology, and has been applied in almost all parts of the world. It not only provides people with a comfortable indoor environment, but also plays an important role in many areas, such as industrial production, health care, information technology and so on. But as people's quality of life improves, the demand for air conditioning increases, and air-conditioning noise becomes a problem that cannot be neglected [1]. Excessive air-conditioning noise can affect the quality of sleep, resulting in difficulties in getting to sleep, being awake or not sleeping well in the long term; in an office or study environment, persistent noise distracts attention and reduces work and learning efficiency, affecting work and academic performance; in a home environment, excessive noise of air conditioning can affect people's leisure and leisure experiences, making their living environment uninhabitable and reducing their quality of life; persistence of noise stimulus can lead to anxiety, stress and unrest, increasing the risk of mental health problems, especially for children and older people. Excessive air-conditioning operating noise can have a multi-faceted impact on people's lives and work environments, including sleeping noise that can disrupt harmony between neighbours, provoke complaints and disputes, and affect interaction between the community environment and residents; and prolonged exposure to high noise environments can lead to hearing loss, cardiovascular disease and other health problems that have adverse effects on physical health. Users of air-conditioning want to reduce noise, noise as a very important R&D indicator of air conditioning, the developer will include noise reduction as one of the main considerations when developing the air conditioner. So this study hopes to be able to build a training neural network for the noise pattern of air conditioning through Matlab to conduct a training, so that a forecast of the noisy patterns of the air conditioner, and then in the beginning of the R & D design of air-conditioning, to fundamentally reduce the impact of noise on people.

The noise source of air conditioning is mainly due to two aspects, one is the noise generated by the air conditioner during normal operation, and the other is noise produced during the abnormal operation of the air-conditioning [3]. For air conditioning abnormal noise problem treatment, we need to know the source of abnormal noise, judging whether high frequency noise or low-frequency sound, whether continuous or instantaneous sound, electromagnetic or resonance noise etc [4]. Air conditioning is a highly integrated product, in the R&D design of different models of air conditioning consisting mainly of compressors, fans, winds and outlets, pipes and accessories, control boards and circuit components. And the size of the noise is closely related to these air-conditioning components. So there are a lot of factors that cause the noise of the air conditioning [5]. The wind speed is also sometimes the reason why the noise is produced, which is due to the friction that occurs in the process of air flow, mainly from the wall of the pipe, vent and valve, and when the speed of the wind will become bigger, which leads to noise increases, so the size of noise at the time depends mainly on the amount of wind speed [6].

The issue of neural network validation was first raised in 2010 by Pulina and others, who used a neural input-based separation refinement method, and used the ideas and techniques of the formalization method for the first time in the safety assessment of the neural networks [14]. The development of neural networks dates back to the 1950s, but breakthroughs have only been made in recent years. The sensor is one of the earliest models of a neural network, proposed by Frank Rosenblatt in 1957. It is a simple one-layer neural network that can be used for binary classification problems [15]. The introduction of the sensor attracted widespread attention from the academic community and industry, but due to its limitations, if only solve the linear divisibility problem, resulted in later gradual elimination. After the study of sensors was eliminated, neural networks entered a hibernation period, due to the lack of effective training algorithms and computational resources, and the suspicion of neural network capabilities. In the late 1980s and early 1990s, the introduction of reverse transmission algorithms reignited the enthusiasm for neural network research [16]. This algorithm allows the Multi-Layer Perceptron (MLP) to be trained to overcome the limitations of the sensor. The results of this period include Backpropagation Through Time (BPTT) and Levenberg-Marquardt. During this period, Multi-Layer Perceptron (MLP) were widely used, especially in the fields of finance, medicine, and speech recognition. In addition, some important algorithms and models such as Support Vector Machines (SVM) and Gaussian Mixture Model (GMM) have been proposed and applied. With the continuous improvement of computing capabilities and the development of big data technology, deep learning has begun to emerge [17]. The introduction of Convolutional Neural Networks (CNN) promoted the development of the field of computer vision, and the application of circular neural network such as Long Short-Term Memory (LSTM) contributed to the advancement of natural language processing.

II. USING MATLAB TO BUILD A NEURAL NETWORK FORECAST MODEL

This study uses Matlab to build a neural network forecast model. first of all, processing the noise data, and then to the Levenberg- Marquardt, the Bayesian Regularization, and the Quantitative Conjugate Gradient were compared, and used by the Levenberg- Marquardt method trains air-conditioning noise data, discusses the results, losses, training performance and learning rate of the model, analyzes the matching effects of the data and the model and exports the results chart.

2.1 Noise data processing formula

The formula for noise calculation can vary depending on the source of noise and the specific situation. Here are some common noise calculation formulas and their application scenarios:

(1)Sound Pressure Level (SPL):

$$\mathrm{SPL} = 20\log_{10}\left(\frac{p}{p_0}\right) \tag{1}$$

p is the sound pressure, and p_0 is the reference sound pressure (generally taken as the standard atmospheric pressure, approximately 20 micropascal).

(2)Sound Power Level (SWL):

$$\mathrm{SPL} = 10\log_{10}\left(\frac{w}{w_0}\right) \tag{2}$$

w is the sound power, and w_0 is the reference sound power (generally taken as 10^{12} watt).

(3)Total Sound Level:

The total sound level can be obtained by adding the sound pressure level of each sound source, with the formula as follows:

$$L_{total} = 10\log_{10}\left(\sum_{i=1}^{n} 10^{\frac{L_i}{10}}\right) \tag{3}$$

L_i is the sound pressure level of the first i sound source, and n is the number of sound sources.

(4)Weighted Sound Level:

The calculation of air-conditioning noise usually involves factors such as acoustic parameters and the working state of the air conditioning system.

$$L = L_r + 10\log_{10}\left(\frac{Q}{Q_r}\right) + K \tag{4}$$

L is the total sound level of air conditioning (units: decibels, dB); L_r is the reference sound level, usually for the basic noise level when the air conditioner is not working (unities: decibel, dB); Q is the amount of cooling or heat generated by air conditioners under a specific operation condition (unity: power, usually in watts); Q_r is the quantity of reference cooled or heat produced, typically for the cooling quantity or heating generated under the condition of air-conditioning design (unit: energy, W); K is the specific adjustment coefficient of the climate system, taking into account the effects of the various factors of the air- conditioning system on the noise.

2.2 Artificial Neural Network

Artificial Neural Network (ANN) is a mathematical model for information processing based on the simulation of the neurosynthesis connected organs of the human brain [11]. A class neural network is a machine learning model inspired by the human nervous system. It consists of a large number of artificial neurons (also known as nodes or units) that transmit and process information through connections [31].

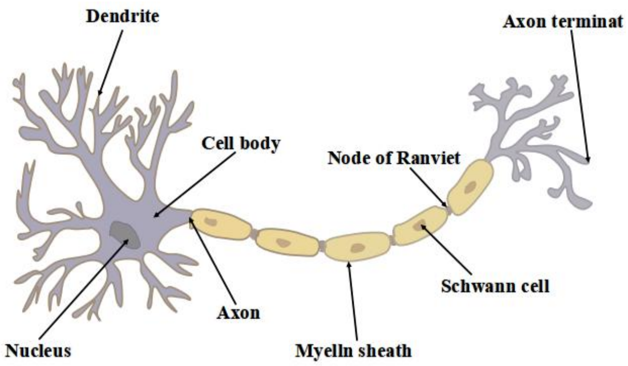

Fig. 1 Neural

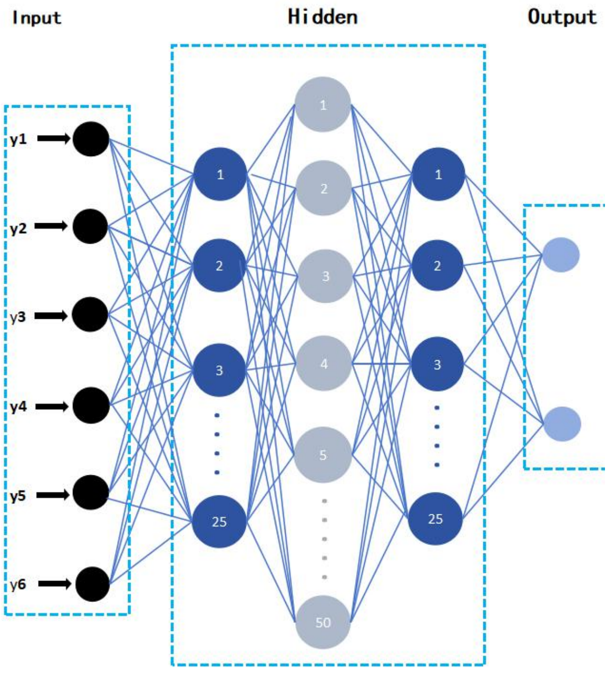

Fig. 2 Artificial Neural Network

In observing the results of neural network training, common evaluation indicators include Mean Squared Error (MSE) and Correlation Coefficient (R). These indicators can be used to assess the predictive performance and suitability of models.

(1)MSE:

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y_i - y_i')^2 \quad (5)$$

n is the number of samples, y_i is the real value, y_i' is the predicted value.

The smaller the MSE, the better the model matches the data.

(2)R:

$$R = \frac{\sum_{i=1}^{n}(y_i-\bar{y})(y_i'-\bar{y_i'})}{\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2\sum_{i=1}^{n}(y_i'-\bar{y_i'})^2}} \quad (6)$$

$\bar{y}$ and $\bar{y_i'}$ are the mean values of true values and predicted values, respectively.

R has a range of values ranging from 1 to 1, near 1 represents positive, near 1 is negative and near 0 is irrelevant.

III. BUILD A MODEL WITH MATLAB

Compare the regression performance of the three training methods: the Levenberg-Marquardt, the Bayesian Regularization, and the Quantitative Conjugate Gradient, the Levenberg- Marquardt, the Bayesian Regularization , and the Quantitative Conjugate Gradient, have Correlation Coefficient R of 0.99519, 0.99913 and 0.98809, respectively, so the Levenberg-Marquardt method predicts better. This study uses Matlab to apply the Levenberg-Marquardt method is used to build training neural networks.

3.1 The Levenberg-Marquardt

Levenberg-Marquardt (LM) is an optimized algorithm for training neural networks, commonly used for regression problems and multi-layer forward input networks. It is a gradient-based algority that combines the advantages of the Steepest Descent Method and Gauss Newton method, and is widely used in practice in training regression issues and multilayer neural network [32]. It can rapidly converge to local optimum solutions, and has faster convergence rates, better stability and robustness [19].

Here is the formula for the LM algorithm:

(1)Objective Function:

Objective Function is usually expressed as a loss function or cost function, used to measure the difference between the model's forecast value and the real label.

$$L(w) = \frac{1}{2N}\sum_{i=1}^{N}(y_i - f(x_i, w))^2 \quad (7)$$

N is the number of samples, y_i is the real label, $f(x_i, w)$ is the predicted value of model for sample x_i, and w is the model parameter.

(2)Gradient Function:

Gradient Function represents the gradient of the target function with respect to the parameter, which is used to guide the direction of the updated parameter.

$$\nabla L = -\frac{1}{N}\sum_{i=1}^{N}(y_i - f(x_i, w))\nabla f(x_i, w) \quad (8)$$

(3)LM Step:

The LM Step is the step length of the parameter update in Levenberg-Marquardt, which achieves rapid convergence and stability through Balanced Gradient Descent and Newton Method.

$$\Delta w = (J^T J + \lambda I)^{-1} J^T \delta \quad (9)$$

J is the jacobic matrix of the target function, λ is the adjustment parameter of the LM algorithm, and δ is the gradient of the goal function.

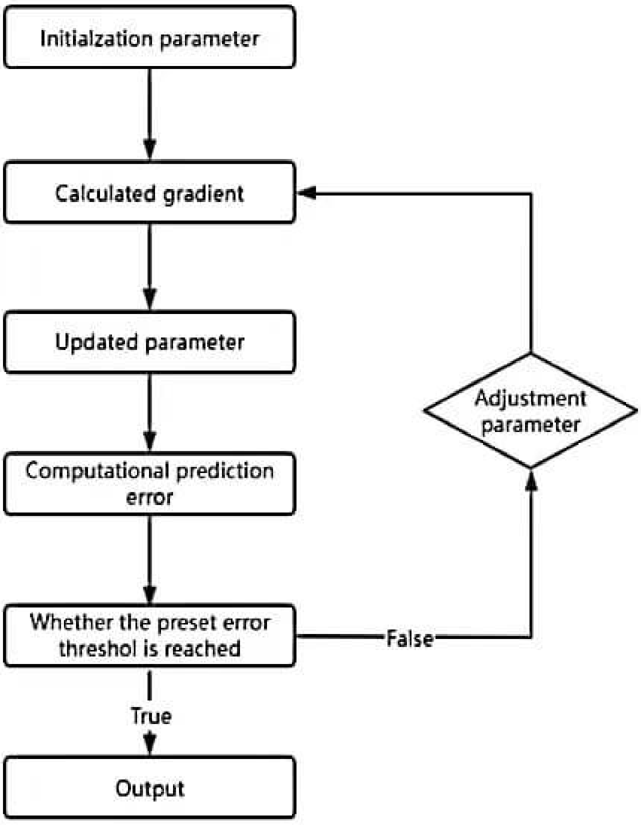

Fig.3 Flow chart of Levenberg-Marquardt

Combine raw data, and LM algorithm formula. LM training results are as shown in Figure 4, from which the LM method neural network model is comparatively good; LM training losses are like Figure 5, the gradient of the training loss curve is 0.23222 which means that the loss function has decreased by an average of 0.23222 units in each iteration; the performance of LM mode Artificial Neural Networks is like Figue 6, which is gradually closer to optimum performance after the eighth round of training, and at the tenth round achieves the optimum validation performance, as shown by Figure 16, generally overlapping with the optimal performance value; the learning rate of the LM method is as shown on Figure 7, from which it is shown that the rate of learning of this Neural Network training model is 0.001; and the validation failure (LM validation Fail) as shown at Figure 8, means that verification failure occurred in the sixth training cycle.

Training result

Training start time: 2024-05-08 17:14:20

Layer size 10

	Observed Values	MSE	R
train	56	0.1178	0.9970
Verification	12	0.1708	0.9972
Tests	12	0.5681	0.9760

Fig.4 LM training results

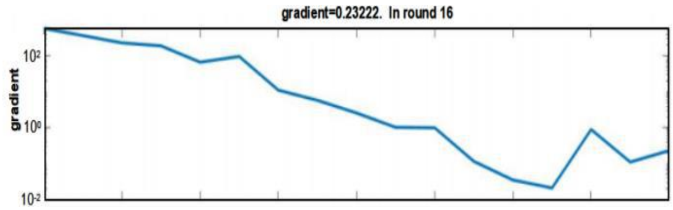

Fig.5 LM training losses

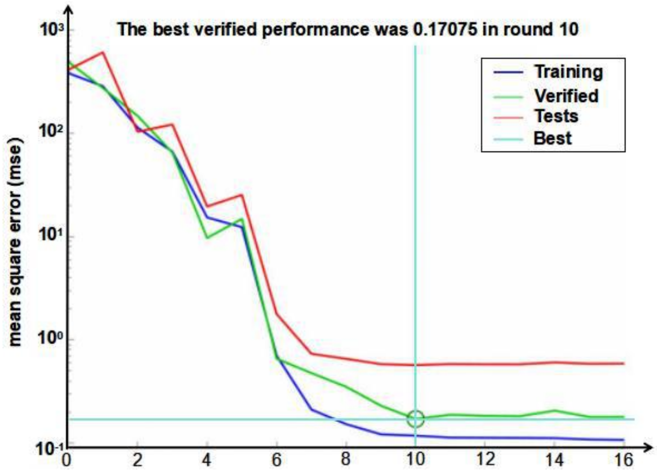

Fig.6 The performance of LM mode Artificial Neural Networks

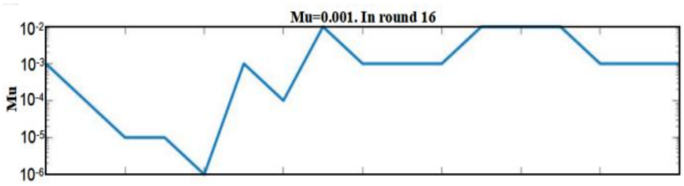

Fig.7 The learning rate of the LM method

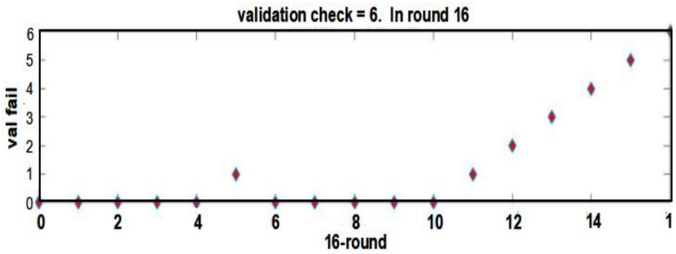

Fig.8 LM validation Fail boken line graph

IV. ARTIFICIAL NEURAL NETWORK TRAINING RESULTS

as shown in Figure 9; verification regression related cofficient is 0.99717, as shown on Figure 10; test regression related coefficent is 0.97599, as shown at Figure 11; total regression related cofficent is 0.99519, as seen in Fig.12.

Neural network training regression diagrams are commonly used to show the relationship between the predicted results of a model and the actual target value to help users evaluate the performance of the model in the regression task. By observing the neural network training regression diagram, users can intuitively understand the performance of the model in the regression task, including the accuracy of the prediction, the degree of deviation and the adjustment effect. This helps to assess the performance of the model, identify problems with the model and guide further model adjustment and improvement. It is not difficult to see through the following regression diagram that the predicted value of the neural network training model based on the LM method and the linear correlation between the actual observation values is very high, close to 1, indicating that the model has a high degree of adaptation on the training data, the prediction and optimization of air conditioning noise has a good effect.

Thus, the R value of 0.99519 represents a high level of linear correlation between the model's predicted value and the actual observed value, indicating that the model has a very good matching effect in the regression task. This means that the model is very similar to the trend between the predicted value and the actual value, can accurately capture the change in the target variable, and has a high predictive ability.

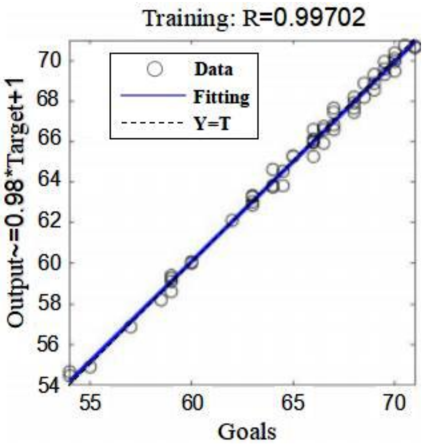

Fig.9 Training regression grap

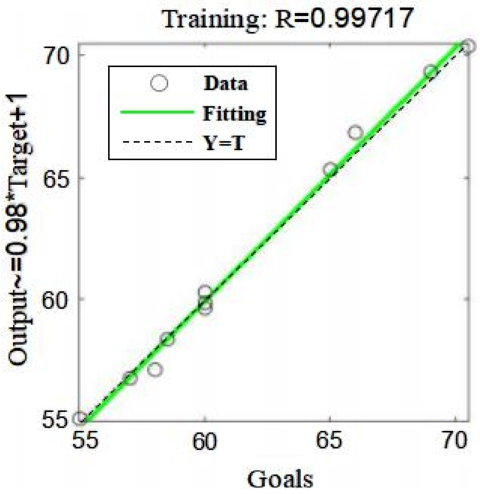

Fig.10 Verification regression grap

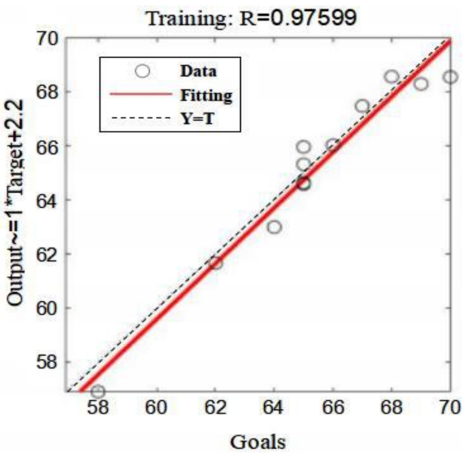

Fig.11 Test regression grap

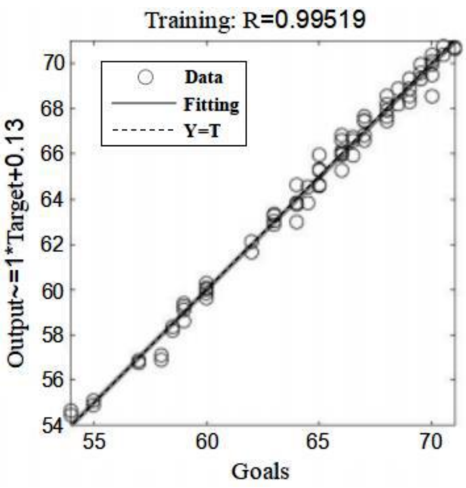

Fig.12 Regression grap

V. CONCLUSION

The conclusion of the Levenberg-Marquardt method training on neural networks is that the model works well on the training data, and there is a high linear correlation between the predicted value and the actual observed value. It should be noted, however, that these conclusions are based solely on the performance of the training data and that generalization performance also requires further evaluation in the validation set or test set to ensure that the model performs well on unprecedented data.

It should also be noted that after the completion of Artificial Neural Network training, a comprehensive evaluation and validation of the model is required and the model and training strategy is adjusted according to the evaluation results to ensure that the model achieves the desired effect in practical applications. You can reasonably design the air conditioning system wind path, selecting the appropriate installation position to reduce the effect of static pressure on the air-conditioning noise. On the one hand, increasing the wind volume can increase the efficiency of air flow and improve the performance of the air-conditioning system; on the other hand, measures such as optimizing the wind path design, using noise-reducing materials, choosing a low-noise fan, etc., are needed to reduce the impact of wind volume on noise.

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REFERENCES

[1] Lu Zhiyun. (2014). Studies on sources, diagnosis and noise reduction of air-conditioning noise. Scientific and technological perspectives (13), 103.

[2] Qiu Song. (2015). Noise analysis and control methods of air-conditioning indoor machines. Technological innovation and applications, (20), 152.

[3] Zhou Yuan Huang. (2014). Experimental methods of control of air-conditioning noise. Science and Technology, (19), 101+203.

[4] Chen Tian Zheng. (2021). Home appliances central air conditioning operation noise problem light analysis. Cooling, 40 (03), 45-49.

[5] Liu Pyeong-woo & Huang-wi-chao. (2017). Comfort assessment of air-conditioning noise. Science and Technology Horizons (06), 323.

[6] Chen Zhi Bing. (2020). Engineering noise control technology for the air-conditioning system of the Nantong Theatre. Construction materials and decoration, (03), 221-222.

[7] Chen Wing, & Wang Dang. (2016). Research on new methods to reduce air-conditioning noise. Science and Technology Vision, (14), 154.

[8] Liu Ming & Liu Liu. (2011). Analysis of improved indoor air-conditioning noise exploration. Home appliances technology, (07), 62-63.

[9] Churchill. (2019). Central Air Conditioning Noise Sources and Noise Reduction Initiatives. Electronic World, (15), 192-193.

[10] Liu Yuan & Zhao Huangmin. (2017). An experimental study to improve air-transmitting noise in the air-conditioning system. Daily electrical appliances, (07), 55-57.

[11] Liu Zhao, Liang Kai-won, Dong-kin-ring. (2024). Construction of a financial early warning model for listed companies based on artificial neural networks. Operations and management, (03), 69-77.

[12] Chen Zhi Li, Liang Shui, Li Khao Ho, etc. (2023). A comparative study of DLC synthesis performance predictions based on different neural networks. Vacuum Science and Technology Journal, 43 (08), 665-673.

[13] Mariah Carey. (2024). Neural Networks Application Analysis in Crop Water Demand Estimates. Intelligent Agriculture Guide, 4 (09), 9-12.

[14] Liu Sheng Xin, Yang Pong Fei, Zhang Liu, etc. (2024). Complete Neural Network Authentication Acceleration Technical Overview. Software Paper, 1-31.

[15] Pennington Conan. (2020). Low-pressure circuit breaker health monitoring and failure diagnostics research (master's thesis, Hubei Industrial University).

[16] Cao Cao Lin. (2019).Deep learning based wireless network traffic prediction (master's thesis, Xi'an University of Electronics and Technology).

[17] Shri Qian & Sun Huang. (2009). Speaker-identified study based on the SMM-GMM hybrid model. Helioguan Engineering Institute Journal (Natural Sciences Edition)

(04), 54-57.
[18] Hong Xiaodong, Dong Huang, Lin Meeking, etc. (2023). Graphic neural networks predict the thermodynamic properties of molybdenum. Journal of Chemical Engineering, 74 (11), 4466-4474.
[19] The Holy Army. (2024). Parallel electrophysical analysis based on Levenberg-Marquardt reactions. Technical Journal of the Jiangsu Institute of Architecture, 24 (1), 15-20.
[20] Huang Pei, Lin Seong, Shen Tian Tao, etc. (2023). Based on the Bayesian normalized LSTM model, the per capita GDP forecast results – for example, in Fujian Province. Economic and Trade Times, 20 (6), 140-144.
[21] Guo Haishim, Zhou Shi, Liu Pei, etc. (2024). Progress in the application of artificial neural networks in the field of mass spectrum. Artificial Intelligence, 1-10.
[22] Chur, Yuan Yuan, Umbrella Ice. (2024). Based on improved experience of molecular decomposition with BiLSTM neural networks, low-end house atherosclerosis timescale forecast. Journal of the University of Hunan (Natural Sciences Edition), 1-12.
[23] Liu, J., Wen, X., & Jian, S. (2024). Toward better equity: Analyzing travel patterns through a neural network approach in mobility-as-a-service. Transport Policy, 153, 110-126.
[24] A.V. F., O.K. S., & V.P.G. (2024). Multigroup Classification of Firing Pin Impressions with the Use of a Fully Connected Neural Network. Programming and Computer Software, 50 (1), 73-84.
[25] Zhang, D., Lv, H., Yan, S., et al. (2024). Multi-objective neural network modeling and applications to microwave power amplifiers. Microelectronics Journal, 149, 106244.
[26] Double, & High Tree Shine. (2024). Research on design and application of heating and air-conditioning energy-saving systems. Technological innovation and applications, 14 (13), 132-135.
[27] Shao Meeling, & Wang Chenglong. (2023). Shandong Industrial Technology, (01), 100-103.
[28] Liu Xiaoping, Du Qingdao, Zhang Into the East. (2015). Paper-oriented identification method based on BP neural networks. Computer Applications and Software, 32 (11), 176-179.
[29] Nguyen. (2023). The study of the technique of selection of the external quality of tomatoes based on the enveloping neural networks. Xinjiang Agricultural University.
[30] Hshu Hui, Li Zhi Jing, Li Yuan, etc. (2023). Remote sensing image classification based on cost-sensitive convoluted neural networks. Computer applications and software, 40 (05), 253-261.
[31] Yellow Valley. (2020). Identity certification studies based on step information (master's thesis, University of Electronics and Technology).