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ARTICLE

RESEARCH AND APPLICATION OF BP NEURAL NETWORK IN PREDICTING FABRIC PROPERTIES

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ABSTRACT

This paper introduces the characteristics of BP neural network. The latest research achievements of BP neural network in predicting fabric properties are discussed in detail, such as predicting fabric heat transfer performance, evaluating fabric formability grade, predicting cotton fabric drapability, predicting fabric tensile properties, fabric feel evaluation, predicting cotton fabric permeability, quality prediction and process control of worsted fabric finishing, temperature perception of touching fabric, and evaluating cotton fabric feel. At the same time, as discussed with BP neural network, it will have more application prospects in predicting fabric properties.

KEYWORDS

BP Neural Network; fabric property; predicting

1. INTRODUCTION

Artificial neural network is a newly developed interdisciplinary new edge discipline. It is a technology to simulate the structure and functional characteristics of the human brain neural network using engineering technology. It has outstanding learning adaptive, fault tolerance, associative memory ability, and other characteristics, which can effectively solve complex nonlinear problems in the textile industry. It has been widely used in textile research, such as successfully optimizing the spinning process, fabric defect identification, fiber and fabric identification, pilling rating, calculation of dye uptake, and garment processing and production.

Artificial neural network simulates the characteristics of human brain structure and intelligence and is composed of a large number of simple neurons. Solving problems does not require an accurate model of the object, but only requires a large amount of original data. Through the variability of its structure, it gradually adapts to external effects, excavates the internal causal relationship of the object, and finally describes it with an imprecise input and output value. At present, hundreds of neural network structures and algorithms have been developed and utilized, and representative artificial neural networks include feedforward neural networks. For the textile field, the feedforward neural network and BP algorithm can solve most of the application problems.

2. BP NEURAL NETWORK STRUCTURE AND ALGORITHM

Since the feedforward neural network uses the famous BP algorithm, the feedforward neural network is also called BP neural network. BP neural network is a feedforward and learning algorithm widely used in the textile industry, and it is an artificial neural network of Back-Propagation. Its network generally consists of an input layer, an output layer, and one or more hidden layers. Each layer contains several neurons, and the neurons between layers are interconnected by nodes, as shown in Figure 1:

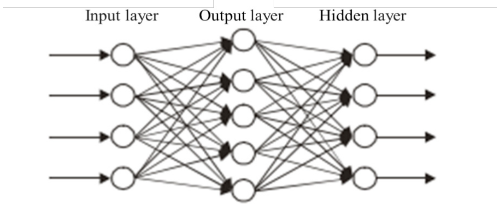

Figure 1: Three-layer BP neural network structure

2.1 Working principle of BP neural network

Data is input into the input layer of the network, and the input layer unit receives the input signal and calculates the weight. The result is forward propagated to the hidden layer node via the transfer function and the output signal of the hidden node is propagated to the output node. Finally, the output result is obtained. Its learning process consists of forward-propagation and backpropagation. In the forward-propagation process, the input information is processed layer by layer from the input layer through the hidden layer and propagated to the output layer. The state of neurons in each layer only affects the state of neurons in the next layer. If the output layer does not get the desired output, it turns to backpropagation. At this time, the error signal propagates from the output layer to the input layer, and the connection weight coefficients and thresholds of neurons in each layer are adjusted along the way so that the error signal is continuously reduced.

2.2 BP learning algorithm

(1) Initial weights and thresholds

(2) Given input x and target output y

(3) Calculate the actual output y

$$y_j = f\left(\sum_{i=0}^{n} W_{ij} X_i\right) j = 1,20...n \quad (1)$$

(4) Correct the weights. From the output layer, the error signal back is back propagated along the connection path, and the error is minimized through the modification of the weights;

$$W_{ij}(t+1) = W_{ij}(t) + \eta\delta_{pj} y_j + \alpha\left[W_{ij}(t) - W_{ij}(t-1)\right] \quad (2)$$

Where: W_{ij} is the weight between the i and j layers of the connection point; η is the step size; t is the number of weight corrections; α is the momentum factor; the difference with the system output y_j is directly obtained.

2.3 BP neural network prediction model establishment

(1) Design of input and output layers

According to user requirements, each fabric structure parameter or the specific performance index to be solved is used as a neural unit of the input or output layer. The difficulty of its design is the determination of the number of nodes as too many nodes will cause interference and it will be difficult for too few nodes to achieve accuracy or increase the number of models.

(2) Number of hidden layers

In fact, different numbers of hidden layers can be used, but any continuous function in a closed interval can be represented by a BP network with one hidden layer.

(3) Determination of the number of hidden layer processing units

Adopting appropriate hidden layer processing units is the key to the success or failure of the model, and the selection of the number of hidden layer units is a very complicated issue. Although there is no accurate theory and method at present, there is always an optimal number of hidden units, and the specific determination can only be determined in the experiment according to the length of training time and the required accuracy balance. For a three-layer network, it can be obtained from experience: the number of hidden-layer processing units = n+m+α, where n and m represent the number of input and output units respectively, and α is a constant between 0 and 10. But in fact, we started with fewer intermediate processing units, which was determined by repeatedly evaluating, training, and performance testing.

(4) Initial weights

The weights are generally random numbers, and the weights are required to be relatively small so that each neuron can be guaranteed to start at the place where its conversion function changes the most.

2.4 Data sources and processing

The selection of experimental samples is closely related to the establishment and training of the model. In general, the selected samples should be extensive and random so that the data obtained are likely to contain the full pattern of the problem.

The specific physical quantity is measured by the corresponding physical evaluation instrument or tester, because the input and output data have different units and large differences in the quantity level, which affects the training of the neural network. To eliminate the influence of the input data on the error due to the magnitude difference, it is often necessary to linearly transform the input data so that the value range is between -1 and 1. In addition, the data is selected to include the minimum and maximum values of each parameter, so that the trained network has the best effect.

2.5 Network training and model validation

According to the network model and data processing method established above, dozens of groups of data are selected as training samples, and several groups are selected as test samples. The neural network toolbox in MATLAB is commonly used to set various parameter indicators of the neural network, and the neural network is trained through dozens of groups (such as 60 groups) of input and output data until the minimum error squared sum is reached. Often after the BP neural network model is established, its prediction accuracy needs to be further verified.

3. TYPICAL APPLICATIONS FOR PREDICTING FABRIC PROPERTIES

3.1 Predict the heat transfer properties of fabrics

The heat transfer performance of fabrics is one of the important indicators to evaluate the comfort of clothing. Fiber properties, yarn structure and properties, and fabric structure and properties all affect the heat transfer performance of fabrics, and there is a complex nonlinear relationship among them. There are many different modeling methods for predicting the heat transfer properties of fabrics, such as mathematical modeling, empirical modeling, computer simulation modeling, and artificial neural network modeling. Among these modeling methods, it is found that the artificial neural network is one of the more effective methods for predicting the properties of fabrics; Kong et al. mainly conduct in-depth research on the neural network to solve the problem of fabric heat transfer [1]. The neural network model is established by computer, the optimal network parameters are selected, and the network is trained. A method for processing experimental data is proposed through application examples. A large number of BP networks is established for comparison to improve the training speed and simulation accuracy so that the network with the most application value can be selected.

3.2 Identify the formability of apparel fabrics

Clothing fabric is the foundation of clothing composition and the key factor to reflect the artistry of clothing products. For a long time, the design of the formability and other properties of clothing fabrics and the evaluation of the formability and other properties when selecting fabrics are mainly based on experience, which can no longer meet the current actual needs. BP artificial neural network has the advantages of solving multivariate and nonlinear problems and has the characteristics of self-learning, fault tolerance, strong classification ability, and parallel processing. Using fabric samples to train and learn the neural network, the neural network system can predict the forming effect of the fabric according to the basic mechanical properties of the fabric for a certain clothing style, which can play an important role in improving the grade of the fabric and clothing.

In the research by Sun et al., fabrics are randomly selected as the training samples of the network [2]. The 11 basic mechanical performance indexes and corresponding grades of fabrics are used as input and output modes respectively to train the network. After training, a network is established to obtain the network evaluation level of the training sample, and then the performance of the BP network is tested with the remaining fabrics. Ratings are then used to test the performance of the BP network with the remaining fabrics. After multiple pieces of training, the BP neural network can effectively predict the appearance and performance level of the fabric for determining the type or style of clothing. Compared with other discriminant methods, the BP neural network system has the advantages of accuracy, convenience, and simplicity in identifying the appearance and modeling performance of clothing fabrics.

3.3 Predicting fabric drape properties

The drape property of the fabric reflects the appearance of the garment to a certain extent and is especially important for skirt garments. The fabric drape coefficient is a synthesis of some mechanical indexes of the fabric to a certain extent, and it has become an indispensable index for evaluating the style of the fabric. Cao takes cotton fabrics as an example to discuss the influence of fabric structure factors such as warp and weft yarn specificity, warp and weft tightness, total fabric tightness, fabric thickness, and fabric surface density on the drape [3]. It is difficult to describe the relationship between the fabric structure parameters and their drape coefficients by traditional mathematical and mechanical methods due to the nonlinear relationship between the parameters of the fabric structure and multiple influencing factors, which together have an effect on the drape of the fabric. Therefore, a three-layer neural network model is established by using BP neural network technology to train the relationship between fabric structure parameters and fabric drape performance. The comparison between the predicted value and the experimental value shows that the neural network method has considerable accuracy in predicting the drape performance of cotton fabrics. This lays the foundation for the further study of BP neural network technology in the drape performance of fabrics and provides the basis for the selection of fabric design.

3.4 Predicting fabric tensile properties

Research on predicting the mechanical properties of fabrics has a long history. The guiding ideology is that the mechanical properties of fabrics are obtained from yarn parameters and fabric structural parameters. Generally, a simplifying assumption is made on the fabric structure, the geometric structure model of the fabric is abstracted, and the mechanical properties of the fabric are obtained by using the mechanical properties of the yarn. These studies have gradually developed into two types of methods: force method and energy method. However, the accuracy of these two methods is poor when the linearly elastic strain range is exceeded, the application methods are complicated, and the adaptability to fabrics in various modulus ranges is poor.

The fabric structure parameters include fiber properties, yarn structure and properties, and fabric structure, which are specifically expressed as the following indicators: warp and weft tensile curves and fabric structure parameters (including warp and weft density, warp or weft interweaving curve). These indicators jointly affect the tensile properties of plain weave fabrics, and there is generally a complex nonlinear relationship between them and the tensile properties of fabrics.

Mei et al. use the neural network to establish the relationship among yarn mechanical properties, fabric structural parameters, and fabric tensile properties, showing the application process of this method in the study of fabric tensile properties, and laying the foundation for further research [4]. According to the experimental requirements, the method adopts a three-layer BP neural network structure and inputs 8 neurons, including warp load value, weft load value, warp elongation value, weft elongation value, fabric warp density, fabric weft density, fabric warp weave angle, and fabric weft weave angle values. There are 4 output neurons, including fabric warp load value, fabric weft load value, fabric warp extension elongation value, and weft elongation value. The number of neurons in the hidden layer is determined according to the size of the error generated when the neural network model of each point is trained. The training results show that when the number of hidden units of the prediction model is from 6 to 9, the performance of the network is better.

3.5 Evaluate fabric style

Fabric style is a property that people evaluate by feel. It is also the combined effect of the material, structure of the fabric itself and all its physical and mechanical properties acting on the human senses. Therefore, the fabric style has become the product of the interaction between the objective characteristics of the fabric itself and the subjective feelings of people, and it has become an extremely complex, abstract and difficult to express concept containing physical, physiological and psychological factors. For many years, sensory evaluation of fabric style has been used, that is, the subjective consciousness of experts plays a decisive role in the evaluation of fabric style. Although this evaluation method is authoritative, it is not easy to operate and difficult to master. Numerous researchers at home and abroad have carried out extensive research on fabric style from mechanism to evaluation using various methods. Among them, the most famous is the Kawabata method headed by Japan's Kawabata Yoshio. According to the degree of closeness and distance of fabric mechanical index, other scholars choose the fuzzy clustering method, systematic clustering method, and other methods. These studies mainly focus on the relationship between the physical and mechanical properties of fabrics and fabric style and establish a mathematical model of fabric style on mechanical properties. However, there is a strong subjective consciousness in fabric style evaluation, so these methods have certain limitations in practical application.

Dong et al. analyzed the relationship between the physical and mechanical properties of fabrics and the style of wool fabrics by neural networks and simulated the nonlinear relationship between them. After many times of training, it is found that the network has a strong pattern recognition ability so that it can effectively evaluate the style of wool fabrics. BP neural network has strong self-organization and self-adaptive ability, so it has strong adaptability to the change of subjective evaluation of wool fabric style. According to actual needs, training on different learning sample sets can adapt to pattern recognition under specific conditions. This has certain advantages compared with previous style assessment models. However, the accuracy of the system needs to be trained with more experimental data, so that it can be continuously improved.

Up to now, the application of artificial neural network technology in wool fabric style assessment is still in the preliminary stage, especially since there are few related types of research in China. However, the characteristics of artificial neural network technology will surely be paid more and more attention by more and more textile technicians, so that the technology can be combined with textile technology and widely used in fabric style assessment.

3.6 Predict the breathability of fabrics

The air permeability of the fabric is mainly realized by the fiber pores between the yarns and the yarns. Xu et al. used the Hagen-Poiseuille formula to discuss the air permeability between the yarns in the fabric and used the stepwise regression method to discuss the air permeability between the fibers and calculate the air permeability between the yarns [6, 13]. The BP neural network method was used to examine the influence of fabric structure parameters on air permeability, and the prediction accuracy of the two methods on fabric air permeability was compared.

Xu et al. used a three-layer BP neural network model [6]. The input layer of the neuron has a total of 11 calculated values, which are respectively taken from the diameter of the warp and weft yarn, the fabric density of the warp and weft, the total fabric tightness, the average floating length, the weight in square meters, the twist coefficient of the warp and weft yarn, and the average diameter of the fibers in the yarn. , and the air permeability of the pores between the yarns of the fabric; the output layer of the neuron contains 1 value, the measured air permeability. The number of hidden layer neurons is initially determined to be 3-8, and the optimal number of hidden layer neurons is selected according to the training effect. Based on the data of 34 worsted wool fabrics, the optimal model was found by running comparisons. The optimal parameter settings are as follows: the number of neurons in the hidden layer is 4, the display frequency is 500, the maximum number of training steps is 5 000, the minimum error is 0.01, and the learning rate is 0.02. Seven samples were collected again for verification, and the results showed that the network model could be used to predict the air permeability of worsted wool fabrics.

Cao also used the method of three-layer BP neural network structure to establish the relationship between fabric structural parameters and fabric air permeability [8]. According to the test requirements, there are 7 input neurons, which are warp fineness, weft fineness, warp tightness, weft tightness, total tightness, fabric thickness, and fabric grammage. The number of output neurons is 1, which is the air permeability of the fabric. The number of neurons in the hidden layer can be determined according to the error value generated by training the established model of each point neural network. The training results show that when the number of hidden layer neurons of the model for predicting the air permeability of cotton fabrics is 4-8, the performance of the network is better. This lays the foundation for the further study of BP neural network technology in the breathability of cotton fabrics, providing a basis for fabric design.

3.7 Predict the finishing quality of worsted wool fabrics

In the process of worsted wool fabric processing, the finishing process plays a decisive role in the appearance quality, and style characteristics of the fabric, and the selection of its processing technology and parameters is very important. At present, the selection of process parameters is generally based on experience, and its drawbacks are insufficient objectivity and poor accuracy. The determination of process flow and parameters is affected by multiple factors. In addition to wool raw material, yarn quality, and product design specifications, the finishing process is the key to enhancing and improving the quality of the physical product. A reasonable finishing process can make the excellent performance of wool come into play. Xiao et al. tried to use BP neural network to model, predict the quality of the fabric according to the known raw material, yarn quality, and finishing process parameters, and invert the process parameters and raw material parameters according to the quality of the fabric, so as to determine the processing technology [7].

Experiments show that the selection of input parameters has a significant impact on the accuracy and speed of network forecasting. Once the BP neural network is trained and learned, it has better nonlinear mapping ability. The BP network established according to the data in the actual processing and the measured parameters of the finished product, the measured value is consistent with the predicted value, and the scouring, milling, crabbing, and decating processes have a great influence on the fabric shrinkage and steam shrinkage. The traditional theory fits perfectly. The inversion prediction can provide an objective and scientific basis for the selection of process, optimization of process parameters, and matching of raw materials, which has extensive practical guiding significance for production.

3.8 Predict warm and cold sensation of fabric contact

The touch of warmth and coldness is one of the important indicators to measure the wearing comfort of fabrics. There are many research reports on the comfort performance of fabrics and clothing at home and abroad, and the research on cool and warm feelings of fabric is also increasing. Kawabata and Akagi [10] developed a test instrument that can be used to measure the amount of heat conduction in the warm state generated by the heat source plate and the fabric in a very short time after contact, thereby simulating the feeling of warmth and coldness when a human hand touches the fabric. Prof. Yao Mu and others designed and developed a fabric contact thermometer by analyzing the change law of skin temperature after the fabric is in contact with the skin [11].

The index of the cool and warm feelings of fabric felt by the human body can be evaluated by the maximum heat flow q_{max}. It is closely related to the raw material of the fabric, the diameter of the warp and weft yarns, the thickness of the fabric, the warp and weft density of the fabric, the area weight of the fabric and the moisture content. Therefore, it is possible to predict the warm and cold feeling of the fabric by analyzing these parameters through the neural network. Kong et al. pointed out that the artificial neural network model is more suitable for multi-factor nonlinear prediction problems such as the warm and cold feeling of the fabric [9]. The experimental results show that the neural network system has a strong adaptive pattern recognition ability, and can effectively solve the problem of detecting cold and warm feelings when touching fabrics.

3.9 Predict the softness of cotton fabrics

Fabric softness, also known as tactile style, is an important part of fabric quality. For wearing fabrics, the feel of the fabric is related to the comfort of wearing. The evaluation method of fabric softness includes subjective and objective evaluation. Cao et al. measured the result of fabric softness by subjective evaluation method and then used the artificial neural network to predict 18 physical quantities obtained by 12 pieces of cotton and cotton-type objects tested via KES-FB, so as to explore the relationship between the subjective evaluation and objective evaluation of the fabric hand and replace the traditional method of fabric hand evaluation [12].

The value of fabric softness uses human subjective feeling as a detection tool to evaluate fabric softness, which is the basic basis for fabric softness detection and evaluation. The artificial neural network is used to predict softness based on 18 physical quantities measured by the KES-FB fabric style instrument test system, and the experimental results are reliable. It is feasible to build a prediction model of the relationship between the subjective and objective evaluation of fabric softness with BP neural network. It does not need to establish a mathematical model, and the system can be trained to obtain the best matching weights and offsets, which are relatively accurate to a certain extent. to predict the fabric softness. Since the KES-FB test of fabric softness is not convenient and fast enough, other eigenvalues of the fabric will be used in the future to study the BP neural network prediction of fabric softness to obtain better and faster results.

4. CONCLUSION

This paper introduces the structure, working principle, and learning algorithm of the BP artificial neural network, and summarizes the idea of establishing the BP neural network fabric performance prediction model. The latest research results of BP artificial neural network in fabric property prediction are deeply discussed, and the latest progress of BP artificial neural network in the following research fields is briefly summarized, including identifying the formability of clothing fabrics, evaluating the fabric style, and predicting the Heat conduction of fabric, fabric drape performance, fabric tensile performance, fabric air permeability, finishing quality of the worsted wool fabric, cold and warm feelings of fabric, the softness of cotton fabric, etc.

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