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Research Article

Evaluating the Vocal Music Teaching Using Backpropagation Neural Network

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The vocal music teaching for evaluating performers is affected by multiple factors. Evaluators are greatly influenced by subjective factors in scoring outputs. The backpropagation (BP) neural network provides a novel technology that can theoretically simulate any nonlinear continuous function within a certain accuracy range. The backpropagation neural network is composed of adaptive feedforward learning network that is widely used in artificial intelligence (AI). In addition, the backpropagation neural network can simulate the nonlinear mapping composed of various factors. The novelty of the neural network is that it can model the nonlinear process without knowing the cause of the data, which can overcome the human subjective arbitrariness and make the evaluation outcomes. Furthermore, accurate and effective scoring systems can be designed using neural networks. In this paper, we establish a vocal music evaluation research system in order to objectivize each vocal music teaching evaluation index. To do so, we use the score vector as the input and obtain a reasonable and objective output score through the backpropagation neural network. Moreover, according to the characteristics of the backpropagation neural network, the factors of vocal music teaching evaluation are analyzed, and a backpropagation neural network model for vocal music teaching evaluation and evaluation is constructed. The experimental outcomes demonstrate that the trained backpropagation network can simulate a stable vocal music teaching evaluation research system. Furthermore, we observed that the backpropagation neural network can be well utilized for vocal music teaching evaluation research.

1. Introduction

With the popularization of vocal music teaching, the public is paying more and more attention to the evaluation of vocal music teaching. More and more people realize that it is crucial to improve their vocal music teaching level and make an objective and fair evaluation of the singer's singing. Most importantly, the results of the evaluation are usually quantified by averaging the scores. Therefore, it is undeniable that these judging methods have certain practicability. Since the subjective evaluation of singing involves people's feelings and thinking, therefore it is difficult to describe them with clear numbers or curves. As a result, the scores that appear to be very accurate cannot accurately describe the evaluation. The specific level or pros and cons of the singing object must be kept in mind when designing quantification methods. Several aspects affect the performances of singing, and the degree of influence of each factor is also different. Therefore, it is essential to account for all these factors. The traditional scoring method uses a simple linear classification mathematical analysis expression [1]. This method ignores the nonlinear relationship between the individual assessment index and the singing effect, which in fact reflect the level of the performer [2].

The evaluation of the singing effect should use the nonlinear classification methods. These methods could be neural network based. The artificial neural network (ANN) should approximate any nonlinear function, and the network itself is a highly complex nonlinear dynamic system identification model. A multilayer forward neural network, which is based on an error backpropagation algorithm, is described as a backpropagation neural network (BP). In fact, the results obtained through the BP network are more objective. The BP algorithm, which can implement any nonlinear mapping between input and output, has become the most commonly used network learning algorithm. The vocal music evaluating system is utilized as the input in this study, and the backpropagation neural network is used to build the evaluation model. Furthermore, with the data training and testing it is confirmed that the model's evaluation results are almost comparable with the real-world situation. This study utilizes the BP neural network algorithm to demonstrate that it is appropriate for people, based on the properties of the neural network. Moreover, it can also be used to evaluate vocal music instruction effectively. The major contributions of this work are as follows:

(i) We establish a vocal music evaluation research system and objectivize each vocal music teaching evaluation index

(ii) A multilayer forward neural network based on an error backpropagation algorithm is described as a backpropagation neural network

(iii) We use the score vector as the input and obtain a reasonable and objective score through the backpropagation neural network output

The remaining of the paper is structured as follows: in Section 2, we discuss the artificial neural network backpropagation algorithm. Furthermore, basics of the ANN and BP algorithms are illustrated. In addition, the mathematical model of backpropagation neural network is discussed. In Section 3, teaching quality evaluation model is elaborated. In Section 4, we construct and evaluate the performance of the proposed evaluation model for teaching quality. Finally, Section 5 concludes this paper and offers several directions for further research.

2. Artificial Neural Network Backpropagation Algorithm

2.1. Basics of Artificial Neural Networks. The Artificial Neural Network (hereinafter referred to as ANN or NN) is a nonlinear data processing system that replicates the structure and purpose of human organs and is a mathematical abstraction and simulation of multiple basic aspects of the human brain. In the 1990s, ANN, as a new discipline, new method, and new technology [1, 2], was widely used in various fields of natural sciences and social sciences and achieved fruitful and productive results. With the widening of applications, it has further promoted the research and development of neural networks, and various network structures and algorithm systems have emerged, gradually forming a relatively complete ANN theoretical system [3].

An artificial neural network is an abstraction and simplification of brain thinking from the perspective of microstructure and role. It is a vital approach for simulating intelligence and mimicking the human brains. It represents several fundamental characteristics of human brain operations, including dispersed information storage, adaptive learning, and association. Moreover, memory, fault tolerance, robustness, etc., are the main features that ANN can successfully mimic. However, it is only a simplification, abstraction, and simulation of the human brain, not a genuine representation. It is a network composed of simple information-processing units (referred to as neurons) interconnected, which can receive and process information [4]. The network information processing is achieved by the interaction of neurons. It expresses the problem as a question between neurons. In addition, connection rights are handled. An artificial neural network simulates some information processing principles and processes of physiological neural networks in animals. In fact, ANN characterizes the mathematical abstraction of a real neural network. It is a network mathematical topology formed by connecting many mathematical neurons in a certain way [5]. Furthermore, ANN is an information processing unit with multiple input and a single output. Similarly, ANN is an information processing unit with multiple input and a single output, according to the neuron model of the basic component of an artificial neural network that consists of (i) a summation unit, (ii) a nonlinear activation function, and (iii) a network of interconnections. The more commonly used activation functions can be attributed to three forms: closed-value, sigmoid, and linear [6].

2.2. The BP Algorithm. In the book (Parallel Distributed Processing), a 1986 group of scientists led by Rumelhart and McClelland modified the weights of multilayer feedforward networks with nonlinear transfer functions and presented: (a) an error backpropagation approach [6, 7] and (b) an algorithm (backpropagation), to realize TMinsky's vision of a multilayer network. The multilayer feedforward network which is trained using the error backpropagation technique is usually referred to as the BP network [7].

The BP algorithm completes a highly nonlinear mapping from input to output by minimizing the error function. The topological invariance is maintained in the mapping. The training process can be divided into the following two processes:

(1) The significant inputs from the input layer to the hidden layer to the output layer is processed layer by layer, and the actual output value of each neuron node is determined. This is considered the information flow's forward assignment procedure. The sample signal is propagated forward layer by layer through the sigmoid function in the forward propagation process, and the state of each layer of neurons only influences the state of the subsequent layer of neurons [8].

(2) Determine the variance between the network actual output and the training sample predicted value. Calculate the weight adjustment amount based on the error, and if the error does not approach the acceptable value, modify the weight of each neuron layer's connectivity nodes layer by layer from back to front. The process is called the inverse modification process of the error [9].

Both processes complete a learning iteration [10]. The forward transfer of this information and the process of modifying the weight of the network according to the reverse of the error is repeated in continuous iterations. The repetition occurs until the output error of the network is gradually reduced to the allowable accuracy or reaches a predetermined number of learning times [11, 12]. The predicted error err-goal, the maximum number of cycles max-epoch, the learning rate 1r, and the number of layers in the network, as well as, the number of neurons in each layer, are all factors to consider. Moreover, these factors' associated activation functions are all parameters that must be specified at the same time [13].

2.3. Advantages and Disadvantages of the BP Algorithm. The BP neural network mainly has four advantages nonlinear mapping, learning ability, parallelism, and distribution [14]. The main effect is to effectively realize nonlinear mapping from input space to output space. Multivariable input mapping and control systems can benefit from the multiinput and multioutput structural model. Personalized learning, or the ability to abstract the main features of the training samples during training, is a key representation of the neural network's intelligence [15]. When processing information, they are independent of each other. They accept input and produce output after action. Because of the features of parallel computing, it will have the ability to rapidly complete information processing and a large number of complicated control algorithms. The information is distributed in independent storage units in a typical serial operating embedded computer, and any component of the damages will invalidate the complete information [16]. Information is scattered throughout the connections of neurons in a neural network, and individual connections and neurons are not particularly useful, but they might represent certain information properties at a macro level.

The BP algorithm is one of the most important artificial neural network networks, as well as the most frequently used network algorithm. This error backpropagation method has been shown in reality to solve a wide range of practical issues, making it an important component of artificial neural networks [17–19]. Status, but the shortcomings of its algorithm itself are unavoidable. The main points are summarized as follows:

(1) Local minima problem: because the BP network is a feedforward network, its actual output is determined only by the network's input and weight matrix, resulting in several global minimum error points. There are a few flat locations where the error changes are minor, and the neural network performs well. The capacity to map such regions is limited, and several local minima occur [20].

(2) The algorithm's convergence speed is very slow: the BP algorithm realizes the identification of objective objects by modifying the weight of the network through the backpropagation of training errors. The identification of a nonlinear equation generally requires thousands of times of training, but to realize the identification of complex nonlinear relationships or fuzzy uncertain relationships, then it needs to be trained tens of thousands, even hundreds of thousands or millions of times, and it takes several hours or ten hours. The measured convergence speed of the backpropagation algorithm is a weakness that is difficult to overcome at present [13].

(3) It is difficult to estimate the number of hidden layer neurons: in terms of determining the sum of nodes in the hidden layer neurons, there is no reliable guiding theory at present, and the method of trial calculation is mostly used. For the problems of the BP algorithm, many scholars have proposed many targeted solutions, some of which have been successfully applied, and some are still in the research stage [21].

2.4. Mathematical Model of the Backpropagation Neural Network. A typical model of the backpropagation neural (BP) network and its training process is shown in Figure 1 [9].

As depicted in Figure 1, a typical BP model has three layers: a hidden layer, an input layer, and also an output layer. Regardless of the fact that there is no theoretical limit to the number of hidden layers, most individuals only use one or two hidden layers in their designed networks. Since it may theoretically be proved that a three-layer BP network can arbitrarily simulate a nonlinear system (BP theorem), as illustrated in Figure 2. This should be noted that this paper simply uses one layer.

For nonlinear equations, x and y are ($1\ x\ n$) and ($1\ x\ p$) vectors (n denotes inputs and p denotes outputs);

$$N(x) = S(y) = \left(S1(y_1), S2(y_2), \ldots, S_p\left(y_p\right)\right), S(*), \quad (1)$$

where d is the expected output, e is the error signal, and k denotes iteration

$$\begin{aligned} e_k &= d_k - N(x_k) = d_k - S(y_k) \\ &= \left(d_{1k} - S(y_{1k}), \ldots, \left(d_{pk} - S\left(y_{pk}\right)\right)\right). \end{aligned} \quad (2)$$

The sum of instant mean variances is given by the following equation:

$$E_k = \frac{1}{2}\sum_{j=1}^{p}\left(d_j^k - s_j\left(y_j^k\right)\right)^2 = \frac{1}{2}e_k e_K^T. \quad (3)$$

The total error is the sum of errors produced over iterations k: $e = \sum_{K=1}^{nT} E_k$ where nT denotes data to total error and $(x_1, d_1; \ldots; x_{nT}, d_{nT})$ the backpropagation learning algorithm that minimizes the objective function at each iteration.

3. Teaching Quality Evaluation Model

3.1. A Technique for Evaluating the Quality of Vocal Music Teaching. Teaching should be focused on the complete development of students' information, skill, and excellence from the perception of teaching concepts. Moreover, from the perspective of teaching content, the teaching methodology should be focused on the complete development of

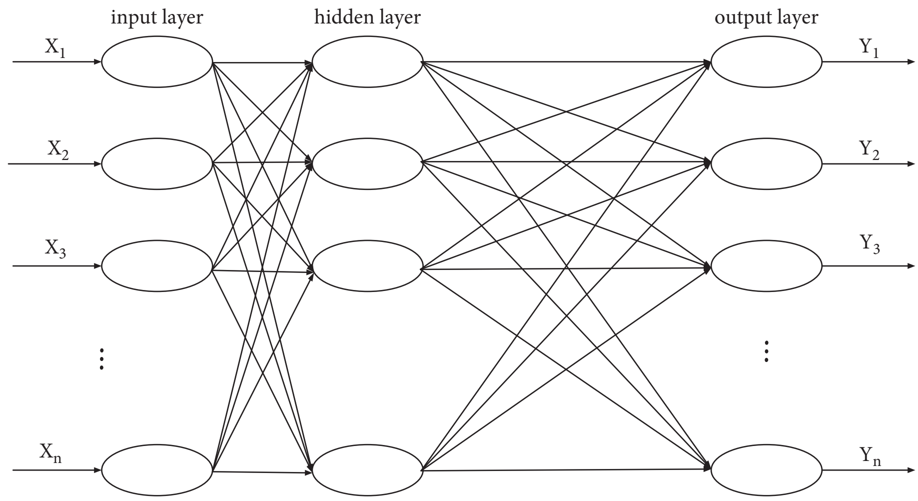

Figure 1: A typical model of the backpropagation neural network.

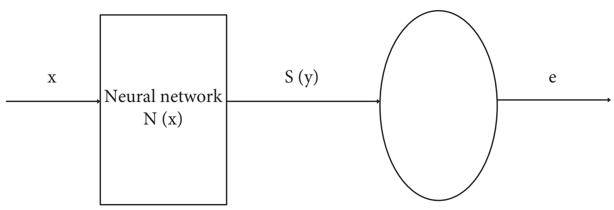

Figure 2: The structure of the backpropagation learning algorithm.

student understanding, capacity, and quality. This should be noted that teaching material should be in step with the evolution of fields and majors. Similarly, both the teaching and training techniques should be based on good scientific research and investigation. Therefore, starting from the overall evaluation of a teacher's teaching work, the following criteria for evaluation systems can be constructed (Table 1).

3.2. A Teaching Evaluation Model Based on Backpropagation Neural Network

3.2.1. Design of the Input Layer. According to the system's performance indicators, the total number of evaluation indicators is equal to the number of nodes in the input layer, which is equal to the number of nodes in the input layer. Moreover, the input data is normalized and utilized as the input volume because it is a discrete data volume.

3.2.2. Design of the Output Layer. The evaluation objective is the network's output, i.e., the output layer's number of nodes is $1 = 1$, and the output data is normalized as the output.

3.2.3. Design of Hidden Layer (Intermediate Layer). A feedforward network with a single hidden layer will map all continuous functions, according to theoretical study, and a 3-layer BP network is chosen based on the network performance. When determining the number of hidden layer nodes, this should be kept in mind that too few or too many nodes will affect the network's ability to obtain information. Moreover, this factor will also affect the generalization ability, and training time of the network. In summary, the determined neural network structure model is shown in Figure 3.

3.3. Application of the Teaching Evaluation Model. The above-mentioned teaching quality evaluation method is identified using a three-layer backpropagation neural network. The network structure is $12 \times 7 \times 1$, and the activation function adopts the sigmoid type. In addition, the learning rate is assumed as $n = 0.8$, and the learning and training algorithm adopts the backpropagation (BP) neural network terminology. The first 10 sets of the data, in Table 2, are used as the neural network identification model's training samples. Similarly, the goal error is set as 0.001. Note that, the MATLAB neural network toolbox is utilized to learn and train the network, and then the mathematical model of the teaching quality evaluation system is produced. The network is then run with the last 5 sets of data, as shown in Table 2, as test data. The obtained results were observed satisfactory, which demonstrates that the proposed model can more accurately determine the teaching model consequences according to each assessment index.

Table 2 shows the test outcomes and the original evaluation objectives (Table 2). The absolute amount of the error among the test results and the unique evaluation results, as shown in the table, ranges from 0.005 percent to 0.039 percent, suggesting that the model performs well. In addition, we observed that the proposed model has good fault tolerance capability and ability to generalization.

3.4. Standard Structure of the Backpropagation Neural Network. The error backpropagation method, which is a neural network learning algorithm with teachers, is used in the learning process of the backpropagation neural network. The backpropagation neural network is a hierarchical neural network with input, middle, and output layers. In fact, the middle layer having the ability to be expanded to several

Table 1: Vocal music evaluation criteria.

Category	Project
Skill	Singing posture (xo), breathing technique ($x1$), breath support and stabilization ($x2$), vocal range ($x3$), articulation clarity ($x4$), pitch accuracy ($x5$), rhythm accuracy ($x6$), and track difficulty ($x7$)
Art	Stage image ($x8$), timbre performance ($x9$), natural sound ($x10$), fluency ($x11$), roundness ($x12$), and melody grip ($x13$)
Style	Expression of emotion to the song ($x14$), level of emotion ($x15$), and originality ($x16$)

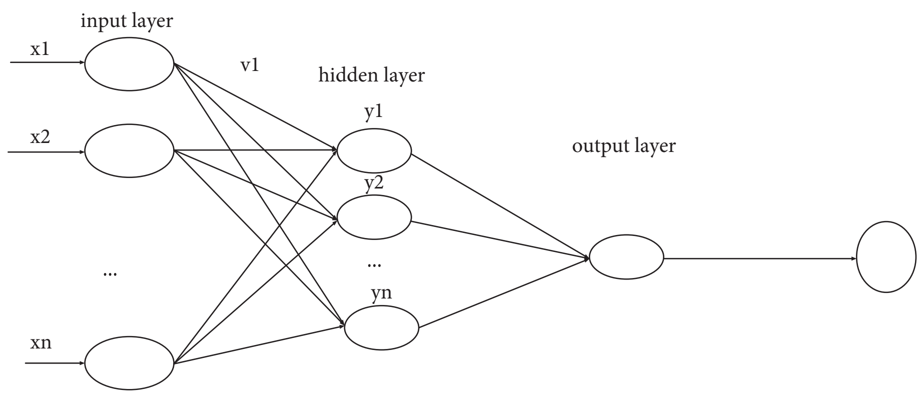

Figure 3: A three-layered BP neural network.

Table 2: The original data and the neural network system's test values.

Sample serial number	Evaluation target	Test value	Error (%)
1	0.7	0.7025	0.039
2	0.71	0.7546	0.037
3	0.7	0.7157	0.026
4	0.73	0.7172	0.005
5	0.66	0.6631	0.019

layers. Furthermore, each neuron between neighboring layers is fully connected, while each neuron in each layer is disconnected. The network learns in the manner that the instructor instructs. The input pattern is input through the network when a couple of learning patterns are presented to the network. An output mode is produced after layer by layer processing of the layer, hidden layers, and output layers. Note that, the difference between the network output configuration and the intended output mode is determined.

The error is transferred in reverse order between the output layer, hidden layer, an input layer. The error is decreased in accordance with the connection weight of each layer and is rectified layer by layer in the direction of training. Finally, the learning process ends when the error is smaller than the predefined value. [22]. The forward propagation and backpropagation are the two aspects of BP network learning. In both cases, we set the weights and thresholds to uniformly distribute lower values after initializing the network and selecting an appropriate network structure. The algorithm steps are as in Figure 4.

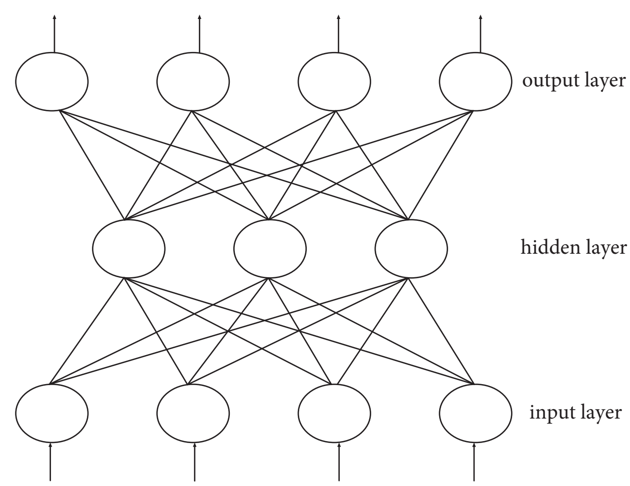

Figure 4: Structure of a basic BP network.

4. Construction of the Evaluation Model

4.1. System for Evaluating Vocal Music Teaching. A set of objective standards that can be quantitatively expressed should be developed for various vocal competitions and evaluations. Table 3 depicts the evaluation scheme's structure.

In this evaluation system, the score interval for each index is [0, 1]. Each expert will evaluate the players' indicators based on their professional knowledge, and each player can then acquire the evaluation matrix A_{ij} row vector e for the ratings of the experts' indicators [23]. Since, experts have various knowledge and expertise, therefore some may only rate particular indications. The experts' score on a particular indication is represented by the column vector x. In this matrix, experts $e0$, and $e1$ are responsible for the scoring of the skill category. Similarly, experts $e2$, and $e3$ are responsible for the scoring of the art category, and experts $e4$ and $e5$ are responsible for the scoring of the style category.

Table 3: Evaluation of training sample output and professional evaluation results.

Serial number	Professionals give value	BP network system gives the value
1	9.6	9.6121
2	9.5	9.5323
3	8.7	8.7245
4	8.1	8.1524
5	7.6	7.6251
6	7.5	7.5128
7	6.8	6.8131
8	6.6	6.5992
9	7.1	7.1005
10	7.5	7.5049
11	8.3	8.3115
12	9.2	9.2132

We calculate the mean of the column vector to get the player's performance vector S of the index. The resulting grade vector S is utilized as the neural network's input.

4.2. The BP Network Model. In order to avoid the fact that sometimes it is "strict" and sometimes "broad" in actual operation, the same singing is given very different scores. Therefore, we first ask experts who have attainments in vocal art and are familiar with the rules of vocal art to give subitems according to each subitem in Table 1 and then make a more objective and fair total score according to the aesthetic rules of vocal art. Using the subitem scores as input, the total score is utilized to train the network, enabling the BP network to gain expert knowledge through modifying the weights of each layer, and effectively simulating a reliable expert scoring system.

According to the theorem of the backpropagation neural network model (i.e., Kolmogrov theorem), given any continuous function: $f\colon [0,1]^n \longrightarrow R^m$ and using the subitem scores as input, the total score is utilized to trained the network. This enables the backpropagation network to gain expert knowledge through modifying the weights of each layer and therefore effectively simulating a reliable expert scoring system.

5. Conclusions and Future Work

The evaluation of vocal music teaching itself is a problem that is not easy to quantitatively describe. Furthermore, in the evaluation, numerous evaluators are greatly influenced by subjective factors. In fact, the unstable situation i.e., the evaluation indicators are inconsistent with the weights of different performers, is also prone to occur in the scoring process. Since the BP neural network can accurately model a nonlinear system, the experimental findings show that the model is consistent with the real-world situation, making it very possible to utilize the BP neural network to replicate stable expert scoring. However, the backpropagation neural network consumes a very common problem i.e., calculating the number of hidden layer nodes, therefore it may fall into the local optimal solution during the training process. This problem impacts the evaluation accuracy to some extent. In this paper, we suggested a BP neural network based algorithm to resolve this issue and checked the feasibility of the proposed algorithm through evaluating the teaching quality. The obtained experimental outcomes show that the use of the backpropagation neural network can be utilized to evaluate the evaluation of vocal music teaching.

Furthermore, the evaluation outcomes can be obtained quantitatively in this way, which is not only: (i) conducive to the evaluation of vocal music teaching and (ii) timely detection of the vocal music teaching but also helps in the improvement of the backpropagation neural network. The shortcomings are also conducive to other people's evaluations of vocal music instruction, and the quantitative findings are more compelling in vocal music teaching evaluations. In the future, we will check the applicability and generalization of the outcomes through using a large training dataset. Moreover, we will also consider different datasets and different parameters to test whether our outcomes apply to a broader level of teaching or not. More research should be conducted on using other neural network based algorithms, in particular, convolutional neural networks for the purpose of designing more advanced scoring systems for evaluating the teaching quality. Another field of interest is to work on reducing the training time of the network which is strongly dependent on the amount of data and the model of neural networks. In the near future, we plan to examine and investigate the impact of amount of hidden layers and the activation functions on the network training and obtained results.

Data Availability

The data used to support the findings of this study may be obtained from the author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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