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Analysis of the Enhancement of Musical Expressiveness Through the Organic Integration of Artistry and Technique in Pipa Performance

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SUMMARY: *The pipa, being one of the classical instruments in China and having a distinctive ethnicity, has had a long history of usage in the country. In this paper, the main concern is to improve the expressiveness of music performance of the pipa through the development of strategies which will include organic integration of art and techniques in musical performance. With the acknowledgment of the importance of the ability of performing pipa, in this paper, multi-feature fusion has been used to acquire features of the acoustic signal from playing of pipa, and then wavelet neural network is used to develop a model for pipa performance quality assessment. On this basis, the participants in the study were pipa students studying in the university. Then experiments have been done to compare the level of expressiveness in music before and after implementing the above model. It was discovered from the results of the experiment that the WNN model is highly accurate for evaluation of pipa performance quality with the accuracy being more than 98%. From the result, the musical expressiveness improved by 2.07%, with scores of emotional attitude, process methods, and knowledge skills increasing from 0.237, 0.259, and 0.225 to 0.238, 0.266, and 0.233 respectively.*

KEYWORDS: *pipa performance; convolutional neural networks; feature extraction; performance quality evaluation; musical expressiveness*

1 Introduction

As one of the traditional musical instruments in China, pipa has been receiving constant enrichment from other cultures as well as skills during its history development and gradually created unique artistic presentation features of China [1, 2]. It should be noted that expressiveness plays an important role in pipa playing. Good expressiveness allows performers to fully express their feelings, thoughts, and conceptions in the process of performance and therefore makes them arouse powerful emotional resonance of audience [3-5]. It is also important to introduce artistic elements to improve the effect of musical performance of pipa and thus deliver profound emotions and thoughts of musicians to audience [6, 7]. Therefore, performers need to have good artistic taste and aesthetic sense to understand how to disclose the inner soul of musical work [8, 9]. For developing artistic performance skills in pipa playing, performers need to have rich imagination and creativity, constantly enrich themselves by new skills, ideas and artistic senses, focus on practical research on performance skills to raise their professional performance skills and continuously improve their artistic requirements [10-14]. Technique proficiency is a necessary basis for creating music expressiveness. Only by acquiring solid techniques can performers successfully express the emotions of musical works [15-17]. Mastering technical skills becomes the first condition for gaining musical expressiveness. For

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the improvement of fundamental techniques such as left-hand fingering and right-hand plucking, one needs constant practice and deep research [18-20]. Only after mastering these skills can the pipa players perform music more accurately and expressively [21, 22]. Nevertheless, the development of musical expressiveness can neither be defined nor achieved by a particular factor alone. Artistic creation and technical skills are two indispensable factors in pipa playing. They support each other in an integrated way to enable performers to better show their musical expressiveness to audiences [23-26].

The article then introduces the integration of artistry and technique in pipa playing and discusses measures to enhance the expressiveness of music. The authors evaluated their pipa playing skills based on the score made by experts and then extracted features of pipa playing with time-domain envelope segmentation ratio, constant Q transform, and Mel frequency envelope coefficient. These extracted signal features were then input into a wavelet neural network for training. The subjective evaluation results of the pipa performance were used as input to the neural network. Mel frequency inversion coefficients to extract feature parameters of the musical tones. A wavelet neural network (WNN) is employed, with the extracted signal feature parameters fed into it for training. The obtained subjective evaluation results of the pipa performance serve as the target labels for the neural network, guiding the learning and training of the supervised network model to yield corresponding predictive evaluation outcomes. Baseline experiments with varying feature inputs and training sample sizes explored optimal feature fusion methods. These were tested on the dataset to analyze the WNN model's accuracy in evaluating pipa performance quality. Subsequently, pipa course students from a university were selected as research subjects. The proposed strategy and evaluation model were applied to their pipa learning process. An evaluation index system for musical expressiveness in pipa performance was constructed. After assigning weights to the indicators, questionnaire data collected before and after the experiment were calculated to obtain expressiveness scores. Score comparisons were used to verify the effectiveness of the proposed strategy and WNN model in enhancing musical expressiveness.

2 Strategies for Enhancing Musical Expression in Pipa Performance

In a sense, pipa performance is a reinterpretation of pipa music compositions. Performers must integrate the emotional, cultural, and stylistic elements of a piece, presenting them to the audience through their own understanding and experience, supported by technical skill and associative perception. As such, improving a performer's expressiveness in music can be done through the harmonious integration of the artistic and technical elements of performing pipa music. Below are ways in which the musical expressiveness of performers in pipa music can be improved in relation to these two categories.

2.1 Artistic Dimension

2.1.1 Mobilizing Artistic Perception

An important element in a performer's expressiveness in music is having excellent artistic imagination and cultural awareness, along with technical proficiency. For starters, cultural awareness needs to be strengthened, since this will enable the performer to have a deepened sense of the music and understand what it conveys and what it means to the artist behind the music piece. Secondly, imagination needs to be cultivated since this will allow the performer to imagine scenes and context out of music rhythms, involving all the senses in order to create an enhanced sense of artistic perception through the process. Most importantly, the performer should focus on developing creativity in themselves. This entails that while performing, the performer uses his or her creativity to interpret the music piece being performed.

2.1.2 Experience the Culture and Essence of Music

Performance is a re-creation of a music composition, which means that a performer must have deep knowledge of pipa works and music tradition. On the basis of a thorough knowledge of a pipa piece's rhythm and characteristic features, innovations in interpretation make it possible for musicians to enrich their musical expressiveness and promote the development of works performed. First, a performer must understand the composer of the piece and its historical background. Second, the musician must develop his/her musical sensitivity. It is necessary to regularly listen to works played by pipa, analyze such aspects as rhythm, tempo, and melody of pieces, as well as conduct an in-depth structure analysis to comprehend the meaning and background of the piece, and thus perform a piece in an authentic way. Pipa being a traditional classical instrument, works created for it carry the spirit of tradition. It is vital for performers to develop their sense of heritage to increase cultural sensibility and perceive the significance and value of each work played. Daily exercises must focus on widening one's knowledge base and expanding the intellect of performers.

2.2 Technical Aspects

2.2.1 Enhancing Pipa Performance Skills

Artists should constantly improve their technical abilities and develop their musical foundation in order to lay the foundations of expression through art. Firstly, artists should give priority to studying the score carefully, as they need to have sufficient knowledge about musical notation and marks, especially playing technique, time signature, and key signature. These aspects will be vital in expressing the emotional meaning of the piece. In addition to that, artists should practice finger techniques and master finger movements. They should learn how to use their finger techniques in interpreting the music and acquire additional knowledge regarding the score. Secondly, artists should engage in auditory practices. By listening, they will be able to dive into the music, understand its meaning, and appreciate it better. Thus, they will be able to understand the artistic idea behind the composition and its emotions. Lastly, artists should improve their rhythmic abilities. Before starting the performance, they should mark all the rhythmic features of the composition and control the tempo.

2.2.2 Gain Performance Experience

Performers need to gain experience through performances, discovering problems in their playing in each of them and improving their skills to improve their musical expressiveness. Performers need to learn how to perform pieces accurately, get rid of stage fright and be able to cope with any environmental influences. Performers may watch concerts of famous musicians, study their stage manners and techniques, actively benefit from other people's performing experience and form their own way. Through integration of their own knowledge and ideas, they will gradually expand their repertoire of performing skills. Every single performance requires sincere dedication and engagement; repetition helps to improve musical expressiveness. Moreover, watching videos of their performances will help performers analyze their weaknesses and improve them.

3 Intelligent Evaluation and Analysis of Pipa Performance Quality

In pipa performance, performers' techniques and skills are significant aspects that affect musical expressiveness. In order to help performers to improve their skills, a method of assessing quality of pipa performances is suggested in this paper.

3.1 Data Collection

A subjective assessment technique was chosen to gather information necessary for evaluating the quality of pipa playing.

The subjective assessment of acoustic quality of the pipa uses a five-point scale:

0-1 points: “Poor” refers to very poor acoustic quality that is unacceptable to listeners.

1-2 points: “Substandard” refers to poor acoustic quality that is reluctantly acceptable to listeners.

2–3 points: “Average” indicates generally acceptable acoustic quality, deemed tolerable by listeners.

3–4 points: “Good” indicates satisfactory acoustic quality, deemed reasonably pleasing to listeners.

4–5 points: “Excellent” indicates outstanding acoustic quality, deemed highly pleasing to listeners. 2–3 points: “Average,” indicating generally acceptable acoustic quality that listeners find tolerable. 3–4 points: “Good,” indicating satisfactory acoustic quality that listeners find relatively pleasing. 4–5 points: “Excellent,” indicating very good acoustic quality that listeners find highly satisfying. The seven evaluation criteria for pipa performances include: clarity, softness, brightness, richness, fullness, balance, and harmony. The expert panel comprised five pipa faculty members and master's students from an arts academy. They scored 50 pipa performance sets, each lasting approximately 3 minutes.

After preprocessing the audio signals from multiple sets of pipa performances using techniques such as frame segmentation with windowing and spectral subtraction filtering, an audio database for evaluating pipa performance quality was established. Each audio file was recorded for 1 minute, comprising a total of 150 audio files, or 150 samples.

3.2 Feature Extraction

Extract tonal characteristics of pipa performance from the time domain, frequency domain, and inverse frequency domain respectively. Specifically, the time domain feature employs the time-domain envelope segmentation ratio, the frequency domain feature utilizes the Constant Q Transform (CQT), and the inverse frequency domain feature adopts Mel Frequency Cepstral Coefficients (MFCC).

3.2.1 Time-Domain Envelope Segment Ratio

The time-domain envelope of the signal is obtained by calculating the root mean square (RMS) of each frame's time-domain signal:

$$x_{r-rms} = \sqrt{\frac{1}{N}\sum_{n=0}^{N-1} |x_r(n)|^2} \tag{1}$$

x is the time-domain signal, r is the frame index, $r = 1, 2, \cdots, R$ and R are the total number of frames, N is the frame length.

Steps for calculating the segment ratio of the time-domain envelope:

(1) Calculate the RMS for each frame of every pitch file; use the resulting RMS envelope as the time-domain envelope.

(2) Fit the time-domain envelope using a polynomial. Experimental results indicate that a 6th-order fit is sufficient, yielding the fitted curve F_r.

(3) Normalize curve F_r and then take the logarithm:

$$F_r^{'} = 20\times\log_{10}\frac{F_r - F_{r-\min}}{F_{r-\max} - F_{r-\min}} \tag{2}$$

Among these, $F_{r-\min}$ is the minimum value of F_r, and $F_{r-\max}$ is the maximum value of F_r.

(4) The normalized segmentation of the time-domain envelope fitting curve is illustrated in Figure 1. By setting $F_r^{'}$ equal to the positions at -3dB and -10dB, four boundary points I_1, I_2, I_3, I_4 are obtained, thereby dividing the time-domain envelope into five segments: start, attack, sustain, release, and end.

(5) Calculate the ratio of the length of each section to the total length of the single note. The total interval of R data is $L = R - 1$. The ratio of the first section is $L_1 = \frac{I_1 - 1}{L}$, that of the second section is $L_2 = \frac{I_2 - I_1}{L}$, that of the third section is $L_3 = \frac{I_3 - I_2}{L}$, that of the fourth section is $L_4 = \frac{I_4 - I_3}{L}$, and that of the fifth section is $L_s = \frac{R - I_4}{L}$.

Thus, the ratio of each five-segment segment of a single note is obtained as the timbre characteristic for classifying instruments.

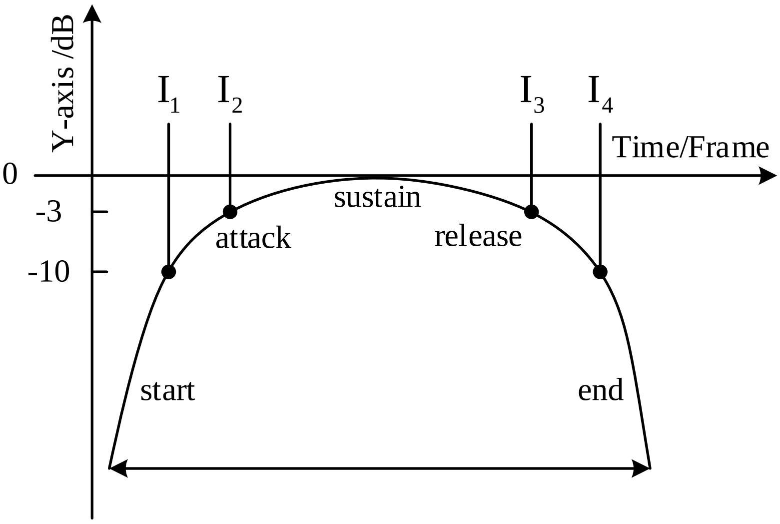


Figure 1: Schematic of the normalization of the fitting curve of the time-domain envelope

3.2.2 Constant Q Transformation

Constant Q Transform (CQT) can be regarded as a type of wavelet transform. The CQT filter bank has a fixed quality factor, with center frequencies increasing exponentially. The nth component of the spectrum of the nth frame signal is:

$$X^{CQT}(k,n) = \sum_{j=n-\lfloor N_k/2 \rfloor}^{n+\lfloor N_k/2 \rfloor} x(j)a_k^*(j-n+N_k/2) \tag{3}$$

Here, $\lfloor \cdot \rfloor$ indicates rounding down to the negative direction, $k = 0,1,\cdots,K$ and k denote the frequency subscripts of CQT, and K represents the total number of frequency subscripts:

$$K = \left\lceil B \cdot \log 2\left(\frac{f_{\max}}{f_{\min}}\right)\right\rceil \tag{4}$$

$\lceil \cdot \rceil$ denotes rounding toward the positive direction, B represents the number of subscripts per octave, $f_{\max}$ and $f_{\min}$ correspond to the highest and lowest center frequencies, respectively. $a_k^*(n)$ denotes the complex conjugate of $a_k(n)$, and $a_k(n)$ is defined as:

$$a_k(n) = \frac{1}{N_k} w\left(\frac{n}{N_k}\right)\exp\left[-i2\pi n\frac{f_k}{f_s}\right] \tag{5}$$

Among these, f_s is the sampling frequency. $w(t)$ employs a Hamming window. t is 0 when outside the range 0 to 1. $w(t)$ is 0, corresponding to the center frequency k of the subscript. f_k is:

$$f_k = f_{\min} 2^{\frac{k-1}{B}} \tag{6}$$

Q denotes the quality factor:

$$Q = \left(2^{\frac{1}{\beta}} - 1\right)^{-1} \tag{7}$$

The window length N_k corresponding to frequency subscript k is:

$$N_k = \left\lceil Q\frac{f_s}{f_k}\right\rceil \tag{8}$$

H_k indicates the selectable frame skip range:

$$0 < H_k \le \frac{1}{2}N_k \tag{9}$$

B is the most critical parameter for CQT, determining its temporal and frequency resolution. When B equals 12, f_k precisely corresponds to the frequency of each semitone. In this paper, frequency indices are assigned at quarter-tone intervals, where B corresponds to 24, meaning each interval has 24 frequency indices. The total number of calculated indices K is thus 177. A filter bank with a quality factor Q of 34 per 1/24-tone interval is selected. Under these conditions, the CQT spectrum of the musical signal is shown in Figure 2.

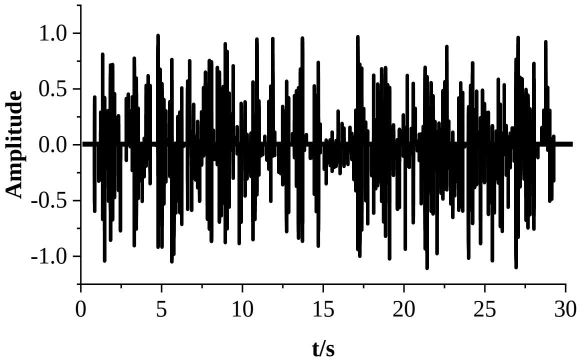


Figure 2: The CQT spectrum of the music signal

3.2.3 Mel-frequency cepstral coefficients

Mel Frequency Cepstral Coefficients (MFCCs) are derived by squaring the amplitude spectrum of a signal, then passing it through a set of Mel bandpass filters. The logarithm of each filter's output is taken, followed by a Discrete Cosine Transform (DCT) to obtain the MFCCs. Equation (11) converts Mel frequencies to Hertz. Equation (11) is used to calculate the center frequencies of each Mel filter band, with the calculated frequency range being $[f_i, f_h]$:

$$F_{mel}(f) = 1125\ln(1+f/700) \tag{10}$$

$$\begin{aligned} f(m) &= F_{mei}^{-1}\left(F_{mei}(f_l) + m\frac{F_{mei}(f_h)-F_{mei}(f_l)}{M+1}\right) \\ &= 700\times\left(e^{\ln(f_i/700+1)+m\frac{\ln(f_h/700+1)-\ln(f_i/700+1)}{M+1}} - 1\right) \end{aligned} \tag{11}$$

Among these, $m = 0,1,2,\cdots M+1$. Typically within the range of $0-f_s/2$, 40 filter banks are selected, where f_i is 0 and f_h is $f_s/2$. The center frequencies of each Mel filter are then mapped to the frequency indices k of the STFT to derive equation (12), where N denotes the number of points in the Fourier transform:

$$700\times\left(e^{m\frac{\ln(f_s/(2^{+}700)+1)}{M+1}} - 1\right) = \frac{f_s}{N}\times(k-1) \tag{12}$$

$$\frac{dk}{dm} = \frac{700\times N}{f_s}\times\frac{\ln(f_s/1400+1)}{M+1}\times(f_s/1400+1)^{\frac{m}{M+1}} \tag{13}$$

Taking the partial derivative of k with respect to m yields formula (13). It can be seen that the derivative of k with respect to m increases exponentially as m increases, meaning that as m grows larger, the rate of increase of k accelerates.

3.3 Pipa Performance Quality Evaluation Model

3.3.1 Wavelet Neural Networks

(1) Structure of Wavelet Neural Networks

Currently, there are two approaches to Wavelet Neural Networks (WNN). This paper employs the second method, which can be considered an improvement over the Backpropagation (BP) neural network. The overall structure of the wavelet neural network is fundamentally similar to that of the BP neural network, consisting of three layers: the input layer, the hidden layer, and the output layer. The most direct difference between the two lies in their training functions. The wavelet neural network replaces the Sigmoid training function with a wavelet function.

(2) Learning Algorithm of the Wavelet Neural Network

Within the wavelet neural network structure described in this paper, the gradient descent search method is employed. This process minimizes the mean squared error between the actual output and the expected value after training the entire network. This involves a forward propagation of the output followed by a backward propagation to adjust the weights. To reduce training time, a learning method based on wavelet networks is adopted. The specific implementation process of the wavelet network is as follows:

1) When the number of neurons in the input layer, hidden layer, and output layer are n, m, and N respectively, then:

$$y_j(t) = f\left(\sum_{j=0}^{N} w_{kj}\psi_{(a,b)}\left(\sum_{k=0}^{m} w_{ik}x_i(t)\right)\right) \quad i = 1, 2, \cdots, n \tag{14}$$

$y_j(t)$ represents the output pattern vector for the jnd input sample, $f(\cdots)$ denotes the result after passing through the training function, W_{kj} denotes the weights from the hidden layer to the output layer, $\psi_{(a,b)}$ denotes the wavelet function, W_{ik} denotes the weights from the input layer to the hidden layer, and x_i denotes the input pattern vector. Then:

$$E = \frac{1}{2}\sum_{j=1}^{N}(y_j(t) - o_j)^2 \tag{15}$$

In the formula, E denotes the error function, $y_j(t)$ represents the output pattern vector, and o_j signifies the desired output.

Let:

$$net_i = \sum_{i=0}^{n} w_{ik}x_i(t) \tag{16}$$

In the formula, net_i denotes the sum of the products of input vector $x_i(t)$ and the weights W_{ik} from the input layer to the hidden layer.

Therefore:

$$\psi_{(a,b)}(net_i) = \psi\left(\frac{net_i - b_k}{a_k}\right) \tag{17}$$

In the formula, $\psi_{(a,b)}(net_i)$ represents the value when the input to the wavelet function is net_i.

Therefore:

$$y_j(t) = f\left(\sum_{j=0}^{N} w_k \psi_{(a,b)}(net_i)\right) \quad i = 1, 2, \cdots, n \tag{18}$$

In equation (18), $y_j(t)$ represents the output vector of the entire function.

2) For the random determination of network connection weights and thresholds, the network is first expanded. Subsequently, the error and backward computation volume for backpropagation are calculated. This process constitutes a forward output propagation followed by backward weight correction propagation. When the actual output approaches the expected value, training concludes, and the network structure is saved.

Under the principle of forward output propagation with backward weight correction, the corresponding parameter adjustment process for wavelet neural networks is expressed as follows:

$$w_{ik}(t+1) = -\eta \frac{\partial E}{\partial w_{ik}} + w_{ik}(t) \tag{19}$$

$$w_{kj}(t+1) = -\eta \frac{\partial E}{\partial w_{kj}} + w_{kj}(t) \tag{20}$$

$$a_k(t+1) = -\eta \frac{\partial E}{a_k} + a_k(t) \tag{21}$$

$$b_k(t+1) = -\eta \frac{\partial E}{\partial b_k} + w_k(t) \tag{22}$$

In the above formula, η represents the learning coefficient. Taking the partial derivative with respect to W_{ik}, W_{kj}, a_k, b_k yields the respective rate of change.

3.3.2 WNN Evaluation Model

(1) Objective Evaluation Process of Pipa Performance Quality Using a Neural Network:

1) Data normalization. The following formula is used:

$$\hat{x} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \tag{23}$$

Normalize the extracted acoustic feature parameters of pipa performance to eliminate scale and dimensionality effects.

2) Data classification: Scores were assigned based on subjective evaluations by experts and graduate students, serving as target values for training network outputs. These constitute the output samples.

3) Establishment of the wavelet neural network: The entire network construction process includes designing the input and output layers, determining the number of neurons in the hidden layer, and finally selecting the training function for the hidden layer.

4) Network training and learning process.

5) Prediction process, i.e., evaluation process.

(2) Input/Output Layer Design

The input layer comprises three feature parameters: time-domain envelope segment ratio, constant Q transformation, and Mel frequency apurap coefficient. Therefore, the input layer consists of three neurons. The output target value is the subjective evaluation score for the song, hence the output layer comprises one neuron.

(3) Determining the Number of Hidden Layer Neurons

This wavelet neural network has 8 neurons in the input layer and 1 neuron in the output layer. The most common approach in current academic research is to set the minimum number of neurons in a wavelet neural network to 2× the number of output layer neurons and the maximum to 3× the number of input layer neurons. Performance is then evaluated experimentally within this range to determine the optimal neuron count. Therefore, experiments were conducted with 2 to 20 neurons in the hidden layer, and comparative testing was used to identify the neuron count yielding the best performance. The error comparison for different neuron counts during network training is shown in Figure 3. The training error varies with the number of hidden layer neurons. When the hidden layer has 5 neurons, the training error is minimized at 1.248. Therefore, selecting 5 neurons in the hidden layer yields the best performance.

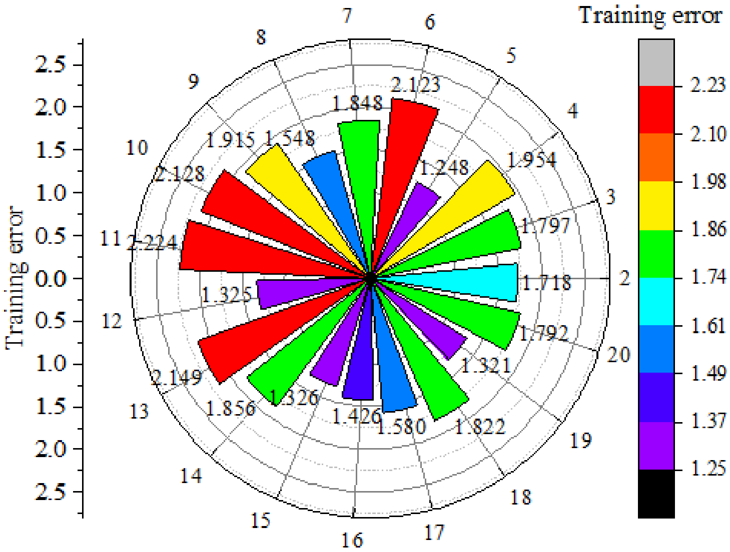


Figure 3: The training error of different hidden layer neurons

(4) Determination of the Training Function

Within the entire wavelet neural network, the selection of the training function plays a crucial role in the overall network performance, directly affecting convergence speed and systematic error. This paper selects the Morlet2 function as the network's training function.

(5) Network Architecture

Following the establishment of the entire neural network and rigorous control over each component, the current architecture of this wavelet neural network is as follows: the output layer consists of 3 neurons, the hidden layer comprises 5 neurons, the input layer contains 1 neuron, and the training function is the Morlet2 function.

(6) Training the Wavelet Neural Network

In the wavelet neural network, training samples are first input into the input layer. Random numbers within the range (0, 1) are selected within the network as connection weights and thresholds, with an expected error of 0.001. The neural network undergoes iterative training. Training concludes when the network's output error reaches or approaches the target error. The function relationship and network structure are then saved, and this trained network architecture is applied for the objective evaluation of pipa performance quality.

3.4 Experimental Validation and Results Analysis

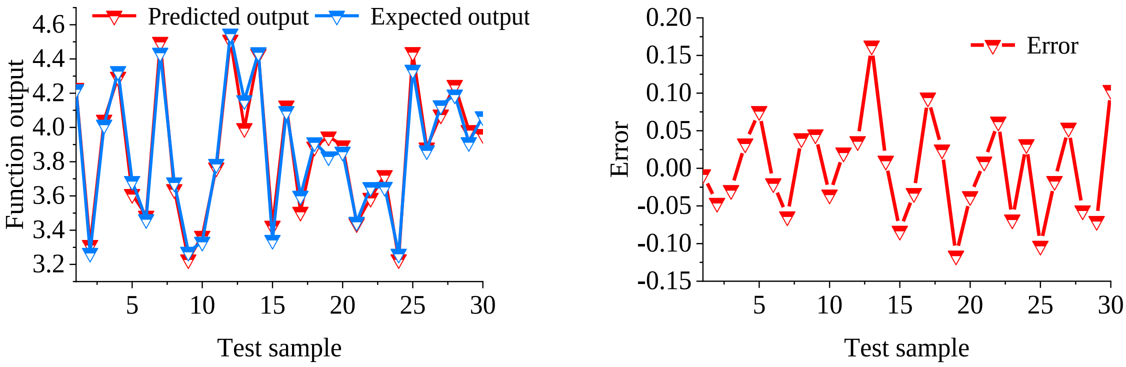
3.4.1 Experimental Simulation

In the MATLAB R2016a environment, a fusion feature set (MFCC + CQT + RMS) was employed as input parameters for training and learning within the pipa performance quality evaluation network model. Subjective evaluation results were utilized as target values to supervise the model's learning and training process. Among 150 sample sets, 100 were designated as training samples, 30 as test samples, and 20 as validation samples.

To further confirm the effectiveness of this method, the combination of MFCC, CQT, and RMS was proved to be the most suitable input feature fusion when entering the wavelet neural network-based pipa performance quality evaluation model. Moreover, comparative experiments were conducted on single features, various combinations of features, and different sample sizes for exploratory data analysis. Finally, predictions of seven sound quality assessment items, including clarity, softness, brightness, richness, smoothness, balance, and harmony, were performed on the validation set, taking the best combination of features as input. This resulted in the prediction accuracy rate of the proposed model for different pipa performance items.

3.4.2 Analysis of Results

In the preliminary experiment, the output and error analysis graph of the pipa performance quality evaluation network are illustrated in Figure 4. In Figure (a), the predicted value and output value of the network model in different testing samples are plotted, whereas Figure (b) demonstrates the difference between the two sets of values. The predicted output value is quite consistent with the actual output value. Even if there is some deviation in a few test samples, the prediction performance is still excellent. The accuracy rate of the test samples is 98.62%, while the validation samples can reach 98.51%.



(a)Predictive value and expected value (b)Error value

Figure 4: The prediction output and error analysis curve of the model

Additional experimental results are illustrated in Fig. 5, and all the experimental results were acquired with the best parameters of the network. Generally, the accuracy rate tends to increase with the increase in the training sample size. The fusion feature (MFCC+CQT+RMS) consistently performs better compared to other combinations of features, with a mean accuracy rate of 95.12% in six experiments conducted. On the whole, the MFCC alone as a single feature and its combination feature (MFCC+RMS) performed poorly in terms of predictive accuracy, with mean accuracy rates of 93.88% and 93.78%, respectively.

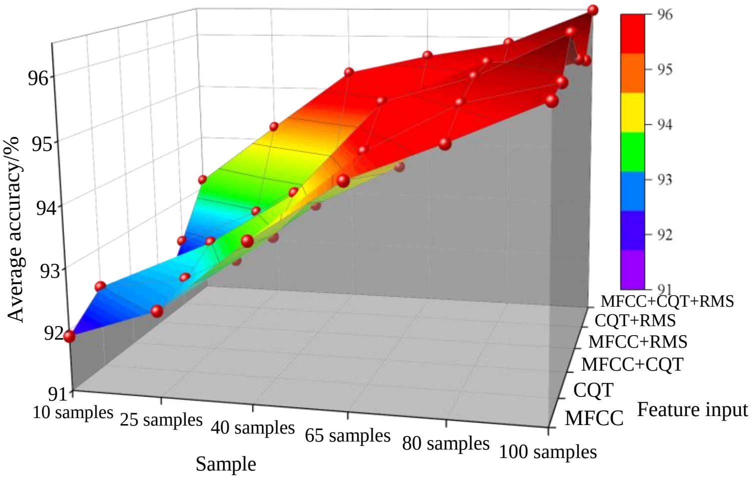


Figure 5: Average accuracy of different eigeninput

The wavelet neural network model was used in predicting seven different criteria of pipa performance quality in 20 samples for validation. Prediction accuracies for these seven different criteria are provided in Figure 6. In this context, evaluation accuracies of the model for different pipa performance quality criteria ranged between 88% to 96%. The average prediction accuracy for different pipa performance quality criteria such as clarity, softness, brightness, richness, smoothness, balance, and harmony was 92.30%.

From experiments, the most efficient set of fusion features (MFCC + CQT + RMS) produced the best results for prediction evaluation, which maximally reflected the quality of pipa performance. Thus, it can be concluded that the pipa performance quality evaluation model developed on the basis of WNN neural network is highly reliable and possesses very good prediction accuracy. The pipa performance quality evaluation method proposed in this paper is highly novel and feasible.

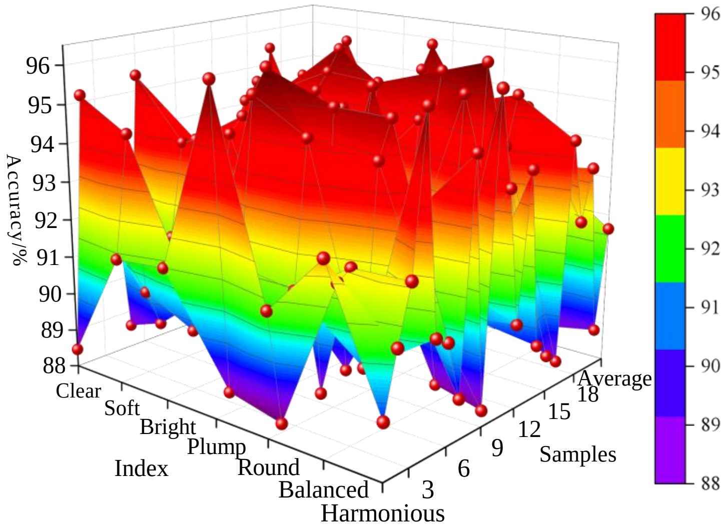


Figure 6: Forecast accuracy of all indicators

4 Analysis of the Effectiveness of Enhancing Musical Expressiveness

4.1 Overall Solution

In order to examine whether the strategy of integrating artistic and technical factors can effectively improve the musical expressiveness of pipa performance, as well as the reliability of the developed WNN evaluation model, this research recruited 30 university pipa course learners as subjects, and ran a three-month teaching experiment where the participants used the above strategy of integrating art and technique factors. In the process, students would conduct basic training on improving technique, learning emotional control, raising music theory awareness, exploring the context of musical pieces, understanding the path of performance, improving audio visual sense, strengthening interpretative effect, gaining stage experience, and using the Pipa Performance Quality Evaluation Method throughout the learning process. It is anticipated that an evaluation model of musical expressiveness of pipa performance will be established. Through before-and-after comparison of the model, one could prove that the combination of art and technique is effective in improving pipa performance expressiveness.

4.2 Music Expressiveness Evaluation Model

4.2.1 Indicator System

Integrating the artistic and technical aspects of pipa performance, the music expressiveness evaluation indicators, as shown in Figure 7, comprise three major indicator systems: emotional attitudes, process methods, and knowledge skills.

Emotional attitudes are summarized into seven secondary indicators: cultivating an optimistic mindset, developing musical aesthetic abilities, fostering musical interest, nurturing a spirit of collectivism, respecting art, refining character, and promoting diversified development.

Process and Methodology encompasses seven secondary indicators: appreciation learning ability, experiential learning ability, imitative learning ability, inquiry-based learning ability, innovative learning ability, collaborative learning ability, and comprehensive learning ability.

Knowledge and Skills objectives include four secondary indicators: instrumental music historical knowledge, instrumental music foundational knowledge, instrumental music fundamental skills, and instrumental music-related cultural knowledge.

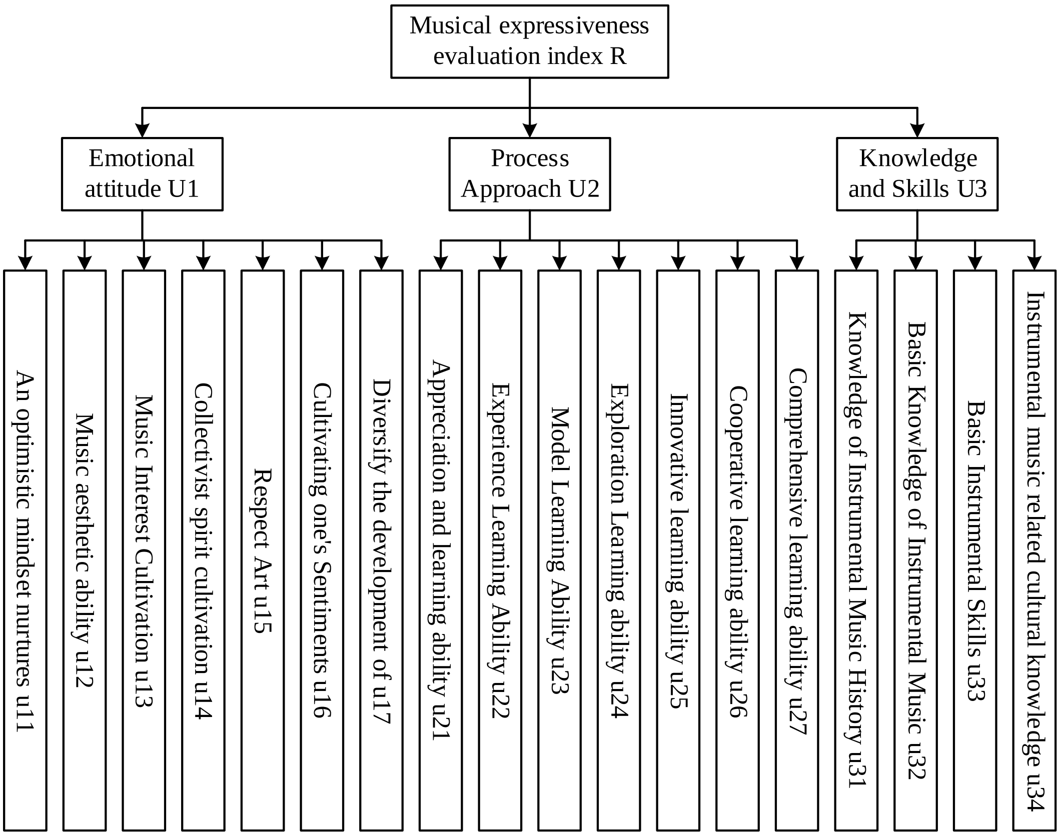


Figure 7: The evaluation index of the music expression

4.2.2 Evaluation Procedure

The evaluation of musical expressiveness in pipa performance involves multiple factors and exhibits significant subjectivity. Therefore, this paper will leverage fuzzy comprehensive evaluation theory to conduct a quantitative, integrated assessment of this nonlinear evaluation domain, based on the nonlinear characteristics of the evaluation process.

(1) Determining Evaluation Indicators and Their Weights

To evaluate musical expressiveness in pipa performance, one must first establish the set of indicators representing various influencing factors and the corresponding weighting set for each indicator. Fuzzy evaluation is sensitive to the determination of the weight for each evaluation factor because the weight directly affects the final evaluation result. An efficient way to do this is through the use of the Analytic Hierarchy Process (AHP).

(2) Setting the Set of Comments for Evaluation

The set of comments for musical expressiveness of pipa playing may be obtained via membership function values that are generally assigned by means of comprehensive grading synthesis. Normally, the set of comments for musical expressiveness of pipa playing is V = {Excellent, Good, Average, Poor}.

(3) One Factor Assessment

One factor assessment of musical expressiveness during pipa playing is the basis of the comprehensive assessment. Generally, depending on a given set of assessment criteria, the scores for each factor need to be calculated for the subject under examination, forming one factor assessment matrix.

(4) Comprehensive Assessment

Comprehensive assessment involves combining one factor assessments. By integrating such assessments, it becomes possible to conduct an overall assessment of the musical expressiveness of the pipa playing. The procedure includes the following stages: calculation of the fuzzy synthesis by multiplying ordinary matrices; normalization of the synthesis results; and evaluation of the subject rating based on the highest membership degree rule.

4.3 Evaluation and Analysis of Musical Expressiveness

4.3.1 Determination of Evaluation Indicator Weights

The following analysis is done through the application of an expert score approach in evaluating the weights of the primary indicators. Ten experts who have been involved actively in pipa instrumental learning were invited to score the weights of the primary indicators. The rating scores assigned to each indicator by the 10 experts are illustrated in Figure 8. After the necessary calculations, the weights of Affective Attitude, Process Methods, and Knowledge Skills are determined to be 0.325, 0.352, and 0.323, respectively. From the expert scores, it can be seen that the weight scores for the three indicators for pipa performance learning are relatively similar.

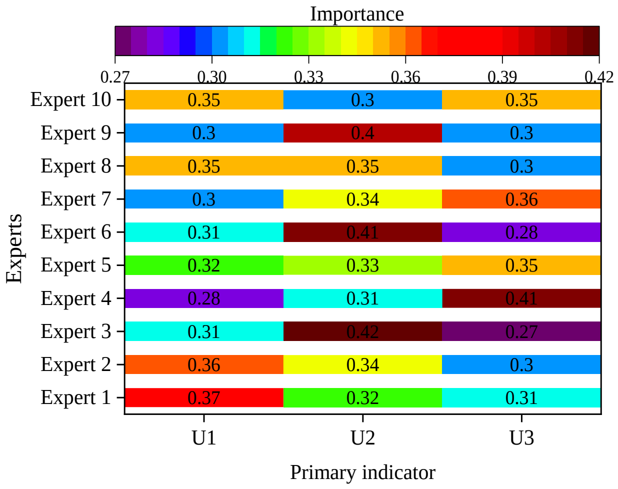


Figure 8: A summary of the importance of the first level index

In respect to the identification of the secondary indicators, there are 18 secondary indicators used in the framework. In this research, the combination of expert scoring and fuzzy comprehensive evaluation is adopted as the means for identifying the weights of the primary and secondary indicators. The ten experts rated all the secondary indicators one after another. With the aid of statistics analysis on the collected data, together with applying formulas for calculating weights, the weights of both the primary indicators and secondary indicators are determined as indicated in Figure 9. U33, U32, and U34 which represent Instrumental Basic Skills, Instrumental Foundational Knowledge, and Instrumental Related Cultural Knowledge have the largest weights of 0.108, 0.081, and 0.068 respectively.

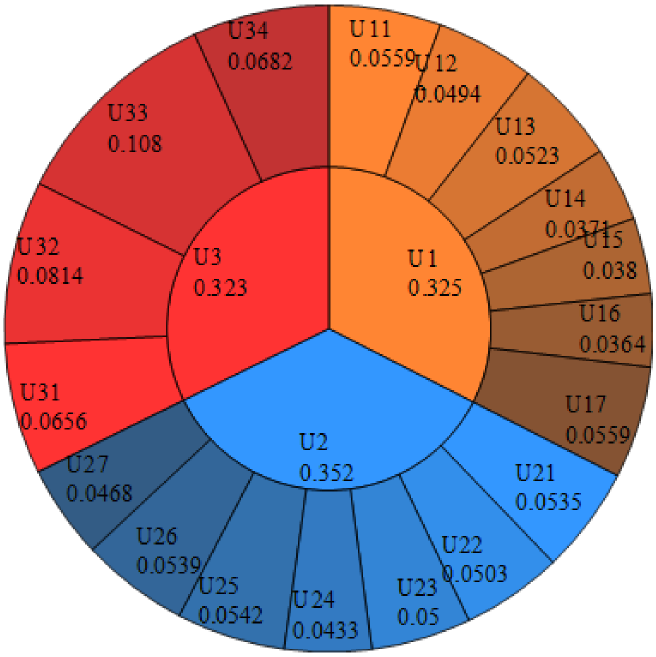


Figure 9: The weight of the primary and secondary indicators

4.3.2 Analysis of Evaluation Results

To obtain the fuzzy relationship matrix between students' musical expressiveness and secondary indicators in a university pipa teaching course, a questionnaire survey was conducted before and after the teaching experiment to assess students' pipa performance expressiveness. The survey participants included five music teachers and students enrolled in the pipa course at the university. Thirty-five questionnaires were distributed to both teachers and students before the experiment and another 35 after the experiment, yielding a total of 70 completed questionnaires.

The aggregated results of the pre- and post-experiment surveys are presented in Figures 10 and 11. The fuzzy grading criteria—Excellent (1.0–0.8), Good (0.80–0.70), Average (0.69–0.50), Poor (0.49–0.0)—were quantified as follows: Excellent = 0.9, Good = 0.7, Average = 0.5, Poor = 0.3. Based on the survey results, the pre-experiment scores for affective attitude, process methods, and knowledge skills were 0.237, 0.259, and 0.225, respectively. Thus, the pre-experiment evaluation scores for students' pipa performance expressiveness were:

$F=0.325*0.237+0.352*0.259+0.323*0.225=0.241$

The post-experiment scores for affective attitudes, process methods, and knowledge skills were 0.238, 0.266, and 0.233, respectively. Consequently, the post-experiment evaluation scores for students' pipa performance expressiveness were:

$F=0.325*0.238+0.352*0.266+0.323*0.233=0.246$

Students' overall musical expressiveness in pipa performance improved by 2.07%, indicating that the strategy of integrating artistic and technical elements, combined with the application of the pipa performance quality evaluation model, can enhance students' expressive capabilities in pipa performance.

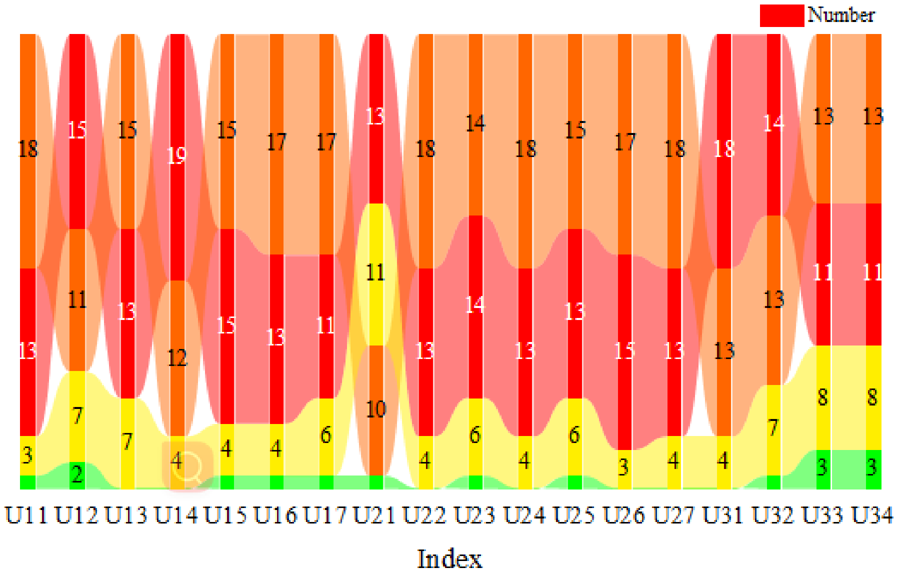


Figure 10: Questionnaire survey summary before experiment

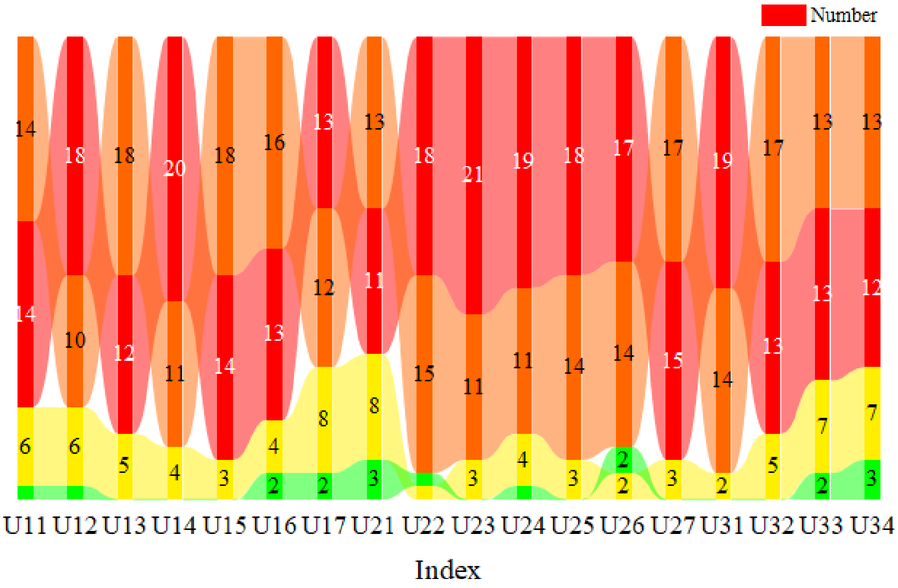


Figure 11: Questionnaire survey summary after experiment

5 Conclusion

As an ancient instrumental art form, pipa performance serves as a vital medium for performers to convey emotion. This study explores strategies to enhance musical expressiveness in pipa performance by integrating artistic and technical elements. To assist learners in improving their pipa skills, a wavelet neural network is employed to construct a pipa performance quality evaluation model. Fourthly, a teaching experiment will be conducted in order to investigate the effectiveness of the above-mentioned integrated artistic-technological strategy and assessment model in improving musical expressiveness of pipa performance. Wavelet neural network model proves its excellent predictive efficiency and yields more than 98% average accuracy both in the test and validation samples. The model provides high average prediction accuracy (92.3%) in seven different criteria, making itself a good auxiliary tool for training of the musician. Instrumental basic skills, fundamental knowledge about the instrument as well as associated cultural knowledge have the strongest impact on musical expressiveness, as the indicator weights equal 0.108, 0.081 and 0.068 correspondingly. As a result of implementing artistic-technological strategy in the training program and using the assessment model in practice, the sample students achieved the following progress – their results in affective attitude, process methods, and knowledge/skills raised up to 0.238, 0.266 and 0.233 correspondingly, making up the total increase in musical expressiveness equal to 2.07%. Only after complete understanding of the essence and culture of a piece and its successful integration into the language of music in terms of artistic conception and achieving the best possible state while performing, the performer succeeds in creating an atmosphere, immersing the listener in his world of emotions. As a result of being immersed in emotions, people perceive ideas of a musician, making musical expressiveness rise up to a new level.

About the Author

Yu Zou was born in Chengdu, Sichuan, P.R. China, in 1985. I obtained a master's degree from the Central Conservatory of Music in China. I am currently an associate professor at the Sichuan Conservatory of Music. My main research direction is Chinese musical instrument performance (Pipa).

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