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A Quantitative Assessment Study of Dynamic Symmetry and Aesthetic Value in Dance Theater Performance

Abstract: - In order to enhance the aesthetic value of dance drama performance, this paper is based on the human gesture recognition technology, extracting angle and gesture distance features, and carrying out normalization to accurately mark the human gesture of dance drama performance. A directed graph model in chronological order is constructed, and time is integrated into the model as a dynamic element. Describe the connection relationship between space and time in the sequence of human skeleton through the spatio-temporal graph, and establish feature vectors containing coordinate information and confidence level to get dynamic spatio-temporal symmetry. Select the nearest elements in the Top codebook to quantize the coding process, and finally get the quantization result of aesthetic value. Comparison with the three methods of convolutional neural network, optical flow method and dynamic temporal regularization reveals that the similarity mean value of this paper's method is 0.56, and the quantization process is more stable. During the iterative process of dynamic symmetry calculation, a high recognition rate of 0.99 is achieved, and the recognition accuracy can reach up to 100%. In addition the results of assessing the symmetry of movements in dance drama performance such as overall aesthetics have a smaller gap with the expert ratings, further proving the effectiveness of the constructed quantitative assessment model.

Keywords: dance drama performance; human gesture recognition; directed graph model; dynamic symmetry; aesthetic value

1. Introduction

Aesthetics is the feeling of affective and emotional aspects induced by perception and thinking activities, and is a philosophical generalization of human aesthetic and artistic practices [1]. The assessment of aesthetics is a highly integrated, yet complex physiological and psychological process [2]. Typically, beauty exists in the eyes or mind of the aesthete, usually based on the judgment of the aesthete, and it is asserted that beauty must be based on the aesthete's subjective aesthetic feelings [3]. Dance movement is the carrier of dance theater performance, which contains rich emotions, in the dance theater performance, actors need to present the corresponding dance movements according to the plot, and ensure the artistic beauty of the movements [4-5]. At the same time, the body language to create the plot, prompting the art of emotional layers to promote the audience into the atmosphere of the dance drama, and then realize the emotional resonance with the art of dance. In terms of its expression, it can be divided into symmetrical and asymmetrical, fixed and non-fixed and other multiple combinations [6]. From the point of view of the dance effect, the symmetrical dance movement reflects the neat and balanced beauty, and meets the expectations of multiple performances.

At this stage, there are fewer studies on quantitative modeling of dynamic symmetry in dance drama

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performance. In this paper, we first analyze 25 joint points under the KinectV2 skeletal coordinate system to construct three-dimensional coordinate information. The distance changes between the joint points of the actor's torso and upper limbs are measured in order to analyze the body shape and movement amplitude distance characteristics of the actor during the performance. The directed graph technology is utilized to obtain the complex spatio-temporal relationship in the skeleton sequence and construct the directed graph model in chronological order. Considering the node features in the directed graph, the edge information is fused using the adjacency matrix, so as to identify the symmetric patterns of dance movements in time and space. In the quantization coding process, the number of joints, the quantization feature order and the number of channels are set up. Through the calculation of specific indexes and the setting of evaluation criteria, the quantized features are transformed into comparable aesthetic value scores to reach the research goal of this paper.

2. Related Words

Giambrone, J et al. in order to improve the performance of competitive dance movements, used multiple baselines across behaviors to evaluate the videos of the research subjects for the purpose of improving the dance movements in their study [7]. Peng, H et al. proposed a machine learning-based mechanism for assessing dance movement aesthetics by firstly applying higher-order clustering features to represent the dance movements, and secondly, constructing a combinatorial classifier to train the aesthetics model. Finally, the simulation environment verifies that the constructed model can better understand and judge the dance movement aesthetics [8]. Monroy, E et al. evaluated synchronous and asynchronous dance videos on eight semantic differential scales using Japan and the United Kingdom as the research subjects and concluded that dance aesthetics is most affected by cultural factors, and that the cultural differences in the concept of aesthetics are related to the cultural background [9]. Orlandi, A et al. addressed the dance aesthetics of movement characteristics, establishing dance sequences to assess the complexity of dance movements, and evaluating the reproducibility and enjoyment of dance performances, etc. [10]. Gorwa, J et al. studied the symmetry technique in classical ballet with 12 professional performers, and found that dance symmetry performance needs to be improved in actual performances [11]. Honglian, S et al. from the movement biomechanics perspective, combined with the rotational characteristics of samba dance, generalized its dynamic distribution and parameter changes, and evaluated the dynamic laws of samba dance [12]. Luo, W and Ning, B for recognizing highly dynamic dance movements, utilized image processing and classification and recognition techniques to characterize the dance movements by constructing pixel points from similar video clips [13].

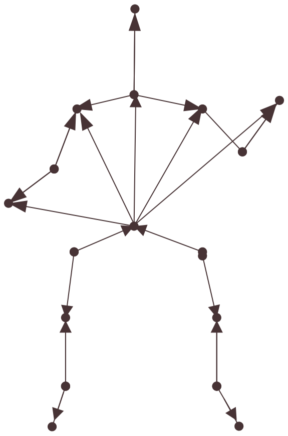
3. Human gesture feature extraction for dance drama performance

Human motion in dance theater performances has a very high complexity, which makes it a challenge to extract effective human gesture features from the motion [14]. In this paper, we propose an invariant feature extraction method based on skeletal information, and the key of this method is to find a balance. That is, to find the optimal number of joint point features between description refinement and computational complexity, and to extract features that satisfy uniqueness, continuity, stability, parsimony and generality. The key parts of the human body are selected for feature extraction, mainly angle features and distance features are extracted for describing the motion state of the human body. Posture feature extraction is a key step in understanding the human body motion, which is fundamental and important for the subsequent dynamic symmetry analysis and aesthetic value assessment [15].

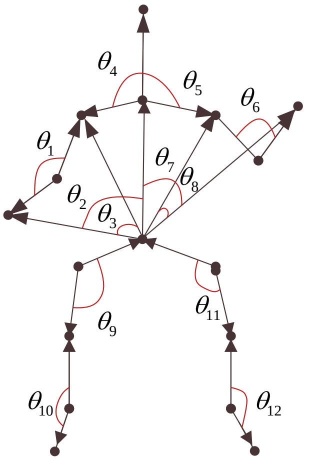
3.1 Characterization of human posture angles

Due to the high degree of freedom and non-rigid characteristics of human body movement, the movement of human skeletal joints is arbitrary, and it is difficult to recognize without a specific posture as a matching object. Therefore, we choose the skeletal information as the technical support, KinectV2 can obtain the 3D coordinates of the joints in real time, and the 25 joints under the skeletal coordinate system of KinectV2 have independent 3D coordinate information. If the 3D information of the 25 joint points is directly used to construct the human body posture, the dimension of the dataset reaches 75 dimensions, the posture characterization information is redundant, and the computational difficulty is very large. The angle features are extracted based on the invariance of the bone structure, and the joint point vectors can be randomly combined with each other to form different vector angles, and the vector angles can both highly characterize the posture information and eliminate the information that is not related to the posture action, which reduces the dataset dimensionality and provides a higher recognition accuracy [16].

Figure 1 shows the KinectV2 angle features, and the joint point vectors are shown in Fig. 1(a). 25 skeletal joint points captured by KinectV2 were particularly focused on in the human gesture feature extraction for the dance drama performance. The joint point vector corners are shown in Fig. 1(b), and 17 of these key joint points are selected to build the feature vectors after careful selection. These key joint points can accurately reflect the various postural changes of the dancers during the performance, and can more accurately capture and describe every subtle movement of the dancers in the dance drama performance, which provides a strong support for the subsequent postural analysis and recognition.



(a) Joint point vector



(b) Joint point vector angle

Figure 1 Joint point angle features

In this paper, the upper limb with a high number of angle combinations is selected for feature extraction, and Fig. 2 shows the 3D coordinate vector angles of the joint points, which are calculated for the angle of the joint vectors combined to form the pinched angle.

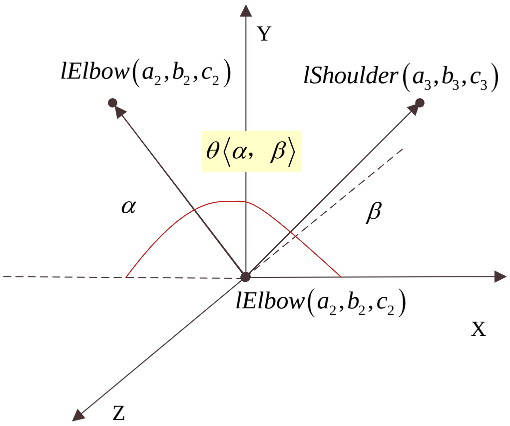


Figure 2 Joint vector angle

After obtaining the joint point 3D coordinate information $lHand(a_1,b_1,c_1), lElbow(a_2,b_2,c_2), lShoulder(a_3,b_3,c_3)$, the joint point vector is obtained:

$$\alpha=(a_1-a_2,b_1-b_2,c_1-c_2) \tag{1}$$

$$\beta=(a_3-a_2,b_3-b_2,c_3-c_2) \tag{2}$$

Next, calculate the value of the angle θ of the vector consisting of vectors α and β:

$$\theta = \cos^{-1}\left|\frac{\alpha \cdot \beta}{|\alpha| \times |\beta|}\right| \tag{3}$$

where $\alpha \cdot \beta$ is the vector inner product, is obtained:

$$|\alpha| = \sqrt{(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2} \tag{4}$$

$$|\beta| = \sqrt{(a_3 - a_2)^2 + (b_3 - b_2)^2 + (c_3 - c_2)^2} \tag{5}$$

The range of the vector pinch angle is 0^*. In the feature extraction process, the corresponding threshold d is set for each posture, and when the calculated value satisfies the posture value range $(\theta - d) \leq \theta \leq (\theta + d)$, the posture angle is extracted successfully. The six angle features construct the human posture angle feature dataset S_θ:

$$S_\theta = \{\theta_1, \theta_2, \theta_3, \theta_6, \theta_7, \theta_8\} \tag{6}$$

The vector angles formed between key skeletal joint vectors in dance movements are shown in Table 1, and these angles are essential for analyzing the dynamic aesthetic value and symmetry of dance movements. θ_1 describes the relative positional relationship between the left hand, left elbow, and left shoulder, reflecting the stance and degree of flexion of the dancer's left arm. θ_1 Measures the spatial relationship between the left hand and the base of the spine and the spine-shoulder, revealing the relative position of the left arm to the centerline of the body. θ_1 Angles more directly relate the left hand, the base of the spine, and the left shoulder. The θ_4 angle relates to the left shoulder, spine shoulder and head, reflecting the overall posture of the dancer's upper body and the degree of spinal curvature. θ_6 Angle describes the relative position between the dancer's right shoulder, spine shoulder and head. Angle measures the angle between the right hand, right elbow and right shoulder, reflecting the posture of the dancer's right arm. Observations θ_7, θ_8 and θ_9, θ_{11} provide insight into the degree of leg flexion and balance of the dancer's posture. When solving the joint vector angles of human skeleton in dance drama performance, the joint points involved in constructing the joint vectors are firstly selected, and then the joint points are labeled and the three-dimensional coordinate information of the skeletal joint points is obtained to construct the joint vectors. In addition, angles like θ_{10} and θ_{12} provide important information about the precision and fluidity of the dancer's footwork. Combining these perspectives can provide an in-depth understanding of the spatial relationships and dynamic changes between different body parts in dance movements, which provides an important basis for analyzing and quantitatively evaluating dance movements [17-18].

Table1 Vector angles are specified

Name	Description	Name	Description
θ_1	LHand-LElbow-LShoulder	θ_7	RHand-Spine Base-SpineShoul
θ_2	LHand-SpineBase-SpineShoulde	θ_8	RHand-SpineBase-Shoulder
θ_3	LHand-SpineBase-LShoulder	θ_9	SpineBase-Lhip-LKneel
θ_4	LShoulder-SpineShoulder-Head	θ_{10}	Lkneel-Lankle-LFoot
θ_5	RShoulder-Spine Shoulder-Head	θ_{11}	SpineBase-Rhip-RKneel
θ_6	RHand-RElbow-R Shoulder	θ_{12}	Rkneel-Rankle-RFoot

Through the combination of joint angle feature dataset, the human posture sample model is constructed according to the human physiological structure, the angle, feature has the advantages of low computational complexity and strong posture characterization ability.

3.2 Human Posture Distance Characterization

When describing human posture, angular features can indeed provide a wealth of information, however, in some specific scenarios through distance features, the relative position of each joint point can be accurately identified, and the torso and upper limb joint points, which are excellent in terms of stability and recognition, are selected. These joints occupy an important position in the human skeletal structure, and are particularly crucial for understanding and analyzing human movements. In dance drama performance, by measuring the distance changes between the joints of the actor's torso and upper limbs, the distance characteristics of the actor's body shape and movement amplitude during the performance can be precisely analyzed, and the distance in a certain direction of the joints can be calculated.

In order to obtain stable distance characteristics, the calculated distances are normalized. Take the left and right joints as an example for distance feature calculation:

$$\begin{aligned} &LHand-SpineBase: L_1^x\frac{|d_2^x|}{|d_1^x|}, L_1^y\frac{|d_2^y|}{|d_1^x|}, L_1^z\frac{|d_2^z|}{|d_1^x|} \\ &RHand-SpineBase: L_1^x\frac{|d_2^x|}{|d_1^x|}, L_1^y\frac{|d_2^y|}{|d_1^x|}, L_1^z\frac{|d_2^z|}{|d_1^x|} \end{aligned} \tag{7}$$

Setting the distance constant value in a certain dimension of the posture, such as the distance constant value f_1 and f_2 in the direction of X, by comparing $\left(f_1 > L_1^x\right) \cup \left(f_2 > L_2^x\right)$, if the conditions meet the requirements, the feature extraction is successful.

Based on the calculation of distance features, this paper selects four kinds of distance features to construct the human posture distance feature dataset S_d:

$$S_d = \{d_2, d_3, d_5, d_6\} \tag{8}$$

Using the method of integrated angle features and distance features, the human posture of dance drama performance is accurately calibrated and described with rotational scaling invariance, which satisfies the posture recognition of different people, different angles and different positions [19].

4. Dynamic symmetry computation of key actions based on directed graphs

4.1 Dynamic skeleton model for directed graphs

In order to explore the dynamic symmetry of key movements, directed graph technique is utilized to accurately capture the complex spatio-temporal relationships in the skeleton sequence. The dynamic symmetry computational model of key actions based on directed graphs is shown in Fig. 3. Motion capture devices or efficient video human pose estimation algorithms are used to collect raw skeleton data, and the coordinate positions of individual joints are recorded in detail in each frame. These coordinates not only reveal the static pose of the human body, but also imply the dynamic changes of the movements [20]. A chronological directed graph model is constructed, in which the graph is composed of joints as graph nodes and human body structure and time as graph edges, and is represented in 2D or 3D coordinates.The input to the ST-GCN is a graph node representation of the joint coordinate vectors, which is subjected to a multilayer spatio-temporal graph convolution operation to generate a more hierarchical feature mapping on the graph, and is classified by a SoftMax classifier to categorize them into corresponding action categories. Each joint is skillfully transformed into a node in the graph, while the connections between the nodes are jointly determined by the natural structure of the human body and temporal continuity, forming directed edges. This modeling approach not only preserves the original structural information of the skeleton, but also incorporates the dynamic elements of time, making the model more vivid and realistic.

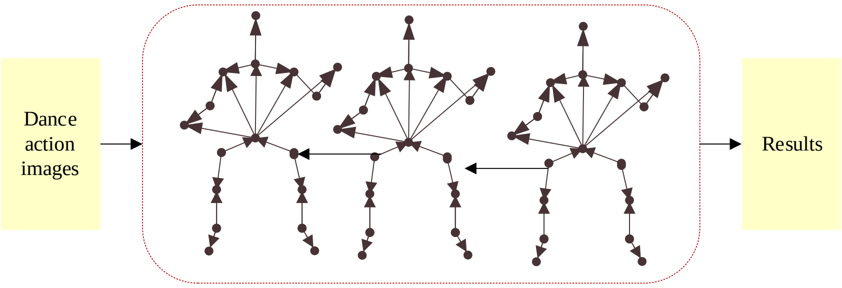


Figure 3 Dynamic symmetry calculation of key actions

4.2 Dynamic spatio-temporal symmetry

In a spatio-temporal graph describing human movements, each node represents a human joint, and the edges reveal the spatial and temporal relationships between the joints. Dynamic spatio-temporal symmetry refers to the symmetrical properties exhibited by human movements in both the temporal and spatial dimensions. Spatial edges in the spatio-temporal graph reflect the natural connectivity between joints, and these edges connect the corresponding joints according to the physiological structure of the human body. Temporal edges connect the states of the same joint at different time points across consecutive time steps, thus depicting the trajectories of the joints. The spatial and temporal connections in the human skeleton sequence of N joints with T frames are represented by the spatio-temporal graph $G=\left(V,E\right)$, where the point V represents all the key points in the skeleton sequence, and the feature vectors of each key point contain the coordinate information and confidence level of the point. The edges E in the spatio-temporal graph include both spatial E_S and temporal E_F, and the formula is as follows:

$$E_S=\left\{v_{ti}v_{tj}\left|\left(i,j\right)\in H\right.\right\} \tag{9}$$

$$E_F=\left\{v_{ti}v_{(t+1)j}\right\} \tag{10}$$

E_F denotes the blue connecting edges of the natural structural connections of the human body, and E_F denotes the same joint point temporal trajectory on different time frames. In the directed graph framework, it is possible to extract and utilize this dynamic spatio-temporal symmetry by graph convolution operations. In particular, in the single-frame case, the uniform labeling method is used to simplify as in Eq:

$$f_{out}=\Lambda^{-\frac{1}{2}}\left(A+I\right)\Lambda^{-\frac{1}{2}}finW \tag{11}$$

where $\Lambda^{ii}=\sum_j\left(\Lambda^{ij}+I^{ij}\right)$, the weight matrix W is the weight vector of several output channels by superposition. In practice, the input feature mapping can be represented as a tensor of $\left(C,V,T\right)$ dimensions in the spatio-temporal case. The map convolution is implemented by performing a standard 2-dimensional convolution of 1xr and then using the resultant tensor to multiply it with a normalized adjacency matrix $\Lambda^{-\frac{1}{2}}\left(A+I\right)\Lambda^{-\frac{1}{2}}$ on the second dimension. In addition, in the face of segmentation strategies with multiple subsets, distance segmentation and spatial configuration segmentation, the adjacency matrix is decomposed into multiple matrices, i.e., $\sum_j\left(\Lambda^{ij}+I^{ij}\right)$, which is able to efficiently handle the data in the spatio-temporal graph. This approach not only considers the characteristics of the nodes, but also fuses the information of the edges through the adjacency matrix, which is able to capture the symmetric patterns of the actions in time and space.

5. Quantitative assessment of the aesthetic value of dance dynamics

In dance theater performance, dynamic symmetry and aesthetic value are two core elements that together constitute the essence of the art of dance. In order to quantitatively assess the dynamic aesthetic value of dance, this paper captures the global and local information of dance movements through a hierarchical structure. A Top codebook and a Bottom codebook are obtained after training, which contain quantitative features representing various dance movements, respectively.The Top codebook captures the global information of the dance movements by utilizing a larger downsampling rate, while the Bottom codebook retains the detailed local information. This hierarchical structure allows both global and local features of dance movements to be considered, providing a powerful tool for quantitatively assessing the dynamic aesthetic value of dance.

5.1 Quantization coding process

The structure of the quantitative assessment of the aesthetic value of dance dynamics is shown in Fig. 4, a piece of dance theater performance dance action $M \in R^{T\times(J\times3)}$, T is the duration, J is the number of joints, which can be represented by a piece of quantitative feature sequence $e^q \in R^{T'\times2C}$, $2C$ is the number of channels of quantitative features. The one-dimensional time domain convolution E_1 encodes the action sequence M into a vector e_{bottom}, which can be continued to be encoded as e_{top} using the one-dimensional time domain convolution E_2 In training, there are two steps, the first training e_{top} part, and then training e_{bottom} part, e_{top} part and e_{bottom} part contains a codebook respectively. As an e_{top} example, the nearest element in the Top codebook is selected for each vector as the quantized vector e_{top}:

$$e_{tq,i}=\arg\min_{z_j\in Z}\left\|e_{top,i}-z_j\right\| \tag{12}$$

Finally, splicing e_{top} and e_{bottom} into e_q, e_q can be re-decoded into a dance movement sequence M by a movement decoder.

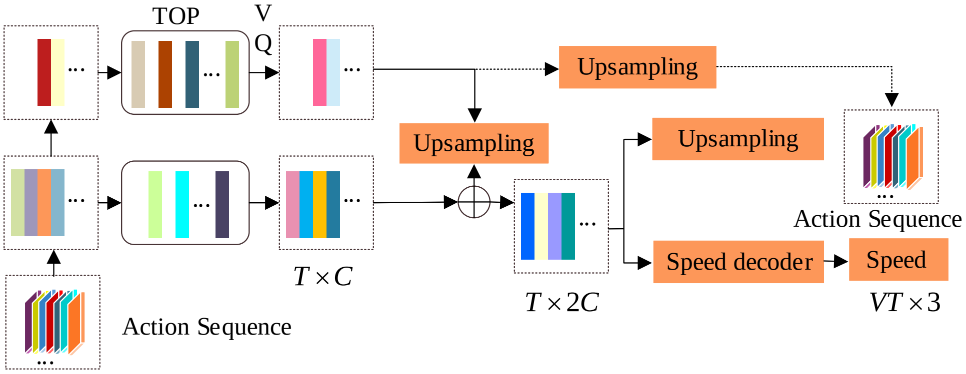


Figure 4 Quantitative evaluation structure of dance dynamic aesthetic value

5.2 Quantitative calculation of aesthetic value

In order to avoid the effect of overall joint displacement on movement encoding, the same movement appearing at different positions should be encoded as the same vector, in this paper, the input movement sequence M is first normalized, i.e., the position of the root joint point is set to zero. In order to represent the overall movement speed of the body when doing a certain dance movement, a speed decoder is used to obtain the overall movement speed V. V is a vector containing the magnitude and direction of the speed. For training, the Top part is trained first, then the Top part is fixed and the Bottom part is trained. Both training methods and loss functions used are basically the same, except that when training the Bottom part, e_{tq} needs to be up-sampled and spliced with e_{tq}. The codebook loss ensures that the encoded features can match the quantized features in the codebook, which can be used to analyze the uniqueness and representativeness of the dance movements when evaluating the aesthetic value of the dance to assess its artistic value. The following is an example of the training Top part, whose loss function is as follows:

$$L_M = L_{rec}\left(M, M_D\right) + \left\| sg\left[e_{top}\right] - e_{tq} \right\| + \omega \left\| e_{top} - sg\left[e_{tq}\right] \right\| \tag{13}$$

where L_{rec} is the reconstruction loss. In this reconstruction loss, the relative position loss of the 3D joint points is included, and the velocity and acceleration loss of the joint point movement is included. Reconstruction loss is an important index to evaluate the degree of information retention of the model in the encoding and decoding process, and the difference between the original dance movement sequence, including the position, velocity, acceleration and other information of the 3D joint points, and the decoded and reconstructed dance movement sequence is calculated. The smaller the difference, the lower the reconstruction loss, indicating that the model has less information loss during encoding and decoding.

The quantitative features were transformed into a quantitative assessment of the dynamic aesthetic value of dance. The set of indicators for assessing the dynamic aesthetic value of dance is shown in Table 2, combining the analysis of global and local information. Through the calculation of specific indicators and the setting of assessment standards, the quantitative features can be transformed into comparable aesthetic value scores, providing valuable references for dance creation and performance. The specifics are as follows:

(1) Evaluate the harmony and balance of the dance by comparing the symmetry of the dance movements in terms of time sequence and spatial structure. The symmetry can be assessed by calculating the similarity between different movement sequences using methods such as dynamic time regularization.

(2) Analyzing whether the transition between key frames in a dance movement sequence is smooth can be assessed by calculating the difference between key frames or the speed change. Dance movements with good coherence look more natural and smooth.

(3) Evaluate the expressiveness of the dance movements in details based on the local features in the Bottom codebook. The range of motion and speed change of each joint in the dance movement, as well as the degree of coordination can be analyzed. Dance movements with high expressiveness in details are more vivid and infectious.

(4) Innovativeness is assessed by comparing the difference in quantitative features between a new dance movement and an existing dance movement, and the difference between quantitative features can be calculated using cosine similarity or other distance metrics, with the larger difference indicating higher innovativeness [21].

Table 2 Quantitative evaluation index set of dance dynamic aesthetic value

Classification	Specific indicators	Calculation method	Evaluation Criteria
Global Information	1. Movement symmetry	Computing the symmetry of dance movements in time and space based on global features in the Top codebook	The higher the symmetry, the higher the aesthetic value
	2. Movement continuity	Analyze the smoothness of transitions between keyframes in a dance sequence	The smoother the transition, the higher the aesthetic value
Local information	3. Detail expression	Evaluating the expressiveness of dance movements in details based on local features in the Bottom codebook	The richer the details, the stronger the expressiveness and the higher the aesthetic value
	4. Innovation	Compare the quantitative characteristics of new dance moves with existing dance moves	The greater the difference, the higher the innovation and

			the higher the aesthetic value
Comprehensive Evaluation	5. Overall aesthetics	Combining the above indicators, the overall aesthetic value is calculated by weighted summation or other algorithms	Set weights and thresholds according to specific application scenarios

6. Dynamic Symmetry and Aesthetic Value Assessment in Dance Theater Performance

6.1 Human posture feature extraction analysis

In this paper, we mainly use the gesture recognition technique to recognize and evaluate the human gesture features in the dance drama performance, in order to prove the effectiveness of this paper's method in extracting the human gesture features, compared with the three methods of convolutional neural network, optical flow method, and dynamic temporal regularization, the results of the dance gesture evaluation are shown in Fig. 5. The variation on the first set of G1 and the second set of G2 data is also smaller than the other three algorithms, and the average result of similarity is at 0.96 and 0.84 respectively, which is more in line with the visual dimension evaluation of these two sets of data. On the third set of data, G3, although the other algorithms were also able to correctly identify the different dance postures, the change in the magnitude of the ratings was relatively large, which could be attributed to the fact that the dance postures represented in the third set of data had large differences in amplitude of movement, tempo, and style, which led to the algorithms experiencing large fluctuations in their ratings. However, this does not have much impact on the practical application of the algorithm. Because in the case of excessive differences in similarity, and the corresponding number of dance postures is much larger, what needs to be paid more attention to is the gradient information that the algorithm is able to provide, i.e., the relative differences between different dance postures and the trend of change. On the third set of data G3 the average result of similarity of this paper's method is 0.56, the convolutional neural network is 0.43, the optical flow method is 0.39, and the dynamic time regularization is 0.41, and it still shows a better performance in recognizing and evaluating the human body postures in the dance drama performance.

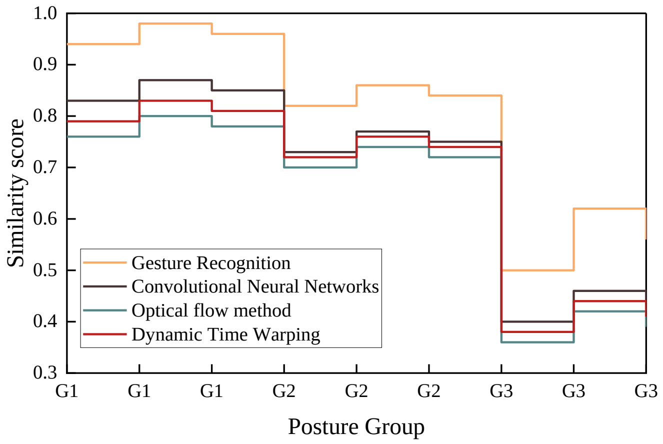


Figure 5 Evaluation results of the three groups of models on dance posture

In order to clearly demonstrate the differences in feature values between different postures the feature data for each posture was randomly selected, and a comparison of the features of different dance drama performance postures is shown in Figure 6. Significant differences between different postures can be seen. In the range of feature numbers 1 to 10, the maximum difference between the upright posture and the raised left hand posture reaches 68.0 cm, which indicates that these two postures are significantly different in terms of specific angle or distance features. Similarly, in the range of feature numbers 10 to 20, the maximum difference between the left hand-raising and right leg-kicking postures reaches 83.5 cm, while the maximum difference between the sitting down and the hands-raising postures is 50.0 cm.These significant differences provide a strong basis for the subsequent recognition of posture classification. The eigenvalues can effectively distinguish different dance theater performance gestures and provide reliable data support for the quantitative assessment of dynamic symmetry and aesthetic value in dance theater performance.

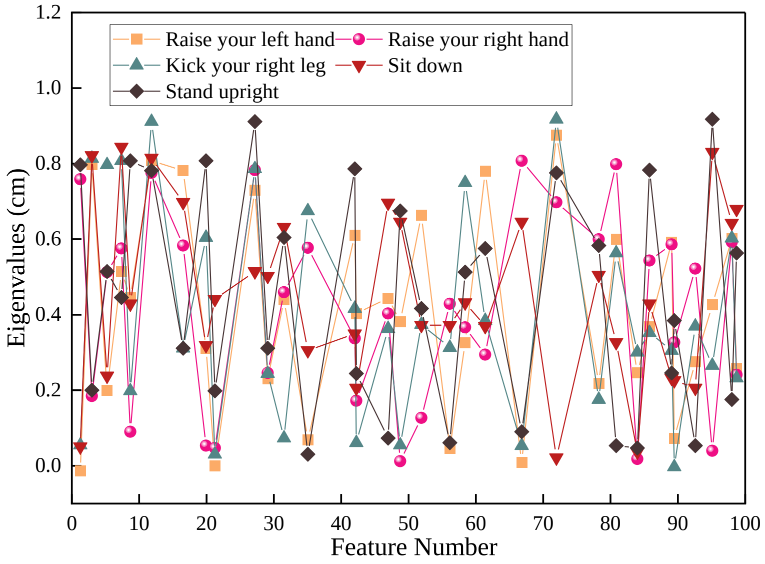
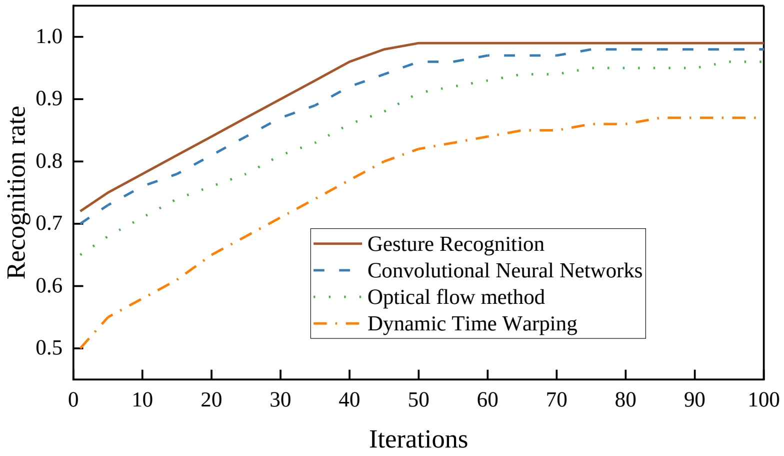


Figure 6 Comparison of posture characteristics of different dance performances

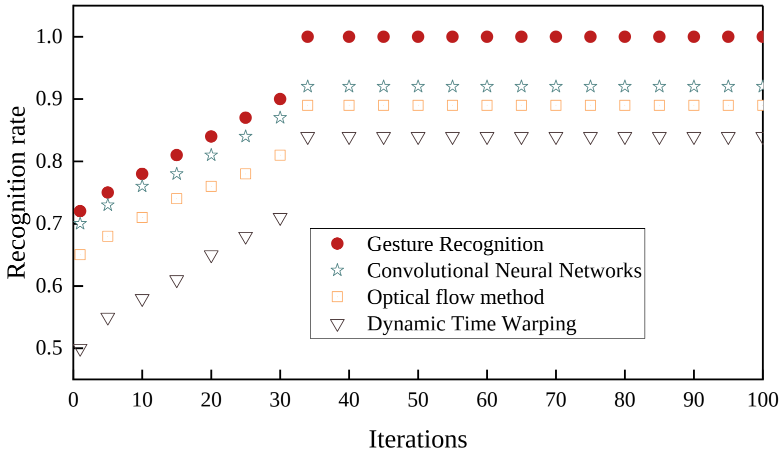
6.2 Dynamic symmetry calculation

In order to comprehensively evaluate the performance of dynamic symmetry detection under different conditions, two datasets were selected, the first continuous motion captured dataset, where each continuous motion data sample contained 3-6 motion segments of a single type covering left and right legs in the forward, backward, left, right, left, right, right, right and right back directions. All samples are captured from different angles to ensure sample diversity. The second is a dance video dataset, which contains symmetrical movements of multiple dance drama types and different styles, such as classical ballet, modern dance, folk dance, etc., and the duration of each clip is between 10 seconds and 30 seconds. Then it is compared with the three methods of convolutional neural network, optical flow method, and dynamic time regularization, and Fig. 7 shows the results of dynamic symmetry detection for dance drama performances.

Figure 7(a) shows the symmetry of the continuous motion capture dataset, and the detection accuracy of various methods is basically improving gradually with the increase of the number of iterations. The method proposed in this paper achieves a high recognition rate of 0.99 when the number of iterations is 50, 0.96 for the dynamic time regularization method, 0.91 for the convolutional neural network, and 0.82 for the red of the optical flow method, proving the accuracy and effectiveness of the method of this paper for dynamic symmetry detection of dance performances on the continuous motion capture dataset. Figure 7(b) shows the dynamic symmetry detection results on the dance performance video dataset, with the recognition rate of this paper's method has reached 1, i.e., 100% accuracy, when the number of iterations is only 34. 0.92 for the dynamic temporal regularization method, 0.89 for the convolutional neural network, and 0.84 for the optical flow method red, reflecting the strong ability in dealing with real dance performance video data. Compared with the other three methods, the method in this paper is able to accurately capture the symmetry features in dance movements and effectively perform symmetry detection when dealing with complex and variable dance performance video data.



(a) Continuous motion capture dataset



(b) Dance performance video dataset

Figure 7 Dynamic symmetry detection of dance performance

6.3 Quantitative assessment of aesthetic value

Combining the VQ-VAE-2 quantitative coding process and the results of dynamic symmetry calculation, we quantitatively evaluate the dynamic aesthetic value of the dance, assess the aesthetic characteristic indexes extracted from the movement data, movement symmetry, movement coherence, detail expressiveness, innovativeness, and overall aesthetics and analyze them in comparison with the experts' scores, so as to validate the performance of this paper's method.

Table 3 shows the results of the quantitative assessment of the aesthetic value in the dance theater performance, and it can be seen that the proposed quantitative assessment method and the expert scores show a better consistency from Action 1 to Action 12 as a whole. For example, movement 2 performed better in all indicators, with an overall aesthetic score of 8.3 and an expert score of 8.4 for movement 2. As in Action 5, despite excelling in action symmetry and coherence at 0.95 vs. 0.93, detailing and innovation were relatively low, resulting in a slightly lower overall aesthetics of 7.6. Reflecting the comprehensiveness and accuracy of the quantitative assessment method, it is able to comprehensively consider multiple aspects of dance movements. The method in this paper comprehensively considers multiple aspects of movement symmetry, coherence, detail expression and innovation to arrive at an overall aesthetic score. This comprehensive assessment makes the scoring results more comprehensive and objective, and avoids the bias that may be brought by a single indicator. This paper provides valuable feedback and suggestions for creators of dance theater performances, and becomes an effective tool for quantitative assessment of the aesthetic value of dance dynamics.

Table 3 Evaluation of the aesthetic value of different dance posture characteristics

Number of dance movements	Symmetry of movements	Consistency of movements	Expressive power of details	Creativity	Overall aesthetic feeling	Expert rating
Action1	0.85	0.92	0.78	0.74	7.9	8.0
Action2	0.94	0.96	0.85	0.72	8.3	8.4
Action3	0.75	0.70	0.90	0.85	7.7	7.5
Action4	0.82	0.85	0.80	0.75	8.0	8.2
Action5	0.95	0.93	0.75	0.64	7.6	7.8
Action6	0.85	0.92	0.78	0.65	7.9	8.0
Action7	0.90	0.86	0.84	0.73	8.2	8.3
Action8	0.75	0.77	0.90	0.85	7.7	7.6
Action9	0.82	0.85	0.80	0.75	8.0	8.2
Action10	0.95	0.98	0.75	0.69	7.8	7.8
Action11	0.84	0.92	0.78	0.65	7.9	8.0
Action12	0.89	0.88	0.86	0.73	8.4	8.5

7. Conclusion

This paper constructs a quantitative assessment model of dynamic symmetry and aesthetic value of dance theater performance based on human gesture feature extraction and directed graph computation, and the conclusions are as follows:

(1) In human posture feature extraction, the mean value of similarity of the quantitative assessment model constructed in this paper is 0.96 and 0.84, and the variation is also smaller than the other three algorithms. In the range of feature number 1 to 10, the quantitative evaluation model found that the maximum difference between the upright posture and the raised left hand posture reaches 68.0 cm, which maintains the stability performance.

(2) At 50 iterations, the constructed model achieved a high recognition rate of 0.99, and the dynamic time regularization method is still lower than the model in this paper although it is 0.96. In addition, the recognition rate of this paper's method can reach 1, i.e., 100%, when the number of iterations is only 34. It is further verified that the examined quantitative model can accurately recognize dance performance movements and can be generalized.

(3) In the aesthetic value assessment, the overall beauty score is 8.3, and the expert score of movement 2 is 8.4, which is a small difference. This reflects the comprehensiveness and accuracy of the quantitative assessment method, which is able to comprehensively consider multiple aspects of dance movements.

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