

Research Article

Research on Dance Teaching Based on Motion Capture System

Yuan Peng 

Art Education Center, Hangzhou Dianzi University, Hangzhou, Zhejiang 310008, China

Correspondence should be addressed to Yuan Peng; pengyuan@hdu.edu.cn

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Ethnic dance is a part of minority culture and an important chapter of intangible cultural heritage. Because the art of dance does not exist in a certain physical form in a certain environment, it is difficult to record and preserve dance. In traditional recording work, dancers' dance movements are mostly recorded through text, photos, videos, etc. However, these methods can only record and preserve dance movements in a two-dimensional manner from a limited number of angles and cannot achieve accurate and comprehensive record protection of dance poses. Moreover, data preserved by traditional methods can only be simply copied and transferred, and cannot be exploited, developed, or innovated. Therefore, motion capture technology can be applied to the protection of ethnic dance art, and motion capture technology can be used to obtain 3D gestures of ethnic minority dance spaces, restore and optimize digital movements, such as establishing a national dance art movement technology database, and combine the protection of the original ecological cultural atmosphere. It can accurately and comprehensively preserve the essence of ethnic minority dance art and provide effective reference for many ethnic minority dances with ethnic characteristics, digital protection of sports, and the future.

1. Introduction

With the development of modern society, the living space of minority dance cultural heritage is increasingly impacted by industrial civilization and economic globalization. Country of ethnic dance cultural heritage protection has gaining more attention; how to better protect ethnic minority dance, rescue, and mining cultural heritage and how to apply information technology to the minority cultural heritage protection, rescue, and mining have become a cultural and information technology in the research of a hot topic. Based on the dance characteristics of ethnic minorities, this article uses computer motion capture technology to carry out three-dimensional digital protection of dance posture of ethnic minorities, combining the original ecological and cultural atmosphere of ethnic dances and the advantages of other protection methods. Under the grammar category, dance movements of people folk dancing to the action of a virtual character library-oriented production process are analyzed emphatically and its corresponding relation is discussed based on the motion style under the emotion model identification theory, put forward based on the

characteristics of action unit properties and associated constraints to implement action cohesion method and define the method in the application of descriptive system framework.

Minority dancing is an essential aspect of the intangible cultural heritage of the United States. However, due to the change of cultural-ecological environment, some excellent Chinese folk performing arts are on the verge of extinction and extinction. It is urgent to protect and inherit them scientifically and effectively through different means. Although the traditional methods of photographing, recording, and video recording are convenient for collection and production, they cannot record the body movements of dancers in detail, let alone carry out scientific analysis and research on them, and apply them to choreography and creation. Therefore, in view of the lack of two-dimensional recording technology of text, photos, and videos, starting from the characteristics of dance, we use my country's motion capture technology to carry out all-round three-dimensional digital minority dance protection, protect minority dance, and provide a digital platform for future film and television programs [1–3]. It expands the scope of

intangible cultural heritage protection and has far-reaching implications for the preservation and scientific advancement of national culture.

Although studies on the protection of individual dances using motion capture technology have been conducted [4, 5], no unified and standardized technical process has been established, and the norms of 3D digitalization of ethnic dances have significant guiding value in promoting the protection of 3D digitalization of dances. As a result, this article examines the technique flow of 3D digital dance protection based on motion capture technology and provides guidance for swing dance collecting. At the same time, it provides a specific application example of motion capture data animation [6].

Motion capture technology can be used to digitize folk dance in three dimensions. Capturing three-dimensional data might be as basic as collecting the spatial position of bodily components, or as complicated as recording the intricate movement of facial expressions.

The research innovations of the article are as follows:

- (1) Applies motion capture technology to the protection of ethnic dance art
- (2) Uses motion capture technology to obtain 3D poses of ethnic minority dance spaces and optimize digital motion restoration
- (3) Establishes a national dance art movement technology database, and combines the original ecological cultural atmosphere and other protection models to accurately and comprehensively preserve the essence of ethnic minority dance art

2. Related Work

2.1. Motion Capture Technology. In Japan, to preserve the cultural heritage of dance, Atsushi, Institute of Industrial Science, University of Tokyo, Japan, Nakazawa1, et al. captured dance movements through motion capture system, decomposed dance movements into some original movement components, generated new dance movements through computer analysis and artificial intelligence technology, and then performed these dance movements through dance robots. In addition, Wayne Siegel and Jens Jacobsen2 of the Danish School of Electroacoustic Music studied interactive dance, in which dancers' dance movements can control performance movements of other devices, such as lights, music, images, and other devices [7].

In addition, the high inspection standard and Li Chao 4 studied the application of computer motion capture technology to our country carry on the omnidirectional three-dimensional digital minority dance protection; establish the minority dance database; save each dance art essence; protect the minority dance for the future research, movie, and TV programs; and restore precision digital platform [8].

In recent years, during the national "Eleventh Five-Year Plan" period, the development of cultural industry planning has been accelerated, and various domestic cultural and creative industries have begun to attach great importance to motion capture technology in high-tech enterprises,

universities, scientific research institutions, and art institutions and have purchased motion capture technology for their own research and development. In the research of motion capture system, especially in the past two years, it has developed very rapidly [9]. In addition, relevant scientific research institutions have established their motion captures laboratories, such as the digital Media Experimental Teaching Center of Century College of Beijing University of Posts and Telecommunications, Motion capture Laboratory of Beijing Practical Technology School, and Software Science of Huazhong University of Science and Technology [10].

Early Disney animation productions were the first to use motion capture technology. Motion capture technology has evolved and become more commonly employed in virtual reality, game design, motion simulation, and other sectors as science and technology have progressed. Motion capture technology is the measurement of an object's motion in 3D space using sensor equipment, recording the object's motion in the form of images, and then analyzing and processing the image data using computer technology to acquire the object's spatial coordinates [11].

This article uses an optical motion capture system. In the system, there are seven digital cameras, each with a different perspective, placed on the edge of the performance area. Dancers are required to wear tight clothing, and 29 "Marker" points are affixed to key parts of the body. The Marker points correspond to the system frame structure of the motion capture system, which can be identified by computer technology. Each camera at the performance was equipped with the body movements of the dancers corresponding to the reflective markers, and the images were formed during the shooting process [12].

2.2. Animation Generation of 3D Data by Dance Motion Capture Technology. Through the national dance, 3D data capture technology can form several national dance databases for minority dance choreography and interactive games provide more image data, in promoting China's animation production level and at the same time can effectively enhance national dance moves of feeling, use animation image table to show national dance art, and make the dance effect more vivid. The realization process of 3D digitization of folk dance is based on motion capture technology [13]. This flow chart intuitively reflects the process of realizing 3D digitalization of ethnic dance by using motion capture technology. By binding the motion capture data of ethnic dance to the data of good role model, the generation of animated characters can be realized as required, and then the 3D digitalization of ethnic dance can be realized.

- (1) The establishment of dancer character models. Taking the Tujia wave dance as an example, in the process of three-dimensional digitalization of dance, it is necessary to capture the wave movements of dancers. Through modeling software, the role model is established in 3D Studio Max according to the actual body proportion of dancers. At the same time, the data of the task model are restored according to

the dance costumes of Tujia nationality, and then the 3D data are bound with the data of the character model so that the dance can be restored [14].

- (2) Bone binding of the human body model. When the motion capture system captures the motion track of dancers, it is realized through the determination of spatial data points. Therefore, to obtain more and more detailed data, it is necessary to bind 3D data according to the dancer's body proportion and skeletal system. The movement data can be captured by binding the dancer's skeleton. It should be noted that during bone binding, the influence of weight should be paid attention to, that is to say, the bone may have different influences on different limb parts of the character model. Only when the strength of these key points is appropriate, can the movements of the character model be smooth and natural [15].
- (3) Motion capture 3D data animation implementation. In order to achieve good recording result, general requirements focus on dance performers performing in the area of rules and the use of multiple cameras at the same time to record performers from different perspectives of different body movements and to deal with the data; the data are then mapped to the 3D character models. At this time, we can use the movement sequence to generate a series of animation and then match with the corresponding music, and we can use the computer to show the dance performance from various angles in an all-round way [16].

2.3. Acquisition of Three-Dimensional Dance Data. Obtaining national dance with motion capture technology, 3D data may be utilized to create minority dances, dance database action choreography, and interactive games [17–20]. Figure 1 depicts the entire process of 3D character animation generation, from the gathering of 3D movement data for folk dance through the generation of character animation.

3. Human Motion Pose Analysis Based on Feature Vector Matching

The process of tracking, collecting, obtaining, and evaluating human body posture features in order to get relevant motion posture parameters is known as motion posture analysis. The system in this paper can decompose the movements they perform in detail, each dance in detail; this parameter helps us to quantitatively analyze the gestures and provides a good help for the dance training to be more scientific and intelligent. A method of human body motion pose analysis based on the similarity matching concept of the feature plane was presented to better evaluate the motion state of dance artists. The method transformed a standard Euclidean distance computation based on several identification points into a calculation based on a feature vector and the angle of the feature plane. To calculate the difference and correlation of motion, the identification points of 21 critical positions are simplified into seven feature planes in this study. This

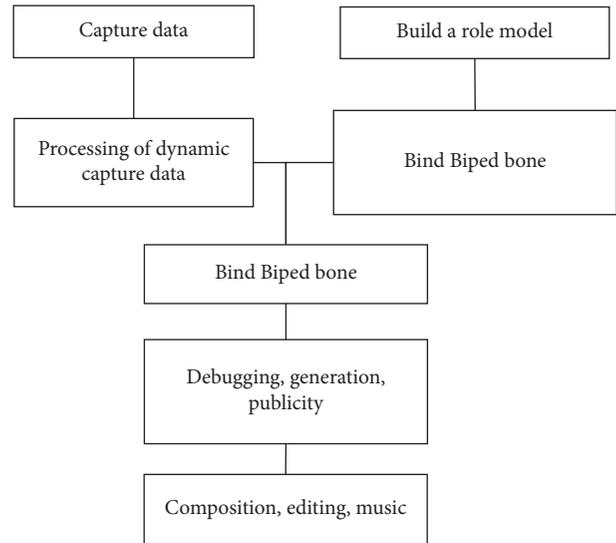


FIGURE 1: Animation generation flow chart based on motion capture data.

method can swiftly and efficiently assess human body motion posture through verification, and it may be applied to dance instruction to increase dance teaching efficiency.

The purpose of human pose similarity matching is to determine the degree of similarity or difference in stance between distinct human bodies. The classic Euclidean distance measurement is currently the most widely used method. The following are the approaches for calculating Euclidean distance in traditional 3D model similarity matching:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}, \quad (1)$$

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2},$$

where $x_1 = (x_{11}, x_{12}, x_{13}, \dots, x_{1n})$, $x_2 = (x_{21}, x_{22}, x_{23}, \dots, x_{2n})$ is the n -dimensional data. A calculating formula based on Euclidean distance can be used to calculate the difference between each two identification points. The standard action is compared to the track of the action to be examined at the same mark point.

The trajectories of two moving targets are compared using the classic Euclidean distance direct comparison method. The related distance difference value is gathered throughout the comparison process of each action sequence, and the data matching degree is calculated using the predefined threshold value. As a result, traditional approaches are limited by the rigid requirements for moving objects, which not only degrade computer performance but also lack universality.

The similarity function utilized in this article is cosine. This approach can determine not only the direction difference between vectors, but also the angle similarity and difference. The following is the method of calculation:

$$\text{similarity}(V_i, V_j) = \frac{v_i \times v_j}{\sqrt{(v_i)^2} \times \sqrt{(v_j)^2}} \quad (2)$$

Cosine similarity, as opposed to Euclidean distance, can better depict the difference in direction between two vectors. As a result, the difference in feature vector direction can be determined, and the calculation error caused by different target positions in Euclidean distance may be avoided. The dance movement to be assessed is compatible with the standard movement if the estimated cosine value is within the range of [0,1] and close to 1. If the value is close to 0, the difference between the dance movement being assessed and the standard movement is too great.

$$\theta_{(i,j)} = \arccos(\text{similarity}(V_i, V_j)). \quad (3)$$

The effective range of motion $Q(i, j)$ between the feature vectors ranges from $[Q_{\min}, Q_{\max}]$ can distinguish the standard of dance motion range.

The percentage of the human body is certain due to individual differences in the human body, such as the presence of height, weight, arm length, and other concerns. As a result, angle similarity must be used to determine whether the limbs' motion amplitude adheres to the norm. The following is the method of calculation:

$$\text{Corr}(\theta_{(i,j)}) = 1 - \left(\frac{\arccos(\text{similarity}(V_i, V_j))}{\pi} \right). \quad (4)$$

The results are shown in Table 1.

Calculate the weights of the joints. The value of A will influence the motion similarity evaluation result. The weight WI of these joints can be computed as follows:

$$\omega_i = \frac{S_i \cdot \alpha}{\sum_{j=1}^m S_j}. \quad (5)$$

The remaining weight is bisected by the rest joints, and the weight calculation formula is as follows:

$$\omega_i = \begin{cases} \frac{S_i \cdot \alpha}{\sum_{j=1}^m S_j} \\ \frac{(T - m)}{(1 - \alpha)} \end{cases}, \quad i = 1, 2, \dots, T. \quad (6)$$

Let p_r^i and q_r^i be the quaternion representations of the i th joint direction data of P and Q , respectively. The joint weight WI of Q can be calculated according to formula (1), and p_r and q_r distance can be obtained for any two frames. The measurement method is as follows

$$\text{dist}(p_r, q_r) = \sum_{i=1}^T \frac{\omega_i + \omega'_i}{2} d(p_r^i, q_r^i). \quad (7)$$

Specific experimental methods are referenced. An array `MapFrame` is created and kept track of the unique mapping relationship between all frame of reference action sequences P and Q . The common path is traversed and the mapping relationship in `MapFrame` is saved. P and Q are simulated using the multidimensional action features collected in the previous phase, and the distance of 2 is calculated and averaged to yield $\text{Dist}(P, Q)$.

TABLE 1: Correlation parameters of left arm gesture.

Subjects	Sim (V_i, V_{stana})	Corr (Q_1)	Corr (g)
Standard object	0.7053	0.8923	0.99
Object under test	0.4585	0.9802	0.8951

$$\text{Dist}(P, Q) = \frac{\sum_{r=1}^R \text{dist}(Kp_r, Kq_r)}{R}. \quad (8)$$

Similarity evaluation is obtained after normalization according to formula (4).

$$\text{Similarity}(P, Q) = \frac{1}{\text{Dist}(P, Q) + 1}. \quad (9)$$

Because the bulk of square dance aficionados are middle-aged and older, they rely heavily on trainers to learn new routines. To some extent, this challenge can be overcome by utilizing a motion sensor to gather motion and evaluating it using a motion similarity evaluation algorithm. The topic data of the sports coach following the motion sensation need to be highly followed and real time in the real-time motion evaluation system, and a relatively accurate evaluation system is the technical assurance to promote the application of rural public culture.

When the pedestrian is walking, it will produce a large torque to the acceleration sensor, that is, the acceleration of human movement. When the accelerometer is used to estimate the attitude direction, we assume that only the gravitational field affects the accelerometer. Therefore, in the "waking state," this premise hypothesis does not exist. We do not use an accelerometer and gyroscope for filtering and fusion and can only use the angular rate integral measured by the gyroscope sensor alone. Therefore, the estimation of attitude direction can be divided into two parts. When the pedestrian is in the "standing state," since the accelerometer is mainly affected by gravity, it can be obtained by combining the characteristics of accelerometer and gyroscope sensors with the method of gradient descent complementary filtering, as shown in the following formula:

$${}^b_g q_{opt,t} = {}^b_g q_{opt,t-1} + {}^b_g q_{opt,t-1}^* \Delta t. \quad (10)$$

When the pedestrian is in the "waking state," as the accelerometer is also affected by other torques of the foot, the continuous use of the accelerometer to estimate the direction will produce a large error. Therefore, in the "waking state," only the integration of the gyroscope is used to obtain the attitude angle, as shown in the following formula:

$${}^b_g q_{w,t} = {}^b_g q_{w,t-1} + {}^b_g q_{w,t-1}^* \otimes {}^b w_{t-1} \Delta t. \quad (11)$$

To calculate the angular rate error of the gyroscope at rest:

$$w_{err} = \frac{1}{N \Delta t} \sum_{i=0}^N ({}^b w_i) \Delta t = \frac{1}{N} \sum_{i=0}^N ({}^b w_i). \quad (12)$$

To correct the zero drift error of the gyroscope:

$$w = \begin{cases} 0, & t_i = t_{\text{sup}} \dots t_{\text{end}}, \\ w - w_{\text{err}}, & t_i = t_{\text{end}} \dots t_{\text{wend}}, \end{cases} \quad (13)$$

where w_{err} represents the drift error of the gyroscope sampled in the “standing state.” Since the movement between stride lengths is short, about 1-2s, it can be assumed that the drift error at this time can be approximated as the drift error of the next state, and the motion attitude angle at the next moment is shown as follows:

$${}^b_g q_{w,t} = {}^b_g q_{w,t-1} + \frac{1}{2} a_g^{b*} q_{w,t-1} \otimes {}^b(w_{t-1} - w_{\text{err}}) \Delta t. \quad (14)$$

The estimation of the track pedestrian motion is calculated, and the acceleration data to get the speed are integrated, and the acceleration data to get the speed are integrated. When integrating again to get the coordinates, it is necessary to transform the acceleration A from the carrier coordinate system B to the geographic coordinate system G, so that the velocity and position obtained are the coordinates and positions in the geographic coordinate system. According to the calculation rules of quaternions,

$${}^g_b q = {}^b_g q^*. \quad (15)$$

According to formula (15), the transformation from carrier coordinate B system to geographic coordinate G system can be obtained. In this way, according to the value b measured by the acceleration sensor in carrier coordinate B system, the value under geographic coordinate G system can be obtained after four-element transformation, as shown in the following formula:

$${}^g_a = {}^g_b q \otimes {}^b_a \otimes {}^g_b q^*. \quad (16)$$

4. Experimental Results and Analysis

The experimental objects are randomly picked college students with dance foundations, and the produced movement database has 18 sets of dance movement fragments, each set of dance movement containing roughly 1200 frames. The subjects were asked to emulate the dance teacher’s standard movements and do equivalent dance moves while using an optical motion capture technology to retrieve movement characteristics of the subjects’ left arm joints. The concluding motions of the left arm of a single dance movement (within 0–10 s) were chosen for experimental comparison with the conventional movements. The disparities between the primary motion changes of the object to be examined and the standard movements are compared using a local motion sequence taken in real time as an example. The experimental results are shown in Figure 2.

Figure 2 shows the time sequence diagram of the parameters related to the movement of the left arm. It can be seen from the figure that the rocking effect of the left arm is recorded in this article in a more targeted manner. The learning of the two groups of students was confirmed

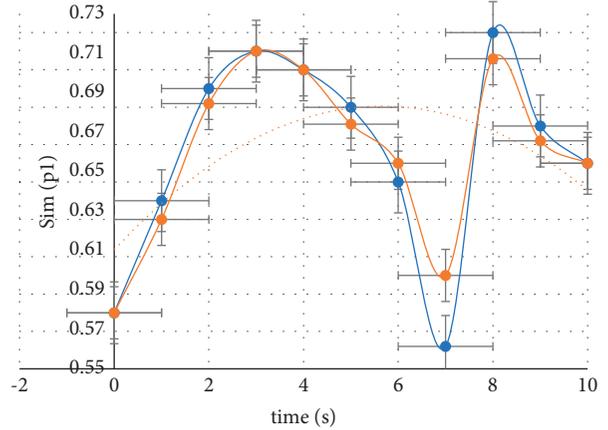


FIGURE 2: Timing sequence diagram of left arm motion correlation parameters.

through evaluation after all of the teaching hours were completed. The range, strength, coherence, and standardization of the two groups of students’ calisthenics motions were rated by the college PE teacher, and the data were analyzed using SPSS19.0. Table 2 displays the test results.

The correlation coefficient error is computed by utilizing the phase-to-phase error method as follows:

$$\Delta \text{corr}_i = \frac{|\text{corr}_i - \text{corr}_j|}{\text{corr}_i} \%. \quad (17)$$

According to the above formula, the relative error is calculated to show the deviation degree of dance movements of each object to be tested compared with standard movements. The calculation results are shown in Table 3 and Figure 3.

The two sets of data are directly compared using the traditional 3D model’s similarity comparison method based on Euclidean distance. The pose analysis results are frequently not accurate enough for dancing motions with considerable motion amplitude. When the person being tested is different in height, fat, and thinness, as well as human body proportions, as shown in Figure 4, errors in the model’s displacement will occur. The spatial displacement deviation is frequently too large when the movement position of the person to be measured is not specified.

To verify the superiority of dividing and considering actions separately according to human body structure, we also implemented human actions as a whole on CityU and HDM05 datasets. The experimental results are shown in the figure below. Recognition accuracy is shown in Figure 5.

The classification performance of the somatic-based scheme was better than that of the somatic-based scheme in both datasets, especially in the HDM05 dataset. This is because the HDM05 dataset covers basic everyday actions, such as running and jumping, which can lead to greater intra-class differences.

TABLE 2: Comparison of experimental results.

Group	Movement range	Strength of action	Action continuity	Normative action
Regular group	73.6 ± 6.4	79.6 ± 7.6	73.4 ± 7.9	77.4 ± 6.5
The experimental group	73.3 ± 6.7	73.7 ± 5.3	73.3 ± 3.6	76.3 ± 4.6
Significant <i>P</i>	0.033	0.067	0.063	0.040

P represents the significance of the experimental effect, where $P < 0.005$ is generally taken as significant. According to the experimental results, students who learn by motion capture have a better grasp of dance movements than those who learn by routine.

TABLE 3: Relative error of main motion pose of the object to be tested/%.

Order	Sim (V, V_{stand})	Corr (V_{Larm}, V_{LFarm})	Corr (V_{LFarm}, V_{stand})
0 ~1 s	2.52	0.92	0.22
1~2 s	0.65	0.2	0.99
2~3 s	0.05	0.22	0.25
3~4 s	0.22	0.65	0.24
4~5 s	0.25	22.54	0.02
5~6 s	2.42	0.22	0.02
6~7 s	5.65	0.95	0.25
7~8 s	0.82	0.02	0.99
8~9 s	2.02	0.99	0.29
9~10 s	0.25	0.4	0.58

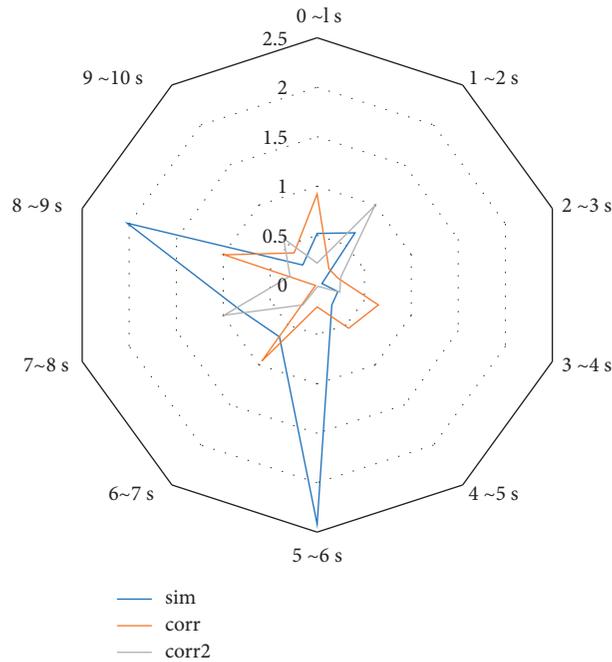


FIGURE 3: Relative error of main motion pose of the object to be tested.

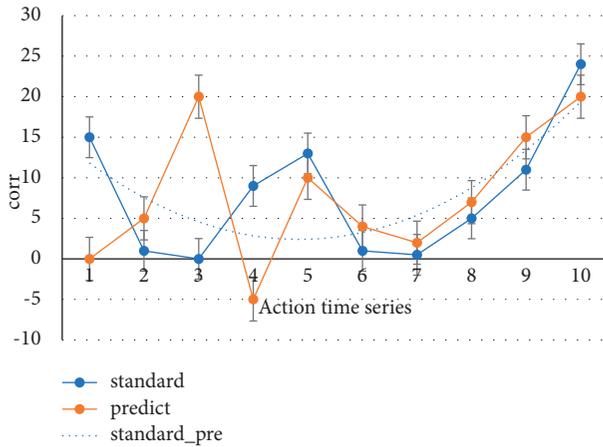


FIGURE 4: Wheelbase deviation of single feature point x.

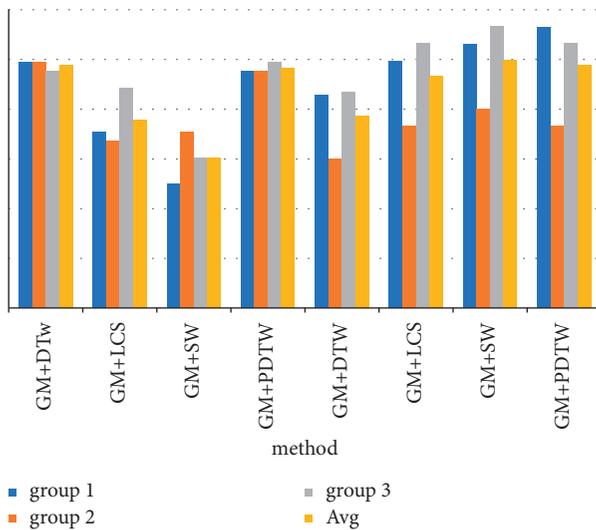


FIGURE 5: Recognition accuracy.

5. Conclusion

This research focuses on how motion capture technology can be used to achieve 3D digitalization of folk dance. Because traditional methods cannot accurately reproduce the original dance posture, reappear the elegant demeanor of art, copy the manufacturing cycle quickly, and low cost, the application of motion capture technology can effectively resolve the problems of incomplete records and provide more analysis data for modern dance choreography. Using photos and videos of traditional methods, this article gets the image data that are incomplete or inaccurately maintained the lack of dance art, explores the application of computer motion capture technology to carry on the omnidirectional 3D digital Chinese national dance protection methods, and shows animation as an example of how to apply the national dance of 3D data. Cultural protection and resource integration of folk dance can play a positive guiding role in the research and application of modern digital means to carry out dance art and, at the same time, promote the combination of culture and technology.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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