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Retraction

Retracted: The Application of Dance Movement Skill Feature Recognition in Dance Teaching Movement Analysis

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] D. Zhang, "The Application of Dance Movement Skill Feature Recognition in Dance Teaching Movement Analysis," *Advances in Multimedia*, vol. 2022, Article ID 5485827, 11 pages, 2022.

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Research Article

The Application of Dance Movement Skill Feature Recognition in Dance Teaching Movement Analysis

Dixin Zhang

School of Music and Dance, Zhengzhou University of Technology, Zhengzhou, Henan 450000, China

Correspondence should be addressed to Dixin Zhang; 20099906@zzut.edu.cn

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In order to improve the effect of dance teaching action analysis, this paper uses dance action skill feature identification method to analyze dance teaching action and combines teaching and technology to simulate dance action. Moreover, this paper conducts dynamic modeling of dance movements and analyzes the typical properties of several dynamic modeling techniques. At the same time, this paper takes the double-joint dance movement limb as the control object for comparative analysis. The comparison shows that the fractional sliding mode approaching law has better smoothing properties. In addition, this paper selects the control method combining fractional calculus and sliding mode control theory to improve the tracking speed and following effect of the double joints of dance movements. Finally, this paper studies the variance virtual spindle cross-coupling control method based on fractional-order sliding mode to further improve the synchronization accuracy of dance movement limb joints. From the experimental data, it can be seen that the application effect of dance movement skill feature recognition in dance teaching movement analysis is very good.

1. Introduction

College dance education is an important part of the national vocational education system. The purpose of higher education institutions is to cultivate technical talents with professional job skills and all-round development. The basic connotation of "integration of industry and education" is "deep cooperation between industry and education" which closely combines the relevant vocational teaching in colleges and universities with the process of production of products by off-campus enterprises [1]. Through the method of "integration of production and education," colleges and universities can cultivate more outstanding workers with high comprehensive quality and practical ability. In this process, colleges/universities and off-campus enterprises have carried out active and comprehensive cooperation (including cooperation in the fields of technology, education, life, etc.), which not only promotes the development of related enterprises, but also enables teachers and students of colleges and universities to broaden their horizons. In practice, we can better understand the relevance and authenticity of work, fully understand our comprehensive ability and practical ability, reflect on this basis, and continuously improve our quality and related ability [2]. Private art education institutions account for the majority of art education institutions [3].Private art education institutions are in the forefront of the times in carrying out work related to the integration of production and education. It plays a guiding and reference role in the reform and development of higher education. Extracurricular practical work is gradually becoming an important way for colleges and universities to cultivate compound talents. In the process of integration of production and education, students' comprehensive ability, communication ability, hands-on ability, and ability to solve unexpected problems have been cultivated, trained, and improved. Colleges and universities should take the initiative to undertake the promotion and dissemination of new technologies developed locally; make use of the advantages of human resources; participate in the research, development, and application of new technologies; and promote the prosperity and development of the local economy [4].

Education and industry are closely related, and the combination of the two can bring huge economic benefits to the society. However, education and production have undergone specific evolutions in their respective development, thereby increasing the gap between the education system and the industrial system. The existence of this gap adds to the process of integration of production and education difficulty [5]. The relationship between education and production has not yet reached the state expected by society. Relevant reports pointed out that the employment difficulties of college students, the homogeneous development of major colleges and universities, the incompatibility between the educational structure of related colleges and the industrial structure of corresponding enterprises, etc. indicate to a certain extent that the gap between education and industry is still wide due to existing problems [6]. To a certain extent, there is separation between education and production. By analyzing the reasons for the separation of production and education, we can find that there are certain differences in the fundamental purpose and corresponding logic of education and production. If these differences are completely ignored, education and production will be disconnected, and education cannot provide suitable talents for generation [7]. The underlying logic of industrial undertakings follows the relevant logic of economics, while the development of educational undertakings must be "people-oriented" and at the same time pay attention to the dissemination of knowledge and the inheritance of culture. Whether culturally or logically, the thought of industry and the thought of academic research and teaching practice in education are difficult to fit. The idea of industrial research is to gradually form technological advantages through the research of new technologies, so as to better improve economic benefits [8].

For dance, dance teachers should strengthen the cultivation of students' performance awareness and emotional expression ability in the process of teaching and strengthen the guidance of students' aesthetic awareness while ensuring that each student truly masters accurate professional basic knowledge. To a certain extent, this can better help students to enrich their personal aesthetic taste and further improve their aesthetic awareness [9]. At the same time, different dance styles determine different dance forms. Therefore, dance teachers should ensure that every student masters the styles and characteristics of various dances as much as possible and correctly guide students to practice solid basic dance skills. In addition, dance teachers should teach students in accordance with their aptitude and use a variety of methods to mobilize and stimulate students' desire to learn dance knowledge and dance movements, so as to maximize students' dance aesthetic awareness and performance ability [10].

Dance movement is one of the most basic elements of dance; no matter what type of dance it is, it is realized through the movement of various parts of the human body. At the same time, in the process of dancing, due to the different directions, speeds, and strengths, the dance emotions conveyed are also different [11]. Therefore, in the process of teaching, dance teachers should choose the difficulty of dance movements in line with the actual situation of the current students and ensure that each movement must be distinctive on the premise of not exceeding the students' basic abilities. For dance, its beauty can reveal the beauty of human nature to a certain extent and can excavate the beauty of human nature. Therefore, in the classroom, dance teachers cannot ignore the fluency and coordination of dance movements [12].

In the process of dance teaching, dance teachers should ask each student to show the emotions expressed by music through dance according to the musical characteristics and dance rhythm of different types of dance, so that the dance is full of strong appeal. In dance teaching, dance teachers should strictly require each student to practice each movement in accordance with the basic dance norms [13]. While practicing, we should pay attention to the unity between dance posture and music style, so as to show the formal beauty of rhythm to a certain extent. At the same time, dance teachers should let every student learn to listen to music, so that students can clearly hear the specific content and emotions expressed in the music melody, so that students can truly feel the rhythm between music and dance to the greatest extent [14].

The relevant skills contained in dance are an important basis for dance performance and play a vital role in showing the beauty of dance [15].

Through the use of relevant methods, students' aesthetic sense of movement is directly or indirectly cultivated. For example, by using simple, basic professional movements for dance training, the beauty of the movements can be increased to a certain extent. For dance teachers, they must exert their own initiative, be good at using refined words to explain the characteristics of relevant dance movements, stimulate the wishes expressed by students through beautiful demonstrations, and further cultivate students' performance awareness. At the same time, dance teachers should also understand and master the individual characteristics of each student in detail, so as to fully tap the performance potential of students [16].

Having a strong physical fitness is the basis for improving the beauty of movements. If you have poor physical fitness, you will not be able to control your body well, which will affect the quality of your movements to a certain extent, so that you cannot fully demonstrate your expressiveness and shaping power. Flexibility is an important physical quality that reflects not only the ability to perform movements, but also the speed of one's own reactions. Therefore, dance teachers should fundamentally strengthen students' physical exercise and dance expressiveness [17].

In the process of dance teaching, dance teachers not only need to explain the technical structure of each movement clearly, but also need to analyze the performance of the movement from different positions. In addition, dance teachers can also effectively use relevant videos, audios, etc. for intuitive teaching, so that each student can carefully understand the details of some movements, which deepens students' understanding of dance movements [18].

This paper uses the method of dance movement skill feature recognition to analyze dance teaching movements and combines teaching and technology to facilitate the cultivation of dance talents needed by society.

2. Research on Single-Joint Tracking Control Method of Dance Simulation Limbs

2.1. Fractional Sliding Mode Approaching Law Analysis. The sliding mode control system includes two aspects, one of which is the approaching motion. Selecting the appropriate approaching law can significantly weaken the chattering and speed up the system motion, so as to ensure the good dynamic quality of the system. The fractional-order sliding mode approaching law that is different from the traditional approaching law is selected, and the expression is as follows:

$$D^{\alpha}s = -k\text{sign}(s), 0 < \alpha < 1. \tag{1}$$

This approaching law is mainly used to adjust the order α and the coefficient k to change the speed of the dance simulation limb system approaching the sliding surface.

First, a representative exponential approaching law is selected for comparative analysis with the fractional sliding mode approaching law used. When $\dot{s} > 0$, the approaching rate of fractional sliding mode approaching law is greater than that of exponential approaching law. The analysis process is as follows.

2.1.1. Exponential Approaching Law's Approaching Time. The expression of the exponential approaching law is shown in the following formula:

$$\dot{s} = -\eta\text{sign}(s) - ks\,\eta > 0, k > 0. \tag{2}$$

From (2), it can be known that

$$dt = \frac{ds}{-\eta\text{sign}(s) - ks}. \tag{3}$$

When $s \neq 0$, the state point of the system reaches the switching surface from any state with an exponential approaching rate. There are two situations:

(1) If $s > 0$, then

$$t_1' = \int_0^s \frac{ds}{-\eta\text{sign}(s) - ks} = -\frac{1}{k}\left[\ln\left(1 + \frac{k}{\eta}s\right)\right]. \tag{4}$$

(2) If $s < 0$, then

$$t_2' = \int_0^{-s} \frac{ds}{-\eta sign(s) - ks} = -\frac{1}{k}\left[\ln\left(1 + \frac{k}{\eta}s\right)\right]. \tag{5}$$

When $s = 0$, $t_3' = 0$.

To sum up, the approaching time of the exponential approaching law is as follows:

$$t\prime = \begin{cases} -\dfrac{1}{k}\left[In\left(1 + \dfrac{k}{\eta}s\right)\right], & s \neq 0, \\ 0, & s = 0. \end{cases} \tag{6}$$

2.1.2. The Approaching Time of Approaching Law of Fractional Sliding Mode.

$$J^{\partial}D^{\partial}s = J^{\partial}(-k\text{sgn}(s)), J^{\partial}f(t) = \frac{1}{\Gamma(\partial)}\int_0^t (t-\tau)^{\partial-1}f(\tau)d\tau. \tag{7}$$

The simplified expression $s(t) - s(0) = J^{\partial}(-k\text{sgn}(s))$ applies a standard derivative:

$$\frac{ds}{dt} = -k\, DJ^{\partial}(-\text{sgn}(s)), J^{\partial}1 = \frac{t^{\partial}}{\Gamma(1+\partial)}. \tag{8}$$

From (8), we can get the following:

$$t^{\partial}dt = \frac{\Gamma(1+\partial)}{k\ D\text{sgn}(s)}ds \Rightarrow t^{\partial+1} = \frac{\Gamma(1+\partial)}{k\ D\text{sgn}(s)(\partial+1)}ds\,. \tag{9}$$

To sum up, the approaching time of the approaching law of fractional sliding mode is as follows:

$$t = \begin{cases} \sqrt[\partial+1]{\dfrac{\Gamma(1+\partial)s}{k\ D(\partial+1)}}, & s \neq 0, \\ 0, & s = 0. \end{cases} \tag{10}$$

The difference between (6) and (10) can be obtained:

$$t\prime - t = \begin{cases} \ln\left(1 + \dfrac{k}{\eta}s\right) - k - \dfrac{\Gamma(1+\partial)s}{k\ D(\partial+1)} = \dfrac{In\left(\eta \cdot e^{-k\sqrt[\partial+1]{\Gamma(1+\partial)s/k\ D(\partial+1)}}/\eta + ks\right)}{k} > 0, & s \neq 0, \\ 0, & s = 0. \end{cases} \tag{11}$$

Therefore, from the analysis of (11), it can be known that the rate of the approaching law of fractional sliding mode is faster than that of the exponential approaching law. Secondly, the asymptotic stability of the fractional sliding mode approaching law is proved. The analysis process is as follows.

The Lyapunov function as (12) is chosen:

$$V(t) = \frac{1}{2}s^T s. \tag{12}$$

If we take the first Caputo-type fractional calculus definition form, then

$$\begin{cases} \dot{s} > 0 \\ \dot{s} < 0 \end{cases} \Rightarrow \begin{cases} D^{\alpha} s > 0, \\ D^{\alpha} s < 0. \end{cases} \tag{13}$$

Taking the derivation of (12) and using (1) and (13), we can get the following:

$$\dot{V}(t) = s^T s = s^T D^{1-\alpha}(-ksign(s)). \tag{14}$$

From the formula $sign(D^{1-\alpha}(-ksign(s))) = -ksign(s)$, it can be seen that

$$\begin{aligned} sign(\dot{V}(t)) &= sign\left(s^T\right) sign\left(D^{1-\alpha}(-ksign(s))\right) \\ &= -ksign\left(s^T\right) sign(s) \\ &= -k. \end{aligned} \tag{15}$$

Then, $\dot{V} \leq 0 \Rightarrow D^{\alpha} V \leq 0$.

2.2. Single-Joint Position Tracking Control Method. The position tracking error of each joint of the dance simulation limb is defined as the following formula:

$$e(t) = q_d(t) - q(t). \tag{16}$$

Among them, $q_d(t)$ is the ideal position of the joint, and $q(t)$ is the actual position of the joint.

Taking the second derivative of the position tracking error, we can get the following:

$$\ddot{e} = \ddot{q}_d - \ddot{q}. \tag{17}$$

The sliding surface is designed as follows:

$$s_1 = ce + \dot{e}. \tag{18}$$

Taking the derivative of (18) and combining (17) and (25), we can get the following:

$$\begin{aligned} \dot{s}_1 &= c\dot{e} + \ddot{e} \\ &= c\dot{e} + \ddot{q}_d - M^{-1}(\tau_1 - G - C\dot{q} + f). \end{aligned} \tag{19}$$

The approaching law of fractional sliding mode is as follows:

$$D^{\alpha} s = -ksign(s). \tag{20}$$

Taking the derivation of (20), we can get the following:

$$\dot{s}_1 = D^{1-\alpha}(-k)sign(s). \tag{21}$$

Combining and simplifying (19) and (21), the control law is obtained as the following formula:

$$\tau_1 = M\left(\ddot{q}_d + c\dot{e} + kD^{1-\alpha} sign(s)\right) + G + C\dot{q} - f, \tag{22}$$

Proof. The Lyapunov function of (16) is chosen:

$$V_1 = \frac{1}{2}s_1^2. \tag{23}$$

Differentiating both sides of the selected Lyapunov function, we get the following:

$$\begin{aligned} \dot{V}_1 &= s_1 \dot{s}_1 = s_1(c\dot{e} + \ddot{e}) \\ &= s_1\left(c\dot{e} + \ddot{q}_d - M^{-1}\right). \end{aligned} \tag{24}$$

Substituting the simplified control law into (24), we can get the following:

$$\begin{aligned} \dot{V}_1 &= s_1 \dot{s}_1 = s_1\left(\ddot{q}_d - \ddot{q} + c\dot{e}\right) \\ &= s_1\left(\left(\ddot{q}_d - M^{-1}(\tau_1 - C\dot{q} - G + f)\right) + c\dot{e}\right) \\ &= s_1\left(-kD^{1-\alpha} sign(s)\right) \leq 0, \end{aligned} \tag{25}$$

$$s_2 = D^{\alpha} e + ce, c = di\ ag(c_1, c_2, \ldots, c_n), c_i > 0. \tag{26}$$

Taking the derivation of (26), we get the following:

$$\dot{s}_2 = D^{\alpha-1}\left(\ddot{q}_d - M^{-1}\left(\tau^2 - C\dot{q} - G + f\right)\right) + c\dot{e}. \tag{27}$$

The commonly used exponential approaching law is as follows:

$$\dot{s}_2 = -\eta sign(s) - ks. \tag{28}$$

By combining and simplifying (27) and (28), the control law is obtained as the following formula:

$$\begin{aligned} \tau_2 = M&\left(\ddot{q}_d + cD^{1-\alpha}\dot{e} + \eta D^{1-\alpha} sign(s) + D^{1-\alpha} ks\right) \\ &+ C\dot{q} + G - f. \end{aligned} \tag{29}$$

Differentiating both sides of (23) and combining it with (27), we get the following:

$$\begin{aligned} \dot{V}_2 &= s_2 \dot{s}_2 = s_2\left(D^{\alpha-1}\ddot{e} + c\dot{e}\right) \\ &= s_2\left(D^{\alpha-1}\left(\ddot{q}_d - M^{-1}\left(\tau^2 - C\dot{q} - G + f\right)\right) + c\dot{e}\right). \end{aligned} \tag{30}$$

By substituting (29) into (30), we get the following:

$$\begin{aligned} \dot{V}_2 &= s_2\left(D^{\alpha-1}\left(-cD^{1-\alpha}\dot{e} - \eta D^{1-\alpha} sign(s) - D^{1-\alpha} ks\right) + c\dot{e}\right) \\ &\leq -k{s_2}^2 - \eta|s_2|. \end{aligned} \tag{31}$$

To sum up, it can be seen from the Lyapunov stability theory that when the parameters are properly selected, the position tracking error of the system will converge to zero, and the purpose of position tracking can be achieved. □

2.3. Simulation and Results Analysis. In order to verify the feasibility of the proposed single-joint tracking control method, a typical double-joint dance simulation limb is used as control object 1. Furthermore, a FOMCON toolbox for fractional-order modeling and control is used to conduct MATLAB simulation experiments on the system to verify the effectiveness of the single-joint tracking control method.

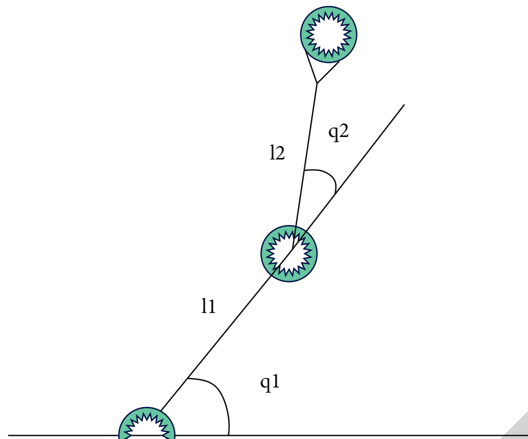

Figure 1: Schematic diagram of a double-joint dance simulation limb.

The schematic diagram of the two-joint dance simulation limb is shown in Figure 1.

The specific parameters of the dance simulation body system are selected as follows:

$$\begin{aligned} M(q) &= \begin{bmatrix} v + q_{01} + 2q_{02}\cos(q_2) & q_{01} + q_{02}\cos(q_2) \\ q_{01} + q_{02}\cos(q_2) & q_{01} \end{bmatrix}, \\ C(q,\ \dot{q}) &= \begin{bmatrix} -q_{02} + \dot{q}_2 \sin(q_2) & -q_{02}(\dot{q}_1 + \dot{q}_2)\sin(q_2) \\ q_{02}\dot{q}_1 \sin(q_2) & 0 \end{bmatrix}, \\ G(q) &= \begin{bmatrix} 15g\cos q_1 + 8.75g\cos(q_1 + q_2) \\ 8.75g\cos(q_1 + q_2) \end{bmatrix} f(t) = 3\sin(2\pi t). \end{aligned} \tag{32}$$

Among them, $v = 13.33, q_{01} = 8.98, q_{02} = 8.75, g = 9.8$.

The position commands of the double joints are $q_{d1} = \cos(\pi t)$ and $q_{d2} = \sin(\pi t)$, and the initial state of the system is given as $[\,q_1\ \ q_2\ \ q_3\ \ q_4\,] = [\,0.6\ \ 0.3\ \ -0.5\ \ 0.5\,]$, where $c_1 = c_2 = 0.5, \eta = 0.5, k = 5, 0 < \alpha < 1$. For the two single-joint position control methods mentioned above, the simulation comparison and analysis are carried out with the traditional sliding mode control method.

strategy 1. Single-joint position tracking control based on the approaching law of fractional sliding mode:

$$\begin{cases} s_1 = ce + \dot{e}, \\ \tau_1 = M\left(c\dot{e} + kD^{1-\alpha} sign(s) + \ddot{q}_d\right) + C\dot{q} + G - f. \end{cases} \tag{33}$$

strategy 2. Position tracking control of single-joint based on fractional sliding surface:

$$\begin{cases} s_2 = D^{\alpha} e + ce, \\ \tau_2 = M\left(\ddot{q}_d + cD^{1-\alpha}\dot{e} + \eta D^{1-\alpha} sign(s) + D^{1-\alpha} ks\right) + C\dot{q} + G - f. \end{cases} \tag{34}$$

strategy 3. Single-joint position tracking control based on traditional sliding mode:

$$\begin{cases} s_3 = ce + \dot{e}, \\ \tau_3 = M\left(c\dot{e} + \ddot{q}_d + \eta sign(s) + ks\right) + C\dot{q} + G - f. \end{cases} \tag{35}$$

When the sinusoidal signal is taken as the desired trajectory of the joint, the simulation results shown in Figure 2 are obtained. Figures 2(a)to2(b) are the position trajectory and control input curve of strategy 1, and Figures 2(c) to 2(d) are the position trajectory and control input curve of strategy 2. Figures 2(e) to 2(f) are the position trajectory and control input curve of strategy 3, and Figure 2(g) is the position error comparison curve of the three control strategies.

The difference between strategy 1 and strategy 3 is that the approach law selected is different; that is, strategy 1 selects the fractional approach law, while strategy 3 selects the exponential approach law. It can be seen from the comparison in Figure 2 that the use of fractional reaching law can weaken the chattering of the system, speed up the tracking speed of the double joints of the dance simulation

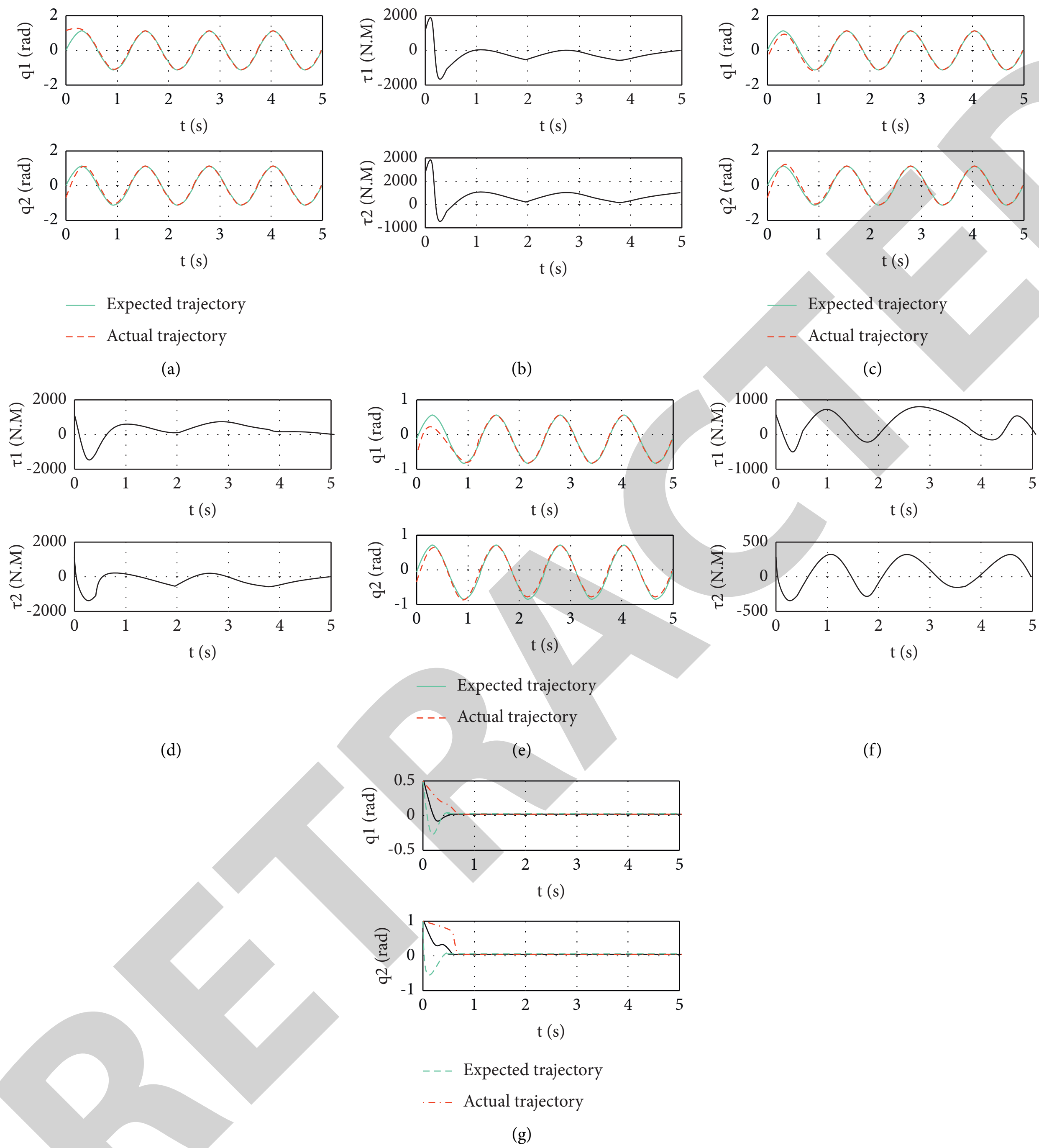

FIGURE 2: Simulation diagram of the desired trajectory. (a)Position trajectory curve of strategy 1. (b)Control input curve of strategy 1. (c) Position trajectory curve of strategy 2. (d)Control input curve of strategy 2. (e)Position trajectory curve of strategy 3. (f)Control input curve of strategy 3. (g)Comparison of position tracking error curves of the three control strategies.

limbs, and soften the motion trajectory. The difference between strategy 2 and strategy 3 is whether the designed controller adopts fractional sliding mode surface. Compared with the traditional sliding mode control method, the second strategy using fractional sliding mode surface design has higher control accuracy, better control effect, and stronger robustness.

However, there are many uncertain factors in the practical application of dance simulation limbs, including the parameter error of the dance simulation limb control system and the unmodeled dynamics of high frequency and low frequency. These factors are mostly aperiodic and can be assumed to be a Gaussian perturbation function: $f(t) = 800\exp(-(t-3)^2/(2\times 0.1^2))$. Using the above simulation parameters for simulation in MATLAB software, the position error comparison curves of the three control strategies under aperiodic disturbance can be obtained as shown in Figure 3. It can be concluded from the figure that under the

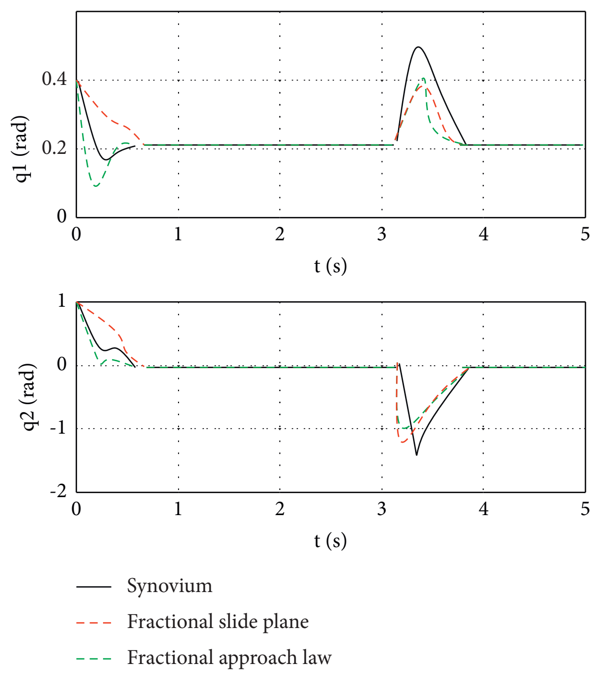

FIGURE 3: Comparison curve of position error of the three control strategies under aperiodic disturbance.

influence of aperiodic disturbance, compared with the traditional sliding mode control, the introduction of fractional calculus can enhance the anti-interference ability of strategy 1 and strategy 2.

3. Research on Synchronous Control Method of Double Joints of Dance Simulation Limbs

At present, the control of dance simulation limb joint tracking is only for a single joint, without considering the coupling relationship between the joints. The control of the dance simulation limb system only reduces the tracking error of the single joint and reduces the synchronization error of the whole system. The tracking performance of the single-joint control cannot guarantee the synchronization performance of the multi-joint control. In order to meet the requirements of high-precision synchronization performance of the dance simulation limb system, the position error and synchronization error are defined, and then the virtual spindle and the cross-coupling control method of the PD virtual spindle are introduced. Due to the chattering phenomenon of this control method, a cross-coupling control method based on fractional sliding mode is proposed, and then this method is further improved to improve the synchronization of each joint of the dance simulation limb system.

3.1. Cross-Coupled Synchronization Control. First, the position error of the i-th joint is the difference between the expected position and the actual position, as shown in the following formula:

$$e_i = q_{di} - q_i. \tag{36}$$

Among them, q_{di} is the desired position and q_i is the actual position.

In the dance simulation limb control system, in order to keep the design simple, it is assumed that the synchronization requirements of each joint are the same; namely,

$$e_1 = e_2 = e_3 = \ldots = e_n. \tag{37}$$

The synchronization error is defined as the difference between the position errors of two adjacent joints; namely,

$$\begin{aligned} \varepsilon_1 &= e_1 - e_2, \\ \varepsilon_2 &= e_2 - e_3, \\ &\vdots \\ \varepsilon_i &= e_i - e_{i+1}, \\ \varepsilon_n &= e_n - e_1. \end{aligned} \tag{38}$$

Among them, ε_i is the synchronization error of the i-th axis. To satisfy the synchronous control requirement in (37), we set $\varepsilon_i \longrightarrow 0, i = (1, 2, \cdots, n)$, and the control of each joint in this system is only related to its adjacent joints, without considering other joints.

$\varepsilon(t) = [\varepsilon_1(t), \varepsilon_2(t), \ldots, \varepsilon_n(t)]^T \in R^n$ is the synchronization error vector of the system; then, (38) can be expressed as follows:

$$\varepsilon = Te. \tag{39}$$

Among them, $e = [e_1, e_2, \ldots, e_n]^T$, and T is the synchronous transfer matrix, which can be expressed as follows:

$$T = \begin{bmatrix} I & -I & & & \\ & I & -I & & \\ & & \ddots & & \\ & & & I & -I \\ -I & & & & I \end{bmatrix}. \tag{40}$$

It can be seen from the above that the synchronization control can make both the synchronization error ε and the position error e converge to zero.

3.2. Basic Concept of Virtual Spindle. The coupling control can improve the dynamic and steady-state synchronization performance of the dance simulation limb movement system. The control adopts the synchronization error compensation method to achieve high-precision synchronization control. In the dance simulation limb movement system, in order to achieve the purpose of coupling between the joints of the dance simulation limb, the difference of the position error between the joints of the dance simulation limb is used as the evaluation index of the control system. Moreover, it is defined as the synchronization error, and the position error of the dance simulation limb system is still defined as the difference between the expected value and the actual value, as shown in the following formula:

$$e(k) = r(k) - x(k). \tag{41}$$

Among them, $x(k)$ is the actual position coordinate, and $r(k)$ is the desired position coordinate. Then, the synchronization error between each joint of the dance simulation limb is shown in the following formula:

$$\varepsilon_i(k) = c_i e(k) - c_j e(k). \tag{42}$$

Generally speaking, there are two compensation methods for coupling control, namely, master-slave compensation and peer-to-peer compensation, among which peer-to-peer compensation has faster response speed and synchronization performance. In the equivalent coupling compensation control system with multiple joints of dance simulation limbs, the "chain" structure is usually used to define the synchronization error, and the coupling relationship between the joints of the dance simulation limbs is shown in the following formula:

$$\begin{cases} \varepsilon_1(k) = e_1(k) - e_2(k), \\ \varepsilon_2(k) = e_2(k) - e_3(k), \\ \cdots, \\ \varepsilon_n(k) = e_n(k) - e_1(k). \end{cases} \tag{43}$$

For the purpose of synchronous control, if $\varepsilon_i \longrightarrow 0, i = 1, 2, \cdots, n,$ then $e_1 = e_2 = e_3 = \cdots = e_n$. However, in practical applications, the synchronization error can only be guaranteed to be within a neighborhood δ close to zero; namely, $\varepsilon_i(k) \in (-\delta, \delta)$. When there are many joints in the dance simulation limb system, we assume that the system has a total of m joints. It is known that the synchronization error of the first $l(l \approx m/2)$ joints and the error of the last $m - l$ joints are both one-way errors, which are δ_- and δ_+, respectively. Then, the synchronization error of two adjacent joints is still within the allowable range of $\varepsilon_i(k) \in (-\delta, \delta)$. The coupling relationship of (43) increases the synchronization error between the first joint and the l-th joint of the dance simulation limb system; namely, $e_1(k) - e_l(k) = l\delta_-$. If the above chain structure is used, there will be a cumulative effect of synchronization errors between the joints of the dance simulation limbs. This cumulative effect will cause the synchronization error to become larger as the number of joints increases, which will inevitably adversely affect the overall synchronization accuracy and performance of the dance simulation limb system. In order to improve the adverse effects caused by the cumulative effect, the concept of virtual spindle is introduced in this paper.

We assume that there is an axis numbered 0 in the dance simulation limb, which controls the given expected position coordinates to be the same as the expected position coordinates of other joints, that is, $R(k)$. The state vector is $x_0(k)$, the tracking error vector is $e_0(k)$, and the synchronization error vector of each joint in the dance simulation limb system is defined based on the assumed axis; that is, $\varepsilon_i = [\varepsilon_i, \dot{\varepsilon}_i]^T$, as in the following formula:

$$\begin{cases} \varepsilon_i(k) = e_i(k-1) - e_0(k-1), \\ \varepsilon_i(1) = 0, \end{cases} \quad i = 1, 2, \cdots, n. \tag{44}$$

After compensating the position synchronization error of each joint of the dance simulation limb, the synchronization error of each joint will reach an allowable range. In the most unsatisfactory case, the synchronization error between any two joints is accumulated as $2\delta_-$. With this synchronization method, the cumulative error caused by the chain structure will not be generated, and the synchronous motion accuracy of the dance simulation limb system can be better improved.

In the physical sense, the imaginary "0" axis does not exist, so it is defined as a virtual main axis, and its state vector $x_0(k)$ and tracking error $e_0(k)$ are defined by the average value as shown in the following formula:

$$\begin{cases} x_0(k) = \dfrac{1}{m} \displaystyle\sum_{i=1}^{m} x_i(k), \\ e_0(k) = \dfrac{1}{n} \displaystyle\sum_{i=1}^{n} e_i(k) = R(k) - x_0(k). \end{cases} \tag{45}$$

3.3. Research on Synchronous Control Method under Different Position Controllers. In this section, we choose the cross-coupling synchronous control as the framework of the control system, aiming at the characteristics that the double joints of the dance simulation limbs need synchronous control. Under the same conditions as the synchronous controller, three different controllers are used for single-joint position control. The first controller is PD controller, the second controller is sliding mode controller, and the third controller is fractional-order sliding mode controller. The simulation results shown in Figure 4 are obtained through MATLAB simulation. Figure 4(a) is the position trajectory comparison curve under three different controllers, and Figure 4(b) is the position error comparison curve under three different controllers. It can be seen from the experimental simulation in Figure 4 that designed controller three, the fractional-order sliding mode controller, can make the actual trajectory better approach the desired trajectory and make the angular displacement adjustment time shorter, which is obviously better than the other two controllers.

3.4. Synchronous Control Method of Double Joints. In order to make full use of the information of the controlled object and make the system parameters easy to adjust, a controller that separates the position tracking error from the synchronization error is designed in this paper. Moreover, this paper introduces the PD control strategy as compensation into the cross-coupling synchronization control and studies the cross-coupling control method of the PD virtual spindle to achieve the purpose of reducing the synchronization error between joints. The control block diagram is shown in Figure 5.

The synchronization error form of the available virtual spindle is shown in the following formula:

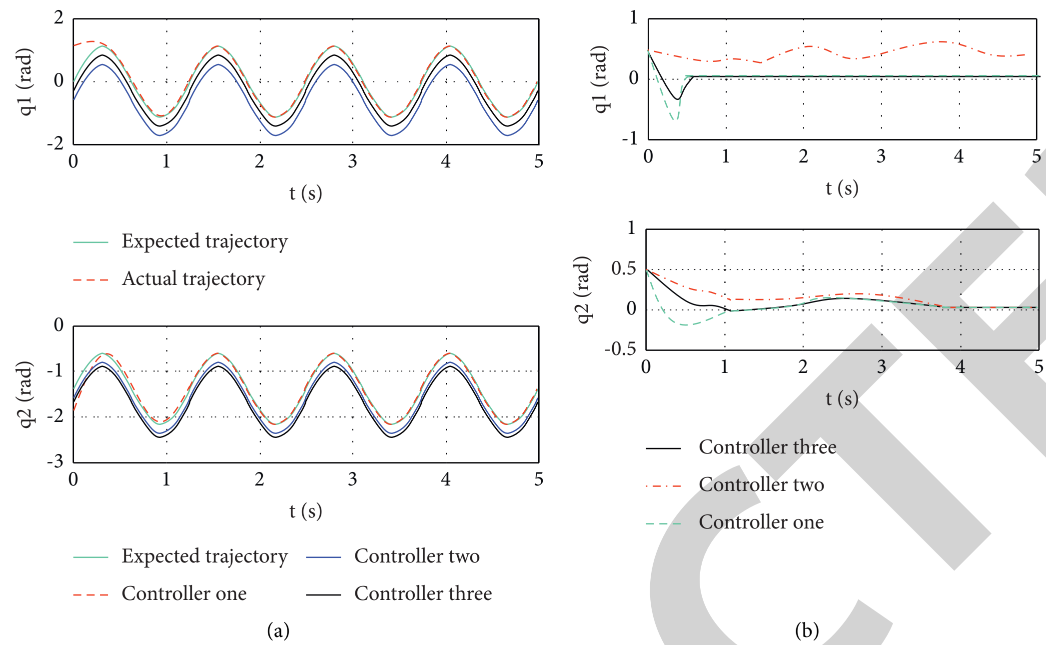

FIGURE 4: Position comparison curve. (a) Comparison curves of position trajectories under three different controllers. (b) Comparison curve of position error under three different controllers.

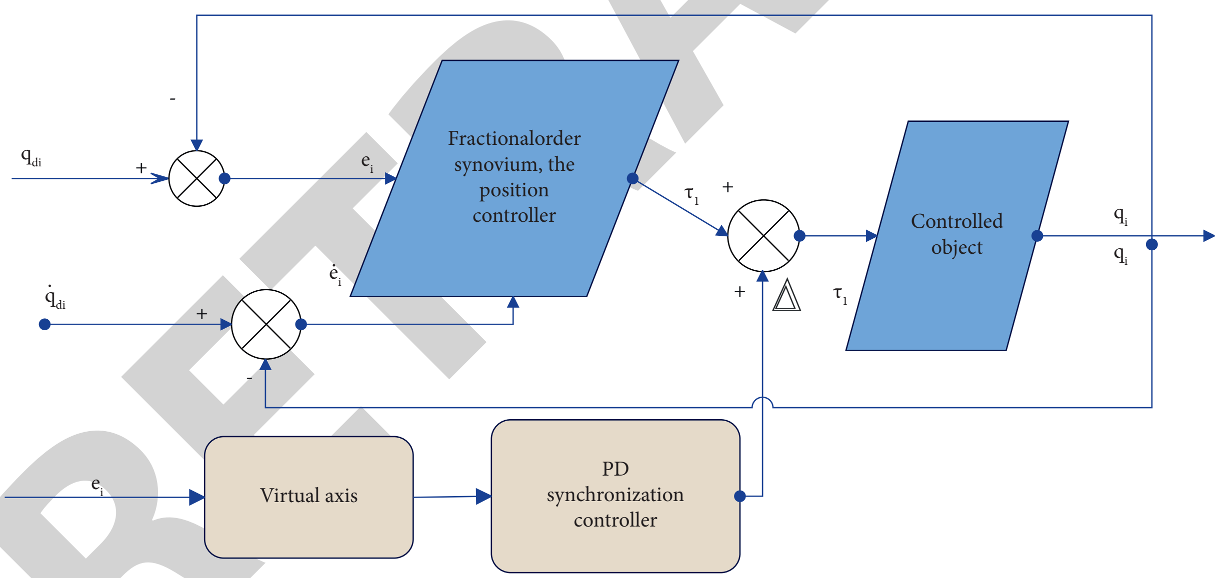

FIGURE 5: Block diagram of cross-coupling control of PD virtual spindle.

$$\begin{aligned} \varepsilon_1 &= e_1 - e_0 \\ \varepsilon_2 &= e_2 - e_0 \\ &\vdots \\ \varepsilon_i &= e_i - e_0 \\ \varepsilon_n &= e_n - e_0. \end{aligned} \tag{46}$$

For the convenience of calculation, it can be described as follows:

$$\varepsilon_i(k) = Ie_i(k) - e_0(k). \tag{47}$$

Among them, I is the identity matrix.

4. Recognition of the Features of Dance Movement Skills

In order to meet the needs of efficient and high-precision human gesture recognition methods, an efficient gesture analysis method based on special dance action feature

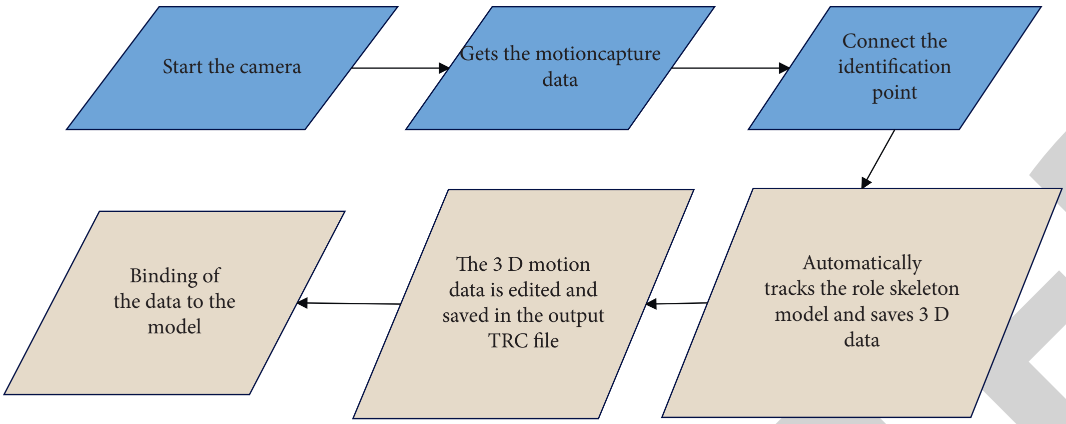

Figure 6: The dance movement skill feature recognition system.

Table 1: The application effect of dance movement skill feature recognition system in dance teaching movement analysis.

Number	Application effects
1	81.842
2	83.570
3	86.725
4	82.476
5	86.068
6	88.360
7	81.586
8	81.939
9	84.263
10	86.508
11	83.309
12	82.003
13	86.008
14	82.648
15	84.370
16	84.793
17	84.378
18	82.001
19	83.834
20	84.582
21	81.602
22	87.293
23	84.445
24	88.832
25	82.420
26	85.491
27	87.537
28	82.576
29	84.681
30	82.213
31	86.846
32	82.046
33	82.708
34	85.099

recognition is proposed. The human motion data is collected in real time through the optical motion capture system, and the skeleton and its human feature plane are effectively extracted. Furthermore, an efficient matching mechanism is established by using the plane feature vector and its included angle as the judgment basis for attitude analysis. The method is combined with dance teaching, and after experimental verification, it can be known that it provides stable and accurate analysis of human posture, as shown in Figure 6.

On the basis of the above research, the application effect of the dance movement skill feature recognition proposed in this paper in the analysis of dance teaching movement is verified, and the test results shown in Table 1 are obtained through the verification of 34 groups of data.

From the experimental data in Table 1, it can be seen that the application effect of the dance movement skill feature recognition system in dance teaching movement analysis is very good.

5. Conclusion

Dance education major is an emerging major opened by colleges and universities, and its purpose and goal are to cultivate dance talents with strong practical ability for the society. The backwardness of teachers' teaching concepts, the imperfect construction of relevant teaching staff, and the insufficiency of teachers' classroom teaching mode make it difficult to achieve the goal of dance education. The strategy of integration of production and education points out an innovative direction for the development of dance teaching in higher education. Therefore, it is particularly important to improve the corresponding mode of the recognition of production and education in dance teaching. This paper analyzes dance teaching movements using the method of dance movement skill feature identification and combines teaching and technology to facilitate the cultivation of dance talents needed by the society. From the experimental data, it can be seen that the application effect of the dance movement skill feature recognition system in dance teaching movement analysis is very good.

Data Availability

The labeled dataset used to support the findings of this study is available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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