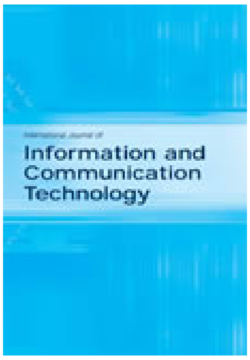

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Multimedia interactive creative dance choreography design integrating hybrid density network algorithms

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Abstract: With the continuous development of society and economy, dance has changed from traditional individual movements to group and interactive movements. Although computers have been introduced for multimedia interactive dance choreography, there are still insufficient simulation accuracy, large calculations, real-time poor performance and other limitations, and relatively difficult to model. In the realm of multimedia interactive dance choreography, the industry is plagued by issues of simulation inaccuracy, high computational demand, and inadequate real-time responsiveness. These limitations impede the seamless integration of dance movements with multimedia elements, demanding a sophisticated solution. This paper introduces a hybrid density network algorithm to address these challenges by integrating a myriad of influencing factors into the choreographic design process to achieve creative interactive dance choreographer. Practice has proved that the algorithm is effective and can effectively support multimedia interactive creative dance choreography.

Keywords: inverse kinematics; hybrid density network algorithm; creative dance choreography design; multimedia interaction.

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1 Introduction

With the continuous development of computer technology, internet technology, film and television media and other related technologies, the means of artistic presentation and development have gradually become richer, which has brought great informational influence to related industries (Rudd et al., 2020; Kim et al., 2020; Scrementi, 2015). With the advent of cutting-edge technologies such as virtual reality and motion capture, the field of multimedia interactive dance choreography has made significant strides. However, these advancements have also unveiled challenges related to cost, technical complexity, and the critical need for real-time interactivity. A notable gap exists in the current methodologies, which lack a cohesive approach to choreographing dances that are both intricate and responsive to multimedia cues. This paper aims to fill this gap by presenting a hybrid density network algorithm that unifies these elements into a singular, efficient framework. For now, the continuous development of these emerging technologies and the continuous improvement of the industry have laid a good theoretical and practical foundation for artistic presentation. Take creative dance choreography as an example. The traditional choreography method is usually based on the actual venue size, environment, lighting, sound and other influencing factors. Choreographers actually perform choreography, but are limited by personnel, energy, technology, etc. and different performance venues will have different presentation effects, this part needs to be paid attention to (Jetsada et al., 2016; Carey et al., 2019). At the same time, in the choreography process, it is difficult to guarantee whether the involved movements are completely consistent with the final movements (Triana, 2015; Chon and Jun, 2015).

With the continuous development of computer technology, people's movements can be simulated by computers, such as using virtual reality methods to simulate the surrounding environment, using kinematics, key frame methods, etc. to simulate people's movements to realise that the human body is at rest and Simulation in motion states, through the computer's capture of human joints and motions, the human body can be captured in high-speed and low-speed motions. However, in terms of actual effects, the simulation of simple motions cannot meet the needs of choreography, because of the choreography. It is continuous, and the action is comprehensive and changing. A variety of new methods and methods have been introduced into the art form of choreography, and interactive creative dance choreography has gradually formed, such as multimedia, lighting, sound, etc. to achieve interactive design, which has become an important research direction of choreographers, that is, 'internet + dance' realises the fusion of technology and art creative innovation. For such creative interaction, there are not only the interaction between the body and the stage carrier, but also the interaction between the computer and the actual dancer, as well as the interaction between the computer and the environment (Hall, 2019; Bell, 2015).

Multimedia interactive dance choreography represents a significant evolution in the performing arts and entertainment industry. It merges traditional dance with modern technology to create immersive and dynamic performances that can captivate audiences in new ways. The integration of multimedia elements, such as lighting, sound, and visual projections, with dance movements allows for a more engaging and sensory experience. This fusion not only enhances the storytelling capabilities of dance but also opens up new avenues for creative expression. By using interactive technology, choreographers can now design pieces that respond to the dancers' movements in real-time, creating a symbiotic relationship between art and technology. This approach has the potential to redefine the future of live performances, making them more interactive and potentially more accessible to a wider audience through virtual or augmented reality applications.

Previous studies have delved into the integration of multimedia in dance performances, exploring the use of technology to augment the dancer's expressiveness and the overall performance experience. Projects such as the use of motion capture technology to translate dancers' movements into digital formats for virtual reality environments or the application of machine learning algorithms to generate choreography have shown promising results. For instance, research has demonstrated that machine learning can analyse patterns in human movement and use these to create new, innovative dance sequences. These studies have paved the way for more sophisticated algorithms, like the hybrid density network algorithm discussed in the paper, which can handle the complexity of interactive choreography by incorporating real-time feedback and adapting to the dancers' movements.

For now, traditional methods are difficult or insufficient for the modelling involved in choreography. Therefore, this paper integrates the hybrid density network algorithm to try multimedia interactive creative dance choreography, aiming to lay the foundation for creative choreography.

2 Several common methods to solve the inverse kinematics problem of choreography

2.1 Analytical method

Analytical method is a method that uses mathematical modelling to simulate human joint points for process simulation. Using analytical method to simulate can effectively solve the modelling in motion state and effectively achieve real-time simulation results. However, it is worth noting that due to the large amount of data on joint points and more dance movements, mathematical modelling will become more and more complicated, and a huge workload may be generated (Jung, 2015; Leonard and Cridland-Hughes, 2019).

2.2 Iterative method based on Jacobian matrix

Set the corresponding dimension through the state of the joint points, and perform the quantitative calculation of the motion equation through the local linearisation of the choreography, as shown in formula (1):

$$dX = J(\theta)d\theta \tag{1}$$

But for computer simulation, it is more important to care about the quantitative calculation of time variables, as shown in formula (2):

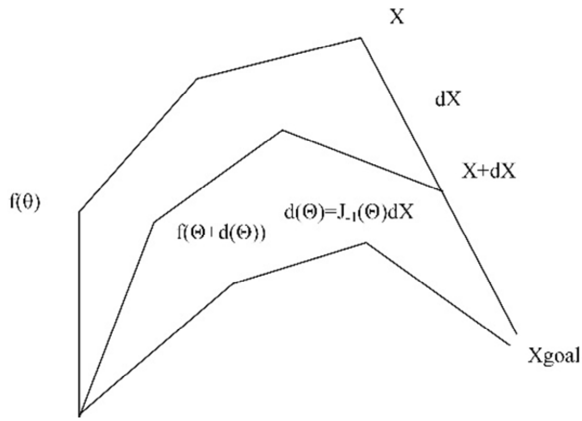
$$X = J(\theta)\theta \tag{2}$$

According to formula (1), the inverse function can be locally linearly approximated by formula (3), as shown in formula (3):

$$d\theta = J^{-1}(\theta)dX \tag{3}$$

Since the Jacobian matrix is not a square matrix, it is irreversible for the Jacobian matrix. Usually, the technique of dangerous pseudo-inverse is used to obtain the inverse matrix of the Jacobian, then let $J_{-1}(\theta)$ be the inverse matrix. Known from formula (3), the stepwise method can be used to approximate the optimal target motion, as shown in Figure 1.

Figure 1 The geometric description of the stepwise approximation method



3 Characteristic description

3.1 Physicality based on dance

For the dance itself, once the 'interactive' innovation mode is carried out, the human choreography becomes visualised, but the movements are still continuous movement, through the interaction and combination of body movements and multimedia, external factors It cannot affect the movement of the body itself, and the body is still important during the entire interaction process (Jung, 2015; Leonard and Cridland-Hughes, 2019).

In the interactive choreography process, it is necessary to pay attention to the factors of the dance itself. Taking the body's centre of gravity as the main smoking hotel, it needs to reflect the person's positioning, direction, and the relationship with other multimedia such as video and audio in the process of interactive creative dance preparation. In addition to the effect of gravity, the centre of gravity of a person often represents a certain physical factor. In the process of exercise, the centre of gravity of a person will change with the change of the movement. Secondly, affected by friction, gravity, etc. the body will have certain effects. The position changes and moves.

3.2 Containment based on interaction

The cross-border performance of body and multimedia interaction shows that there are certain key problems in the entire interaction. The biggest difference between interactive dance and traditional dance is that interactive dance requires a certain amount of interaction between people and external multimedia, and get corresponding feedback, realise human-computer interaction, and create a new range and mode of dance. As far as the current development is concerned, new interactions are realised through technical means such as projection and large screens through virtual reality, motion capture, sensing devices, and somatosensory detection. From the perspective of interaction, one is to arrange the corresponding environment, the dancers directly perform dance performances, and interact with the dancers through human control; the other is to interact with multimedia devices in real-time. The equipment and environmental requirements are very high (Poutanen et al., 2017; Rowe et al., 2020.

In the real-time interactive dance performance, because of the mutual influence between the body and the multimedia device, the whole performance will have a clear transition of the movement process, especially in the unfinished state, that is, in the process of rehearsal and choreography. Because of the uncertainty of the settings with the multimedia device, it is impossible to achieve perfect or complete chain processing during the interaction process, which will bring more responsible interactive instructions. For this reason, interactive choreography needs to introduce certain the relationship of "to achieve gravitational field, and bring virtual reality, overlap, space around the body, to achieve basic movements such as jumping, leg raising, flipping, reincarnation and so on."

For semi-open, it means that in the interactive relationship, the interaction between the body and the multimedia device is not fixed and closed, but through the interactive relationship to achieve unconscious and irregular interaction, and to play freely under unspecified rules and conditions. Realise the interactivity and freedom of interaction (Payne and Costas, 2020; Tsompanaki, 2019). Therefore, in the multimedia interactive technology, the specific realisation of choreography can be realised, such as the orientation, angle, speed, posture and other aspects that need to be tested to achieve the best results.

3.3 The emergence of new art forms

Interactive creative choreography uses the dancer's body to achieve communication with multimedia media, which makes it possible to rebuild relationships and create infinite possibilities for creative art. The dancer's body interacts with multimedia, so that both the choreographer and the audience re-recognise the body. The importance and innovation of interaction with multimedia, compared with traditional presentation methods, is undoubtedly eye-catching and can achieve very good results. Therefore, for the emergence of this new art form, further exploration and optimisation are needed to give choreographers new ideas and new inspirations to present more beautiful and updated dances.

4 Classification and advantages and disadvantages of motion capture technology

For the present, capturing the movements of choreographers is one of the important methods of creative dance choreography. The existing capture techniques are divided into optical, mechanical, electromagnetic, acoustic, and video capture methods.

4.1 Optical motion capture

The first is the optical motion capture of dance movements. From the perspective of the realisation principle, it uses multiple multimedia setting devices distributed in the air to perform complete motion video capture of the characteristics of a specific captured object. It is common in competitions during the motion capture. Therefore, it can be found that the advantages of optical capture are mainly changed. The performers have a larger range of activities and a higher sampling rate, which can satisfy the capture of multiple and continuous actions. And more importantly, the price of the capture system is relatively low and the cost is cheap.

But on the other hand, the disadvantage of optical capture is that it requires a large number of multimedia devices to capture from multiple angles, which increases the investment cost of hardware; secondly, it brings a lot of post-processing work for a large number of multimedia devices. The video needs to be processed effectively, and this part needs to be clarified; therefore, it is precisely due to a large amount of processing work that the real-time performance is insufficient, that is, the unified capture of the data volume cannot be satisfied.

4.2 Mechanical motion capture

Different from optical motion capture, mechanical motion capture is connected through multiple multimedia joints and levers, that is, using different angles and different positions to achieve mechanical motion capture. The advantage of this method is that it can accurately restore the waiting the movement characteristics of the capture; real-time capture can be achieved; for multiple objects to be captured, the objects can be captured at the same time, which saves a lot of costs and realises the completeness, real-time, and comprehensiveness of the capture.

4.3 Electromagnetic motion capture

Electromagnetic motion capture is slightly different from optical and mechanical capture. Its main feature is to rely on electromagnetic capture. First, a stable low-frequency electromagnetic field is simulated and generated. The sensor device carried by the object to be captured is moved in the electromagnetic field to realise the sensor. The electromagnetic analogue signal is captured, the electrical signal is converted by the electromagnetic field signal, and then converted into a data signal, so as to realise the spatial orientation of the signal.

Different from other methods, its advantage is that this method can achieve real-time capture, and the cost is relatively low, but at the same time, it still has certain limitations, for example, it is easy to be affected by external factors for electromagnetic fields, especially when waiting When the measured object is moving at a high speed, real-time capture cannot be carried out, which may lead to misjudgment, missed judgment, etc. if there is a metal substance on the scene, the electromagnetic field may change to a certain extent, resulting in inaccurate results.

4.4 Acoustic motion capture

Acoustic motion capture, as the name suggests, is to capture motion by sound. In fact, it uses ultrasonic waves to achieve positioning. First, ultrasonic waves are generated, and then 3–4 ultrasonic probes are used to form related receivers. The receiver's spatial position and time difference are realised through the time difference of ultrasonic reception.

Therefore, the advantages of its capture are also more obvious, and its cost is the lowest compared to other methods, but its disadvantages are also more obvious, that is, there may be a significant delay, and real-time capture is almost impossible to achieve; secondly, the accuracy is not enough, the error is large, and it is easy. Misjudgment occurs; finally, it is more affected by external factors, such as air humidity and temperature.

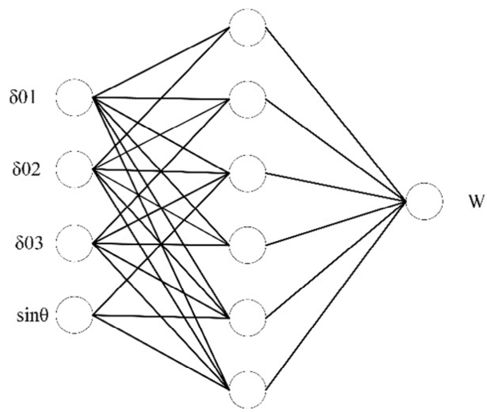
4.5 Video capture motion capture

Video capture is done by simulating the human body to a certain extent, using two multimedia devices to instantaneously shoot the same effect to compare and capture the object to complete the positioning. It uses the principle of bionics, and has no clear requirements on the moving object and the range of motion, and the real-time capture effect is better. Good, but its realisation is also relatively difficult, it is difficult to complete and effective simulation calculation, and the accuracy needs to be further improved.

5 Hybrid density network algorithm

This section outlines the methodology employed in integrating the hybrid density network algorithm into the design of multimedia interactive creative dance choreography. The process begins with the initial capture of dancer movements and culminates in the simulation and generation of choreography that dynamically responds to multimedia inputs. Detailed descriptions of data processing techniques and the translation of inputs into choreographic outputs are provided. For multimedia interactive creative dance choreography, a two-layer perception network is used. The specific network topology is shown in Figure 2. It mainly consists of three parts: the input layer, the hidden layer, and the output layer. However, due to the choreography layer of the dance it is not only related to the backward inversion sparseness, but also related to the relevant input angles and position parameters of the multimedia. The hybrid approach is a strategic choice that leverages the strengths of different data types to create a more comprehensive and responsive choreography system. Motion capture data provides detailed information on the dancers' movements, audio can offer rhythmic cues and emotional tones, while video can capture the visual ambiance and the dancers' expressions. Integrating these data types into the algorithm allows for a multifaceted representation of the dance performance, which can lead to more nuanced and adaptive choreography. The hybrid density network algorithm uses these inputs to estimate conditional probability density distributions, enabling it to handle the complex, nonlinear relationships between a dancer's movements and the multimedia elements that accompany them. The hybrid density network algorithm presented in the paper is a sophisticated model designed to handle the intricacies of multimedia interactive dance choreography. The model's architecture consists of an input layer that takes in various data types, a hidden layer that processes this information through a series of nonlinear transformations, and an output layer that provides the final choreographic output. Feature representation in this model is achieved through the use of Gaussian kernel functions, which can capture the statistical properties of the input data. The integration of multimedia inputs is managed by the algorithm's ability to estimate the conditional probability density of the dance movements given the multimedia context, allowing for a choreography that is both creative and responsive to the performance environment. Therefore, in the real simulation, the input includes the backward inversion sparseness, the quantification of the hidden layer and the output layer. The check function adopts logarithmic and linear functions, as shown in Figure 2.

Figure 2 Inverted neural network topology



In principle, the hybrid density network can estimate any conditional probability density distribution, and is mainly used to solve the inversion problem where the mapping relationship from input to output is not one-to-one. The choreographer's inversion of the dance is not only related to the installation environment, position, angle and other coefficients of the multimedia device, but also related to the location of the arrangement and the size of the venue. Therefore, the input (x) of the mixed density network includes the inverse scattering coefficient, The angle and position of the multimedia device and the relevant information obtained from the inversion; the output of the network is the conditional probability density of the wind direction under the condition of the input network [$P(t|x)$]. The output of the network $p(t|x)$ can be expressed as a linear combination of several Gaussian kernel functions (mixed components) with different weights:

$$p(t \mid x) = \sum_{i=1}^{m} a_i(x)\phi(t \mid x) \tag{4}$$

In the formula, $a_i(x)$ is the prior probability; m is the number of mixed components; $\phi_i(t|x)$ is the kernel function in Gaussian form, as shown in formula (5):

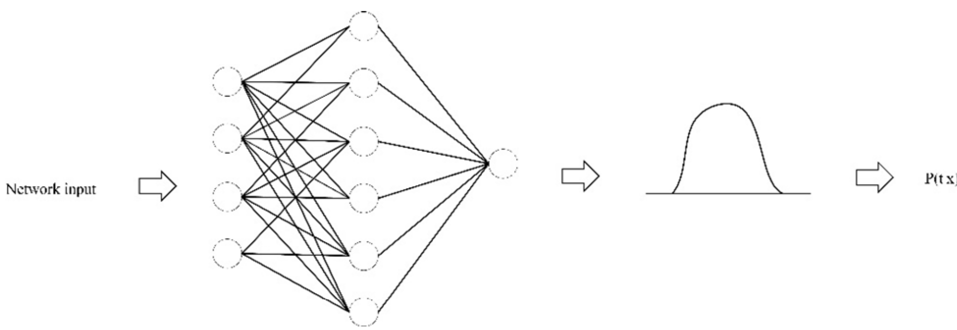
$$\phi_i(t \mid x) = \frac{1}{(2\pi)^{1/2}\sigma_i(x)} \exp\left\{-\frac{\|t - \mu_i(x)\|^2}{2\sigma_i(x)}\right\} \tag{5}$$

Among them, $\mu_i(x)$ and $\sigma_i(x)$ are the parameters of the Gaussian kernel function, that is, the mean and the variance. $a_i(x)$, $\mu_i(x)$ and $\sigma_i(x)$ are all related to the input x of the network. If the output of the network $p(t|x)$ is expressed by three Gaussian functions, it can be expressed as, as shown in formula (6):

$$p(t \mid x) = a_1\phi_1(t \mid x) + a_2\phi_2(t \mid x) + a_3\phi_3(t \mid x) \tag{6}$$

In the formula, α_1, α_2, α_3 must satisfy the condition $\alpha_1 + \alpha_2 + \alpha_3 = 1$. The multilayer perceptron network of the hybrid density network has two hidden layers (Figure 3), and its output is the input parameters of the hybrid density model, namely the prior probability $a_i(x)$, the mean $\mu_i(x)$ of the kernel function and the variance $\sigma_i(x)$.

Figure 3 Hybrid density network topology



5.1 The idea of hybrid density network algorithm

The hybrid density network algorithm is an iterative heuristic search algorithm. Its main purpose is to reduce the position error by changing the parameters of a joint point at a time. The process of each iteration is a step from the top to the low end of the structure of a joint point. In the traversal process, the parameter θ of each joint point is optimised to the minimised objective function. The joint chain problem of the joint points of the hybrid density network algorithm can be transformed into a simple problem of each joint, and the objective function of each joint point is optimised It is relatively simple, and traditional methods can be used for calculation processing, which brings higher and faster iteration efficiency and steps.

After the parameters of the joint points are calculated, they are introduced into the forward and reverse kinematics equations for separate calculations.

When starting from the end of the movement, gradually change the dancer's rotation, the angle of raising the legs, etc. first by changing the joint points of the end, that is:

Cyclic-coordinate descent (CCD) is a heuristic iterative search algorithm that gradually reduces the position error and attitude error by changing only the parameters of one joint at a time. Each iteration process includes a process from the top of the joint chain structure to the base point. Traverse the process. Each joint parameter θ is immediately modified to minimise the objective function. Since the CCD method simplifies the multi-joint joint chain problem to a single-joint problem, and the problem of minimising the objective function of each joint is simple and can be handled by an analytical method, the iteration of each step can be quite fast.

Figure 4 Processing joint point J_0

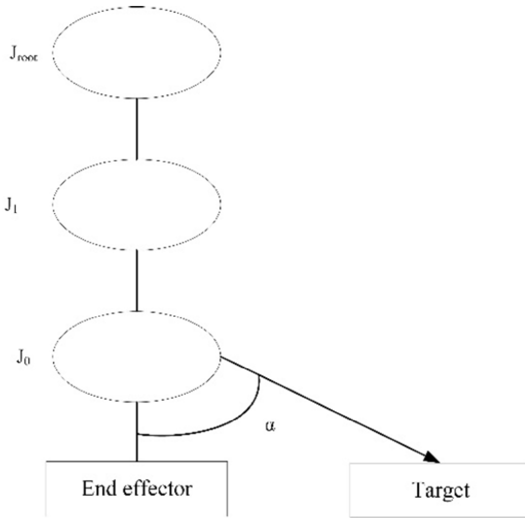
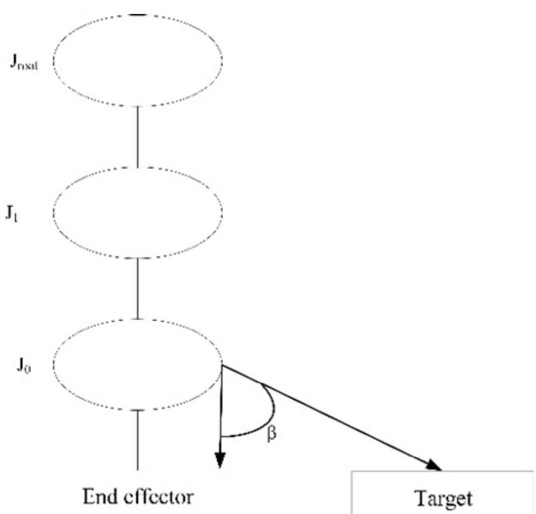


Figure 5 Processing joint point J_1



When the parameter (rotation angle) θ of each joint is obtained, it is substituted into the forward kinematics equation to obtain the position of the end effector and each joint.

The algorithm idea is as follows:

Starting from the end of the kinematic chain, gradually change the rotation angle of each joint. First, change the end joint J_0, from J_0 to the end effector E as the vector V_1, from J_0 to the target point D as the vector V_2, and find the angle α of the two vectors and the rotation axis VR, so that the sub-chain under J_0 rotate the rotation axis VR by an angle of α (as shown in Figure 4), and the end effector E reaches a new position. If E does not reach the target D, then take the parent node J_1 of J_0, and also use the vector V_1 from J_1 to E, and the vector V_2 from J_1 to D to find the angle β between the vectors V_1 and V_2 and the rotation axis VR, so that J_1. The lower sub-chain rotates β angle around the rotation axis VR (as shown in Figure 5), and the end effector E reaches a new position. If E does not reach D, continue to take the parent node of J_1 and change its rotation angle until the root node J_{Root} is selected. If E has not reached D, start a new round of movement from the end joint J_0 until the distance between E and D is small enough or the given number of cycles is reached.

5.2 Implementation of hybrid density network algorithm in running

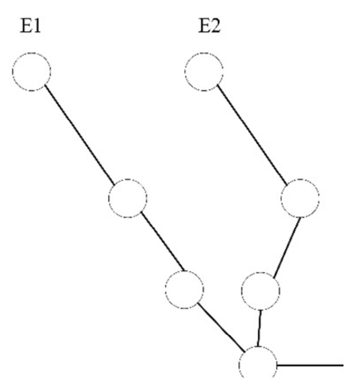
Through the movement control of the dance choreography and the simulation and analysis through the hybrid density network algorithm, the corresponding values of the upper limbs and legs of the dancers are clarified and determined.

Step 1 According to gravity, kinematics and other related theories, divide the dancer's initial stage to a certain extent, and clarify the key steps and moments, such as the left foot off the ground, the centre of gravity, the forefoot off the ground, the sole of the foot Key steps such as landing and crossing the vertical position of the supporting surface.

Step 2 According to the key steps of step 1, clarify the position of the centre of gravity of the person's body at the moment of the key step.

Step 3 According to the position of the person's centre of gravity, the mixed density network algorithm is introduced to calculate the support angle, and then the corresponding kinematics chain is used for simulation. The specific figure is shown in Figure 6. According to the person's centre of gravity, the person's foot is taken as in a fixed section, the dancer's footsteps are used as the end, and the inverse kinematics method is used to solve the support angle.

Figure 6 Movement diagram of the supporting leg



The dance choreography running action is realised through the corresponding CCD algorithm, as shown in Figure 7, where 1–6 are the six instantaneous frames of the choreography process.

Figure 7 Motion simulation results

6 Conclusions

Interactive creative choreography provides new ideas and directions for choreography. This article uses a hybrid density network algorithm to simulate multimedia interactive creative dance choreography, and compares it with the analytical method, the Jacobian matrix iteration method, and the hybrid density network method. The simulation of the human body state is more accurate, more natural and more realistic than the other two methods.

When comparing the hybrid density network algorithm with existing choreography generation methods, it demonstrates a higher degree of creativity by generating dance sequences that are not only novel but also contextually relevant to the multimedia inputs. The synchronisation between the dancers' movements and the multimedia elements is enhanced due to the algorithm's real-time processing capabilities, leading to a more cohesive performance. Audience engagement is also likely to be higher with interactive choreography, as the element of unpredictability and the fusion of art and technology can make performances more engaging and exciting to watch. The algorithm's use of iterative heuristic search and its ability to optimise joint parameters contribute to a more natural and realistic simulation of dance movements, which is a significant advancement over traditional methods that may struggle with the complexity and fluidity of dance as an art form.

The study's findings suggest that the hybrid density network algorithm is effective in generating interactive choreography that is both innovative and technically sound. The implications of this research are profound for the future of multimedia interactive dance choreography design and performance. Choreographers now have a tool that can assist in the creative process, enabling them to design performances that are not only visually and audibly stunning but also interactive and adaptive. The potential for audience interaction and the creation of unique, immersive experiences are significant. This research opens the door for further exploration into the role of technology in the performing arts, suggesting a future where the line between dancer and technology is blurred, and the possibilities for creative expression are limitless.

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