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Research on System Architecture Design and Implementation Path for the Integration of Dance Theater Performing Arts and Technology

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Abstract: - In this paper, we fit the performance information by constructing an LSTM-based fusion model and a fully connected layer to recognize the dance performance movements. A system architecture for fusion of dance performance and technology is designed to manipulate the stage position through system hardware and software. The system functional modules can be divided into four key modules: data processing, machine learning and prediction, visualization and display, and system management and maintenance. In the case of 60/MB-150/MB of action information, the action recognition latency of the proposed system is always around 3.5/ms, and in the case of 150/MB of action information, the action recognition latency of the proposed system for the dance drama performance recognition method is 1.3/ms. The recognition latency curve changes more gently, and does not have a large floating fluctuation. It proves that the action recognition method proposed in this paper has a greater advantage in recognition efficiency and can better meet the needs of the fusion of dance drama performance art and technology, and explores the implementation path from the content side, theoretical side and market side.

Keywords: dance drama performance movement; data processing; visualization display; movement recognition; implementation path

1. Introduction

As a comprehensive art form integrating multiple elements such as dance, music, theater and visual art, dance drama has a unique performance form, and its deep cultural heritage and unique artistic charm make the integration with science and technology have great potential and value [1-2]. The traditional performing art of dance drama relies on the exquisite skills of the dancers and the creative choreography of the director, but with the support of science and technology, dance drama can show richer visual effects, more delicate emotional expression and more profound thematic connotations [3]. From stage lighting to sound design, from virtual reality to artificial intelligence, the application of science and technology has brought infinite possibilities for the performing art of dance drama [4]. However, the integration of dance theater performing arts and technology is not an easy task. It is necessary to deeply understand the nature and laws of the performing arts of dance drama to ensure that the application of technology can truly serve the artistic performance [5]. Fully grasp the latest technological trends, and constantly explore and try new technical means. Therefore, it is of great significance to construct a scientific and reasonable system structure and clarify its implementation path to promote the integration of dance drama performing arts and technology.

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To address the technical challenges of dance performance, Rallis, I et al. extracted human skeletal data through 3D points and combined it with techniques such as computer graphics to create a technical model aimed at preserving dance-related information with low resource overhead [6]. Gao, Y and Xu, D utilize human detection, computer interaction algorithms to construct a standard dance posture recognition platform based on IoT technology. The platform was validated and found to be able to reduce the error rate of difficult dance movements and improve the dance ability of coaches to a certain extent [7]. Berg, T discusses the extent to which social media influences dance education in the context of digitization, in the hope of reinforcing the aesthetic value of dance in the form of closed-circuit television technology [8]. Herrow, M. F. M and Azraai, N. Z investigated the core concepts of choreography through a qualitative description of the use of motion capture technology to construct a digital 3D platform to mine high quality dance movements to enhance the cultural viewing experience [9]. Hsia, L. H et al. applied mobile technology in teaching dance and verified that mobile technology was found to improve students' motivation to learn and could be used as an effective way in dance performance integration research [10]. Jin, N et al. used deep learning for visual image extraction to recognize dance movement motion trajectories. The visual network was first optimized, then human skeletal motion was recognized, and finally a human-computer interaction system was constructed, and the simulation results showed that the constructed system played a significant role in dance education [11]. Landry, S and Jeon, M. designed an online survey to evaluate sound vibration strategies, which showed that interactive audible forms of stage performances resonate better than dance movements or music alone, providing new ideas for music creation [12]. Hsia, L. H et al. constructed a flipped learning platform for teaching dance, which is an online learning platform based on observation-summary-problems that promotes students' refinement of stage performance skills more than the traditional teaching model [13].

In this paper, we design an LSTM-based fusion system architecture, which aims to bring a new digital and intelligent expression to the performing art of dance drama through the combination of technology and art. The system processes time-series data of dance movements through LSTM models to accurately capture and recognize key features in the performance, and at the same time utilizes a fully connected layer to fit the performance information to enhance the system's nonlinear fitting capability. The system consists of four functional modules: data processing, machine learning and prediction, visualization and display, and system management and maintenance, which are responsible for ensuring data accuracy, analyzing and predicting dance performances, displaying the data visually, and guaranteeing the smooth operation of the system. The realization of this system not only improves the accuracy and efficiency of dance drama performance identification, but also provides strong technical support for the creation, performance and promotion of dance drama art, showing the great potential of the integration of science and technology with art. The implementation path of the fusion of dance theater art and technology involves content innovation, theoretical support and market promotion, and promotes innovation and development in the field of performing arts.

2. Converged system total architecture design

2.1 LSTM-based fusion model

The fusion of art and science and technology produces changes in some essential issues of human cognition, and

randomly produces innovations. The fusion of science and art is not just about creating new artistic media, and it is not realistic to rely on the invention of new technologies to create the so-called new media language, because it is difficult to cut into the essence of the fusion of art and technology [14-15]. Dance is a kind of art form that takes the refined and processed human body movements as the main means of expression, and utilizes a variety of basic elements such as dance language, rhythm, expression, and composition to shape a dance image with intuition and dynamics, and express people's thoughts and feelings. Therefore, in the design of the fusion system, the LSTM-based fusion model is constructed to ensure the smooth operation of the system architecture.

Long Short-Term Memory Network, abbreviated as LSTM, is an artificial intelligence algorithm commonly used to process sequence data, and Figure 1 shows the basic structure of LSTM. In the internal connection of LSTM, the main structure consists of dance memory cells, rhythmic inputs, expression output gates and stage composition. Among them, the dance memory cell decides which states need to be saved or forgotten, the rhythmic input gate decides how the current input should update the long-term state, and the expression output gate decides which information should be output.

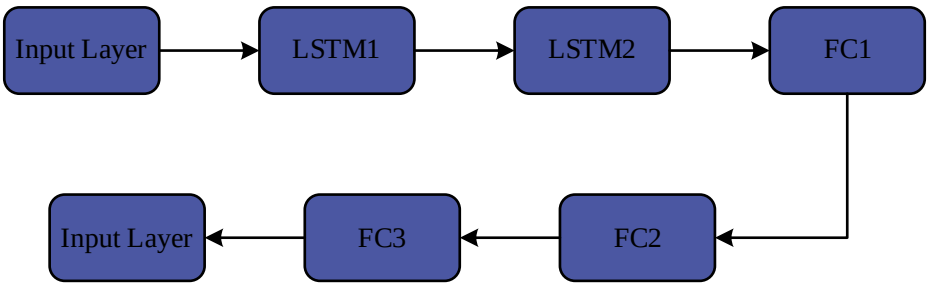


Figure 1 LSTM basic structure

Rhythmic inputs are mainly responsible for memorizing the performance state at the moment, calculating the value of input message i_t and the input memory cell at moment t:

$$i_t = \sigma\left(W_{ih}h_{t-1} + W_{ix}x_t + b_i\right) \tag{1}$$

$$a_t = \tanh\left(W_{\bar{c}h}h_{t-1} + W_{\bar{c}x}x_t + b_{\xi}\right) \tag{2}$$

Where: W_{ih} is the weight of the dance memory cell to the expression output, W_{ix} is the weight of the dance memory cell to the rhythm input, b_i is the bias coefficient of the dance movement, and b_{ξ} is the real-time bias in the choreography performance.

The activation value f_t of the dance movement at moment t is calculated by controlling previous performance information at the rhythm input gate:

$$f_t = \sigma\left(W_{fh}h_{t-1} + W_{fx}x_t + b_f\right) \tag{3}$$

Where: W_{fh} is the weight of the rhythm to the output of the movement unit, W_{fx} represents the weight of the rhythm to the input of the tempo unit, b_f is the rhythm bias coefficient, and σ is the sigmoid function.

The state of the dance theater performance is constantly and dynamically changing according to the input information and calculation results, and the t -moment dynamic update vector is obtained:

$$C_t = f_t \circ c_{t-1} + i_t \circ \overline{c}_t \tag{4}$$

By updating the state of the dance performance, the dynamic information function is output, which updates the values according to the memory cells to the output result O_t :

$$O_t = \sigma\left(W_{oh} h_{t-1} + W_{ax} x_t + b_o\right) \tag{5}$$

$$h_t = o_t \circ \tanh\left(C_t\right) \tag{6}$$

Where: W_{oh} is the weight from the performing action to the output of the rhythm unit, W_{ax} is the weight from the rhythm unit to the action, and b_o is the bias of the output message.

2.2 Fitting Performance Information to Fully Connected Layers

A fully connected layer is a common type of layer in neural networks that allows matrix multiplication and bias addition operations to be performed on the obtained performance features with connection weights between each neuron to obtain the output.

In full connectivity, each neuron is connected to all the neurons in the previous layer and each action input feature has a certain connection weight with each neuron. The role is to map the input features to the output results and is usually used in the last layer of the neural network for tasks such as systematic data classification and regression. In this layer, the output result can be viewed as a nonlinear transformation of the input features, and this transformation maps the input feature space to the output result space, thus realizing the complexity of the fusion system and the nonlinear fitting ability. It should be noted that the number of parameters in this module is very large, and thus overfitting is prone to occur. In order to avoid overfitting, it is necessary to continue recognizing the real-time movement information in the dance drama performance.

2.3 LSTM-based model for recognizing dance performances

The dance activity data collected using the fully connected layer belongs to time series, and the LSTM model has a greater advantage in processing the sequence data. Therefore, a deep learning model based on LSTM is proposed in the paper for recognizing dance performance actions.LSTM can automatically mine the temporal features in the performance video, and then achieve classification by the features. The network structure of the recognition model is shown in Fig. 2, which has a total of seven layers, including one input layer, two LSTM

networks, three FCs and one output layer.

Firstly, the feature information in the original video action is fully mined by two-layer LSTM, and then the extracted feature information is nonlinearly transformed using a three-layer network, and a Dropout layer is introduced to randomly discard some neurons with a certain probability to prevent the model from overfitting. Finally, the probability of each category is output by softmax function, and the one with the largest probability is the result of model recognition.

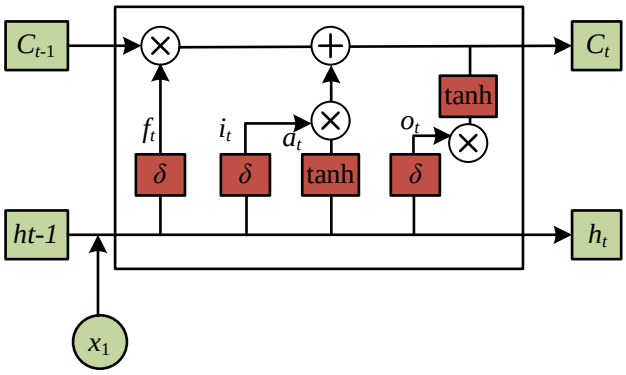


Figure 2 LSTM dance drama performance recognition network model structure

3. System Architecture Design for Dance Performance and Technology Integration

Commonly used stage machinery and equipment, including on-stage equipment and off-stage equipment, on-stage equipment mainly includes boom, rotating stage and car platform. Off-stage equipment mainly includes lifting pool, lifting stage and so on. In addition, there is a rotating stage, in the stage machinery and equipment, the boom plays an important role. Stage booms are mainly used for hanging curtains, scenes and other stage appliances, the operation mode can be a single boom uniform speed, speed operation, more than one boom group uniform speed operation, more than one boom group variable speed operation. Mechanical platform used on the stage, from the function can be simply regarded as a continuous linear or curved movement of the movable floor, the actors can stand on these movable floor performances, but also can be utilized to relocate the scenery, transportation scenery and props. Elevated music pool can meet the special needs, when there is a chorus or concert when the band often plays in the music pool, no performance when the music pool can fall to the bottom of the stage. Different elevated stages can be used to quickly move scenery, change the shape of the stage or create special atmosphere and effects according to the needs of the show. Of course, you can also use the lifting stage as a vertical transportation of goods, rotating stage is often combined with lifting action to show the audience special stage effects. In short, through the reasonable combination of these stage machinery and equipment movement mode, in the performance process, frequent replacement of the performance background, changing the shape of the stage, and with the help of lighting and sound changes, and stage performances mirror each other, to strengthen the stage art effect, adding the charm of stage art.

3.1 System hardware structure and function

The block diagram of the hardware system structure for the integration of dance performance and technology is shown in Figure 3. This system hardware in addition to the stage machinery and equipment, related protection,

braking device also includes industrial control machine, but also uses the inverter and PLC as the lower machine, and the inverter and PLC are networked separately, the upper machine through the serial port and the lower machine for communication. It is able to obtain the real-time dance performance data and transmit the dance movements to the data processing port in time to realize the innovative generation of dance movements and so on.

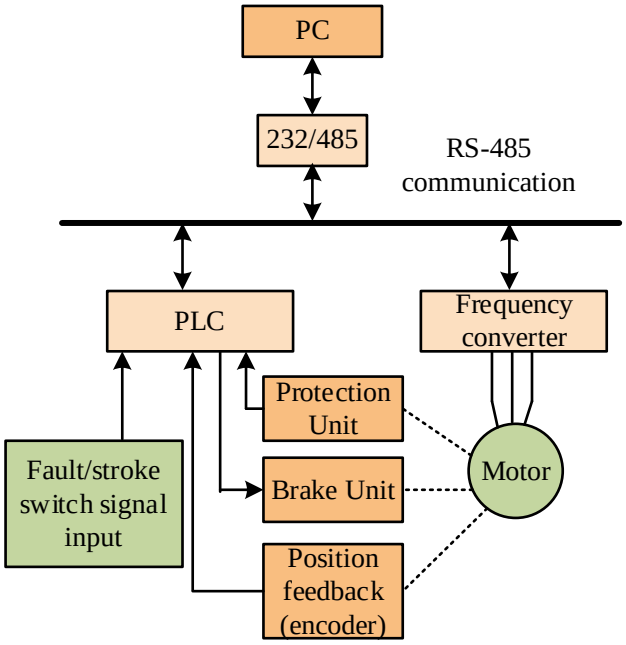


Figure 3 System structure

3.2 System software environment and functions

The upper computer monitoring software of stage machinery and equipment is installed on PC and based on Windows operating system. It is compiled by Visual Basic 6.0, which has the advantages of fast running speed, compactness and flexibility, simple installation and configuration, and high cost-effectiveness compared with the use of configuration software.

In the monitoring software design phase should follow the reliability, real-time, ease of use and operability, manageability and fault tolerance. Monitoring software can be a number of plays all the time stage action pre-set to the file format on the hard disk, and can be stored on floppy disks and other storage media. During the performance, you only need to call up the relevant scene of the corresponding play. Then press the start button on the console, the set stage can run from the current position to the set position, stage machinery and equipment computer control system main interface.

3.3 System Functional Module Design

For the needs of the integration of dance drama performing arts and technology, the system functional modules can be divided into four key modules, namely, the data processing module, the machine learning and prediction module, the visualization display module, and the system management and maintenance module.

3.3.1 Data processing module

The data processing module is responsible for integrating the data related to the dance drama from multiple data sources, such as the dance drama script, actor information, audience feedback, and dance drama video [16]. A professional data processing tool, Pandas library, is used for data cleaning, including handling missing values, outliers, duplicate data, etc., to ensure the accuracy and completeness of the data. At the same time, the module is also responsible for the conversion and standardization of data, and the text data of audience feedback is converted into emotional scores for subsequent analysis and presentation. The action data of different actors are standardized to the same scale to facilitate comparison and analysis. During the data cleaning process, the module fills in missing choreography movement data using averages or other statistical methods to ensure data integrity. The expression is:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{7}$$

Where $\bar{X}$ represents the average audience value of a dance drama, i represents the total number of performances, x_i represents the value of each data point in the data set, and n represents the total number of data points. The module provides data filtering and sorting functions, allowing users to filter the dance drama data based on specific conditions, such as by type of dance drama, actor or performance date. At the same time, users can also sort the data according to different criteria, such as by audience rating or number of performances. Aggregate summary function is realized by aggregation function, which supports all kinds of statistical calculations on the dance drama data. In order to ensure the accuracy of the data, the module also adopts the automatic outlier detection method and utilizes the Z-score statistical method to identify and handle abnormal dance drama data. Through these data processing functions, the module is able to provide high-quality data support for the integration of dance theater performing arts and technology [17-18].

3.3.2 Machine Learning and Prediction Module

Machine learning and prediction modules play a key role in the integration of dance theater performance art and technology, helping choreographers, actors and audiences better understand the art of dance theater performance. For example, a linear regression model can be used to predict the audience rating of a dance drama, calculated as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{8}$$

In the formula, the response variable Y indicates the audience rating, and the explanatory variable $X_1, X_2, \cdots X_n$ includes factors such as the type of dance drama, cast, publicity investment, etc. Adjusting the model parameter $\beta_1, \beta_2, \cdots \beta_n$ can predict the impact of different factors on the box office or ratings of the dance drama, and provide decision-making support for the dance drama performance.

The module provides model evaluation and result interpretation functions, which allow users to view the system's training effect, prediction accuracy and other indicators through the graphical interface or programming interface, and to understand the impact of different factors on the dance drama performance. This helps choreographers and actors to better understand the audience's needs and preferences, so as to optimize the performance content and form of the dance drama.

The Machine Learning and Prediction module plays an important role in the integration of dance drama performance art and technology, using machine learning algorithms to deeply analyze and predict data related to dance drama, providing valuable support for the creation, performance and promotion of dance drama.

3.3.3 Visual display module

The Visualization Display Module plays a crucial role in the integration of dance theatre performing arts and technology, supporting multiple chart types through the use of advanced JavaScript visualization libraries to intuitively present data related to dance theatre.

In terms of user interaction, the visualization module also adopts an innovative user experience calculation method. By recording the number and manner of interactions with the visualization interface using audience, choreographers, actors, etc., and combining them with the characteristics of the dance drama performance, a specific algorithm can be constructed to evaluate the user experience effect. For example, the number of user interactions, depth of interaction, length of interaction and other factors can be considered comprehensively, and the user's experience score can be calculated by the algorithm. This experience score can not only help choreographers and actors understand the audience's preferences and feedback on the dance drama performance, but also provide valuable reference for the creation and performance of the dance drama. In terms of user interaction, the sum-of-equivalent-difference series algorithm is used to calculate the user experience effect, and the expression is:

$$E = \frac{n\left(n+1\right)}{2} \tag{9}$$

In the formula, E represents the effect of the user experience of the stage play performance after the implementation of technology integration, and n represents the number of interactions between the audience, choreographer, and actors. The relationship between the number of user operations and user experience can be analyzed through equation (9) to ensure that the new technology can enhance the audience's viewing experience.

3.3.4 System administration and maintenance module

In the integration of dance theater performing arts and technology, the system management and maintenance module plays an important role in ensuring the smooth operation of the digital performance platform and related technologies. This module includes key functions such as user account management, dance theater project monitoring, logging, data backup and recovery, and software updates and technical support. First, user account management allows administrators to create, modify, disable or delete accounts for choreographers, performers, technicians and audience members, and assign appropriate access rights to different roles to ensure data security

and orderly management. Secondly, the Dance Theater Project Monitoring function focuses on real-time monitoring of the status of digital equipment and systems related to the dance theater performance, including the stability of the dance theater performance capture equipment, the processing power of the dance theater rendering system, and the responsiveness of the interactive devices, etc. It ensures that the technical aspects of the performance are seamlessly integrated to provide the audience with a smooth viewing experience. The logging function automatically captures and records all operations related to technical support during the dance drama performance, including equipment adjustment, parameter setting, troubleshooting, etc., providing powerful data support for subsequent auditing, problem analysis and performance optimization. Fourth, the data backup and recovery function is responsible for regularly backing up key data generated during the dance drama performance, such as choreography data, scene design, performance parameters, etc., to prevent data loss or damage. When the data suffers damage, it can quickly recover the data to ensure the continuity and integrity of the performing art of dance drama. Finally, the software update and technical support function continuously monitors the software versions and patches in the system, pushes update notifications in a timely manner, and provides the necessary technical support to ensure that the software in the system of integration of performing arts and technology in dance drama is always kept in the best state to meet the ever-changing needs of dance drama performance.

4. Systematic verification of the integration of dance theater performing arts and technology

4.1 Test environment

A total of 8 different dance movement postures were collected in this experiment, and the types of dance movement recognition are shown in Table 1. In order to improve the generalization of the experimental data, six subjects, three males and three females, were selected for data collection. In order to facilitate the subsequent processing of data, the obtained echo signal matrix size is unified as 512x1300.The human motion data is divided into training set and test set according to the ratio of 2:1 for the training and performance evaluation of the model, and the algorithm validation is done in MATLABR2018b.

Table 1 Types of dance movement recognition

Dance number	Action class	Specific description
1	Fall forward	Fell down and ended up on all fours
2	Fall on the spot	Fell down and ended up sitting on the ground
3	Jump in place	Jump up and land in the same place
4	Jump forward	Jump forward some distance
5	Turn around	Turn right in place
6	Run	Jog at an even pace
7	Squat	Squat down and bring one knee to the floor
8	Walk	Walk at a constant pace, swinging your hands freely

The experimental environment of this paper is shown in Fig. 4, the subjects are facing the direction of the radar to perform the action, each person each action is collected 10 times, the duration of each action is about 4s, 480

sets of experimental data are obtained.

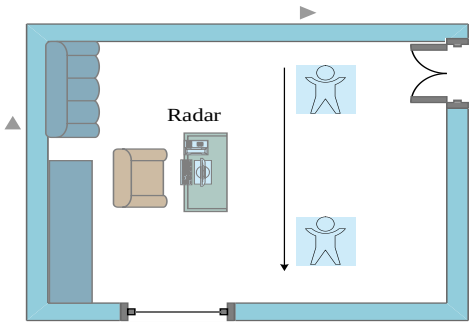


Figure 4 Plane structure of experimental environment

4.2 System Performance Test

4.2.1 Performing action modeling

The experimental dataset selected for the experiment is the KTH dataset, which is a large-scale human action dataset at present. The dataset contains more than 1000 groups of action data for different human actions, and each group of action data has different motion scenarios, including fixed indoor scenarios, fixed outdoor scenarios, human body wearing change scenarios, and outdoor lighting conditions change scenarios. The human action data in the dataset is mainly video data, and the size of the video image is 160x120. In order to ensure the reliability of the experimental results, the experiments randomly selected video data from the KTH dataset with different motion scenes, including the dance performance action as the experimental object, and used simulation software to model the dance action in the video, and the specific modeling effect is shown in Fig. 5. In order to evaluate the performance comparison before and after the fusion of dance drama performance art and technology, this experiment divides the original dance drama performance data into two groups, one is the original performance data without technology fusion, and the other is the performance data after technology fusion. By comparing the performance of these two groups of data on dance movement recognition, the actual impact of technology fusion on the performing art of dance drama can be assessed.

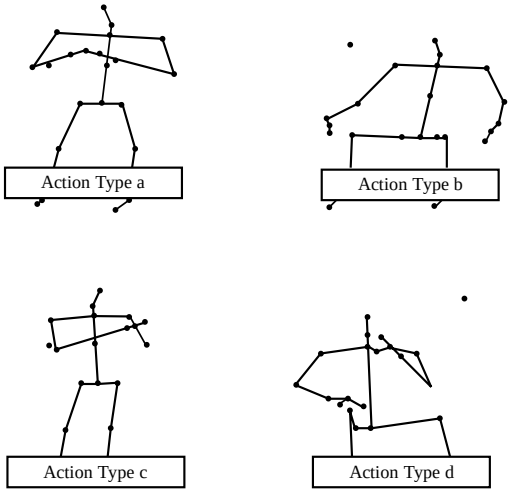
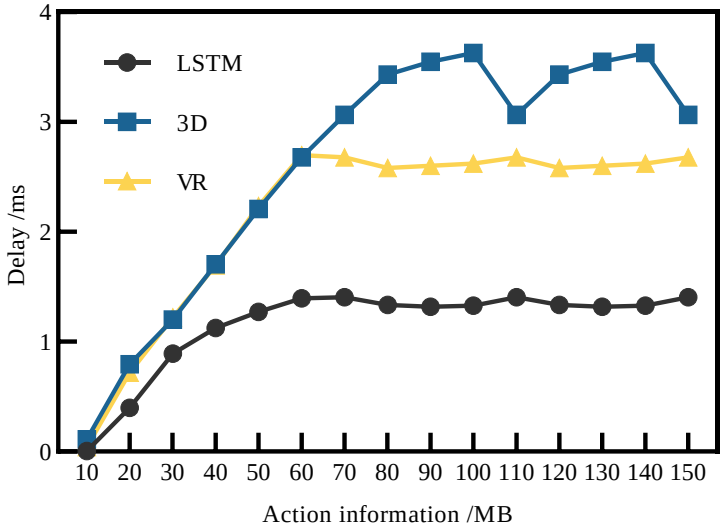


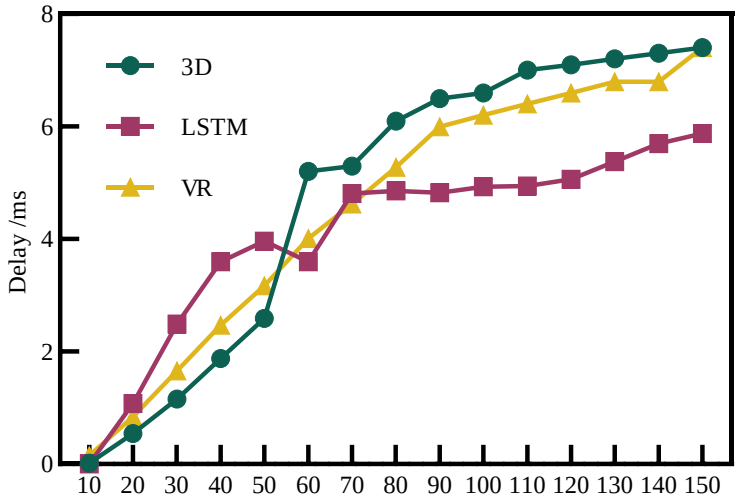
Figure 5 Dance movement modeling in data set

4.2.2 System performance test

The LSTM-based dance drama performance recognition method proposed in this paper is compared with the recognition methods proposed by 3D technology and VR technology. The comparison index selected for the experiment is the recognition efficiency of the sharp stop and jump action, and the specific measurement index is that the lower the action recognition delay represents the higher recognition efficiency of the recognition method. The system delay recognition results are shown in Fig. 6. Fig. 6(a) shows the original performance data without technology fusion, and the recognition delay of the action recognition method increases significantly with the increase of the amount of action information. When the amount of action information is 150/MB, the action recognition delay of the LSTM proposed in this paper for the dance performance recognition method is 1.3/ms, the action recognition delay of the 3D technology recognition method is 3.1/ms, and the action recognition delay of the 3D technology recognition method is 4.0/ms. compared with this paper's method has an obvious advantage. Fig. 6(b) shows the performance data after technology fusion. With the amount of action information in the range of 60/MB-150/MB, the action recognition latency of the LSTM proposed in this paper for the dance performance recognition method always stays around 3.5/ms, and there is no continuous growth. The action recognition delay of the 3D technology recognition method grows from 5.2/ms to 7.4/ms, and the action recognition delay of the VR technology recognition method grows from 6.1/ms to 6.8/ms. It can be clearly seen by observing the action recognition delay curves that the recognition delays based on the LSTM-based dance drama performance recognition model proposed in this paper are obviously lower than those of the two conventional recognition methods and the recognition delay curves change more gently and do not appear to have a constant increase. Curve is relatively smooth and does not show large floating fluctuations. It can be proved that the proposed action recognition method has a greater advantage in recognition efficiency.



(a) Raw data



(b) Technology fusion of data

Figure 6 Comparison of recognition delay of different algorithms

5. The implementation path of the integration of dance performing arts and science and technology

5.1 Content side

In the creation of the fusion of performing arts and technology in dance drama, technology carries new ideas, providing a new presentation pattern for dance creativity, as well as diversified creative expression, constructing an operable art space, thus promoting the transformation of the concept of dance creativity, and realizing the fusion of the dance art and the use of technological innovation. Dance creativity in the digital media era focuses on the interaction between the dancers themselves and the digital media technology, the dance movements and the scenes or scenarios constructed by the digital technology are fused and interacted with each other, and the three-dimensional space is interspersed with the real image, which is then transformed from the figurative to the abstract, and from the real to the virtual, to form a simulation of the effect of the perception. Dance on the basis of visualization, to achieve virtual contact between dance and the audience, so that the traditional dance creation has entered the era of writing simulation performance.

5.2 Theoretical end

The fusion of performing arts and technology in dance drama takes a non-personalized perspective, requiring close cooperation between members of the creative team, and is no longer centered on the director, but rather on the fusion between the director, dancers, technology, photography, lighting, programming and other personnel, and between technology and art, which means that the fusion of the performing arts of dance drama with science and technology is a comprehensive artistic creation activity. Dance creation in the support of science and technology, the comprehensive use of multiple media, dance creation from the traditional meaning and content of the sculpture turned to the concept and program of the drill, the creative process into science and technology, to achieve creativity, presentation, dissemination of the whole field of coverage, and further improve the effectiveness of communication.

5.3 Market Side

From an objective point of view, compared to art forms such as opera, musicals and national operas, there is a need to accelerate and strengthen the establishment of a literary criticism team for dance dramas, to guide the practice of dance dramas, and to promote the improvement and healthy development of the ecological and market issues of dance dramas. At the market end, it is necessary to improve the competitiveness of works and create wonderful dance drama performances. On the one hand, in the publicity and marketing of dance dramas, it is necessary to guide the market demand as the central link, strengthen the humanistic consciousness, respond to the public's realistic emotions and spiritual aspirations, play the circle-breaking benefits to win the market, and cultivate a more diversified aesthetic audience group. On the other hand, in the creative direction of dance drama, we should closely follow the audience's artistic consumption concept, consumption demand, consumption ability, etc., to accurately grasp the potential performance market, to create a profound ideological connotation, excellent artistic production, industry evaluation and recognition, the audience welcome the favorite, the market box-office sales of dance drama works.

6. Conclusion

In this paper, an LSTM-based model for recognizing dance drama performances is proposed, and the effectiveness of the model is verified through experiments. The experimental results show that by comparing the original data with the data after STM fusion, the positive effect of STM fusion on the recognition performance can be clearly seen. In the original data, as the amount of action information increases, the recognition delay of this paper's method is only 1.3/ms, which is much lower than the other two methods. And in the data after technology fusion, even if the amount of action information increases, the recognition delay of this paper's method is stable at about 3.5/ms, which shows very high stability and recognition efficiency. This advantage is not only reflected in the lower latency, but also in the smooth change of the recognition latency curve, which further proves the stability and reliability of this paper's method in dealing with complex dance movements. In summary, the LSTM-based dance drama performance recognition method proposed in this paper provides new ideas and methods for the digital recognition and technology integration of dance drama performing arts, and has high practical application value.

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