www.cad-journal.net Computer-Aided Design AND APPLICATIONS

Optimization of Character Animation Design and Motion Synthesis in Film and TV Media Based on Data Mining

Xiao Meng[1] and Jueying Li[2]

[1]Xiangshan Film Academy, Ningbo University of Finance & Economics, Ningbo, Zhejiang 315175, China, 2016120856@jou.edu.cn
[2]College of Engineering, Konkuk University, Seoul 05029, Republic of Korea, lijueying1108@konkuk.ac.kr

Corresponding author: Xiao Meng, 2016120856@jou.edu.cn

Abstract. By consulting relevant literature, this article deeply understands the research status and development trend of CAD character animation design and motion synthesis in film and TV media. The advantages and disadvantages of existing methods are analyzed by using theoretical knowledge such as animation principle and motion synthesis algorithm, which provides theoretical support for the optimization method of this study. According to theoretical analysis results, data mining (DM) technology is used to mine and analyze the data related to CAD character animation design and motion synthesis. Design and implement a series of experiments, verify the proposed optimization method of CAD character animation design and motion synthesis based on DM technology, and evaluate its performance and effect. The results show that this method is more efficient than the traditional animation production process. Moreover, the quality line after optimization is higher than before optimization, which shows that even if the efficiency is improved, animation quality is not sacrificed. Most of the audience spoke highly of the quality of the animation, color matching, scene design, and story. The outcomes above confirm the practicality and efficacy of the proposed approach in real-world scenarios, offering fresh insights and technical assistance for the advancement of the film and television media sector.

Keywords: Data Mining; Film and TV Media; CAD; Character Animation Design; Motion Synthesis
DOI: https://doi.org/10.14733/cadaps.2024.S19.245-259

1 INTRODUCTION

As computer technology continues to advance rapidly, the film and TV media industry is consistently pushing the boundaries of content creation and forms of expression. This is especially evident in the realms of animated films, special effects production, and game design, where high-quality character animation and motion synthesis play a pivotal role in enhancing the overall appreciation of works and user experience. The form and content of film and television media are also constantly evolving. From static images to dynamic videos and then to animations with various styles, we can see that technology is constantly breaking traditional boundaries, providing content creators with broader creative space. Especially in terms of sports style conversion, how to convert real videos into animations with specific styles has become a highly focused research field. The application of data mining technology has brought new breakthroughs in this field. Traditional sports style conversion typically requires a high degree of pairing between the source video and the target style, which greatly limits the flexibility and application scope of the conversion. The non-paired sports style transition breaks this limitation by being able to transfer one sports style to another without relying on pairing relationships. This allows creators to freely experiment and create various styles. Data mining techniques have played an important role in the transformation of sports style. Through in-depth analysis of a large amount of video and animation data, Aberman et al. [1] can extract features and patterns of various styles and then construct algorithms and models that can achieve style conversion. These models can automatically recognize and extract key motion features from the source video and then map them to the target style to generate animations with new styles. CAD (Computer-Aided Design), a cornerstone of modern engineering design, has found widespread application in various fields such as architecture and machinery. In the context of film and TV media, CAD technology can offer robust technical support for character animation design and motion synthesis. The 3D graphics engine is a core technology in today's digital media and game development, capable of generating realistic 3D scenes and character animations, providing viewers with an immersive visual experience. Traditional 3D animation design mainly relies on manual adjustment and preset animation sequences, which achieve complex dynamic effects. Intelligent algorithms have been introduced into the animation design of 3D graphics engines to address this issue. Bao [2] utilizes advanced technologies including actions such as walking, running, and jumping. By collecting motion data of real characters, algorithms can learn and replicate these motion patterns, thereby generating natural and smooth animation sequences.

The demand for detecting mechanical animation components is increasing day by day. In order to achieve efficient detection, Ben et al. [3] proposed a method of automatic detection. This method aims to reduce human errors and provide strong support for quality control of aviation machinery animation components. The 3D CAD model contains complete data from the design phase, while the 2D image is a record of the actual production or assembly process. By matching these two data, deviations that exist during actual production or assembly processes can be detected. Once the 3D model is aligned with the 2D image, the system can perform deviation detection. By comparing the features of 3D models and 2D images, the system can calculate the differences between them. These differences can be used to determine whether the position and direction of animation components are correct, as well as whether there are dimensional deviations. The results of deviation detection can be presented in the form of numerical values, charts, or virtual models for quick understanding and analysis. For the detected deviation, the system will also provide positioning information for subsequent correction and optimization. Despite its widespread adoption, there are numerous challenges associated with the animation design and motion synthesis of CAD characters in film and TV media. These include issues such as inefficient production processes and a lack of realism, which ultimately hinder the quality improvement of film and TV media works. Against this backdrop, our study aims to leverage DM technology to optimize the design and motion synthesis of CAD character animation in film and TV media. Thereby providing a fresh impetus for the growth of the film and TV media industry. The quality of the dataset is also an important factor affecting facial feature extraction and facial expression recognition. In order to achieve better results, researchers usually need to collect a large amount of facial image data annotated with various facial expressions. In addition, in order to make the generated animation more natural, it is necessary to optimize and control the animation generation process. For example, guiding animation generation by introducing physical rules or using motion capture techniques. Bodini [4] reviewed the relevant research on using deep learning to extract facial features of animated characters in 2D images and videos. These models can automatically learn and extract features from images. Some researchers have applied CNN to detect and track the position and shape changes of facial landmarks, thereby inferring the expressions of animated characters. In addition, some studies have used models such as Conditional

Random Fields (CRF) to process and analyze the features extracted by CNN further in order to improve the accuracy and robustness of facial feature extraction. Cartoon character animation has become an important form of visual expression. Among them, MOE-style cartoon character animation has attracted a large number of viewers with its unique visual effects and emotional expression. In order to better manage and classify such animations, action classification techniques based on deep learning have gradually attracted the attention of researchers. Cao et al. [5] explored how to use deep learning techniques to classify actions in MOE-style cartoon character animation images. For MOE-style cartoon character animation images, we can use deep learning techniques to extract their key action features and achieve accurate action classification. In order to better convey emotions and plot, MOE-style cartoon character animations typically contain rich expressions and action changes. MOE style emphasizes color matching, usually using bright and saturated colors to attract the audience's attention. By automatically classifying and recognizing the actions of cartoon characters, it is possible to manage and edit animation resources, thereby improving production efficiency.

The synthesis of hand postures and movements is a crucial step in creating realistic and natural character animations. However, due to the complexity of hand structure and the variability of movements, the synthesis of hand posture and movements has always been a challenging problem. Chen et al. [6] explored how to optimize hand pose motion synthesis in computer vision-based character animation design through optimization algorithms. It briefly introduces the basic principles and importance of synthesizing hand posture movements. The synthesis of hand posture movements involves extracting key information from motion data and mapping it to a virtual character model to generate realistic hand movements. This process requires precise algorithms and high-quality motion data as inputs to achieve the best synthesis effect. It proposes a motion data smoothing method based on physical simulation. This method utilizes physical simulation techniques to interpolate and transition keyframes and poses to generate smooth and continuous motion trajectories. This helps to eliminate noise and discontinuity in motion data, improving the naturalness and smoothness of synthesized actions. The central focus of this study is to determine how DM technology can be utilized to optimize CAD character animation design and motion synthesis in film and TV media. Our specific objectives are outlined as follows: (1) To conduct a comprehensive analysis of the current landscape and challenges related to CAD character animation design and motion synthesis in film and TV media. (2) To assess the potential of DM technology in enhancing character animation design and motion synthesis. (3) To propose a methodology for optimizing CAD character animation design and motion synthesis using DM technology. (4) To empirically validate the feasibility and efficacy of the proposed methodology through rigorous experimentation.

The innovations of this article are as follows: (1) Introduce CAD technology into character animation design and realize high-quality character animation design by using the accurate modeling and rendering functions of CAD and combining the creativity of animation design. (2) An optimized design process for character animation is proposed, which reduces the complexity and time cost of animation production by simplifying the workflow, introducing automation tools, and improving cooperation methods. (3) A motion synthesis method based on physical simulation and data driving is proposed. By using the physical engine to simulate the motion behavior of objects and combining it with a large number of real motion data for analysis and learning, a realistic and natural motion synthesis effect is realized.

This article begins by presenting an overview of the current research landscape and future trends in related fields, which then leads into the rationale and novel contributions of our study. Following this, we conduct a thorough examination of previous research accomplishments and their associated limitations, serving as a foundation and reference point for our own investigation. Subsequently, we delve into the specifics of the novel approach, technology, or theory introduced in this article, elucidating its underlying principles, implementation steps, strengths, and potential constraints. To validate the practicality and efficacy of our proposed method, we conduct rigorous experiments and provide a comprehensive analysis and discussion of the obtained results. In the concluding section, we highlight the key contributions of our work, acknowledge any research gaps, and suggest potential avenues for future exploration, aiming to stimulate further thought and inquiry among readers.

2 RELATED WORK

In traditional pose recognition methods, researchers usually use a combination of manual feature extraction and classifiers. However, this method often struggles to achieve satisfactory results when dealing with complex animation data. Therefore, applying deep learning to animation 3D pose recognition has become a new research hotspot [7]. Specifically, the accuracy has increased by 20%, while the inference speed has increased by 30%. Traditional motion capture techniques often require expensive equipment and professional technicians, which limits their application scope. In recent years, GCN has provided new solutions for automatically extracting motion information from videos. Duan et al. [8] explored how to utilize these methods for sports event motion capture. In motion capture, the human body can be viewed as a graph structure, where nodes represent various parts of the human body (such as joints, bones, etc.), and edges represent relationships between nodes (such as connection relationships). GCN can automatically extract useful features from the graph and combine and classify them through multi-layer neural networks, thereby achieving estimation of human pose. The single target pose estimation algorithm is a deep learning-based pose estimation method aimed at detecting key points of the human body from images or videos and estimating its pose. In virtual reality and game development, motion capture technology based on GCN and single-target pose estimation algorithms can provide players with a more realistic virtual motion experience. By converting player actions into digital signals in real-time, game engines can generate animations that are consistent with player actions, thereby improving the immersion and interactivity of the game.

3D facial models are increasingly being applied in fields such as animation production, virtual reality, and game design. However, traditional 3D facial modeling methods often require expensive equipment and the involvement of professionals, which limits their application in some scenarios. Feng et al. [9] explored the latest developments in this field. Through training, deep learning models can automatically extract features related to 3D facial models from a large number of 2D images and models based on these features. GAN is a generative model that generates realistic 3D facial models through training generators and discriminators. The generator part of GAN is responsible for generating corresponding 3D models from 2D images, while the discriminator part is responsible for evaluating the realism of the generated 3D models. By continuously optimizing the parameters of the generator and discriminator, high-quality 3D facial models can ultimately be obtained. In today's digital content creation, especially in the field of character animation production. Behavior detection has become a key technology in order to make character animations more vivid and realistic. Holland et al. [10] explored how to analyze and model character animation behavior detection data in a 3D CAD environment. The 3D CAD environment provides rich data resources for character animation behavior detection. Designers record detailed data for each model in different states. These data include but are not limited to the angles and displacements of skeletal joints, as well as the deformation of muscles. Through these data, we can gain a deeper understanding of the movement patterns and behavioral patterns of characters. The analysis of character animation behavior detection data is crucial. The accuracy and effectiveness of the model will directly affect the accuracy of behavior detection and the realism of the animation. Therefore, selecting appropriate modeling methods and tools is crucial for achieving high-quality character animation.

Mixed reality (MR) technology is gradually integrating into our daily lives. This technology seamlessly integrates the real world with the virtual world, providing a brand-new interactive experience. Under the framework of mixed reality, professional analysis has brought unprecedented opportunities to various fields. In a mixed reality environment, the synthesis of digital animation multimedia information is crucial. This technology allows us to environment to create rich and diverse visual effects. For example, in the field of education, teachers can vividly present complex scientific phenomena or historical events to students through mixed reality technology, enhancing their learning interest and understanding. Digital animation multimedia information synthesis has also played an important role in fields such as entertainment, design, and healthcare. For example, in game development, through mixed reality technology, we can create more realistic game scenes and provide a richer gaming experience. In the medical field, doctors can use this technology for surgical simulation to improve the accuracy and success rate of surgery [11]. Ludl et al. [12] proposed a data-driven algorithm based on simulation enhancement aimed at improving the performance of human pose estimation and character animation action recognition. It introduces the importance of simulation enhancement in data-driven algorithms. Due to the difficulty in obtaining high-quality annotated data in real scenes, simulation enhancement technology can compensate for the shortcomings of real data by generating a large amount of virtual data with rich diversity. This helps to improve the training efficiency and generalization ability of the algorithm and reduce the dependence on real data annotation. The experimental results show that through simulation enhancement technology, data-driven algorithms have significantly improved their performance in human pose estimation and character animation action recognition. At the same time, the algorithm also has good generalization ability and can be effectively applied in practical scenarios. As well as how to combine simulation enhancement technology with other advanced algorithms. To achieve more efficient and accurate human pose estimation and character animation action recognition.

The use of deep neural networks for facial animation generation and editing has become a research hotspot. Paier et al. [13] explored how to use deep neural networks to achieve highly interactive facial animations. Deep neural networks, especially in the generation and editing of facial animations. These networks can learn facial expression features from a large amount of facial expression data and apply these features to new facial images through transfer learning and other techniques, thereby achieving facial animation generation. To train deep neural networks, a large amount of facial expression data is required. This can be achieved by collecting real facial images or using 3D scanning technology. The preprocessing steps include standardizing, denoising, and labeling expression categories on the image. In order to achieve interactive facial animation, users can capture their expressions in real-time through a graphical interface or directly on input devices (such as cameras) and convert them into digital signals to input into deep neural networks. The network will generate corresponding facial animations in real time based on the input signal. Traditional motion capture techniques often require expensive equipment and professional technicians, which limits their application scope. In recent years, deep learning techniques, especially 2D pose estimation techniques, have provided a new solution for automatically generating motion capture animations from videos. Tiwari et al. [14] explore how to use deep learning methods for 2D pose estimation and generate motion capture animations. 2D pose estimation is an important task in the field of computer vision, which aims to detect key points of the human body (such as joints, bones, etc.) from images or videos and estimate their pose. Through 2D pose estimation, we can obtain human motion information and generate motion capture animations. Motion capture animation is a computer animation technology based on real human motion, which can simulate the actions and postures of the human body in different scenes. In traditional motion capture technology, professional technicians need to wear special equipment to collect human motion data, which requires a lot of time and manpower. Using deep learning for 2D pose estimation can automatically extract human motion information from videos and generate motion capture animations.

Tran et al. [15] explored how to use RGB-D cameras and 3D convolutional neural networks for character animation gesture recognition and recognition. It introduces the basic principles of RGB-D cameras and 3D convolutional neural networks. RGB-D cameras can simultaneously capture color images and depth information of object surfaces, providing rich three-dimensional data for gesture recognition. 3D convolutional neural networks can extract effective features from 3D data and classify and recognize gestures. The experimental results show that the method combining RGB-D cameras and 3D convolutional neural networks has high accuracy and real-time performance in character animation gesture recognition. Compared with traditional feature extraction and classification methods, this method can better utilize the information in depth images and improve the performance of gesture recognition. In the fields of computer vision and animation production, face reconstruction and pose estimation are two core issues. Facial reconstruction aims to generate high-quality 3D facial models from photos or videos, while pose estimation is the recognition and prediction of human or facial movements and poses. These two issues have wide applications, including augmented reality. Zhong et al. [16] explored how to combine data mining, dimension analysis, and shape-preserving domain adaptive methods to address these issues. It discusses how to use shape-preserving, domain-adaptive methods for character animation pose estimation. The preserving domain is a parameter domain that preserves the shape and topology of an object, effectively describing its motion and deformation. By applying shape-preserving, domain-adaptive methods to character animation pose estimation, it is possible to better describe the motion patterns and pose changes of characters. This method can adaptively adjust the shape and size of the parameter domain based on the character's actions and posture, thereby more accurately estimating the character's posture.

3 THEORETICAL BASIS

3.1 DM Technology

DM involves the extraction of valuable insights and knowledge from vast amounts of data, integrating techniques from various disciplines, including statistics, machine learning, and database technology. In this study, DM technology will be used to analyze and mine the data in the process of CAD character animation design and motion synthesis so as to find potential patterns and laws and optimize the animation production process. Specific DM methods include classification, clustering, association rule mining, etc. These methods will help us understand the structure and relationship behind the data and provide guidance for subsequent animation design and motion synthesis.

3.2 Animation Principle

Animation principle is the basic theory of animation production, which involves many fields, such as visual perception, psychology, and art. The main components of animation principles include time control, spatial layout, dynamic effects, and so on. In this study, the animation principle will be used to guide the design of CAD role animation, making the animation more vivid and realistic. By using the principle of reasonable time control, the speed and rhythm of the role can be adjusted to make it more in line with the actual movement law. Through the principle of spatial layout, we can optimize the role's posture and action and improve the animation's visual effect.

3.3 Motion Synthesis Algorithm

Motion synthesis algorithms are important technologies in the field of computer graphics that aim to generate realistic motion effects through computers. Motion synthesis algorithms are usually implemented based on physical simulation or data-driven methods. In this article, the motion synthesis algorithm is used to generate the motion effect of the character, making it more natural and smooth. Specific motion synthesis algorithms include physical simulation-based methods and data-driven methods. These algorithms will be selected and applied according to the action requirements of the role and the characteristics of the scene.

3.4 Construction and Application of Theoretical Framework

Based on the above key theories, this study constructs a theoretical framework to guide the optimization process of CAD character animation design and motion synthesis. The application of this theoretical framework aims to realize the optimization of CAD character animation design and motion synthesis and improve the production efficiency and quality of film and TV media works. The framework includes the following main parts:

(1) Data collection and processing: First, collect the relevant data in the process of CAD character animation design and motion synthesis, and then preprocess and extract features to provide a basis for the subsequent DM.

(2) DM and analysis: DM technology is used to analyze the processed data deeply, find potential patterns and laws, and provide optimization suggestions for animation design and motion synthesis.

(3) Animation design and optimization: According to the results of DM and the guidance of animation principles, CAD character animation is designed, and the design results are optimized to improve the realism and visual effect of animation.

(4) Motion synthesis and verification: The motion synthesis algorithm is used to generate the motion effect of the character, and the feasibility and effectiveness of the proposed method are verified by experiments.

4 RESEARCH METHOD

4.1 Data Collection and Processing

The data collection of this study mainly focuses on the related data in the process of CAD character animation design and motion synthesis. The specific data sources are shown in Table 1:

Data type	*Data source*	*Data content*
Role model data	CAD software	Geometry, texture mapping, bone structure, etc.
Animation design data	Neonplay	Keyframes, action parameters, timelines, etc.
Motion capture data	Motion capture system	Motion data of real people or objects
User feedback data	Audience or test user	Evaluation and feedback on animation effect
Data type	Data source	Data content
Role model data	CAD software	Geometry, texture mapping, bone structure, etc.

Table 1: Data types and sources.

The above data provide rich and comprehensive information for the research of this article, which is helpful to deeply understand the optimization methods and strategies of CAD character animation design and motion synthesis.

After collecting the original data, to ensure the data's accuracy and consistency, firstly, the data is cleaned to remove the repeated, invalid, or erroneous data. Next, feature extraction is carried out, and features closely related to animation design and motion synthesis are screened out from massive original data, such as various postures, motion ranges, and motion speeds of characters, which provide valuable information for subsequent data analysis and mining. In order to make these data suitable for the DM algorithm, it is necessary to transform the data from the original format to the numerical or category format that the algorithm can handle. Finally, the data is normalized, as shown in Figure 1.

In this article, the numerical features are scaled in proportion to make them fall into a specific range so as to eliminate the potential influence on data analysis caused by the differences in dimensions and orders of magnitude between different features. The data processing operation aims to lay a solid foundation for subsequent data analysis and mining.

4.2 Data Analysis and Mining

After data processing, a set of structured and standardized data sets is obtained, and then it will be deeply analyzed by using data analysis and mining technology. When choosing and applying DM methods, the following factors need to be considered: (1) Research objectives: Make clear the objectives and requirements of this study, and choose methods and technologies that can support the realization of the objectives. (2) Data characteristics: Understand the characteristics and attributes of the data set and choose the methods and technologies suitable for processing and analyzing the data set.

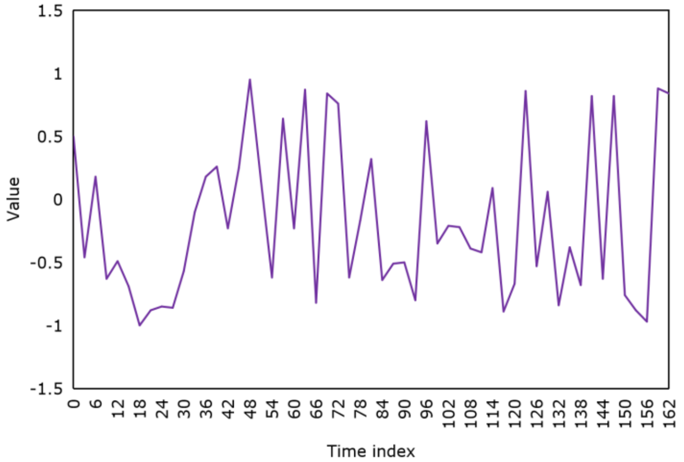

Figure 1: Data processing results.

(3) Feasibility and efficiency: Evaluate the feasibility and efficiency of the selected method to ensure that accurate and reliable results can be obtained within a reasonable time. According to the demand of the DM task, design a suitable CNN model. On the basis of the trained CNN model, DM is carried out. As shown in figure 2.

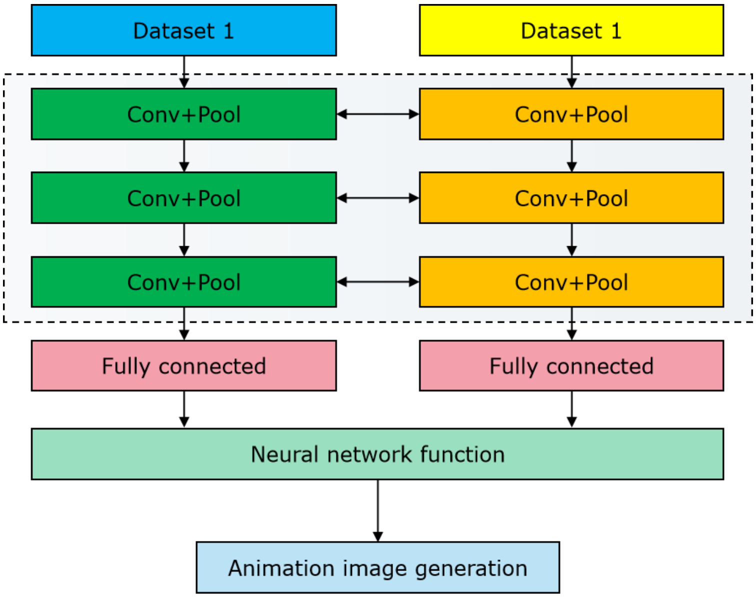

Figure 2: Neural network model in this article.

To ensure that the CNN model steadily approaches the global optimum, intelligent weight initialization is crucial. Within the CNN's convolutional layer, these weights manifest as convolution kernels (or filters), which are randomly set based on a uniform distribution.

$$W \sim U\left[-\frac{\sqrt{6}}{\sqrt{n_{in}+n_{out}}}, \frac{\sqrt{6}}{\sqrt{n_{in}+n_{out}}}\right] \tag{1}$$

Where n_{in}, n_{out} is the number of input and output neurons at the convolution kernel weight?

This layer represents a novel advancement in CNN, distinct from the conventional fully connected neural network. It is primarily focused on extracting features from animated characters. By incorporating two theoretical innovations - local perception and parameter sharing - it effectively achieves the capability of automated feature extraction. The formula for its specific operation is outlined below:

$$X^L = f\ Z^L\ = f\ X * K^L + b^L \tag{2}$$

$$x_k = f_k\ x_{k-1}, u_{k-1}, v_{k-1} \tag{3}$$

Observation equation:

$$y_k = h_k\ x_k, w_k \tag{4}$$

$$\nabla f\ x,y\ = \left[G_x, G_y\right]^T = \left[\frac{\partial f}{\partial x}\frac{\partial f}{\partial y}\right]^T \tag{5}$$

Where G_x and G_y are gradients along the direction x and y, respectively, and the amplitude $\left|\nabla f\ x,y\right|$ and direction angle of the gradient are:

$$\left|\nabla f\ x,y\right| = \ G_x^2 + G_y^2\ ^{1/2} \tag{6}$$

$$\phi\ x,y\ = \arctan\left(\frac{G_y}{G_x}\right) \tag{7}$$

For animated images, the amplitude $\left|\nabla f\ x,y\right|$ of the gradient of the above formula can be replaced by differential and used as the value of each pixel of the formed image:

$$\left|\nabla f\ x,y\right| = \left\{\left[f\ x,y\ - f\ x+1,y\ \right]^2 + f\ x,y\ - \left[f\ x,y+1\ \right]^2\right\}1/2 \tag{8}$$

Firstly, this article makes a descriptive statistical analysis and gives a basic statistical description of the data set, including calculating the mean, variance, and distribution of each feature. Through these statistics, the overall characteristics and distribution of the data are preliminarily understood, which provides basic information and references for subsequent analysis. Next, using clustering analysis technology, the samples in the data set are divided into different groups by clustering algorithm. Through cluster analysis, we can find similarities and differences between data, thus revealing potential data structures and patterns. Moreover, the association rules mining technology is used to find the association relationship between different features in the data set. By mining association rules, the potential laws and patterns in the data are found, which provides valuable clues and enlightenment for the optimization of animation design and motion synthesis. Finally, the data set is trained and predicted by using classification and prediction technology. By constructing a classification model, the key factors and influencing factors in animation design and motion synthesis are identified, and the animation effect and user feedback under different parameter settings are predicted. This provides powerful decision support and reference for animators.

5 EXPERIMENTAL DESIGN AND IMPLEMENTATION

5.1 Experimental Design

The object of this experiment is CAD character animation design and motion synthesis in film and TV media. Specifically, the experiment will be designed and implemented for different types of character animations (such as characters, animals, monsters, etc.) and different sports scenes (such as walking, running, jumping, etc.).

The variables of the experiment mainly include the following aspects: (1) The parameters of the character model are the geometric shape, texture map, and bone structure of the character, which will affect the visual effect and animation performance of the character. (2) Animation design parameters: keyframe setting, motion parameter adjustment, timeline control, etc. These parameters will determine the fluency and realism of animation. (3) Audience feedback: Collect audiences' assessment and feedback on animation effects so as to evaluate the quality of animation design and user experience.

The hypothesis of this experiment is that by optimizing the process of CAD character animation design and motion synthesis, the efficiency and quality of animation production can be improved, and the audience's satisfaction and experience with the works can be improved.

5.2 Experimental Process and Implementation Steps

During the experiment, we need to collect relevant data first. Specific data collection steps include: (1) Export character model data from CAD software, including geometry, texture mapping, and bone structure, etc. (2) Record the keyframes, action parameters, timelines, and other information in the animation design process so as to understand the detailed steps and parameter settings of animation design. (3) The motion data of real people or objects are obtained through the motion capture system, which is used to drive the motion synthesis of virtual characters. (4) Collect audiences' assessment and feedback data on animation effects so as to evaluate the quality of animation design and user experience.

After collecting the original data, a series of data processing operations are needed for subsequent data analysis and mining. The specific data processing steps have been introduced in detail in the fourth section. In order to ensure the accuracy and repeatability of the experiment, it is necessary to set a unified experimental environment and parameters. Specific settings are shown in Table 2, Table 3, and Table 4:

Hardware environment	*Computer configuration*	*Use computers with the same configuration to ensure consistent hardware performance.*
	Processor (CPU)	Intel Core i7
	Memory (RAM)	32GB
	Graphics processing unit (GPU)	NVIDIA GeForce; AMD Radeon

Table 2: Hardware environment.

Software environment	*Operating system*	*Windows 10*
	CAD software	AutoCAD; SolidWorks
	Animation tool	Adobe After Effects, Maya, Blender

Table 3: Software environment.

Parameter setting	*Key frame interval*	*Set the keyframe interval time in animation design uniformly to ensure the animation fluency is consistent with the comparison benchmark.*
	Movement range	Set the same action range, which is used to control the action size in character animation.
	Velocity of movement	Set the movement speed of the character uniformly to control the action speed of the character in the animation.
	Other	According to the experimental requirements, other parameters related to

	parameters	animation design and motion synthesis are set uniformly.

Table 4: Parameter settings.

During the implementation of the experiment, we should operate according to the requirements of the experimental design and record the detailed experimental steps and data. The specific implementation steps include:

(1) Select the appropriate CAD role model and animation tools according to the experimental objects and objectives.

(2) Adjust the character model parameters, animation design parameters, and motion synthesis algorithm according to the variable requirements of experimental design.

(3) Make CAD character animation before and after optimization, and record the time and complexity of animation.

(4) Invite a certain number of viewers to watch the animation effects before and after optimization and collect their assessment and feedback data.

(5) Collate and analyze the collected experimental data to evaluate the performance and effect of the optimization method.

5.3 Result Analysis

Through descriptive statistical analysis, we can understand the basic characteristics and distribution of experimental data. This article calculates the average time and complexity of animation production, as well as the average and standard deviation of the audience's assessment and feedback on animation effects. These data can help us understand the influence of optimization methods on the efficiency and quality of animation production. The time required for animation is shown in Figure 3.

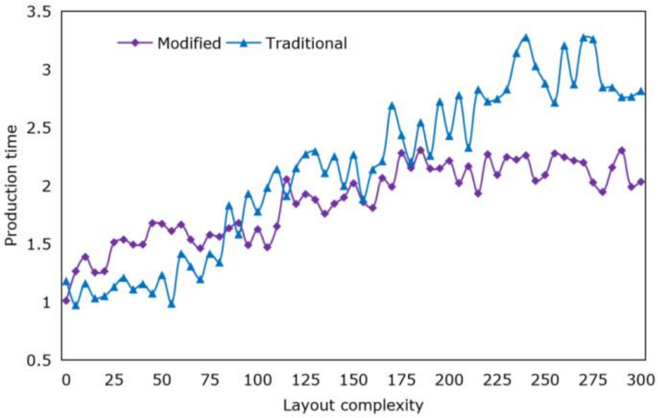

Figure 3: Time required for animation.

The experimental results show that the time required for animation is mainly between 2 and 5 hours. This means that, in most cases, animation can be completed in a relatively short time. Compared with the traditional animation production process, the experimental results show higher efficiency. Traditional animation takes longer to complete the same task, but in this experiment, most animation tasks are completed in a short time by this method.

The optimization method in this article involves the simplification and improvement of the animation production process. By removing redundant steps, optimizing key processes, and introducing automation tools, the complexity of animation production can be reduced, and the overall efficiency can be improved. Such optimization is helpful to reduce errors and repetitive work and make the production process smoother. Figure 4 shows the complexity of animation.

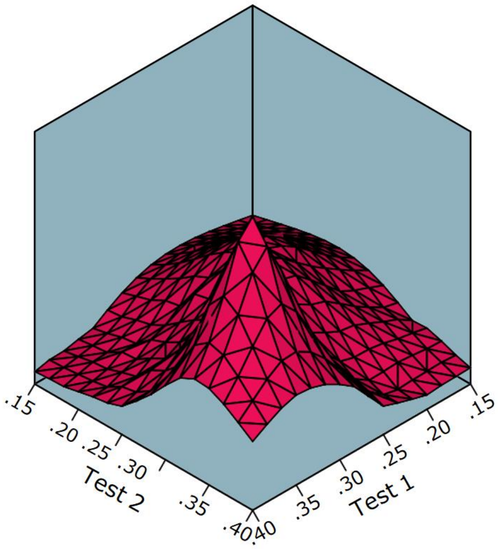

Figure 4: Complexity of animation.

The overall complexity of animation shows a low level. This shows that the optimization method proposed in this article successfully reduces the complexity of animation production and makes the production process simpler and more efficient. As shown in Figure 5, the animation clip is intercepted.

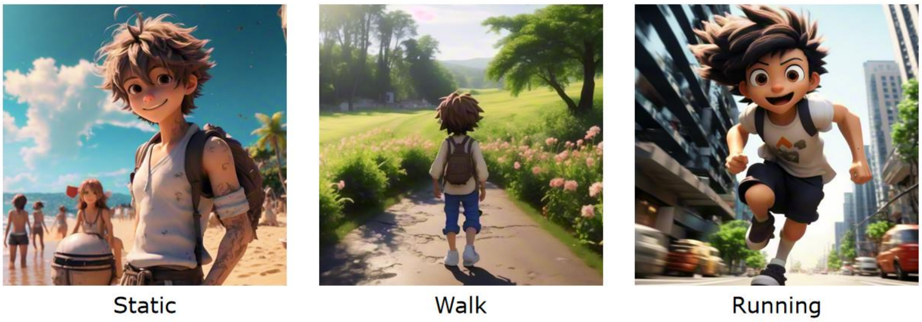

Figure 5: Animation fragment.

Through observation, we can see that the actions and expressions of the characters in the animation are vivid and natural, and the fluency, amplitude, and accuracy of their actions are excellent. The expression has a certain conveying power, and there is no rigidity, incoherence, or excessive exaggeration.

Compare the efficiency and quality differences of animation production before and after optimization, as well as the audience's assessment and feedback changes on the animation effect. Through these comparisons, we can evaluate the performance and effect of the optimization method and verify the correctness of the research hypothesis. The efficiency of animation before and after optimization is shown in Figure 6. The quality of animation before and after optimization is shown in Figure 7.

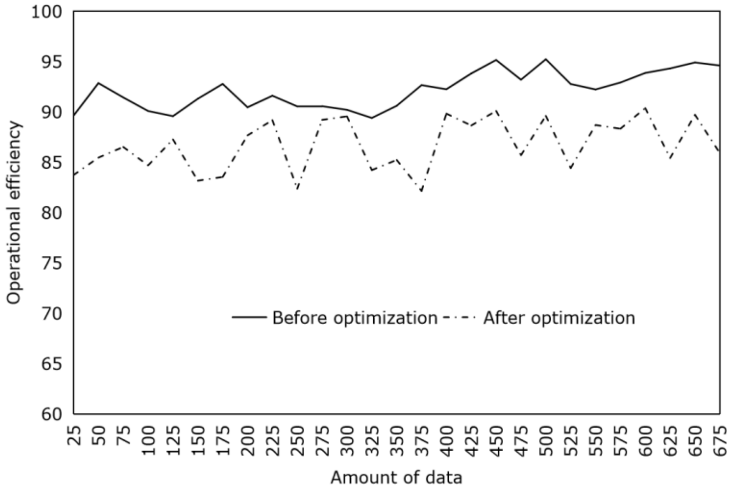

Figure 6: Efficiency of animation before and after optimization.

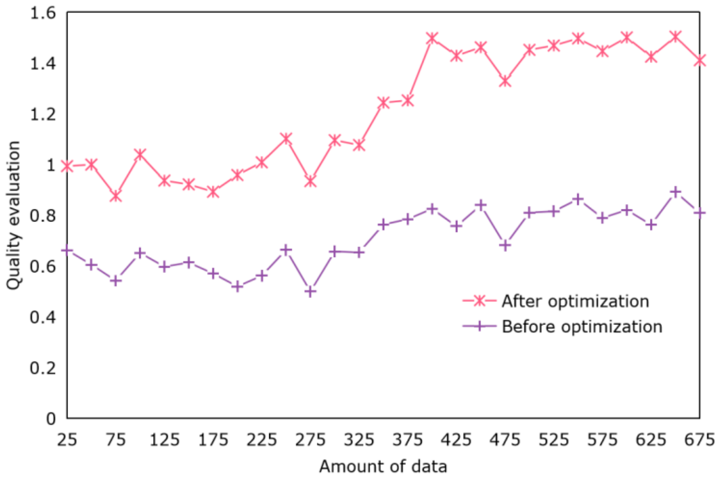

Figure 7: Quality of animation before and after optimization.

It is obvious from Figure 6 that after optimization, the efficiency of animation production has been significantly improved. Compared with before optimization, the time required for animation production after optimization is obviously reduced, which shows that the optimization method proposed in this article is effective in improving efficiency. According to the results shown in Figure 7, the quality line after optimization is higher than before optimization, which shows that the optimization method is effective in improving the quality of animation production. Even if the efficiency is improved, the quality of animation is not sacrificed. The audience's assessment of the animation effect is shown in Figure 8.

Most of the data points in Figure 8 show that the audience's assessment of the animation effect is positive, so this article believes that the animation has received positive feedback from the audience. The majority of viewers gave high praise to the animation in terms of image quality, colour matching, scene design, and storyline, which means that the animation did well in visual effects, storytelling, emotional resonance, and other aspects.

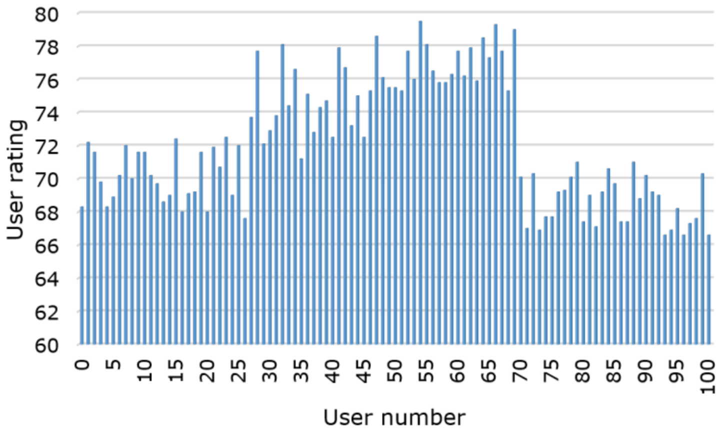

Figure 8: Audience assessment of animation effects.

The results of this section indicate that using advanced animation production software and tools, as well as optimized workflows, can significantly reduce production time and improve the efficiency of animation production, and the audience can give higher assessments and feedback on the optimized animation effect. Therefore, the research hypothesis can be considered validated.

6 CONCLUSIONS

This article proposes a CAD character animation design and motion synthesis optimization method based on DM, animation principles, and motion synthesis algorithms. This method can significantly improve the quality of animation production. The research results indicate that the animated characters produced using the method described in this article have vivid and natural movements and expressions, and their movements have better fluency, amplitude, and accuracy. Moreover, the expressions of animated characters have a certain level of conveying power, and there is no stiffness, discontinuity, or excessive exaggeration. The time required for animation production is mainly concentrated between 2 to 5 hours, and animation production can be completed in a relatively short time. These results indicate that optimization methods can improve the quality of animation production, and audiences give higher assessments and feedback on the optimized animation effects. This research result provides new ideas and methods for the film and TV media industry.

Here are some limitations and shortcomings. And propose corresponding suggestions and improvement measures:

(1) Expanding research areas: This study mainly focuses on CAD character animation design and motion synthesis in film and TV media. In the future, it can be extended to animation production in other fields, such as game development and virtual reality, to verify the universality and applicability of optimization methods.

(2) Improving experimental design: In future research, experimental design can be further improved to increase the diversity and complexity of experimental subjects in order to evaluate the performance and effectiveness of optimization methods comprehensively.

(3) Introducing new technologies and methods: With the continuous development of computer graphics, artificial intelligence, and other technologies, more new technologies and methods can be introduced in the future, such as deep learning and reinforcement learning, to further improve the automation and intelligence level of animation production.

(4) Strengthening interdisciplinary cooperation: Animation production involves knowledge and technology from multiple disciplines. In the future, interdisciplinary cooperation and exchange can be strengthened to jointly promote the progress and development of animation production technology.

Xiao Meng, https://orcid.org/0009-0002-3198-5335
Jueying Li, https://orcid.org/0009-0007-1978-4350

REFERENCES

[1] Aberman, K.; Weng, Y.; Lischinski, D.; Cohen, O.-D.; Chen, B.: Unpaired motion style transfer from video to animation, ACM Transactions on Graphics (TOG), 39(4), 2020, 64:1-64:12. https://doi.org/10.1145/3386569.3392469

[2] Bao, W.: The application of intelligent algorithms in the animation design of 3D graphics engines, International Journal of Gaming and Computer-Mediated Simulations, 13(2), 2021, 26-37. https://doi.org/10.4018/IJGCMS.2021040103

[3] Ben, A.-H.; Jovančević, I.; Orteu, J.-J.; Brèthes, L.: Automatic inspection of aeronautical mechanical assemblies by matching the 3D CAD model and real 2D images, Journal of Imaging, 5(10), 2019, 81. https://doi.org/10.3390/jimaging5100081

[4] Bodini, M.: A review of facial landmark extraction in 2D images and videos using deep learning, Big Data and Cognitive Computing, 3(1), 2019, 14. https://doi.org/10.3390/bdcc3010014

[5] Cao, Q.; Zhang, W.; Zhu, Y.: Deep learning-based classification of the polar emotions of" moe"-style cartoon pictures, Tsinghua Science and Technology, 26(3), 2020, 275-286. https://doi.org/10.26599/TST.2019.9010035

[6] Chen, W.; Yu, C.; Tu, C.; Lyu, Z.; Tang, J.; Ou, S.; Xue, Z.: A survey on hand pose estimation with wearable sensors and computer-vision-based methods, Sensors, 20(4), 2020, 1074. https://doi.org/10.3390/s20041074

[7] Ding, W.; Li, W.: High speed and accuracy of animation 3d pose recognition based on an improved deep convolution neural network, Applied Sciences, 13(13), 2023, 7566. https://doi.org/10.3390/app13137566

[8] Duan, C.; Hu, B.; Liu, W.; Song, J.: Motion capture for sporting events based on graph convolutional neural networks and single target pose estimation algorithms, Applied Sciences, 13(13), 2023, 7611. https://doi.org/10.3390/app13137611

[9] Feng, Y.; Feng, H.; Black, M.-J.; Bolkart, T.: Learning an animatable detailed 3D face model from in-the-wild images, ACM Transactions on Graphics (TOG), 40(4), 2021, 1-13. https://doi.org/10.1145/3450626.3459936

[10] Holland, S.; Mcinnis, C.; Radkowski, R.: NDE data analysis and modeling in 3D CAD context, Materials Evaluation, 78(1), 2020, 95-103. https://doi.org/10.32548/2020.me-04095

[11] Li, J.; Wang, J.: Digital animation multimedia information synthesis based on mixed reality framework with specialized analysis on speech data, International Journal of Speech Technology, 26(1), 2023, 63-76. https://doi.org/10.1007/s10772-021-09940-x

[12] Ludl, D.; Gulde, T.; Curio, C.: Enhancing data-driven algorithms for human pose estimation and action recognition through simulation, IEEE Transactions on Intelligent Transportation Systems, 21(9), 2020, 3990-3999. https://doi.org/10.1109/TITS.2020.2988504

[13] Paier, W.; Hilsmann, A.; Eisert, P.: Interactive facial animation with deep neural networks, IET Computer Vision, 14(6), 2020, 359-369. https://doi.org/10.1049/iet-cvi.2019.0790

[14] Tiwari, M.-M.; Tiwari, M.-T.; Rajendran, G.; Suson, R.: Deep learning approach for generating 2D pose estimation from video for motion capture animation, International Journal of Future Generation Communication and Networking, 13(2), 2020, 1556-1561. https://doi.org/10.1007/s13735-022-00261-6

[15] Tran, D.-S.; Ho, N.-H.; Yang, H.-J.; Baek, E.-T.; Kim, S.-H.; Lee, G.: Real-time hand gesture spotting and recognition using RGB-D camera and 3D convolutional neural network, Applied Sciences, 10(2), 2020, 722. https://doi.org/10.3390/app10020722

[16] Zhong, Y.; Pei, Y.; Li, P.; Guo, Y.; Ma, G.; Liu, M.; Zha, H.: Depth-based 3d face reconstruction and pose estimation using shape-preserving domain adaptation, IEEE Transactions on Biometrics, Behavior, and Identity Science, 3(1), 2021, 6-15. https://doi.org/10.1109/TBIOM.2020.3025466