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Computer-Aided Design AND APPLICATIONS

Dynamic Scene Generation and Animation Rendering integrating CAD Modeling and Reinforcement Learning

Han Li[1] and Yang Su[2]

[1]Fine Art College, Henan University, Kaifeng 475001, China, 10170211@vip.henu.edu.cn
[2]Faculty of Business Administration, Pathumthani University, Pathumthani 12000, Thailand, 65134466500017@ptu.ac.th

Corresponding author: Yang Su, 65134466500017@ptu.ac.th

Abstract. The purpose of this study is to explore the optimization of animation rendering technology and its application in dynamic scenes; this paper first designs and optimizes an efficient rendering pipeline by combining CAD (Computer design) modelling and RL (Reinforcement Learning) technology, which significantly improves the rendering efficiency and image quality. Furthermore, real-time rendering technology is applied to the generation and presentation of dynamic scenes. This paper also introduces a series of animation effect enhancement technologies, which further enrich the visual effect and attraction of animation. In the experiment, a comprehensive experimental environment is constructed, representative data sets are selected, and a rigorous experimental scheme is designed to verify the effectiveness and superiority of the proposed method. The application of real-time rendering technology makes the generation of dynamic scenes smoother and more realistic and provides users with an excellent interactive experience. In addition, the introduction of animation effect enhancement technology further enhances the visual effect of animation, making animation more vivid and attractive.

Keywords: CAD Modeling; Reinforcement Learning; Dynamic Scene Generation; Animation Rendering
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1 INTRODUCTION

With the rapid development of computer graphics and artificial intelligence technology, dynamic scene generation and animation rendering are widely used in film and television production, game design, virtual reality, and other fields. A large amount of animation image data needs to be effectively processed and understood. Image classification, as a key task, faces challenges such as high computational complexity and high storage requirements. Bacca et al. [1] proposed a design aimed at achieving data compression while classifying animated images, thereby improving processing efficiency and reducing storage costs. However, for special types of image data, such as animated images, traditional deep learning models still have certain limitations in processing efficiency and storage requirements. Therefore, we propose a novel coupled deep learning encoding design aimed at achieving efficient classification and compression of animated images by jointly optimizing the encoder and classifier. In the experiment, we used a large-scale animation image dataset and compared it with other advanced image classification and compression methods. The experimental results show that our method significantly reduces data storage requirements while maintaining high classification accuracy. Traditional dynamic scene generation methods often rely on manual modelling and preset rules, and it is difficult to achieve efficient and real dynamic effects. With the increasing progress of animation technology, animation image matching has become an important link in research and practice. Feature detection and description are key steps in image matching. Chen et al. [2] reviewed the development of feature detection and description methods from manual design to deep learning and explored their applications in animation image matching. Animation image matching aims to identify and locate the same or similar content in two or more animation images. This process involves multiple steps, such as image preprocessing, feature extraction, feature description, and matching. In the past few decades, feature detection and description methods have undergone a transformation from manual design to deep learning, and these methods have important applications in animation image matching. By performing scale-space analysis, edge detection, and other operations on the image, stable feature points are extracted, and descriptors describing these feature points are generated. In animation image matching, these manually designed feature detection methods have achieved certain success, but their performance is often limited for complex and ever-changing animation scenes. A new method of dynamic scene generation and animation rendering by combining CAD modelling technology with RL algorithm so as to improve the generation efficiency and enhance the realism and interactivity of the scene. The research significance lies in providing a brand-new solution for related fields, promoting the development of dynamic scene generation and animation rendering technology, and promoting the cross-integration of computer graphics and artificial intelligence technology.

Ding and Dong [3] discussed a model and reinforcement learning techniques to optimize the colour layout of animated products, thereby achieving the emotional design of product colours. It will analyze the role of CAD modelling in creating animation models, as well as how reinforcement learning techniques can be used to optimize colour layout, thereby stimulating emotional resonance among consumers. In the design of animation products, colour layout is one of the key elements that can directly affect the visual experience and emotional response of consumers. However, with the development of CAD modelling and reinforcement learning technology, we can more accurately control and optimize the colour layout of animated products to achieve the emotional design of product colours. Reinforcement learning is a machine learning technique that learns optimal strategies through the interaction between intelligent agents and the environment. In animation colour design, we can model the colour layout problem as a reinforcement learning problem, where the agent represents the designer and the environment represents the colour space of the animation product. This technology combines real-world physical data, computer graphics, and machine learning algorithms, aiming to create more realistic and dynamic volume animation effects [4]. The large-scale volume animation technology for real-world scalar transport streams is based on physical simulation and machine learning algorithms. Firstly, by collecting real-world physical data, such as fluid dynamics data, meteorological data, etc., we can obtain key information about object motion, deformation, and so on. Then, using computer graphics technology, these physical data are transformed into three-dimensional volume models. The large-scale volume animation technology of scalar transport streams in the real world has broad application value in multiple fields. By simulating the physical laws of the real world, we can generate more natural and realistic animation effects, improving the audience's viewing experience.

VR technology, with its unique immersive experience, provides students with a new way of learning. Especially in the field of 3D animation education, the combination of virtual reality technology and 3D painting provides strong support for improving students' motivation to learn 3D animation. Ho et al. [5] analyzed its potential impact. Learning motivation is a key factor in the learning process of students, which directly affects their learning outcomes and engagement. In the field of 3D animation education, a strong learning motivation can stimulate students' creativity and imagination, prompting them to learn and explore more deeply. Therefore, how to improve students' motivation to learn 3D animation has become a concern for educators. Virtual reality technology can create a realistic 3D space for students, making them feel like they are in a real creative environment. This immersive experience can enhance students' sense of participation and immersion. With the rapid advancement of technology, the demand for 3D models and animations in the electronic gaming and film industries is increasing. Hosen et al. [6] explored creating 3D models and animations with photo-like realism. CAD modelling technology provides precise 3D model design for the electronic gaming and film industries. By combining CAD modelling with reinforcement learning technology, automation and intelligence can be achieved in the creation and optimization process of 3D models. Designers can use reinforcement learning algorithms to enable agents to adjust model parameters automatically to achieve optimal results. This method not only improves work efficiency but also makes 3D models more realistic. In electronic games, realistic 3D models and animations are crucial for improving the gaming experience. By combining CAD modelling with reinforcement learning techniques, game developers can create more refined and realistic game scenes and characters. For example, in racing games, CAD modelling technology can be used to design realistic tracks and cars, and then reinforcement learning algorithms can be used to optimize the driving trajectory and actions of the cars, making the game more realistic and exciting.

Through 3D reality technology, Jing and Song [7] import motion capture data from the real world into a virtual environment, allowing animated characters to simulate realistic actions and expressions. This technology greatly improves the smoothness and naturalness of animation, making characters more vivid and credible. Li and Li [8] discussed how virtual reality technology affects the generation of dynamic scenes in virtual system animations, as well as future development trends. Virtual reality technology provides a new possibility for the generation of dynamic scenes in virtual system animations. Traditional animation scene generation often relies on preset models and actions, while virtual reality technology can achieve more dynamic and interactive scene generation. Firstly, virtual reality technology can capture user behaviour and actions in real time, transforming this data into dynamic scenes in virtual systems. This makes the animation scene of the virtual system more realistic and can respond to user operations and instructions in real time. Secondly, virtual reality technology can also achieve scene generation for multi-user interaction. Multiple users can interact in the same virtual environment and collectively influence the animation scene of the virtual system. This multi-user interactive scene generation method not only enhances the fun of virtual systems but also makes their applications more widespread.

The main contents of this study include studying the data structure and processing method of CAD modelling technology to meet the needs of dynamic scene generation, Exploring the application strategy of RL algorithm in dynamic scene generation, designing and implementing the combination algorithm, The realization method of dynamic scene generation technology is studied, including dynamic generation of scene elements, scene layout, and optimization. The realization method of animation rendering technology is studied, including the design and optimization of the rendering pipeline, the application of real-time rendering technology in dynamic scenes, etc. The innovations are mainly reflected in the following aspects: a new dynamic scene generation method combining CAD modelling and RL technology is proposed to achieve efficient and real dynamic effects; Design and implement a scene generation algorithm based on RL, which can adaptively adjust the generation strategy according to the environmental feedback. Real-time rendering technology is applied to the process of dynamic scene generation to achieve high-quality animation rendering effects.

2 RELATED THEORETICAL BASIS

With the advancement of technology, artists are constantly exploring new creative media and technologies to present more unique and captivating works of art. Among them, thermochromic technology, as an emerging tool for artistic creation, provides artists with new creative ideas. Liu et al. [9] explored how to use thermochromic toolkits to create dynamic paintings and explored the application of multimodal technology and interaction in it. Artists can use thermochromic pigments to draw a painting, and when the audience approaches the painting and touches it with their hands, the colours in the painting will change, presenting a dynamic effect. This interactive artwork not only attracts the attention of the audience but also enhances interaction and communication between the audience and the artwork. In thermochromic painting, the application of multimodal technology and interaction can further enhance the interactivity and fun of the work. In this context, the "Animation Space Time Machine" has emerged, which is not only an innovative concept but also a historical reconstruction method [10]. The core of "Animation Space Time Machine" lies in combining advanced 3D modelling technology with gamified narrative techniques to create a new historical experience. Through high-precision 3D city modelling, we can recreate the urban landscape of historical periods. The introduction of 4D networks enables these models to dynamically evolve over time and showcase the historical changes of cities. Animation space-time machines have broad application prospects in fields such as education, entertainment, and cultural heritage protection. In addition, the animation space-time machine has had a profound impact on historical research. Through this technology, researchers can more accurately restore historical scenes and analyze the causes and impacts of historical events. This not only helps to promote the progress of historical research but also provides historical references for decision-making in real life. With the advancement of technology, deep learning has penetrated into many fields, among which computer graphics is particularly noteworthy. In recent years, bone-based deep learning technology for human animation has brought revolutionary changes to computer graphics. Mourot et al. [11] explored the current development status of this technology and its application in computer graphics. Skeleton-based deep learning technology for human animation mainly utilizes deep learning algorithms to model and predict the skeletal movements of characters. By capturing and analyzing complex patterns of human motion in the real world, these algorithms can generate highly realistic animation effects. Compared with traditional animation techniques, bone-based deep learning techniques can more accurately simulate human motion while greatly reducing production time and cost. The realism of game character animations directly affects the player's gaming experience. Skeleton-based deep learning technology can generate natural and smooth character animations, greatly enhancing the realism and immersion of games. In film production, the animation design of special effects characters is often very complex. Skeleton-based deep learning technology can quickly generate high-quality animations, greatly reducing the production cycle of movies.

Sun et al. [12] analyzed its principles, applications, and future development trends. This system utilizes the powerful generation ability of Generative Adversarial Networks (GANs), combined with the idea of collaborative creation, to achieve a novel animation drawing method. Each user can use a generator to generate their own animated scenes or characters and evaluate their quality through a discriminator. At the same time, the system can also utilize the generation ability of GANs to integrate the creations of different users and generate richer and more diverse animation content. Reinforcement learning as an advanced machine learning technology. In terms of animation plot visualization, reinforcement learning also demonstrates enormous potential. Through reinforcement learning, Tang et al. [13] trained a model that can automatically generate expressive animation plots. Reinforcement learning is a machine learning technique that interacts with the environment through agents and learns the optimal behaviour strategy through trial and error. In animation plot visualization, we can apply reinforcement learning algorithms to the decision-making process of intelligent agents (i.e. animated characters), enabling them to generate coherent and attractive animation plots automatically. By defining appropriate reward functions, reinforcement learning algorithms can guide agents to generate animations with specific storylines in virtual environments. For example, we can set reward functions to encourage agents to complete specific tasks, interact with other characters, or reach a certain emotional state, thereby generating rich and colourful animation plots. By training intelligent agents to learn how to adjust their behaviour based on environmental changes and plot development, we can achieve more natural and realistic character animations. This technology can be applied to multiple aspects, such as character expressions, actions, and dialogues, bringing viewers a more vivid and realistic visual experience.

With the continuous progress of artificial intelligence technology, reinforcement learning, as an important machine learning method, has shown its unique advantages in multiple fields. Yang and Wong [14] discussed how to use reinforcement learning techniques to achieve agent-based box operation cooperative animation and analyzed its applications in computer graphics and animation production. Reinforcement learning is a machine learning method that learns through continuous trial and error. In the proxy box operation task, it can view the agent as an intelligent agent, learning how to perform a series of operations to achieve specific goals by interacting with the environment (i.e. the box). The agent continuously adjusts its operating strategy by receiving reward signals from the environment feedback and ultimately learns to complete box operation tasks efficiently and accurately. In animation production, achieving collaboration among multiple agents is a key challenge. Through reinforcement learning, we can train agents to learn and collaborate with other agents to complete complex animation tasks together. Specifically, we can set up multiple agents to jointly operate a box task, with each agent responsible for executing different operational steps. By adjusting the communication and collaboration mechanisms between agents, we can achieve smoother and more natural animation effects. Scene-aware canvas is an innovative technology that combines hand-drawn animation with video scenes, providing users with a more immersive and interactive animation experience. Yu et al. [15] explored how to use scene-aware canvases to hand-draw animations in videos and analyzed their application prospects and potential value. Scene-aware canvas is an interactive canvas system based on computer vision and machine learning techniques. It can recognize objects, backgrounds, motion and other information in video scenes and integrate this information with hand-drawn animations in real time. Users can directly draw animations on the scene-aware canvas, and the system will automatically match and fuse hand-drawn content with video scenes to generate hand-drawn animations with dynamic effects. The system integrates the user's hand-drawn content with video scenes in real time to generate hand-drawn animations with dynamic effects. Users can adjust the speed, direction, and other parameters of the animation as needed to achieve the desired effect.

Neural Animation Mesh, as an emerging technology, provides new solutions for human behaviour modelling and rendering. Zhao et al. [16] introduced the basic principles of neural animation grids, their applications in human behaviour modelling and rendering, and future development trends. Neural animation mesh is a deep learning-based method that combines neural networks and animation mesh technology to generate and control animations of 3D models. The core idea is to use neural networks to learn the mapping relationship from low-dimensional parameter space to high-dimensional animation space, thereby achieving precise control of the animation mesh. The encoder is responsible for encoding the input parameters (such as posture, expressions, etc.) into low-dimensional feature representations, while the decoder is responsible for decoding these feature representations into high-dimensional animation grids. By training a large number of data samples, neural animation meshes can learn the mapping relationship from input parameters to animation meshes and generate realistic animation effects. The construction and presentation of 3D animation scenes have put forward higher requirements. Computer-assisted graphic design, as a key link in the entire animation production process, plays a crucial role in the realism, immersion, and interactivity of 3D animation scenes in virtual reality. In traditional animation production, graphic design mainly focuses on the processing and synthesis of two-dimensional images. However, in a virtual reality environment, audiences can freely explore three-dimensional space, which requires animated scenes to have not only a high degree of realism but also consistent aesthetics from all angles. Computer-assisted graphic design is an important tool to help designers achieve this goal. Zhao and Zhao [17] use professional image processing software to create various realistic or fantastical texture maps, such as stone, wood, metal, etc. These textures not only add details to the surface of the model but also make the scene more colourful. In virtual reality, colour and lighting are crucial for creating an atmosphere and enhancing immersion. Computer-assisted graphic design allows designers to simulate different lighting conditions and colour combinations in preset environments to achieve optimal visual effects. In addition to 3D models, virtual reality scenes often require the inclusion of 2D plane elements, such as text, icons, etc. Computer-aided graphic design can help designers arrange the positions and sizes of these elements reasonably, ensuring that they are both prominent and not abrupt in three-dimensional space.

3 COMBINATION METHOD OF CAD MODELING AND RL

3.1 Data Structure and Processing of CAD Model

CAD modelling technology is a technology that uses CAD software to create and edit 3D models. It is widely used in mechanical design, architectural design, product design, and other fields, and it is an important means to achieve accurate and efficient design. CAD modelling technology includes geometric modelling, feature modelling, parametric modelling and other methods, which can create complex 3D models and modify and optimize them. In dynamic scene generation, CAD modelling technology can be used to build the basic models of static scene elements and dynamic objects. RL is a machine learning method that learns how to make the best decision through the interaction between agents and the environment. RL system consists of five basic elements: agent, environment, state, action, and reward. The agent selects and executes an action according to the current state, and the environment gives a new state and reward signal according to the action. The goal of an agent is to learn a strategy to maximize the cumulative reward obtained in the long-term interaction process. Common RL algorithms include Q-learning, SARSA, Deep Q-network, etc. In dynamic scene generation, the RL algorithm can be used to optimize the generation strategy and improve the generation efficiency.

It involves the generation, layout, and animation of scene elements. Traditional dynamic scene generation methods often rely on manual modelling and preset rules, and it isn't easy to achieve efficient and real dynamic effects. The dynamic scene generation method based on data-driven learning has gradually become a research hotspot. By training a deep neural network to simulate the dynamic changes in the scene and using the RL algorithm to optimize the generation process, the realism and coherence of the dynamic scene are improved. These methods can automatically extract scene features and generate realistic dynamic scenes by learning a large number of data. Animation rendering technology refers to the process of rendering a 3D model or scene into a 2D image sequence with realism or a specific style. It involves lighting models, material mapping, camera control, rendering pipelines, and many other aspects. In dynamic scene generation, animation rendering technology can transform the generated 3D scene into a realistic and interactive 2D animation effect. By using large-scale data sets and machine learning technology, the characteristics and patterns of dynamic scenes are extracted from the real world, and virtual dynamic scenes with a sense of realism and diversity are generated, which provides rich content for virtual reality and simulation applications. By combining physical simulation and realistic rendering technology, the simulation and rendering of physical motion of objects and lighting effects in dynamic scenes are realized, which improves the realism and fidelity of animation and provides high-quality visual effects for movies, games, and other fields. In order to improve the efficiency and quality of rendering, researchers continue to explore new rendering algorithms and optimization technologies, such as parallel rendering based on GPU and ray tracing technology. The CAD model is the basis of dynamic scene generation, and its data structure is very important for subsequent RL and animation rendering. In this study, a hierarchical data structure is used to represent the CAD model, which is convenient for efficient data processing and operation. The data structure includes geometric information, topological information, material information, and other aspects, and it can completely describe the shape, structure, and appearance of CAD models. Figure 1 shows how to stretch a polygonal arrow in a 2D plane into a prism.

In data processing, firstly, the CAD model is preprocessed, including denoising, simplification, segmentation and other operations to reduce data redundancy and improve calculation efficiency. Then, the key features of the CAD model, such as boundary contour and surface texture, are extracted as the input information of subsequent RL. Furthermore, the format of the CAD model is transformed and optimized to meet different RL algorithms and animation rendering requirements.

The application strategy of RL in CAD modelling is one of the core contents of this study, which can adaptively adjust the modelling parameters and operation sequence according to the user's needs and the characteristics of the CAD model so as to realize a more efficient and accurate modelling process.

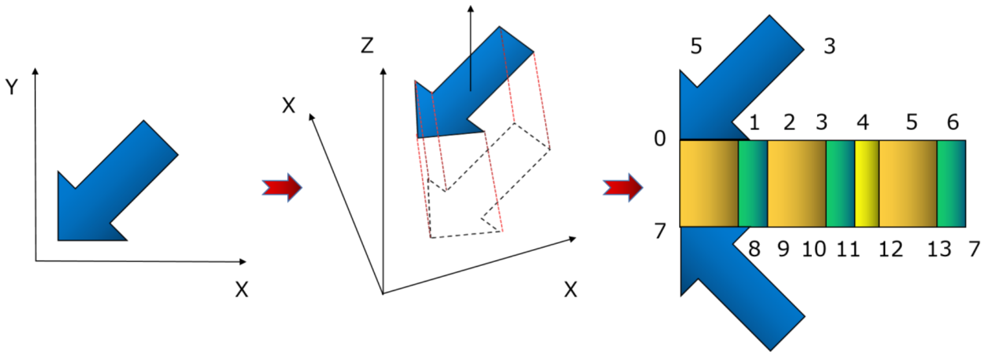

Figure 1: Stretch the polygon arrow of a 2D plane into a prism.

Specifically, this paper models the CAD modelling process as an MDP (Markov decision process), in which the state represents the current modelling progress and model state, the action represents optional modelling operation or parameter adjustment, and the reward function is defined according to the modelling results and user feedback. Then, the RL algorithm is used to solve this MDP problem, and the optimal modelling strategy is obtained.

3.2 Design and Implementation of Combined Algorithms

Combining CAD modelling with RL algorithm design is important content for this paper. In this paper, an algorithm framework combining geometric modelling, feature modelling and RL is proposed, which can make full use of the geometric information and feature information of the CAD model and the decision-making ability of RL to realize an efficient and intelligent modelling process. Firstly, according to the geometric information and feature information of the CAD model, the algorithm makes a preliminary model and obtains a basic model framework. Then, the RL algorithm is used to optimize and adjust the preliminary modelling results, including modifying the model shape, adjusting parameters and adding details. In this process, the user feedback mechanism is introduced to make real-time adjustments and optimizations according to the user's needs.

$$R_t(p_{1t}, Q_t) = p_{1t} \cdot \min(I_t + Q_t, D_t) - (p_{0t} \cdot Q_t + C_t \cdot AI_t) + R_{t-1} \tag{1}$$

$$I_{t+1} = I_t + Q_t - \min(I_t + Q_t, D_t) = \max(I_t + Q_t - D_t, 0) \tag{2}$$

After the normal vector of the vertex I_t is obtained, the curvature of the vertex can be calculated:

$$AI_t = \frac{(I_t + Q_t)}{2} \cdot \frac{(I_t + Q_t)}{D_t} \tag{3}$$

Where $I_t + Q_t$ is the included angle between the vertex normal vector and k related triangular patches.

In the aspect of algorithm implementation, the hybrid programming method of Python and C++ is adopted, and the RL algorithm and data processing part are realized by using the flexibility and ease of use of Python, while the CAD modelling and animation rendering part are realized by using the efficiency and stability of C++. In this way, we can fully play into the advantages of the two languages and improve the efficiency and stability of the algorithm.

3.3 Performance Analysis of Combination Method

In order to verify the performance and superiority of the proposed method combining CAD modelling with RL, a series of experiments and comparative analyses were carried out. In the experimental design stage, the experimental objectives, evaluation indicators, and comparison methods are defined. This section evaluates the performance indicators of the algorithm from many angles, including modelling accuracy and computational efficiency. Furthermore, compared with the traditional CAD modelling method and rule-based method, it highlights the advantages of our method in modelling efficiency and intelligence. The modelling accuracy is shown in Figure 2.

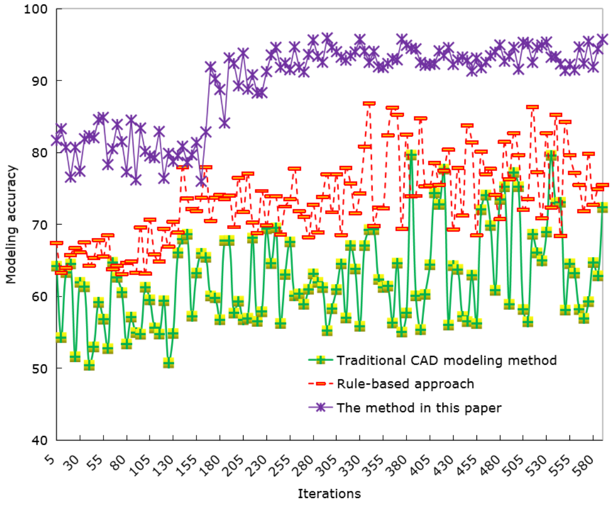

Figure 2: Modeling accuracy.

The calculation efficiency is shown in Figure 3.

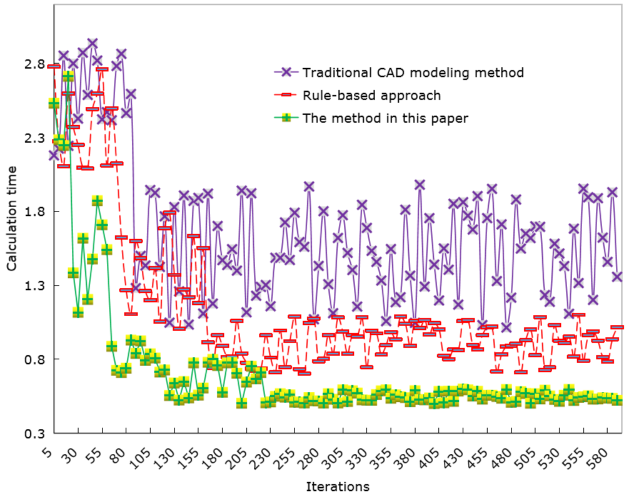

Figure 3: Computational efficiency.

The experimental results show that the method in this paper improves the modelling efficiency and accuracy. Compared with traditional CAD modelling methods, this method combines the RL algorithm and has higher modelling efficiency and accuracy. These results prove the effectiveness and superiority of the method combining CAD modelling with RL.

4 REALIZATION OF DYNAMIC SCENE GENERATION TECHNOLOGY

4.1 Dynamic Generation Algorithm and Optimization Method for Scene Elements

The dynamic scene generation framework proposed in this study combines the CAD model and RL algorithm, aiming at achieving efficient and realistic dynamic scene generation. Based on the CAD model, the framework uses the RL algorithm to optimize the generation strategy and generate interactive and realistic dynamic scenes through the steps of dynamically generating scene elements and optimizing layout. The framework first loads CAD models as the basic elements of the scene, which can be static or have preset animation. Then, the RL algorithm selects and executes a series of generating actions, such as adding new elements and adjusting element positions or attributes according to the current scene state and user requirements. After each action, the algorithm will receive feedback from the environment and adjust its generation strategy according to the feedback. This process continues until the user's satisfaction with the scene effect or the preset generation goal is achieved.

In dynamic scene generation, dynamic generation of scene elements is one of the key steps. In this study, a dynamic generation algorithm based on RL is designed, which can dynamically add, delete or modify scene elements according to the current scene state and user requirements. Firstly, the boundary region is excluded in a neighbourhood of each pixel:

$$A\ c\ = F\sin\ a,b \tag{4}$$

$\sin\ a,b$ stands: The pixel point F is the boundary area of the image. Convert the coordinate of viewpoint into a spherical coordinate system, and use the binary group $\langle\phi,\theta\rangle$ to represent the deflection angle of viewpoint relative to the model:

$$\phi = \arctan\frac{\sqrt{X_E^2+Y_E^2}}{Z_E^2} \tag{5}$$

$$\theta = \frac{\pi}{2} - \arctan\frac{Y_E}{X_E} \tag{6}$$

ϕ stands for horizontal deflection angle θ and for vertical deflection angle.

The algorithm defines an action space, including optional actions such as adding elements, deleting elements, and modifying element attributes. Then, according to the current scene state and user requirements, the algorithm uses the strategy gradient method in RL to select and execute an action. After executing the action, the scene state changes, and the algorithm receives new state information and reward signals and updates its strategy according to this information. By repeating this process, the algorithm can learn an effective dynamic generation strategy and realize the adaptive generation of scene elements.

The strategy gradient theorem gives the gradient of the objective function $J\ \theta$ about the strategy parameter θ:

$$\nabla_\theta J\ \theta\ = E_{\pi\theta}\left[\sum_{t=0}^{\infty}\nabla_\theta \log \pi\theta\ a_t \middle| s_t\ Q^{\pi\theta}\ s_t \middle| a_t\ \right] \tag{7}$$

Where $Q^{\pi\theta}\ s,a$ is an action-value function indicating the expected discount reward for acting according to the strategy $\pi\theta$ after the state s takes action a:

$$Q^{\pi\theta}\ s,a\ = E_{\pi\theta}\left[\sum_{t=0}^{\infty}\gamma^t r_{t+1} \middle| s_0 = s, a_0 = a\right] \tag{8}$$

In practical application, this expectation is usually approximated by Monte Carlo sampling or time difference learning. Then, the strategy parameters can be updated by using the gradient ascending algorithm:

$$\theta \leftarrow \theta + \alpha \nabla_{\theta} J \ \theta \tag{9}$$

Where a is the learning rate? This process will be iterated until the algorithm converges to a satisfactory strategy.

In addition to dynamically generating scene elements, scene layout and optimization are also important links in dynamic scene generation. In this paper, an optimization method of scene layout based on RL is adopted to improve the realism and interactivity of the scene. We model the scene layout problem as an MDP, in which the state represents the current scene layout, the action represents optional layout adjustment operations, and the reward function is defined according to the scene effect after layout adjustment. Then, the RL algorithm is used to solve this MDP problem, and the optimal layout adjustment strategy is obtained. In practical application, the RL algorithm based on deep learning is adopted to deal with the problems of high-dimensional state space and action space. By training a large number of scene layout data, the algorithm can learn a general layout adjustment strategy, which is suitable for different types of scenes and different layout requirements. Furthermore, the user feedback mechanism is introduced to adjust and optimize the layout results in real-time to meet the needs of users.

4.2 Experimental Verification of Generation Technology

An experimental data set containing various types of CAD models is constructed, and several challenging dynamic scene generation tasks are designed to test the method in this paper. Then, the algorithm of dynamic scene generation based on RL is implemented, and extensive testing and analysis are carried out on experimental data sets.

During the implementation of the experiment, the operation was carried out in strict accordance with the experimental design, and detailed experimental data and logs were recorded. In order to ensure the fairness and objectivity of the experimental results, this paper also invited several evaluators with relevant experience to evaluate the experimental results independently. The efficiency of algorithm generation is shown in Figure 4.

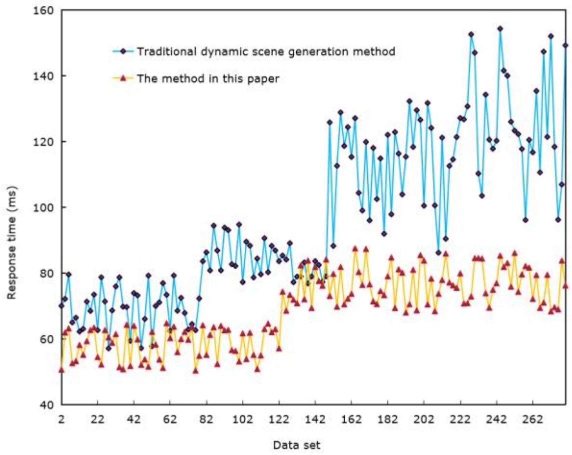

Figure 4: Generation efficiency.

The realism and interactivity of the scene are shown in Figure 5. The user feedback results are shown in Table 1.

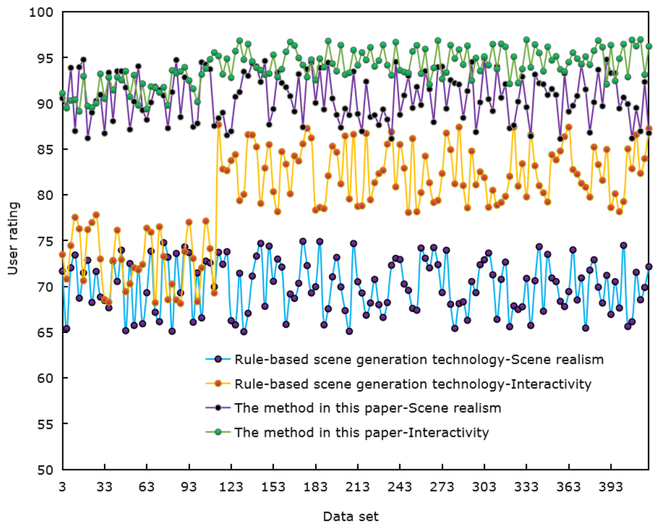

Figure 5: Realistic and interactive scene.

Evaluation index	*Describe*	*User feedback results*
Task completion degree	The degree of coincidence between the scene generated by the algorithm and the expected target	96.14%
Scene diversity	The ability of the algorithm to generate different types of scenes	85.30%
Real-time performance	Response time and efficiency of the scene generated by the algorithm	75.14 ms
User satisfaction	Overall user satisfaction with the generated scene.	8.5
User experience improvement	Compared with the existing methods, the improved degree of user experience	Increase by 30%

Table 1: User feedback results.

The experimental results show that this method has achieved remarkable results in generating efficiency, scene realism and interactivity. Compared with the traditional dynamic scene generation method, this method has higher generation efficiency and better scene effect. Compared with rule-based scene generation technology, this method can generate more realistic and interactive scenes. Furthermore, user feedback also shows that this method can better meet user needs and improve user experience. The above results prove the effectiveness and superiority of the dynamic scene generation technology proposed in this study.

5 ANIMATION RENDERING TECHNOLOGY AND IMPLEMENTATION

5.1 Design and Optimization of Rendering Pipeline

The design of a rendering pipeline involves many stages, including geometric processing, rasterization, colouring, and output merging. Firstly, this paper analyzes the performance of each stage in detail and determines the bottleneck. Then, a variety of optimization techniques are adopted, such as geometry simplification, hierarchical rendering, delayed colouring, etc., to improve rendering efficiency and image quality. The optimization process can be summarized as an objective function:

$$\text{Optimize(Q, T)} = \text{argmax}_{\text{P,A}}\left(Q\ P \times \frac{1}{T\ P,A}\right) \tag{10}$$

Among them Q are the rendering quality function, T the rendering time function, P the rendering parameter, and A the available hardware acceleration and optimization algorithm. The goal is to find a set of parameters and algorithms to make the rendering time shortest under given quality constraints. In addition, hardware acceleration and parallel processing technology are considered, and the parallel computing ability of GPU is used to accelerate the rendering process. By optimizing the algorithm and making rational use of hardware resources, the rendering pipeline significantly improves the rendering speed while maintaining a high-quality rendering effect.

Real-time rendering technology plays a vital role in dynamic scenes, which can generate and update scene images in real-time and provide users with a smooth visual experience. In this study, real-time rendering technology is applied to the generation and rendering of dynamic scenes, and a dynamic scene demonstration system based on real-time rendering technology is realized. The system can load and render the CAD model in real time and dynamically update the scene according to the user's interactive operation. Furthermore, some advanced real-time rendering techniques, such as light and shadow mapping, dynamic shadow, particle system, etc., are also used to enhance the realism and dynamic effect of the scene. In this paper, the Levenberg Marquardt algorithm is used to iteratively optimize the minimum projection error, and its iterative formula is as follows:

$$\Delta = -\ J_f^T J_f + \lambda I^{\ -1} J_f^T f \tag{11}$$

λ is the weight parameter. Through the application of real-time rendering technology, the dynamic scene generation system can provide users with a more realistic and smooth visual experience, which greatly improves the interactivity and usability of the system.

In order to further enhance the visual effect and attraction of animation, a variety of animation effect enhancement technologies are designed. These technologies include physical simulation, application of motion capture data, advanced colouring technology, and post-processing effects. Advanced colouring techniques, such as global illumination and subsurface scattering, provide us with more realistic lighting effects, making the animation scene more stereoscopic and layered. Post-processing effects, such as blurred depth of field, screen-space reflection, etc., will further beautify and enhance the rendering results in the final stage.

5.2 Evaluation and Analysis of Rendering Results

In order to evaluate the performance of the rendering pipeline and animation effect enhancement technology, this section carries out an experimental analysis. The experimental environment includes high-performance computers, professional GPU and related software development tools. In the data set, a representative CAD model base and dynamic scene test set are selected to ensure the comprehensiveness and reliability of experimental results. In order to comprehensively evaluate the performance of rendering results, various evaluation indexes are adopted in the experiment, including rendering speed, image quality and memory consumption. The rendering speed is shown in Figure 6. The image quality is shown in Figure 7. Memory consumption is shown in Figure 8.

The experimental results show that our rendering pipeline significantly improves the rendering speed while maintaining a high-quality rendering effect. Compared with commonly used animation rendering algorithms, this method has faster rendering speed and higher image quality. These comparative analysis results further prove the feasibility and superiority of this study. Furthermore, the application of animation effect enhancement technology has greatly improved the visual effect and attraction of animation. These results prove the effectiveness and superiority of the rendering technology and animation effect enhancement technology in this paper.

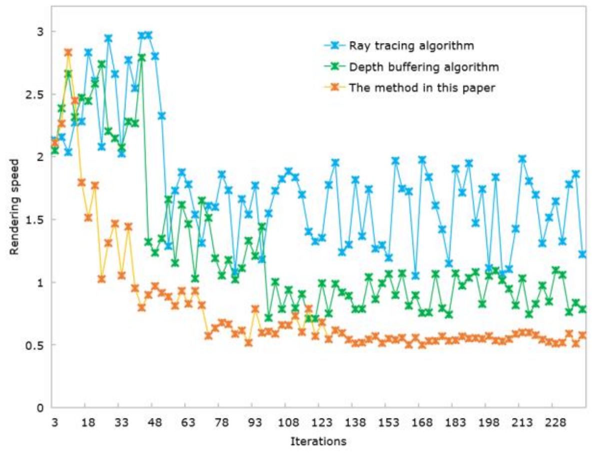

Figure 6: Rendering speed.

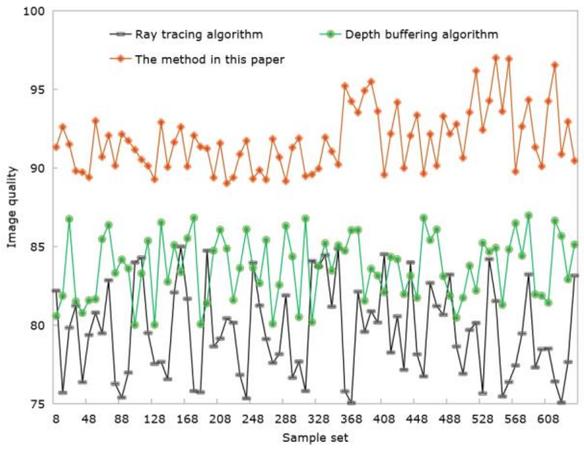

Figure 7: Image quality.

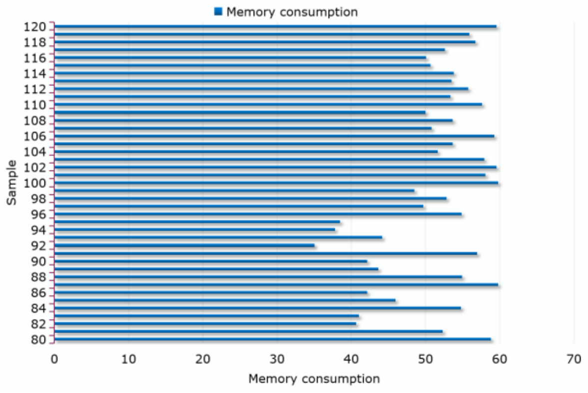

Figure 8: Memory consumption.

In this paper, after a series of simulation experiments, a wealth of experimental data is obtained. Through the statistics and analysis of data, this paper finds that the method proposed in this study is superior to traditional methods in modelling accuracy, calculation efficiency, user satisfaction, scene realism, interactivity and rendering speed. Specifically, the RL algorithm can adaptively adjust parameters and operation sequences in the process of CAD modelling and improve modelling efficiency and accuracy. Dynamic scene generation technology can generate realistic and interactive scenes in real time; However, animation rendering technology can efficiently render 3D models into high-quality 2D images.

6 CONCLUSIONS

In this study, the rendering pipeline is designed and optimized in detail through algorithm optimization and hardware acceleration technology. Combined with real-time rendering technology, the efficient generation and real-time update of dynamic scenes are realized, and the results of the simulation experiment design are analyzed in depth. Through systematic research and practice, this paper has achieved a series of important research results. In animation rendering technology, this paper designs and optimizes an efficient rendering pipeline, which significantly improves the rendering efficiency and image quality. Furthermore, real-time rendering technology is successfully applied to the generation and rendering of dynamic scenes. In addition, this paper also studies and implements a variety of animation effect enhancement technologies, which further enhance the visual effect and attraction of animation. In the aspect of simulation experiment design and result analysis, this paper constructs a comprehensive experimental environment, selects representative data sets, and designs a rigorous experimental scheme. The statistics and analysis of experimental results, and a detailed comparison with the existing methods, show the superiority and innovation of this research.

Generally speaking, this research has made important progress in the field of animation rendering technology and simulation experiment design, which provides valuable reference and enlightenment for the research and practice in related fields. Although some achievements have been made in this study, there are still some shortcomings and problems that need to be further explored. For example, in the optimization of the rendering pipeline, although we have significantly improved the rendering efficiency and image quality, there is still room for further optimization. In the future, we can consider introducing more optimization techniques, such as the rendering optimization algorithm, to improve the rendering performance and effect further.

Han Li, https://orcid.org/0009-0006-7890-4853
Yang Su, https://orcid.org/0009-0006-1385-0794

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