Dynamic Simulation and Real-time Rendering of Environmental Design Using Computer-aided Design and Multimedia Technology

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Abstract. The swift advancement of information technology has rendered Computer-aided design (CAD) an essential tool in environmental design, and the integration of multimedia technology has further diversified the forms and enhanced the meaning of design expressions. This article initially presents the utilization of CAD and multimedia technology within the realm of environmental design. Subsequently, it proposes an innovative, dynamic simulation and real-time rendering framework that integrates CAD software with multimedia technology. Through the creation of 3D models, the integration of interactive design principles, and the employment of cutting-edge rendering algorithms, this framework facilitates rapid iteration and optimization of environmental design concepts. Experimental findings reveal that the utilization of CAD and multimedia technology for dynamic simulation and real-time rendering in environmental design not only enhances design efficiency significantly but also imparts greater intuitiveness and interactivity to the design process. Designers can seamlessly adjust parameters and visualize the effects in a virtual setting, enabling them to refine their design approach more precisely and cater to users' diverse preferences.

Keywords: Computer-Aided Design; Multimedia Technology; Environmental Design; Dynamic Simulation; Real-Time Rendering
DOI: https://doi.org/10.14733/cadaps.2024.S25.108-123

1 INTRODUCTION

Computer-aided design (CAD) and multimedia technology are playing an increasingly important role in landscape practice. The integration of these technologies not only improves design efficiency but also provides designers with more intuitive and accurate spatial orientation and real-time drawing tools. Carbonell et al. [1] explored the application of spatial orientation technology and real-time rendering based on CAD and multimedia technology in landscape architecture practice. In the process of landscape design, accurate spatial positioning is the key to ensuring that the design scheme is consistent with the actual situation. CAD technology provides designers with powerful spatial orientation support through precise modelling and measurement functions. Designers can use

CAD software to draw topographic maps, establish 3D models, and gain a comprehensive and detailed understanding of the spatial layout and terrain features of the site by adjusting perspectives, zooming, and other operations. The spatial interpretation of architectural conceptual design is a crucial aspect of landscape environment design. The widespread application of multimedia technology provides designers with a more intuitive and vivid way to present and interpret the space of architectural conceptual design. Chen and Stouffs [2] discussed how to use multimedia technology to express and learn spatial interpretation of architectural conceptual design and analyzed its advantages and applications in landscape environment design. Multimedia technology provides a rich means for spatial interpretation in architectural conceptual design through various forms of expression such as images, animations, and videos. Designers can transform abstract architectural concepts into concrete visual images through these forms, enabling observers to have a more intuitive understanding of design concepts and spatial layouts. Using 3D modelling software, designers can construct a 3D model of architectural concepts and showcase the changes and flow of space through animation and roaming functions. This presentation method not only allows observers to have a more comprehensive understanding of the spatial form and scale of the design but also helps them better feel the spatial atmosphere and visual effects. It is suitable for different industries such as construction, machinery, and electronics, significantly improving design efficiency and overall quality [3]. Cloud analysis technology can achieve real-time monitoring and prediction of smart home environments by collecting and analyzing large amounts of data. In the design phase of smart environments, cloud analysis can help designers better understand user needs and behaviour patterns, thereby designing smart home systems that better meet user expectations. The introduction of artificial intelligence technology makes demand side management of smart home environments more intelligent and efficient. In smart home environments, edge analysis can help systems perceive and respond in real time to changes in the needs of family members, thereby optimizing the operational efficiency and comfort of the home environment. CAD drawing programs greatly improve the efficiency and quality of interior architectural design due to their high efficiency, accuracy, and convenience. Denerel and Anil [4] discussed the application and advantages of CAD drawing programs in indoor environmental architectural design. In indoor architectural design, CAD drawing programs are widely used to draw floor plans, elevations, sections, and various detailed drawings. Designers can use CAD drawing programs to accurately express design proposals through graphical means. CAD drawing programs provide rich drawing tools and editing functions, allowing designers to easily draw various complex indoor environment layouts and detailed designs. In addition, CAD drawing programs also support 3D modelling capabilities, allowing designers to simulate real indoor spaces in virtual environments. Through 3D modelling, designers can better understand and optimize spatial layout, predict actual usage effects, and discover and solve problems in advance.

Du [5] delved into the application and advantages of CAD-assisted intelligent technology in environmental landscape design. In the initial stage of environmental landscape design, designers usually need to draw a large number of sketches to explore different design schemes. CAD intelligent technology can automatically generate multiple possible sketch schemes for designers to choose and further modify by identifying their intentions and styles. This not only greatly reduces the workload of designers but also stimulates their creative thinking. In environmental landscape design, spatial layout is a crucial aspect. CAD-assisted intelligent technology can analyze spatial data through algorithms, automatically optimize layout schemes, and make spatial utilization more reasonable and efficient. As a high-precision and high-fidelity data representation method, point cloud 3D models are playing an increasingly important role in dynamic simulation and real-time rendering of environmental landscape art design. Herrero et al. [6] explore how to use point cloud 3D models to record the dynamic simulation and real-time rendering process of environmental landscape art design and analyze its advantages and application prospects. A point cloud 3D model is a collection of a large number of spatial points obtained through techniques such as laser scanning and photogrammetry. These points record the surface morphology, spatial position, and colour information of objects, which can accurately reproduce the three-dimensional structure of the real world. In environmental landscape art design, designers can collect on-site point cloud data through professional equipment to construct high-precision 3D models. Meanwhile, multimedia technology refers to the simultaneous processing of text, images, audio, and video. In environmental design, it mainly enhances the expressiveness and interactivity of the design.

As information technology swiftly advances, CAD and multimedia technology have found widespread applications across diverse domains, particularly in environmental design. Traditional approaches in this field are often constrained by static displays and a lack of interactivity, making it challenging to accurately depict the intended design effects. This study, therefore, aims to integrate CAD and multimedia technology to achieve dynamic simulation and real-time rendering in environmental design. This integration will enhance design visualization and interactivity, ultimately offering designers and users a more intuitive and seamless design experience. The significance of this research lies in promoting the innovation of environmental design methods and improving design efficiency and user satisfaction. Through dynamic simulation and real-time rendering technology, designers can foresee the actual effect of the design scheme at the early stage of design find and modify potential problems in time, thus saving time and cost. Furthermore, users can understand the design scheme more intuitively, put forward targeted feedback and promote effective communication between designers and users. Its innovations include: (1) A dynamic simulation algorithm based on the physical engine is proposed, which can simulate the physical phenomena in environmental design more truly; (2) Design and implement a real-time rendering algorithm based on GPU acceleration, which significantly improves the rendering speed and effect; (3) Build an environment design system integrating dynamic simulation and real-time rendering to realize quick preview and interactive editing of the design scheme.

This article begins by presenting the research background, significance, current status, development trends, content, and innovations within the field. Subsequently, it delves into the fundamental concepts of CAD and multimedia technology, along with their applications in environmental design. A comprehensive exploration of dynamic simulation algorithms and real-time rendering techniques in environmental design follows. The integration and practical application of these two technologies are then discussed, accompanied by a showcase of experimental results. Concluding the paper, a summary of the key findings and a forward-looking perspective on future research directions are provided.

2 RELATED WORK

In the field of environmental landscape architecture design, digital nonlinear design methods based on computer big data are gradually emerging, bringing new possibilities for the creation of spatial forms. Hu et al. [7] explored the spatial form of digital nonlinear environmental landscape architecture design based on computer big data and analyzed its advantages and application prospects. In environmental landscape architecture design, digital nonlinear design methods based on computer big data can create more diverse and creative spatial forms. Designers can use big data analysis results, combined with digital nonlinear design methods, to construct spatial sequences with unique rhythms and rhythms. Meanwhile, through parameterized modelling and algorithm optimization, designers can achieve precise control and optimization adjustment of spatial form, making design works more in line with people's aesthetic needs and usage habits. The dynamic simulation of environmental design and the application of fog computing technology provide strong technical support and innovative means for the construction of smart cities. Javadzadeh and Rahmani [8] conducted a systematic investigation on dynamic simulation and fog computing applications in environmental design in smart cities. The dynamic simulation technology of environmental design provides important decision support for urban planners and designers by simulating and predicting changes in the urban environment in different scenarios. Through dynamic simulation, designers can view the implementation effect of design schemes in real-time, predict potential environmental problems, and make necessary adjustments and optimizations. This not only improves design efficiency but also provides strong guarantees for the sustainable development of the urban environment. Meanwhile, fog computing can also achieve collaborative work among intelligent devices, improving the intelligence level of the entire urban system. As an important design tool, parameterized models can greatly improve design efficiency and quality. Jia [9] discussed the computer-aided design method of parameterized models for environmental landscape planning and analyzed their advantages and application prospects. In environmental landscape planning, parameterized models can automatically adjust various parameters of the model according to the designer's intentions and needs, thereby quickly generating planning schemes that meet the requirements. By using professional computer-aided design software, designers can easily construct parametric models. This software typically provides rich modelling tools and parameter setting options, allowing designers to accurately define the various parameters of the model. Through computer-aided design, designers can adjust the parameters of the model in real-time, observe the changes in the model, and optimize it.

Jin and Yang [10] discussed the application of computer-aided design software in dynamic simulation and real-time rendering of environmental art design, and the changes it brings. Dynamic simulation is an important part of environmental art design. It simulates the design scheme, allowing designers to intuitively understand the design effect and make necessary adjustments and optimizations. Computer-aided design software plays a crucial role in this process. Real-time rendering is another important technology in environmental art design, which allows designers to view and modify design effects in real-time during the design process, greatly improving design efficiency. Computer-aided design software also plays an important role in this regard. Designers can view the rendering effect of the design scheme in real time during the design process without waiting for a long rendering process. This not only improves work efficiency but also enables designers to receive design feedback more quickly and make necessary adjustments. The enhanced soft 3D environment design technology of iterative matching cost update combines iterative matching algorithms and cost update strategies, achieving precise simulation and efficient rendering of environment design by continuously optimizing model parameters and cost functions. This technology can simulate the lighting, material, and texture characteristics of the environment more realistically by constructing soft 3D models, improving the realism and visualization of the design. Lee et al. [11] delved into the principles, applications, and future development trends of this technology. The enhanced soft 3D environment design technology with iterative matching cost updates has broad application prospects in multiple fields. In the field of urban planning, this technology can be used to simulate urban spatial layout, traffic flow, etc., providing a scientific decision-making basis for urban planners. In the field of architectural design, this technology can simulate the exterior and interior space of buildings, helping architects better understand and present design creativity. CAD virtual reality technology is gradually becoming an important tool in the field of environmental landscape design. By combining virtual reality technology with CAD software, designers can present design solutions comprehensively and intuitively in the early stages of design, optimize design details, and improve design efficiency and quality. Shan and Sun [12] discussed the auxiliary use and detail optimization methods of CAD virtual reality technology in environmental landscape design. By utilizing CAD virtual reality technology, designers can adjust design schemes in real time in a virtual environment and observe the impact of different parameter changes on design effectiveness. This real-time interaction method enables designers to quickly identify problems and optimize them, improving the flexibility and efficiency of design.

The integrated application of software such as CAD, SketchUp, and Photoshop (PS) provides strong technical support and innovative design methods for environmental landscape planning and design. Song and Jing [13] discussed the application prospects of CAD SketchUp PS integrated software technology in environmental landscape planning and design and analyzed the changes and potential advantages it brings. The intuitive design advantage of SketchUp enables designers to quickly construct 3D scenes compare, and optimize solutions. Integrated software technology provides more innovative means for environmental landscape planning and design. Through the application of integrated software technology, the quality of environmental landscape planning and design will be significantly improved. Designers can utilize the precise modelling capabilities of CAD to ensure the accuracy and reliability of design solutions, Utilize SketchUp's 3D scene construction capabilities to present more realistic design effects, Utilize the image processing function of PS to enhance the visual effect and expressiveness of the design scheme. These will help improve design quality and meet people's pursuit of a beautiful environment. The field of environmental landscape art design is facing unprecedented development opportunities. Especially the intelligent environment landscape art dynamic simulation and real-time rendering technology based on distributed integrated models, with its unique advantages, is gradually becoming a new hot topic in industry research and application. Tang [14] delved into the principles, applications, and future development trends of this technology. In the field of intelligent environment landscape art, this model can effectively integrate various design tools, analysis software, databases and other resources to form a unified design platform. Through this platform, designers can more conveniently obtain the required information to improve design efficiency and quality. Intelligent environmental landscape art emphasizes the integration of technological elements into design and achieves dynamic simulation and real-time rendering of the landscape through intelligent means. This not only helps designers better understand and present design effects but also brings a more vivid and realistic visual experience to the audience. Zhang and Deng [15] discussed the colour effects of environmental landscape architecture design in CAD systems and analyzed their advantages and challenges in the design process. Colour has a unique emotional expression function in environmental landscape architectural design. The CACD system can help designers create different emotional atmospheres through precise colour control and simulation. A warm colour scheme can bring a warm and comfortable feeling, while a cool colour scheme may create a calm and solemn atmosphere. The creation of this emotional atmosphere helps to enhance the comfort and sense of identity of environmental landscape architecture. Colour can also be used in environmental landscape architectural design to enhance the sense of space and hierarchy. The CACD system allows designers to create rich spatial layers and visual effects through techniques such as colour gradient, contrast, and resonance. This design technique helps to enhance the spatial and three-dimensional sense of environmental landscape architecture, making it more vivid and interesting.

3D CAD technology not only improves the efficiency and quality of landscape design but also makes design schemes more intuitive and vivid. Zhao et al. [16] explored the application of 3D CAD in landscape design, with a focus on how to improve design effectiveness through hierarchical detail optimization. 3D CAD software can accurately simulate terrain and landforms, including natural elements such as hills, lakes, and rivers. Designers can easily achieve undulating changes in terrain by adjusting terrain parameters, providing rich spatial layers for landscape design. The 3D CAD software is equipped with a rich plant library, including various trees, shrubs, flowers, etc. Designers can choose appropriate plant species and configuration methods based on the design plan to simulate a real landscape of garden plants. In landscape design, the expression of details is crucial for improving the overall design effect. Designers can utilize the powerful features of 3D CAD software to finely process the details of design proposals. Looking ahead, the focus of dynamic simulation and real-time rendering in environmental design will increasingly gravitate towards realism and interactivity. This will be achieved by incorporating physical engines, light, and shadow simulation to heighten realism while embracing natural interaction modalities such as gesture recognition and voice interaction to enrich the user experience. Furthermore, with the evolution of cloud computing, big data, and related technologies, the environmental design will attain a higher level of collaborative design and data sharing in its dynamic simulation and real-time rendering endeavours.

3 DYNAMIC SIMULATION ALGORITHM AND REAL-TIME RENDERING TECHNOLOGY OF ENVIRONMENTAL DESIGN

3.1 Dynamic Simulation Algorithm of Environmental Design

The dynamic simulation algorithm is mainly used in environmental design to simulate physical phenomena and dynamic processes in the real world, such as illumination changes, water flow, plant growth, and so on. These algorithms are based on the basic principles of physics, mathematics, and computer science and simulate and predict dynamic behavior in the real world by establishing mathematical models and calculation methods. In this article, an efficient dynamic simulation algorithm is designed and implemented according to the specific requirements of environmental design. Edge detection is a core step in image processing, which involves identifying and locating the edge or contour of an object in an image. This edge information is very important for subsequent image analysis, understanding, recognition, enhancement and compression. Before edge detection, it is usually necessary to preprocess the image, such as filtering and smoothing, to reduce the influence of noise and other interference factors on the edge detection results. Therefore, improving SNR (Signal-to-noise ratio) is an important preparation before edge detection. In image processing, SNR is defined as the ratio between the intensity of useful signals (such as edges, textures, etc.) in the image and the intensity of background noise. A high SNR means that the signal component in the image is more prominent than the noise component, so it is easier to be detected and identified. Methods to improve SNR include increasing signal strength, reducing noise strength or both. SNR is defined as:

$$SNR = \left| \int_{-\infty}^{+\infty} G(-x) f(x) dx \right| / \left[\sigma \sqrt{\int_{-\infty}^{+\infty} f^2(x) dx} \right] \tag{1}$$

The filter's impulse response in the $[-w,w]$ region is denoted by $f(x)$, whereas $G(x,y)$ represents the edge detection function and σ indicates the Gaussian noise's mean square root. A crucial evaluation metric for edge detection algorithms is their positioning precision, which quantifies the closeness of the detected edge points to the actual ones. This precision has a direct bearing on the outcome of subsequent image-processing tasks. Herein, positioning accuracy is delineated as follows:

$$ACC = \left| \int_{-\infty}^{+\infty} G'(-x) f'(x) dx \right| / \left[\sigma \sqrt{\int_{-\infty}^{+\infty} f'^2(x) dx} \right] \tag{2}$$

Among them, $G'(-x)$ is the first derivative of $G(-x)$ and $f'(x)$ is the first derivative of $f(x)$. The larger the value, the higher the positioning accuracy is represented by ACC.

Corner detection is a common and important task in image processing. Corner points can be regarded as significant points of local feature changes in the image, which are usually found at the intersection or inflection point of the edge of the object. In many corner detection methods, E value is a measure of whether a pixel is a corner. The calculation of E value is usually based on the gray change of the area around the pixel. Specifically, it may examine the grayscale differences of pixels in different directions and choose the minimum value of these differences as E value. The purpose of this is to capture the minimum change of pixels in all directions so as to detect corners more robustly. If the calculated E value is greater than the preset threshold, then the pixel is considered as a corner. The selection of threshold is an important parameter in corner detection, which affects the sensitivity and specificity of corner detection. A higher threshold will lead to fewer corners being detected, while a lower threshold may detect more corners, but it may also include some false positives. In this article, the value E is calculated as follows:

$$E_W(x,y) = \sum_{u,v} W_{u,v} \left| f(u+x, v+y) - f(u,v) \right|^2 \tag{3}$$

$$E(x,y) = \min E_W(x,y) \tag{4}$$

Where $E_W(x,y)$ represents the gray level change value in the window neighborhood of point (x,y); W stands for sliding window; $W_{u,v}$ represents the weight at point (u,v) in the window; and $f(\cdot)$ is the gray value of the pixel; (u,v) is the coordinate value of the window relative to the pixel in the sliding process.

If a pixel has a maximum or minimum value in its neighborhood, it usually means that the pixel may be a noise point, especially when the value of this extreme point is significantly different from that of the surrounding pixels. In this case, using the median filtering algorithm to replace the value of the pixel is an effective denoising method because it can remove those values that are significantly different from the surrounding pixels while retaining important image features such as edges. Let $y_{i,j}$ represent the expression of the output image, then:

$$y_{i,j} = \begin{cases} med\ W\left[f_{i,j}\right], & f_{i,j} \in N \\ f_{i,j}, & f_{i,j} \in S \end{cases} \tag{5}$$

Where S is the signal point class? In order to simplify the operation, this article converts RGB images into grayscale images, and its formula is as follows:

$$F\ x,y\ = 0.299 \times R\ x,y\ + 0.587 \times G\ x,y\ + 0.114 \times B\ x,y \tag{6}$$

Where $F\ x,y$ represents the gray value of the corresponding pixel point in the gray image, $R\ x,y$ represents the gray value of the pixel on the corresponding R component, $G\ x,y$ represents the gray value of the pixel on the corresponding G component, and $B\ x,y$ represents the gray value of the pixel on the corresponding B component.

3.2 Real-Time Rendering Technology

Real-time rendering technology is the process of creating and presenting 3D graphics instantaneously within computer graphics. This technology demands that the pace of graphics rendering matches the frame rate perceptible to the human eye, ensuring a seamless interactive encounter. Its applications span across games, virtual reality, augmented reality, and beyond. In the realm of environmental design, real-time rendering finds its utility in achieving 3D visualizations and interactive adjustments of design blueprints. Designers can leverage this technology to preview and fine-tune the 3D aspects of their designs in real-time, thereby enhancing both the speed and quality of their work. For the purposes of environmental design, an efficient real-time rendering algorithm has been devised and executed, as outlined in Figure 1.

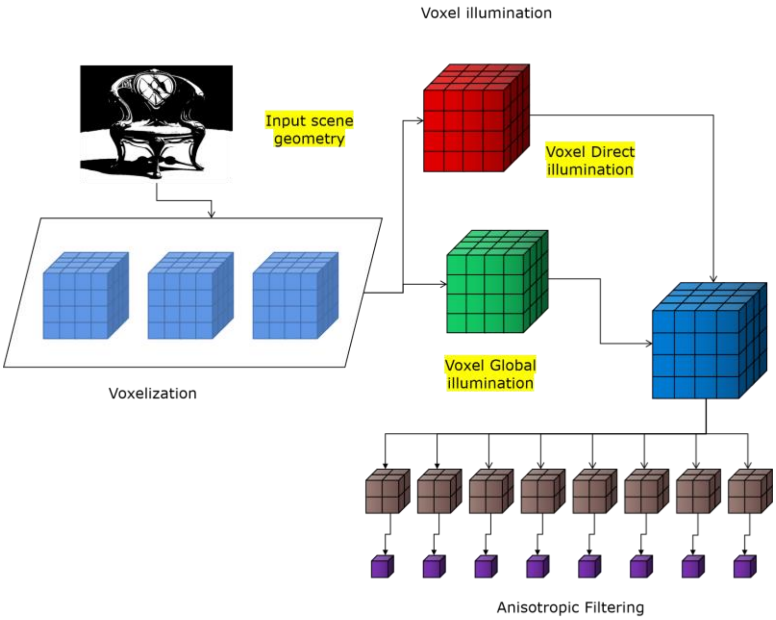

Figure 1: Technical process of dynamic simulation and real-time rendering.

The illumination model is the core of realistic rendering, which defines how objects interact with light sources in the scene and how light is distributed and reflected on the surface of objects. This algorithm will adopt the PBR (Physics-based rendering) model, which can simulate the principle of light scattering and energy conservation in the real world and generate more realistic light and shadow effects. Compared with the traditional lighting model, the PBR model provides more accurate material representation and richer lighting details. In order to make full use of the PBR model and achieve a highly realistic rendering effect, a fine physics-based material system must be established. This system should be able to accurately describe various properties of the surface of the object, including but not limited to roughness, metallicity, reflectivity and so on. These properties are the key parameters for calculating BRDF (Bidirectional Reflection Distribution Function) in the PBR illumination model, which together determine how the light is scattered and reflected on the surface of the object. Roughness defines the micro-roughness of the surface and affects the scattering mode of light on the surface. Metal degree describes the conductivity of the surface and determines the colour and intensity of reflected light. Reflectivity is directly related to the specular reflection ability of the surface, that is, the reflection ratio of the object to the incident light. These attributes can be sampled from high-resolution texture maps to achieve detailed surface material representation.

When calculating BRDF, a typical PBR formula may use these material parameters. The formula in the Cook-Torrance BRDF model is as follows:

$$f_r\left(\omega_i,\omega_0\right)=k_d f_{\text{lambert}}+k_s f_{\text{cook torrance}} \tag{7}$$

$$f_{\text{cook torrance}}=\frac{D\left(h\right)F\left(v,h\right)G\left(\omega_i,\omega_0,h\right)}{4\left(\omega_i,n\right)\left(\omega_0,n\right)} \tag{8}$$

Where f_r is the reflection function; k_d and k_s are the proportional coefficients of diffuse reflection and specular reflection, respectively, which can be calculated according to material parameters such as metallicity and reflectivity. f_{lambert} It is a Lambertian term describing diffuse reflection; $D\left(h\right)$ it is a micro-plane distribution function that is related to roughness and describes the statistical distribution of surface micro-planes. $F\left(v,h\right)$ It is a Fresnel term that indicates the proportion of light reflected from the surface of an object at a given viewing angle and is also affected by parameters such as metallicity. $G\left(\omega_i,\omega_0,h\right)$ It is a geometric function that takes into account the self-shadow and occlusion effects between micro-planes and is also related to roughness. n Is the surface normal, h is the half-angle vector, and v is the observation direction.

In real-time rendering, the processing of light sources is an extremely critical link because they directly affect the brightness and visual effects of the scene. However, the increase in the number and types of light sources will significantly increase the computational burden of rendering, thus affecting performance. In order to solve this problem, this article adopts a variety of technologies to optimize the processing of light sources. Dynamic light source clipping technology can eliminate those light sources that have little contribution to the final image according to the relative position of the light source and camera during operation, thus reducing unnecessary calculations. The light source merging technology merges a plurality of adjacent light sources with similar properties into one to simplify the calculation process. Pre-calculating illumination map is a method of calculating and storing illumination information in advance, which can quickly apply lighting effects at runtime without calculating the influence of each light source in real time. For a long-distance light source, because its influence on the scene is indirect and uniform, cube mapping or spherical harmonics can be used to approximate its global lighting effects efficiently. By storing and sampling illumination information in different directions, these technologies can quickly simulate the illumination distribution of long-distance light sources in the scene, thus achieving efficient and realistic real-time rendering.

3.3 Experimental Verification of Algorithm

To thoroughly assess the algorithm's efficacy in environmental design and identify possible areas for improvement, a range of experiments have been devised in this section. These experiments are aimed at collecting key data such as running time, memory consumption, frame rate and rendering time of the algorithm in different scenarios, and analyzing its performance bottleneck. Furthermore, we also pay attention to the scalability and compatibility of the algorithm under different hardware configurations. The experiment was carried out under various hardware configurations, including different models of CPU, GPU and memory configurations, to ensure the wide applicability of the results. In the experiment, a variety of algorithms commonly used in the field of environmental design are selected, which cover from basic rendering technology to advanced dynamic simulation and real-time interaction technology. In order to simulate real application scenarios, this article constructs a series of test scenarios with different complexity, including simple static scenarios and complex dynamic scenarios. For each algorithm and scene combination, we collect data such as running time, memory consumption, frame rate and rendering time. All data is collected through automated test scripts to ensure consistency and accuracy. The running time of the algorithm in different scenarios is shown in Figure 2.

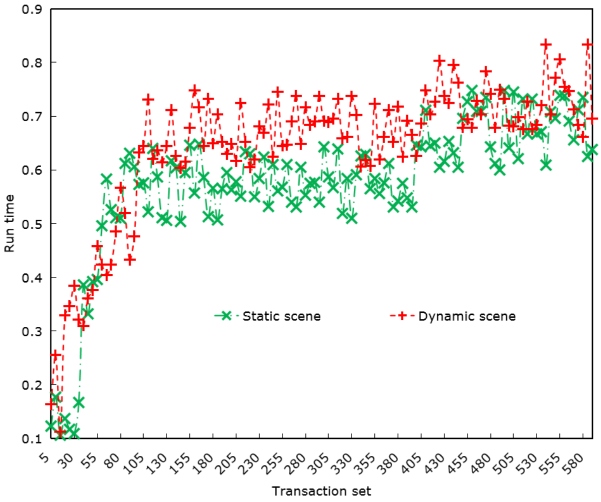

Figure 2: Running time of the algorithm in different scenarios.

The method proposed in this article has a short running time in both simple static scenes and complex dynamic scenes. In a simple static scene, due to the low complexity of the scene, the algorithm needs to process relatively little data, so the running time is short. In the complex dynamic scene, although the complexity of the scene increases, the algorithm in this article can still maintain a low running time by optimizing the calculation process and data structure, showing its good scalability and adaptability. The memory consumption of the algorithm in different scenarios is shown in Figure 3. The method in this article also performs well in memory usage, and its memory consumption is controlled at a relatively low level, that is, below 50%, whether in simple static scenes or complex dynamic scenes.

For real-time rendering applications, rendering time directly affects the fluency of user experience. Traditional algorithms show a long rendering time when rendering complex scenes, which is caused by bottlenecks in the rendering pipeline or insufficient utilization of GPU. In order to solve these problems, this article adopts optimizing the rendering pipeline, reducing the number of rendering calls, improving GPU utilization, and using asynchronous rendering technology to improve rendering performance. The comparison of the rendering time of different algorithms is shown in Figure 4.

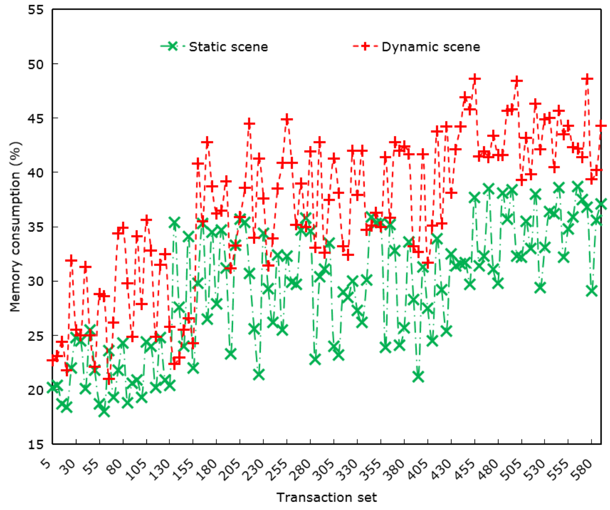

Figure 3: Memory consumption of the algorithm in different scenarios.

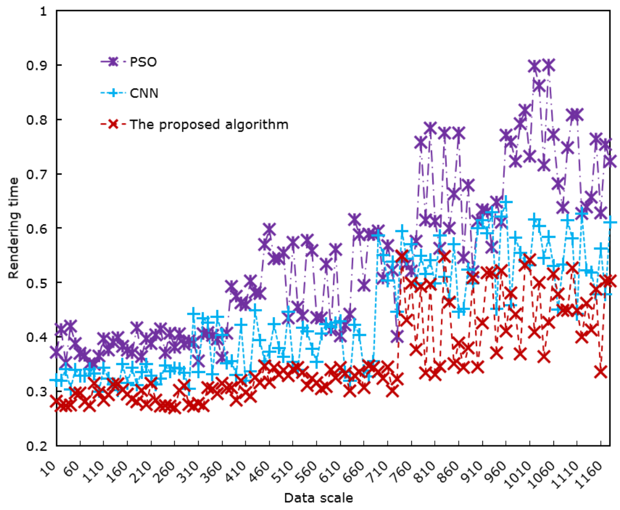

Figure 4: Algorithm rendering time comparison.

Stability is an important index to measure the reliability of the algorithm, especially when running for a long time or processing large-scale data. We noticed that the traditional algorithm showed unstable behaviour in some scenarios, such as crash, deadlock or performance degradation. These problems are caused by algorithm design defects, resource management problems or concurrent conflicts. In order to improve the stability of the algorithm, this article strengthens the error handling mechanism, optimizes the resource management mode and introduces a more robust concurrency control strategy. The stability comparison of different algorithms is shown in Figure 5.

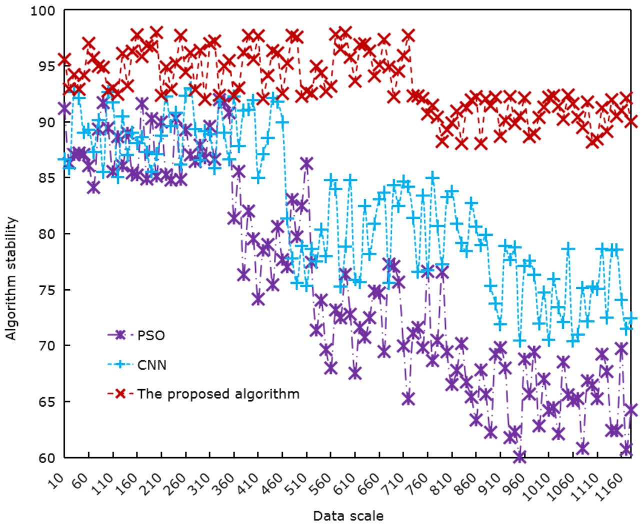

Figure 5: Comparison of algorithm stability.

According to the comparison results of rendering time shown in Figure 4, we can clearly see the time difference required by different algorithms when rendering the same scene. Among them, the algorithm proposed in this article shows a shorter rendering time than the PSO (Particle swarm optimization) algorithm and CNN (Convective Neural Network) algorithm. According to the data in Figure 5, it can be observed that the algorithm in this article is more stable than the PSO algorithm and CNN algorithm. The high stability of the algorithm in this article provides a strong guarantee for its reliability and persistence in practical application.

By comparing and analyzing the rendering time and stability of different algorithms, we can find that the algorithm proposed in this article has obvious advantages in real-time rendering. Its short rendering time and high stability make it an ideal choice for real-time rendering tasks in processing environment design.

4 INTEGRATED APPLICATION OF DYNAMIC SIMULATION AND REAL-TIME RENDERING

4.1 Integration Solution and System Architecture Design

In environmental design, the integrated application of dynamic simulation and real-time rendering aims to provide a more realistic and intuitive design preview and interactive experience. Therefore, this section designs an integration scheme, which combines a dynamic simulation algorithm with real-time rendering technology to realize dynamic display and real-time interaction of the design scheme. The core idea of the integration scheme is to take the output of the dynamic simulation algorithm as the input of real-time rendering and generate the 3D view of the dynamic scene in real-time through the rendering engine. Specifically, in this section, the static elements and dynamic elements in the environmental design scheme are modeled separately, and then the dynamic elements are simulated and calculated by using the dynamic simulation algorithm to get their state data at each moment. Then, these state data are passed to the real-time rendering engine and are rendered together with static elements to generate a 3D view of the dynamic scene. Users can view and modify the design scheme in real-time through interactive devices and get a more intuitive design experience.

In order to realize the above integration scheme, this section constructs a system architecture with multiple functional modules. The system architecture is divided into three layers: data layer, algorithm layer and application layer (see Table 1 for details).

Architecture hierarchy	*Functional module*	*Describe*
Data layer	Static element data management	Store and manage static element data in the environmental design scheme.
	Dynamic element data management	Store and manage dynamic element data and its state changes in an environmental design scheme.
	Data access interface	Provides interfaces for reading, writing and updating data.
Algorithm layer	Dynamic simulation algorithm	Responsible for simulating the state change of dynamic elements.
	Real-time rendering algorithm	Generating a 3D view according to the state data.
Application layer	Design scheme import and export	Support the import and export functions of environmental design schemes.
	Dynamic analog control and adjustment	Provide a user interface for controlling and adjusting parameters and states of dynamic simulation.
	Real-time rendering viewing and editing	Provides a user interface for viewing and editing the results of real-time rendering.
	Interaction and cooperation of functional modules	The functional modules interact and cooperate with each other through data interface, and function calls to realize integrated applications.

Table 1: System architecture function module table.

The above functional modules interact and cooperate with each other through data interface and function call and jointly realize the integrated application of dynamic simulation and real-time rendering of environmental design.

4.2 Key Technical Difficulties and Solutions

In the process of integrated application, this article encountered some key technical difficulties and put forward corresponding solutions.

First of all, the data exchange between the dynamic simulation algorithm and the real-time rendering algorithm is a difficult point. Because the data formats and processing methods of the two algorithms are different, direct data exchange may lead to data loss or format errors. In order to solve this problem, this article designs an intermediate data format to uniformly represent the state data of dynamic elements. The dynamic simulation algorithm converts the calculation results into the intermediate data format, and the real-time rendering algorithm reads the state data from the intermediate data format for rendering.

Secondly, the performance optimization of real-time rendering is a challenge. Because the environmental design scheme may contain a large number of static elements and dynamic elements, direct real-time rendering may lead to a decrease in frame rate and rendering quality. In order to improve the performance of real-time rendering, this article adopts a variety of optimization techniques, such as cone clipping, occlusion removal, texture compression and so on. These techniques can effectively reduce unnecessary rendering operations and memory occupation and improve rendering speed and quality.

Finally, the design of the user interface is also an important issue. In order to provide an intuitive and easy-to-use interactive interface, this article adopts a graphical interface design tool and customizes several interactive controls and function menus according to the needs of users. Users can complete tasks such as importing and exporting design schemes, controlling and adjusting dynamic simulation, and viewing and editing real-time rendering through simple clicking and dragging operations.

4.3 Experimental Verification of Integrated System

To validate the accuracy and efficacy of the integrated system, several experiments are conducted in this section. Initially, an environmental design scheme encompassing both static and dynamic components is formulated and incorporated into the system. Subsequently, the dynamic elements undergo simulation and computation employing a dynamic simulation algorithm, yielding moment-by-moment state data. This data is then relayed to the real-time rendering engine for visualization, resulting in a 3D representation of the dynamic scene. Ultimately, the system's interactive capabilities and rendering quality are verified by examining and modifying the design scheme via the user interactive interface.

The user's assessment of the interactive performance is shown in Figure 6.

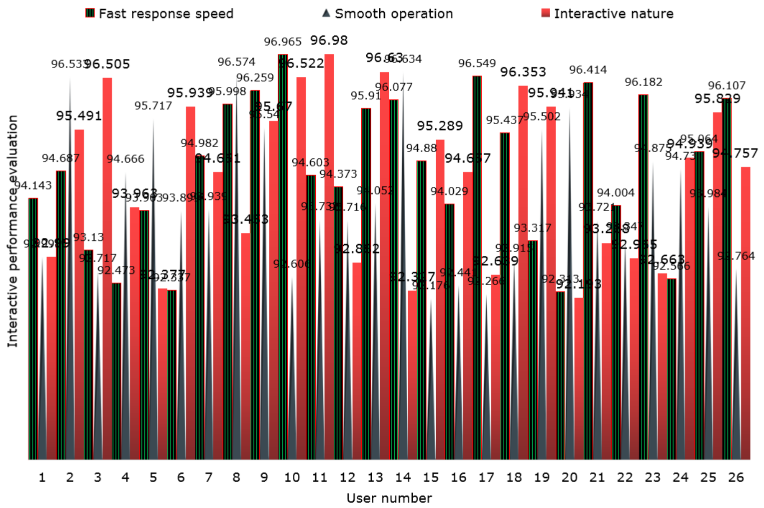

Figure 6: User's assessment of interactive performance.

As shown in the above figure, users generally have a high assessment of interactive performance. They think that the system has fast response, smooth operation and natural interaction, and can meet their various needs in the process of environmental design. This is due to the optimized dynamic simulation algorithm and efficient real-time rendering technology. The system stability is shown in Figure 7. It shows that the system shows good stability during operation. Whether dealing with complex scenes or a lot of user interaction, the system can maintain a stable frame rate and rendering quality. This is due to the well-designed system architecture and strong hardware support.

The above results fully verify the correctness of the integrated system. The integrated system can correctly combine dynamic simulation algorithms with real-time rendering technology to realize dynamic display and real-time interaction of design schemes. The system can not only improve the design efficiency but also enhance the interaction and immersion between users and design schemes.

Furthermore, the system has good performance and stability, which can meet the needs of practical applications.

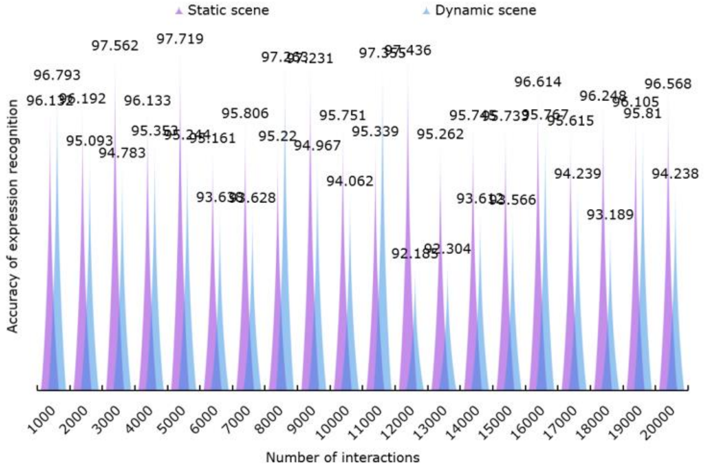

Figure 7: System stability.

4.4 Application Case Analysis

To further demonstrate the practical impact and significance of the integrated system, this section presents an analysis of a real-world environmental design case. Specifically, an indoor home design project is chosen, encompassing multiple rooms and a diverse range of furniture elements. These elements are meticulously modelled in CAD software, complete with appropriate materials and textures. Additionally, this article incorporates multimedia technologies, such as interactive interface design and 3D scene rendering, to achieve dynamic simulation and real-time visualization. Through the interactive interface, users have the freedom to view and modify various elements within the design scheme, including adjusting furniture positions and angles and changing materials and colours, among other customizations. Moreover, the system offers instant real-time rendering feedback, enabling users to visualize their modifications in real time. Through the application of the integrated system, this article successfully generated a realistic 3D scene view, as shown in Figure 8.

The system can accurately simulate the actual effect of indoor home design, including furniture placement, material selection and light irradiation. Furthermore, users can freely edit and adjust the design scheme through the interactive interface, which realizes the visualization and interactivity of the design process.

In addition, the experimental results also show that the integrated system has high performance and stability when dealing with large-scale scenes and complex models. Furthermore, the interactive interface design of the system also fully considers the user's usage habits and experience needs, making the operation process more simple and intuitive.

5 CONCLUSION AND PROSPECT

5.1 Summary of Research Work

This study is devoted to the in-depth exploration and practice of dynamic simulation algorithms and real-time rendering technology in environmental design. By constructing an integrated system, this article successfully combines dynamic simulation with real-time rendering, which brings innovative solutions to the field of environmental design. In the aspect of dynamic simulation algorithm, this article studies its basic principle in detail and designs and implements the algorithm accordingly.

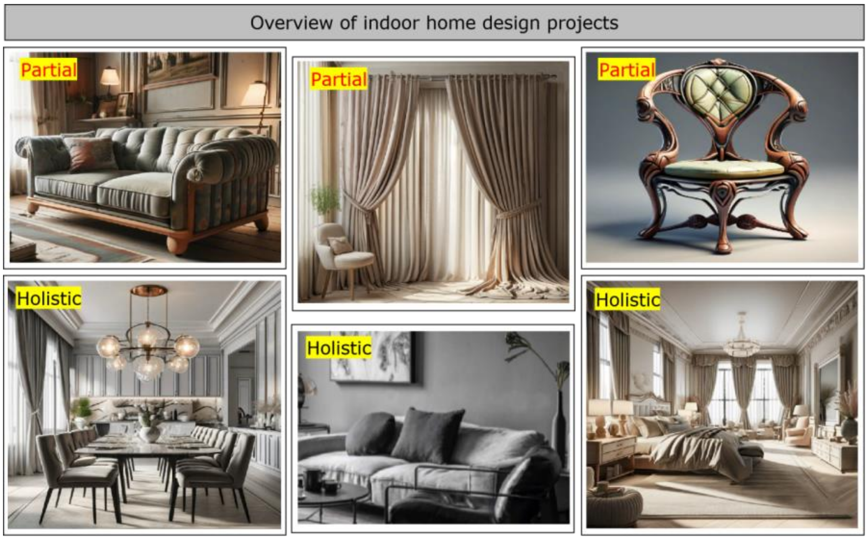

Figure 8: Indoor home design display effect.

Through performance analysis and optimization, the stability of the algorithm in different scenarios is ensured. Experimental verification and result analysis further prove the effectiveness and accuracy of the algorithm. In the aspect of real-time rendering technology, this article designs and implements real-time rendering algorithms according to the actual requirements of environment design. Furthermore, this article puts forward a series of optimization strategies for rendering effect, which significantly improves the rendering quality and efficiency. Through experimental verification and performance assessment, the great potential of real-time rendering technology in environmental design is fully demonstrated. Finally, this article applies the integration of dynamic simulation algorithms and real-time rendering technology to environmental design and realizes the seamless connection between them by designing the integration scheme, building the system architecture and solving key technical difficulties. The application case analysis further verifies the practicability and advancement of the integrated system and brings new design concepts and interactive experiences to the field of environmental design.

5.2 Research Deficiency and Future Work Prospect

Although some achievements have been made in this study, there are still some shortcomings: in terms of dynamic simulation algorithm, although this article has achieved efficient algorithm design and performance optimization, it may still face challenges in computing resources and time when dealing with more complex and larger-scale scenes. Because of the above shortcomings, this article puts forward the following future work prospects: an in-depth study of more efficient dynamic simulation algorithms and numerical calculation methods to meet the needs of larger and more complex scene simulation. Furthermore, parallel computing and distributed computing technology are considered to improve the computing power of the algorithm further. Explore new real-time rendering techniques and optimization methods to achieve higher quality and lower resource consumption.

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