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Individuation and Interaction Enhancement of Landscape Design Based on Computer-Aided Design and Reinforcement Learning

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Abstract. The traditional approach to landscape design primarily hinges on the designer's expertise and gut feeling, greatly constraining the design's adaptability to diverse and personalized user needs. Current research, therefore, focuses on integrating cutting-edge technology into landscape design to enhance its individuality and user engagement. This article aims to pioneer innovative methods that enhance the uniqueness and interactivity of landscape designs, thus catering to the escalating demands of users. To this end, we introduce a novel approach that seamlessly merges Computer-Aided Design (CAD) with Reinforcement Learning (RL) algorithms. This approach allows us to capture users' preferences in real-time and leverages RL technology to continuously refine the design proposal, fostering a profound interaction between users and the design process. Rigorous experimental validations and user evaluations reveal that this approach significantly outperforms traditional design methodologies in terms of user satisfaction, design efficacy, and an overall superior score. The findings underscore that this method not only elevates the individuality and interactivity of designs but also propels the automation and intelligence of the design process.

Keywords: Computer-Aided Design; Strengthen Learning; Landscape Design; Individuation; Interactivity
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1 INTRODUCTION

Landscape design, once limited to a mere amalgamation of functionality and aesthetics, has evolved with the advancements of science and technology and the enhancement of people's quality of life. Nowadays, it incorporates increasingly individualized and interactive elements. Traditionally, designers primarily relied on experience and intuition, which often fell short of addressing the diverse and personalized needs of users. In terms of three-dimensional spatial syntax analysis, these technologies provide designers with a new perspective and tools to optimize the attributes and performance of landscape architecture projects. Ascensão et al. [1] explored the application and potential of 3D spatial syntax analysis based on CAD and reinforcement learning in landscape architecture projects. Computer-aided design technology provides precise modelling and analysis tools for landscape architecture projects. Designers can use CAD software to create 3D models to simulate and predict the performance of different design schemes in terms of space, lighting, airflow, etc. This technology not only improves the accuracy and efficiency of design but also enables designers to better understand and control the attributes and details of the project. Reinforcement learning is a machine learning algorithm that learns and optimizes decision strategies through the interaction between intelligent agents and the environment. In landscape architecture projects, reinforcement learning algorithms can be used to optimize 3D spatial syntax analysis. Simulate different spatial layouts and design schemes in a virtual environment by training intelligent agents. Consequently, current research is actively exploring how to integrate cutting-edge technological tools into landscape design, aiming to elevate its individuality and interactivity. The reinforcement learning algorithm is a machine learning algorithm that learns and optimizes decision strategies through the interaction between intelligent agents and the environment. In landscape architecture conceptual design, Chen and Stouffs [2] apply reinforcement learning algorithms to decision-making and optimization in the design process. By defining appropriate states, actions, and reward functions, reinforcement learning algorithms can automatically explore the design space and find the best design solution that meets design requirements. In the conceptual design of landscape architecture, reinforcement learning algorithms can be used to solve multiple problems. For example, optimizing the layout and form of buildings can enhance the overall aesthetics and functionality of the landscape. Alternatively, by optimizing vegetation configuration and selecting landscape elements, the ecological and environmental benefits of the landscape can be enhanced. In addition, reinforcement learning algorithms can also be combined with other design tools, such as computer-aided design software, virtual reality technology, etc., to promote innovation and development of landscape architecture conceptual design jointly.

The rapid development of urbanization has led to an increasingly significant impact of the urban environment on wind. In order to better understand and predict the wind and fluid dynamics in urban environments, a continuous and semi-automatic workflow has emerged, which combines geometric optimization of 3D urban landscape models, computational fluid dynamics (CFD) simulation, and wind visualization. Deininger et al. [3] provided a detailed introduction to this workflow. We need to build an accurate 3D urban landscape model. This model should include buildings, roads, vegetation, and other elements in the city, and it should consider their geometric shape, size, and location. To ensure the accuracy of the model, it is necessary to perform geometric optimization on the landscape model, including removing redundant data, correcting geometric errors, and optimizing grid quality. The optimized model will serve as the basis for subsequent CFD simulations. After obtaining the optimized 3D city model, proceed with CFD simulation. In urban landscape environments, CFD simulation can help us understand the flow of wind in the city, including wind speed, direction, turbulence intensity, etc. By setting appropriate boundaries and initial conditions, wind and flow dynamics under different landscape conditions can be simulated, providing an important basis for urban landscape planning, architectural design, and more. With the rapid development of computer technology, computer-aided design (CAD) assisted intelligent technology has become an important tool in the field of landscape design. It not only greatly improves design efficiency but also enhances the accuracy and innovation of design. Du [4] discussed the application of CAD-assisted intelligent technology in landscape design and the changes it brings. CAD-assisted intelligent technology makes the landscape design process more intelligent. Designers can quickly collect and process data through intelligent analysis software and automatically generate preliminary design proposals. On this basis, CAD software is used to adjust and optimize details, ultimately achieving a digital presentation of the design scheme. This intelligent design process greatly improves design efficiency and quality.

With the advancement of technology and the acceleration of urbanization, smart urban landscapes have gradually become a new trend in urban planning and design. In this context, the integration of interactive and modular technologies has injected new vitality into smart urban landscapes, greatly enhancing the interactivity and user experience of urban landscapes. Interactive technology is a technology that enables real-time interaction with users, achieving two-way communication with users by capturing their behaviour and feedback. The introduction of interactive technology in smart city landscapes enables urban elements to no longer be static but to respond accordingly to user needs and behaviours. For example, interactive fountains in smart parks can adjust the height and shape of the fountain water column according to the proximity of tourists, providing visitors with a more vivid viewing experience. In addition, the interactive navigation system can provide personalized attraction recommendations and route planning based on the location and interests of tourists, helping them better understand and explore the city [5]. Landscape design is a comprehensive discipline that involves multiple fields, requiring students to possess innovative thinking and practical abilities. The traditional teaching methods of landscape design often focus on the separation of theoretical teaching and practical operation, making it difficult to cultivate students' comprehensive abilities. The emergence of computer-aided design and reinforcement learning algorithms has provided new possibilities for landscape design teaching. The reinforcement learning algorithm is a machine learning technique that optimizes decisions by allowing models to learn in interaction with the environment. In landscape design teaching, reinforcement learning algorithms can be used to optimize the selection and adjustment of design schemes. For example, algorithms can automatically adjust design parameters based on students' historical data and feedback to generate design solutions that better meet their needs. This can not only improve design quality but also help students better understand the process and principles of design decision-making [6]. Traditional urban landscape design methods are often based on linear theory, which makes it difficult to fully describe the complexity and nonlinear characteristics of urban landscape systems. In order to simulate and predict the dynamic behaviour of urban landscape systems more accurately, a multidimensional urban landscape design parameter simulation method based on nonlinear theory has emerged. Liu et al. [7] explored the basic principles, applications, and potential of this method in urban landscape design. Multidimensional urban landscape design parameter simulation refers to the comprehensive simulation and analysis of urban landscape systems by constructing multidimensional parameter models. These parameters include but are not limited to terrain height, vegetation coverage, building density, traffic flow, etc. By integrating these parameters into a unified model, we can gain a more comprehensive understanding of the structure and function of urban landscape systems. Improving the quality of life of residents and promoting sustainable development are playing an increasingly important role. However, traditional landscape design methods are often time-consuming and labor-intensive, and it is difficult to accurately predict the long-term effects of design schemes. To this end, Luo [8] constructed an online design platform based on machine learning and computer simulation technology. This provides a new perspective and solution for the design of green urban landscape architecture. Computer simulation technology can simulate both natural and artificial environments, helping designers predict and evaluate the actual effectiveness of design solutions in the early stages of design. In landscape design, through computer simulation, designers can simulate the growth process of different plants, the evolution of ecosystems, and the interaction between humans and the environment, thereby identifying potential problems and optimizing design solutions. In addition, computer simulation can improve the accuracy and efficiency of design and reduce possible errors and waste in actual construction. Wang [9] discussed how to use virtual reality technology and intelligent algorithms for coastal landscape design and analyzed its potential advantages and challenges. Virtual reality technology provides an immersive experience for coastal landscape design. Designers can use virtual reality technology to create highly realistic coastal environments, making users feel as if they are in a real scene. This immersive experience helps designers better understand the characteristics of coastal environments, enabling more precise and effective design. In coastal landscape design, virtual reality technology can also be used to simulate different conditions such as climate, tides, and natural disasters to test the stability and adaptability of the design. By simulating these actual environments, designers can identify and solve potential problems in the early stages, improving the feasibility and sustainability of the design. The emergence of CAD technology has revolutionized landscape design. This technology enables designers to draft, refine, and optimize design proposals more efficiently, paving the way for a more dynamic and responsive design process. It is still impossible to realize the individuation and interactive enhancement of design only by relying on CAD technology. This is because CAD software itself cannot understand and respond to user preferences, nor can it adjust the design scheme according to real-time feedback from users. RL algorithm can find the optimal decision-making strategy by trial and error without prior knowledge through interactive learning between agent and environment. This characteristic gives the RL algorithm unique advantages in dealing with complex decision-making problems.

This article aims to explore the use of CAD and RL algorithms in landscape design individuation and interactive enhancement. Combining these two technologies is expected to build a new landscape design model that can integrate user preferences and real-time feedback to generate a design scheme that meets individual needs. The model needs to be able to express various attributes of the design scheme, such as spatial layout, plant configuration, material selection, etc., and to quantify users' preferences for these attributes. By collecting users' feedback data, we can learn and model these preferences, thus providing a basis for the subsequent RL algorithm.

This study will explore how to use the RL algorithm to optimize the design process. In optimization, it is necessary to define appropriate state space, action space, and reward function to describe various decisions and results in the design process. By interactive learning between the agent and the environment, an optimal decision-making strategy can be found so that the design scheme can meet the user's preferences to the greatest extent. By introducing advanced interactive technology and visualization tools, users can view and modify the design scheme in real time during the design process, thus providing a more intuitive and individualized design experience. The validity and feasibility of the proposed model have been confirmed through rigorous experiments. By comparing the traditional design approach with the novel method leveraging CAD and RL algorithms, the superiority of the model in terms of individualization and interactivity enhancement becomes evident.

In conclusion, this study holds significant theoretical importance and practical value. The integration of CAD and RL algorithms not only enhances the individuality and interactivity of landscape design but also offers fresh perspectives for design challenges across various fields. As technology advances and its applications deepen, the individualized and interactive enhancements in landscape design, driven by CAD and RL algorithms, will play a pivotal role in the future. Furthermore, this research positively impacts the landscape design industry's growth. By incorporating advanced technology, we aim to improve design efficiency, reduce costs and risks, and provide users with superior, personalized services. Additionally, it fosters cross-industry collaboration and innovative development between landscape design and other sectors, propelling the overall industry's progress and prosperity.

The key innovations and contributions of this research are as follows:

(1) This article introduces a novel approach that combines CAD and RL algorithms to address individualization and interactivity challenges in landscape design. This combination leverages CAD's efficiency in design and RL's decision-making optimization, offering a fresh perspective in the field.

(2) This study establishes a mathematical model that encapsulates landscape design complexities, enabling the expression of design scheme attributes and the quantification of user preferences for these attributes.

(3) Traditional landscape design methods often lack the ability for real-time adjustment and user interaction. By introducing advanced interactive technology and visualization tools, this article enables users to view and modify the design scheme in real-time during the design process, thus providing a more intuitive and individualized design experience.

(4) This article compares the traditional design method with the new design method based on CAD and RL algorithms through experiments and verifies the advantages of the proposed model in

individuation and interactive enhancement. This provides strong support for future research and application.

This article begins by introducing the importance of enhancing individualization and interactivity in landscape design. It then proceeds to delve into the proposed methodology framework, encompassing data collection and processing, the implementation of RL algorithms, and the achievement of interactivity. The study further validates the method's effectiveness and feasibility through experimental design and evaluation, highlighting its superiority in terms of user satisfaction, design performance, and overall rating. Lastly, the research findings are discussed and summarized, outlining the potential application value and future research directions of the proposed approach.

2 RELATED WORK

With humans' increasing attention to the natural environment, landscape design is no longer just an aesthetic issue but involves interdisciplinary fields such as ecology, architecture, and environmental science. In order to create an ecologically sound and fully functional landscape, we need to integrate various professional knowledge and utilize advanced technological means such as computer-aided design and reinforcement learning to optimize design solutions. Weisser et al. [10] explored how to integrate ecology, architecture, and ecologically sound landscape design based on computer-aided design and reinforcement learning. In landscape design, reinforcement learning algorithms can be used to optimize design schemes to meet various requirements such as ecology, architecture, and aesthetics. By training intelligent agents to simulate different landscape design schemes in virtual environments, reinforcement learning algorithms can automatically find the optimal design strategy to maximize the ecological benefits and aesthetic value of the landscape. As a new computing model, edge computing is gradually penetrating various industries, providing a strong impetus for digital transformation. In the field of landscape design, the application of edge computing has brought designers a new design mechanism and experience. Wu and Yan [11] discussed the digital landscape design mechanism under edge computing and the changes it brought. Traditional landscape design methods often rely on manual drawing and physical models, which are inefficient and prone to errors. With the development of digital technology, landscape designers have begun to use software such as CAD and BIM for design. However, this software often runs on central servers, which suffer from data transmission delays and insufficient processing capabilities. In addition, digital landscape design also requires processing a large amount of environmental data, user feedback, etc., which requires extremely high computing power and real-time performance. Xu and Wang [12] explore how to use colour effects to achieve both aesthetic and economical plant landscape design in the CDS environment. Low-cost plant landscape design has become a new trend in the field of landscape design. This design approach emphasizes not only resource conservation but also the use of local plants and low-cost materials to create an ecological, beautiful, and economical landscape space. As an indispensable element in landscape design, the application of colour is crucial for improving design quality. The computer-aided collaborative design system provides convenience for low-cost plant landscape design by integrating multiple design tools and technologies. It allows designers to perform plant configuration, colour matching, and effect simulation in virtual environments, thereby more accurately predicting and optimizing design effects. In addition, CDS also supports collaborative work among multiple people, promoting communication and collaboration among team members and improving design efficiency and quality.

Chinese landscape painting, as a treasure of Chinese culture, showcases the harmonious unity of nature and humanity with its unique composition, brushstrokes, and colours. However, with the changes of the times, the inheritance and development of traditional landscape painting face many challenges. In recent years, with the rapid development of computer technology, the application of computer-aided design and reinforcement learning in the field of art has gradually emerged. This provides new opportunities for the fine-grained style restoration and visual intelligence of Chinese landscape painting. Xu et al. [13] used CAD software for precise terrain modelling, stroke simulation, and colour matching in order to restore the style characteristics of traditional landscape painting more realistically. In addition, CAD technology can also help designers quickly generate multiple design schemes and conduct comparative analyses, improving creative efficiency and quality. With the continuous improvement of people's demand for environmental aesthetics and personalization, landscape design is gradually shifting from traditional fixed modes to more flexible and configurable directions. In this context, configurable landscape design based on hierarchical imitation models has emerged, bringing new ideas and methods to modern landscape design. The configurable landscape design based on the hierarchical imitation model first needs to establish a library containing multiple design elements, which can be combined and configured according to different design requirements. Then, a hierarchical imitation model is used to evaluate and select each design element, generating a design solution that meets user needs and aesthetic principles. Yavich et al. [14] adjusted and optimized the model according to the actual situation to ensure that the final design scheme meets both functional requirements and has good visual effects.

Computer vision interaction design, with its unique advantages, provides innovative solutions for sustainable urban development. Zhang and Kim [15] explored the application of computer vision interaction design in sustainable urban development through a case study of rooftop garden landscape plants in ocean cities. As a rapidly developing coastal city, ocean cities face challenges such as limited land resources and ecological pressure. To alleviate these issues, urban planners have decided to build gardens on rooftops to increase urban green space and improve the ecological environment. In this process, computer vision interaction design played an important role. The designer first used computer vision technology to measure and analyze the roof space accurately and determine the layout and plant configuration of the garden. Then, through computer vision interaction design, designers interact with users to collect their expectations and suggestions for the garden landscape. Based on this feedback, the designer optimized the garden design. The importance of colour in landscape design is increasingly prominent. Zhang and Deng. [16] explored how colour affects the effectiveness of landscape design in the CDS environment and how to optimize the colour application to enhance the overall quality of design. Colour is a crucial visual element in landscape design, which can evoke emotional resonance, affect spatial perception, and create an overall atmosphere. The computer-aided collaborative design system provides powerful tools for landscape designers, making colour applications more precise and efficient. The computer-aided collaborative design system integrates multiple design tools and technologies, allowing designers to work collaboratively on a shared platform to communicate and modify designs in real-time. In terms of colour design, CDS allows designers to accurately simulate and predict the effects of different colour combinations, enabling more scientific and systematic colour planning. It utilizes the real-time simulation function of CDS, allowing designers to instantly view the effects of different colour combinations and make adjustments and optimizations as needed.

Traditional gait training methods often rely on fixed impedance settings and lack personalized adjustments tailored to individual differences. However, with the rapid development of artificial intelligence technology, especially the application of reinforcement learning algorithms, new solutions have been provided for impedance control in gait training. Zhang et al. [17] analyzed how reinforcement learning shapes personalized impedance landscape design for gait training. Reinforcement learning is a machine learning technique that learns optimal behavioural strategies through trial and error. It continuously optimizes behavioural strategies based on feedback signals (rewards or punishments) through interaction with the environment, ultimately achieving the goal of maximizing cumulative rewards. In gait training, we can apply reinforcement learning algorithms to impedance control, optimizing the patient's gait performance by continuously adjusting impedance parameters. It uses advanced algorithms such as deep reinforcement learning to shape personalized impedance landscapes. 3D CAD technology is playing an increasingly important role in landscape design. Zhao [18] introduced the basic application of 3D CAD in landscape design. Subsequently, it delved into how to use this technology to optimize the levels and details of design, aiming to provide more efficient and accurate design methods for landscape designers. Landscape design is a complex and comprehensive process that involves multiple aspects, such as terrain, plants, water bodies, and architecture. Traditional two-dimensional design methods often struggle to fully showcase the three-dimensional effects of design, and the emergence of three-dimensional CAD technology has brought revolutionary changes to landscape design. By utilizing 3D CAD technology, designers can accurately simulate and display the ups and downs of terrain, providing basic data for subsequent plant configuration, water body design, and more. Through 3D CAD, designers can simulate the growth effects of different plants under different terrain and lighting conditions, achieving more reasonable plant configuration. 3D CAD technology can simulate the flow, reflection, and other effects of water bodies, allowing designers to adjust and optimize design schemes more intuitively.

Although scholars have done a lot of meaningful research in the field of landscape design, there are still some shortcomings. These studies often only focus on one aspect of technology or method and fail to form a comprehensive solution. Some studies have limitations in data collection and processing and user feedback mechanisms, which affect the accuracy and reliability of the results. This article puts forward a comprehensive individualized and interactive enhancement method of landscape design and forms a comprehensive and systematic solution by integrating many advanced technologies, such as CAD, RL algorithm and user preference modelling.

3 METHODOLOGY

The evolving landscape of computer science and artificial intelligence technology is driving unprecedented changes in the realm of landscape design. Traditional methods, often reliant solely on designers' experience and intuition, struggle to meet the escalating complexity and diversity of user needs. This article introduces a novel approach to landscape design, leveraging mathematical modelling and RL algorithms. The aim is to craft intelligent and precise designs tailored to the unique preferences of each user. To capture users' preferences and real-time feedback, we've developed a comprehensive data collection mechanism. This mechanism collects a wide range of user preferences for landscape design, including spatial layout, plant configuration, and material selection. It also gathers real-time feedback data to ensure designs align with users' evolving needs. To ensure the integrity and reliability of this data, we employ advanced data cleaning and preprocessing techniques. This involves removing duplicate data, addressing missing values, and handling any abnormalities. This rigorous data processing enhances the quality and analytical value of the information, ensuring it forms a solid foundation for our design decisions. To translate landscape design challenges into mathematical frameworks, we have established the following mathematical models:

⊖ Design Variables: We define the set of design variables as:

$$X = \; x_1, x_2, \ldots, x_n \tag{1}$$

Where x_i represents the i design element or parameter, such as plant species, layout, etc.

⊜ Objective function: Define the objective function $f\ X$ to measure the overall performance of the design solution. According to the needs of landscape design, the objective function can include multiple aspects such as aesthetic value, functionality, and ecological sustainability. The specific form of the objective function depends on the specific design task and user needs.

⊛ Constraints: In actual design, the design scheme needs to meet certain constraints, such as budget constraints, space constraints, etc. We represent these constraints as inequalities:

$$g_j\ X\ \le 0 \tag{2}$$

Where j represents the j th constraint.

Landscape design problems can be transformed into the following mathematical optimization problems:

$$g_j\ X\ \le 0 \tag{3}$$

Where m represents the number of constraints.

RL is a machine learning method that teaches the optimal decision strategy through trial and error. In landscape design, the design scheme can be regarded as the "action" of the agent, the user satisfaction and design performance as the "reward," and the optimal design scheme can be found through trial and error. The RL structure of landscape design is shown in Figure 1.

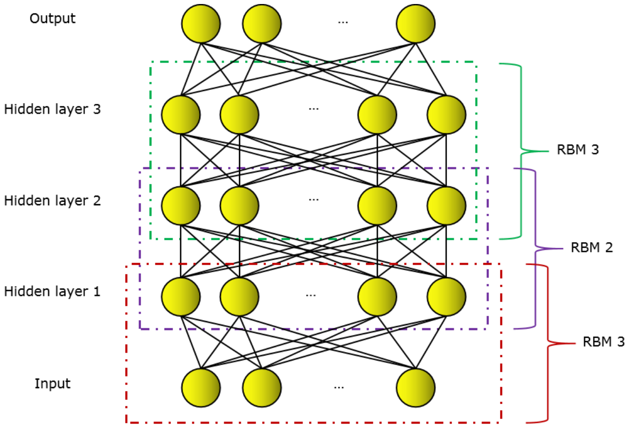

Figure 1: RL structure.

Convolution is essentially filtering the signal. In landscape design, the user's real-time feedback signal can be regarded as an input signal, which can be processed by convolution operation to extract useful information to guide the optimization of the design scheme. By constructing a special convolution kernel (also called a filter), we can control the image to achieve different image processing effects. In landscape design, the convolution principle can be used to process the image of the design scheme to highlight the key areas or details concerned users and enhance the visual effect and interactivity of the design scheme. Figure 2 shows the convolution principle of the model.

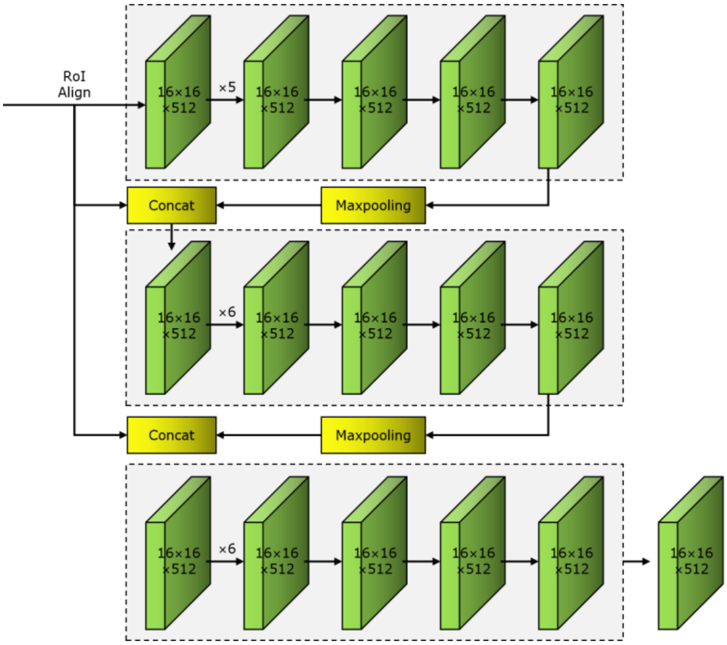

Figure 2: Convolutional principle of the model.

The system needs to collect a large amount of user preference and real-time feedback data. The collected data often contains noise and inconsistencies, necessitating preprocessing steps such as data cleaning, normalization, and feature extraction to ensure its accuracy and usability. In RL, the environment refers to the entity with which the agent interacts. For landscape design systems, the environment includes various attributes of the design scheme and models of user preferences. The system needs to convert these attributes and preferences into states and reward signals that can be processed by the RL algorithm. The state usually describes the characteristics of the current design scheme and the degree of satisfaction with user preferences, while the reward signal reflects the satisfaction or preference changes of users towards the design scheme. Once the environment modelling and algorithm configuration are completed, the system can begin the training process. During training, intelligent agents learn strategies for optimizing design solutions through interaction with the environment. Specifically, the intelligent agent selects an action based on the current state (i.e., modifying the design scheme) and then observes the changes in the environment's state and reward signals. Based on this information, the agent updates its strategy to make better decisions in subsequent interactions. The training process of the landscape individualized design system is shown in Figure 3.

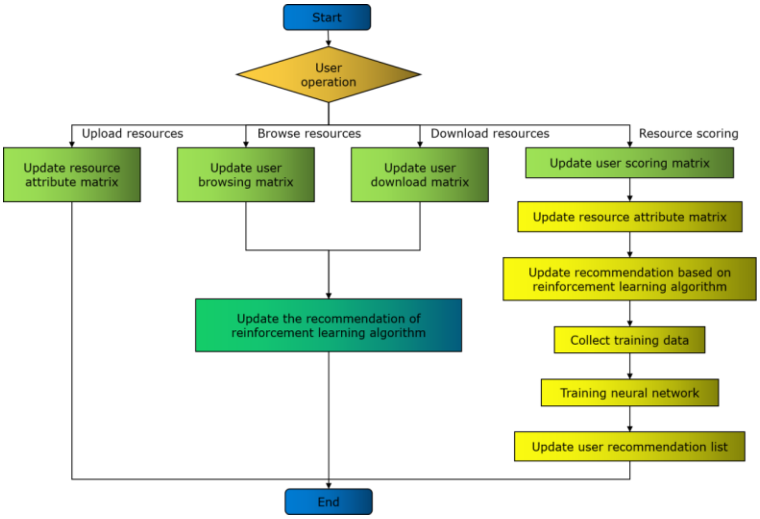

Figure 3: System training flow.

⊖ State space: State space S describes the current state in the design process. In our method, the state can be expressed as the current design scheme X.

⊜ Action space: Action space A represents the set of actions that agents can take. In our method, the action can be to modify or adjust the design scheme, such as changing the plant configuration and adjusting the spatial layout.

⊛ Reward function: The reward function $R(s,a)$ defines the reward obtained by the agent after taking action a in the state s. In order to quantify user satisfaction and design performance, we designed the following reward functions:

$$R(s,a) = \alpha \cdot UserSatisfaction(a) + \beta \cdot DesignPerformance(a) \tag{4}$$

Where α and β are weight coefficients, which are used to balance the importance of user satisfaction and design performance. $UserSatisfaction(a)$ And $DesignPerformance(a)$ respectively represent the user satisfaction and design performance score corresponding to action a.

④ Strategy function: the strategy function $\pi(a|s)$ indicates the probability of choosing the action a in the state s. We use the RL algorithm based on value iteration to optimize the strategy function. Specifically, we use the Q-learning algorithm to estimate the value function $Q(s,a)$ of each state-action pair and update the strategy function according to the value function:

$$Q(s,a) \leftarrow Q(s,a) + \alpha\left[r + \gamma \max_{a'} Q(s',a') - Q(s,a)\right] \tag{5}$$

For any policy π and state s, there are:

$$V^{\pi}(s) \leq V^{\pi'}(s) \tag{6}$$

Among them π' is a greedy strategy, and actions are selected according to the current value function:

$$\pi'(a|s) = \begin{cases} 1, \ if \ a = \arg\max_{a \in A} Q(s,a) \\ 0, \ otherwise \end{cases} \tag{7}$$

This theorem shows that the performance of the strategy can be improved by greedily selecting the best action currently considered.

4 EXPERIMENTAL VERIFICATION AND RESULT ANALYSIS

The core goal of the experiment is to assess the performance of this method in improving user satisfaction and design performance and realizing comprehensive optimization. In the preparation stage of the experiment, we collected and arranged a lot of landscape design data in real scenes, including topography, vegetation, architecture, water systems and other elements. These data not only enrich the experimental scene but also provide a basis for the subsequent data-driven design. During the experiment, we adopted the design idea of a control experiment. On the one hand, the comprehensive method proposed in this article is applied to generate an individualized landscape design scheme for users, and the interactive behaviour and feedback of users in the design process are recorded. On the other hand, we also use traditional design methods to generate solutions for users as the control group of the experiment. By comparing the results of two groups of experiments, we can clearly see the advantages of this method in individuation and interaction. We chose several typical landscape design tasks as experimental objects, including park design and courtyard design (Figure 4). For each task, we collected the user's preference data and established the corresponding mathematical model and RL algorithm.

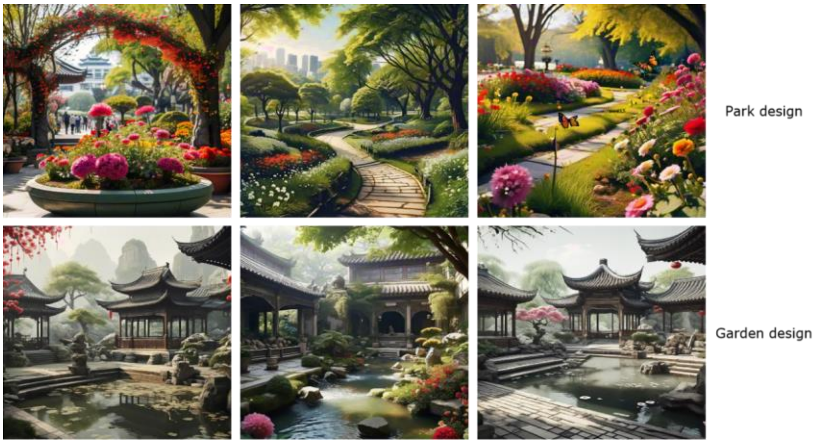

Figure 4: Landscape design task objects.

To assess the performance of the proposed method, we conducted a comparative experiment with the traditional landscape design approach. Both methods were applied to the same task and dataset. Subsequently, users were asked to assess the two design outcomes, and their satisfaction and preferences were recorded. To present the experimental findings more clearly, this study utilized the following formula for quantitative analysis:

User satisfaction rating:

$$UserSatisfactionScore = \frac{\sum_{i=1}^{N} UserSatisfation_i}{N} \tag{8}$$

Design performance rating:

$$DesignPerformanceScore = \frac{\sum_{i=1}^{N} DesignPerformance_i}{N} \tag{9}$$

Comprehensive rating:

$$OverallScore = \alpha \cdot UserSatisfactionScore + \beta \cdot DesignPerformanceScore \tag{10}$$

Where N is the number of users participating in the assessment, and α and β are the weight coefficients. By calculating these scores, the performance differences between different methods can be compared more intuitively.

User satisfaction is one of the key indicators to measure the success of a design system. As evident from Figure 5, the proposed method outperforms the traditional approach in terms of user satisfaction. This is primarily attributed to the proposed method's enhanced ability to seamlessly integrate user preferences and real-time feedback, ultimately resulting in a design scheme tailored to individual needs. Through the optimization of the RL algorithm, the system can better understand the needs of users and make corresponding adjustments in the design process, thus improving the overall satisfaction of users.

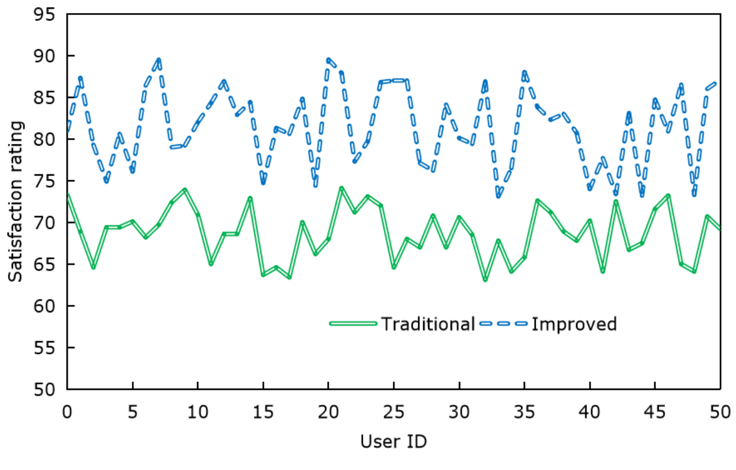

Figure 5: User satisfaction rating.

The design performance score reflects the efficiency and effect of the system in completing the design task. Figure 6 shows that the proposed method has also achieved a higher score in design performance. This is mainly due to the ability of the RL algorithm in the optimization design process. Through continuous trial and error and learning, the agent can find a more efficient design strategy so that the design scheme can meet the functional and aesthetic requirements but also better reflect the individual needs of users.

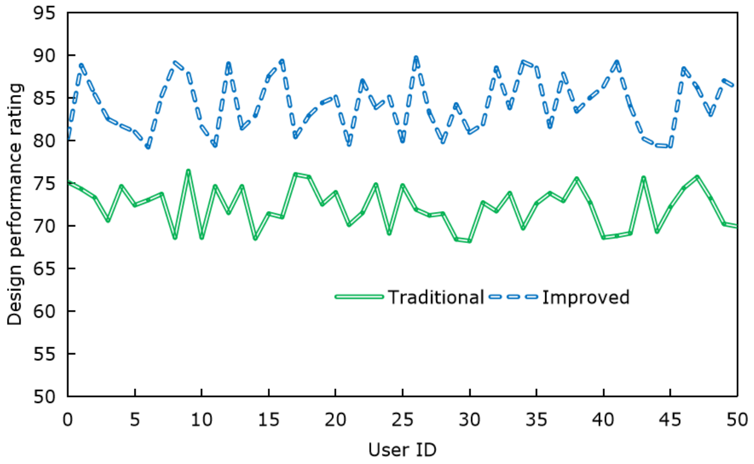

Figure 6: Design performance rating.

A comprehensive assessment is a comprehensive consideration of user satisfaction and design performance. As can be seen from Figure 7, the proposed method is also significantly superior to the traditional method in comprehensive scores. This fully demonstrates the advantages of the proposed method in individuation and interactive enhancement. By integrating CAD and RL algorithms, the proposed method not only improves the efficiency and quality of design but also provides users with a more intuitive and individualized design experience. This comprehensive advantage makes the proposed method have a broader application prospect and development potential in the future.

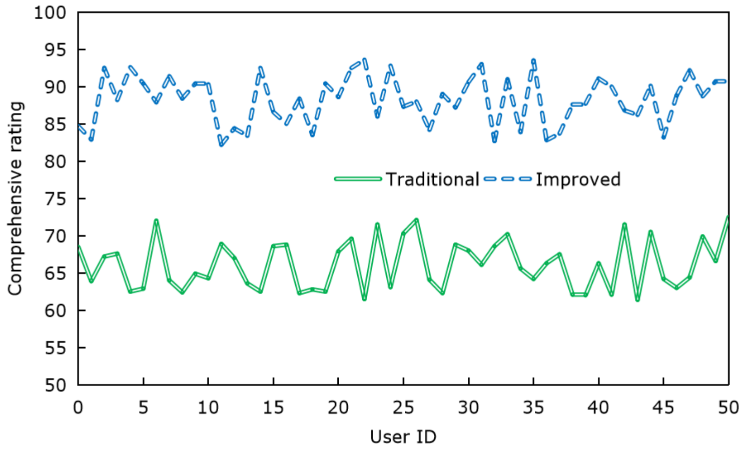

Figure 7: Comprehensive rating.

The results show that the proposed method is obviously superior to the traditional method in individuation and interaction. Specifically, users are more satisfied with the scheme designed by the proposed method and are more willing to interact with the design scheme. In addition, we also assess the convergence speed and stability of the proposed method, and the results show that the method has good convergence speed and stability.

5 DISCUSSION

This study is devoted to exploring the individualized and interactive enhancement methods of landscape design and puts forward an innovative solution by integrating CAD and RL algorithms. After experimental verification and user assessment, the proposed method shows significant advantages in user satisfaction, design performance and comprehensive score.

In terms of user satisfaction, this method can capture the individualized needs of users more accurately and adjust them in real-time during the design process to meet these needs. The traditional design method often ignores the real-time feedback from users, which leads to the deviation between the design scheme and the expectations of users. Our method continuously optimizes the design scheme through the RL algorithm, which makes the final result closer to users' psychological expectations, thus significantly improving users' satisfaction.

In terms of design performance, the proposed method shows excellent efficiency and quality. RL algorithm can find a balance between exploration and utilization, which not only ensures the innovation of the design scheme but also avoids unnecessary trial and error. At the same time, the introduction of CAD tools further improves the automation of the design process, reduces the workload of designers, and enables them to devote more energy to creative ideas and user communication.

In terms of overall evaluation, the proposed method has achieved a significant victory due to its dual strengths in user satisfaction and design performance. This clearly demonstrates the effectiveness of our approach in terms of individualization and interactive enhancement. It is noteworthy that our method exhibits excellent scalability and adaptability, making it suitable for a wide range of landscape design projects.

In conclusion, by combining CAD with RL algorithms, we have successfully achieved both individualized and interactive enhancements in landscape design. This innovative approach not only elevates the design quality but also offers users a more intuitive and personalized design experience. However, there are still challenges to be addressed, such as computational efficiency and memory consumption when dealing with complex scenes and vast datasets. To address these issues, we plan to explore more advanced algorithms and technologies in our future research, aiming to further enhance the method's performance and usability.

6 CONCLUSIONS

Addressing the need for individualized and interactive landscape design, this study introduces an innovative approach that seamlessly integrates CAD and RL algorithms. Simulation experiments and user tests reveal that this method significantly outperforms traditional methods in terms of user satisfaction, design performance, and overall rating. This demonstrates its immense potential in elevating design experiences and enhancing design efficiency.

The essence of this method lies in its ability to capture and respond to real-time changes in user preferences. Continuously optimizing the design scheme through RL ensures that the final outcome aligns closely with user expectations. This innovation not only enhances design individuality but also significantly boosts user interaction with the design process, delivering a richer and more immersive experience.

Furthermore, this study highlights the advantages of automation and intelligence offered by this method. By integrating CAD tools, the design process becomes more automated and intelligent, elevating the design quality. This not only affords designers greater creative freedom but also reduces associated costs and time.

In conclusion, this study paves the way for the evolution of landscape design, enhancing both its individuality and interactivity while promoting automation and intelligence in the design process. The widespread application and popularization of this method are expected to bring significant contributions to the design industry's innovation and advancement.

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