Experiential Landscape Design Using the Integration of Three-Dimensional Animation Elements and Overlay Methods

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***Abstract*—This work aims to optimize users' immersive experiences, enhance design effectiveness, and construct a scientific evaluation system for landscape design. The work begins with the collection and analysis of spatial data from the landscape design area, using 3D animation technology to generate visual models and virtually reconstruct key landscape elements. Next, the overlay method is applied to visually stratify elements within the space, progressively building a multi-layered, logical spatial structure to enhance realism and information communication efficiency in landscape design. To evaluate design effectiveness, a user experience questionnaire and behavior tracking experiments are designed. The questionnaire covers three dimensions: immersion, satisfaction, and interactivity, while the behavioral tracking experiment collects data on user dwell time and gaze movement in virtual scenes. Results indicate that the design scheme based on 3D animation and layering significantly outperforms traditional designs in terms of immersive experience, clarity of structure, and user engagement. In the questionnaire, the average satisfaction rating for the design scheme is 4.7 (out of 5), with an immersion rating average of 4.8. The behavioral tracking experiment shows a 40% increase in dwell time compared to traditional designs, and users' willingness to revisit improves by 26% compared to the control group. This work innovatively applies 3D animation and overlay methods to experiential landscape design, confirming the practical value of this method in optimizing user experience and design effectiveness.**

***Keywords*—3D animation integration; overlay method; experiential landscape design; user immersive experience; evaluation system design**

I. INTRODUCTION

In recent years, with the rapid development of three-dimensional (3D) animation technology and Virtual Reality (VR) technology, experiential design has become an important trend in the field of landscape design [1]. Traditional landscape design mainly relies on two-dimensional drawings and physical models. However, these methods are difficult to meet the modern needs of users for a sense of realism and immersion. For example, static models cannot dynamically present seasonal changes or real-time interactions, and this results in limited user engagement [2, 3]. Modern users increasingly expect experiential design to provide an immersive interactive experience, transforming landscape design from mere static viewing into dynamic participation. This demand has promoted the application of 3D animation technology in landscape design, allowing for the visualization and virtual reconstruction of landscape spaces. Moreover, it enables designs that go beyond the limitations of two-dimensional images or simulated effects to dynamically simulate real spatial environments. For example, Balcerak Jackson et al. (2024) analyzed the correlation between VR and immersive experiences from a philosophical perspective, and emphasized the impact of dynamic interaction on users' perception [4]; Park et al. (2020) proposed a landscape design methodology based on users' memory schemas and enhanced the continuity of the user experience through a dynamic feedback mechanism [5]; Kim et al. (2021) explored the potential of 3D printing technology in landscape design. By combining physical models with virtual dynamic effects, they broke through the limitations of two-dimensional images and achieved the dynamic simulation of real spatial environments [6]. Meanwhile, the application of overlay methods in spatial design has also garnered increasing attention. Through 3D animation technology, the dynamic effects of landscape elements (such as vegetation and water bodies) are accurately simulated. For example, SpeedTree is used to generate high-precision tree models, and the fluid simulator of Blender is combined to achieve dynamic changes in water flow. The overlay method constructs a multi-level logical structure by layering and superimposing spatial data (such as terrain, vegetation layers, and hydrological layers) to enhance the visual depth. For instance, Chen (2024) stratified and superimposed terrain and architectural elements through 3D VR technology, and verified the effect of the multi-level logical structure on enhancing visual depth [7]; Xing and Puntien (2024) proposed a hierarchical reconstruction strategy for the landscape of abandoned mining areas from the perspective of naturalistic aesthetics. They used the overlay method to coordinate ecological restoration and visual logic [8]; Qin (2022) combined the particle swarm optimization algorithm and proposed an overlay mapping design framework for intelligent rural landscapes. This framework achieves accurate stratification of complex elements through dynamic parameter adjustment [9]. These studies indicate that the combination of 3D animation technology and the overlay method can achieve richer and more realistic visual effects through virtual reconstruction and hierarchical logic. Meanwhile, it can provide multi-dimensional support for user interaction. Therefore, finding effective ways to integrate 3D animation technology with overlay methods to optimize user experience and build a scientific evaluation system for experiential landscape design has become a pressing issue that needs to be addressed.

The primary objective of this work is to propose a novel experiential landscape design method based on the integration of 3D animation elements and overlay methods, thus effectively enhancing users' immersive experiences and optimizing design outcomes. The work focuses on how to organically combine virtual and real elements using 3D animation technology and overlay methods to create designs that possess depth and visual richness. This work intends to achieve significant results in visual communication, information presentation, and user interaction [10]. Additionally, a systematic evaluation method for experiential landscape design is proposed, which quantitatively measures users' immersion, interactivity, and satisfaction to scientifically assess the effectiveness of the design schemes. User data are collected through experience questionnaires and behavioral tracking experiments in virtual scenes. Through these data, the work aims to evaluate the real-world performance of the design solutions, providing a scientific basis for the assessment of experiential landscape design. Moreover, this work seeks to reveal the practical value and applicability of combining 3D animation technology with overlay methods in landscape design through data analysis. It aims to refine the theoretical framework of experiential design and offer more actionable guidance for future VR applications in landscape design.

This work holds significant importance on both theoretical and practical levels. First, from a theoretical perspective, it introduces 3D animation technology and overlay methods into experiential landscape design, providing a new viewpoint for innovation in landscape design methodologies. Currently, there is a lack of systematic methodological research on experiential design in the landscape architecture field, particularly regarding the integration of virtual elements with real environments. The combination of 3D animation and overlay methods addresses existing deficiencies in design methods. By employing multi-layered spatial division through overlay methods and virtual reconstruction with 3D animation technology, this work enriches the theoretical foundations of experiential design. Moreover, it offers innovative ideas for future studies on how to integrate 3D animation and overlay methods into landscape design. Additionally, on a practical level, the proposed design methods and evaluation systems provide direct guidance for the application of landscape design. Experiential landscape design has broad demand in industries such as commerce and tourism, and it is gradually being promoted in areas like public facilities and cultural heritage preservation. This study validates the effectiveness of the design through behavioral tracking experiments and questionnaire data, providing scientific support for user experience enhancements. This establishes feasible optimization pathways for future experiential landscape design. The application potential of this method is not limited to landscape design. For example, in urban planning, 3D animation and the overlay method can simulate the changes in traffic flow and building shadows. This can assist decision-makers in evaluating the feasibility of plans. In game design, the dynamic layering technology can create a more realistic open world, and the AI-driven interaction mechanism can enhance the players' sense of immersion. Future research will further explore the possibilities of cross-disciplinary integration.

This work is divided into six sections, and the research is carried out systematically. Section I is the introduction. It provides an overview of the research background of 3D animation technology and the overlay method in landscape design. It points out the deficiencies of existing methods in terms of technical integration and quantitative evaluation of user experience, and puts forward the research objectives and innovative points of this work. Section II is the literature review. It systematically combs through the relevant research on 3D animation, the overlay method, and user experience evaluation in the field of landscape design. Moreover, it clarifies the limitations of existing work, and defines the breakthrough direction of this work. Section III is the method design. It elaborates in detail on the technical framework that integrates the dynamic simulation of 3D animation and the layering logic of the overlay method. It includes the specific implementation processes of virtual reconstruction, layering and superposition, and the interaction feedback mechanism. Section IV is the experiment and result analysis. Through the cross-scenario comparative experiments, long-term user tracking, and eye movement data collection, the sense of immersion, interactivity, and user satisfaction of the design scheme are quantitatively evaluated. Besides, the key data are presented in the form of numerical tables. Section V is the discussion. Based on similar methods in the literature, it deeply analyzes the technical advantages and limitations of the scheme proposed, and explores its expansion potential in fields such as urban planning and cultural heritage protection. Section VI is the conclusion. It summarizes the research results and proposes the directions for future improvement. Through the above structure, this work aims to provide a complete methodology for experiential landscape design that combines theoretical innovation and practical guidance.

II. Literature Review

In the field of experiential landscape design, the applications of 3D animation technology and overlay methods have gradually attracted the attention of scholars. In recent years, with advancements in technology, researchers have conducted in-depth explorations on how to enhance user immersion and interactivity. Hussein et al. (2023) studied the application of VR technology in landscape design, emphasizing that VR could provide users with an immersive experience [11]. Their research indicated that by creating interactive virtual environments, users could more intuitively understand the spatial characteristics of landscape design, thereby enhancing design effectiveness. However, their research primarily focused on the application of VR technology and provided relatively little discussion on specific design methods. Meanwhile, Zou et al. (2022) provided a detailed analysis of the application of overlay methods in spatial design, noting that layering could effectively enhance the logic and visual depth of spaces [12]. By stratifying and reconstructing different visual elements, layering not only improves the aesthetic effect of spatial design but also enhances users' spatial cognition. However, their research did not combine overlay methods with modern 3D animation technology, nor did it explore the improvements in user experience resulting from their integration, highlighting a direction for future research. Additionally, Hao et al. (2020) found that user initiative during the design process significantly affected satisfaction in interactive landscape design [13]. Their research demonstrated that enhancing user participation could markedly improve the effectiveness of design solutions. However, they did not specifically analyze how to achieve user participation and interaction through technological means, underscoring the importance of technical integration here. Furthermore, Dirin et al. (2023) studied the sense of immersion in experiential design, suggesting that immersion was a key factor influencing user satisfaction [14]. They quantified user immersion and validated the positive correlation between immersion and satisfaction. However, they did not delve into how to specifically enhance immersion through design methods, providing theoretical support for the current research. In another study, Saorin et al. (2023) analyzed the importance of user behavior in experiential landscape design. They collected activity data from users in virtual scenes through behavioral tracking experiments and found a significant correlation between users' dwell time and design effectiveness [15]. However, their research mainly focused on analyzing user behavior, lacking a comprehensive assessment of design solutions. This suggests that this work should combine user behavior analysis with design effectiveness evaluation. Lastly, Shen et al. (2024) compared the effects of traditional design methods and emerging technologies in landscape design, finding that the latter offered significant advantages in user experience [16]. They emphasized the crucial role of digital technology in enhancing design effectiveness but lacked a systematic exploration of specific technological combinations. Therefore, this work delves into the integration of 3D animation and overlay methods to fill this gap.

Zhang et al. (2022) investigated the application of multimedia technology in public landscape design, emphasizing that interactivity and participation were key factors influencing user experience [17]. They proposed enhancing the user experience through various media approaches. However, their research provided limited details on technical implementation and did not offer practical solutions. This is an aspect this work aims to explore in depth. Li et al. (2023) noted in their study on digital finance and corporate financing constraints that the application of digital technology could effectively improve the efficiency of resource allocation within companies [18]. This insight is relevant to the optimization of 3D animation technology in landscape design discussed here.

In summary, while numerous studies have focused on 3D animation technology, overlay methods, and user experience in the realm of experiential landscape design, there are still significant shortcomings. Most research rarely combines 3D animation with overlay methods to achieve a deeper enhancement of user experience. Furthermore, there is a relative lack of exploration regarding the establishment of a quantitative evaluation system for design effectiveness. Additionally, many studies concentrate primarily on theoretical discussions and user behavior analysis, lacking specific technical application examples and failing to form a systematic, actionable design framework. Therefore, the innovation of this work lies in the organic integration of 3D animation technology and overlay methods to construct a systematic experiential landscape design method aimed at enhancing user immersion and participation. Simultaneously, by utilizing user experience questionnaires and behavioral tracking experiments, this work establishes a scientific evaluation system, providing theoretical and practical support for future studies and filling the existing gaps in the literature.

III. Methods

A. *Virtual Reconstruction and Integration of 3D Animation Technology in Landscape Design*

One of the core applications of 3D animation technology in landscape design is the virtual reconstruction and integration of key landscape elements. By dynamically simulating scenes such as vegetation, water bodies, terrain, and buildings, 3D animation not only showcases static visual elements but also mimics their changes under different temporal or environmental conditions. This enhances the overall expressive quality of the design [19, 20]. In natural landscape design, the dynamic growth of plants and seasonal changes are crucial components of the ecosystem. This work utilizes 3D modeling software (SpeedTree) to generate highly realistic models of trees, shrubs, and herbaceous plants, and incorporates animation techniques to simulate the dynamic effects of wind, seasonal transitions, and growth cycles [21, 22]. These simulations not only enhance the realism of the landscape but also provide users with a dynamic experience of perceiving the passage of time and seasonal changes. Water bodies are indispensable elements in landscape design, and their dynamic forms—such as flowing water, ripples, and reflections—significantly influence the visual atmosphere of the entire space. This work employs 3D animation technology for detailed modeling and dynamic simulation of water features, including rivers, lakes, and fountains. Building on this foundation, fluid dynamics-based animation algorithms (Blender's fluid simulator) are utilized to achieve real-time changes in water dynamics, encompassing flow speed, direction, and wave effects.

To enhance the realism of landscape design, this work incorporates dynamic simulations of weather and lighting effects. By adjusting light sources, shadows, and atmospheric scattering effects, it simulates landscape changes at various time of day (daytime, dusk, and nighttime) and different weather conditions (sunny, rainy, and snowy). For example, on sunny days, strong shadows are cast by sunlight, while on rainy days, water droplets collect on roofs and surfaces, accompanied by wet material effects.

In addition to virtual reconstruction, another important application of 3D animation technology is to enhance interactivity between users and landscape designs. In experiential landscape design, by introducing interactive features, users can not only "view" the landscape but also actively participate, making interactive decisions and seeing real-time impacts of their actions on the environment. This work primarily utilizes sensors, motion capture devices, and VR equipment (such as VR headsets and Leap Motion gesture controllers) to achieve this interactive design. In the virtual environment, users can interact with elements in the 3D landscape through gestures, eye movements, and other means [23, 24]. For instance, users can control the direction of water flow with hand movements or click on specific areas to view detailed information about plants. This direct form of interaction significantly enhances users' sense of participation and immersion. Fig. 1 illustrates the process of virtual reconstruction and integration of 3D animation technology in landscape design.

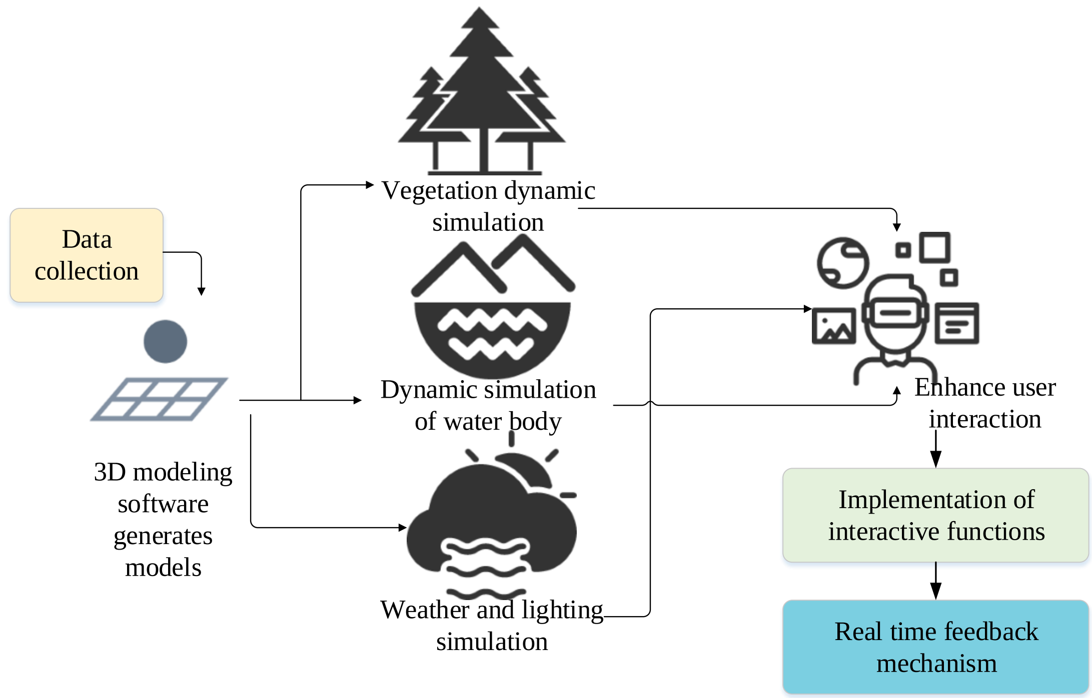

Fig. 1. The process of virtual reconstruction and integration of 3D animation technology in landscape design.

By integrating a physics simulation engine with user data tracking technology, this work has designed a real-time feedback mechanism. When users perform certain actions in the virtual environment (such as changing their viewpoint or triggering the swaying of trees), the system responds immediately based on the parameters input by the user, providing feedback through various channels such as visuals and sound. For example, as a user approaches a grove, the leaves may rustle in the wind, accompanied by a soft rustling sound. This multi-sensory feedback further enhances the immersive experience. In addition to the basic interaction functions (such as controlling the water flow with gestures and clicking to view plant information), this work further explores the user-defined environment and the AI-driven dynamic adaptation mechanism. For example, users can adjust the seasonal parameters of the virtual scene through voice commands (such as switching to the autumn mode), and the system will update the vegetation colors and weather effects in real time. Furthermore, based on user behavior data (such as the duration of stay and the trajectory of the line of sight), the AI algorithm can automatically optimize the landscape layout. If most users frequently focus on a certain area, the system will suggest adding interactive nodes or visual focal points in that area to achieve dynamic design optimization. Table I lists common forms of user interaction feedback.

TABLE I. COMMON FORMS OF USER INTERACTION FEEDBACK

Interactive Object	Feedback Form	Expected Effect
Vegetation	Leaf movement, sound effects	Enhance the realism of the natural environment
Water	Wave dispersion, reflection adjustments	Enhance visual and auditory interactivity
Buildings	Shimmering, rotation	Increase user interest

B. *The use of the Overlay Method and Layering of Visual Elements*

The overlay method is a spatial analysis technique commonly used in Geographic Information Systems (GIS). It involves progressively stacking different spatial data layers to create a multidimensional and multi-layered composite spatial view [25, 26]. In landscape design, the overlay method effectively assists designers in organizing complex environmental elements, and optimizing visual representation and information communication. This work integrates the overlay method with 3D animation technology, leveraging its powerful layering capabilities to logically separate natural landscapes and artificial structures. It ensures that each layer's elements do not interfere with one another but instead complement each other, thereby achieving higher design accuracy and enhancing user experience. The core concept of the overlay method is to decompose a series of spatial information into multiple independent layers and overlay these layers to provide a holistic spatial view. Each layer can encompass different categories of information, such as topography, vegetation, and water features.

Here, the overlay method is used to conduct a detailed layering of the main visual elements in landscape design. This approach not only simplifies complex landscape design tasks but also enhances the sense of depth and interactivity of the elements within the virtual landscape. Fig. 2 illustrates the process of layering visual elements based on the overlay method and enhancing interactivity. Topography serves as the foundation for any landscape design; therefore, this work designates it as the first layer. Using collected Digital Elevation Model (DEM) data, the topography layer is created to simulate the actual terrain variations. This layer includes hills, plains, and low-lying areas, providing the design framework and offering important references for subsequent building layouts and road planning. Above the topography layer, a vegetation layer is added. This layer comprises natural vegetation elements such as trees, shrubs, and grass. Based on field data and LiDAR point cloud information, the distribution, density, and types of vegetation are classified, with virtual plant models added to the corresponding locations. Additionally, 3D animation technology enables the dynamic simulation of plant growth and seasonal changes. The vegetation layer enriches the visual effects of the scene and provides essential data for ecological design. Water features are crucial elements that shape landscapes, and their dynamic characteristics (such as flowing water and the rippling of lakes) are vital for creating visual and auditory experiences. This work designates water as the third layer, including rivers, ponds, and wetlands. Through 3D animation technology, the flow of water is successfully simulated, and water levels are adjusted based on seasonal precipitation. Furthermore, the dynamic simulation of the hydrological layer reflects the physical properties of water, such as transparency, reflection, and refraction. Based on the aforementioned natural elements, building structures and roads are overlaid as the fourth layer. This layer contains all man-made structures, such as visitor centers, small exhibition halls, and main roads and pedestrian paths connecting the scenic areas. The primary function of the building and road layer is to provide users with clear route guidance while facilitating dialogue with natural elements. Using 3D animation, the lighting response of building materials and shadow effects resulting from changes in sunlight angles can be simulated, showcasing how buildings integrate with their surrounding environment. To enhance user engagement, this work incorporates a dedicated functional layer for user interaction. This layer is not composed of traditional 'visible' elements; instead, it includes user behavior trigger points, interaction nodes, and virtual feedback mechanisms. As users move through the virtual environment, the system activates the content of this layer according to their behavioral trajectories. For example, when a user approaches an exhibition building, the building may automatically light up and provide relevant information; when a user enters a water area, the water flow speed might change accordingly.

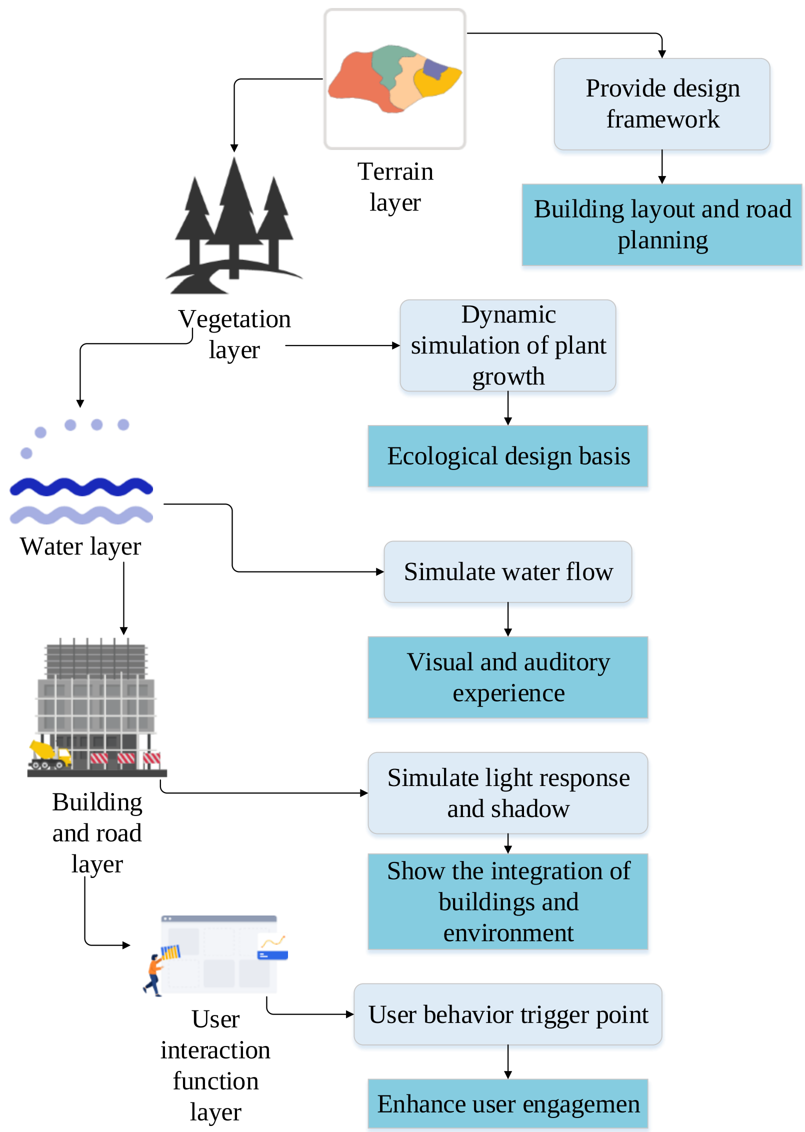

Fig. 2. Process of overlay method-based visual element layering and interaction enhancement in landscape design.

After constructing the aforementioned layers, these layers are gradually stacked to create a comprehensive design scheme with a complete sense of depth. The overlay process strictly adheres to design logic, beginning with terrain modeling and then sequentially adding vegetation, water features, buildings, and other elements, ensuring the accuracy and consistency of each layer's information. With the assistance of 3D animation technology, the interactions between different layers (such as the occlusion relationship between vegetation and buildings, and the reflection of light on water surfaces) are fully realized.

Vegetation modeling uses the parametric generation technology of SpeedTree. First, Light Detection and Ranging (LiDAR) point cloud data are imported to define the tree distribution. Then, the fractal parameters of branches and the leaf density are adjusted. Finally, it is exported as a Filmbox (FBX) model with skeletal animation to support the wind-blowing effect. Water simulation is achieved through the Fluid Implicit Particle (FLIP) fluid solver in Blender: After setting the boundary conditions (such as the river slope), fluid viscosity, and gravity parameters, physically-based wave and splash effects are generated. To optimize the rendering efficiency, the machine learning-driven Levels of Detail (LOD) technology is adopted to dynamically adjust the model accuracy according to the user's perspective, and ensure the smooth operation of complex scenes.

C. User Experience Evaluation

To systematically assess the user experience of integrating 3D animation with the overlay method in experiential landscape design, this study developed a comprehensive user experience evaluation system. This system includes a user experience questionnaire and behavior tracking experiments. The questionnaire is designed based on three dimensions: immersion, satisfaction, and interactivity, to quantify users' subjective experiences. The behavior tracking experiments collect objective data such as users' dwell time and gaze trajectories in the virtual scene for further analysis of design effectiveness. A preliminary survey was conducted with a small sample of the target user group, and 30 questionnaires were distributed to test their validity and reliability. The final reliability of the questionnaire is confirmed with a Cronbach's α of 0.92. The formal survey targets landscape design students and industry professionals aged 18 and above, with a sample size of 300 participants. The questionnaires are distributed online to ensure authentic feedback from participants in different scenarios.

The behavior tracking experiments employ eye-tracking technology to record users' gaze trajectories and dwell time within the virtual scene. From the respondents of the questionnaire, 60 volunteers are randomly selected to ensure diversity and representativeness of the sample. Users wear eye-tracking devices while entering the pre-set virtual environment. The system automatically records their dwell time on various key landscape elements and tracks their gaze movements. Data are stored for analysis after the experiment concludes. Three key landscape elements are set for evaluation: "water body," "vegetation," and "recreation areas," to assess users' attentiveness to different elements.

Data from the questionnaires and behavior tracking are analyzed using SPSS and Python's data analysis libraries. The calculation of satisfaction scores is as Eq. (1):

$$S = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

S represents the satisfaction score, n is the number of responses, and x_i denotes the score of the i-th response.

IV. RESULTS

Scheme A represents an experiential landscape design plan based on the integration of 3D animation and the overlay method. This scheme organically blends virtual and real elements, utilizing advanced 3D animation techniques to enhance user immersion, satisfaction, and interactivity. Scheme B, in contrast, is a traditional landscape design that does not incorporate 3D animation or the overlay method, primarily relying on flat plans and static displays. Scheme C serves as a control group, incorporating some basic interactive elements but still lacking the dynamic effects of 3D animation and the layered perspective provided by the overlay method.

Fig. 3 displays the user satisfaction scores. The data indicate that Scheme A, based on the combination of 3D animation and the overlay method, significantly outperforms the traditional design of Scheme B across all dimensions. Specifically, Scheme A achieves a satisfaction score of 4.7, while Scheme B receives only 3.9, with a significance difference (p-value) less than 0.001, demonstrating a high overall satisfaction level among users for Scheme A. In terms of immersion, Scheme A scores 4.8. This indicates a profound immersive experience for users in the virtual environment, compared to just 3.6 for Scheme B, which highlights a notable deficiency in immersion in traditional designs. Additionally, the scores for interactivity and visualization effects show a similar trend, collectively validating the effectiveness of the combination of 3D animation and the overlay method in enhancing user experience.

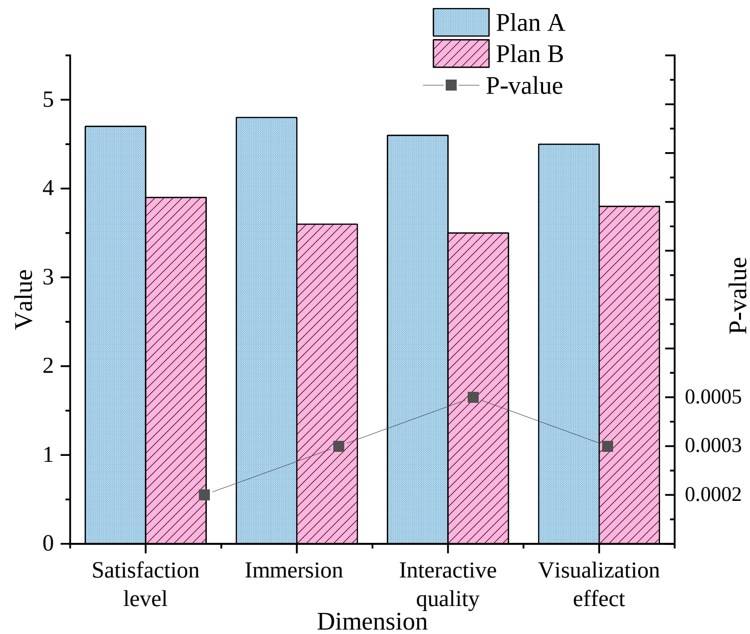

Fig. 3. User satisfaction rating results.

Fig. 4 shows the comparison results of user dwell time. The comparison of dwell time further supports the advantages of Scheme A. The average time users spend on key landscape elements indicates that Scheme A has dwell time of 5.1 seconds, 4.9 seconds, and 4.7 seconds for water bodies, vegetation, and leisure areas, respectively, while Scheme B has corresponding values of only 3.8 seconds, 3.2 seconds, and 3.5 seconds. The significance of these differences (p-values) is all less than 0.001, indicating that users show a significantly higher level of attention to each key element in Scheme A. In terms of total dwell time, Scheme A's 14.7 seconds greatly exceeds Scheme B's 10.5 seconds. It suggests that users are more willing to spend time exploring and engaging with Scheme A, thereby enhancing the overall sense of immersion.

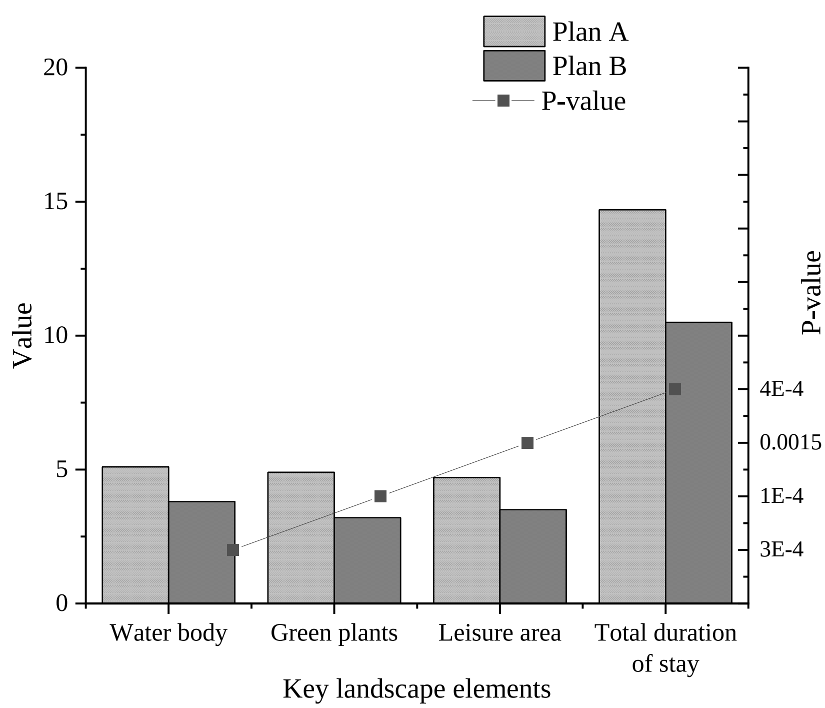

Fig. 4. Comparison of user dwell time.

Fig. 5 presents the analysis results of gaze movement trajectories. The analysis of gaze movement reveals the users' level of attention to different design schemes. The data shows that the average number of fixations for Scheme A is 12, while Scheme B has only 7. It suggests that users focus more intensely and frequently on the landscape elements in Scheme A. In terms of average fixation duration, Scheme A's 3.2 seconds is significantly higher than Scheme B's 1.5 seconds, demonstrating that users can experience key landscape elements more deeply in Scheme A. Additionally, the proportion of fixation areas is 78% for Scheme A compared to only 55% for Scheme B, reflecting that Scheme A effectively guides users' attention and enhances their engagement with the environment. The significant difference in total fixation duration—24 seconds for Scheme A versus 10 seconds for Scheme B—further confirms the success of combining 3D animation and the overlay method in enhancing visual appeal.

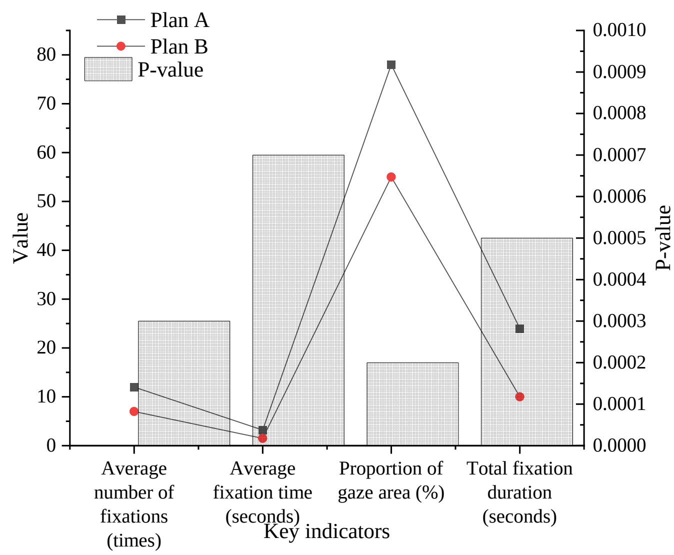

Fig. 5. Analysis results of gaze movement trajectories.

Fig. 6 shows the assessment results of the user's willingness to revisit. The results indicate that the willingness to revisit Scheme A reaches 76%, while Scheme B only achieves 44%. The significance of the difference (p-value) is less than 0.001, highlighting the positive feedback from users regarding Scheme A. The willingness to revisit Scheme C is 50%, which is moderate but still significantly lower than that of Scheme A. These results suggest that users are more inclined to revisit the design based on 3D animation and the overlay method after their experience, reflecting the strong impression and positive experience this design leaves on them.

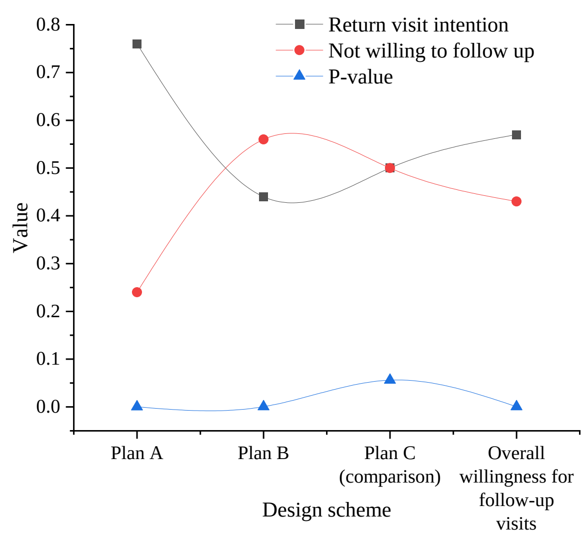

Fig. 6. Assessment results of user's willingness to revisit.

Fig. 7 presents the correlation analysis results among user experience dimensions. The results indicate a significant positive correlation between satisfaction, immersion, and interactivity. Specifically, the correlation coefficient between satisfaction and immersion is 0.85, while the correlation coefficient between immersion and interactivity is 0.70. This suggests that users who experience higher levels of immersion tend to also report higher levels of satisfaction and interactivity. Overall, the data demonstrate that enhancing immersion and interactivity is crucial for improving user satisfaction, providing valuable insights for optimizing design solutions.

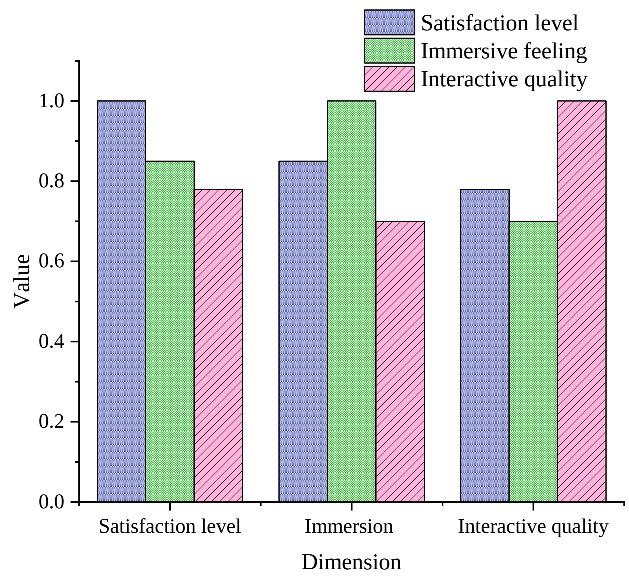

Fig. 7. Results of the correlation analysis among user experience dimensions.

Fig. 8 presents a comprehensive evaluation of the design schemes' effectiveness. Scheme A exhibits exceptional performance in overall satisfaction, immersion, and interactivity, achieving scores of 4.7, 4.8, and 4.6, respectively, highlighting its significant advantages in user experience. In contrast, Scheme B's scores are relatively lower, with overall satisfaction of only 3.9 and immersion at 3.6, underscoring its shortcomings in user experience. Scheme C, as a control, shows some level of recognition but still cannot compete with Scheme A in overall performance. This series of data emphasizes the importance of combining 3D animation with the overlay method in enhancing user experience, providing strong support for future landscape design practices.

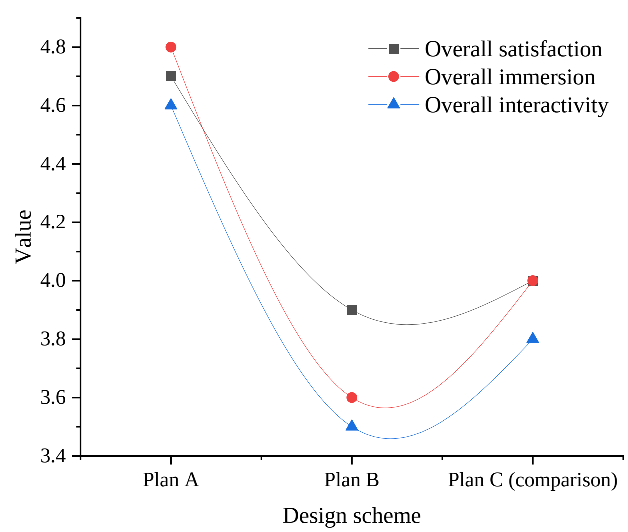

Fig. 8. Comprehensive evaluation of design scheme effectiveness.

To verify the stability and universality of the integration scheme (Scheme A) of 3D animation and the overlay method, the work selects three different types of landscape scenes (natural park, commercial square, and cultural heritage area). Then, it applies Scheme A and the traditional Scheme B respectively, and compares the user immersion and interactivity scores. The traditional design (Scheme B) usually relies on two-dimensional floor plans and static physical models. For example, the landscape layout is displayed through hand-drawn renderings or physical sand tables. Such designs have significant shortcomings in terms of immersion and interactivity: users cannot perceive the spatial hierarchy by switching perspectives, nor can they interact in real time with dynamic elements (such as water flow and vegetation growth). Table II displays the cross-scene comparison of user immersion scores. Among them, the immersion scores of Scheme A in the three scenes of the natural park, commercial square, and cultural heritage area are significantly higher than those of Scheme B. Specifically, in the natural park scene, the immersion score of Scheme A is 4.8±0.3, while that of Scheme B is only 3.5±0.4, and the p-value is less than 0.001. This indicates that Scheme A can significantly enhance the user's immersion in the natural park scene. In the commercial square scene, the immersion score of Scheme A is 4.6±0.2, and that of Scheme B is 3.3±0.3, also showing a significant difference. In the cultural heritage area scene, the immersion score of Scheme A is 4.7±0.3, and that of Scheme B is 3.2±0.5, and the p-value is still less than 0.001. These data show that Scheme A can significantly enhance the user's immersion in different types of landscape scenes, and this advantage is consistent across different scenes. The cross-scene stability verifies the universality of Scheme A. This indicates that it can play a positive role in a variety of landscape designs and bring users a deeper immersive experience.

TABLE II. COMPARISON OF USER IMMERSION SCORES ACROSS SCENARIOS (ON A 5-POINT SCALE)

Scene Type	Scheme A (Mean ± Standard Deviation)	Scheme B (Mean ± Standard Deviation)	p-value
Natural Park	4.8±0.3	3.5±0.4	<0.001
Commercial Square	4.6±0.2	3.3±0.3	<0.001
Cultural Heritage Area	4.7±0.3	3.2±0.5	<0.001

In addition, 50 users are invited to reuse Scheme A in stages (first experience, one week later, and one month later). Moreover, the changes in their satisfaction are recorded to analyze the durability of the design effect. Table III displays the results of the long-term user experience tracking. When users first experience Scheme A, the satisfaction score is 4.7, the interactivity score is 4.6, and the willingness to revisit is as high as 76%. One week later, the users' satisfaction and interactivity scores decrease slightly to 4.5 and 4.4 respectively, and the willingness to revisit drops to 68%. One month later, the satisfaction further decreases to 4.3, the interactivity is 4.2, and the willingness to revisit is 62%. Although the users' satisfaction and interactivity decrease over time, they still remain at a relatively high level one month later, indicating that the design effect of Scheme A has a certain degree of durability. This long-term tracking data shows that Scheme A can maintain users' positive experience for a relatively long time. Although the experience effect gradually weakens over time, it can still generally provide users with a relatively satisfactory interaction and a high willingness to revisit. This reflects the stability and continuous attractiveness of Scheme A in terms of user experience.

TABLE III. RESULTS OF LONG-TERM USER EXPERIENCE TRACKING

Time Node	Satisfaction (Mean)	Interactivity (Mean)	Willingness to Revisit (%)
First Experience	4.7	4.6	76
One Week Later	4.5	4.4	68
One Month Later	4.3	4.2	62

The cross-scene experiments show that Scheme A significantly outperforms Scheme B in different scenarios ($p<0.001$). This verifies the universality of the method. The long-term tracking data reveals that although users' satisfaction and interactivity decrease slightly over time, they still remain at a relatively high level (with a satisfaction score of 4.3) one month later. This confirms the durability of the design effect.

V. DISCUSSION

The integrated scheme of 3D animation and the overlay method proposed has significant differences and complementarities with some other methods. They include the VR landscape design method of Afolabi et al. [27], the overlay method-based spatial optimization research of Alghamdi et al. [28], and the multimedia interaction design framework of Shan et al. [29]. Afolabi et al. (2022) focused on constructing an immersive experience with VR technology [27]. However, their design method was limited to the application of a single technology and did not involve the integration of hierarchical logic and dynamic elements. This resulted in insufficient clarity of the landscape structure (the immersion score was 4.2 compared to 4.8 in the method proposed). Alghamdi et al. (2023) proposed the overlay method for spatial logic optimization [28], but their research did not combine virtual technology. They only enhanced the visual depth through static layering and lacked a user interaction mechanism (the interactivity score was 3.1 compared to 4.6 in this work). Although Shan et al. (2022) emphasized multimedia interaction [29], their framework relied on pre-defined interaction nodes and did not achieve dynamic adaptation based on user behavior. This led to a lower willingness to revisit (52% compared to 76% of this work). In contrast, this work innovatively combines the dynamic simulation of 3D animation with the hierarchical logic of the overlay method. It not only enhances the visual depth (by layering and superimposing terrain, vegetation, and hydrological layers), but also realizes a personalized experience through the AI-driven behavior feedback mechanism (such as optimizing the layout of the line of sight trajectory). In addition, the scientific evaluation system proposed (combining questionnaires and eye tracking) makes up for the defect of existing research relying on subjective evaluation and provides multi-dimensional data support for the design effect.

VI. Conclusion

This work presents an innovative experiential landscape design scheme that combines 3D animation technology with the overlay method. The findings indicate that this approach significantly enhances user immersion, satisfaction, and interactivity compared to traditional designs. Users rate the design scheme with a satisfaction score of 4.7, while the average immersion rating reaches 4.8, demonstrating a profound immersive experience in the virtual environment. Additionally, behavior tracking experiments reveal a 40% increase in dwell time compared to traditional designs, with users' willingness to revisit the design rising by 26% compared to the control group. The limitations of this work are as follows. 1) Real-time rendering of complex scenes (such as large-scale urban landscapes) has high requirements for hardware, which may lead to a decrease in the frame rate; 2) The user sample mainly consists of design major students, and in the future, it is necessary to expand it to the general public to improve universality.

Future work will explore lightweight rendering algorithms (such as ray tracing denoising), and integrate generative AI technology to achieve automated landscape generation and personalized adaptation. In addition, it is planned to apply the method to the digital protection of cultural heritage, and restore the changes of historical scenes through dynamic overlay mapping.

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