Application of CAD Aided Intelligent Technology in Landscape Design

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***Abstract*—The current landscape design methods ignore the depth rendering of scene elements, resulting in low spatial utilization of landscape plant diversity index and landscape spatial pattern. Therefore, this study explores the application of CAD in landscape design. AutoCAD aided intelligent technology is adopted to display the scene in multiple directions and from all angles with terrain design, planning design and planting design as the main contents. Using 3D graphics engine to render landscape elements. On this basis, the spatial coordination planning model of plant landscape is established. The color attribute of landscape space staggered pattern is added to 3D visual reconstruction model by image library function, and the CAD intelligent technology is applied in landscape design. The results shows, the method scored higher in graphic refresh rate, visual brightness and visual contrast, a higher plant diversity coefficient in multiple iterations, and a higher spatial utilization ratio of the landscape pattern than the other two design methods, and the spatial utilization ratio of the landscape pattern of the proposed method is higher than that of the reference method.**

Keywords*—Landscape design; CAD intelligent technology; engine rendering; image library function; 3D visual reconstruction; digital design; landscape architecture

I. Introduction

Landscape design requires consideration of relevant theories, based on landscape planning and the integrated use of scientific, technology and art means to create and protect the outdoor environment. The design work needs to be both aesthetically pleasing and coherent [1]. These landscape elements provide a lot of material for creating a high-quality urban spatial environment, but to form a unique urban landscape, it is necessary to organize various landscape elements systematically and combine them with the layout to make them form a complete and harmonious landscape system and orderly spatial form. Regardless of the scale of landscape design, it is expected to achieve a step-by-step effect in space organization. Therefore, it is very important for designers to express their works in an all-round, real and even dynamic way. Current landscape design process mostly uses AutoCAD to draw the 2D construction drawings [2].

Contemporary society with the development of information technology, production methods from the past empirical to knowledge-based, scientific and information direction transition, as the human habitat of the landscape because of the impact of computer network technology, multimedia technology, electronic communication technology is showing unprecedented changes. The landscape design is also deeply engraved with the brand of information technology. Multimedia technology, computer network technology and other information technology are becoming an indispensable part of contemporary landscape design, and they are also an important driving force of landscape design changes. Through the use of information technology and from the information expression of the landscape, people feel the comprehensive impression of the landscape's efficiency and smoothness [3]. As the most widely used CAD software at present, it has rich drawing and editing functions, and provides convenient operation under friendly user interface, so it has a good reputation in the design industry. In particular, AutoCAD software can also provide various editing interfaces and tools, and strengthen the function of 3D modeling and image processing, supporting ActiveXAutomation program design interface.

The study [4] puts forward the reconstruction method of landscape spatial staggered pattern based on the coupling mechanism of pattern and process, analyzes the connotation and extension between landscape spatial pattern and ecological development process, considers that human activities will interfere with and control the reconstruction of landscape spatial pattern, and reveals the external performance and internal mechanism of landscape spatial pattern from the aspects of function and connectivity of landscape spatial pattern, Finally, the steps of landscape spatial pattern optimization are summarized to realize the optimization of landscape spatial pattern. The research [5] proposed a landscape spatial staggered pattern reconstruction method based on remote sensing image, analyzed the landscape spatial pattern characteristics of northern rural areas by using remote sensing image technology, reflected the characteristic changes of northern rural spatial pattern, and calculated the forest land area of northern rural areas by using the patch density and type of landscape spatial pattern, experiments show that proposed method can improve optimization effect of landscape spatial pattern.

The existing methods ignore the depth rendering of scene elements, which leads to the low spatial utilization of landscape plant diversity index and landscape spatial pattern. Therefore, this study explores the application of CAD in landscape design. Therefore the study uses CAD as the development platform.

II. Application of CAD Intelligent Technology in Landscape Design

A. CAD Software in Landscape Image Processing

AutoCAD (hereinafter referred to as "CAD") [6]: developed by Autodesk, USA, is the core software of choice for landscape design. It has powerful 2D graphics editing function and powerful 3D drawing and solid modeling function. It assisted intelligent technology to generate vector graph, its main feature is to generate a variety of editable straight lines, circles, text and size. It has many other editing features, such as copy, pruning, mirroring, and rotation. Mainly used for the drawing of landscape plans, elevations, sections, construction drawings, so that the main line of landscape graphics. Before making landscape, it is better to collect and set up various elements of the library system, which is of great significance to the completion of image processing quickly and beautifully. Different software needs different atlas types, according to the mountains, rocks, plants, architecture, sculpture, sketching and other related factors, you can establish different atlas system. In addition, thinning classification can improve the efficiency of graphics processing.

CAD has become an important technology for landscape designers, and CAD technology is widely used in the landscape design process because of its convenience, creativity and visual impact. It has become a mainstream technology for landscape design due to its easy modification and fast and beautiful drawing. At present, the methods applied to landscape design are mainly divided into two categories: one is the application of GIS technology; the other is the application of traditional image processing software. The former is mostly used in the planning and design of scenic spots, which can generate real topography, landscape and background, and manage and analyze geographic data. And the latter is more widely used in garden planning, elevation drawings, section drawings and rendering, which can draw more beautiful effects. The software can be divided into several modules of modeling, editing, terrain design, planning design, planting design, sprinkler design, data statistics, construction drawing production, rendering and animation production, and the overall structure of the software is shown in Fig. 1.

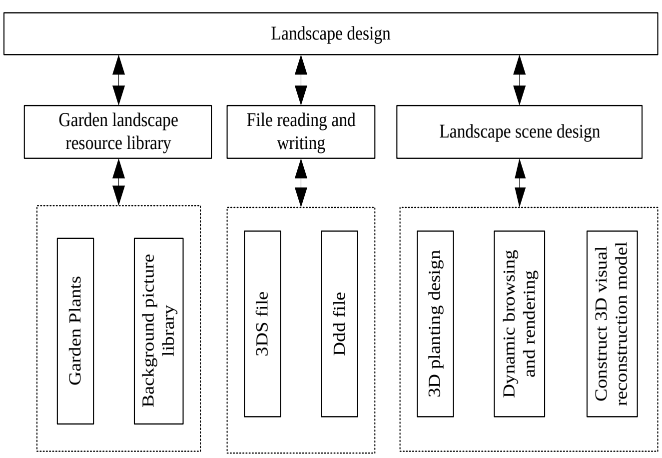

Fig. 1. Application of CAD in landscape architecture design

B. *Scene Multi Feature 3D Rendering*

In the digital technology of garden design, the system through three-dimensional animation, three-dimensional rendering, virtual scene design, the design intention is well expressed, so that the design technology of garden landscape from the original two-dimensional construction drawing stage gradually upgrade, really reach the stage of three-dimensional simulation, so that the efficiency of garden design greatly improved, in China has been applied as a commercial software, its development prospects are very promising [7-8]. 3D graphics engine is a set of functional modules that allow building full-fledged graphics applications with minimal effort. The visualizer has the ability to extend the architecture, so developers can create their own object classes, inherit them from existing objects, and thus place their own properties and rules in them. Classes can be set up as needed until the objects in the scene are rendered. 3D graphics engine creates graphics applications that use a geometric representation of the scene, i.e. lines, surfaces, edges and other objects drawn in the active window. The direct interaction of the user with the graphics application has some kind of representation of the scene display. This can complicate the use of efficient methods if the view does not have a hierarchical structure, but is represented, for example, by a simple linear array of objects. Using hierarchical scene views has several advantages. In this case, scene objects have very similar functionality and can be grouped into individual groups and then combined into higher-level groups. The advantages that platform has over 2D design drawings are shown in Table I.

Platform can be used to build the texture and transparency of water body, but it cannot reflect the refraction and reflection of the dynamic water body under the illumination of light. Static water body needs to be built by platform software first, and then the refraction and reflection of water body can be realized by animated walkthrough software, so that the water body model has strong vividness and authenticity [9, 10]. There are a large number of tree models in landscape design. If the number of trees is too large, the data and rendering consumption will be too large. TreeEngine engine can be used to load and render tree models in landscape. The tree model rendering consumption can be effectively reduced by adding the branch and leaf information of the tree model to the hierarchical detail model and building the leaf information with the Billboard model. The TreeEngine engine effectively draws and renders parameterized tree models, and includes all the functions of the OSG scene. Load the created tree model into the rendering process of the created 3D terrain scene model, as shown in Fig. 2.

TABLE I. COMPARISON WITH PREVIOUS METHODS

/	2D design drawings	Platform
Models	2D	3D
Similarity	Possible detail errors	Realistic restoration
Reuse	Inheritance is strong and conducive to innovation	Inheritance is not possible

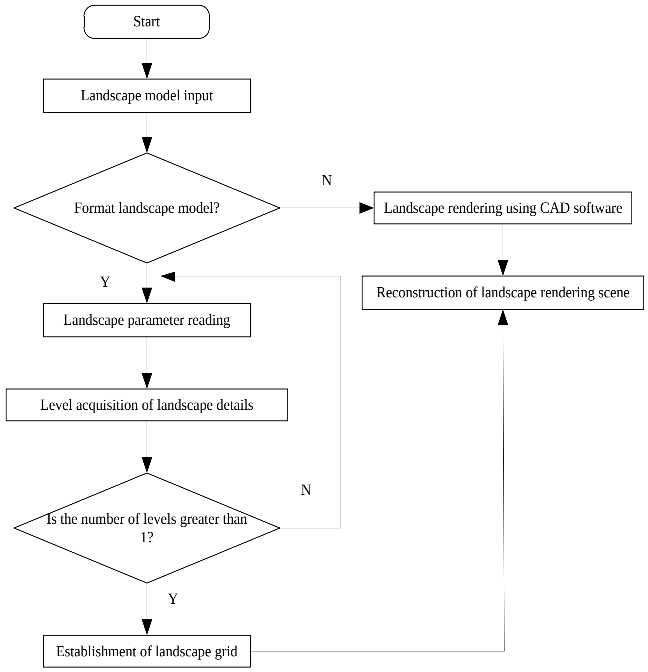

Fig. 2. Tree model rendering flow chart

The tree model is read into the TreeEngine engine, the tree format is parameterized, and the tree multi-level detail is obtained. When the multi-level detail level is more than one, the tree trunk and the whole texture and mesh are established.

C. Spatial Coordination Planning Model of Plant Landscape

According to the analysis results of landscape pattern, the following formula is used to extract the spatial information characteristics of ecological plant landscape in green city:

$$Q(x,y) = Q^{n}(x,y) + \Re \qquad (1)$$

In the formula, $Q(x,y)$ represents the feature information existing in the landscape group space, $Q^{(n)}(x,y)$ represents the feature information existing in the landscape group space in block n, $\Re$ represents the feature extraction coefficient, and (x,y) represents the position of the landscape group in the whole ecological plant landscape space.

Combining the information of decision variables, the relationship between landscape spatial planning and different decision variables was determined. The utility function is used to solve the problem of ecological plant landscape spatial planning from the perspective of ecological plant landscape spatial coordination planning. Through the above analysis, the following formula is used to describe the spatial planning of green urban ecological plant landscape:

$$\max R = \sum_{i=1}^{I} \Im_i \cdot Q(x,y) \cdot \delta \qquad (2)$$

Formula (2) satisfies the following formula:

$$\Im_i = Q_i(x,y), i = 1, 2, \cdots \qquad (3)$$

In the formula, I represents the number of planning objectives, $\Im_i$ represents the importance of i corresponding to ecological plant landscape management objectives, δ represents the rationality coefficient of spatial planning, and q_i represents the value of i corresponding to the objective variable.

Utility functions generally consist of sub-efficacy functions (Fig. 3), restrictive efficacy functions (Fig. 4), evenly increasing efficacy functions (Fig. 5) and evenly decreasing efficacy functions (Fig. 6).

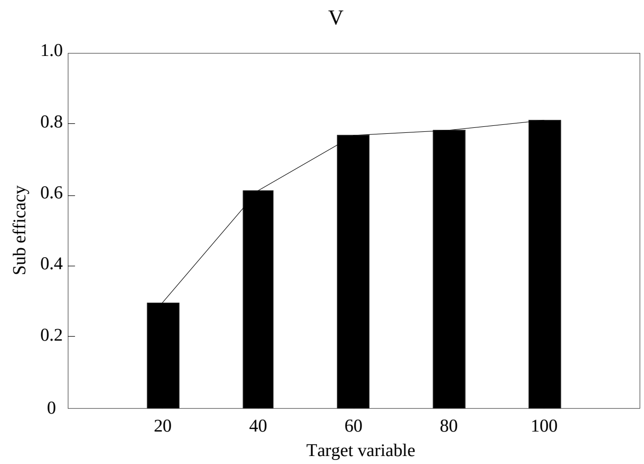

Fig. 3. Sub efficacy function

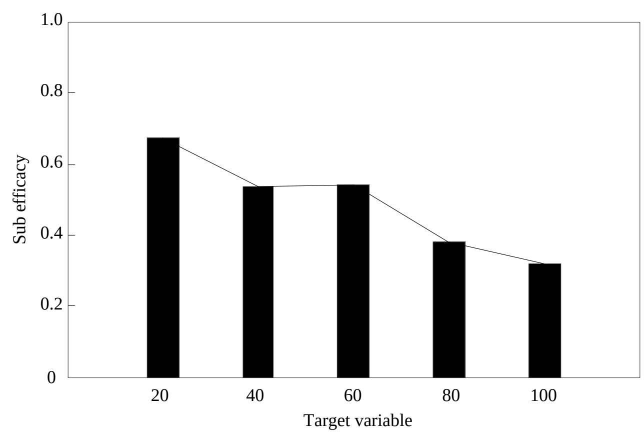

Fig. 4. Restricted efficacy function

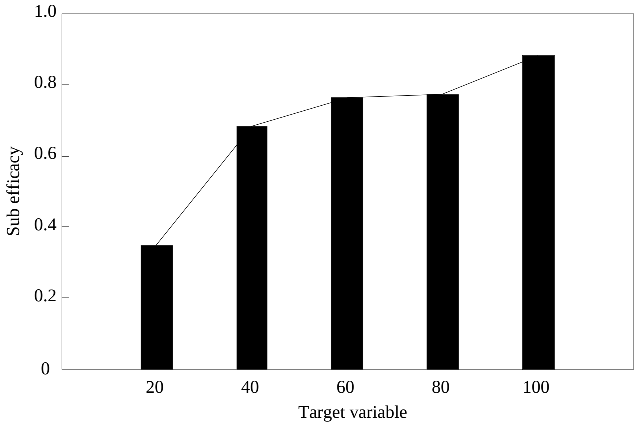

Fig. 5. Uniformly increasing efficacy function

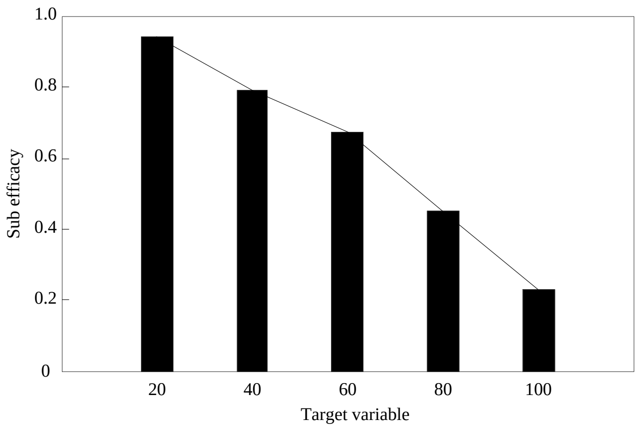

Fig. 6. Efficacy function of uniform decline

Taking green urban ecological plant landscape planning as an object, a green urban ecological plant landscape coordination and planning model is established by maximizing the utility function combined with basic model and utility function theory:

$$U = \frac{\aleph_1 + \aleph_2 + \aleph_3 + \aleph_4}{\delta \cdot \sum_{i=1}^{I} \Im_i} \tag{4}$$

Where, $\aleph_1$, $\aleph_2$, $\aleph_3$ and $\aleph_4$ represent the weight of sub objectives.

D. 3D Planting Design

a) Description of planting method: 3D graphics engine can provide a lot of drawing tools, such as grass point filling, garden corridor, water barge, slate road, gravel road, hedge line, forest edge line, etc., and can also be used to mark plants, positioning line, elevation, garden road, angle, radius and area, etc. The system also has similar to AutoCad fill pattern function and rich content of the two-dimensional library, and the corresponding effect can be printed. The system also has similar functions to AutoCad and a rich library of 2D drawings, and can print out the corresponding effect drawings. In general, the system is used for parameterization, definition of plots, road planning, generation of steps, fences and walls, ponds, planters, planters, ramps, curbs, and other landscape models and design of mountain roads. The design function also provides a rich plant database and pictures, and records the various plant habits, providing a variety of planting methods such as mixed planting, piece planting, column planting, and solitary planting, as well as modifying the number and properties of some already planted plants, and expanding the planting on flat surfaces to undulating terrain. The expression of plantation plan should meet the standard of landscape design. It should be shown according to plantation legend or plantation point and plant contour. In order to achieve the unity of 2D and 3D planting design, the planar planting plan is displayed in the top view and the plantation plan is displayed in the perspective view.

b) Methods of representation for plants: In landscape construction, many plants may be used. If a 3D model is used to represent plants, then a plant will use a large number of patches, which back use a larger system space and even cause the software to crash. Based on the above reasons, the system provides another plant representation, using platform bulletin board, using pictures to simulate the plant. Bulletin board is a very useful technology, it can be a simple way to achieve a lot of special effects, but it is most attractive to achieve these effects with very low system resources. So for each plant entity, it only needs to store its location and the index information of the picture, instead of the storage cost of the 3D model, so it saves the system space greatly. In the display effect, the system will collect nearly a thousand kinds of plants in the south and north of the picture have done the hollow processing, using platform expansion function to achieve the hollow texture display effect, the results more realistic.

E. Dynamic Browsing and Rendering Technology

After the creation of a 3D model, after assigning materials to entities and setting up light sources and viewpoints (cameras), dynamic browsing can be conducted at any time, 3D realistic rendering or animation can be made, and the rendering effects and texture can be reflected by the rendering effect pictures. As can be seen, the difficulty of building a three-dimensional model is that it is difficult to achieve a large volume and a large amount of data for the implementation of the model to browse. The landscape design software uses a more cost-effective display card and its mature interface language for acceleration. At the same time, data processing is greatly reduced by smoothing the special 3D mesh. Landscape design software rationally uses the triangle belt and triangle fan mode provided by platform to reduce the repetition of records on nodes and reduce number of nodes representing stereotyped objects [11-12].

In addition, the use of a specific 3D mesh surface smoothing processing also greatly reduces the data processing, in practical applications played a significant effect. Since the platform requires the map to be a power of two in size. Therefore, it will be sorted when it is passed to the platform. Considering the characteristics of landscape design, we cannot use a simple cutting method, but a combination of color compression, color combination and softening technology to achieve the desired results.

Through reading transparent channel information of 32-bit color bitmap and combining with application of platform template, the hollowed-out texture display technology is realized. The tree image is mapped by hollowing out, and the tree image size is set to power of two to improve the display accuracy. In the aspect of realistic rendering and rendering algorithm, by comparing the depth buffer, ray tracing and radiance, the improved radiance algorithm is used to solve the problem of low rendering speed. The light module in the platform can realize the whole scene, and can display various effects such as daytime and nighttime scenes. In a daytime environment, ambient lighting consists of “parallel light”, “light” and “sky light” by way of simulated sunlight. The camera is equivalent to another point and determines the final rendering type. The landscape design software can drag and modify the position of the camera, display the position and angle of the camera in real time, and display the observation range of the camera in the camera view to achieve a WYSIWYG effect. Meanwhile, the software also supports six types of light sources, including point light source, cone light source, parallel light source, column light source, surface light source and sunlight source. Each light source can be interactively set and modified.

F. Construct 3D Visual Reconstruction Model

Based on the index of landscape spatial staggered pattern, the characteristic points of landscape spatial staggered pattern are mapped into the 3D visual reconstruction model, and the 3D visual reconstruction model is established [13-14]. If there are A points in the 3D visual reconstruction model, the space coordinate of the scanning base station of texture mapping is (X, Y, Z), and the a point coordinate of the staggered pattern of A points and landscape space is E, the mapping relationship between (x, y) points and a points of the staggered pattern of landscape space in the 3D visual reconstruction model is as follows:

$$\begin{cases} x = h_1(X, Y) \\ y = h_2(X, Y) \end{cases} \tag{5}$$

$$\begin{cases} x = \sum_{i=0}^{n} \sum_{j=0}^{n-i} a_{ij} X^i Y^j \\ y = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{ij} X^i Y^j \end{cases} \tag{6}$$

Because of the error of data transmission and the noise in the feature data of landscape pattern, the coordinates of X and Y axes are different, but the coordinates of Z axes are the same. In order to make the mapping result more accurate, the threshold σ is introduced, and the A_i is assumed to be a point in the 3D visual reconstruction model. The threshold σ is used to find A‘s adjacent point $\dot{A}_i$ in the A_i-point range. By expanding formula (6), the mapping model of A and $\dot{A}$ from 3D visual reconstruction model to point a can be obtained:

$$\begin{cases} h_1(X, Y) = x = A_{00} + A_{10}X + A_{01}Y + A_{20}X^2 + A_{11}XY + A_{02}Y^2 \\ h_2(X, Y) = y = B_{00} + B_{10}X + B_{01}Y + B_{20}X^2 + B_{11}XY + B_{02}Y^2 \end{cases} \tag{7}$$

$$\begin{cases} \dot{h}_1(\dot{X}_i, \dot{Y}_i) = C_{00} + C_{10}\dot{X} + C_{01}\dot{Y} + C_{20}\dot{X}^2 + C_{11}\dot{X}\dot{Y} + C_{02}\dot{Y}^2 \\ \dot{h}_2(\dot{X}_i, \dot{Y}_i) = D_{00} + D_{10}\dot{X} + D_{01}\dot{Y} + D_{20}\dot{X}^2 + D_{11}\dot{X}\dot{Y} + D_{02}\dot{Y}^2 \end{cases} \tag{8}$$

In the formula, A represents the landscape autocorrelation coefficient; B represents landscape heterogeneity coefficient; C represents the basic characteristics of landscape pattern; D represents the global characteristics of landscape pattern [15].

Using formula (7) and formula (8), it can be obtained that the mapping model includes 24 positions. When the number of 3D visual reconstruction model and its corresponding landscape spatial staggered pattern is greater than 12, the 3D visual reconstruction models of $h_1(X, Y)$, $h_2(X, Y)$, $\dot{h}_1(\dot{X}_i, \dot{Y}_i)$ and $\dot{h}_2(\dot{X}_i, \dot{Y}_i)$ can be calculated according to the principle of least square method.

Substituting $\dot{A}_i(\dot{X}_i, \dot{Y}_i, \dot{Z}_i)$ into formula (7), respectively obtain that the coordinates of $\dot{a}_i$ are $(\dot{x}_i, \dot{y}_i)$ and the distance between $\dot{a}_i$ and a is d_1; Substitute $A(X, Y, Z)$ into formula (8) and obtain that the coordinate of a' is (x', y') and the distance between a' and a is d_2.

Comparing the size of d_2 and d_1, the size of the sum is compared and the corresponding polynomial with smaller distance is selected to express the mapping relationship of the 3D visual reconstruction model.

III. Experimental Design of Performance Test of the Proposed Method

A. *Presentation of Landscape Design Effect*

Select Visual Studio 2021 as the development platform, using VC+ language as the development language to develop this landscape design software. The landscape design of a residential quarter in a certain city is selected as the verification object. The residential quarter is located in the southeast of the city and is a newly developed ecological residential quarter. The total area of the residential quarter is $38759m^2$, the total construction area is $16748m^2$, and the residential quarter includes eight residential buildings, including villas, multi-storey areas and high-rise areas. The landscape design requires that the green area within the residential quarter shall be more than 40%.

As can be seen in Fig. 7, the 3D model built using the platform can contain all the architectural information needed in the relevant landscape project, and the 3D terrain scene model and the actual building can be presented in a 1:1 scale, which makes the design drawings more intuitive and easy to modify.

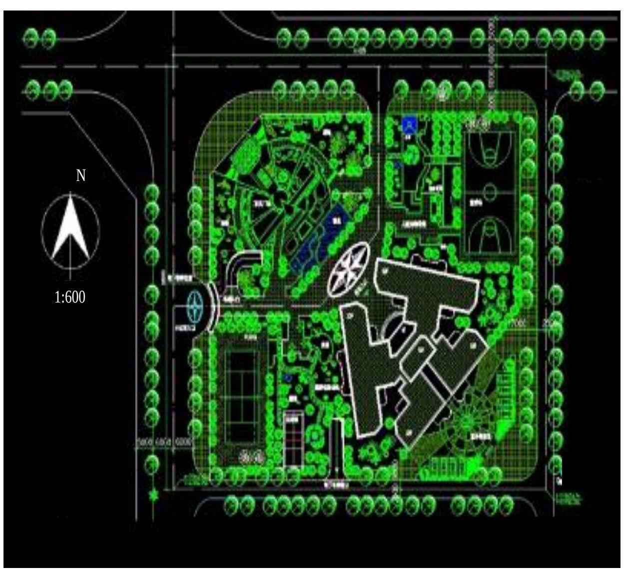

Fig. 7. Reconstruction of 3D terrain scene model

Fig. 8. Final effect of landscape design

The final effect drawing of landscape design for this residential area is shown in Fig. 8.

The simulation results of Fig. 8 show that the proposed method can effectively reduce the labor intensity of landscape designers and shorten the design cycle. Compared with the 2D landscape design, the 3D terrain scene model is more accurate. Because the 3D terrain scene model is 1:1, the accuracy of landscape design is improved effectively. The method of this paper can be used to design landscape in 3D scene model.

Analytic Hierarchy Process is selected to evaluate the effect of landscape design in this paper. Analytic Hierarchy Process is a quantitative and qualitative multi-objective decision analysis method. The results of AHP evaluation of the landscape designed by this method are shown in Table I.

TABLE II. Landscape Design Results of this Method

Evaluating indicator	Weight	Evaluation results / score
Illumination	0.08237	94
Visual contrast	0.09263	98
Resolving power	0.08356	94
Visual brightness	0.06657	91
Shadow processing	0.16849	98
Graphics refresh rate	0.26478	99

As can be seen from Table II, the AHP method can be used to evaluate the final effect of the landscape design using the 10 indicators listed in the table to rate each indicator, and the average of each score sought is 93.7. The result shows that the method has high design effectiveness.

B. Application Performance Test of the Proposed Method

In order to the overall effectiveness of the proposed method, it is necessary to test the analysis method of green urban ecological plant landscape spatial coordination planning model. This test is completed in Simulink platform. Set the plant diversity coefficient in the interval [0,1]. The larger the plant diversity coefficient, the more categories of plants in the landscape space, and the better the diversity. The proposed method, the landscape spatial design method based on pattern coupling mechanism proposed in study [4] and the landscape spatial design method based on remote sensing image proposed in research [5] are tested respectively.

The plant diversity coefficients of different methods are shown in Fig. 9.

By analyzing the data in Fig. 9, it can be seen that the plant diversity coefficient obtained by the proposed method in multiple iterations is more than 0.8, and the plant diversity coefficient obtained by the landscape spatial design method based on pattern coupling mechanism proposed in study [4] fluctuates around 0.5. The plant diversity coefficient obtained by research [5] method in multiple iterations fluctuates around 0.5. Comparing the test results of different methods, it can be seen that the plant diversity coefficient of the proposed method is high in multiple iterations.

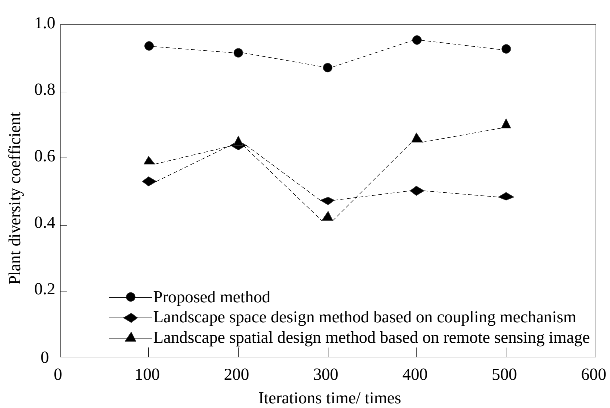

Fig. 9. Plant diversity coefficients of different methods

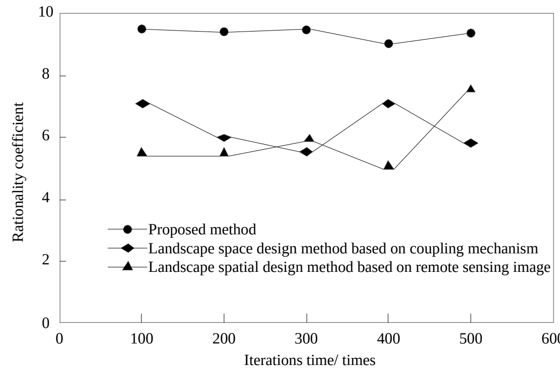

Fig. 10. Rationality coefficients of different methods

The above methods are further tested through the rationality coefficient of green urban ecological plant landscape spatial planning. The rationality coefficients of different methods are shown in Fig. 10.

According to the data in Fig. 10, when the proposed method is used to design the ecological plant landscape space of green city, the rationality coefficient is more than 8, When the landscape space design method based on pattern coupling mechanism proposed in study [4] and the landscape space design method based on remote sensing image proposed in research [5] are used to plan the ecological plant landscape space of green city, the rationality coefficients obtained are within the interval [4, 8]. The comparison shows that the rationality coefficients of the proposed methods in multiple iterations are higher than those in references. Because the proposed method uses 3D graphics engine to render garden landscape scene elements. Based on this, the spatial coordination planning model of plant landscape is constructed. Color attribute of landscape spatial staggered pattern is added to 3D visual reconstruction model through image library function, which improves the planning rationality of the proposed method.

The landscape spatial design method based on pattern coupling mechanism proposed in study [4], the landscape spatial design method based on remote sensing image proposed in research [5] and the proposed method are used to calculate the utilization rate of landscape spatial pattern. The calculation formula is as follows:

$$\eta = \frac{S_0}{S} \quad (9)$$

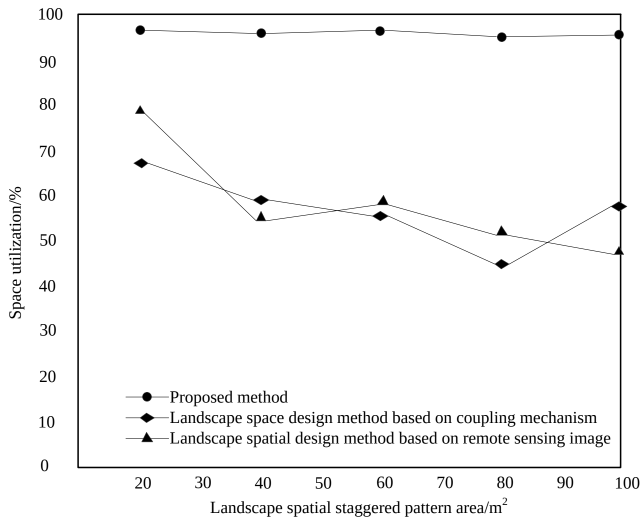

Fig. 11. Comparison results of landscape spatial pattern utilization

In the formula, S_0 represents the area of the utilized landscape spatial pattern; S represents the area of reconstructed landscape spatial pattern. The results are shown in Fig. 11.

As can be seen from the results in Fig. 11, the spatial utilization rate of landscape spatial pattern is significantly higher than that of the other two design methods, indicating that the design method has advantages in spatial utilization rate and can effectively improve the spatial utilization rate of landscape spatial pattern.

IV. Conclusion

This study explores the application of CAD in landscape design. It has powerful 2D graphics editing function and powerful 3D drawing and solid modeling function. In this paper, platform technology is used to generate landscape vector map. Topographic design, planning design and planting design are main contents. Landscape can be dynamically browsed and displayed. After reconstructing terrain and environment information of landscape to be designed by binocular stereo vision camera, landscape elements are rendered by 3D graphics engine. Based on this, coordination and planning model of plant landscape space is constructed by maximizing utility function combined with basic model and utility function theory. The color attribute of landscape space staggered pattern is added to the 3D visual reconstruction model by using image library function, and the platform intelligent technology is applied in landscape design. The results show that the design evaluation index score of the proposed method is higher, the plant diversity coefficient is higher, and the spatial utilization ratio of the landscape spatial pattern is higher.

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