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Research on Landscape Design Optimization and Spatial Layout Planning Method Based on AI Algorithm

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ABSTRACT
Traditional landscape design methods have low efficiency, poor subjectivity and insufficient goal optimization. This paper proposes a landscape design optimization and spatial layout method based on artificial intelligence (AI) algorithms to achieve scientific and efficient landscape design through the combination of collected information data and algorithms. The optimization design of landscape facility paths and spatial dimensions is carried out by adopting a heuristic polygonal layout algorithm, establishing a data model based on the database and scene templates, and combining the landscapes in the polygonal space after landscape matching. The optimal sequence of the landscape is obtained by using the scoring function, and then combined with the particle swarm algorithm to realize the optimization of the landscape layout. The Hypervolume index is stable to about 0.815 in 30 generations, which has a good quality of Pareto optimal solution set. In this paper, the algorithm formulates three groups of landscape design optimization and spatial layout planning schemes for different situations, making full use of the land that is utilized for a certain place. The implementation of the sustainable development scenarios improves the local environmental and social benefits significantly, and the average annual growth rate of employment in related industries reaches 3.16%. Satisfaction survey results show that local residents are most satisfied with the green environment and cultural atmosphere after the implementation of the program, respectively 80.03, 79.35, through the smart management to improve the local environmental quality and cultural atmosphere.

Keywords: AI algorithm, polygonal layout, particle swarm algorithm, landscape design optimization, spatial layout planning

1. Introduction

Landscape is an important part of modern urban construction, which plays a pivotal role in improving the natural environment of the city and shaping a good urban image [1-2]. At the same time, due to the popularity of artificial intelligence (AI), it has been widely used in all aspects of today's society, and its

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application to landscape design optimization and spatial layout planning will certainly promote the innovation of the overall landscape design [3-5].

AI is a kind of intelligent computer program, which can simulate human action and thinking, and can even be used to deal with a series of problems [6-7]. The design of landscape is based on artistry, versatility and human nature, ecological and cultural inheritance features, and under the premise of meeting the actual function of the project, the landscape layout is planned, the landscape structure is improved, and the basis is provided to meet the people's life and spiritual needs [8-11]. And the design optimization content of AI includes modeling, lighting, artificial landscaping and other aspects, only to ensure that the design content is coordinated with each other and effectively cooperated, in order to achieve wholeness and characterization [12-14]. Landscape engineering design is characterized by complexity, comprehensiveness, and rapid technological update, so it must keep abreast of the times to ensure that the content of the design meets the aesthetic requirements and appreciation of the people [15-17]. And artificial intelligence technology can well solve this problem, especially in landscape design, many technical problems can not be effectively solved by a single designer, AI solves the technical difficulties through precise calculation and scientific analysis [18-21]. In addition, the traditional manual design method has the influence of the human factor, which causes the inoperability of the design scheme, thus causing problems in the project, which reduces the efficiency and quality of the project, and increases the cost of the project [22-25]. Artificial intelligence technology, can timely identify the defects in the design program, thus improving the accuracy and reliability of the design, and laying a solid foundation for the future construction of the project [26-27].

Literature [28] proposed a study on landscape design strategy optimization based on intelligent algorithms and evaluated this study, emphasizing that intelligent algorithms perform better than standard swarm algorithms in terms of landscape design strategy optimization accuracy and time to influence variables under specific evaluation conditions. Literature [29] emphasized the importance of urban landscape, and based on literature review and case study, it elaborated the original process of urban landscape design, analyzed the degree of involvement of AI in landscape design by applying AI painting to design practice, and provided designers with innovative ideas. Literature [30] describes the development of AI provides a brand new development opportunity for landscape architecture (LA), emphasizing that, AI provides innovative solutions for the planning, design and maintenance of urban buildings, providing theoretical and practical guidance for LA designers. Literature [31] proposed an interactive design system (IDS-Al) based on AI with artificial intelligence, which uses GIS to optimize landscape vision and is able to create 3D dynamic landscape models based on realistic environmental scenarios, which exhibit very high area coverage. Literature [32] identifies a knowledge gap in the application of AI in landscape design and addresses this gap by searching for and evaluating research in the planning and design of landscapes, synthesizing emerging AI-LA themes and advocating for uniform dissemination and compilation in research and practice. Literature [33] aims to deploy computer-aided design in landscape planning using the Artisan plug-in for environmental planning, which assists landscape planners to accurately study the characteristics of the landscape and proposes a four-phase model to aid the process of development of landscape planning activities by working with micro-factors. Literature [34] proposed a spatial pattern optimization model for landscapes based on AI algorithm, which highlights the higher optimization accuracy of this algorithm than layout optimization algorithms based on SVM algorithm, which provides the landscape planner with decisions for overall planning. Using a combination of quantitative and qualitative analysis and based on a literature review, literature [35] aims to provide a comprehensive understanding of automated spatial layout planning + AI, emphasizing its impact on both academia and industry in facilitating the use of AI in spatial layout planning. Literature [36] examined the application of VR technology in landscape planning and design to minimize the impact on landscape greening, and realized 3D scene roaming by using the A+ algorithm to obtain the optimal paths for 3D scenery, showing that the algorithm obtained more realistic and clearer 3D landscape figures and scene models through texture mapping. Literature [37] analyzes the application of computer-aided design (CAD) and VR in landscape design and layout, and proposes a landscape layout optimization algorithm based on the improved particle swarm algorithm (PSO), which proves the reliability of the landscape layout optimization algorithm of the algorithm, and provides a new perspective for the application of CAD and VR in landscape design and layout.

The article formulates a landscape design optimization model and spatial layout strategy based on AI algorithm for the planning concept, functional zoning, landscape nodes and plant allocation of a landscape. The path of landscape facilities is optimized by establishing the distance matrix between landscape facilities. The adaptability function about the price, cost and quantity of landscape facilities is constructed to realize the precise control of landscape facility design, and the satisfaction function is used to evaluate the visitors' sense of landscape experience. Through the polygonal layout algorithm, the landscape spatial layout area is represented as a set, and the landscape diversity combination layout is realized according to the polygonal spatial landscape distribution probability. At the same time, the particle swarm algorithm is combined to find the global optimal solution of the landscape layout sequence. The data collected in the article are used to analyze the performance of the algorithm, and the method of this paper is applied in the landscape design of a certain place.

2. Landscape master plan for a site in city A

2.1. Landscape design and planning concept

The planning and design of the landscape should take into account the current status of local planning and the integration of natural resources, facilities and climatic conditions with the environment. Based on the creation of beautiful dynamic landscape, the following planning and design concepts should be followed:

1) Take the dynamic landscape theory as the core, make full use of local natural resources to create a dynamic landscape with local characteristics. In addition, it should take into account the sustainability of the landscape, changeability, combinability and other characteristics, so that the landscape can continue.

2) Enrich the landscape pattern. Dynamic landscape to show the environment in a variety of planning and design, multi-faceted consideration of the needs of different residents and tourists, emphasizing the use of existing landscape resources, to improve and optimize the environment.

3) Create dynamic landscapes with the theme of environment and humanistic landscape to protect the ecological environment. Architecture and landscape facilities in terms of appearance, scale and quantity should be in line with the environmental background and factors such as history and culture, resource conditions, humanities and geography, and vernacular characteristics, to promote the harmony of landscape and nature.

2.2. Functional zoning

The landscape design of a certain place is mainly divided into four major areas, such as B&B area, activity center area, water-friendly flower viewing area, and historical and cultural area. Such a division not only improves the practicality and functionality of the landscape, but also enhances the dynamic effect and attractiveness of the landscape. The B&B zone is located in the east of the site, with B&Bs, resident studios and cafes as the main nodes, enriching the vacation experience of people who come for leisure and tourism. The Activity Center Area is located in the south of the site, providing basic supporting facilities, serving all kinds of people, providing convenient leisure space for residents and tourists, and also injecting vitality into the whole site. The water-friendly and flower-viewing area is located in the north central part of the site, using local characteristic flowers and trees for planting, forming a plant diversity landscape, and the center of the area's water features to create a rich and varied characteristic landscape. The historical and cultural area is located in the northern part of the site, adjacent to the parking lot, through the village history museum and cultural landscape wall nodes, to understand the regional culture and folk customs, in-depth understanding and experience.

2.3. Landscape nodes

According to the background of the project and the theme positioning of a certain place, combined with the design concepts and objectives, the landscape planning and design of the area therein. In the planning, taking into account the existing topography and local land attributes, to follow the principle of natural form, site as the core, industry as the basis, as the background, the theme to position, to create a dynamic landscape with characteristics. For the function of the site, the dynamic landscape planning and design is based on the field conditions to meet the needs of residents and tourists.

2.4. Plant allocation

The vegetation landscape of a certain place is mainly distinguished by color distribution, combined with the center of dynamic water features, forming four major plant water features: red, blue, green and yellow. The red color system dominates the planting of flowers and trees, such as roses, azaleas, crocus, hydrangeas, hibiscus, dahlias, chrysanthemums, etc. The green color system dominates the planting of trees, such as poplar trees, citrus trees, and so on. The green color system is dominated by trees such as poplar trees, citrus trees, lemon trees, banana trees, pine trees, osmanthus trees, and so on.

3. Landscape design optimization and spatial layout methods based on AI algorithms

Aiming at the landscape design and planning concept of a certain place, this section uses AI algorithms to explore its landscape design optimization and spatial layout planning from different perspectives, and to realize the study of landscape functional zoning and plant allocation in this place.

3.1. Landscape Design Optimization Model

3.1.1. Landscape amenity path optimization:

1) Problem Analysis. In order to improve the quality of tourists' visit, the efficient and reasonable tour path of landscape facilities directly affects the affordability and economic benefits of scenic spots. Generate the optimal route for tourists to visit landscape facilities, efficient and simple at the same time in the limited conditions to find the optimal tour route program.

2) Optimization process. Algorithm condition assumption: the premise of the construction of the path optimization model of tourism landscape facilities, to make assumptions and the definition of each element of the optimization problem. Assuming that the distance of each landscape facility is known, the main landscape facility in the selected research scenic area is (F_n), and the shortest distance between any two landscape facilities is $d(n_1,n_2)$ respectively, indicating the shortest path from facility n_1 to facility n_2. Define the fitness function for the distance between the two selected landscape facilities to sum the minimum value, that is, the optimal path program. To η_k represents the sequence of $(F_0,F_1,\cdots,F_n)$ landscape facilities, and $\eta_k(0)=F_0$, $\eta_k(n)=F_n$, F_n for the landscape facility number, $d\left(F_{\eta_k}(i),F_{\eta_k}(i+1)\right)$ for the distance from landscape facilities $F_{\eta_k}(i)$ to $F_{\eta_k}(i+1)$.

Construct the algorithm objective function: set $X=(F_1,F_2,\ldots,F_n)$ and find $\min f(X)$, see equation (1).

Build the distance matrix between every two landscape facilities: the elements on the diagonal of the matrix are all 0, see equation (2).

From this, the fitness function is known as equation (3).

Add the constraints that a landscape facility has only one route pointing to it and only one route to the next landscape facility. $i = 0$ is the start term and $j = n$ is the end term, see equation (4):

$$f(X) = \sum_{i=0}^{n} d\left(F_{\eta_K}(i), F_{\eta_K}(i+1)\right) \tag{1}$$

$$D = \begin{bmatrix} d(0,0) & d(0,1) & \cdots & d(0,n) \\ d(1,0) & d(1,1) & \cdots & d(1,n) \\ \vdots & \vdots & \ddots & \vdots \\ d(n,0) & d(n,1) & \cdots & d(n,n) \end{bmatrix} \tag{2}$$

$$d\min = \sum_{i=0}^{n-1} \sum_{j=1}^{n} \left(d_{ij} * X_{ij}\right) \tag{3}$$

$$\sum_{j=1}^{n} X_{ij} = 1, \sum_{j=1}^{n-1} X_{ij} = 1, \left(i = 0, 1, \cdots, n\right) \tag{4}$$

3.1.2. Spatial scale optimization of landscape facilities:

1) Problem analysis. Landscape environment is an open whole, landscape facilities and the environment are integrated with each other to make the environment play a greater role and complement each other. Optimizing the reasonable distribution and scale grasp of landscape facilities in the scenic space is the focus of enhancing the tourists' sense of visiting experience, which is the infrastructure guarantee for building a beautiful tourist landscape.

2) Optimization process. Selection of optimization variables and calculation of weights: Based on the evaluation factors obtained by hierarchical analysis method in the analysis of the previous research data, the optimization variables are selected for weight calculation, and the weight values are determined by using the proportion of each factor in the total factor score w, y indicates the number of evaluations, x indicates the number of evaluation factors, and w_n indicates the weights of the j th evaluation factor, and the evaluation weight of the landscape facilities obtained by hierarchical analysis method is used to construct the indicator layer judgment Matrix W, see equation (5).

Build the cost fitness function: the cost fitness function contains the price, cost and quantity of the landscape facilities to be optimized, where C represents the construction cost of the landscape facilities, F_j represents the price of the landscape facilities, and ΔS_j represents the quantity of the landscape facilities. The adaptation function formula is (6).

Visitor satisfaction function: when the proportion of landscape facilities in the scenic area is set fixed, the larger the number of facilities, the higher the visitor satisfaction. However, when in a certain spatial environment, the larger the size of the facilities, the smaller the number of facilities, the more difficult for tourists to use, and consequently, the satisfaction of tourists decreases. However, when the size of the facilities becomes smaller and the number increases accordingly, the landscape space becomes dense, which affects the overall landscape aesthetics and leads to a decrease in satisfaction. Therefore, in summary, consider the visitor satisfaction function formula:

$$W_n = \sum_{i=1}^{n} k_{ij} \Big/ \sum_{j=1}^{m} k_{ij} \tag{5}$$

$$\min C = \sum_{1 \le j \le n} F_j \times \Delta S_j \left(j = 1, 2, 3 \cdots, n, \Delta S \in E\right) \tag{6}$$

$$\max F = \sum_{1 \le j \le n} W_j \times \left(S_j + \Delta S_j\right), \Delta S_j \in E \tag{7}$$

Where W_j represents the weighted value of landscape amenities, S_j represents the number of amenities that have been planned and arranged in the space, and ΔS_j represents the number of landscape amenities that need to be increased or decreased.

3.2. Landscape Spatial Layout Planning Strategies

3.2.1. Heuristic polygon layout algorithm. The heuristic polygon layout algorithm [38] in this paper, uses simple polygons, given a set $P=\{P_1,\cdots,P_n\}$, and a set of permissible rotation angles $\Omega=\{\Omega_1,\cdots,\Omega_m\}$, where $\Omega_i(1\le i\le m)$ is represented by P_i all the directions of rotation that can be taken. In a given scene $M=(X,Y)$ represented by a matrix, O the point is the center of the scene $\left(\frac{X}{2},\frac{Y}{2}\right)$. Scene M is labeled with the type of layout in the current unit area, where grass is the standard layable area, represented by set $A=\{\sigma_1\}$. Scene M is labeled with buildings, water bodies, and roads, and is represented by set $B=\{\sigma_2,\sigma_3,\sigma_4\}$, denoting standard non-layoutable areas.

Given a polygon P_i and a translation vector $v=(v_x,v_y)$ such that $p=(p_x,p_y)$ is represented as the current position of polygon P. Define the translation function for the polygon as follows:

$$P_i\oplus v=\left\{\left(p_x+v_x,p_y+v_y\right)\middle|p=\left(p_x,p_y\right)\in P_i\right\},x\in X,y\in Y \tag{8}$$

The center of the polygon, denoted $g_i=(g_{ix},g_{iy})$, is the position of the polygon. The state of P_i is determined only by its center g_i and the angle of rotation a_j, so the current polygon can be represented as the following equation:

$$\begin{aligned}P_i(a_i)=\Big\{\Big(&g_{ix}+(p_x-g_{ix})\cos(a_i)-(p_y-g_{iy})\sin(a_i),g_{iy}\\&+(p_x-g_{ix})\sin(a_i)+(p_y-g_{iy})\cos(a_i)\Big)\Big|p\in P_i,a\in\Omega\Big\}\end{aligned} \tag{9}$$

The unit layout area will be traversed from the center of the scene outward in a ring-like hierarchy, and the current unit layout area will be scored by the scoring function $F=\{f_1,f_2,\cdots,f_k\}$ during the traversal.

Scoring function:

$$\begin{aligned}&f_1(P_i(a_i))=|P_i(a_i)|\times\omega_1\\&f_2(P_i(a_i))=|(P_i(a_i)\mid p\in A)|\times\omega_2\\&f_3(P_i(a_i))=|(P_i(a_i)\mid p\in B)|\times\omega_3\\&f_4(P_i(a_i))=|(P_i(a_i)\mid p\in(P-P_i))|\times\omega_4\\&f_5(P_i(a_i))=|(P_i(a_i)\mid p\notin(P-P_i),p+d\in(P-P_i))|\times\omega_5\end{aligned} \tag{10}$$

$\omega_1,\omega_2,\omega_3,\cdots,\omega_k\,(-\infty<\omega<+\infty)$ indicates the weight of each scoring function in the total score, which creates a slight distinction based on the distribution of standard layable and standard non-layable areas in the scene.

If $mscore=\max\{p_{1score},p_{2score},\cdots,p_{nscore}\}>0$, the polygon is allowed to be mapped to the unit layout area corresponding to the midpoint of the polygon: $P_j(a_j)\to M$, until traversal is complete. The mapped polygon contains the following data: number, polygon type, total area occupied by the polygon, and all coordinate points occupied by the polygon.

3.2.2. Plant community mix. Park plant communities are an important part of urban green space, and plant species diversity is the basis of plant communities, vegetation types and plant landscape diversity. The composition of the plant community determines the appearance and changing character of the plantscape. Therefore, it is necessary to combine the layout of plants in the form of polygons which are subdivided into whole trees, whole shrubs, mixed trees and shrubs and empty distributions. Below is a schematic representation of a part of the distribution and its probability of appearing in a polygon. The composition of the plant community, which determines the appearance and changing characteristics of the plant landscape, requires a combination of plant layouts within the polygon, which are subdivided into common distributions such as whole trees, whole shrubs, mixed trees and shrubs, and empty distributions. Figure 1 shows the distribution of some plant communities and the probability of their occurrence within the polygon.

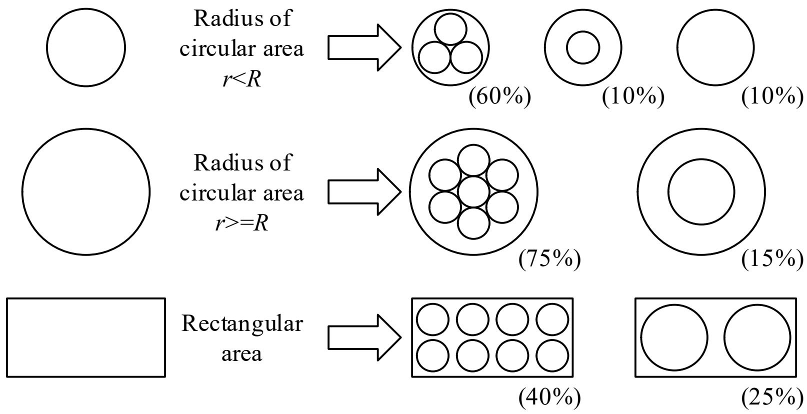

Fig. 1. Landscape plant community layout style

3.2.3. Global optimization. By analyzing the form of landscape space creation, this paper proposes the following rules:

Define a single landscape facility as T, type T_{type} as categorized into recreation and rest, and spatial coverage area as $C=T_{crown}$. Define clusters $G=\{T_1,T_2,\cdots,T_n\}$, and define polygons $B=\{G_1,G_2,\cdots,G_m\}$. Randomly select all landscape facilities that are not arranged in a repetitive manner, and calculate their scores T_{iscore}, corresponding to the scoring function $Q=\{q_1,q_2,\cdots,q_k\}$, by the following formula:

$$T_{iscore}=\sum_{j=1}^{k}q_j(T_i),q\in Q \tag{11}$$

Scoring function:

$$q_1\left(T_j\right)=\begin{cases}\mu_1 & T_{itype}=\ tree\ ,\sigma 2\in T_{icrown}\vee\sigma 3\in T_{icrown}\\ \dfrac{\mu_1}{\gamma} & T_{itype}=\ shrub,\ \sigma 4\in T_{icrown}\\ 0 & otherwise\end{cases} \tag{12}$$

$$q_2\left(T_j\right)=\begin{cases}\mu_2 & T_{itype}=\ tree\ ,T_{icrown}\notin G-T_j\\ \dfrac{\mu_2}{\gamma} & T_{itype}=\ shrub\ ,T_{icrown}\notin G-T_i\\ 0 & otherwise\end{cases} \tag{13}$$

$$q_3\left(T_j\right)=\begin{cases}\mu_3 & T_{itype}=\ tree,G-T_i=\varnothing\\ \mu_3-\varphi & T_{itype}=\ shrub\ ,G-T_j=\varnothing\\ 0 & otherwise\end{cases} \tag{14}$$

$$q_4\left(T_j\right)=\begin{cases}\mu_4 & \left|T_i-T_{i-1}\right|\cong\left|T_j-T_{i+1}\right| \\ 0 & otherwise\end{cases} \tag{15}$$

The optimal sequence of landscape amenities can be found based on a scoring function:

$$\min SEQ\left(T\right)=\min\sum_{m}^{1}\sum_{i=1}^{n}\sum_{j=1}^{k}q_j\left(T_i\right),q\in Q,T\in G \tag{16}$$

Where γ , φ for the parameters $\left(0<\gamma<+\infty,0<\varphi<+\infty\right)$. global optimization is completed, take out the polygon number, landscape facilities parameters, the polygon number as a number stored in the landscape facilities parameters as a layout of the landscape facilities parameters, all landscape facilities and their parameters are integrated into the landscape facilities list P .

The optimization of the layout sequence is done using Particle Swarm Algorithm (PSO) [39]. The basic idea of the particle swarm algorithm is to simulate the activity habits of birds in a flock, where individual birds are represented by particles whose properties are determined by two parameters: speed and position. Each particle searches for an optimal solution in the search space and marks the current optimal solution as an individual extreme value. And the individual extreme value is shared among the whole particle swarm, all of which have adjusted their positions and velocities. The particles optimize the current global optimal individual values shared by the entire swarm based on the current individual extreme values they can find, and the individual extreme values of the found optimal solution are referenced as the global optimal solution for the entire swarm.The PSO is initialized as a swarm of random solutions, which here corresponds to the solution obtained by the heuristic polygon algorithm, and is iterated to find the global optimal solution. In each iteration, the particles perform state refreshment by keeping track of the velocity and position (pbest, gbest), and the particles update their velocity and position by using the following equation.

Set, $i=1,2,\cdots,N$, N is the total number of particles in this particle swarm. V is the velocity of the particle, $rand\left(\ \right)$ is a random number between $\left(0,1\right)$, x is the current position of the particle, and c_1 , c_2 is the learning factor, usually $c_1=c_2=2$. Then the formula is as follows:

$$v_i=v_i+c_1rand()\cdot\left(pbest_i-x_i\right)+c_2rand()\cdot\left(gbest_i-x_i\right) \tag{17}$$

$$x_i=x_i+v_i \tag{18}$$

ω is the inertia factor, when different values are taken, there is a possibility that the global optimization seeking ability of the particle swarm optimization algorithm will change to some extent, and here the strategy of linear decreasing weights (LDW) is used:

$$v_i=\omega v_i+c_1rand()\cdot\left(pbest_i-x_i\right)+c_2rand()\cdot\left(gbest_i-x_i\right) \tag{19}$$

$$\omega^{(t)}=\left(\omega_{ini}-\omega_{end}\right)\left(G_k-g\right)/G_k+\omega_{end} \tag{20}$$

G_k is the maximum number of iterations.

ω_{ini} is the initial inertia weights.

ω_{end} is the inertia weights when iterating to the maximum number of evolutionary generations.

After determining the rules iterations are performed until a stable state is reached, or until the end of an iteration.

4. Data sources and pre-processing

4.1. *Preliminary data collection*

The collection of landscape resources is mainly based on internet research and government documents. Natural and humanistic resources are mainly obtained through the official websites of related departments such as cultural relics, water conservancy, forestry and tourism, while non-formal landscape resources are obtained from the list of non-heritage projects above the municipal level obtained from the local Bureau of Culture, Tourism, Radio, Television and Sports, and the place of attribution is based on the place of declaration.

4.2. Selection of resources

Since a resource point may belong to many types at the same time, after collation, through merging and de-weighting, except for settlements, for the small resource points within a large range of deletion and take a large range of landscape resource points to enter the way, to get the final list of a total of 164 items of a certain place landscape resources.

4.3. Data pre-processing

The spatial locations of the resource points were picked up by comparing with the Baidu coordinate picking system and 91 satellite maps. In this study, the spatial analysis methods that need to use point coordinates for analysis, such as the nearest neighbor index method and kernel density method, will not include the natural landscape resources in the large-scale distribution of weather and climate landscape resources, as well as the immaterial landscape resources that can not be represented by a specific point location. Finally, 81 landscape resources with spatial locations were obtained, and the criteria for determining the location of points:
1) Wetland parks, forest parks, tourist attractions, etc.: the location of the visitor center or main entrance.
2) Settlements: the location of the village committee is adopted for villages, while the people's government prevails for townships.
3) Humanistic relics, characteristic buildings, etc.: the geometric center of the structures on the map is taken to prevail. In the process of determining the points, some of the provincial cultural relics protection units can not be found on the map of the specific location of the situation, through the Provincial Cultural Relics Bureau of the Government and the people's exchange to obtain its specific coordinates. By organizing and checking recorded in the Excel database.

5. Landscape design optimization and spatial layout planning solutions and applications

5.1. Analysis of the quality evaluation of the landscape design planning solution set

In this section, an attempt is made to characterize the overall quality of the solution set using the Hypervolume metric [40], which represents the volume of the hypercube enclosed by the individuals in the solution set and the reference points in the target space, and the larger the value, the better is the quality of the solution set, and vice versa.The Pareto and Hypervolume metrics are always consistent with each other, i.e., if the solution set N is inferior to solution set N ', then the Hypervolume value of the solution set N will also be less than the Hypervolume value of the solution set N. There are various ways to calculate the Hypervolume metric and the procedure is as follows:
1) Rank the points in the solution set in descending order according to the first-dimensional objective.
2) Slice the entire hypervolume according to the value of the first dimension from largest to smallest, and each slice is a d-1 dimensional hypervolume.
3) Finally, the hypervolume of each d-1 dimensional slice is calculated and multiplied by the depth of the corresponding slice in the first dimension to obtain the value of the d-dimensional subhypervolume, and the values of all these subhypervolumes are summed to obtain the value of the entire d-dimensional hypervolume.

The greater the distance of the Pareto optimal solution from the reference point, the better the convergence and the greater the Hypervolume indicator value will be. In addition, an increase in the optimal solution will improve the homogeneity of the solution set, causing the length along the line to increase, which will also cause the Hypervolume value to increase. In the third case, if the extreme solutions extend more widely and extensively, the Hypervolume value will also be larger. It can be seen that the Hypervolume value comprehensively reflects the convergence, uniformity and extensiveness of the solution set, and the larger the index value, the better the comprehensive quality of the solution set.

Figure 2 represents the experimental results using the best optimization algorithm and the optimization process, and it can be seen that the Hypervolume indicator is roughly on the rise with the increasing number of generations. The fluctuations of rising and falling locally in the middle may be related to the random changes of the design variables or may be caused by the difference in the number of optimal solutions in each generation. When approaching 30 generations, the Hypervolume value stabilizes and stabilizes around 0.815, indicating that the obtained Pareto optimal solution set is of good quality.

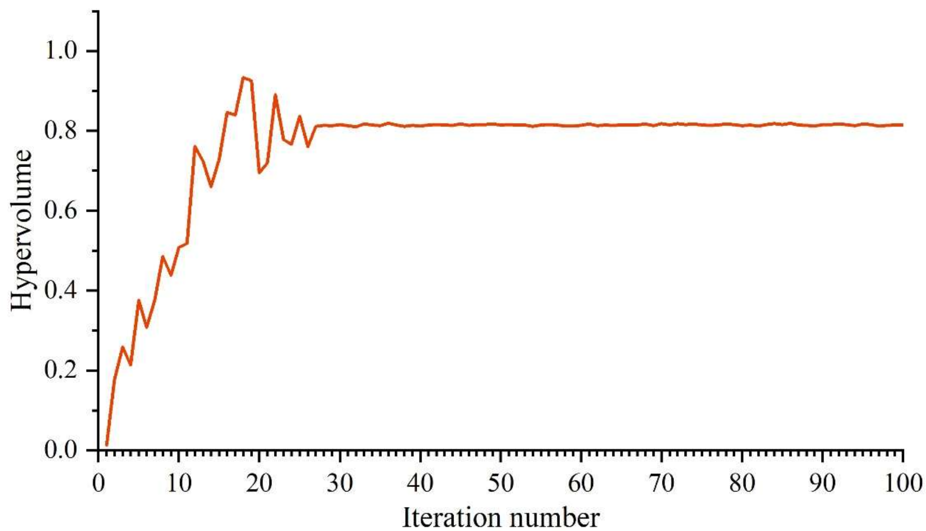

Fig. 2. The Hypervolume index varies with evolutionary algebra

5.2. Multi-scenario Landscape Design Layout Program Determination

In this section, in order to cope with the landscape design optimization and spatial layout planning under different development scenarios of a certain place, different scenarios are generated for the economic development scenario, the ecological protection priority scenario, and the sustainable development scenario by using the above method.

Based on the multi-objective particle swarm algorithm, the area and proportion of each land use type under different scenarios are calculated as shown in Table 1. Due to the different size of benefit coefficients of each land use type under different goal orientations, the area prediction results of each land use type under the three scenarios are quite different. This can reflect the trend of the future land use structure of the study area under the ecological protection orientation, economic development orientation and sustainable development orientation, thus providing decision makers with a land use layout plan targeting specific goals.

The results of the multi-objective optimization show that under the scenario of economic development priority, the construction land and cultivated land area in the study area have both increased substantially. The area of cultivated land increased by 8.83% and the area of construction land increased by 16.18%, which also proves that the study area itself has the economic advantages of developing new types of agriculture and efficiently utilizing construction land, and it is likely that the increase in economic land will be more pronounced in the future. The amount of unutilized land likewise declined to zero, due to the fact that unutilized land is not economically efficient, and in this scenario, unutilized land is uniformly converted to construction land use.

Under the scenario of giving priority to ecological protection, the areas of forest land and grassland have increased by 4.82% and 18.18% respectively, with an obvious expansion of ecological land area, and the declining trend of water area has been mitigated, which is conducive to the further realization of ecological civilization in the area. Under this scenario, as ecological land is strictly protected, the areas of cultivated land and construction land show a slight increase, while the area of construction land increases by only 0.92 per cent, which mainly comes from unutilized land.

Under the sustainable development scenario, there is an expansion of arable land, water and built-up land to varying degrees, with an increase in the area of arable land by 2.67 per cent, water by 2.09 per cent and built-up land by 9.05 per cent. In contrast, the area of parkland and unutilized land decreases significantly, because parkland and unutilized land cannot provide high economic or ecological benefits. In this scenario, the ecological space and urban space show a balanced development, and the sustainable development goal takes into account both ecological and economic benefits, which not only realizes the flexible guidance and rigid control of ecological land, but also encourages the construction land to exchange for equal economic benefits through spatial agglomeration under the control of the increase in area.

Table 1. Area and proportion of land use type

Type	2020 area (hm2)	2021					
		Economic development		Ecological protection		Sustainable development	
		Area (hm2)	Difference (%)	Area (hm2)	Difference (%)	Area (hm2)	Difference (%)
Ploughing	157.5	171.4	8.83	161.7	2.67	161.7	2.67
Woodland	143.3	123.2	-14.03	150.2	4.82	142.1	-0.84
Garden land	33.4	20	-40.12	21.7	-35.03	10.3	-69.16
Grass	1.1	0.9	-18.18	1.3	18.18	1.1	0.00
Waters	71.9	57.1	-20.58	71.9	0.00	73.4	2.09
Construction land	224.3	260.6	16.18	226.4	0.94	244.6	9.05
Unexploited	1.7	0	-100	0	-100	0	-100
In total	633.2	633.2	0	633.2	0	633.2	0

5.3. Comprehensive Benefits Analysis of Landscape Design Planning Programs

In response to the demand of a local government, it is determined that the landscape design and spatial planning program under the sustainable development scenario in the above text will be implemented locally in the year 2021, and this section evaluates and analyzes the comprehensive benefits after implementation.

The environmental benefit assessment is to evaluate the extent to which the landscape design practice affects and improves the environment. It aims to measure the positive impacts on environmental quality and ecosystems after project implementation, and provides quantitative and qualitative data to support this. The environmental benefits assessment mainly includes, air quality improvement, water conservation and ecosystem protection and restoration. Social Benefits Assessment (SBA) aims to measure the positive impacts of project implementation on the well-being, quality of life and social connectivity of residents and communities, and to provide quantitative and qualitative data support. The social benefit assessment usually covers the improvement of quality of life, community connectivity, and social integration and cultural exchange. A questionnaire was designed and 50 local residents were invited to conduct a comprehensive benefit analysis of the landscape planning scheme on the above indicators using a five-point Richter scale.

Figure 3 illustrates the results of the survey on the impact of the project implementation on the environmental and social benefits of a site. It can be seen that the average scores of air quality improvement, water resource protection and ecosystem protection and restoration indicators in the environmental benefit assessment are 4.49, 4.15 and 4.72 respectively, which have gained high recognition from residents. The ecosystem protection and restoration index score of 4.72 means that the landscape design and planning scheme provided in this paper can protect biodiversity and realize the protection and restoration situation of wildlife habitats. The social benefit assessment of quality of life improvement, community connectivity improvement and social integration and cultural exchange 4.20, 4.25, 4.28, three of which have a high level of recognition by residents without large differences. This paper's proposal can provide better road traffic conditions, green environment and public service facilities, improve residents' travel convenience and quality of living environment, increase the frequency of communication and social interaction among residents, and promote residents' cultural exchange.

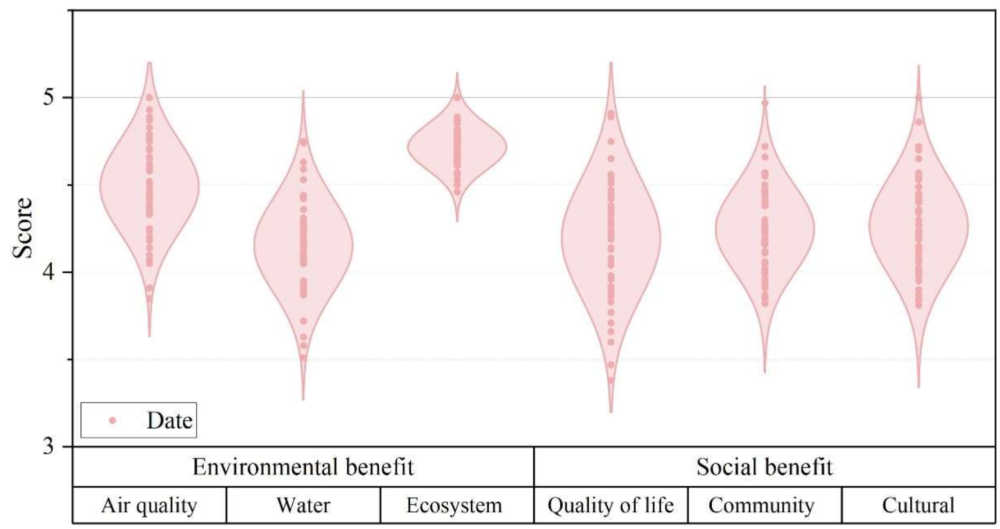

Fig. 3. Environmental benefits and social benefits survey results

The purpose of economic benefit assessment is to measure the positive impacts on economic output, employment, return on investment, etc. after the implementation of the project and to provide quantitative and qualitative data support. The implementation of landscape optimization and design can lead to the development of related industries and promote economic growth. This subsection assesses the economic benefits by comparing the value added, tax contribution, employment growth, and return on investment of related industries after the project implementation is provided. The statistical results of economic benefits are shown in Table 2. From the table, it can be seen that before the implementation of this paper's program in 2020, there are only 2 companies in related industries in a certain place until 2024 when the number of companies in related industries has reached 20. According to the survey, the tax contribution of related industries also shows an increasing trend year by year, and in 2024 it has exceeded 200,000, which indicates that this program increases the economic income of related industries. The employment rate of related industries increases from 0.5444% in 2020 to 13.175%, with an average annual growth rate of 3.16%. And the investment cost of landscape design and layout planning in 2020 is 2174921 yuan, until 2023 the cumulative investment income is more than 330,000 yuan, that is, the implementation of this paper's program can be profitable in only three years. In summary, this paper shows that the program for the local industrial development, employment promotion has shown a positive role in promoting.

Table 2. Economic benefit statistics

	Industry increase	Tax contribution(Yuan)	Employment rate(%)	Investment cost/income(Yuan)
2020	2	326152	0.544	-2174921
2021	5	541656	2.612	752926
2022	9	1167926	6.193	1027823
2023	14	1749427	9.447	1564372
2024	20	2449231	13.175	2149268

5.4. Satisfaction survey based on multilevel fuzzy judgments

In this paper, for the residents of a place and landscape satisfaction survey, through the hierarchical analysis method [41] to establish the landscape design and spatial layout planning satisfaction indicators as shown in Table 3.

Table 3. Landscape design and spatial layout planning satisfaction index

Primary indicators	Secondary indicators	Number
Public space	Number of active space	A1
	Space use	A2
	The distribution of leisure site is reasonable	A3
	Leisure venue open	A4
Green environment	Species diversity	B1
	The species is aesthetic	B2
	Plant greening ecology	B3
Supporting facilities	The number of recreational facilities	C1
	Number of parking and security facilities	C2
	The number of intelligent facilities	C3
External environment	Architectural aesthetics	D1
	Building and environmental coordination	D2
	Architectural feature	D3
	Environmental protection	D4
Road traffic	Internal road convenience	E1
	The design rationality of the car	E2
	The accessibility of the outside road	E3
	Road environmental protection	E4
Cultural atmosphere	Characteristic culture	F1
	Heritage	F2
	Ambience	F3
Operational maintenance	Maintenance of health greening facilities	G1
	The affairs residents are involved in the cooperation	G2

"Affiliation is a concept in fuzzy set theory used to quantify the degree to which an element belongs to a fuzzy set. The range of values is usually a real number between [0, 1], where 0 means not belonging at all, 1 means belonging completely, and values between 0 and 1 indicate different degrees of affiliation. The affiliation value of the evaluation level = the number of evaluators of the level / the total number of evaluation samples. In accordance with the principle of maximum affiliation, the evaluation level at which the maximum value of affiliation is taken is the evaluation level represented by the indicator.

A total of 50 questionnaires were recovered from the satisfaction survey of landscape design and spatial layout in a certain place, all of which were valid questionnaires, and the satisfaction data obtained from the survey were input into SPSS26.0 software and EXCEL2022 software, and the results of the evaluation of the secondary indicators were outputted after sorting the results of the data of the degree of affiliation. Secondary indicators questionnaire results affiliation statistics are shown in Figure 4. From the statistics of the questionnaire results alone, according to the principle of maximum affiliation, most of the indexes in the public space element, green environment element, supporting facilities element, cultural atmosphere element and operation and maintenance element tend to be satisfied with the evaluation, while most of the indexes in the external environment element and road traffic element tend to be generally evaluated, and the situation in general is showing a good trend.

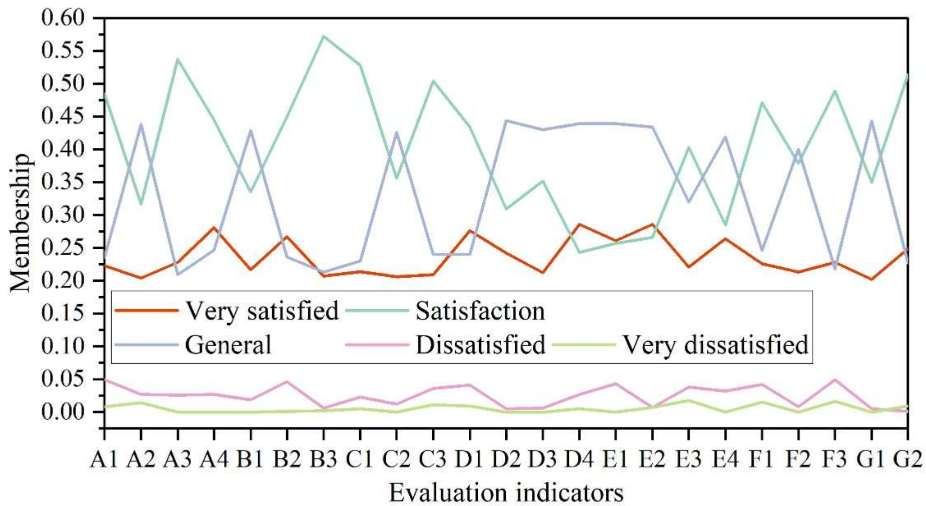

Fig. 4. Secondary index membership statistics

According to the questionnaire affiliation evaluation statistics obtained from the above survey, using SPSS and EXCEL software after the type of generalization and organization, using the fuzzy comprehensive evaluation method [42], the results of the fuzzy evaluation of landscape design and spatial layout planning level 1 indicators are shown in Figure 5.

As can be seen from the figure, the landscape of the site shows the highest trend in the green environment element and cultural atmosphere element after design optimization and layout planning, with satisfaction scores of 80.03 and 79.35 respectively. The evaluation on public space elements, supporting facilities elements, and operation and management elements shows a higher trend, with satisfaction between 73.44 and 75.08 points. This site has a high degree of intensive development of landscape space, and actively promotes neighborhood interactions between the districts in the process of future community creation. The site has a high degree of openness to the public, and is more unified for the management and operation level. However, the evaluation is relatively low in terms of the elements of the built environment and road transportation, with satisfaction scores of 71.17 and 70.27 respectively. In a comprehensive analysis, the overall indicators of the site all tend towards a satisfactory evaluation. It has given full play to the power of intelligent governance and digital camping, and through digital governance, it has improved the aspects of transportation, cultural atmosphere creation, maintenance and operation management, so that the satisfaction of residents has been improved.

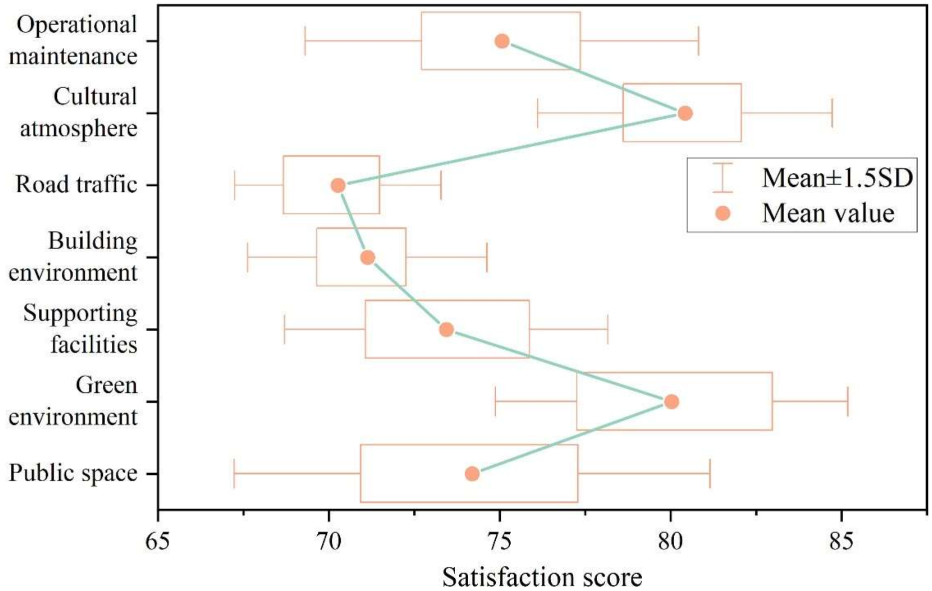

Fig. 5. The results of the fuzzy evaluation of the first level index

6. Conclusion

The study deeply analyzes the master plan of landscape design in a certain place, and designs a landscape design optimization and spatial layout strategy based on AI algorithm. The strategy optimizes the design routes of landscape facilities by constructing the shortest landscape facility browsing path objective function and establishing the shortest distance matrix between landscape facilities. Meanwhile, the landscape cost adaptation function is established to accurately design the number of landscape facilities and layout space. Then utilize the heuristic polygon layout algorithm to score the layout situation by scoring function for the unit layout area. And calculate the probability of landscape facilities appearing in the polygon, using particle swarm algorithm to solve the global optimization of landscape layout sequence, so as to optimize the spatial layout of landscape facilities. The feasibility of this paper's method is jointly verified through simulation experiments and practical applications.

The solution set of landscape design optimization and spatial layout planning is of good quality, and the evaluation index Hypervolume converges to around 0.815 in 30 rounds of iterations. In this paper, the landscape design optimization and spatial planning strategy under the sustainable development scenario is designed to expand the arable land, water and construction land by 2.67%, 2.09% and 9.05% respectively. The adoption of this scheme has improved the environmental benefits, social benefits and economic benefits to different degrees, in which the local residents' recognition of the environmental benefits and social benefits assessment indicators are more than 4 points. Local residents' satisfaction with the implementation of the program in this paper is shown to be satisfactory overall, with satisfaction scores for each indicator ranging from 70.27 to 80.03.

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