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Article

Research on optimization method of landscape design based on computer algorithms

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Abstract: Traditional landscape design primarily depends on the experience and subjective judgment of designers, lacking systematic and scientific algorithmic support, making it difficult to find the optimal solution in large-scale and complex scenes. This article proposes an interactive genetic algorithm for landscape design, which searches for the optimal solution in large-scale design spaces and improves design efficiency. Collect a large amount of landscape-related data, preprocess it, and ensure its quality, and ensure the quality of the data. Introduce elements such as plants, water bodies, and hard structures to initially design the space, extract features from landscape design images, and perform 3D reconstruction to obtain richer design space information. Generate initial design schemes using genetic algorithms and introduce subjective opinions from designers through interactive processes. The experimental results show that the average aesthetic score of interactive genetic algorithm for landscape design optimization is 9.0, and the average design time of interactive genetic algorithm is 34.5 days. Introducing the subjective opinions of designers into landscape design optimization based on heritage algorithms can effectively improve design aesthetics and shorten the total design time.

Keywords: landscape architecture; design optimization; interactive genetic algorithm; subjective opinions

1. Introduction

In recent years, considerable achievements have been made in the construction of urban landscaping projects, with constantly updated and improved engineering design concepts and construction techniques, bringing new vitality and vigor to urban landscaping. In urban landscape engineering design, landscape design is an important content. By exploring regional natural resources to design natural landscapes with diverse forms and rich connotations, it can shape a good urban environment and bring people a unique aesthetic experience [1,2]. However, many cities tend to have similar landscape design styles and lack distinctive features, making it difficult to provide people with unique emotional experiences and losing their due role.

The feature reconstruction of landscape spatial environment art is based on the visual reconstruction of landscape spatial environment design images, using visual image distributed fusion and binary recognition methods for visual reconstruction of landscape spatial environment design images, extracting geometric feature analysis models of landscape spatial environment design images, and using computer vision feature 3D reconstruction methods, realize the design of garden landscape spatial environment and image visual reconstruction, and improve the geometric recognition ability of visual features.

This article proposes an interactive genetic algorithm based method for optimizing the design of garden landscape spatial environment. Constructing a visual feature space distributed detection and fuzzy pixel region feature fusion reconstruction model for landscape design images, achieving landscape art landscape design. Finally, through simulation testing and analysis, interactive genetic algorithm can significantly improve the beauty of landscape design and shorten design time.

2. Related work

The overall planning and design level of landscape design needs to be improved, the landscape construction lacks technical innovation, the urban landscape construction lacks unity with the ecological environment utility, the plant varieties in landscape planning are unreasonable, and the landscape planning generally emphasizes construction and ignores management. Zhou Jian discussed the development trend of modern urban landscape planning and design, and emphasized that we should establish an ecological garden concept that meets the requirements of modern urban development, plan long-term goals based on the overall development requirements of modern cities, combine biodiversity, science and artistry, give consideration to economic, ecological and social benefits, clarify the theme of humanized landscape design, and stress the highly comprehensive application of multiple disciplines [3]. Zou Mo pointed out that under the climate change scenario, the negative impact of urban heat island will be aggravated due to unsustainable urban planning and human activities. In landscape design, crown density, natural structure and ground cover density, waterscape shape, color and texture of materials and the scale of sunshade structure have different cooling effects and performances in improving outdoor thermal comfort [4]. He Mei pointed out that urban forest park is an important community resource to support sports activities of people of all ages, and the high plant diversity in the park creates a functional therapeutic landscape that can be perceived by the five senses [5]. Hussein Heba Adel Ahmed integrated augmented reality technology into landscape design education, thus creating a more beneficial educational environment, providing an interesting learning atmosphere and deepening students' understanding of the landscape design process [6]. Traditional garden landscape design may be subject to empiricism and single design idea, lacking the scientific nature of overall planning. The design level may be limited by the experience and aesthetic point of view of individual designers, and it is difficult to realize the optimal planning of large-scale and complex scenes.

The introduction of computer algorithms can provide a comprehensive solution for landscape design. Through the optimization algorithm, the overall planning can be scientific and efficient, and at the same time, the ecological environment utility can be optimized comprehensively. Garden landscape is a key part of the scenic tourist area. In order to effectively improve the design effect of garden plant landscape, Yulu analyzed the problems existing in garden plant landscape design and the principles of plant landscape design based on visual characteristics, so as to carry out targeted landscape optimization [7]. Wortmann Thomas uses genetic algorithm to optimize the structure, building energy and sunlight in landscape design [8]. Lu Yao builds three-dimensional space model and virtual reality scene. On the platform of lumion software, the dynamic visual virtual campus is transformed to cultivate students' professional overall architectural design and space display ability, and provide a scientific, simple, intuitive and vivid interactive reference platform for landscape education, visual construction of digital campus, school management and social public service [9]. Hermansdorfer Mariusz proposed a new method for digital terrain simulation of climate adaptation planning. Designers only need to describe the drainage mode required for a given site and use the genetic solver for subsequent optimization [10]. The application of computer algorithm can improve the effect of landscape design, but the computer algorithm used is not optimal. Xie ZW researched the key technology for the realization of CIM-based urban planning assisted decision-making system, gave the realization path of the assisted decision-making system, and the practice shows that the system has high feasibility and practicability in urban planning decision-making [11].

3. Methods

3.1. Data collection and preprocessing

Landscape design is an important component of urban planning and construction, which not only relates to the quality of life of urban residents, but also involves the sustainability of the urban ecological environment. Modern urban development has put forward higher requirements for landscape architecture, requiring more innovative and sustainable design solutions. Optimizing design can better adapt the landscape to the process of urbanization and coordinate with various needs such as urban planning, construction, and cultural heritage.

The goals of landscape design optimization include aesthetics and design efficiency. In order to effectively obtain information on landscape architecture, collect data related to landscape architecture. Collect geographic information using satellite images or geographic information systems, collect meteorological data through meteorological stations, and conduct geological surveys. The collected data related to some garden landscapes are shown in **Table 1**.

Table 1. Partial landscape related data.

Serial number	Longitude(°)	Latitude(°)	Soil types	Wind speed (m/s)	Humidity (%)	Precipitation (mm)
1	116.6(E)	40.1(N)	Clay	2.5	65	15
2	115.9(W)	40.0(N)	Sandy soil	3.2	75	20
3	117.3(W)	41.2(N)	Yellow soil	2	60	10
4	114.7(W)	38.8(N)	Brown earth	2.8	70	18
5	116.8(W)	39.9(N)	Clay sand mixed soil	3.5	80	25
6	115.4(W)	40.6(N)	Red earth	2.2	68	12
7	117.7(E)	41.3(N)	Clay	2.7	72	22
8	115.0(W)	39.0(N)	Sandy soil	2.9	78	16
9	116.1(W)	39.9(N)	Yellow soil	2.3	63	14
10	115.4(W)	40.2(N)	Brown earth	3.1	74	19

In **Table 1,** some landscape related data are described, including longitude, latitude, soil type, wind speed, humidity, and precipitation. The collected data can comprehensively understand the precise geographical location of the design area, which helps to understand the sunshine situation, climate zone classification, and other information of the design area, thereby helping to design a reasonable plant layout and landscape element arrangement. Different soil types affect the growth status of plants, including soil permeability, nutrient content, etc. Considering wind speed in design can help select plants that are adaptable to wind, optimize the layout of hard structures, and reduce the adverse effects of wind on the landscape. The use of humidity data helps designers select plants that adapt to humidity conditions and improve the ecological adaptability of the landscape. By integrating various aspects of data for design optimization, landscape design can be closer to the natural environment, improve the survival rate of plants, and enhance the sustainability of the landscape.

In order to effectively analyze the collected data further, it is necessary to improve the quality and availability of the data through data preprocessing. The content of data preprocessing includes data cleaning and data standardization. Check for missing values in each variable, and fill in the missing values using the average of the data.

Use box plots to display the spatial distribution of data, detect outlier data points, and replace outlier values with the average of the data. Check if there are identical records in the dataset, merge duplicate records, and ensure the uniqueness of the data.

Data standardization is the process of adjusting data to the same scale or distribution to ensure comparability between different features.

The standardized equation for Min Max is expressed as:

$$X_{nor} = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{1}$$

X_{min} and X_{max} represent the minimum and maximum values of data features, respectively.

3.2. Visual feature extraction

Use computer-aided design tools to provide an intuitive design interface and a rich library of design elements. Introduce elements in landscape design, including plant elements, water body design, and hard structures. Choose plants that are suitable for the local climate and soil conditions, and make a reasonable layout, considering the growth cycle and height differences of plants. Add water elements such as ponds, fountains, or streams, considering the shape, size, and location of the water body on the landscape. Introduce hard structures, including slate roads, outdoor seating, sculptures, etc., to enhance the diversity of the landscape.

Obtain sufficient design space images through camera equipment, use image processing algorithms to perform distributed fusion of images, and improve image clarity and details. In order to improve the quality of images, image information is preprocessed. The equation for grayscale transformation of images is expressed as:

$$Gray = 0.299 \times R + 0.587 \times G + 0.114 \times B \tag{2}$$

Perform median filtering on grayscale images, sort the values of all pixels in the neighborhood, and then select the middle value as the new pixel value. The results of image preprocessing are shown in **Figure 1**.

Figure 1. Results of image preprocessing.

In **Figure 1**, the results of image preprocessing are described, and the image is subjected to grayscale processing and then denoised using a median filter. Median filtering preserves the main features and details of the image while removing high-frequency noise. Achieve a balance of image clarity, preserving details, and reducing noise.

Use binary recognition methods to convert images into black and white binary images, highlighting the main features in the landscape. Using image processing algorithms to extract shape information of landscape elements, such as contours, boundaries, etc. Extract color information of elements such as plants and water through color analysis. Obtain surface texture features of landscape elements such as plants and land through grayscale co-occurrence matrix, in order to better understand and express the design space.

Use point cloud technology to convert 2D image information into 3D point cloud data. Using structured light scanning technology to obtain the three-dimensional shape of landscape elements. Using computer vision algorithms for feature point matching to enhance the geometric recognition ability of landscape elements. Optimize the generated 3D model, remove noise, and ensure the authenticity of geometric shapes. Taking into account the growth needs of plants, the water cycle system of water bodies, and the structural stability of hard structures.

3.3. Interactive genetic algorithm optimization design

Genetic algorithm is a search and optimization algorithm inspired by natural selection and genetic theory, which iteratively searches for the optimal solution in the solution space. The goal of optimizing landscape design is aesthetics and design efficiency.

So the fitness function is expressed as:

$$F = w_1 \times x_1 + w_2 \times x_2 \tag{3}$$

In Equation (3), w_1 and w_2 represents the weight of aesthetics and design efficiency, respectively.

In interactive genetic algorithms, the subjective opinions of designers are incorporated into the fitness function to better reflect their preferences. The new fitness function is represented as:

$$F' = F + w_3 \times S \tag{4}$$

In Equation (4), S is the subjective opinion of the designer.

Use selection operators to select a portion of individuals as parents based on fitness values, and perform crossover operations on the selected parent individuals to generate new ones. Perform mutation operations on newly generated individuals and introduce some randomness. Apply fitness functions to new individuals generated through crossover and mutation to evaluate their strengths and weaknesses.

A selection strategy is used to combine newly generated individuals with existing individuals to form the next generation of the population, and the selection, crossover, mutation, and fitness assessment of the new individuals are repeated until a set number of iterations is reached or stopping conditions are met. Specifically, at the beginning of each generation, the advantages and disadvantages of all individuals in the current population are first evaluated according to the fitness function, and a certain number of excellent individuals are selected from the current population as the parent generation using random traversal sampling, which is used to generate new individuals for the next generation. The selected individuals of the parent generation will be paired two by two to generate new offspring individuals through crossover operation, and after the crossover operation, mutation operation will be performed on the newly generated offspring individuals, and then fitness assessment will be performed on the new individuals generated after crossover and mutation operation, and based on the results of fitness assessment, the individuals with higher fitness can be screened out to be a part of the population of the next generation, and the individuals with higher fitness can be used as a part of the next generation population by combining the new individuals generated after the selection, crossover, mutation, and The new individuals generated after selection, crossover, mutation and fitness assessment are combined with existing individuals to form the next generation population. The interactive genetic algorithm is shown in **Figure 2**.

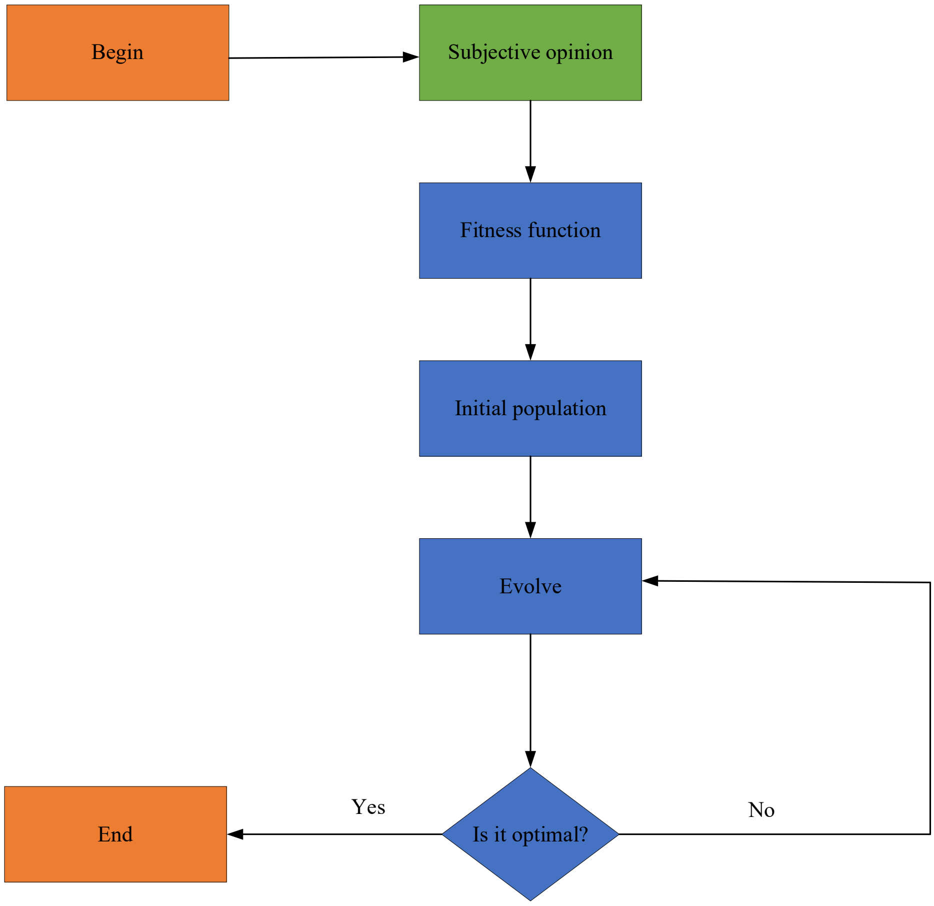

Figure 2. Interactive genetic algorithm.

In **Figure 2**, the interactive genetic algorithm is described. The subjective opinions of the designer are included in the optimization process of the algorithm. This interaction enables the designer to directly participate in the optimization process and adjust the design scheme to meet his personal preferences and needs. The subjective opinions of designers are conveyed through visual tools, allowing them to see the evolution of the design in real-time.

Using image blur detection algorithm to detect blurry pixel areas in the image. Blurred pixels may represent certain details or distant scenery in the landscape. Build a feature fusion model to fuse visual feature space and blurred pixel region information. Using convolutional neural networks to learn feature fusion rules in an end-to-end manner.

Use image similarity algorithm to extract similar regions and elements in the image, including color similarity, texture similarity, etc. Integrate similarity information with the features output by the feature fusion model to perceive the information of garden art landscapes. Divide the image into several blocks, each containing a certain number of pixels. Using template matching algorithms to match landscape elements such as flower beds, trees, etc. Integrate the matching results with the similarity information mentioned above and the information output from the feature fusion model to obtain a more complete landscape information of the segmented area.

Using computer-aided design tools and 3D modeling functions to create a 3D model of landscape design, simulating the growth changes of plants in different seasons, including plant height, flowering period, etc. It is also necessary to simulate factors such as lighting conditions, water bodies, and seasonal changes to construct a realistic environment.

4. Results and discussio

4.1. Aesthetic analysis results

Randomly select 50 users for subjective evaluation of the aesthetics of landscape design, with a score range of [0, 10] for aesthetics. The higher the score, the better the aesthetics. A comparison was made between interactive genetic algorithm, ordinary genetic algorithm, and linear programming algorithm. The comparison results of the aesthetics of landscape design optimization using different algorithms are shown in **Figure 3**.

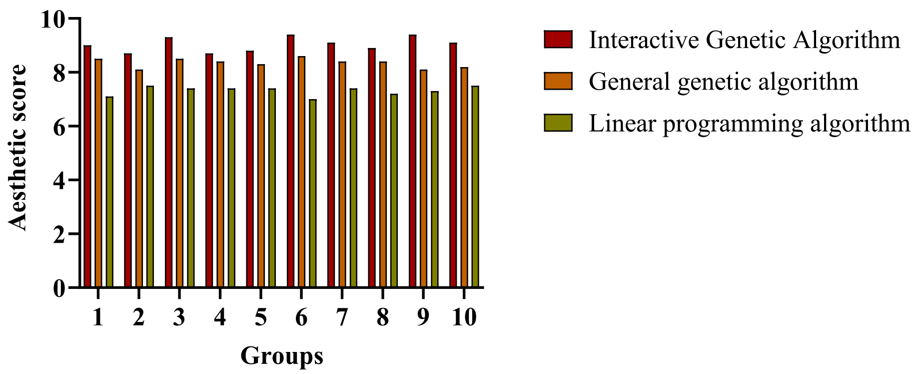

Figure 3. Aesthetic analysis results.

In **Figure 3**, the results of aesthetic analysis are described, with the horizontal axis representing the division of users into 10 groups and the vertical axis representing the aesthetic score. It is obvious that the aesthetic score of interactive genetic algorithm is higher than that of ordinary genetic algorithm, and the aesthetic score of ordinary genetic algorithm is higher than that of linear programming algorithm. The average aesthetic score of interactive genetic algorithm is 9.0. Interactive genetic algorithm allows designers to directly participate in the optimization process, guiding the evolution process through repeated interactive evaluations. The subjective opinions of designers are incorporated into the optimization process, making the optimization direction more in line with the personalized aesthetic needs of designers.

4.2. Design efficiency

Design efficiency is reflected by the total working time required for the design. The total working time for designing different algorithms is shown in **Figure 4**.

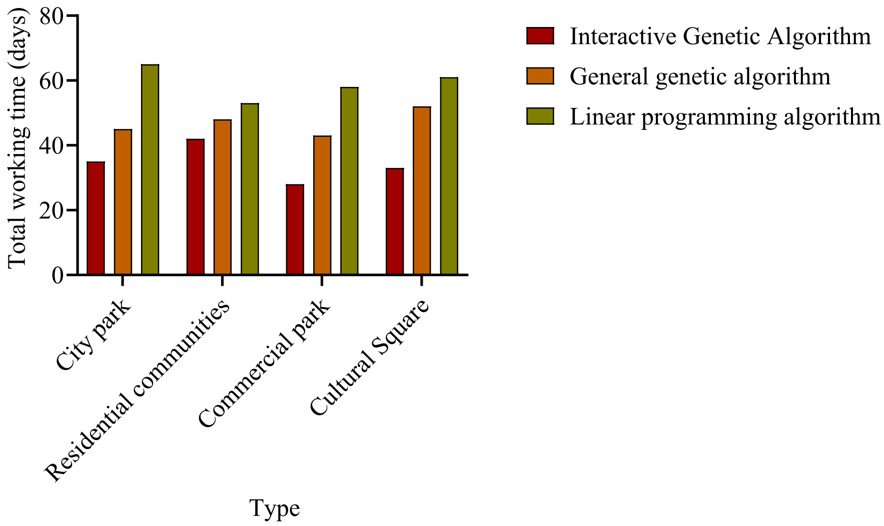

Figure 4. Total working time of different algorithm designs.

In **Figure 4**, the total design work time for different algorithms is described. The horizontal axis represents four design types, including urban parks, residential communities, commercial parks, and cultural squares, while the vertical axis represents the total design work time. Interactive genetic algorithm can significantly shorten the total design work time, mainly because it allows designers to directly participate in the design evolution process. Through real-time interaction, designers can intuitively guide the search direction of the algorithm. The average design time of interactive genetic algorithm is 34.5 days.

4.3. Ecological analysis

In this design, interactive genetic algorithm is used to pass the optimization design, in the design process, the protection and restoration of natural landscape and the maintenance of biodiversity can be fully considered, which makes the urban landscape design more in line with the principle of ecological protection, and the urban green space system with ecological function can be constructed through the reasonable planning layout and vegetation configuration.

5. Conclusion

Landscape design is a key area in urban planning and architectural design, with the goal of creating outdoor spaces that are both aesthetically pleasing and practical. With the continuous development of urbanization and people's attention to the ecological environment, landscape design has become an important component of urban construction. This article adopts an interactive genetic algorithm for landscape design optimization, allowing designers to make flexible adjustments and optimizations at different stages of the design. By introducing the subjective opinions of designers, the algorithm can explore the design space more flexibly. The results show that interactive genetic algorithm for landscape design optimization can significantly improve the aesthetic appeal of the design and significantly shorten the design time. The use of advanced computer algorithms for design optimization helps to provide more innovative and sustainable landscaping for future cities. However, this article lacks analysis of more types of landscape design, and in the future, more types of landscape design can be expanded.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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