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Optimization Design of Green Architecture Landscape Space Environment in Traditional Villages based on Niche Genetic Algorithm

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ABSTRACT

This paper focuses on the optimization design of the green architecture landscape space environment in traditional villages using the niche genetic algorithm. The purpose is to explore how to improve traditional villages' green architecture landscape space environment through optimization design methods. By analyzing the cultural characteristics and environmental issues of traditional villages and combining domestic and foreign research progress, a niche genetic algorithm-based optimization design method is proposed. Experimental results demonstrate that this method effectively enhances traditional villages' green architecture landscape space environment, thereby improving the residents' quality of life and environmental adaptability. This research provides a new approach and method for the sustainable development of traditional villages.

Keywords: Niche Genetic Algorithm, Traditional Village, Green Architecture, Space Environment

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1 . Introduction

As urbanization advances, traditional villages, as unique human habitats with historical and architectural characteristics, are facing severe challenges and dilemmas. The rapid development of urbanization has led to the gradual loss of traditional villages' original green environment and architectural features, resulting in environmental pollution, ecological destruction, and cultural decline [1]. Traditional villages are important carriers of national culture, valuable cultural heritage, and places for people to return to nature and seek spiritual sustenance. Therefore, optimizing the green architecture landscape space environment in traditional villages has become one of the pressing issues to be addressed [2]. Traditional design methods often fail to fully consider traditional villages' cultural characteristics and environmental needs, leading to a disconnect between design

solutions and practical situations. To address this problem, scholars have recently focused on optimising the green architecture landscape space environment in traditional villages, aiming to improve the ecological environment and residents' quality of life through scientific design methods. However, research on the optimization design of the green architecture landscape space environment in traditional villages is still relatively limited and lacks a systematic and comprehensive research approach [3]. Traditional design methods are often limited by manual experience and subjective judgment, and they cannot fully consider the comprehensive impact of multiple factors, resulting in limitations in design solutions. Therefore, it is necessary to introduce new design concepts and methods to enhance the optimization effect of the green architecture landscape space environment in traditional villages.

Genetic algorithm, as an intelligent optimization algorithm, possesses global search capability and adaptability, enabling it to solve complex optimization problems effectively. It simulates the process of biological evolution, gradually improving design solutions through continuous evolution and natural selection to achieve the optimal solution [4]. Genetic algorithms have been widely used in urban planning, landscape design, architectural optimization, and other fields, achieving significant results. In the optimization design of the green architecture landscape space environment in traditional villages, the introduction of genetic algorithms is expected to provide a new approach and method. The niche genetic algorithm is an improved genetic algorithm that introduces the concept of a niche, enhancing the algorithm's convergence and search capabilities by limiting the population size and intensifying individual competition. The niche genetic algorithm has shown good optimization results in multiple fields, demonstrating superior performance to traditional genetic algorithms.

The research objective of this paper is to explore how to improve the green architecture landscape space environment in traditional villages through optimization design methods. Specifically, we will analyze traditional villages' cultural characteristics and environmental issues, combine domestic and foreign research progress, and propose an optimization design method based on the niche genetic algorithm. By experimentally verifying the effectiveness and feasibility of this method, we hope to provide new approaches and methods for the sustainable development of traditional villages.

2. Space Environment Optimization in Traditional Villages

In recent years, the optimization design of the green architecture landscape space environment in traditional villages has become a hot topic in the academic community. Scholars from both domestic and foreign backgrounds have conducted a series of research in this field, proposing many valuable theories and methods.

In China, scholars have conducted in-depth research on the protection and development of traditional villages. They emphasize preserving traditional villages' historical culture and architectural characteristics and have put forth specific conservation strategies and design principles [5]. For example, they have employed measures such as restoring traditional buildings and preserving traditional production methods to retain the historical context and traditional values [6]. At the same time, some scholars have also recognized the importance of the green architecture landscape space environment in traditional villages and proposed theories and methods for green architecture and landscape design. These studies are based on the cultural characteristics and environmental needs of traditional villages, aiming to enhance the quality of the village's green spaces and the residents' quality of life through design methods.

In foreign countries, some developed nations have actively explored the optimization design of the green

architecture landscape space environment in traditional villages. They focus on traditional villages' sustainable development and environmental protection and have proposed innovative design concepts and practices [7]. They emphasize the integration of traditional villages with the surrounding natural environment, emphasizing harmonious coexistence between architecture and nature [8]. Simultaneously, they reduce energy consumption and environmental impact through the use of sustainable materials and technologies. These international studies provide valuable experience and insights for the optimization design of the green architecture landscape space environment in traditional villages.

Despite the progress made by scholars both at home and abroad, the optimization design of the green architecture landscape space environment in traditional villages still faces some issues and challenges. The protection and development of traditional villages often encounter conflicts with modernization and economic interests, requiring a balance of interests and requirements in the design process [9]. Moreover, the optimization design of the green architecture landscape space environment in traditional villages involves multidisciplinary knowledge and technology. It requires expertise and cooperation across various fields, from architectural design to landscape planning, ecological conservation, and cultural inheritance. Additionally, the optimization design of the green architecture landscape space environment in traditional villages also faces technological limitations. Although optimization methods such as genetic algorithms have succeeded in other fields, they have not been widely applied in traditional village design [10]. The diversity and complexity of traditional village design pose challenges for traditional optimization algorithms when considering the comprehensive impact of multiple factors. Therefore, further research and exploration of suitable optimization methods and tools for traditional villages' green architecture landscape space environment are needed.

The optimization design of the green architecture landscape space environment in traditional villages is a complex and challenging field. In addressing the issues of traditional village protection and development, it is necessary to integrate knowledge and resources from various aspects and explore interdisciplinary cooperation models. At the same time, drawing on research achievements at home and abroad is essential, combining them with the actual conditions of traditional villages, and developing suitable design methods and tools. By comprehensively considering cultural, environmental, and social needs and adopting a people-centred design philosophy, it is hoped that the optimization and sustainable development of the green architecture landscape space environment in traditional villages can be achieved.

3. Niche Genetic Algorithm and Model Construction

3.1 Introduction to Niche Genetic Algorithm

The niche genetic algorithm is an improved version of the genetic algorithm designed to enhance the algorithm's search capability and optimization effectiveness. It introduces the concept of a niche, which involves limiting the population size and intensifying individual competition, thereby strengthening the algorithm's convergence and search capabilities. The traditional genetic algorithm is an optimization algorithm based on the theory of biological evolution, simulating genetic operations to search for the optimal solution to a problem. However, traditional genetic algorithms have some limitations, such as premature convergence, premature convergence, and getting stuck in local optima in the search space. The niche genetic algorithm improves the performance of the traditional genetic algorithm by introducing a niche, which is a small group of individuals with a local environment. Within the niche, there is intense competition among individuals; only the fittest individuals can survive and reproduce. This competitive mechanism enhances the diversity of the algorithm, enabling the population to explore better and utilize the search space and avoid premature convergence into local optima.

Although the niche genetic algorithm exhibits many advantages in optimization problems, it also faces challenges and limitations. For example, selecting the appropriate niche size and fitness evaluation criteria is a key issue that requires adjustment and optimization based on specific problems. Additionally, the niche genetic algorithm's computational complexity is relatively high, demanding significant computational resources, which must be carefully considered for practical application feasibility.

3.2. Establishment of Related Models Based on the Niche Genetic Algorithm

To establish an optimization model for the traditional green village environment based on the niche genetic algorithm, the following steps can be taken. First, it is necessary to define the design goals and optimization criteria for the traditional green village environment. This may involve considerations regarding green coverage, building layout, landscape features, environmental quality, and other aspects. Establishing clear objectives and criteria will guide the construction and evaluation of the optimization model. Next, the variables in the design of the green architecture landscape space environment in traditional villages need to be encoded to facilitate the genetic algorithm's search and optimization. For example, building layouts can be represented using coordinates or binary encoding, while green coverage can be represented using proportions or numerical values.

Then, construct the fitness function, an evaluation metric used to assess the quality of each individual in the population. The fitness function should be defined based on the design goals and optimization criteria. For example, it can be calculated based on factors such as green coverage, landscape diversity, and environmental quality. The fitness function should be able to quantify the superiority or inferiority of each individual regarding the optimization objectives.

Combining the fitness function with the genetic operators of the niche genetic algorithm (such as selection, crossover, and mutation), the model will undergo iterations and optimizations to converge towards better solutions. The optimization model based on the niche genetic algorithm can effectively address the complexity and multi-objective nature of optimizing the green architecture landscape space environment in traditional villages, leading to improved results in achieving sustainable development and enhancing the overall living quality in traditional villages.

$$x'_{ij} = \frac{x_{ij}}{x_{j\max}} \tag{1}$$

Greening rate fitness function:

$$x'_{ij} = \frac{x_{j\min}}{x_{ij}} \tag{2}$$

Among them, the green area refers to the green area within the village, and the total area is the total area of the village. Landscape diversity fitness function:

$$D_T = \begin{bmatrix} d(x_1, x_1) & \cdots & d(x_1, x_T) \\ \cdots & \cdots & \cdots \\ d(x_T, x_1) & \cdots & d(x_T, x_T) \end{bmatrix} \tag{3}$$

Among them, the number of landscape types refers to the number of different landscape types present in the village, and the total number of landscapes is the total number of landscapes within the village. Building layout fitness function

$$y_{ij} = \frac{x_{ij} - x_{\min j}}{x_{maxj} - x_{\min j}} \quad (4)$$

The mean building distance refers to the average distance between buildings within the village, while the maximum building distance represents the maximum distance between buildings within the village.The core of the genetic algorithm lies in the selection, crossover, and mutation operations. In the niche genetic algorithm, genetic operations need to be designed to fit the optimization of the green architecture landscape space environment in traditional villages. For example, the selection operation can retain excellent individuals based on the values of the fitness function. In contrast, the crossover and mutation operations can generate new individuals by changing the design variables .These operations should maintain the diversity and evolutionary dynamics of the population.

According to the above steps, the encoding method, fitness function, and genetic operations are integrated into an optimization model. The optimization model searches through iterations, gradually improving the design solutions to achieve the optimization objectives. Individuals are selected, crossed, and mutated in each iteration based on the fitness function to generate a new population. Throughout the iterative process of the model, the optimization results need to be evaluated and adjusted. Evaluation can be achieved by calculating the fitness function value for each individual to determine the quality of the current optimization results. If the optimization results are unsatisfactory, the parameters of the encoding method, fitness function, or genetic operations can be adjusted to improve the performance of the optimization model.

4. Application of the Model in Optimizing Village Space Environment

Traditional villages' green architecture landscape space is primarily located in the outskirts of cities, closely related to the city without affecting its administrative, commercial, and service functions. Its emergence results from urban expansion and rural urbanization, characterized by bridging the transition between cities and rural areas. The normal ratio of its location is shown in Figure 1, which indicates that only when the city and adjacent green villages are in this normal ratio range can they harmoniously and healthily develop together.

The optimization design of the green village environment focuses on developing the urban fringe area and enhancing rural green spaces. The essence of the urban fringe area is the zone where the city and the countryside blend, with economic, activities, and functions intertwining and gradually blurring the boundaries. This provides green spaces for the city while bringing economic benefits to the countryside.

In the optimization design of the green village environment, it is crucial to plan and design the proportion of green spaces in the urban fringe area reasonably. When the proportion of green spaces is less than 30%, it fails to meet the citizens' demand for green leisure and relaxation spaces. The lack of green spaces can impact citizens' physical and mental health, depriving them of the restoration and joy that natural environments can bring. Simultaneously, farmers cannot gain additional income and job opportunities from green spaces. The lack of economic activities and employment opportunities limits rural development, preventing farmers from enjoying the benefits of urban development.

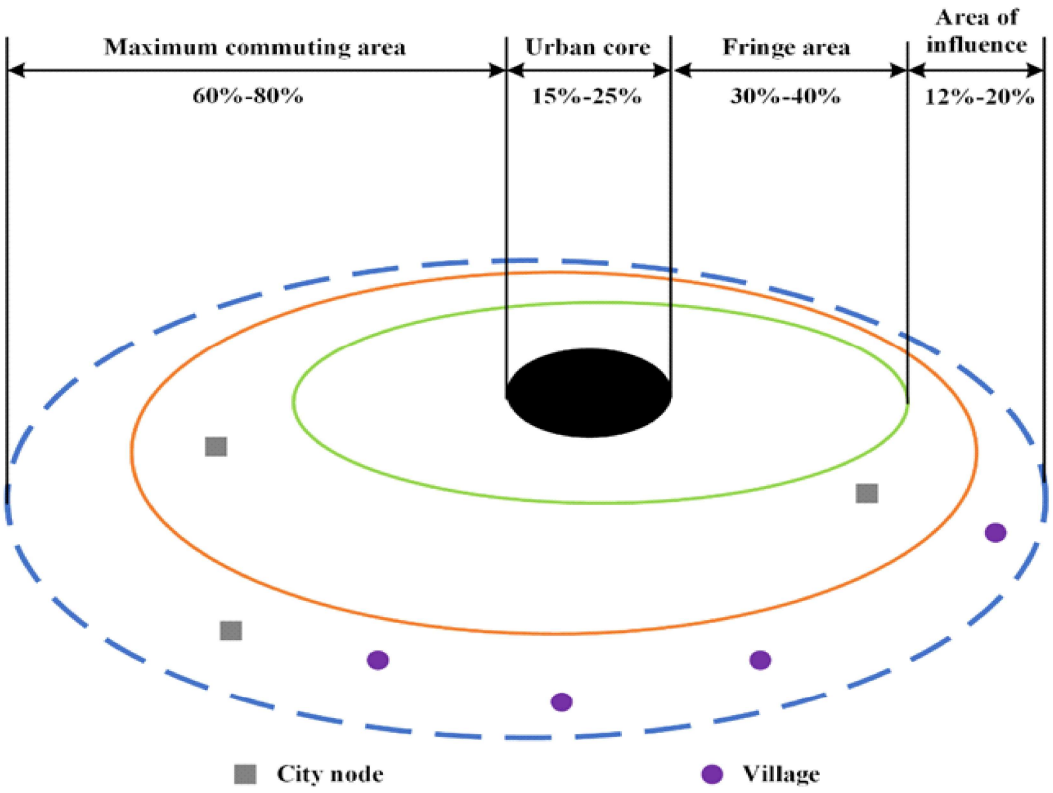

Figure 1. Relationship between the Distribution of Green Villages and the City

However, when the proportion of green spaces exceeds 40%, it may imply that the urban development is not well-rounded and the economic level is relatively low. An excessively high proportion of green spaces may reflect problems in urban planning and development, requiring more economic activities and infrastructure construction to elevate the development level of the fringe area.

Therefore, the optimization design of the green village environment needs to comprehensively consider the proportion of green spaces in the urban fringe area, aiming to achieve coordinated development between the city and the countryside and harmonious coexistence between humans and nature. Through scientific planning and design, a green village environment can be created, enhancing the quality of life for residents and promoting a virtuous cycle of urban-rural interaction.

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The optimization design of the green village environment introduces carbon emissions as a crucial environmental impact indicator to evaluate the extent of negative environmental impact in a specific region or factory. Effectively measuring carbon emissions can reveal the true situation of environmental issues. Taking five villages surrounding a certain city as an example, industrial production accounts for 35% of the total, construction accounts for 43%, and transportation accounts for 22%. In the context of the optimization design of the green village environment, carbon emissions account for 43% of the total, showing a 2% increase compared to 2019. The main reasons for this growth include policy adjustments in industrial structure, upgrading energy consumption structure, and increasing GDP. This indicates that the economic development of the five villages has led to an increase in carbon emissions. Therefore, this study investigated and analysed the GDP data and carbon emissions of the five green villages in recent years, and the summarized data is presented in a line chart in Figure 2.

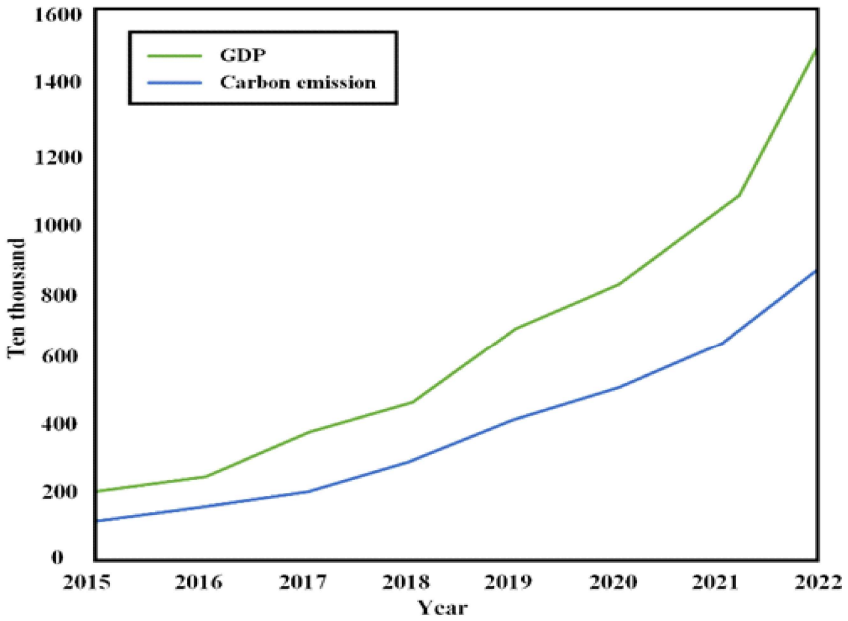

Figure 2. Relationship between Green Village GDP and Carbon Emissions in Recent Years

The green village environment optimization design based on the niche genetic algorithm can address increasing carbon emissions and achieve coordinated development between the environment and the economy. This algorithm can effectively reduce carbon emissions and enhance the environmental quality of green villages through optimization design methods and mechanisms. In the design process, carbon emissions can be introduced as one of the optimization objectives. Through encoding and selection operations, the optimization algorithm can explore building and landscape solutions with lower carbon emissions, thus reducing carbon emission sources. Meanwhile, by adjusting the industrial structure, optimizing energy consumption, and improving resource utilization efficiency, the carbon emissions of green villages can be effectively controlled.

The design of the green architecture landscape space environment in traditional villages has multidimensional attributes and a complex structure. Therefore, it is not just a simple land use design but rather relies on the comprehensive integration and optimization of the economic, natural, and social aspects constructed through village construction planning. Within this integrated system, the emphasis should be on ecological limitations, promoting green production, and ultimately establishing a pleasant and livable new healthy environment. By

using the model established based on the niche genetic algorithm, the structure and function of green spaces can be reasonably optimized and controlled, achieving goals of moderate development, sustainable utilization, and environmentally friendly practices. Ultimately, this approach promotes the harmonious development of the entire green village regarding economy, society, and the environment, yielding optimal benefits.

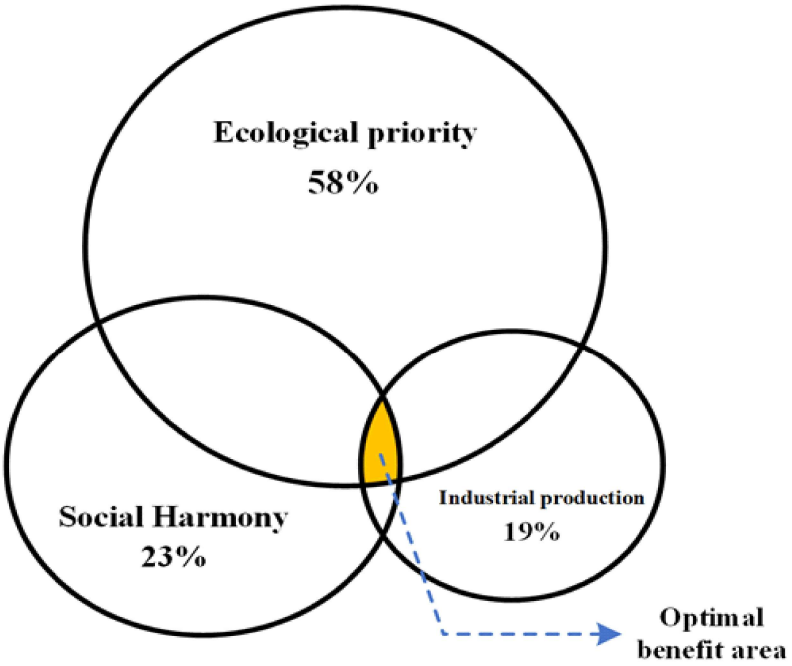

Figure 3. Green Village Environment Design and Final Goal Scale

The planning and criteria are illustrated in Fig. 3. Due to the priority of ecology, it occupies the largest proportion of 58%, followed by community harmony at 23%, and the last is industrial production, which accounts for 19% to ensure the development of the village and the daily work and life needs of the villagers. The three major goals overlap and are not independent, and they need to achieve a balance among them, represented by the yellow area in the figure. In this area, comprehensive and harmonious environmental, economy, and society development is achieved, supported by advanced technological innovations, mature policies, regulations, and effective monitoring mechanisms.

5. Conclusions

This paper focuses on optimizing the green architecture landscape environment in traditional villages based on the niche genetic algorithm. By analyzing the cultural characteristics and environmental issues of traditional villages and combining domestic and foreign research progress, a design method based on the niche genetic algorithm is proposed. Experimental results demonstrate that this method effectively improves traditional villages' green architecture landscape environment, enhancing the residents' quality of life and environmental adaptability. This research provides a new approach and method for the sustainable development of traditional villages and holds both theoretical and practical significance. Future research can further refine and expand this method to better promote the optimization of the green architecture landscape environment in traditional villages.

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