Building Space Optimization Algorithm Based on Multi-Agent

Zilin He

{1700239063@qq.com}

Shenyang Jianzhu University, Shenyang, 110000, Liaoning province, China

Abstract: In the design of museum buildings, reasonable use of space plays a key role in the exhibition effect of the museum. However, due to space constraints, in the existing architectural design, it is often difficult to obtain a better display effect. In addition, in the design of museum buildings, how to make the audience more comfortable and convenient to appreciate the exhibits is also a key issue. This paper introduces the multi-agent technology into the optimization design of museum building space, and adopts a multi-agent based optimization method of museum building space. Through the experiment, it is found that the multi-agent based building space optimization design can improve the space utilization rate to 97.7%.

Keywords: Multi-Agent, Architectural Space, Spatial Optimization, Spatial Utilization

1. Introduction

Museums are an important part of national culture and tourism resources, and play an important role in promoting the development of culture and tourism industry, disseminating advanced culture and enhancing human civilization exchanges and cooperation. With the development of museums, how to let more people know about the exhibits displayed in museums and how to let the audience better appreciate the exhibits has become an important research topic. With the extensive application of artificial intelligence technology in various fields, intelligent building design has been developed rapidly. Intelligent building design is to use computer technology and scientific research results to achieve building design and management through information integration, knowledge sharing and independent collaboration.

In recent years, many excellent scholars and experts have studied the spatial optimization. In order to improve the scientificalness of building edge space design and maximize the use of space resources, Zhang Zhengyang took a certain building project as the research object, based on the space syntax theory, quantitatively analyzed the space parameters through Depthmap software, and optimized the building edge space from three aspects: road space, activity space and landscape space [1]. Xu Qianyi conducted an in-depth investigation of the outdoor public space of Hebei Institute of Architecture and Engineering by using methods such as cognitive maps, questionnaire surveys, and field surveys, and analyzed them using methods

ICSETPSD 2023, November 17-18, Coimbatore, India

DOI 10.4108/eai.17-11-2023.2342741

such as heat maps, walking isochrones, and Pearson correlation analysis[2]. Pei Xin used virtual reality technology to improve the basic structure of architectural space; through the design of spatial reorganization, he optimized the design of concrete structure architectural space functions. The experimental test results showed that compared with the traditional space optimization design, the proposed space optimization design method had a higher proportion of building space optimization, and it could be seen that virtual reality technology had a better matching effect on concrete structures [3]. Wan Zhiyuan briefly described the theory and application of bionics in architecture and urban space design. Finally, he applied the analogy experiment of tourist activities and bacterial colony growth trajectories, combined with computer bionic simulation, to the graduation design of traffic control optimization for the Songkran Festival in Bangkok, thus completing the whole process of bionics education for the professional master's degree in the Bartlett School of Architecture[4]. Wu Shijia discussed strategies for improving the quality and efficiency of public spaces in cultural and educational buildings from the aspects of network reconstruction, functional compounding, humanistic care, natural landscape, and spatial characteristics, focusing on solving problems such as chaotic functional streamlines, outdated landscape facilities, lack of characteristics, and loss of vitality, in order to provide reference for the optimization design of cultural and educational building public spaces in the context of stock improvement [5]. Although the above content has played a certain role in space optimization, it still lacks key factors.

Based on the research of multi-agent simulation technology, this paper introduces multi-agent technology into the optimization of museum building space, and establishes the optimization model. Finally, the improved ant colony algorithm is used to optimize the model, and the simulation results show that the improved ant colony algorithm has a good effect in museum space optimization. This algorithm can provide a new method for space optimization of museum buildings.

2. Basic Concept of Architectural Space Optimization

Museum is a space with multiple attributes, its spatial structure, functional zoning, route and exhibits will have an impact on the effectiveness of the visit. The basic functions of museums are display, education and research. Different functional divisions determine their display methods, spatial layout, display contents and service facilities [6]. Therefore, the museum space optimization design mainly considers the exhibition and the education two big functions. For the exhibition, the exhibition hall design is a very important issue. A good exhibition hall design can improve the exhibition effect of the museum and promote the audience's understanding of the exhibits. For education, in addition to ensuring the quality of exhibits, but also consider how to make the audience more convenient to appreciate the exhibits, which requires the exhibition space to optimize the design.

The optimum design of museum building space mainly includes three aspects: ① optimum design space structure; ② optimum function division; ③ optimum display content. Optimal design of space structure mainly refers to the museum building space planning and division, so that it can meet the space needs of different functional areas and different types of exhibits. At the same time to ensure that the interaction between the functional areas, so that the functional areas can work in harmony [7]. In the space optimization design of museums, the functions of museums should be rationally allocated so as to ensure that the functions of museums can work harmoniously. In the space optimization design of museum buildings, all kinds of exhibits should be reasonably planned and classified. At the same time, according to the characteristics of different types of exhibits to be targeted display, so that all types of exhibits in the exhibition process to be fully displayed [8].

Two problems need to be solved in the optimization design of museum building space: ① how to make the exhibition content better reflected; ② how to make the audience more convenient to appreciate the exhibits [9]. Therefore, this paper adopts a multi-agent based space optimization method for museum building, which can solve the above two problems.

Multi-agent technology is a computer-based artificial intelligence technology, which simulates human intelligent behavior to establish a virtual environment and interact with the real environment, thus realizing the simulation and optimization of various complex behaviors in the environment [10]. Multi-agent technology has a good application prospect in space optimization design of museum buildings.

3. Principles of Architectural Space Optimization Design

For a multi-agent system, the information transfer between agents is accomplished by communication. In multi-agent system, each agent has its own knowledge representation, which includes semantic, semantic network and knowledge management. In practice, various kinds of information are transmitted between agents in some form, such as: when receiving information, it needs to be completed by logic operation in multi-agent system, when sending information, it needs to be completed by operation logic in multi-agent system [11]. Therefore, the communication process in multi-agent system can be regarded as a semantic information exchange process.

The communication process of a multi-agent system mainly includes:

(1) Establishing the necessary knowledge system by analyzing, inducing and summarizing historical data;

(2) Establishing a knowledge system and a knowledge base and store the required knowledge;

(3) Learning and reasoning new knowledge according to established knowledge base and knowledge system;

(4) Updating the knowledge base based on newly acquired knowledge and reasoning;

(5) Updating knowledge systems and repositories by updating current status [12].

Based on the theory of multi-agent system, this paper regards the optimization of museum building space as a multi-agent system problem. Aiming at the problem characteristics of the system, this paper adopts semantic-based multi-agent technology and semantic network-based multi-agent technology as the basis of multi-agent system algorithm.

3.1 Multi-agent System Based on Semantics

The definition of semantics is that all agents in a multi-agent system have specific semantics and can control the whole system by understanding the semantics. In a multi-agent system, each agent has different semantics, but they all share a common goal of maximizing their own interests [13]. A semantic-based multi-agent system is also known as a Non-deterministic Multiagent System (NMDS) or an uncertain multi-agent system.

Multi-agent systems based on semantics are different from traditional multi-agent systems in the following aspects [14]: (1) There is not only communication between agents, but also interaction, such as: using information entropy and data conflict detection algorithm to detect information conflict; using learning mechanism to constantly update knowledge system; (2) Formalizing the definition of knowledge, and expressing knowledge by formalizing the definition, such as: formalizing the basic unit, basic element, basic relationship, basic attribute and basic semantics of knowledge; (3) In terms of reasoning mechanism, semantics-based multi-agent systems uniformly use "knowledge base" to infer the required knowledge, instead of directly inferring the existing knowledge; (4) Information transmission and communication through semantic expression.

3.2 Multi-agent Technology Based On Semantic Web

In the optimization of museum building space, the use of semantic network technology can describe the building space, thus providing a basis for the communication of agents in the system. In a multi-agent system, the communication between agents is carried out through semantic network. Each agent needs to understand the information according to its own understanding. At the same time, each agent in the multi-agent system describes its own behavior through the semantic network established within itself [15].

The semantic network can be divided into three forms: the formal description of ontology concept, attribute and relationship, the description of ontology relationship and the description of ontology relationship. Describing architectural space through semantic network can express all kinds of elements and related knowledge in architectural space, and provide a basis for communication among agents in multi-agent system. In the semantic network, each agent is independent, through the understanding of the knowledge needed, and then reasoning through the rules of reasoning, and finally get the final conclusion [16].

3.3 Ontology-Based Architectural Space Design Theory

The theory of architectural space optimization design based on ontology is a new method used in the research of architectural space optimization. This method is based on architectural ontology. The method has two characteristics: one is to abstract the elements of architectural space design by building ontology model, so that it has good logical and formal language description ability; the other is to automatically complete the optimization design of architectural space by analyzing and studying the ontology model, and utilizing the logical relationship and reasoning mechanism between concepts in the ontology model [17]. The theory of architectural space optimization design based on ontology is to summarize and generalize the existing architectural design theories and methods, so as to enrich the existing theories and methods and provide a more comprehensive, more accurate and more specific architectural space optimization design method for designers. At present, this method is still in the preliminary research stage. In this paper, the ontology-based multi-agent system algorithm is used as the basis of architectural space optimization design algorithm.

4. Research Contents of Architectural Space Optimization

The research content of architectural space optimization includes two aspects: optimization of architectural space form and optimization of architectural space layout. Among them, the optimization of architectural space form is mainly to adjust the overall design of the building, through the comparison of different architectural layout to find a more appropriate architectural layout, so as to achieve the best overall design effect [18]. The optimization of architectural space layout is mainly aimed at adjusting the layout of exhibition in museums, and choosing a more reasonable and efficient layout scheme.

In the optimization algorithm of museum space based on multi-agent technology, by applying multi-agent technology to the optimization of museum space, the optimization model of museum space can be established. Multi-agent technology is used to simulate different museum space, to analyze the visitors' appreciation effect and comfort of museum exhibits under different architectural layout, and finally adjust the museum exhibition plan according to the results [19]. In this process, it should be noted that each agent has its own unique characteristics, so it is necessary to consider the characteristics of each agent in building the model. In the simulation experiment, we should ensure that the simulation model is consistent with the actual situation.

4.1. Optimization of Architectural Space Form

Architectural space form is an important content in architectural design. It is not only the important basis of architectural space design, but also the main factor that determines the design effect. In the optimization of architectural space form, different architectural space form can be optimized to meet the needs of visitors to the museum. According to the related research, in the museum interior exhibition space, the visitor has certain randomness to the exhibition location choice. Therefore, multi-agent technology can be used to simulate the randomness and select a more suitable display position by comparing the audience's viewing effect and comfort. At the same time, multi-agent technology can also be used to simulate different display positions, and compare the results of the experiments to choose more suitable display positions.

4.2. Optimization of Architectural Spatial Layout

In this process, it should be noticed that multi-agent technology should be applied to museum space optimization because of its strong interaction and self-organization. In this process, it should be noted that different museum spaces have different characteristics and functional needs, so it is necessary to conduct specific analysis according to specific circumstances when optimizing the layout of architectural space [20].

5. Actual Measurement Analysis of Architectural Space Optimization

First of all, the optimized space, the utilization rate, equality and comfort of the questionnaire survey, the results as shown in Table 1.

Table 1. Questionnaire

	Very poor	Poor	General	Good	Very good
Spatial utilization	5%	9%	37%	28%	21%
Spatial equality	4%	7%	39%	25%	25%
Spatial comfort	6%	6%	39%	25%	24%

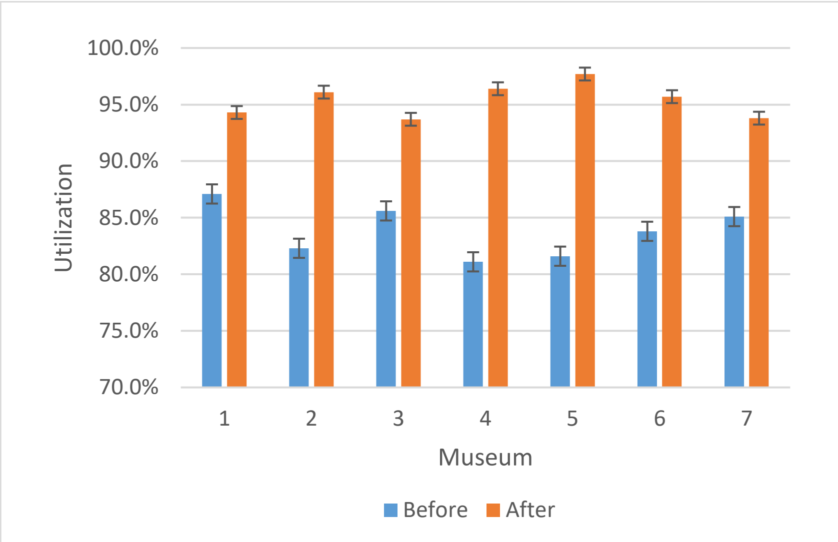

Fig.1 Spatial utilization

As can be seen from Table 1, the proportion of people with "good" or above rating in terms of utilization rate, equality and comfort has reached about 50%, while the "poor" or below rating accounts for less than 15%. Therefore, it can be concluded that the multi-agent -based architectural space optimization design is very effective in practical application, and the following is a comparative analysis before and after optimization. The comparative analysis of spatial utilization is shown in Figure 1.

As can be seen from Figure 1, prior to optimization, Museum 1 had the highest utilization rate of 87.1 per cent and Museum 4 81.1 per cent, with an average utilization rate of 83.8 per cent for 7 museums; after optimization, Museum 5 had the highest utilization rate of 97.7 per cent and Museum 3 had the lowest but also 93.7 per cent, with an average utilization rate of 95.39 per cent for 7 museums. Thus, the multi-agent based building space optimization design can effectively improve the utilization of museum space, so that the museum can exhibit more exhibits. The results of comparative analysis of spatial equivalence are shown in Figure 2, which is judged by scores.

As can be seen from Figure 2, prior to optimization, Museum 2 had a maximum spatial equivalence score of 87.2, Museum 7 had a minimum spatial equivalence score of 82.2, and the calculated average spatial equivalence score for the seven museums was 84.54; after optimization, Museum 5 had a spatial equivalence score of 97.5 per cent, Museum 6 had a minimum of 94.6 and the calculated equivalence score was 96.5. Thus, the multi-agent based building space optimization design can effectively enhance the space equality of the museum. The results of the comparative analysis of spatial comfort are shown in Figure 3, which is also judged by ratings.

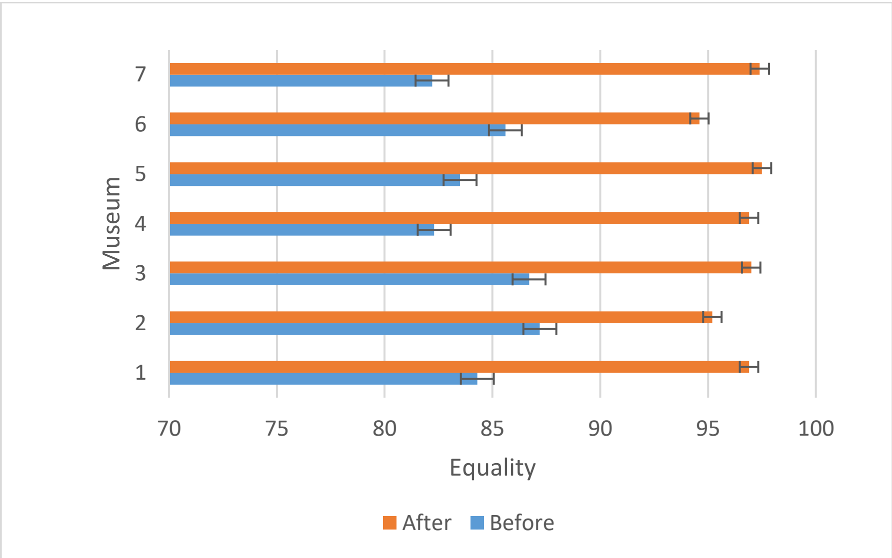

Fig.2 Spatial equality

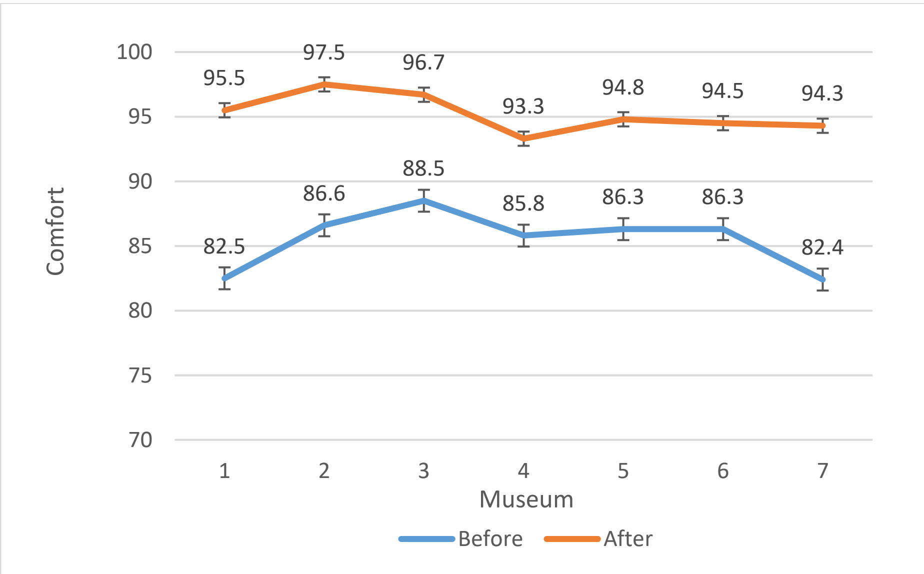

Fig.3 Spatial comfort

As can be seen from Figure 3, prior to optimization, Museum 3 had a maximum spatial comfort rating of 88.5 and Museum 7 had a minimum spatial comfort rating of 82.4, with an average calculated comfort rating of 85.49; after optimization, Museum 2 had a maximum spatial comfort rating of 97.5, Museum 4 had a minimum rating of 93.3, with an average calculated comfort rating of 95.23. It can be concluded that multi-agent based building space optimization design can effectively improve the comfort of museum space, so as to attract more visitors.

6. Conclusions

Aiming at the problem of museum space optimization, this paper establishes a model of museum space optimization by introducing multi-agent technology. The experimental results show that the optimization method based on multi-agent technology can not only improve the display effect of museum buildings, but also make the visitors enjoy the exhibits more conveniently.

In the future, we can further study the application of multi-agent technology in the optimization design of museum building space, such as: to further improve multi-agent technology to adapt to the optimization design of museum building space; to further improve multi-agent technology to improve its implementation efficiency; to integrate multi-agent technology with other disciplines.

The multi-agent simulation platform used in this paper is built on the existing simulation software platform, and the lack of integration with architectural expertise. In the future work, we can try to combine Agent technology with architectural expertise, so that it can play a greater role in the optimization design of museum building space.

References

[1] Zhang Zhengyang, et al."Optimized design of architectural edge space based on spatial syntax."Urban Architectural Space 29.12(2022): 108-110.

[2] Xu Qianyi, and Jiang Xianni."Research on the optimization design of outdoor public spaces in colleges and universities based on place theory--Taking Hebei Institute of Architectural Engineering as an example."Modern gardening 45.21(2022):34-39.

[3] Pei Xin."Optimized design of concrete structure building space based on virtual reality technology."Journal of Chengdu Institute of Technology 25.01(2022):29-32.

[4] Wanzhiyuan, and Yang Yundi."Optimization of urban urban transportation space based on biological behavior--Taking the master's training in bionics in the Bartlett School of Architecture as an example."Huazhong Architecture 39.10 (2021): 148-153.

[5] Wu Shijia, et al."Research on the optimization design of public spaces in cultural and educational buildings in the context of stock enhancement--Taking Cangshan Youth Activity Center as an example."Huazhong Architecture 39.01(2021):53-57.

[6] Yang, Haifeng, Guofang Zhai, and Yan Zhang. "Ecological vulnerability assessment and spatial pattern optimization of resource-based cities: a case study of Huaibei City, China." Human and Ecological Risk Assessment: An International Journal 27.3

(2021): 606-625.
[7] Rahmat, Ali. "Standards for dimensions of space and environment in buildings for people with special needs (ie Wheelchairs, crutches, canes for the visually impaired)." Indonesian Journal of Community and Special Needs Education 1.1 (2021): 19-24.
[8] Chen Ke, Lei Guangming, and Zhang Chengyun."An optimization algorithm for building space utilization based on spatialized particle clusters."Electronic Design Engineering 28.21(2020):47-50+55.
[9] Liu Qian."Research on the optimization method of building space utilization based on particle swarm algorithm."Electronic Design Engineering 28.16(2020):17-20+25.
[10] Mo Xiuqing."Research on the optimization strategy of secondary waiting space in General Hospital."Urban Architectural Space 29.03(2022):105-107.
[11] Oroojlooy, Afshin, and Davood Hajinezhad. "A review of cooperative multi-agent deep reinforcement learning." Applied Intelligence 53.11 (2023): 13677-13722.
[12] Liu, Yu, et al. "Prospects for multi-agent collaboration and gaming: challenge, technology, and application." Frontiers of Information Technology & Electronic Engineering 23.7 (2022): 1002-1009.
[13] Amirkhani, Abdollah, and Amir Hossein Barshooi. "Consensus in multi-agent systems: a review." Artificial Intelligence Review 55.5 (2022): 3897-3935.
[14] Wang, Jianrui, et al. "Cooperative and competitive multi-agent systems: From optimization to games." IEEE/CAA Journal of Automatica Sinica 9.5 (2022): 763-783.
[15] Feriani, Amal, and Ekram Hossain. "Single and multi-agent deep reinforcement learning for AI-enabled wireless networks: A tutorial." IEEE Communications Surveys & Tutorials 23.2 (2021): 1226-1252.
[16] Novati, Guido, Hugues Lascombes de Laroussilhe, and Petros Koumoutsakos. "Automating turbulence modelling by multi-agent reinforcement learning." Nature Machine Intelligence 3.1 (2021): 87-96.
[17] Gao, Chen, et al. "A survey on fault-tolerant consensus control of multi-agent systems: trends, methodologies and prospects." International Journal of Systems Science 53.13 (2022): 2800-2813.
[18] Bao, Guangyan, Lifeng Ma, and Xiaojian Yi. "Recent advances on cooperative control of heterogeneous multi-agent systems subject to constraints: A survey." Systems Science & Control Engineering 10.1 (2022): 539-551.
[19] Zhang, Dan, et al. "Physical safety and cyber security analysis of multi-agent systems: A survey of recent advances." IEEE/CAA Journal of Automatica Sinica 8.2 (2021): 319-333.
[20] Jing Yongnian, et al."Multi-agent formation control and simulation of improved DDPG algorithm."Journal of Guangxi University of Science and Technology 34.03(2023):62-71.