APPLICATION OF PARAMETER OPTIMIZATION ALGORITHM IN DIGITAL ARCHITECTURE DESIGN

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Abstract. In recent years, digital technology has been used in all aspects of peoples work and life more and more frequently and has exerted a certain impact on the design of buildings. More and more architectural design teams add mathematical logic and digital technology to the early stages of their design to better control the design work and implement the construction. Digital building design mainly includes parametric design and algorithm generation design, the former of which is mainly studied in this paper. As a modeling design algorithm which puts an emphasis on logic and reason, parametric design emphasizes the scientific nature of architectural design. In order to achieve the optimal design of the combination of building physics, institutional performance and parameterization, this paper applies the Dijkstra algorithm and the most energy efficient scheme generation (MEESG) energy consumption prediction method to the optimization design of wiring and performance and achieves good results, suggesting that the parameter optimization algorithm has a good impetus to the design of digital building.

Keywords: Digitization, parameterization, optimization algorithm, architectural design.

Introduction

Nowadays, digital technology has played an increasingly important role in architectural design. Under the influence of digital technology, the contemporary architectural design and construction has undergone a significant change [1]. Through computer-aided design (CAD) software, architects can do some simple design work such as construction drawing, etc. However, shortages, for example, sunshine distance can not be timely calculated, exist [2]. Zhou C et al. [3] applied the digital technology to the design and planning of the landscape architecture industry. Oxman R [4] introduced the architectural design concept and digital design model and introduced the concept of digital architecture into a series of architectural design programs and studied them. Hence, the emergence of parametric design makes up for the above shortcomings. Parametricism based on the theory of complexity science is the new architectural design paradigm acknowledged by the majority of architects [5]. Through enhancing the advantages and avoiding the disadvantages of modern, postmodern and minimalist design, parametricism not only makes architectural performance more scientific, but also breaks the limitation of traditional architectural style and design [6, 7]. Besides, parametricism is applied to the creation of ancient architectural styles through book calligraphy design and can be applied to designs of different architectural styles [8]. This paper introduces three parameter optimization algorithms: Dijkstra algorithm, simulated annealing algorithm and most energy efficient scheme generation (MEESG) energy consumption prediction method and applies the Dijkstra algorithm into the optimization design of the wiring parameters and the MEESG energy consumption prediction method into the performance optimization design and achieves good effect, suggesting that the parameter optimization algorithm can produce a good effect on the design of digital buildings, which is worth popularizing.

1. Digital building

Digital building refers to the buildings designed by applying computer technology, the process of which includes digital design and digital construction [9]. Digital design is embodied in the design concept and the concept modeling. The architects carried out conceptual design and idea modeling of the simple schematic diagram through imagination earlier, which was inefficient and time consuming with great limitations. When the digital design intelligence tool appears, architects can design a more scientific solution through three-dimensional model, spatial modeling and color design [10] combining with the real environment. Digital technology has a good application prospect for the design and special analysis of buildings. Through the qualitative and quantitative analysis of the physical, environmental and other design, determining the indicators and clarifying the range values which are the most consistent with the requirement, the architectural design can be more scientific and rational. In the special analysis, the parameters can be adjusted to obtain a variety of programs to improve the efficiency of architectural design and the geometric algorithm and intelligent algorithm are used to design a complex and efficient architectural form. In addition, by encoding the information into the form of space, the parameters of the program are adjusted to prepare for a variety of changes [11]. In general, the parametric design transforms the 2 dimensional drawing parameters into digital information and plays a large role throughout the life cycle of the building.

2. Parameter optimization algorithm

2.1 Dijkstra algorithm

Taking the starting point as the center, Dijkstra algorithm extends outward layer by layer until reaching the end point. In short, the Dijkstra algorithm uses the vertices currently found as the initial point to find the path closest to the destination. Taking as the vertex set and the center to extend the collection, the computation formula is as follows: write W as a set of nodes in the graph, make $W = \{1\}$ and the nodes not on W is denoted by

$$\text{dist}[x] = \text{Disttan}ce(1, x), \tag{1}$$

$$\text{dist}[x] = \infty \tag{2}$$

equation (1) represents that node x and node 1 are linked directly, equation (2) represents that node x and node 1 are not linked directly. When applying the computer to seek a solution, a value that is longer than any path can be used to replace ∞, such as $\infty = 100000$. Then, make y the node not on W and the value of dist$[y]$ the minimum, add y to W; for all the nodes x that are not on W, a smaller value of $[\text{dist}[x], \text{dist}[y] + \text{Dis}\tan ce(y, x)]$ is used to replace the original dist$[x]$ until all the nodes are added to W.

2.2 Simulated annealing algorithm

The simulated annealing algorithm is a heuristic stochastic optimization algorithm, which firstly determines the initial temperature and then simulates the temperature decrease of solid annealing, i.e., the process of internal ion movement from continuous strengthening, slow weakening to the equilibrium state, with the energy tending to be minimal. Due to the impact of high temperature, the molecular movement is constantly strengthened at first, with the equilibrium point becoming farther and farther and the search range of the algorithm gradually increasing. With the decrease of annealing temperature, the search area is decreasing, and the probability of sudden jump sampling is repeated to get the optimal solution. The specific algorithm is as follows: take an initial temperature T_1 and make $T = T_1$; take an initial solution A_1 and determine the number of iterations during each T, i.e., the Metropolis chain length M. According to temperature T and $n = 1, 2, \ldots, M$ a new solution A_2 is obtained through solving stochastic perturbations and increments $df = f(A_2) - f(A_1)$ of A_2 is calculated, with $f(A_1)$ as the evaluation function of A_1. When $df < 0$, A_2 is selected as the current new solution and $A_1 = A_2$; otherwise, the acceptance probability of is a uniformly distributed random number rand during $(0, 1)$ interval of $\exp(-df/T)$; when $\exp(-df/T) > rand$, A_2 is selected as the current new solution and $A_1 = A_2$; in other cases, A_1 is selected as the current solution.

2.3 MEESG energy consumption prediction method

A large number of literature shows that the early decision of the architectural design of the building has great impact on lighting, ventilation, sun exposure of the building. Besides, the size of the building's energy consumption is related to the lighting of the building. Hence, a relationship expression needs to be established. Taking architectural lighting and natural light rate as an example, the relationship between the two can be expressed as follows: $Q = DA \times S \times \rho$, where Q refers to the lighting energy consumption, DA refers to the lighting rate, S refers to the lighting outer region area and ρ refers to power density. The lighting total energy consumption of both the outer and inner lighting region is $Q_{all} = \sum(1 - DA_i) \times \rho \times S_{out} + \rho \times S_{in}$, where DA_i refers to the lighting rate at different building orientations.

3. Wiring optimization based on Dijkstra algorithm

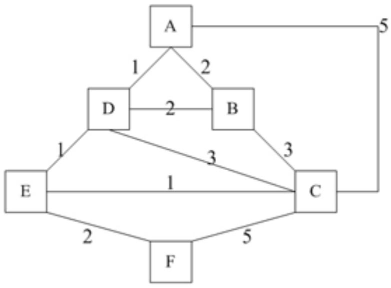

Figure 1. Line laying network map

As shown in figure 1, A is the wiring room and B, C, D, E and F are the wiring intakes. The weight (arc length) is the distance between the intakes. Through the Dijkstra algorithm, the shortest distance between the wiring points of each room and the wiring room is determined.

	W	$dist[2]$	$dist[3]$	$dist[4]$	$dist[5]$	$dist[6]$
initialization	{1}	2	5	1	∞	∞
1	{1,4}	2	4	(1)	2	∞
2	{1,4,5}	2	3	1	(2)	4
3	{1,2,4,5}	(2)	3	1	2	4
4	{1,2,3,4,5}	2	(3)	1	2	4
5	{1,2,3,4,5,6}	2	3	1	2	(4)

Table 1. Values obtained through Dijkstra algorithm

As shown in the table, the minimum value of dist[] is calculated for five times. The numbers in the brackets are the solutions of each calculation, as follows: $prev[2] = 1$, $prev[3] = 5$, $prev[4] = 1$, and $prev[6] = 5$. Hence, the shortest path from A to F is A-D-E-F.

4. Simulated annealing algorithm

In the study, the central air conditioning system of the college is taken as an example. The size of the central air-conditioning system room is $1m * 0.5m * 0.5m$, which can work for four classrooms. The refrigeration capacity of the compressor is 3060W and the heat transfer capacity and condensation temperature of the condenser are 4000W and $40°C$; The heat transfer capacity and the evaporation temperature of the evaporator are 3060W and $°C$; The heat transfer capacity and the rated water quantity of the cooling tower are 7550W and 0.8kg/s; the power and the rated flow of the pump are 400W and 0.8kg/s. The initial annealing temperature is $T_1 = 100°C$. Suppose A_1 and A_2 are one of the solutions and the attenuation factor is 0.95.

During the annealing process, when the inner balance is 5, the annealing temperature is $60°C$ and the terminating algebra is 100. The results obtained by simulated annealing algorithm are shown in the following figure:

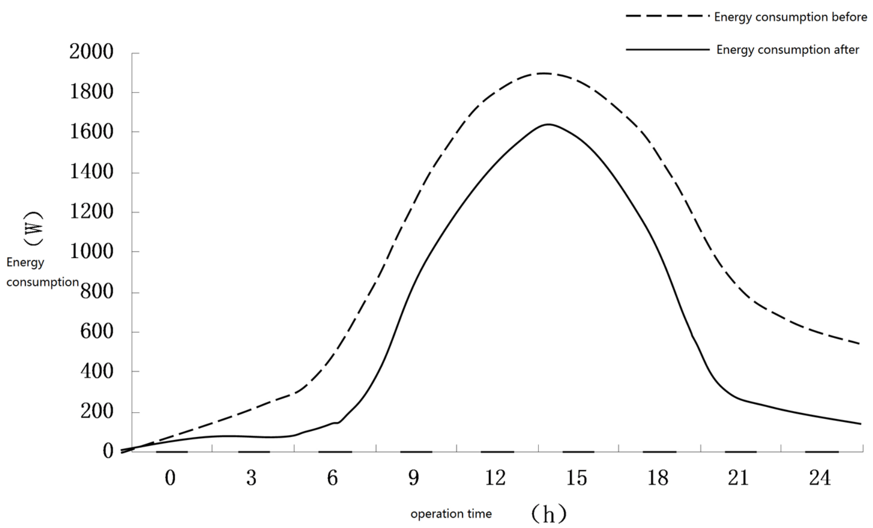

Figure 2. Comparison of energy consumption

From figure 2, we can see that the energy consumption showed a decline with the application of the algorithm, which reduced by 330W during the operation time of 12-15h and 24 hours after operation, suggesting that the energy consumption was greatly reduced.

5. Optimization design of parametric performance

A large number of literature shows that the early decision of an architectural design largely influences the lighting and ventilation of a building. Here, Neijiang City in Sichuan Province was taken as an example. Neijiang City has a subtropical humid monsoon climate, where the weather is mild and light and heat are adequate, with a total solar radiation of 89.3km/cm2. Combined with the meteorological information of the city, the following parameters are obtained: the simulated window ratio is 0.3, 0.4, 0.5 and the outer depth is 4, 6 and 8 m. The physical parameters of the school building are as follows: the construction area is 5000m2, the floor number is 5, the height of each floor is 3 m, the length of the south direction is 45m and the permeability is 0.4ac/h.

With the MEESG energy consumption prediction method, the consumption when the equipment heat is 20W / m2 is obtained, as shown in table 2.

Window wall ratio	Outer region depth 4				Outer region depth 6				Outer region depth 8			
	heating	air conditioning	illumination	amount	heating	air conditioning	illumination	amount	heating	air conditioning	illumination	amount
0.3	19.49	21.47	16.38	57.34	19.46	21.46	15.04	55.96	21.18	21.78	16.29	59.25
0.4	19.97	22.64	55.89	98.5	19.50	22.49	11.02	86.01	22.01	22.86	12.14	57.01
0.5	20.47	23.89	57.96	102.32	19.94	23.79	8.45	52.18	22.56	24.03	8.31	54.88

Table 2. Energy consumption values under certain equipment heat (kWh/m^2·a)

As the depth of the outer region increases, the impact on heating and air conditioning is small while that on illumination is relatively bigger. The calculation results of the deviation values show that the relative deviation of air conditioning energy consumption is negative in all cases and the relative deviation of the three increases with the increase of outer depth and window ratio.

6. Discussion

By combining building design with digital technology, not only the rising material needs of human society can be met, but also the contemporary architectural philosophy and culture can be inherited. The use of digital technology in architecture has changed the performance of traditional architecture so that peoples building space awareness is becoming more diversified. In addition to improving the efficiency of existing architectural design, parametric technology can achieve the design ideas which were unable to be achieved and control the complex forms which were not possible earlier. It can cost-effectively implement complex geometries, efficiently create multiple options, encode other information efficiently and translate them into space forms, and can respond to changes in the project in a manner that can be efficiently adjusted by parameters. Niroumand et al. [12] studied the sustainable development of buildings in Malaysia, Iran and the United Kingdom; Cho J H et al. [13] used the OLAP evaluation system to define the characteristics of the architectural design as parameters of quantitative changes and established a parametric model to predict the cost of the building.

7. Conclusion

Based on the parameter optimization algorithm, this paper studied the wiring, energy consumption and construction performance in building design and found that the application of parameter optimization algorithm to architectural design can greatly help the design of the building and make the architectural design more scientific.

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