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Research Article

Smart Building Skin Design with Dynamic Climate Adaptability of Smart Cities Based on Artificial Intelligence

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As the separation and carrier of indoor and outdoor energy and climate conditions, building skin plays an important role in indoor environment regulation and effective utilization of outdoor environmental resources. The traditional fixed skin of residential buildings in cold regions lacks the ability to respond to the external climate, so it is difficult to meet the dual requirements of building energy efficiency and indoor comfort. In the long river of architectural development, the most important thing of architectural design is how to meet the climate adaptability. Traditional architectural forms have long been unable to meet the current social development, climate conditions, and user needs. Based on the basic theory, this paper establishes a systematic understanding of inlay, studies the design method of complex skin with geometric algorithm as the operating tool, discusses the application of this method in architectural design in combination with practice, more systematically and comprehensively studies the building skin with dynamic climate adaptability, and makes a physical model of building skin with dynamic climate adaptability. The contrast experiments under different control modes were carried out using the climate chamber experimental system. This research focuses on taking geometric principles as the prototype, trying to break the common design idea of generating skin by overlapping cells, and providing a systematic skin design method with strong operability and modular structure, hoping to help expand creative thinking.

1. Introduction

The most important reason for the emergence of architecture in human social life is that at the moment when human beings have the need to settle down, in the book "On Architecture" written by M. A. Lauger, Barbarians, in the shelter made of leaves, do not know how to protect themselves in a humid environment [1]. The reason is that the climate environment has advantages and disadvantages. Different global climates have produced different forms of buildings. As G. Brodepont said, "This early house has many inspirations: the basic reason for building a house is to change the climate given by nature and to carry out some human activities conveniently and comfortably" [2]. China has a wide area and different architectural forms. For example, traditional dwellings in China, in the northeast of China, because of the small sun elevation angle, tend to have larger courtyards and thicker walls to resist the cold. In northwest China, however, cave dwellings are the main ones. Because of the land characteristics of the Loess Plateau, people dig caves on the mountain, and the caves are warm in winter and cool in summer, which is suitable for the local climate. In order to adapt to the hot weather, people in the south of China build dry-column buildings, and this kind of steep roof and overhead ground floor can provide good ventilation and shade for the buildings [3].

Commonly used building envelope structures include walls, roofs, and curtain walls of doors and windows, which are generally fixed envelope structures, while dynamic building skin, as a kind of intelligent variable building envelope structure, can respond to environmental changes in a dynamic way. Architects and engineers need to weigh many factors when considering the design of the enclosure structure, including environmental issues, aesthetics, and indoor comfort. [4]. These factors make the building envelope a multifunctional component, so the integration method is the best way to solve the design of building envelope. In the design of building energy consumption and building climate adaptability, the building skin has sufficient regulation and control capability is an important factor affecting both [5]. As the separation interface between indoor and outdoor, the building skin ensures a comfortable and stable indoor environment in terms of sound, light, heat, wind, and other aspects by selectively filtering various outdoor climate factors and selectively using favorable outdoor energy such as solar energy and reduces the use frequency of energy consumption equipment [6]. Therefore, building skin energy-saving design plays an important role in energy-saving building design. Some of the environmental factors have a favorable impact on the indoor environment, while others will have an adverse impact, and the two factors transform into each other with different times and different environments. From the early civilization of human beings to modern times, the practice and exploration of building to resist uncertain climate change to create a suitable indoor environment have never stopped [7]. From the 1960s to the present, the intelligent evolution of building skin has gone through many stages, gradually expanding into a multidisciplinary cross research field facing the requirements of multigreen performance optimization of buildings, evolving the theories and methods of intelligent skin design of buildings such as dynamic buildings and climate adaptive skin and emerging intelligent skin design works such as the Arab World Research Center and Al Bahar Building. Under the joint action of the demand of contemporary construction industry and the thrust of artificial intelligence technology, there is a diversified development trend.

Dynamic building skin is completely controlled automatically by control software. The control software is connected with three main sensors located at the top of the tower, including wind sensor, light sensor, and rain sensor. By collecting the environmental values fed back by sensors, the sun movement is simulated in the control software, and the opening and closing degree of each dynamic skin unit is controlled [8]. This period of time is often nonworking time, so it is unnecessary to set up a dynamic sun shading unit in the north area. In order to determine the curtain wall area where shading units need to be set, the solar heat gain on the curtain wall surface is simulated and analyzed first, and 400 Wh/m^2 is taken as the extreme value. Dynamic shading units are set in front of the curtain wall area that exceeds this extreme value. Building skin is a multifunctional “interaction and filtering system” of indoor environment and outdoor climate, which needs to solve the contradiction between “utilization” and “protection” caused by the changing climate [9]. With the development of science and technology, there are more choices of materials and technologies in the design of building skin, which provides conditions for solving the abovementioned contradictions. With the deepening of the integration of computer and artificial intelligence, the powerful data processing ability of computer provides efficient technical support for studying and solving complex problems, which drives and catalyzes the process of subject integration. According to statistics, from 1901 to 2008, the proportion of interdisciplinary research achievements awarded in the Nobel Natural Science Prize was 52% of the total, which has risen to 66.7% in recent years, and has been on the rise. Among them, as a series of logical judgments and operations organized in sequence, the algorithm makes the design process more controllable, rational, and efficient than traditional methods [10]. The introduction and development of intelligent skin systems can use limited materials and technologies to cope with more changing conditions, generate more green building skin systems, and make intelligent buildings develop in a more sustainable direction. Therefore, intelligent skin has become a major trend and inevitable choice of intelligent buildings.

With the disintegration of this far-reaching mathematical theory, non-Euclidean geometry is gradually accepted by people, and it is performing a new type of aesthetics characterized by fuzziness and deformation. Topological geometry, as one of non-Euclidean geometry, has gradually become the main theoretical basis of architectural skin, and with the independence of skin, it has gradually become one of the main means for architects to express architectural form. Up to now, scholars have made a certain scale of research on the skin of intelligent buildings with dynamic climate adaptability, but there is still little research on the application of artificial intelligence methods to the skin design of intelligent buildings with dynamic climate adaptability. This research is supported by the National Natural Science Foundation’s general project “Research on the Design of Climate-Adaptable Building Skin Based on Thermal Ambient Intelligence Regulation.” It aims at classifying, analyzing, and summarizing the existing research and builds cases of dynamic climate-adaptive building skin, classifying it according to its environmental factors, trying to sort out its design strategy, sorting out the design realization forms, and summarizing the common design realization forms. For the analysis of the control mode, we try to divide the control mode into four levels and analyze its control principle. We also carried out model experiments to get rid of the dilemma of talking on paper, explore new ideas on how to build models and carry out experimental tests, illustrate the feasibility of dynamic climate adaptive building skin by building solid models, establish a technical basis for further experiments, and compare the advantages and disadvantages of different control modes under the experimental environment conditions through the collation, analysis, and comparison of experimental data. Its innovation lies in the following points: (1) The coverage of research on dynamic climate adaptive building skin is more comprehensive. In many research studies, the concept of dynamic climate adaptive building skin is often limited to intelligent mechanical design, but in fact, the dynamic climate adaptive building skin also includes other forms of design, so the research on dynamic climate adaptive building skin in this paper will be more systematic and comprehensive. (2) The Arduino platform is used as the control system, and the physical model of the building skin with dynamic climate adaptability is made, and the comparative experiments under different control modes are carried out by using the climate cabin experimental system, which provides a new idea for studying the adjustment ability of the building skin with dynamic climate adaptability and the influence of different control modes on the adjustment ability of the building skin with dynamic climate adaptability.

2. Related Work

In the movement of modern architecture, due to the development of architectural technology, architectural skin expresses itself as an independent identity, and the innovation of skin that follows attracts the attention of many architects. The unitary pattern of modern architecture began to be greatly challenged in the second half of the century, and the architectural skin began to appear in the world with a pluralistic tendency.

Kuru A takes many architectural forms of Shanghai World Expo as the basic breakthrough point and studies the topological evolution process of architectural form of Shanghai World Expo by the topological analysis method, so as to understand the modern architectural form and explore the topological framework system of architectural form, so as to promote the development of architectural form [11]. Perino and Serra proposed an equivalent thermal analysis model based on frequency response and numerical simulation on the heat transfer process of building envelope under natural climate conditions in heating areas [12]. Baduge et al. verified the energy-saving effect by adopting the research method of theoretical analysis, numerical simulation, and experimental test on the new dynamic composite envelope of 000PK building, which provided valuable basic data and conclusions for theoretical calculation and application of dynamic skin [13]. EVIR and others applied the parametric design method to optimize the layout of the hexagonal skin module, so that it can reasonably adjust the building light environment in different seasons [14]. Alqiaa summarized the related research of intelligent building and found that most of the research focused on the development of new intelligent control technology and its application in HVAC system, lighting system, fire protection, elevator, security, and communication system. In addition, there are some comparative studies on dynamic climate adaptive building skin [15]. Zhai et al. analyzed the influence of different control logic of the intelligent control system of a building in Denmark on its building energy consumption and indoor thermal comfort, got a relatively optimized control strategy, and put forward a simple algorithm of building energy consumption and thermal environment [16]. Ilbeigi gives full play to the potential of "frame," a modern architectural load-bearing system. It replaces the wall with cross-shaped steel columns. With the characteristics of free flow in the plane, the load-bearing and enclosure functions of the skin are weakened or even disappeared, and great freedom is obtained. With the vigorous development of industrial technology and modern architectural theory, skin has not only become an independent subject in the objective world but also has a series of formal rules and design theories for itself, creating another "real" world outside the objective world [17]. Shaikh et al., starting from solving the adverse impact of China's specific continental climate on buildings, put forward the concept of strain architecture, that is, buildings should adapt to China's changing continental climate, adapt to the dramatic changes in climate, and take coping measures, and the architectural form should change according to the changes in climate [18]. Barozzi et al. believe that the development of information technology makes intelligent and dynamic building facades an inevitable requirement for sustainable building development. While giving the concept, functions, and characteristics of intelligent and dynamic facades, dynamic building facades are divided into four categories according to design strategies, namely, integrated dynamic sunshade system, integrated dynamic solar reflection system, integrated dynamic natural ventilation system, and integrated dynamic energy production system [19]. Khalil and Abu-Nasser studied the evolution and development of building dynamic system. The evolution of building dynamic system is divided into three stages. In the preindustrial revolution period, traditional doors, windows, vertical ladders, and other components with manual or mechanical braking were the representatives of building dynamic components. During the industrial revolution, the components such as steam engine and vertical ladder braked by motor were regarded as representatives of dynamic components of buildings in this period [20, 21].

3. Methodology

3.1. Summary of Research on Dynamic Climate Adaptive Building Skin Design. As the manifestation of human evolution, architecture has always been branded with the times. In this chapter, the theoretical research on climate adaptive movable building skin is divided into two aspects, namely, climate adaptive skin and movable building skin. Through the analysis of the relevant theories of these two aspects, the relationship between architecture, people, and environment is examined. With the development of the construction industry, more and more movable building skins are concerned by architects for their adjustable and adaptable features, which has triggered a lot of theoretical research. Through these studies, movable building skins are no longer just the imagination of architects but have become an important form of building skins for the development of the times. Among them, the most famous are the "skeleton support theory," "symbiosis theory," and "philosophy of change." Climate factors have a particularly prominent impact on architectural design and construction. In 1994, the Ministry of Construction issued the Standard for the Division of Building Climatic Zones, which divides the building climate zoning system of China into two levels, namely, first level zone and second level zone. The purpose is to distinguish the differences in the impact of climatic conditions on buildings in different regions of China in terms of design and construction, define the basic requirements for buildings in each climate zone, provide building climate parameters, and make rational use of climate resources in general, preventing adverse impacts of climate environment on buildings. When the building skin is not able to adjust this difference to meet people's comfort needs, it needs the assistance of equipment that can adjust the indoor environment, which leads to more energy consumption and more serious environmental pollution. The relationship between outdoor climate conditions, skin adjustment capacity, and equipment energy consumption can be expressed as shown in Figure 1.

Building users have certain standard values for indoor temperature and humidity, ambient radiation temperature, ventilation rate, indoor air quality, indoor illumination, and sound. Compared with the traditional building skin, the dynamic adaptive skin has stronger adjustment ability, which can selectively control the amount of outdoor temperature and humidity, solar radiation, wind, and noise entering the room, adjust the indoor environment to meet people's comfort requirements, and reduce the building's energy consumption in heating, cooling, and lighting. The indoor air environment is related to the indoor air quality. The indoor air quality can be improved from the perspective of control approaches through natural ventilation of the skin and structural design related to mechanical ventilation. The indoor acoustic environment is related to the sound pressure level of the indoor environment and the characteristics of the sound. The skin is related to the acoustic design of the skin material and structure to control the noise entering the room. The indoor light environment is related to the indoor illuminance. According to the room's function, users have different light environment requirements, and the skin is related to the lighting design including the form, size, structure, materials, and other lighting openings. In summer, too high relative humidity makes people feel "sultry," while too low relative humidity makes people feel "dry heat." In winter, too high relative humidity can make people feel wet and cold, while too low relative humidity can make people have sore throat and dry and itchy skin. The average radiation temperature refers to the average temperature of the radiation effect of the surrounding surfaces on the human body, and the amount of radiant heat exchange only depends on the temperature of each surface and the relative position between people and the surface. According to the Technical Specification for Healthy Housing Construction formulated by China Engineering Construction Standardization Association in 2009 [22], the design reference target values of relevant factors are shown in Table 1.

Among the abovementioned factors affecting thermal comfort, people pay more attention to air temperature, humidity, and airflow velocity. Building heating, cooling, and ventilation equipment also focuses on these three factors to change the indoor environment but pays less attention to the average radiation temperature. In winter, people pay more attention to the indoor air temperature and ignore whether the internal surface temperature of walls or windows is too low. Similarly, in summer, the internal surface temperature of the building skin with poor thermal performance is too high, and people still feel hot. The inner surface temperature of the building skin is comfortable only when it is 34°C lower than the human surface temperature. The thermal conductivity of the skin is reduced, the gap between the radiation temperature of the inner surface of the building skin and the indoor design temperature is narrowed, and the indoor air flow rate and indoor humidity within the appropriate range are maintained by enhancing the natural ventilation effect of the skin, so as to reduce the compensation of energy consumption equipment for indoor environmental comfort and achieve the purpose of reducing energy consumption.

3.2. Artificial Intelligence Combined with Climate Adaptive Optimal Design of Building Skin. In a broad sense, epidermis includes biological level and material level. The epidermis is interpreted as follows: first, the most superficial layer of plants and animals; second, the outer layer of human and animal skin. The inner skin refers to maintaining the surface of the internal functional space or having independent functions. The outer skin refers to the outermost interface directly contacting with the outer space. In the single skin of some buildings, the inner and outer skins are integrated. In addition, the epidermis can be divided into differential homeomorphism epidermis, namely, topological homeomorphism epidermis and nonhomeomorphism epidermis according to the degree of topological transformation. Homeomorphic epidermis can be divided into differential homeomorphic epidermis and topological homeomorphic epidermis. Differential homeomorphism skin refers to the skin formed in the process of differential homeomorphism extrusion, stretching, bending, and torsion. Topological homeomorphism skin refers to the skin formed in the process of topological homeomorphism transformation of buildings. Nonembryo skin refers to the skin formed by the nonembryo changes of buildings. Then, after more than 30 years of development, fruitful application results and theoretical research progress have been made. Especially in recent years, the upsurge of evolutionary computation has been formed in the century, computational intelligence has become an important direction of artificial intelligence research, and later the rise of artificial life research has made the genetic algorithm receive extensive attention. The basic idea of the algorithm is that referring to the basic principle of Darwin's theory of biological evolution, the problem to be solved is simulated as biological evolution, and chromosomes are selected and reserved according to the principle of survival of the fittest, so that new individuals are constantly generated in iterative evolution, and individuals are constantly optimized. The architecture of AI application is shown in Figure 2.

The multiobjective genetic algorithm puts forward niche theory for the first time, which can effectively keep the diversity of the population in the operation of the algorithm, and introduces the concept of Pareto rank to classify individuals, which has an important influence on the development of the later multiobjective optimization. When selecting individuals, individuals with small Pareto rank and large fitness value are preferred. When encountering individuals with the same Pareto rank, the niche theory is introduced to maintain the diversity of the population, and the individuals with smaller niche numbers are selected as

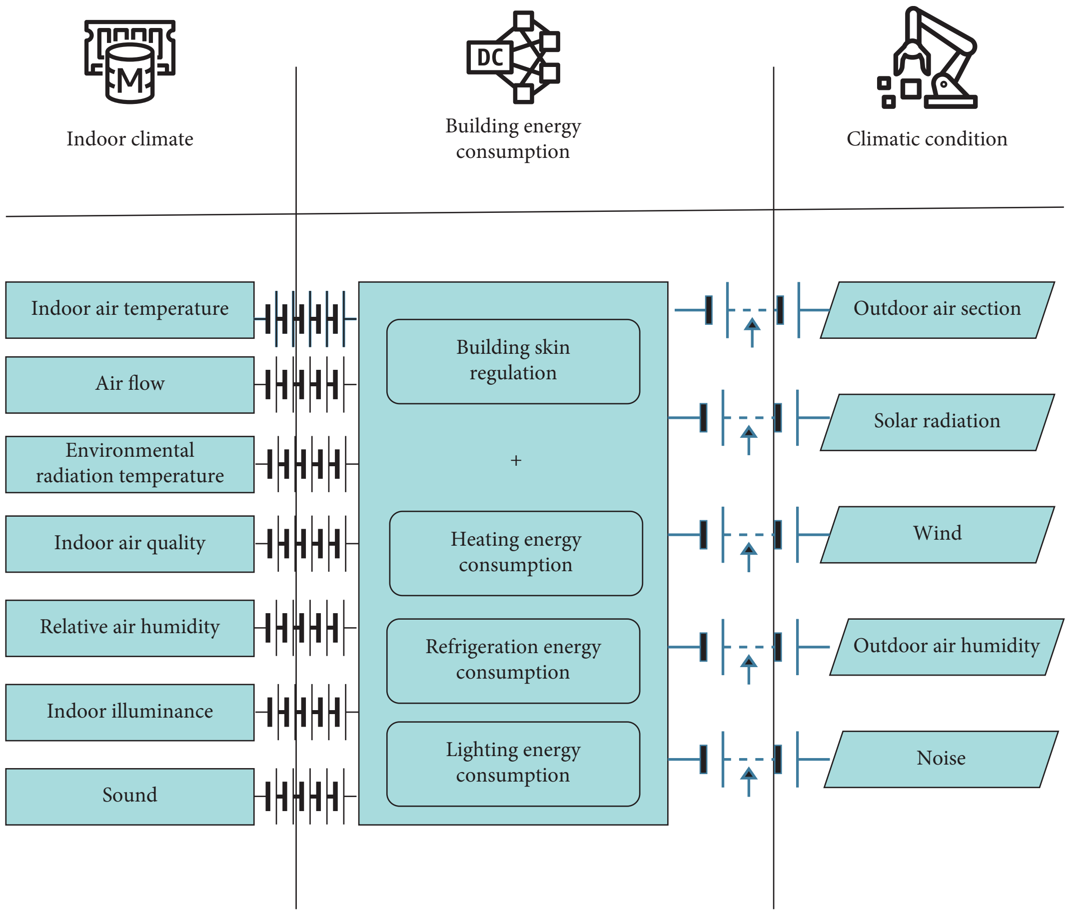

FIGURE 1: Relationship among indoor environment, building energy consumption, and climatic conditions.

TABLE 1: Reference index of indoor thermal environment.

Parameter	Standard value	Remarks
Temperature (°C)	24~28 18~22	Refrigeration in summer Heating in winter
Air velocity (m/s)	≤0.3 ≤0.2	Refrigeration in summer Heating in winter
Air tightness ventilation rate	1 0.5	Hot summer and warm winter, hot summer and cold winter area And cold and severe cold areas
PMV index	0.5~0.5	—
Relative humidity (%)	40~65 30~60	Refrigeration in summer Heating in winter

excellent individuals to be reserved for the next generation. However, MOGA is too simple in the distribution of fitness value, sensitive to the density of niche search space and the shape of Pareto optimal solution, and easy to rely too much on the convergence radius of niche.

The basic operation of noninferior hierarchical sorting is as follows: in the current population, first, we construct a noninferior solution set F_k (noninferior solution refers to individuals who are not dominated by any individual in the population, and the set composed of noninferior solutions is called a noninferior solution set), set the highest dominance level of $k = 1$, and assign a larger virtual fitness value of f_d^k to individuals in the solution set. We ignore the individuals in the noninferior solution set F_k, let $k = k+1$, and construct the noninferior solution set F_k again in the current population. Similarly, the dominance level of the solution set is k, and we assign a virtual fitness value to the individuals in the solution set, which is smaller than the fitness value assigned by the previous dominance level. We repeat the abovementioned process until the stratification of individuals in the population ends.

The algorithm uses the shared niche technology to calculate the new fitness value according to the assigned virtual fitness value for each individual within the

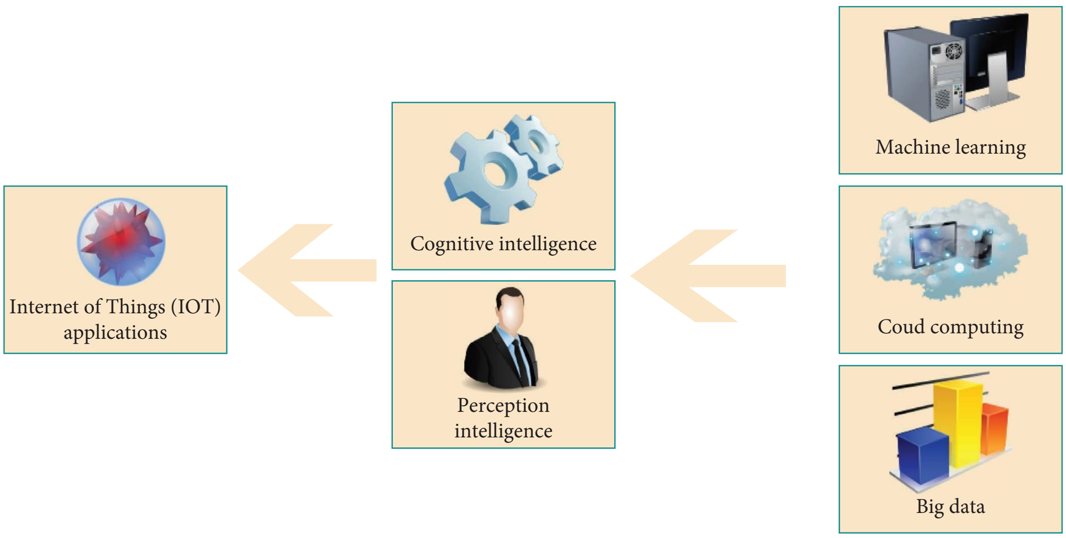

Figure 2: Structure diagram of artificial intelligence.

dominance level as the basis for the selection operation. The specific steps are as follows:

$$d(j-i) = \sqrt{\sum_{n-1}^{N} \left(\frac{M^{i}_{n-} M^{j}_{n}}{M_n^{\max} - M_n^{\min}} \right)^2}, \quad (1)$$

where N is the number of objective functions and $M_n^{\max}$ and $M_n^{\min}$ are the maximum and minimum values of the n objective function, respectively.

We use formula (1) to calculate the sharing function of individual j and individual i:

$$\mathrm{Sha}\left(d_{j-i}\right) = \left\{ \begin{array}{c} 1 - \left[\dfrac{d_{j-i}}{\sigma_{\text{share}}} \right]^2, d_{j-i} < \sigma_{\text{share}} \\ 0 \end{array} \right\}, \quad (2)$$

where σ_{share} is a predetermined niche parameter, also known as the shared radius.

We calculate the niche number of individual j.

$$M_j = \sum_{i}^{N_k} \mathrm{Sha}\left(d_{j-i}\right), \quad (3)$$

where N_k refers to the number of individuals in the noninferior solution set k corresponding to the F_k dominance level.

We calculate the new fitness value of individuals as

$$f_{sha}^{k}(j) = \frac{f_d^k}{M_j}. \quad (4)$$

The nondominated sorting genetic algorithm (NSGA) is a genetic algorithm based on Pareto optimal solution. Among many multiobjective optimization genetic algorithms, NSGA more directly and comprehensively reflects Goldberg's non dominated sorting idea. Its theory is mature and has been applied to many fields. However, NSGA also has some shortcomings. For example, when the population size is large, the adoption of the noninferior stratification method will lead to the extension of the running time of the program. The algorithm lacks elite retention strategy. Although niche theory ensures the diversity of the population, it cannot retain outstanding individuals. In addition, NSGA is also sensitive to the sharing radius, which has certain limitations in application.

Artificial intelligence is a branch of computer science. Its fundamental goal is to enable machines to think like human beings, which includes many technologies that are currently being developed and is still far from reaching the true meaning of "artificial intelligence." In the application of dynamic climate adaptive building skin, because it is difficult to grasp the law of changes in outdoor climate environment, the quantitative relationship between changes in skin components and the ability to adjust environmental factors is also difficult to determine, and whether based on preset automatic control or intelligent control based on feedback mechanism, its controller follows a fixed control logic. It cannot be perfectly adapted to the outdoor climate and environmental changes with low regularity. The inspiration of big data to dynamic climate adaptive building skin can be divided into two following aspects: one is that a large number of similar skin usage data supports the machine learning of this skin and the support of big data speeds up the learning progress of machine learning of dynamic climate adaptive building skin. Secondly, it will be the future trend to connect the dynamic climate adaptive building skin with other intelligent building equipment, share information, become a system, coordinate with each other, and jointly adjust the indoor environment.

3.3. Improved Multi-Pareto Evolutionary Algorithm. The solar thermal gain coefficient is one of the physical quantities used to evaluate the performance of a window, which represents the ratio of the amount of solar radiation passing through the window interface to the total amount of sunlight incident. Dynamic skin is different from traditional window components, and its form is complex. At present, there is no software that can directly calculate the SHGC value of dynamic skin. In the process of photon propagation, there are three forms of interaction with the medium surface, namely, light reflection, light absorption, and light transmission through the medium. The geometric arrangement state between the molecular chains in the medium determines its properties. For materials with an isotropic aggregate structure, light can pass through rather than be fully reflected or absorbed. For materials with an anisotropic aggregate structure, light cannot pass through but can only be reflected and absorbed. With the rapid development of architectural technology, the skin represents itself independently, and the form of architectural skin is becoming more and more rich. Building skin can be divided into two basic types from the perspective of space enclosure and volume form, namely, exterior skin and interior skin. Generally speaking, the topological structures such as square, round, or sheet are usually formed by the tight combination of the outer skin. However, there is no direct connection between the inner epidermis, which is mainly connected by the internal space.

Minimal surface is favored by designers because of its unique aesthetic feeling and mathematical connotation, and popular three-dimensional software on the market has gradually built it in. For example, the implicit equation of spiral minimal surface Gyroid adopted by Taichung Opera House is $\cos(x)\sin(y) + \cos(y)\sin(z) + \cos(z)\sin(x) = 0$, which can generate lattice in Grasshopper and make the coordinate values of each point meet this equation, and then it can be shaped with the help of ISO surface arithmetic unit in millipede plug-in. In the paper "Weierstrass representation of minimal surface and architectural modeling," the general solution of minimal surface in three-dimensional space is analyzed as

$$\left\{\begin{array}{c} x = 2\mathrm{Re}\int \varnothing_1 d_z = \mathrm{Re}\int f\left(1-g^2\right)d_z \\ y = 2\mathrm{Re}\int \varnothing_2 d_z = \mathrm{Re}\int if\left(1+g^2\right)d_z \\ z = 2\mathrm{Re}\int \varnothing_3 d_z = \mathrm{Re}\int \mathrm{fgd}_z \end{array}\right\}. \tag{5}$$

Before the Pareto selection, the meaning of Pareto optimal solution theory and the specific process of Pareto selection should be clarified. Pareto optimal solution theory clarifies the idea of domination, assuming that multiobjective optimization is a minimum problem, set m objective functions to constitute vector $f(x) = (f_1(x), f_2(x), \ldots, f_m(x))$, and take any of the two variables $x_1, x_2 \subset U$. When $\forall i \in \{1, 2, \ldots, m\}$ makes $f_i(x_1) < f_i(x_2)$, x_1 governs x_2. When $\exists i \in \{1, 2, \ldots, m\}$ makes $f_i(x_1) < f_i(x_2)$ and $\exists i \in \{1, 2, \ldots, m\}$ makes $f_i(x_1) > f_i(x_2)$, it is said that x_1 and x_2 do not dominate each other.

We use formula (6) to calculate the distance between candidate j and other individuals in the population:

$$\mathrm{dji} = \sqrt{\sum_{k=1}^{N}\left[\frac{M_k^i - M_k^j}{M_k^{\max} - M_k^{\min}}\right]^2}. \tag{6}$$

In the genetic algorithm, the crossover process and mutation process may cause the individual to mutate into a better individual, which plays an important role in increasing the diversity of the population but may cause certain damage to the excellent individual. To reduce this damage, after each crossover process and mutation process, the offspring and the parent are compared using Pareto optimal solution theory. If the fitness value of the offspring is indeed better than that of the parent, the offspring will be retained; if the fitness value of the offspring is lower than that of the parent, the parent will be retained.

The construction unit expects to complete the project with the lowest cost and the shortest time limit. Formula (7) can make the processes in the scheme meet the logical relationship, and formula (8) ensures that the daily resource usage does not exceed the upper limit of resource supply. Then, formulas (9) and (10) are used to determine the project time limit and cost. Finally, Powertrain control module (PCM) multiobjective selection theory is used to compare and choose multiple schemes.

$$t_j - t_i - d_i \geq 0, j \in S_i, \tag{7}$$

$$\sum_{t_{j\in A t_j}} r_{\mathrm{dik}} \leq b_k\,(k = 1, 2, \ldots, p), \tag{8}$$

$$\min T = \max\{t_i + d_i \mid i = 1, 2, \ldots, n\}, \tag{9}$$

$$\min M = \sum_{i=1}^{n} m_{ig}\,(g = 1, 2, \ldots, q). \tag{10}$$

For PCM-driven dynamic skin, light first enters the skin from the outside through the glass, and part of the light will be emitted from the cavity inside the skin to the outside or indoors through the glass. Therefore, in the incident phase, the external medium is outdoor air, and the adjacent medium is glass. In the emergent stage, the external medium is air in the cavity, and the adjacent medium is glass. It can be seen that for the dynamic skin prototype, the incident light entering the skin and the outgoing light passing through the skin are both air medium incident to the glass surface and then transmitted to indoor or outdoor. For the abovementioned problems, the following solutions are adopted. First of all, the reflection, absorption, and transmission coefficients of the glass material are based on the data provided by the manufacturer in LBNLWindow. The heat absorption effect is considered, and multiple Fresnel reflections between the inner and outer surfaces of the glass are also included in the data provided by the manufacturer. At the same time, according to the reflection law, computer tools are used to simulate the propagation of light waves in the dynamic skin unit to avoid manual calculation, and energy transfer calculation is carried out in the process of ray tracing. The computer solves a problem by using all the possibilities collected in the database to analyze and deal with one thing. The speed of solving problems varies with different computing power of computers. The answers are very scientific and reasonable but not humanized. Because human beings have leaping thinking ability and emotional factors, solving problems is often unexpected. It is a solution that greatly protects human interests or their own interests. Finally, the reflected energy, transmitted energy, and absorbed energy of the dynamic skin as a whole are obtained, and the overall reflection coefficient, transmission coefficient, and absorption coefficient of the skin are calculated. Similarly, for the light ray reflecting the interior side glass surface, the next time it will not reflect and refract the interior side glass surface. For the light reflected from the sunshade or the edge structure, the next time and the four types of materials may reflect or refract.

4. Result Analysis and Discussion

The building skin not only has the function of limiting space, enclosing the main body of the building and expressing form but also should effectively use the favorable factors in the environment to resist the unfavorable factors from entering the room. In the last chapter, many shortcomings of the existing building skin in adjustability and utilization of outdoor environmental factors are analyzed. Although the traditional fixed skin has excellent thermal insulation performance, it "shuts out" the outdoor environment, and its environmental adaptability and application range are greatly limited. In order to cope with the changing climate conditions, we should give full play to the dual functions of building skin as "use" and "prevention." At the beginning of the design, the dynamic skin should consider various solutions to the complex climate in the life cycle of the building and increase its adjustability to solve the comprehensive adaptability of the building skin. The World Health Organization has found that the long-term stability of indoor thermal environment will lead to "sick building syndrome." Because of the popularity of air-conditioned environment, people who stay in air-conditioned environment for a long time will have a decline in human adaptability, physiological resistance, and immunity. For another example, the air interlayer can collect the solar radiation heat and heat the indoor temperature, which is a part of the heat storage system. If some openings are designed on the outer glass, hot air pressure can be used to make the air in the glass interlayer flow and help indoor air ventilation, which is part of the ventilation system.

The purpose of skin integration is to improve its performance, that is, more "use" of favorable climatic conditions and "protect" unfavorable climatic conditions from entering the room. In the skin energy-saving design, the basic strategies of each technical key point have been analyzed one by one in the previous section and are summarized as shown in Table 2.

It can be seen from Table 2 that due to the immutability of traditional building skin, different energy-saving performance improvement strategies may contradict each other and different energy-saving performance improvement strategies may be combined with each other. In winter, the building skin mainly plays the role of lighting, heat preservation, and solar energy utilization, while in summer, it mainly plays the role of shading, ventilation, and heat insulation.

Octopus provides a variety of machine learning tools, including support vector machine, artificial neural network, and composition pattern generation network. This paper uses support vector machine as a supervised learning tool. Support vector machine is actually a kind of classifier that classifies data according to the supervised learning method. For linear separable data, basic linear separable data, and linear nonseparable data, support vector machine can segment the data through two-dimensional linear functions, planes, or hyperplanes to find the existence range of input instances. The value of c specifies the acceptable error range of SVM. The larger the value of c, the smaller the allowable error range and the more accurate the classification. On the contrary, the smaller the value of c, the larger the allowable error range and the lower the classification accuracy. The SHGC, U, and VT values corresponding to the dynamic skin with different diameters of shading balls are obtained above, and these initial parameters are used as training data to be learned by support vector machines. Figures 3–8 show the original data of some parameters and the functional relationship obtained after training.

The energy consumption simulation module adopts Ldybug and Honeybee based on Grasshopper platform, and its kernel is software such as Energy Plus, Radiance, and Daysim, LBNLThermal. By calling this software, the building energy consumption simulation, lighting simulation, and window heat transfer calculation are completed. As can be seen from the previous part, the evaluation index is the typical daily load in winter and summer. Therefore, according to the four design working states of dynamic skin, the cold and heat loads of experimental buildings with dynamic skin in typical summer days and typical winter days are simulated. In summer, the dynamic skin is in shading state, radiating state at night, gaining heat during typical winter days, and keeping warm at night, and finally the typical daily load in winter and summer is obtained.

The temperature field and velocity field in the whole area after the dynamic adaptive skin cover the insulation board. As shown in Figure 8, the natural convection intensity of air is further weakened compared with that in the figure. Similar to the daytime rule, the weakening of convection heat transfer makes the temperature change of the inner wall relatively small, and the temperature is increased by 0.1°C compared with the 1500 mm buffer layer. Thanks to the influence of convective heat transfer changes, the thermal insulation performance of 1200 mm buffer layer is better than that of 1500 mm buffer layer.

At the same time, in combination with the construction costs and operating energy costs of the experimental and benchmark test pieces, the economic analysis of the dynamic skin can be conducted through the investment recovery period to verify the economic feasibility of the application of the dynamic skin in the project. Two comparison test pieces, including dynamic skin model test piece and benchmark test

Table 2: Basic strategies for key technical points.

Lighting	Increase sunlight into the room
Heat preservation	Enhance the tightness of the skin and reduce the heat transfer coefficient of the skin
Solar energy/power	Increase solar radiation into the room, and more solar energy is converted into thermal energy
Hide from sunlight	Reduce the sun's rays into the room
Ventilate	Reduce the airtightness of skin
Insulate against heat	Reduce skin heat transfer coefficient, increase heat storage, and reduce indoor and outdoor energy exchange

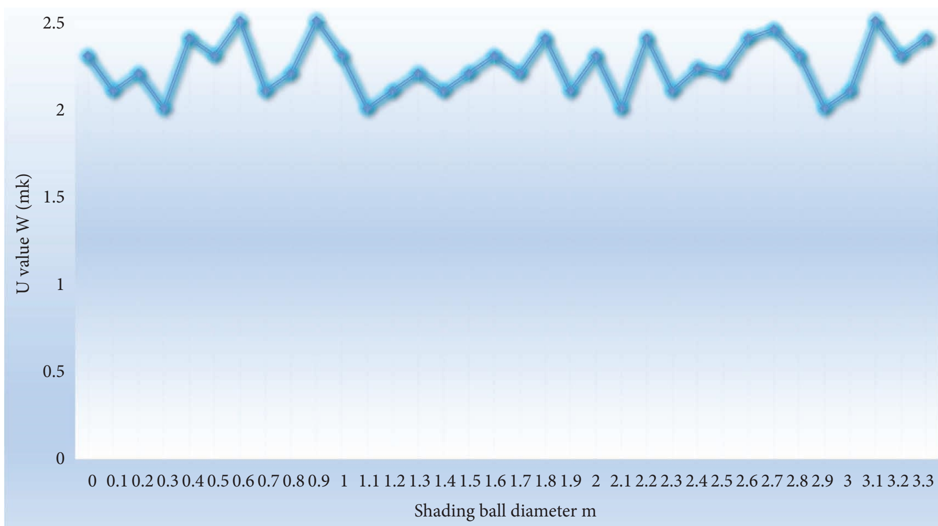

Figure 3: Simulation U value of dynamic skin driven by PCM of various sizes in summer shading state.

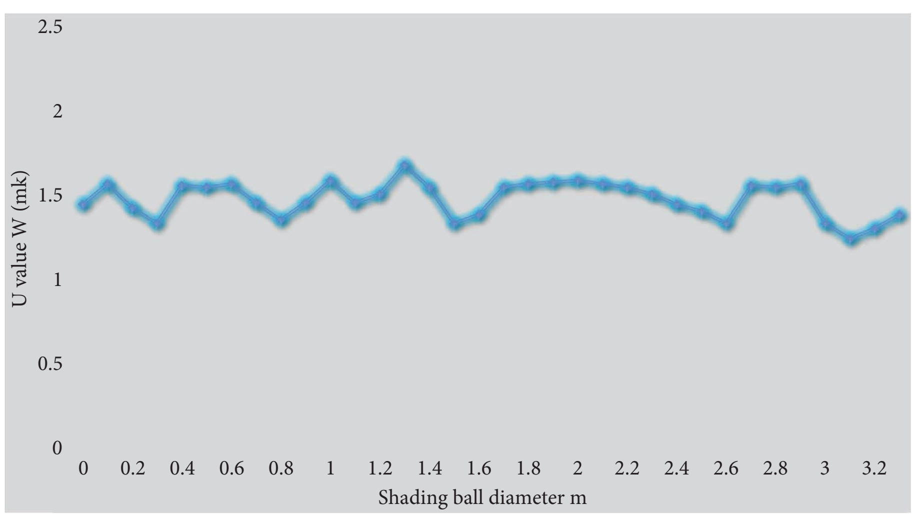

Figure 4: Relationship function between shading ball diameter and skin U value obtained by machine learning.

piece, are set up for the hot box comparison experiment, which are installed on two identical hot boxes, respectively. During the experiment, they are placed in the same outdoor environment. The internal temperature of the hot box, the internal and external surface temperature of the test piece, and the change of heat flow are monitored and recorded to evaluate the relative thermal insulation performance of different test pieces and their impact on the internal thermal environment of the hot box. At the same time, the dynamic skin driven by PCM can also become an economical and reasonable low-energy building curtain wall scheme as long as the reasonable price of sunshade spherical film material is selected. Compared with ordinary glass windows, PCM-driven dynamic skin has obvious energy-saving

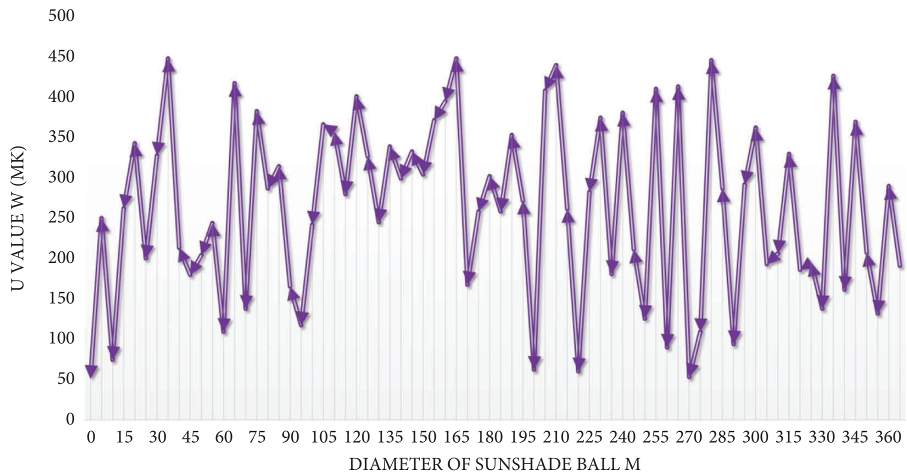

FIGURE 5: *U* value of dynamic skin simulation driven by PCM of all sizes in summer heat dissipation state.

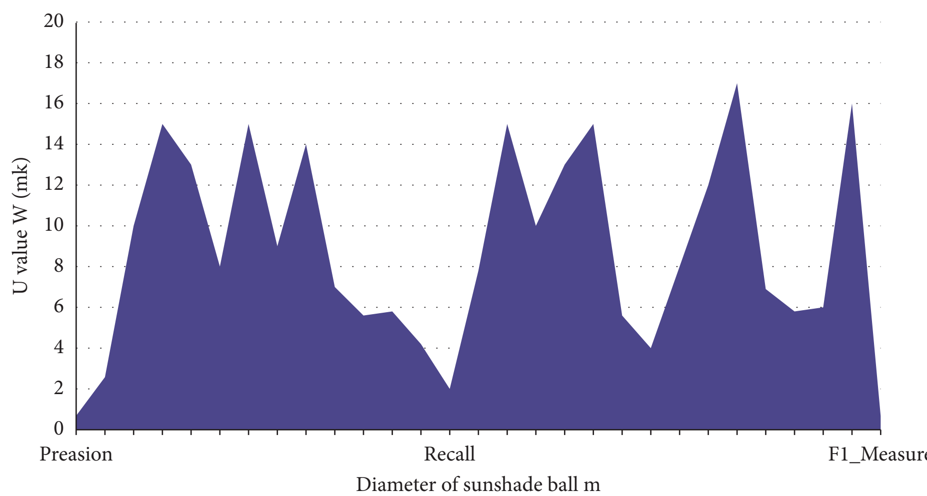

FIGURE 6: Relation function between sunshade ball diameter and skin *U* value obtained after machine learning.

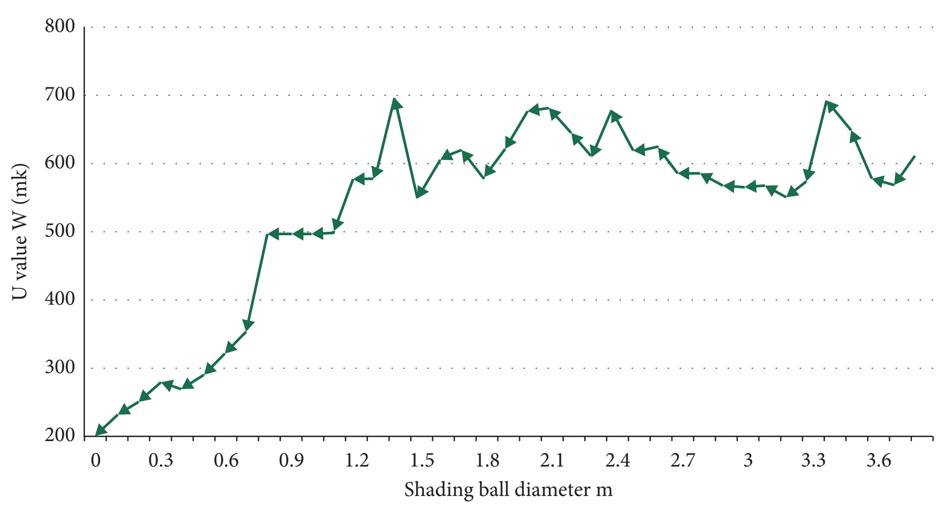

FIGURE 7: Dynamic skin simulation *U* values of PCM drivers of all sizes in winter insulation state.

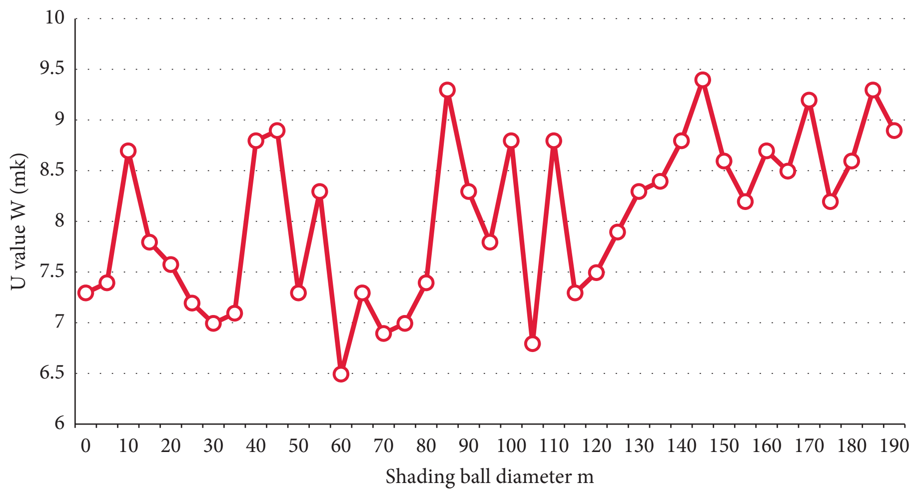

Figure 8: Relation function between sunshade ball diameter and skin U value obtained after machine learning.

advantages in summer climate, which can effectively block indoor heat gain during the day, and its effect is more obvious in sunny weather compared with cloudy weather with little direct sunlight.

5. Conclusions

Building skin is an important part of the intelligent building perception system. It has gone through three stages of development, namely, variable devices, information feedback, and intelligent interaction. Now, it can undertake more and more functions by combining machine learning, big data, and Internet of things technology. The maturity of modern industrial technology and information technology has been very high, and now it has ushered in the era of artificial intelligence. Parametric design, modular design, and other design-related technologies are also becoming mature. Because of its intelligent, organic, and sustainable characteristics, the dynamic climate-adaptive building skin can adapt to the development trend of the times, and it is bound to be accepted by the times. How to maximize the function of technology while bringing aesthetic characteristics different from those of previous times is a question that needs to be considered in the future development of dynamic climate-adaptive building skin. Based on the abovementioned reasons, this paper mainly studies several key methods in the design process of climate responsive dynamic building skin in hot summer and cold winter regions and puts forward corresponding solutions around three main work contents in the design process, namely, design response to climate, selection and application, performance evaluation and optimization. The heat transfer and fluid flow in the dynamic skin are simulated. Through comparing and analyzing the temperature field and flow field distribution under different working conditions, it is proved that the dynamic adaptive skin model has good thermal performance. Even if all possible parameters are considered, the model proposed in this paper is still relatively simple compared with the variables of the natural model. A more accurate model is the future research work.

Data Availability

The figures and tables used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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References

[1] A. P. Melo, D. Cóstola, and R. Lamberts, "Using artificial neural networks to develop alternative models for building shell energy labels," *Energy Policy*, vol. 69, pp. 4–6, 2014.

[2] H. S. M. Shahin, "Adaptive building envelope of multi-storey building as an example of high-performance building skin," *Alexander Journal of Engineering*, vol. 58, no. 1, pp. 34-35, 2019.

[3] R. C. G. M. Loonen, M. Trčka, and D. Cóstola, "Climate-adaptive building shell: the latest technology and future challenges," *Review of Renewable and Sustainable Energy*, vol. 25, pp. 43–49, 2013.

[4] J. Ngarambe, G. Yun, and M. Santa Mouris, "Application of artificial intelligence (AI) method in thermal comfort prediction of buildings: the energy impact of thermal comfort control based on AI," *Energy and Architecture*, vol. 211, pp. 10–17, 2020.

[5] D. K. Bui, T. N. Nguyen, and T. D. Ngo, "Artificial neural network (ANN) expert system based on electromagnetic firefly algorithm (EFA) is used to predict building energy consumption," *Energy*, vol. 190, pp. 11–17, 2020.

[6] J. W. Moon, S. H. Yoon, and S. Kim, "Development of thermal control logic for double leather jackets in winter based on artificial neural network model," *Architecture and Environment*, vol. 61, pp. 14–19, 2013.

[7] B. Si, J. Wang, and X. Yao, "Multi-objective optimization design and algorithm performance evaluation of complex

buildings based on artificial neural network," *Advanced Engineering Informatics*, vol. 40, pp. 13–19, 2019.
[8] Al-Masranism and K. M. Al-O Baidi, "Dynamic shading system: a summary of design parameters, platforms and evaluation strategies," *Building Automation*, vol. 102, pp. 19–26, 2019.
[9] Y. Zhou, S. Zheng, and Z. Liu, "And passive phase change materials combine building energy system with advanced climate adaptive design based on machine learning, intelligent operation, analysis and optimization based on uncertainty: the latest review," *Review of Renewable Energy and Sustainable Energy*, vol. 130, pp. 25–28, 2020.
[10] D. K. Bui, T. N. Nguyen, and A. Ghazlan, "Improving building energy efficiency through adaptive facade: a computational optimization method," *Applied Energy*, vol. 265, pp. 16–19, 2020.
[11] A. Kuru, P. Oldfield, and S. Bonser, "Biomimetic adaptive building skin: building energy and environmental regulation," *Energy and Architecture*, vol. 205, pp. 12–20, 2019.
[12] M. Perino and V. Serra, "Transformation from static to adaptive and dynamic building envelope: paradigm shift of building energy efficiency," *Journal of Facade Design and Engineering*, vol. 3, no. 2, pp. 14–16, 2015.
[13] S. K. Baduge, S. Thilakarathna, and J. S. Perera, "Artificial intelligence and intelligent vision for building construction 4.0: machine and deep learning methods and applications," *Building Automation*, vol. 141, pp. 20–25, 2022.
[14] R. Evins, "Review of computational optimization methods applied to sustainable building design," *Review of Renewable and Sustainable Energy*, vol. 22, pp. 24–28, 2013.
[15] A. A. Alnaqi, H. Moayedi, and A. Shahsavar, "Energy performance prediction of building integrated solar-thermal system based on artificial neural network and hybrid particle swarm optimization model," *Energy Conversion and Management*, vol. 183, pp. 13–18, 2019.
[16] C. Zhai, T. Li, and H. Shi, "Discovery and design of soft polymer bionic materials based on multi-scale simulation and artificial intelligence," *Journal of Materials Chemistry B*, vol. 8, no. 31, pp. 16–24, 2020.
[17] M. Ilbeigi, M. Ghomeishi, and A. Dehghanbandaki, "Prediction and optimization of office building energy consumption based on artificial neural network and genetic algorithm," *Sustainable City and Society*, vol. 61, pp. 26–28, 2020.
[18] P. H. Shaikh, N. B. M. Nor, and P. Nallagownden, "Review of optimal control system for energy saving and comfort management of sustainable intelligent buildings," *Review of Renewable Energy and Sustainable Energy*, vol. 34, pp. 20–24, 2014.
[19] M. Barozzi, J. Lienhard, A. Zanelli, and others, "Sustainability of adaptive envelopes: development of dynamic architecture," *Procedia Engineering*, vol. 155, pp. 27-28, 2016.
[20] A. J. Khalil and B. S. Abu-Nasser, "Energy efficiency prediction based on artificial neural network," *International Journal of Academic Education Research (IJAPR)*, vol. 3, no. 9, pp. 15–24, 2019.
[21] R. C. G. M. Loonen, F. Favoino, and J. L. M. Hensen, "Overview of the present situation, requirements and opportunities of adaptive facade building performance simulation," *Journal of Building Performance Simulation*, vol. 10, no. 2, pp. 20–22, 2017.
[22] Department of National Housing and Residential Environment, *Department of National Housing and Residential Environment Engineering Technology Research Center China Association for Engineering Construction Standardization Standard Technical Specification for Healthy*, Housing Construction China Planning Press, Urban, China, 2009.