Research on the Teaching of Building Intelligent Dynamic Skin Design

Haiying Li(✉)

School of Architecture and Art, North China University and Technology, Beijing 100144, China
lhy@ncut.edu.cn

Abstract. Compared with the traditional static building skin, the intelligent dynamic building skin can sense the changing external climate environment, adjust the state of the skin to improve the indoor physical environment, and achieve the role of energy saving. It is one of the effective technical means to realize green and sustainable building. This paper discusses the basic curriculum, simulation control approach and curriculum teaching system of intelligent dynamic skin teaching based on environmental factors.

Keywords: Building intelligent dynamic skin · Teaching system · Architectural bionics · Simulation approach · Basic course and functions

1 Introduction

The building skin is the barrier between indoor and outdoor environment and can regulate the physical environment inside the building. When the external physical environment is constantly changing, the structural form of traditional envelope cannot adjust with the external environment in time. However, with the rapid development of building technology and the popularity of ecological concepts, the progress of building energy consumption simulation technology, computer-aided design technology, 3D printing, automatic control system and other technologies are constantly driving the new changes in building skin design, so as to dynamically adjust to adapt to the changes of the external environment.

2 Building Intelligent Dynamic Skin

Intelligent dynamic Skin can dynamically regulate the changeable components on the Skin and adjust various environmental factors to meet the requirements of Building Climate adaptability. Therefore, intelligent dynamic skin can also be called CABS (climate Adaptive Building Skin). For intelligent dynamic skin, there are multiple words for "dynamic and intelligent" as responsive, adaptive, variable, kinetic, interactive and movable.

External environmental factors such as solar radiation, outdoor temperature, humidity, wind, precipitation and noise change all day or all year round, which affect human

A. Volodin and I. Roumbal (Eds.): ICECIDT 2022, ASSEHR 677, pp. 459–466, 2023.
https://doi.org/10.2991/978-2-494069-02-2_51

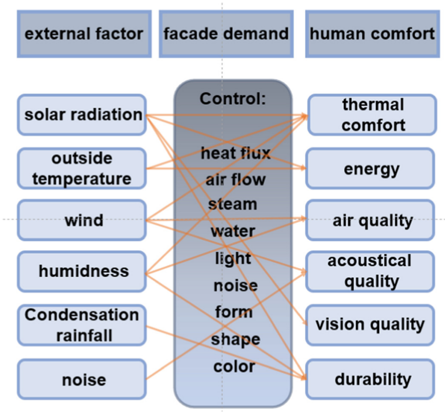

Fig. 1. Function and evaluation of dynamic epidermis.

comfort and need to be considered in facade design. The intelligent dynamic skin responds to external factors and forms an acceptable internal environment that can be evaluated comprehensively in terms of thermal comfort, energy performance, air quality, acoustic quality, visual quality and durability ("Fig. 1"). In view of the change of external environment, intelligent dynamic skin is intelligent, adaptive and dynamic.

3 Basic Courses and Functions of Intelligent Dynamic Epidermis Teaching

3.1 Architecture Composition

Composition art is the foundation of architectural skin modeling language. Plane composition explores the visual rules of two-dimensional space, the establishment of images, the organization of bones, and the composition rules of various elements. Color composition studies color collocation and color feeling; Solid form is the composition of solid form and space form of three dimensions. Three-dimensional composition is inseparable from materials, technology, mechanics, aesthetics, art and science. The design and generation of intelligent dynamic skin of architecture are inseparable from the design basis of "three components", whether from the plane generation logic of skin, structural system, color collocation, or the rotation, folding and sliding of dynamic skin [1].

3.2 Architectural Mathematics and Geometry

The rhythmic beauty in the formal beauty of architectural skin is actually a kind of order, a combination rule between the same and similar elements. "Rhythm" can also be reduced and reproduced by mathematical logic and geometric relations. Functional shading elements for the Simon Center for Geometry and Physics, each panel is a unique geometric perforated plate pattern ("Fig. 2").

Architectural geometry is arising at the historic moment with architecture into the digital era, it is theoretically by differential geometry, topology, geometry, fractal how,

Fig. 2. Geometric pattern dynamic shading. a. Elmira Jamei, Zora Vrcelj. Biomimicry and the Built Environment, Learning from Nature's Solutions[J], Appl. Sci. 2021, 11(16)

the influence of several main used in architecture design, analysis and application in the process of building research, the research content including free surface discrete, generate create, surface design, digital prototyping, etc. [2] With the development of computer technology, nonlinear mathematical logic of complex body has the possibility of application.

3.3 Building Materials

Architectural materials can reflect aesthetic rules, carry historical context and reflect regional characteristics. Different building skin materials, such as wood, metal, glass, ceramic, stone, film and other types, have different properties, combination methods, visual characteristics and emotions conveyed. With the development of modern construction techniques and building materials, the skin has gained more and more freedom. In particular, based on the characteristics of texture, lightness, weight, transparency, hierarchy and so on, materials and their construction mode and formal expression show unprecedented diversity and richness. Some smart skin materials require additional energy to drive, while others, such as photosensitive materials, shape memory alloy material [3] and phase change materials, change the physical properties of the original material when the environment changes and can be restored with the restoration of environmental conditions.

3.4 Building Construction

Architectural construction should not only explain the common structural knowledge in China, but also discuss the logical generation process of the skin form and space of a building from the perspective of design from the aspects of material, skin, structure, connection nodes and so on. More and more products are being constructed using integrated components that combine renewable energy and multifunctional building elements.

3.5 Building Physics

According to the different environmental factors, the variable building skin can be divided into five categories: wind environment regulation, thermal environment regulation, light environment regulation, solar energy regulation and comprehensive control.

Variable skin is a comprehensive system, which consists of adjustable skin components, environmental parameter sensing equipment, system control equipment and other parts. According to the different design methods, the variable skin can adjust one or several environmental factors, and adopt different adjustment cycles according to the changing rules of environmental factors.

3.6 Architectural Bionics

Bionic design of building skin can be carried out on three levels. First of all, in terms of morphology, bionics refers to the partial or overall architectural mimicry design of animals, plants and other biological individuals. This simulation is relatively easy for architects to implement; second, bionics at the behavioral level means that the building skin simulates the behavior of individual organisms. Thirdly, bionics at the ecosystem level means that architecture simulates the smooth survival of the ecosystem in the whole ecological environment. In the second and third stages, the behavior and mechanism of simulating the behavior of individual organisms and ecological responses requires the cooperation of biologists, and also involves the support of various technologies, such as climate measurement, collection of refrigeration continuing operation status, power system configuration, building system and computer control to assist in the completion [4].

4 Simulation Approach of Intelligent Dynamic Epidermis Teaching

4.1 Parametric Design and Implementation

As a part of digital architectural design, parametric architectural design mainly refers to a design method that transforms all elements of design into several related functional variables and obtains different design schemes by modifying the variables. At the same time, with the increasingly mature computational manufacturing technology, it provides great convenience for the molding of complex forms and Spaces, such as the current prevailing 3D printing technology, mechanical arm construction, assembly building and so on.

Parameterized design includes parameterized aided architectural design and parameterized guiding design (see "Fig. 3"). Parametrized aided architectural design mainly depends on the designer himself, who actively controls the design results. Parameterized guided design transforms architectural design itself into logical reasoning and replaces designer's subjectivity with rational thinking. Designer does not foresee the result and design is automatically generated by calculation. The performance and editability of three-dimensional panoramic simulation provided by digital technology provide a very powerful aid for architects to control the whole design process, and push the controllability of architectural design to the extreme. Digital technology can be integrated into the whole life cycle of a building. The development of NUMERICAL control technology also makes it easier to realize complex forms, numerical control machine tools, three-axis to five-axis milling machines, 3D printing, rapid prototyping and other technologies are increasingly mature, and even through three-dimensional digital model information technology for building manufacturing and processing.

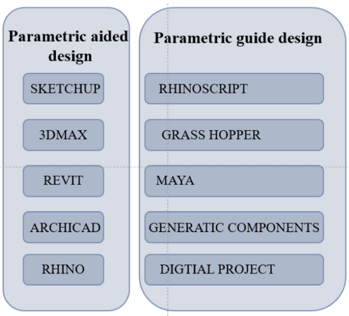

Fig. 3. Parametric design approach.

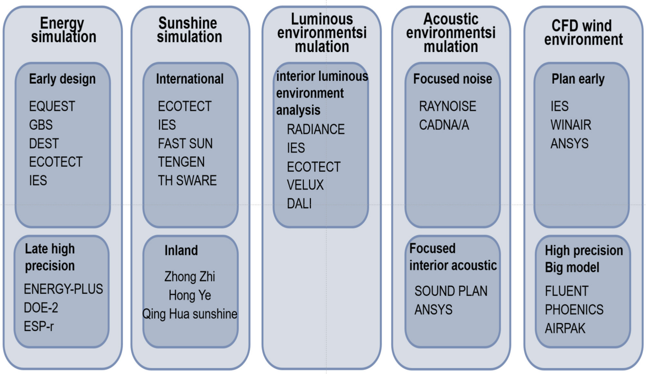

Fig. 4. Different physical environment simulation platform and emphasis.

4.2 Building Physical Environment Simulation

For the built living environment, the comfort and energy consumption index of the building can be evaluated by means of actual measurement, but the post-evaluation cannot adjust the deficiencies of the planning and design in the early stage. Therefore, the current research on building physical environment is reflected in not only the optimal quantification of physical indicators of building energy consumption, optimization of design factors at the initial stage of design, but also the continuous adjustment, correction and improvement of design elements such as building shape, size of hole in building skin, shading facilities, etc., but also in the late stage of design, high-precision simulation can be carried out. At present, the simulation platform of physical environment has different emphases (see “Fig. 4”), which is mainly reflected in energy consumption simulation, sunshine analysis, daylighting analysis, acoustic analysis and CFD wind environment analysis [5].

4.3 Computer Control

Based on the Building Automation System (BAS), the intelligent dynamic skin is a new architectural element with both shapes and equipment. Material science provides

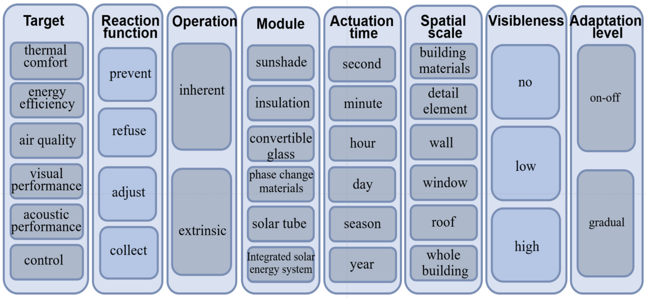

Fig. 5. Control characteristics of BAS based intelligent regulatory skin [6].

hardware support for building skin, and automation technology provides soul for building skin. BAS system is the core subsystem of intelligent building, which can monitor and control building energy use, environment, traffic and safety facilities, so as to provide a safe, economical and comfortable indoor environment. The smart skin introduced by BAS system can improve the high energy consumption of traditional skin, which is in line with the sustainable concept. BAS system involves time in the design, feeds back the environment to the computer through sensors, and changes the skin according to preset rules, so that the building can respond to the environment. According to the adjustment degree of intelligent skin, it can be divided into overall control and unit control. The overall control is to control the whole skin system, while the unit control is to modularize the outer skin, so that each module can complete complex transformations such as rotation and closure at specific angles. It not only responds to the external environment, but also accurately adjusts the indoor physical properties, which can be regarded as a fine technical means based on the whole skin. "Figure 5" shows the depth and characteristics of skin control by building automation system foundation.

5 Intelligent Dynamic Skin Design Teaching System

In recent years, the University of Santiago in Chile, Columbia University, National University of Singapore, Yale University, Harvard University, University of Stuttgart in Germany and Delft University in the Netherlands have opened research courses on dynamic architectural skin design. Therefore, referring to the curriculum of other countries, the curriculum system of intelligent dynamic skin design is proposed, as shown in "Table 1". Compared with the traditional training system of architecture, programming foundation is added in the lower grades, and the role of architectural mathematics and geometry in formal aesthetics is emphasized. Architectural bionics is combined in the creative thinking, and computer physical environment simulation and parameterized guided design are used as the means of realization. Through this training system, students can basically master the design method of intelligent dynamic skin. At the same time, it is also recommended to conduct project design research in the fourth year, graduation project or graduate stage.

Table 1. Course setting of skin design

Curriculum	Highly correlatedcourse	Set grade	Practical studies
Programming basics	U ni ty/Ard uino/C++/Python	First/Second Grade	Special topics in creative programming
Computer-aided design	Sketchup/ 3DMAX	First/Second Grade	Preliminary Architecture Course, Architectural Design Course
Architectural mathematical geometry	Architectural formal beauty and mathematical verification	First grade	Preliminary course in architecture, special topics in architectural composition
Architectural composition	Flat, color, three-dimensional composition	First grade	Combined with cardboard, gypsum, wood and wire
Architectural bionics	Biomorphology and adaptability	Second grade	Combined with the second grade design class
building material	Characteristics of the epidermal material	Second grade	Combined with building materials design topics
Architectural construction	Building wall, material connection	Third grade	Combined with the small semester construction design
Building physics	Architectural sound and light thermal principles	Third grade	Combined with the special topic design of the third grade design class
Parametric guidance for design	GRASSHOPPER RHINOSCRIPT	Third grade	Combined with the third grade design class
Computer controlled	BAS-based building skin control	Fourth grade	Special topic classes
Computer simulation	Simulation of the physical environment of the building	Fourth /fifth grade/First year of graduate school	Combine fourth-year, graduation design and graduate design special courses

6 Conclusion

The design process of intelligent dynamic building skin is a process in which architecture integrates learning from other disciplines, including materials, control, ecology and aesthetics. In order to cope with this trend, the curriculum system of dynamic skin design based on environmental factors should be developed and perfected. The development of intelligent dynamic building skin can better adapt to the changing climate environment, play an important role in improving the indoor physical environment and saving energy, and is an effective technical means to achieve green and sustainable building.

Authors' Contributions. This paper is independently completed by Haiying Li.

References

1. Miao, Zhantang, Gang Feng, and Juanli Guo. 2016. Design of Variable Architectural Surface in Response to External Environmental Changes. *Dynamic (Eco-City and Green Building)*. 11: P48–P55.
2. Liu, Hongtao. 2013. *Mathematical Logic and rhythm in the Image of Building Skin*. P12–P17. Tianjin University.
3. Jamei, Elmira, and Zora Vrcelj. 2021. Biomimicry and the Built Environment, Learning from Nature's Solutions. *Applied Science* 11: 7514.
4. Wang, Jialiang. 2011. *Biomimicry Kinetics Sustainablity—Study on dynamic building skin based on biological Acclimatization*. pp. 101–105. Tianjin University.
5. Lei, Lixing. 2016. *Research on the Method of Parametric Architectural Design Based on the Performance of the Physical Environment*. P19–P23. Hefei University of Technology.
6. Aelenei, Daniel, and Laura Aelenei. 2016. Catarina Pacheco Vieira. Adaptive Façade: Concept, Applications, Research Questions. *SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry*. pp. 269–275.