


Research Article

Building Virtual Scene Construction and Environmental Impact Analysis Based on Image Processing

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With the rapid development of computer technology, the virtual scene construction technology of image processing has gradually become a hotspot in computer research. The application of virtual scene construction technology in the construction industry is also expanding, with the intelligentization of architectural design and construction. With the rapid development of the industry, virtual technology can better provide users with diversified services and experiences. The main content of the article is as follows: (1) The article introduces image construction technology and analyzes the three-dimensional presentation of virtual technology in construction design and the diversified application of virtual technology in construction design. (2) The article introduces two virtual scene construction techniques: one is to combine the real scene obtained by taking pictures with the virtual scene by image technology processing to construct a natural virtual scene; the other is the use of geometric construction by architects. The virtual building model is drawn by the model method, and the virtual building model is thus obtained. (3) The article chooses two representative buildings as cases. The virtual platform monitors and records the movement trajectory of volunteers in the virtual environment in real time. The experimental results show that the number and shape characteristics of the escalators in the building all have a little impact on volunteers' awareness. (4) The article sets up three control groups of normal mode, fixed skin, and variable skin. It analyzes the environmental impact of buildings from three different aspects of wind environment, thermal environment, and light environment and proposes related control measures.

1. Introduction

With the advent of the information age, the construction industry has also entered an intelligent field; the application of virtual scene construction technology in the construction industry is also expanding. The use of virtual reality technology when designing buildings can not only visually display the art of the building. The effect is also a great advantage in saving energy and labor. Huaqin et al. [1] discussed a remote virtual platform based on VRML-JAVA language, which is constructed and scene-oriented with realistic and interactive information. Jin et al. [2] used virtual reality 3D holographic projection technology to realize the 3D image imaging scene of the building suspended in the air. The article combines image technology with the real estate

industry, analyzes the building's modeling and imaging steps, improves the expressiveness of the building, and also brings great value and development prospects to the construction industry. Hou and Li [3] proposed a collision detection strategy based on enclosure and enclosure hierarchy to meet the performance requirements of virtual hoisting collision detection. R. Joseph and Perera [4] introduced the mechanism of applying internal and external design structures after converting 2D drawings into 3D building information models (BIMs). In the early stage of construction, it is very useful to create a 3D model according to the customer's requirements. The article introduces the method of 3D model creation. Pruss et al. [5] introduced a computer-implemented method for generating building block instructions for building block models. Guo and Chen

[6] discussed the role and significance of AR in airport construction projects. In the early stage of building construction, designers have to apply many advanced technologies, such as image processing technology and virtual model construction to generate virtual building models with computers. Zhao et al. [7] produced a hierarchical model to describe the 3D dynamic geographical process. Describing the geographical factors that change with time during the construction process and simulating visual scenes with computers are of great significance to the management and decision-making of the building. In [8], large eddy simulation (LES) was performed on the airflow around various types of block arrays to estimate the pedestrian wind environment. The experiment selected five different arrays for simulation. The experimental results show that the area ratio is an important indicator for estimating the wind environment. We can use the area ratio to simulate the height change of the building. Lang [9] proposed a model for estimating solar radiation based on existing weather records and determining typical meteorological months and interpolation procedures for missing data. Kajikawa et al. [10] discussed the benefits, limitations, and future directions of the evaluation framework [11]. Do [12] proposed an analysis method for building environmental service plans that are verified throughout the year. The service plan of building environment service is a very important part of the whole design. The designed plan must meet the requirements of the indoor environment. The article proposes an analysis method of building service that can meet most of the requirements. Yun and Won [13] uses machine learning algorithms to establish a built environment model, which can be used to evaluate the comfort of occupants. We have proposed an energy control measure, which can effectively record the energy consumption of the room and record the comfort of the residents, so as to provide a better accommodation environment for the owners. Ivanova [14] focused on using anisotropic sky-viewing angle factors to estimate the background component of incident diffuse solar radiation on building facades under the orthogonal obstructed sky. Because the Earth's available resources are very limited, we have to design buildings that can use solar energy. Xueping [15] tested the 4 most commonly used heating methods and discussed indoor thermal environmental conditions for different heating methods. The temperature in the north is relatively low in winter, and many citizens choose certain heating measures in winter. The experiment compares common heating methods and provides a reference for citizens to choose heating methods.

2. Virtual Reality Technology

2.1. Three-Dimensional Presentation of Virtual Reality Technology in Architectural Design. Architectural design work is very complicated. In the design work, designers will inevitably encounter some problems, such as the size of the building being not clear enough and the structural drawings of the building having some problems. But, the reason is that building virtual scene construction technology can solve these problems very well. The design drawings are presented

in three-dimensional graphic construction technology, which largely avoids architectural errors, facilitates designers to find problems, and improves work efficiency.

When faced with a single two-dimensional or three-dimensional overprofessional drawing model, the construction personnel cannot make a correct understanding of the construction operation of the building, causing deviations between the design and the actual building, making the construction impossible and causing serious losses from many parties. Participants can immerse in the virtual space and intuitively understand the designer's description of the main structure, spatial layout, and details of the building or building group, so as to grasp the detailed requirements in the work and avoid repeated construction problems that cause irreparable losses to subsequent construction. The three-dimensional sensory presentation allows participants to better complete the construction requirements and tasks during construction and finally realizes the application, economy, solidity, and beauty of the building.

Architectural designers use the immersion, interactivity, and conception of virtual reality technology to fully integrate with the architectural concept [16]. First, the building participants have an immersive feeling during use. Second, the building participants can interact with most of the objects in the virtual environment by using sensing devices. This makes the complex and abstract architectural design become concrete with the use of virtual reality technology. The greater advantage is that designers can communicate with other architectural participants remotely, thereby reducing time costs, breaking geographical restrictions, and making architectural design more wide-area.

2.2. Application of Virtual Reality Technology in Architectural Design. The technical personnel input the engineering information and design parameters of the architectural design into the three-dimensional modeling software through the computer, and the three-dimensional modeling software builds the three-dimensional architectural model and supporting database based on the input data. Technicians issue operating commands to the model drive system through the computer, adjust the building model information, display the progress of the building project design plan in real time, follow up the project, and adjust the model parameters in time. Building participants are immersed in the virtual simulation space created by virtual reality technology and feel the reality of the lighting changes, architectural pattern, modeling structure, and surrounding environment in the virtual simulation space [17]. Compared with the method of drawing building models from ordinary drawings, the use of virtual technology not only is environmentally friendly and cost-saving but also allows more people to participate in the process of architectural design and better understand architectural details and specific construction conditions. It provides convenience for designers to modify the architectural design plan in the later stage of construction, and at the same time, it is convenient to save the architectural design, which is conducive to the comparison and update of future designs [18]. The virtual building model is the basis

for constructing the virtual real scene. The size ratio between the measurement unit of the model and the real scene and the parameter values of the entire model all affect the final presentation effect of the virtual real scene.

2.3. Analysis of Building Environmental Impact. Environmental performance is reflected in the park design as the external and internal environments of the park. The external environment of the park includes ecological environment, traffic environment, outdoor functional space created by the building, and environmental impacts around the park. According to different time domains, environmental quality assessment can be divided into environmental quality review assessment, environmental quality status assessment, and environmental quality forecast assessment. Environmental quality assessment of construction projects mainly refers to the assessment of environmental quality status. Environmental postassessment refers to the systematic investigation and evaluation of the actual impact degree of the environment after the development and construction activities are carried out, so as to test the implementation degree and effectiveness of reducing the impact and test the true credibility of the environmental assessment results. To evaluate the effectiveness of the implementation of the proposed environmental protection countermeasures, and to analyze and discuss the influencing factors that are not fully understood in the environmental assessment, check the implementation degree and implementation effect of reducing the impact and test the true credibility of the environmental assessment results. After evaluating the effectiveness of the proposed environmental protection measures, the fully understood environmental impact problems are classified and studied, so as to improve the technical methods and levels of environmental assessment and implement remedial measures, thus achieving the effect of reducing the impact.

3. Theory and Technology Based on Image Construction

3.1. Image Deformation Technology. The image deformation technology can realize the excessive viewpoint, while interpolating the shape and texture of the image [19], as shown in Figure 1.

A pair of line segments can define the mapping relationship between the source image and the target image [20]; the specific algorithm is as follows: calculate PQ based on line segment u, v , where

$$\begin{aligned} u &= \frac{(X - p) \cdot (Q - P)}{\|Q - P\|^2}, \\ v &= \frac{(X - P) \times \text{perpendicular}(Q - P)}{\|Q - P\|}. \end{aligned} \quad (1)$$

Then, find u, v based on $P'Q'$ and line segment X' ; when using multiple pairs of line segments, it is necessary to perform a weighted average on the multiple offsets obtained, as shown in Figure 2.

The specific algorithm is as follows, for each pixel on the target image:

$$\begin{aligned} \text{Dis_Sum} &= (0, 0), \\ \text{Weight_Sum} &= 0. \end{aligned} \quad (2)$$

Calculate the offset of the line segment as

$$D = X'_i - X'_i. \quad (3)$$

Calculate the shortest distance from X to P_iQ_i as

$$\text{weight} = \left(\frac{\text{length}^p}{(a + \text{dist})} \right)^b, \quad (4)$$

$$\text{Dis_Sum} += D_i * \text{weight},$$

$$\text{Weight_Sum} += \text{weight}.$$

Finally,

$$X' = X + \frac{\text{dis_Sum}}{\text{Weight_Sum}}. \quad (5)$$

3.2. Projection Reconstruction Algorithm. The Euclidean motion theory is used to explain the geometric relationship between the two-dimensional image and the three-dimensional image captured using the same camera. All points $p \in E^3$ in the space can be represented by a certain three-dimensional coordinate point in R^3 :

$$X = [X_1, X_2, X_3]^T = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} \in R^3. \quad (6)$$

The coordinates of p and q in space are X and Y , respectively, by the vector formed by p and q :

$$v = Y - X \in R^3. \quad (7)$$

The inner product of two vectors $v, u \in R^3$ in space is

$$\langle u, v \rangle = u^T v = u_1 v_1 + u_2 v_2 + u_3 v_3 \quad \forall u, v \in R^3. \quad (8)$$

The vector product is

$$u \times v = \begin{bmatrix} u_2 v_3 - u_3 v_2 \\ u_3 v_1 - u_1 v_3 \\ u_1 v_2 - u_2 v_1 \end{bmatrix} \in R^3. \quad (9)$$

We define a matrix $\hat{u} \in R^{3 \times 3}$:

$$\hat{u} = \begin{pmatrix} 0 & -u_3 & u_2 \\ u_3 & 0 & -u_1 \\ -u_2 & u_1 & 0 \end{pmatrix} \in R^{3 \times 3}. \quad (10)$$

The vector product can be expressed as

$$u \times v = \hat{u}v. \quad (11)$$

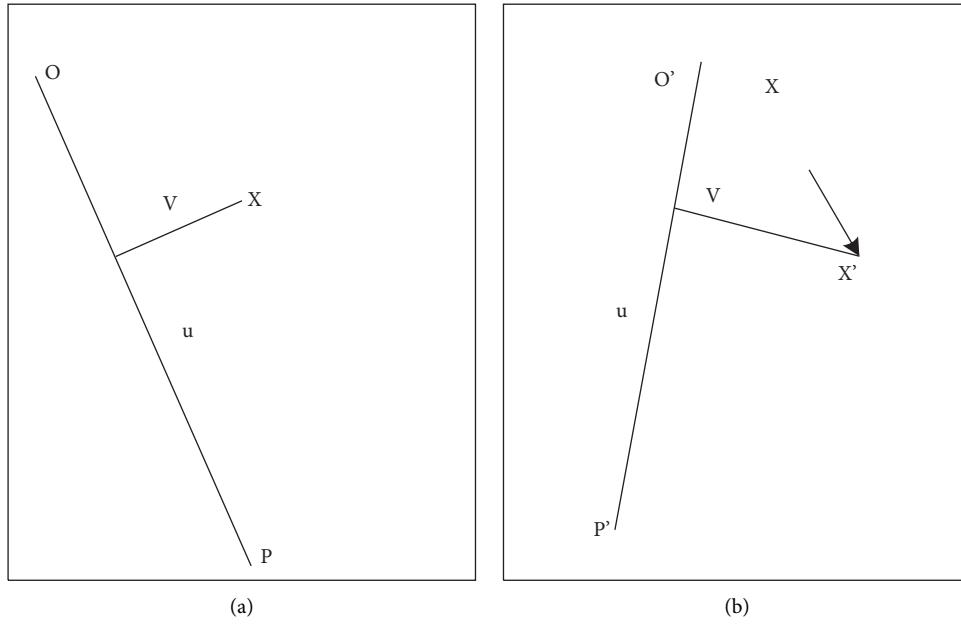


FIGURE 1: Deformation of a pair of corresponding line segments. (a) Target image. (b) Source image.

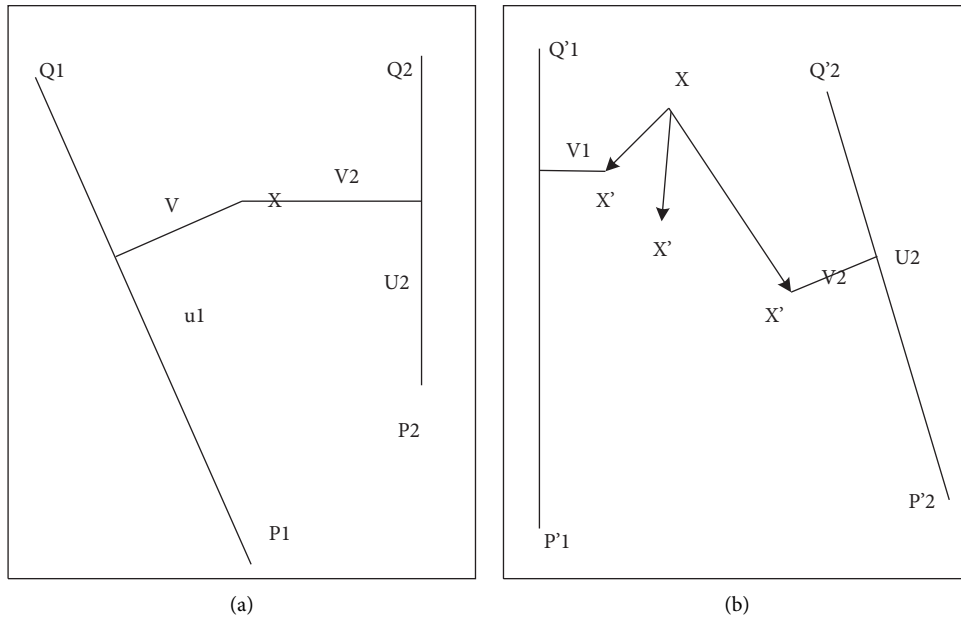


FIGURE 2: Deformation of multiple pairs of corresponding line segments. (a) Target image. (b) Source image.

It is also necessary to introduce rigid body motion theory, as shown in Figure 3.

The formula can be expressed as

$$X_w = R_{wc} X_c + T_{wc}. \quad (12)$$

Figure 3 coordinates of point P in the camera coordinate system are (X, Y, Z) , and the two-dimensional coordinates

on the plane are $X = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \in R^3$ [21]:

$$x = \begin{bmatrix} x \\ y \end{bmatrix} = \frac{f}{Z} \begin{bmatrix} X \\ Y \end{bmatrix}. \quad (13)$$

The homogeneous coordinate form is as follows:

$$Z \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{pmatrix} f & 0 & 0 \\ 0 & f & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}, \quad (14)$$

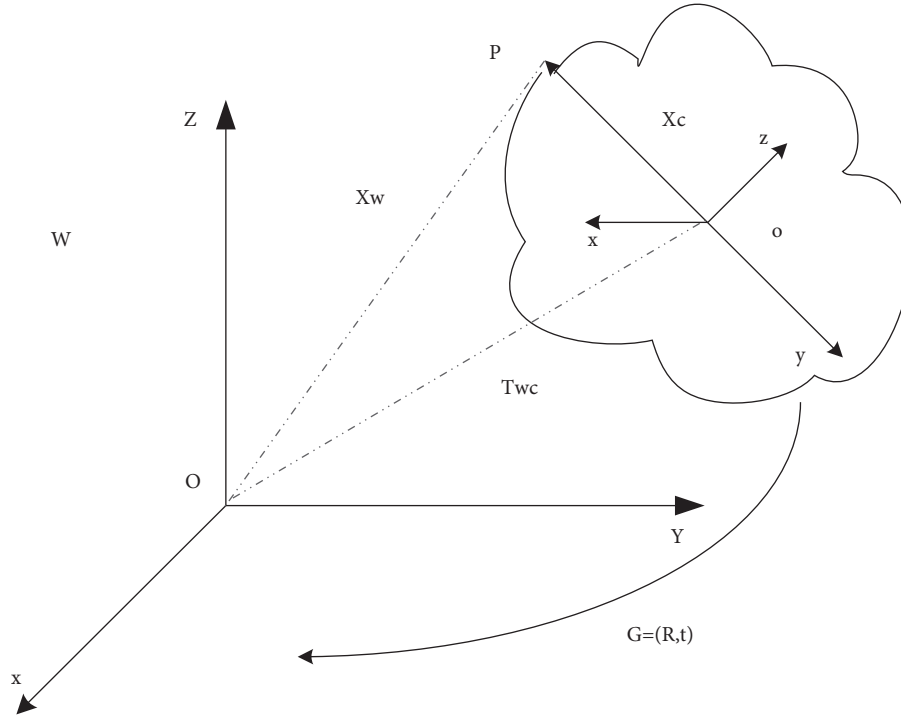


FIGURE 3: Rigid body motion between the world coordinate system and its own coordinate system.

where

$$K_f = \begin{bmatrix} f & 0 & 0 \\ 0 & f & 0 \\ 0 & 0 & f \end{bmatrix} \in R^{3 \times 3}, \quad (15)$$

$$\prod_0 = K_f = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \in R^{3 \times 4}.$$

Let $\lambda \doteq Z$, and the formula can be written as

$$\lambda x = K_f \prod_0 X \quad (16)$$

3.3. Uncertain Measurement of Environmental Impact. The environmental impact of the construction process includes building materials, construction machinery, resources, and labor, which can be abstracted into mathematical formulas [22]:

$$E_{\text{total}} = \sum_{i=0}^I E_i. \quad (17)$$

Here, E_{total} is the total emission of environmental pollutants [23]:

$$E_i = E_m + E_e + E_r + E_l. \quad (18)$$

The formula for environmental pollutant emission per unit amount of environmental influencing factors is

$$E = e \times Q. \quad (19)$$

During the construction process, the simulation module provides dynamic data under the influence Q_v [24]:

$$Q_v = f(Q | \prod). \quad (20)$$

According to the environmental pollution impact assessment method, the damage value of the human body, ecology, and natural resources can be calculated:

$$p_k = \sum_k \left(\sum_j (E_j \times EF_j)_k \times CF_k \right). \quad (21)$$

4. Experimental Simulation

4.1. Virtual Building Scene Construction Technology. Computer graphics technology is one of the methods of constructing virtual scenes. We usually use the technology of “combination of virtual and real” to construct the virtual environment required by users [25]. The nonexistent scene is the virtual scene. The combination of the real scene and the virtual scene creates the most natural virtual scene, as shown in Figure 4.

The virtual model can also be drawn by the architect using the method of geometric modeling. It must be drawn according to the real size of the building, and then, a virtual model is constructed based on the geometric model and the real map drawn by the architect, as shown in Figure 5.

This section is mainly on the virtual technology and real technology of building analysis, through the combination of



FIGURE 4: Building scene diagram combining virtual and real scenes. (a) Real scene image. (b) Virtual scene image. (c) Architectural scene combining virtual and real scenes.

virtual and real ways to effectively integrate the two styles, forming a more perfect building simulation map.

4.2. Simulation Experiment. This study selects the more representative architectural model 1 and architectural model 2 of our country's construction projects as cases. Architecture 1 and architecture 2 are widely distributed in our country and have a large amount of construction; we took photos and measurements of the case on the spot, and then, according to the experiment, it is required to construct a virtual simulation scene. In order to avoid the interference of environmental factors on the experiment, when constructing the virtual scene, the dimensions, position, and other

factors must be consistent with the real environment, as shown in Figure 6.

We selected 30 volunteers to participate in the experiment. The average age of volunteers is 20–40 years, and the proportion of males and females is not equal. The virtual experiment platform is used to collect volunteers' path-finding trajectories in building 1 and building 2, in order to reduce certain volunteers. The experiment error is caused by the proficiency of the scene, so before the formal start of the experiment, each volunteer needs to enter the venue in advance to get familiar with the interactive process of the virtual scene. The specific data are shown in Table 1.

The experiment monitors and records the movement trajectory of volunteers in the virtual environment in real



FIGURE 5: Image after combining virtual and real scenes. (a) Virtual geometric model. (b) Real image. (c) Building mockup.

time through the virtual platform. Combined with the experimental results, we can find that the volunteers' route selection in building 2 is more consistent, because the number of escalators in the visible range of the volunteers is different. When there are a large number of escalators within the visible range, volunteers' choices are more scattered, such as building 1; each volunteer has a different strategy for seeking roads. The local characteristics of building 1 and building 2 are shown in Table 2.

Volunteers conducted research on the overall form cognition and local feature cognition of the scene layout. Volunteers' cognitive biases were mainly concentrated on the turning angle of the horizontal channel. The specific data are shown in Table 3.

From Table 3, we can see that there are significant differences in the volunteers' awareness of the atrium content, shape, and size characteristics of the two buildings.

Building 2 is superior to Building 1 in the number of escalators in the atrium. In terms of information, the information of Building 1 is obviously better than that of CapitaLand, in terms of atrium shape recognition, building 1 and building 2 do not show a significant difference, but building 1 has a higher score than building 2.

4.3. Environmental Performance Analysis

4.3.1. Environmental Analysis. In order to verify the impact of building energy consumption on the indoor environment, we have adopted a series of measures such as ventilation and lighting to simulate and analyze the building. The simulated building is in an area where the sunshine is strong and the average temperature is medium and high. Details are set out in Table 4, and the rate of indoor personnel in the room is shown in Figure 7.



(a)



(b)

FIGURE 6: Continued.



(c)

FIGURE 6: Building virtual map. (a) Building 1. (b) Building 2. (c) Virtual simulation scene.

TABLE 1: Virtual data types and their variable contents.

Category	Variable content	Data sources
Personal attributes	Number, age, gender, virtual environment experience	Experimental questionnaire
Path trajectory	Path selection, path length	Coordinate data, process record
Spatial cognition	Overall layout: plane configuration (geometric form, path turning angle) Local features: atrium space (number of escalators, atrium shape, size) Initial entrance (location label)	Cognitive map

TABLE 2: Local characteristics of building 1 and building 2.

Case study	Building 1	Building 2
Ground floor plan		
Standard floor plan		
Overall arrangement	Linear layout There are angle changes in the horizontal channel, with two obvious turning points	Circular layout The horizontal paths intersect at an angle, forming a unequal triangle
Atrium features	Atrium (including escalators): 5 : 3 squares, 2 round/ellipse; squares are arranged along the main passage; round/ellipse is at the turning point	4 atriums (including escalators): all oval 3 are located at the vertices of the triangle and 1 is located on the longer side

TABLE 3: Analysis of the test results of the atrium space awareness under different layout situations.

Atrium features	Building 1 mean	Standard deviation	Building 2 mean	Standard deviation	F value	Significance (P)
Number of escalators	0.52	0.51	0.85	0.37	6.90	0.011
Traits	3.36	0.99	3.15	1.19	0.45	0.506
Dimensional characteristics	3.00	1.29	1.81	0.90	14.79	0.000
Cognitive total score	6.88	1.79	5.81	1.44	5.58	0.022

TABLE 4: Building simulation situation.

Name	Design building model
Building orientation	Zhengnan
Number of indoor personnel	3 people
Air conditioning system COP	Cooling 3.2, heating 1.7
Indoor temperature (°C)	Summer 26, winter 18
Air changes (mechanical ventilation ach)	1
Indoor illumination (lux)	The illuminance of the bedroom, living room, and kitchen is 300, and the rest is 150
Lighting power density (W/m ²)	5
Glare index (DGI)	The bedroom, living room, and kitchen are less than 27, and the rest of the rooms are less than 28

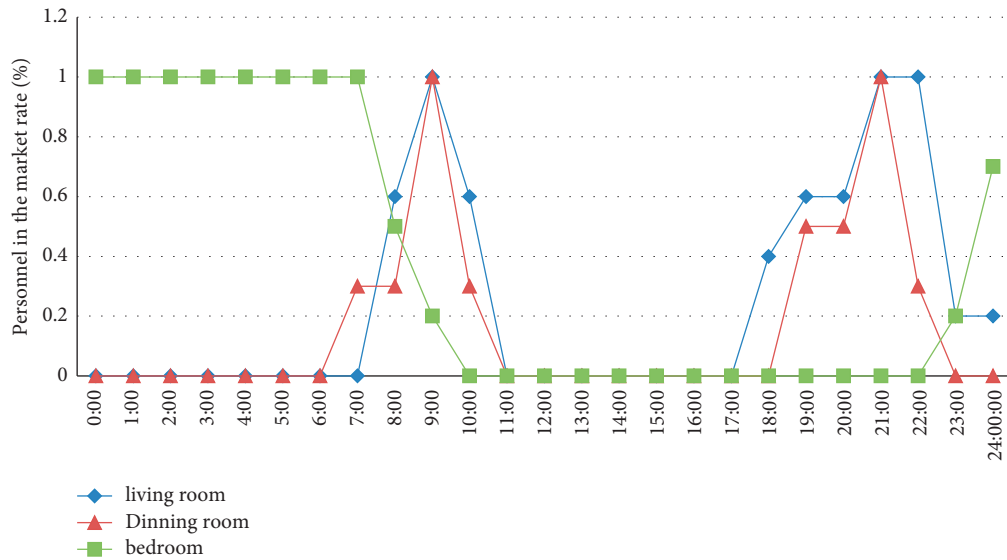


FIGURE 7: Statistic chart of staff in-room rate.

4.3.2. *Experimental Verification.* In order to test the impact of building energy consumption and the built environment, we set up three control groups: normal mode, fixed skin, and variable skin. The normal mode is only the building itself, and the variable skin is the additional skin in addition to the building itself. The building skin will have a certain impact on the indoor thermal environment and building energy consumption. We compared these modes, analyzed the three environmental performances of wind environment, thermal environment, and light environment, and recorded their design elements and related control measures; the specific data are shown in Table 5.

According to Figure 8, we can conclude that compared with the normal mode, the variable skin mode has good ventilation and relatively less energy consumption. It saves

energy to a certain extent and can also highlight its own architectural characteristics.

Thermal environment influencing factors and control measures are shown in Table 6.

To verify the thermal environmental impact and total energy consumption data of the building under three different modes, we adopt three modes of lighting, cooling, and heating to analyze the thermal environmental impact, as shown in Table 7.

From Figure 9, we can see that the total energy consumption of buildings in the cooling mode is the largest. In terms of lighting, fixed skin and variable skin will increase certain energy consumption. The normal mode is the most energy efficient. By comprehensive comparison, variable skin has the highest energy-saving efficiency.

TABLE 5: Wind environment influencing factors and control measures.

Environmental performance	Design phase	Design elements	Control measures
Wind environment	Park planning	Landscape	The dominant wind direction in winter sets trees and shrubs facing the wind
		Site design	The opening direction of the open space faces the dominant summer wind direction
		Longitudinal design	The setting of the sunken square is conducive to controlling the winter wind field
	Architectural design	Layout of the building	Staggered arrangement of dominant winds is seen in winter Ventilation channels are reserved for the dominant wind direction in summer
		Building space layout	The staggered height of the building is conducive to ventilation, and the height difference should be controlled not to be too large to avoid sudden wind
		Architectural form	The sharp corners of the building's facade should be reduced on the windward side in winter and should be replaced with a streamlined design
		Main entrance design	Roundabout design is to be done, to avoid the dominant wind direction in winter
Landscape design	The actual situation of architectural design is combined to optimize the wind environment of landscape design		

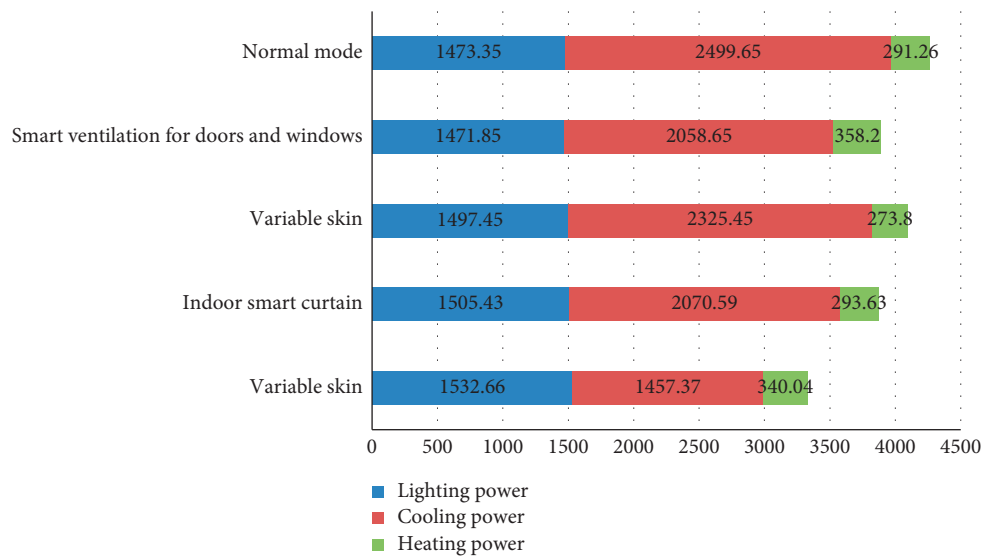


FIGURE 8: Data statistics of different modes.

Factors affecting the light environment and control measures are shown in Table 8.

We introduced natural light and recorded the sunshine in winter and summer at different locations of the building under three different conditions, as shown in Figure 10.

We can see from Figure 10 that compared with the normal mode, the variable skin can effectively reduce the glare time in the room to a certain extent, can reduce the energy consumption caused by architectural lighting, and increase the comfort of natural lighting.

TABLE 6: Thermal environment influencing factors and control measures.

Environmental performance	Influencing factors	Design phase	Design elements	Controlling factor
Thermal environment	Sun radiation	Park planning	Landscape	Increase greening rate Design landscape water bodies Increase shade measures
			Traffic design	Adopt light color series for road laying materials
		Architectural design	Facade design	Control the ratio of windows to walls Take sun protection measures Optimize sunroof settings Optimize building layout
	Urban heat island	Park planning	Layout of the building	In addition to meeting the sunshine requirements, the building spacing should also consider the sunshine requirements of the green space
		Site design	Landscape garden	Buffer isolation zones such as water body, green space, and vertical greening are set up with the surrounding strong heat island environment
	Personnel activities	Park planning	Traffic design	The human-shaped area is far away from the heat dissipation facilities such as the outdoor unit of the air conditioner
Architectural design		Electromechanical design	Cooling towers, outdoor units of air conditioners, and other heat dissipation measures take heat isolation measures	

TABLE 7: Thermal environment energy consumption data table under different modes.

Architecture	Normal mode	Fixed skin	Variable skin
Lighting (kWh)	1473.35	1831.93	1532.66
Refrigeration (kWh)	2499.65	1793.94	1457.37
Heating (kWh)	291.26	541.91	340.04
Total energy consumption analysis (kWh)	4264.26	4167.77	3330.07
Energy-saving efficiency		2.26%	21.91%

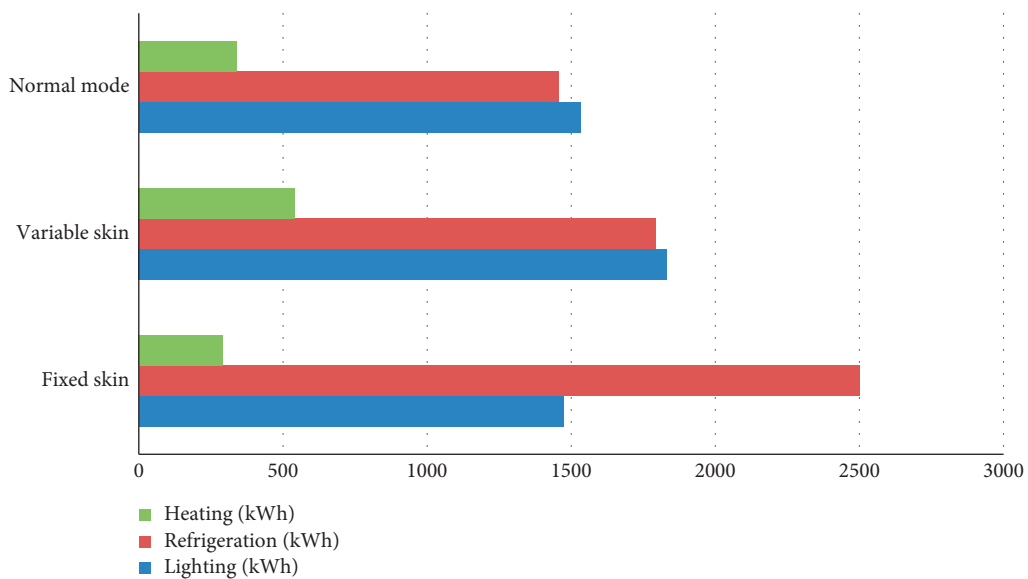


FIGURE 9: Thermal environment impact statistics under different modes.

TABLE 8: Factors affecting the light environment and control measures.

Environmental performance	Design phase	Design elements	Control measures
Light environment	Park planning	Construction layout	Sunshine analysis in the park considers the impact of green space Park sunshine analysis appropriately increases the sunshine duration of outdoor functional spaces
		Longitudinal design	The setting of the square is conducive to the lighting of the underground space
	Architectural design	Graphic design	Control the depth of the room and optimize the architectural pattern Optimize the ratio of windows and walls
		Facade design Curtain wall design	The curtain wall adopts low-reflectivity materials to control glare

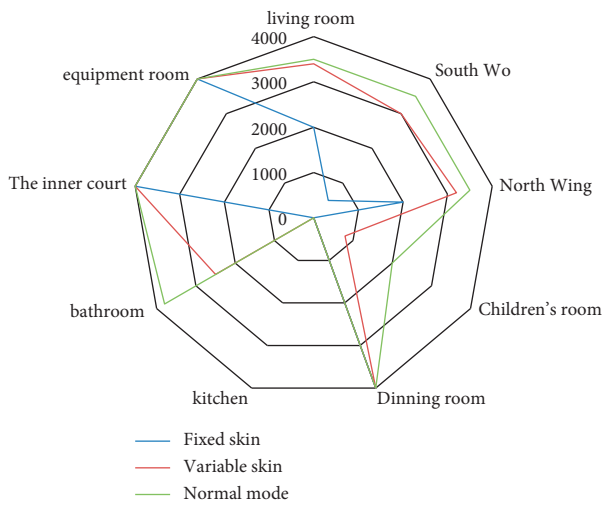


FIGURE 10: The glare exceeds the standard in each room.

5. Conclusion

Starting from virtual reality technology, this paper analyzes the influence of buildings in the environment from the perspective of architectural model. The main conclusions are as follows: (1) This paper introduces two kinds of virtual scene construction technologies: one is to combine the real scene obtained by taking pictures with the virtual scene by image technology, so as to construct a natural virtual scene; the other is that architects draw virtual building models by using geometric modeling methods, thus obtaining virtual building models. (2) This paper chooses two representative buildings as cases and monitors and records the moving track of volunteers in the virtual environment in real time through the virtual platform. Through the experimental results, it can be concluded that the number and shape characteristics of escalators in buildings have a little influence on the cognitive degree of volunteers. (3) This paper sets up three control groups, common mode, fixed skin, and variable skin, analyzes the environmental impact of buildings from three different aspects of wind environment, thermal environment, and light environment, and puts forward relevant control measures.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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