The Application of Computer-Aided Design in the Layout of New Rural Houses

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Abstract. Computer aided design (CAD) is one of the important ways to design an architectural layout. Digitizing furniture, lamps and pavement can quickly help users choose the layout they want. In addition, CAD also helps to enhance the connection between the living environment and the external environment, making the living environment more comfortable and energy-saving. This paper focuses on the application of CAD in China's new rural construction. Firstly, it introduces in detail the process of using computer-aided modeling to help customers choose furniture layout, lighting layout and electrical circuit layout. Then, the application field of CAD in architectural layout design is expanded. Taking the backyard sunshade that customers need to install in reality as an example, the effect of sunshade has been simulated, and the influencing factors were analyzed. In conclusion, the use of CAD can significantly save the time and cost of designers and customers.

Keywords: computer aided design; layout; rural house; environment simulation
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1 INTRODUCTION

Computer aided design (CAD) is very attractive. Due to the excellent data storage and transferability, computing ability and interaction ability of computer, CAD has been widely used in chemical activator design, biomaterial design and additive manufacturing. In addition, for engineers in the field of architecture, CAD of building structure and decoration has become an indispensable technology. Moreover, with the development of network technology, people can get fashionable decoration schemes in time. It is also important to use CAD to turn people's ideas into visual pictures to help owners make decisions.

On the premise of considering the using characteristic, environment and corresponding standards of the building, the layout design creates a living environment with reasonable functions,

comfort, beauty and meets the needs of people's material and spiritual life. At the same time, China's new rural construction is in full swing. As we all know, China has achieved economic take-off and turned 60% of its population into an urban population. After a large number of migrant workers became rich, they are building their own rural homes with great ambitions after returning to their hometowns. At present, the traditional handmade interior design is gradually eliminated by society, and a more scientific and efficient new interior design method emerges as the times require. The layout of the house is not only limited to the arrangement of indoor furniture; more importantly, it is the interaction with the external environment, considering that the living environment actually always exchanges sound, light, electricity, heat, and matter with the external environment. In particular, for the carbon peaking and carbon neutrality proposed by the Chinese government, the characteristics of low energy consumption should also be considered in designing the layout of new rural houses in China.

In this study, the important role of CAD in the process of China's new rural construction has been focused on, including the application of CAD in layout, decoration and material selection. With the application of CAD in interior decoration, people can get visual perception more quickly. and help people make decoration choices. At the same time, a more detailed study of the layout using CAD is also discussed. In particular, it explores the issue of whether parasols are needed for self-built homesteads in rural areas in Changsha, China. The impact of parasol selection on the ground temperature also has been discussed. After we used CAD to help us convince our client, the building became cooler in summer, and more energy-efficient. These methods can be used to explore other arrangements of buildings, including sound and noise suppression, light perception and light pollution reduction, geothermal furnishing methods.

2 LITERATURE REVIEW

There are many computer-aided design software packages, involving two-dimensional and three-dimensional visualization, the representative ones are AutoDesk CAD and 3DMax. Researchers are also developing some small applications. Keshavarzi and Rahmani-Asl [1] developed a visualization platform that could combine with traditional CAD software or other performance estimators. Designers can intuitively combine various floorplanning and evaluation components, define goals and constraints, and receive visual feedback in real-time. Dubey et al. [2] presented a new design tool that supports signage layouts in complex buildings. Aided design can reduce the total walking distance and optimize the number of signs, thereby reducing the cost of installing signs and the total walking time. At the same time, through VR technology, users can have a more intuitive feeling of signage, which is an unparalleled advantage of computer-aided design. Zhou and Camba [3] also pointed out that VR in CAD is a powerful tool that can serve the entire life cycle of immersive experience products. Through CAD, the development process can be optimized, the maintenance efficiency and safety can be improved, and the cost of the whole product life cycle can be shortened. At the same time, artificial intelligence also makes the prospect of computer-aided design broader. Morteza et al. [4] introduced machine learning into architectural layouts, they introduced deep learning into agent-based modeling to automatically generate 2D architectural layouts. Designers have complete control over the process of creating layouts based on specified constraints and geometric features.

However, the computer-aided design building is carried out based on physical objects. First, the materials that exist in reality should be modeled in the computer or related software. It is complicated to make computer automatic modeling, Liu et al. [5] firstly proposed a two-step meme algorithm considering Chinese codes for automatic masonry cell layout in the process of researching the automatic modeling of building blocks. The algorithm could be embedded in the BIM software, allowing the software to automatically model and greatly improve the efficiency. For CAD in construction, the establishment of the database is very important.

CAD can also minimize the influence of human tendencies on architectural design, and users can further optimize according to goals and constraints based on parameter simulation and

visualization. In addition, CAD has also made outstanding contributions in the comprehensive consideration of building energy consumption. The designer studied the energy-saving effect of new phase change materials in buildings with the help of computers. The simulation results show that in summer, compared with cement mortar, paraffin/EVC-D FSCPCM composite mortar saves 17.03% of energy consumption. Phase change materials enhanced mortar reduces the maximum temperature in testing room by 3.1 degree Celsius when using phase change material to replace 70% of the sand. Moreover, the content and distribution characteristics of phase change materials can also be designed with the help of CAD. Sher et al. [6] used Autodesk Ecotect Analysis software to calculate the energy demand of buildings under the influence of daylight factors, and demonstrated that buildings with atriums are more energy efficient. By introducing daylight, 15.7% of total energy consumption can be saved annually. The research of Deng et al. [7] pointed out that 34% of building energy consumption is attributed to residential heating, and the residential pattern is a key factor affecting heating energy consumption. In their research, Ecotect and htb2 are used to model and calculate the impact of different layouts on energy consumption. The results show that the heating energy consumption of the courtyard layout is lower than that of row and staggered layout, and the appropriate floor spacing can increase the daylighting of buildings and reduce the heating energy consumption.

At the same time, CAD also plays an important role in the selection of building materials. Jiao and Tang [8] creatively used bamboo as a raw material to design buildings in a graduate architectural design class. In China, the use of bamboo as the main raw material for construction, furniture and agricultural tools has a very long history, and the work of the two researchers using bamboo as a modern building material is an important breakthrough. In this process, the digital 3D model of the building created by CAD made the software simulation and physical model promote each other. Moreover, the non-destructive 3D scanning and modeling workflow developed by Lorenzo and Mimendi [9] could accurately capture and process relevant digital information describing the geometric properties of bamboo poles. The efficient digitization of bamboo poles and their integration with modern platforms can provide the construction industry with the necessary support to design, build and maintain high-quality structures. In addition to using computer-aided in the architectural design process, Jaina and Pathak [10] also redesigned the thermal insulation layer of an existing residential building with the help of CAD and finite element analysis. The results show that the use of solar reflective coating on the roof and wall can reduce 25% of the heat in the house.

3 APPLICATION OF CAD IN INTERIOR LAYOUT

During the interior design process of the new rural house, the designer has explored a complete set of technical routes. As shown in Figure 1, we first summarize the common design layouts on the market, and extract the furniture design, lighting design, circuit design, sewer design and pavement design in these housing layouts. After classification, the relevant images are established in the software and summarized into the corresponding databases. In general, customers will provide their own room size, as shown in Figure 2 (a). The designer imports the precise house layout into the design software, and quickly forms the distribution map of the main furniture. In this process, the bed, sofa, table, wardrobe and toilet should be considered first, as shown in Figure 2(b). After designing the main furniture, the daylighting of the building shall be considered, and chandeliers shall be preferentially arranged in the lobby, living room and dining room, followed by other lights. Then, the layout of the electrical circuit is automatically generated according to the software. Through the scene simulation layout, the abstract design ideas can be displayed intuitively by using 2D drawing software; then the model is established through 3D software. Finally, use editing tools to beautify, repair and render images and graphics in the later stage, and you will get a more complete interior design work. This is followed by final optimization with the client, based on the client's preferences and constraints.

Figure 3 shows the two-dimensional graphic design drawing and the three-dimensional visual sensory map. In this process, the designer often needs to call the existing image and physical

comparison library. However, with the development of the Internet, designers can upload design drawings to the cloud to generate three-dimensional layout drawings with the help of free visualization software. With the help of the three-dimensional layout, the designer can complete the optimization of the top, wall and bottom surfaces of the room. In addition, designers can recommend their own pavement materials during this process. Such a house layout process greatly improves the efficiency of designers. In our company, 90% of house designs can be completed within 30 minutes, which greatly accelerates the construction and decoration of urban and rural houses. According to our survey, 85% of customers like this design method, and the generated 3D view map can also be spread on the communication software, which greatly promotes communication between designers.

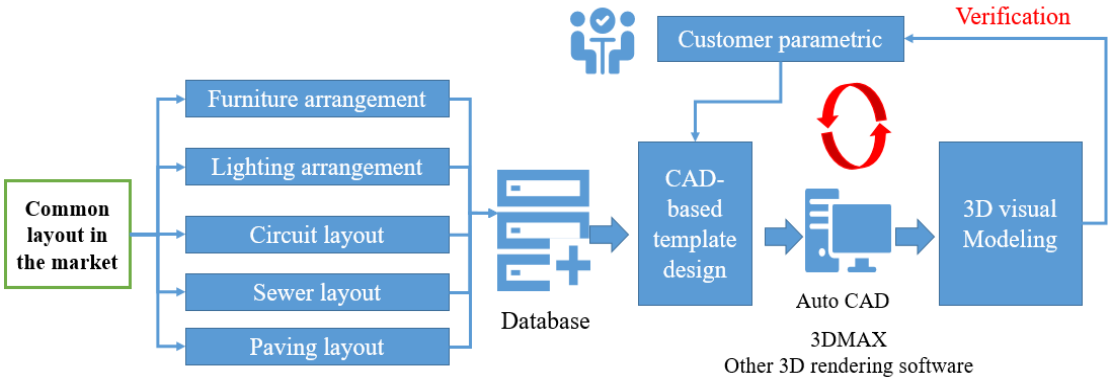
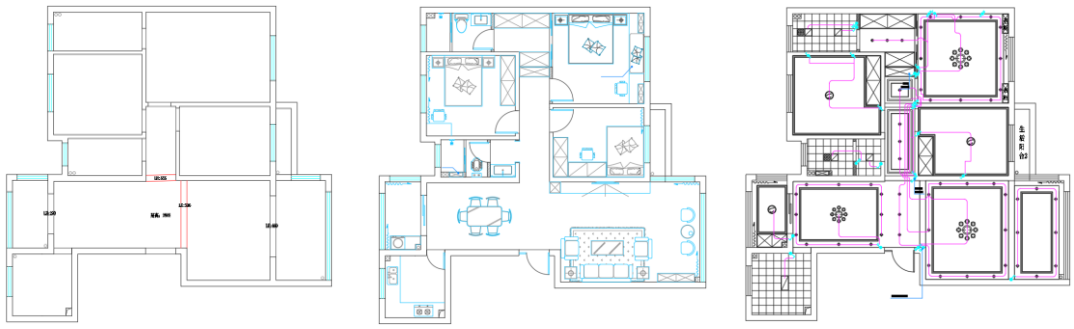


Figure 1: Technical route of CAD-based interior design.



(a) (b) (c)

Figure 2: Application example of computer aided design of interior layout: (a) housing drawings provided by clients; (b) the layout of indoor furniture; (c) arrangement of indoor electrical appliances and wires.

4 APPLICATION OF CAD IN IMPROVING LIVING ENVIRONMENT LAYOUT

The design of the house layout is not isolated, and the influence of the external environment needs to be fully considered. In addition to the macro interior design, in the process of designing the house layout for rural residents, we often encounter the problem of whether to need a sunshade. When the direct sunlight enters the courtyard in hot summer, the temperature of the courtyard can become extremely high. In particular, new houses in rural areas often like to use concrete as raw materials for courtyards. Designers actually measured that the ground temperature of the

backyard in summer was close to 65 ℃. Excessive temperature not only affects the use of the backyard, long-term exposure to high temperature and sunlight can also easily lead to concrete cracking, which could affect the use and even safety of the structure. The price of a parasol is indeed not expensive, but as a designer, we should show convincing evidence to convince customers that it is necessary to install sunshades.

(a) (b)

Figure 3: Floor plan and 3D rendering picture of the parlor: (a) floor plan of the designed parlor; (b) 3D rendering picture of the parlor.

The designer analyzed this situation through COMSOL Multiphysics software, and examined the differences in temperature rise between the ground covered by the parasol and the ground without the shade of the parasol. The courtyard mentioned in the article is the backyard of a farmer's house. The house faces south and is located in the south of Changsha City, Hunan Province, China. Among the relevant parameters of the sun, the designer selected the summer sunshine in Changsha as the research object. The annual average solar irradiance is 1361W / m^2. As shown in Figure 4, a backyard with a length and width of 10 meters was constructed. Considering the foundation gravel, the thickness of the concrete paving surface reached 0.5 meters. The parasol was placed in the northwest corner of the courtyard, and the radius of the umbrella was 1.5 meters. After the 3D model is established, the mesh is divided for finite element calculation. The material parameters involved in the study are shown in Table 1. The designers chose such materials as acrylic panels and PVC, which were common in the market. Some villagers especially love wood materials for sunshade roofs. When looking for the density, thermal conductivity and heat capacity of these materials, the designers input them into the simulation software.

Types	Density (kg/m3)	Thermal Conductivity (W/(m·K))	Heat capacity (J/(kg·K))
Concrete	2300	1.8	880
Acrylic plastic	1190	0.18	1470
Wood	532	0.11	2700
Polyvinyl chloride	1760	0.1	1.05

Table 1: Parameters of various materials.

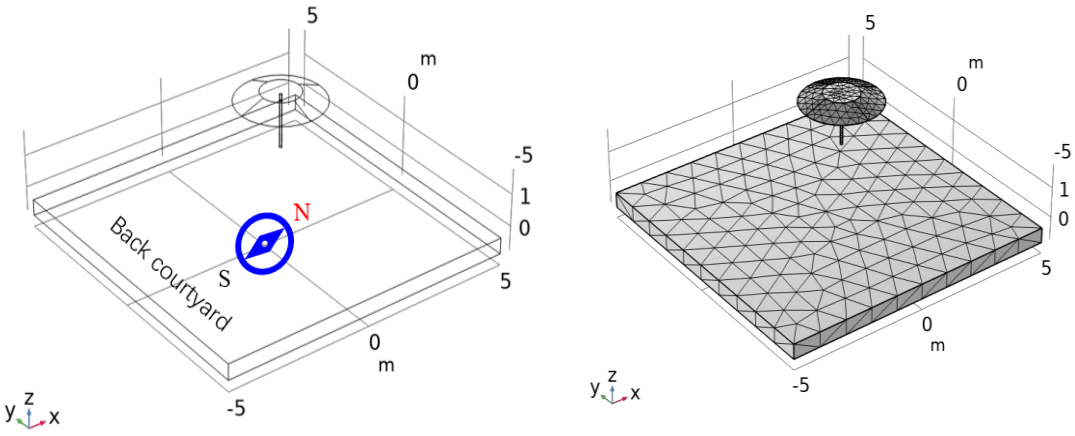


Figure 4: Model building and meshing: (a) 3D modeling of backyard; (b) meshing of the model.

4.1 The Mitigation Effect of Parasols on Courtyard Temperature

Firstly, the designer confirmed the efficacy of the parasol through computer assistance. As shown in Figure 5, at 11:00 in the morning in summer, there has been a significant temperature difference in the courtyard. The maximum temperature of the concrete surface could reach about 51 °C, while the temperature of the foundation is between 16 and 25 °C. The results showed that the direct sunlight in summer could quickly increase the temperature of the courtyard, especially for the building material with a high absorption rate, such as concrete. In addition, the large temperature difference between the surface and of the base also increased the risk of cracking.

Under the shade of the sun umbrella, the temperature under the umbrella was only about 25℃. Obviously, the sunshade could greatly reduce the temperature of the courtyard. With the extension of sunshine time, the temperature in the courtyard rises more dramatically. Without shelter, the temperature of other concrete parts of the courtyard reached about 60°C, while the temperature under the umbrella was only 30°C. The temperature changes of unshaded concrete, concrete under the umbrella and the surface of the umbrella over time are shown in Figure 6. Under the irradiation of sunlight, the temperature of the unshaded concrete could rise rapidly, reaching about 50°C at noon; and the temperature in the courtyard could reach its peak at about 3:00 p.m. Under the condition of the shade of a parasol, the temperature of the ground was always around 30 ℃. The layout of the parasols in the courtyard could also be accurately arranged through computer assistance. When the sun temperature was at its highest at 14:00, the shadows of the parasols gathered in the northeast direction. Thus, umbrellas should be placed in the southwest corner of the courtyard to maximize the shaded area. The client was quick to accept the opinion after observing the 3D analysis results.

4.2 Selection of decoration materials with the help of CAD

In the process of designing the courtyard sunshade, the designer made a more detailed study on the material of the sunshade. As shown in Figure 7, the parasols made of wood and PVA have better effects, mainly because wood and PVA have lower thermal conductivity. In addition, with the greater heat capacity of wood, the heating rate of the umbrella surface was slower than that of the acrylic surface. The maximum temperature of the wooden umbrella surface was about 1°C lower than the temperature of the acrylic umbrella. Under the shading of PVA parasols, the temperature of the ground dropped by 1 degree Celsius at most.

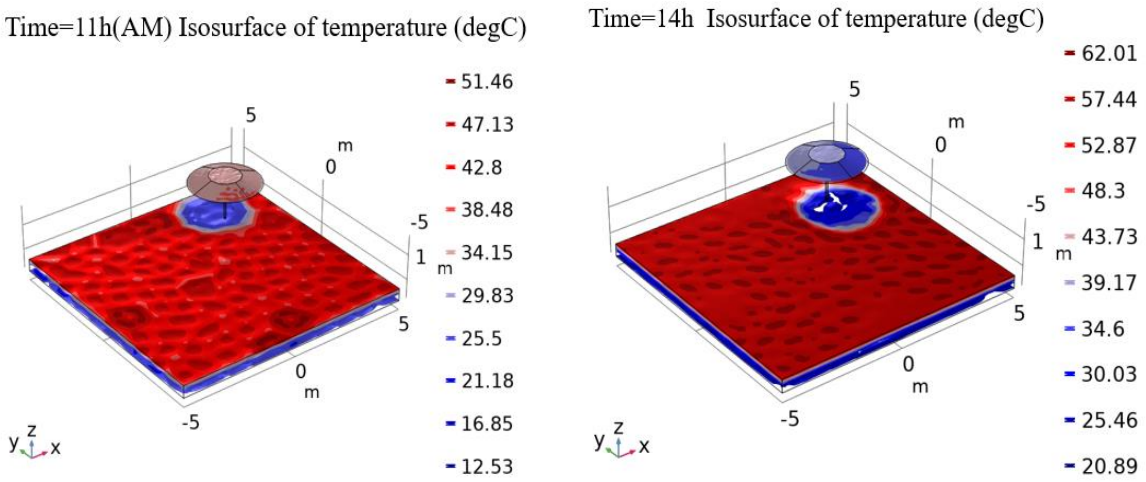


Figure 5: Computer-aided simulation of the temperature distribution in the backyard: (a) the distribution of isothermal surfaces at 11:00 am; (b) the distribution of isothermal surfaces at 14:00.

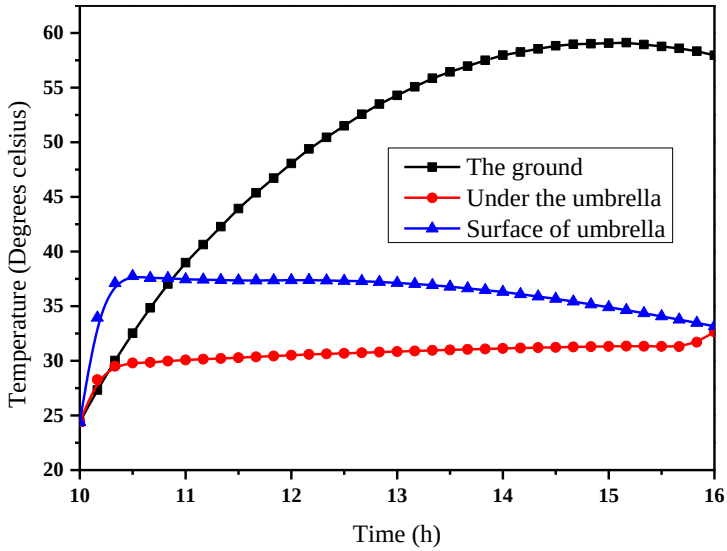


Figure 6: the changes of temperature at different positions under sunlight.

However, without changing the surface reflectivity, the effect of changing the material alone is very limited. The designer finally chose to paint white paint on the surface of the parasol to increase the reflection of sun radiation. After installing the parasol, the final temperature under the umbrella was 27 degrees Celsius, and the cooling effect of the reflective paint coating has also been reported in other studies.

When designers were investigating the material of parasols, many researchers recommended phase change materials. When investigating whether phase change materials were needed, we tried to simplify our experiments with computer assistance.

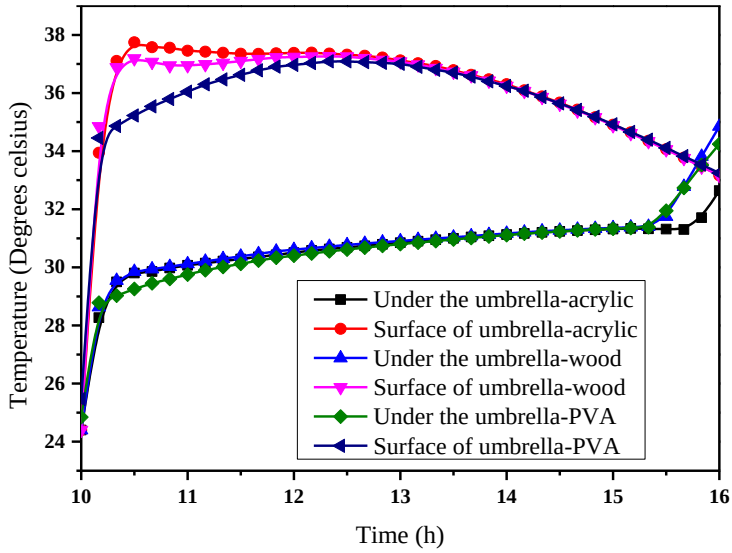


Figure 7: Effects of different materials of umbrellas on the temperature under the umbrellas.

When the phase change material was assembled in the PVC parasols, its specific heat capacity was about 1200 J/kg·K. The results are shown in Figure 8. It could be found that the temperature under the parasol and the surface of parasol indeed reduced by about 1 °C initially after the phase change material was assembled. However, after receiving solar radiation for 2 hours, the sunshade containing the phase change material would have greater heat radiation, and the temperature under the sunshade will increase significantly. The temperature under the umbrella with phase change material was higher than that of the ordinary umbrella throughout noon and afternoon. Since phase change materials had the ability to absorb and store heat, the stored heat was continuously released into the courtyard, increasing the radiation in the environment after sunset. Phase change materials can be used as wall materials to reduce the energy consumption of buildings, but they are not ideal raw materials for sunshades.

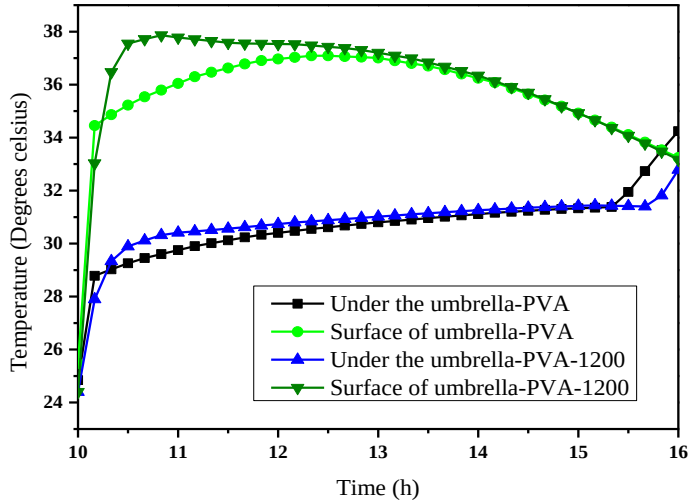


Figure 8. Effect of phase change material on temperature under umbrella.

5 CONCLUSION

With the development of China's new rural construction, more and more urban residents and farmers need to rebuild their homes, and designers face greater challenges. With the help of computer-aided design to help designers complete the indoor and outdoor layout, it can greatly reduce the workload of designers and improve work efficiency. In addition, with the help of CAD, the designer's thinking can be more completely communicated to customers visually. When customers watch the design, they can not only update the emission of furniture and the choice of paving in real-time, but also share it with relatives and friends in time to convey the joy of building a new home; this kind of enjoyment cannot be given by traditional design. In addition, the analysis of design details with the help of simulation analysis software will undoubtedly help designers make better decisions and come up with better layout schemes in the process of considering the sound, light, electricity and heat exchange between the living environment and the outside world.

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