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Computer-Aided Design AND APPLICATIONS

Optimization Design of Indoor Space Layout Driven by Big Data of User Behaviour

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Abstract. With the development of modern society and cities, people have higher and higher requirements for living environment and working environments, which further promotes continuous research in the field of interior design. Among the existing design elements, the use and planning of interior space layout are the main factors that affect human behaviour and quality of life. Most of the previous studies focused on the building structure's physical function and functional efficiency and paid little attention to the related content of spatial layout planning. With the help of big data-driven and computer-aided CAD technology, this paper analyzes user behaviour. Explore the relationship between user behaviour and interior space layout, and study the automatic generation and optimization of interior space layout. Firstly, from multiple perspectives, this paper analyzes the types and characteristics of interior space layouts and their influence on human activities. In view of the difference in the characteristics of users' individual needs, big data is used to drive the processing of high-dimensional and non-linear complex features, and the user demand response behaviour model is built to correlate the changes in user behaviour with the impact of spatial layout. On this basis, automatic spatial planning is designed by using data fusion rules. Finally, the application of CAD computer-aided technology in interior design and interior space layout is analyzed. According to the CAD layout drawing strategy, a computer-aided optimization spatial automatic layout drawing system is established. According to the intelligent evolution algorithm, the model after automatic layout optimization is displayed in three dimensions. The results show that big data-driven and computer-aided technologies can analyze user behaviour and correlate it with indoor space layout. The needs and tendencies of occupants are included in the automatic generation of space layout design schemes, which improves the rationality of space layout.

Keywords: User Behaviour; Big Data-Driven; Interior Space; Spatial Layout; CAD
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1 INTRODUCTION

Interior space design is not only about the decoration, color, material, and other contents but also about the historical culture, humanistic feelings, spiritual connotation, spatial layout, and other aspects of analysis [1]. In short, interior design is not limited to technology and art but extends to the visual feeling of space. The rationality of indoor space function can affect the emotional experience of occupants [2]. Functional areas need coordination, unity, complete transition, and integration and cannot give users an abrupt feeling. The public area is generally divided into restaurants, reception areas, leisure areas, etc., so it should provide space partition as much as possible to separate it from other functional areas. The reception area should be simple, and the light should be bright and can achieve a warm and friendly feeling [3]. The leisure area is relatively quiet, and the area does not have to be too large, but it should give people a comfortable and elegant experience. There is no obvious distinction in the separation of major spatial functions. The partition of space layout is used to visually give people the feeling of having been divided [4]. In addition, the design of interior colour and light can also affect the spatial layout to a certain extent, and the planning of colour and lighting is an important means to reflect the aesthetic personality of designers [5]. Too much colour will make the space appear messy, and the functional area during the day should be dominated by natural lighting, natural light is introduced into the room, and artificial lighting is mainly used at night. It can be seen that the interior space layout must be combined with many factors such as light, colour and decoration [6].

The type of interior space layout is multiple and diverse and can be customized according to the functional needs and the personality of the user. Generally speaking, the layout can be divided into the following categories; the first is the open space layout, which emphasizes the continuity and mobility of the space and integrates multiple areas. For example, modern open-plan dining rooms and living rooms can increase the sense of space and improve interaction, making them suitable for residents who like to socialize [7]. The second type is the closed layout, which pays more attention to the isolation of areas, and each space has clear boundaries and functions, such as the traditional living room and bedroom, which can not only protect privacy and provide a quiet environment but also provide rest for people who need an independent space [8]. Finally, the hybrid layout, which combines the characteristics of open and closed-space planning, can be flexibly used in the required scenes. Each interior space layout design has its own unique characteristics, and the shape and size of the layout usually affect the functionality as well as the overall visual feeling of the space. Designers can create different visual effects through different layout plans, reflecting the designer's own lifestyle and personality but also reflecting the occupants' needs for modern interior space. To sum up, we find that when planning indoor space layout, it is necessary to take into account the concept of being people-oriented, combine user behaviour and psychological tendency, and consider user habits. The layout of the space should serve people, not violate the normal way of using it. Young people like open and flowing space layouts, while more groups who need private space choose closed layouts [9]. The interior space layout design has brought technical and data processing tests. In our research, we use big data-driven analysis and computer-aided CAD systems to optimize spatial layout. The design scheme is automatically generated by combining the changes in user behaviour generated by different spatial layouts.

With the increasing complexity of indoor space performance simulation, especially when it involves large-scale data analysis and a deep understanding of user behaviour, exploring the impact of new technologies on the design process and results has become particularly important. These data are collected through various channels such as sensors, IoT technology, and social media feedback, providing unprecedented insights for optimizing indoor space layout design. Driven by user behaviour big data, the design process will place greater emphasis on the actual efficiency of space utilization and user experience. Therefore, in computer-aided optimization design that combines user behaviour and big data, the best balance between automation and humanization should be sought. Integrating these big data into computer-aided design (CAD) tools can achieve more accurate and personalized spatial planning. User behaviour big data, as an emerging resource in the field of modern design, contains rich information such as people's movement patterns, stay preferences, interaction habits, etc. in indoor spaces. The performance-driven environment is not limited to traditional structural and energy indicators but also encompasses multidimensional goals such as space utilization, comfort, and traffic efficiency. By providing suggestions through intelligent algorithms and giving designers the final decision-making power, we ensure that the design scheme meets performance requirements while also being full of creativity and humanistic care. Research can invite more diverse participants (such as architects, interior designers, end-users, etc.) to use CAD platforms that integrate big data analysis functions to obtain and respond to user behaviour data feedback in real-time, and dynamically adjust design schemes. At the same time, designers can maintain higher design flexibility based on real-time feedback, quickly adjust plans according to subtle changes in user behaviour patterns, and achieve more user-friendly design results. In this context, the concept of computer-aided optimization design for indoor space layout is driven by user behaviour big data. On the basis of existing research, we can design an extended study that not only focuses on the overall structure and energy performance of buildings but also delves into how user behaviour big data affects the optimization of indoor spatial layout. The study also found that although automated optimization methods have significant advantages in efficiency, designers often value creativity and flexibility in the design process more.

2 CURRENT SITUATION OF DATA-DRIVEN AND COMPUTER-AIDED TECHNOLOGY

In the context of the digitalization of information resources, various application scenarios are built around users, and interior design and related markets are expanded around user needs. Mourtzis et al. [10] have found that innovative digital resources centred on users and guided by social practice have become a breakthrough for high-quality development in various industries. The concept and operational capabilities of big data have been increasingly recognized in various fields, and interpreting the meaning behind data has become an important component of data analysis systems. Industrial big data helps the telecommunications and financial industries provide commercial services, effectively protecting the reliability of user behaviour and information. With the advent of the big data era, data and users are shaping each other. On the one hand, users are always carving production data, and more and more researchers are starting to analyze user behavior and preferences quantitatively; On the other hand, from the perspective of optimizing service levels and feasibility, collecting and analyzing data can be used with the help of science to complete design and planning. The concept of data-driven is also a core competitive advantage for academia and industry to leverage user trends and behavioural changes. His focus is on improving the accuracy of data analysis and driving models. Parekh [11] Neglects the role of the audience in data prediction and only considers the impact of data behaviour on quantitative analysis. In the subsequent data-driven optimization, the application of big data technology is becoming increasingly widespread. Some fields that are highly dependent on customers, such as interior design and finance, have increased profits with this help.

Computer-aided CAD technology is based on computer technology and electronic engineering, and its functions are very comprehensive, involving design drawings, engineering data management, drawing, simulation experiments, modelling calculations, and analysis. In recent years, CAD technology has achieved tremendous application results in industries such as clothing, chemical, construction, electronics, automotive, and machinery. CAD technology is the combination of human intelligence and computer systems. In the field of mechanical design, it is a comprehensive, high-tech, efficient, and high-quality advantage. In addition to assisting in the completion of blueprint design, it can also optimize parameters. Vyas et al. [12] applied CAD computer-aided systems in the generation of mechanical drawings, which can not only complete drawing and modification but also convert 2D images into 3D views, effectively reducing unnecessary manual input. In the past decade of development, computer-aided interactive graphics systems have proposed many ideas such as hierarchical storage for computing graphics.

The configuration of CAD technology has also been comprehensively improved. The UK and other countries have already used CAD computer-aided systems to present product visual design concepts. CAD systems are only used as tools for designing and applying model drawings, without adjusting the interior of the design space. This not only preserves the designer's thinking but also conforms to practical application situations. Wang et al. [13] used it in a single stage to improve the scene effect generated by drawing. In addition, the advantage of CAD computer-aided technology lies in integration. In terms of information integration, parameter information can be adjusted according to changes in quantity. As long as the provided data is within the standard range, the design scheme can be parameterized and standardized during the modelling process, thereby improving the design quality. It can be seen that big data-driven and computer-aided technologies each have advantages in data processing and graphic design.

In the case study of residential floor planning tasks, Xin and Daping [14] not only focused on the system's ability to find known optimal solutions but also delved into how the system can combine user behaviour big data to generate diverse floor plans that meet practical usage needs. The proposed O-Tree and B * - Tree spatial layout representation methods show great potential in improving the efficiency and flexibility of layout algorithms. Dynamo, as a visual programming tool, provides powerful platform support for the implementation of GenFloor. Yang [15] can evaluate the adaptability and robustness of the system in different scenarios by comparing layout schemes under different user behaviour patterns. This enables designers to intuitively see how user behaviour data affects layout design and adjust design parameters in real time to optimize spatial performance. In addition, the platform can also support interactive feedback loops between designers and users, promoting continuous optimization of design solutions. Meanwhile, observing how the system automatically adjusts the layout based on small changes in user behaviour data can provide valuable practical experience and a theoretical basis for future intelligent indoor space layout design. When integrated with user behaviour big data, these representation methods can be further developed to capture dynamic changes in spatial usage in more detail. After integrating user behaviour big data, customized GUI interfaces and evaluation functions can be further developed on the Dynamo platform. Zhou [16] adjusted the branch weights or node attributes of the tree structure to dynamically respond to the behavioural differences of different user groups and generate layout solutions that better meet personalized needs.

3 RESEARCH ON INTERIOR SPACE LAYOUT DESIGN BASED ON USER BEHAVIOUR BIG DATA-DRIVEN ANALYSIS AND COMPUTER-AIDED OPTIMIZATION

3.1 Research on the Influence of Big Data-driven User Behaviour Analysis on Spatial Layout

Indoor space layout has a profound impact on the activity behaviour of residents, and the change in users' behaviour also restricts the design of indoor space layouts. The way space is organized and functionally divided can bring different visual feelings. First of all, space can affect the movement behaviour of occupants. The open layout itself has continuity and mobility, which makes people's activities in the space freer. The enclosed space has a clear sense of boundary, which can make people more regular in their behaviour in space. In addition, the planning of moving paths in spatial layout design can also have an impact on human behaviour. Multi-functional areas encourage residents to develop a wider variety of activities. For example, if a space is suitable for reading, then people will be more inclined to read in that area. On the contrary, if the space is arranged more socially, then people will use this area for daily interactions. On the one hand, spatial layout can determine not only the attributes of social activities but also the way of social activities. Most of the spaces are designed to be continuous and inclusive, encouraging more activity and allowing people to gather for discussion and interaction. On the contrary, if the sense of boundary and functional limitations in the space is greater, it is more suitable for private social activities.

In this study, big data is used to drive the analysis of user behavior and explore the impact of user behavior on spatial layout so as to combine the two and optimize the spatial layout design. In data-driven, the user's interactive behavior is characterized by analyzing and modeling the user's elasticity. The individual behavior tendency and spatial layout needs are analyzed in a condition that does not involve the user's personal privacy. We divide the space layout into three types: openness, privacy, and hybrid. The data-driven mining function is used to analyze the individual tendency of user groups towards these three spatial layouts, as shown in Table 1.

Group	*Open*	*Privacy*	*Mixed*
User 1	65%	23%	56%
User 1	77%	12%	66%
User 1	85%	32%	72%
User 1	68%	19%	87%
User 1	63%	12%	78%
User 1	71%	34%	69%
User 1	88%	28%	87%
User 1	79%	12%	59%
User 1	95%	11%	73%

Table 1: Individual preferences of user groups towards these three spatial layouts.

As can be seen from Table 1, different group characteristics were selected in the survey to improve the reliability of statistical results. Among the individual tendencies of the three spatial layouts, most people tend to be more open, mixed, and less private. The method of using the data graph is expressed in detail below.

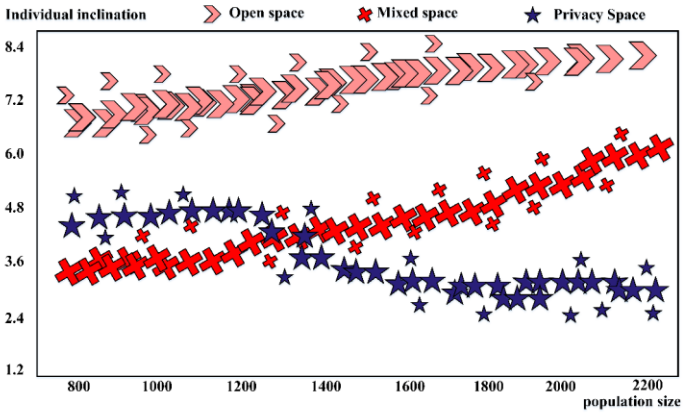

Figure 1: The tendency of groups towards three spatial layouts.

As can be seen from Figure 1, with the increase in the number of survey groups, the individual tendency of open space layout has remained at a high level. The individual tendency of mixed spatial layout increased gradually from a slow degree. The spatial layout of privacy is reduced to a certain extent. This also shows that the majority of user behaviours show preferences for different indoor space layouts under the statistics of data-driven analysis. In the complex environment of data management and data integration, human bias and behaviour prediction will inevitably face the problems of data missing and abnormal. The core content of data-driven is also to ensure the accuracy of data calculation, so in the early collection of user behaviour, the sensor data needs to be converted into a data set that the computer can store. We will subdivide the model architecture based on the user behaviours required for indoor space layout, as shown in Figure 2.

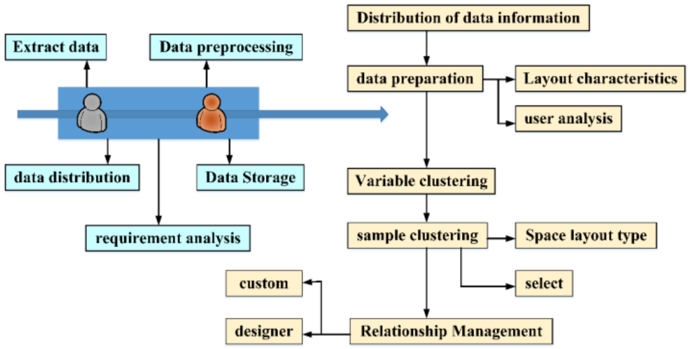

Figure 2: User behaviour segmentation model architecture.

As can be seen from FIG. 2, feature extraction, data pre-processing and demand analysis for different users are first carried out to explore the relationship between data drive, and data preparation and variable clustering are added according to the distribution of data information. In the sample clustering, the spatial layout type is selected, and the relationship network between the designer and client is established. In the subdivision model architecture of user behaviour, designers can analyze the functional requirements of each user for space according to the network of relationships. The realization process of training data needs to use a covariance matrix for calculation:

$$Cov = \frac{1}{m}\sum_{i=1}^{m} x(i)x(t) \tag{1}$$

$$[U,S] = svd(Cov) \tag{2}$$

Singular value decomposition is performed on the covariance matrix, and the decomposition sequence is as follows:

$$U = re[1:r](x \bullet y)^2 \tag{3}$$

Among them U represents the value of a singular vector matrix. Variable clustering is the most common task in data-driven. We define the maximum likelihood estimation function:

$$J(x)_i = \min \| x - c \|, n = 1,...,k \tag{4}$$

$$p = \frac{J(x)_i}{\sum_{i=1}^{m} j(o)} \tag{5}$$

Among them $J(x)_i$ representing multiple cluster centres, the initial cluster centres are randomly selected to be added to the design parameter adjustment. The association between the generated user behaviour data-driven auxiliary model and the interior space layout is combined. The structure of the combined data-driven behaviour analysis model is shown in Figure 3.

It can be seen from Figure 3 that in the data-driven behaviour analysis model, users select the spatial function of the design requirements and complete the individual preference filling in various spatial types. Example graphs of various spatial types are shown in the model. Through spatial environment variables and cost prices, complete big data-driven demand analysis and analyze the results for data training so as to establish a deep learning network for user behavior. We also add users' individual characteristics and emotional changes into the behaviour network to improve the accuracy of user behaviour prediction. Through data training and analysis, the model established a deep learning network for user behavior. This network can automatically learn the complex relationship between user behavior patterns and spatial requirements, thereby achieving accurate prediction of user future behavior.

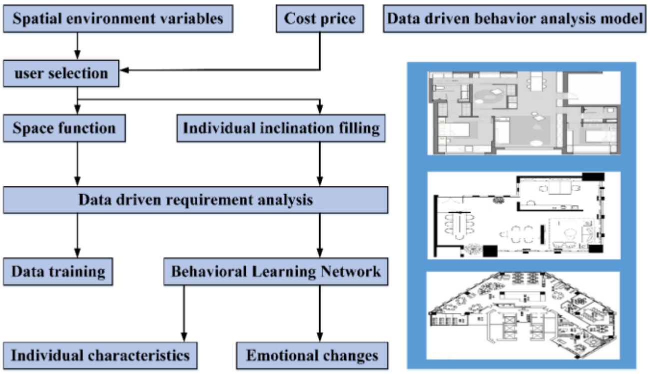

Figure 3: Structure of data-driven behavior analysis model.

With the continuous accumulation of data and the continuous optimization of models, the accuracy of predictions will continue to improve, providing users with a more intimate and personalized design experience. Of particular note is that the model innovatively incorporates users' personal characteristics and emotional changes into the behavioral network. This measure fully considers the complexity and variability of people, making the design process more closely aligned with users' real needs and psychological states. For example, users' personal characteristics, such as age, gender, and occupation, can affect their preferences for spatial functionality. And emotional changes may lead to immediate adjustments in the demand for spatial atmosphere. By monitoring and analyzing these variables in real time, the model can dynamically adjust the design plan to ensure that the design results are always synchronized with the needs and emotions of users.

3.2 Interior Space Layout Design and Three-Dimensional Display Research Based on Computer-Aided Optimization

The interior space design needs to focus on simplicity in function; one is to ensure the normal rest of the occupants, and the other is that the rich level can also meet the development of various activities. Designers need to do this in the completion of spatial layout optimization is actually not difficult, but to achieve excellence, unique characteristics need to use computer-aided software to generate more intelligent design drawings. When we analyze the interior space layout, according to the particularity of the space layout function, the master bedroom design needs to pay attention to the unification of the bedroom and the outdoors, as well as the application of simple and clear space planning. For the layout of public areas, it is necessary to pay attention to the compound of functions, combined with the connection with other functional areas, to play a perfect transition effect. In addition, designers also need to make use of diverse geometric shapes. The line rhythm and rhythm of the space layout are fully displayed, and the three-dimensional application techniques are used to create a sense of space. CAD drawing software has two drawing methods, model and layout; designers in the long-term project construction process will form their own drawing style; everyone's habits and hobbies are different. No matter which method is used to draw, the main criterion is fast and accurate. Both layout space and model are carriers of drawing elements. In order to explore the application environment of CAD computer-aided technology in spatial layout, we analyzed the application times of CAD, 3DMAX, and BIM modeling software. In our research, we established a new layout in order to show the interior space layout design model generated by CAD model in a three-dimensional way. According to the three-dimensional simulation imaging system, the space regions are divided by different colour features. The overall structure of the CAD three-dimensional simulation spatial layout system is shown in Figure 4:

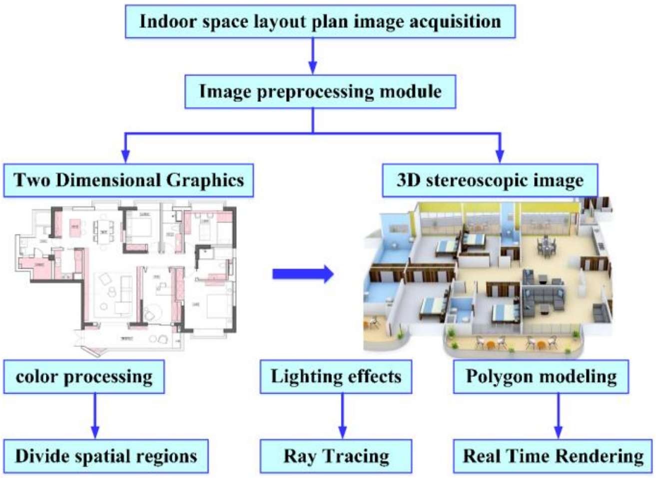

Figure 4: The overall structure of CAD three-dimensional simulation spatial layout system.

As can be seen from Figure 4, the interior space layout must first complete the plane image acquisition, and transform the two-dimensional image into the three-dimensional image after image preprocessing. Then the color analysis is carried out to divide the space area and add light and shadow effects. Calculate the content of wall lighting, ray tracing, polygon modelling, etc., and output the 3D model after real-time rendering. The generated CAD computer-aided optimization design system can determine the input and output devices in software. According to the actual space size, the three-dimensional space in the system is set to ensure that the final solution can be displayed in a 1:1 ratio. At the same time, in the window layout, a CAD computer-aided optimization system can also enlarge details, hide display layers, rotate, typesetting, splicing and other functions. Create multiple Windows in the same drawing, independent of each other, and automatically modify parameters in each view. This special marking method and window type can ensure that the interior space layout can be automatically generated. Before using CAD computer-aided optimization design, we added the user behaviour data of data-driven analysis, and expressed the mathematical relationship among users, designers and spatial layout as follows:

$$Z_K = a(w_z[c_{k-1}, x]) \tag{6}$$

The formula w_z represents the weight coefficient between the three. According to the activation function and linear function, the output calculation formula is expressed as follows:

$$h_k = (1 - z_k)h_{k+1} + z \bullet h \tag{7}$$

The planar image of an interior space layout in a CAD system needs to go through several calculation modules, such as acquisition and preprocessing, respectively. Therefore, after the acquisition and processing, we also need to adjust the resolution of the relevant information, complete the stitching with other modules, and finally transmit it to the three-dimensional simulation imaging. In the process of 3D simulation imaging, it is necessary to complete the processing of the visual features of the spatial layout display, and analyze the relevant color information, coordinate information, lighting, and other contents. Data features with high resolution, integration and sensitivity are divided into spatial markers by dynamic sensing, and real-time Mosaic processes dynamic images. The main function of the interior space layout collection information is to clarify the differences between the layout area and the CAD assist system. We calculate the light and shadow effects of indoor objects:

$$p = \delta[Y, E]_{x+g} \tag{8}$$

In the light and shadow changes, the correlation between the sensor and the space mirror is as follows:

$$r = a_t(w,h) + pf(x) \tag{9}$$

In the formula w h they represent the matching coefficient and the space coordinate. Explore the correlation between plane images and spatial layout 3D images:

$$h_2 = Qh + r(t) \tag{10}$$

Introduce light and shadow formula into correlation calculation:

$$p = \delta \begin{bmatrix} j(\| Qh_2 + t \| \\ d(\| Qh_2 + r \| \end{bmatrix} \tag{11}$$

Since there is still a certain gap between the actual situation of spatial layout and the 3D model design, in order to improve the accuracy of the generation scheme, we also need to use the objective function to complete the optimization:

$$f(\| h \|) = a + a^2 \| W + E \|_{(X-T)} \tag{12}$$

After using objective function optimization, the three-dimensional image of spatial layout is affected by many external factors. The large probability deviation generated at this time needs to be transformed according to the non-ideal model to meet the needs of the CAD auxiliary system:

$$pm = f(AQ_i + h)_0 \tag{13}$$

Finally, after determining the functional area of the interior space, the three-dimensional feature points are constructed according to the layout panoramic two-dimensional image to determine the relevant parameters, and the colour information in the space where the same feature points are located is calculated:

$$f(x,y) = g(x) + u_t - mn_i \tag{14}$$

The calculated colour information can distinguish the spatial layout area according to different functions. The interior space layout system, after computer-aided optimization, mainly reflects the function and effect of visual features in space. After the three-dimensional model is built, the spatial layout and display shape will also change with the change of features. The extraction expression of shape is as follows:

$$U = \begin{bmatrix} 1, l = 0, L \\ 2\pi \bullet \frac{D}{2} \sin \end{bmatrix} \tag{15}$$

The spatial shape extraction results provide reliable parameters for the 3D auxiliary system. The interior space layout is automatically generated after rendering and obtaining advanced texture imaging. Shape extraction is a crucial step in 3D modeling. We can extract concise and expressive shape elements from complex three-dimensional spaces through specific algorithms and expressions. These shape elements provide reliable parameter support for 3D assistive systems and enable dynamic adjustment of spatial layout and display shapes as design requirements change. This flexibility provides designers with great creative space, allowing them to continuously optimize design solutions based on actual situations and customer needs, achieving the best design results. After the completion of the 3D model construction, we can obtain high-quality texture imaging effects through advanced rendering techniques. These images not only showcase the aesthetic appearance of the space but also simulate physical phenomena such as lighting and shadows in the real world, making the design results more realistic and vivid. Meanwhile, advanced texture imaging technology also supports fine adjustments to material properties such as glossiness and transparency, further enhancing the precision and texture of the design. In summary, the 3D modeling and optimization process after determining the functional areas of the internal space involves a multidimensional and multi-level integration of technology and art. By accurately constructing three-dimensional feature points, deeply integrating color information, emphasizing the role and effect of visual features, dynamically adjusting shape elements, and using advanced rendering and texture imaging techniques, we can create indoor space layout solutions that meet functional requirements and are full of personality charm.

4 ANALYSIS OF INDOOR SPACE LAYOUT DESIGN BASED ON BIG DATA-DRIVEN ANALYSIS OF USER BEHAVIOUR AND COMPUTER-AIDED OPTIMIZATION

4.1 Analysis of the Impact of Big Data-Driven User Behaviour Analysis on Spatial Layout

A reasonable interior space layout will bring people different feelings, a warm and comfortable space environment can create a relaxed atmosphere. People are more relaxed and open up when they socialize. On the contrary, the serious spatial layout will make people feel the pressure of activity. Space layout has a profound impact on people's behaviour and psychology, and conversely, the change in users' behaviour will also affect the generation of indoor space layouts. In our research, we use big data to drive the analysis of the impact of user behaviour on spatial layout, so as to automatically generate spatial layout schemes. First of all, in the process of big data analysis, we found that most users query indoor space layout information through social networks, which tend to be functional and aesthetic. In order to verify the reliability of the big data-driven analysis results, we obtained the differences between the spatial layout type selection of 2000 different occupants and the actual predicted results, as shown in Figure 5.

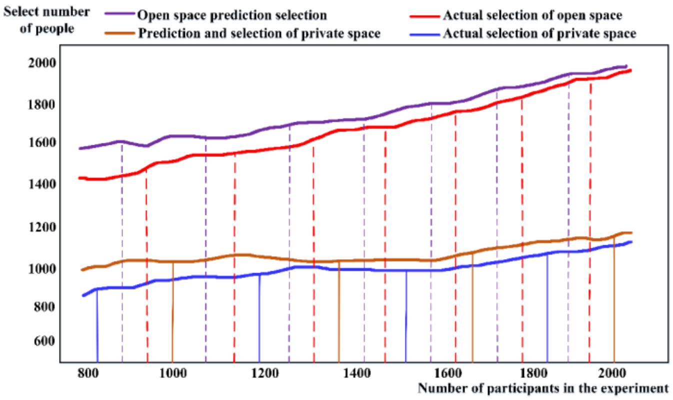

Figure 5: The difference between the selection of spatial layout types in data-driven analysis and the actual prediction results.

As can be seen from Figure 5, the amount of user behaviour data is too large. However, most users have little difference between the spatial layout type selection and the actual data-driven prediction results. This further validates the reliability and relevance of big data-driven user behaviour analysis and spatial layout generation. Next, we conduct a semantic analysis of user behaviour and add the semantic analysis data to the data-driven network. According to the feature data provided by the driving network, three kinds of indoor space layouts are intelligently generated, as shown in Figure 6.

As can be seen from Figure 6, semantic features in user behaviour include liveliness, calmness, and different choices of colour, material, and function. The three spatial layouts of intelligent generation are open, closed, and mixed, which not only contain certain semantics in user behaviour but also meet the needs of spatial functions. Big data-driven user behaviour is closely related to indoor space layout planning.

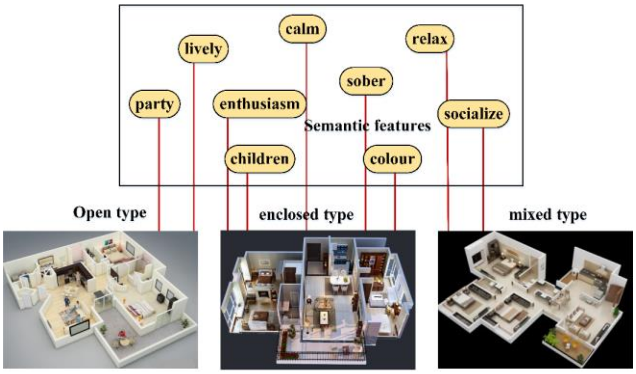

Figure 6: Three types of indoor space layouts generated by data-driven methods.

The three types of spatial layouts generated intelligently - open, closed, and mixed - are not just simple divisions of physical space but also a profound understanding and precise response to user behavior semantics. Open layout emphasizes the transparency and fluidity of space, which is suitable for users who pursue social interaction and open vision; closed layout emphasizes privacy and security, meeting the needs of users who need to work or rest independently. The mixed layout cleverly combines the characteristics of openness and closure, providing users with diverse spatial experiences and meeting the needs of different scenarios. These layout designs not only reflect precise capture of user behavior semantics but also maximize space utilization efficiency through functional zoning and streamlined organization of space.

4.2 Interior Space Layout Design Based on Computer-Aided Optimization and Analysis of 3D Display Research Results

The space layout design can divide the specified space area by parameter constraints under a variety of objective and subjective conditions and also adjust the placement of the target object in the space. Over the years, traditional interior design methods have been inefficient and unable to meet the needs of users for modern living areas, and the functional layout of space has severely limited the development of designers. In this paper, the CAD computer-aided system is used to optimize the spatial layout design, and the characteristics of user behaviour data are combined to help the design scheme complete the automatic generation. In order to verify the optimization effect of CAD computer-aided system, we compared the generation speed of interior space layout design schemes before and after adopting CAD technology, as shown in Figure 7.

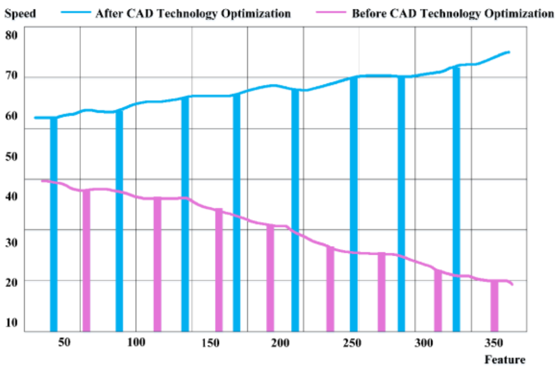

Figure 7: The generation speed of indoor spatial layout design schemes before and after adopting CAD technology.

As can be seen from Figure 7, before the optimization with CAD technology, the schemes generated by the interior space layout were mostly two-dimensional images, which contained relatively simple data information. The rapid increase in the amount of data in the face of functional division and spatial requirements has brought greater pressure on the system before optimization, so the generation speed of spatial layout design is low. After using CAD technology to optimize, CAD computer-aided systems have an obvious optimization effect in the face of dynamic information and feature data, which can improve the generation speed of target schemes. In our research, we also used the three-dimensional pairs of CAD systems to simulate the spatial layout in order to provide users and designers with an immersive feeling. The traditional two-dimensional image is converted into a three-dimensional effect, and after scene rendering is completed, the space layout scene generated by CAD computer-aided optimization system is applied as follows.

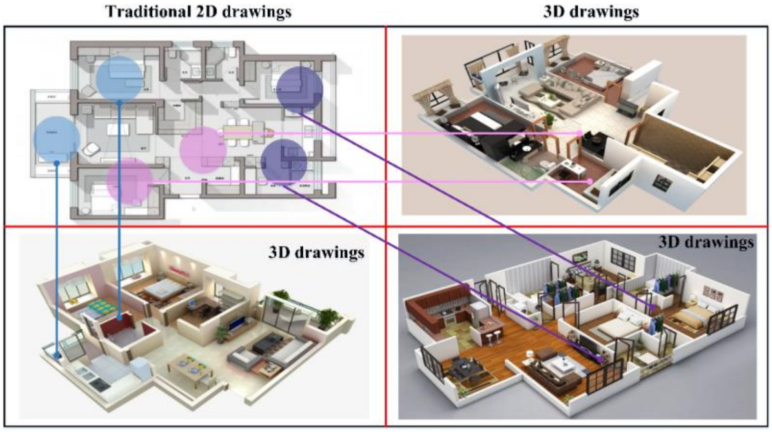

Figure 8: The spatial layout scene generated by CAD computer-aided optimization system.

As can be seen from Figure 8, different from the traditional two-dimensional design drawing, not only can the functionality of the space area be seen in detail in the three-dimensional scene, but also the designer and user experience can complete the interaction in the virtual space.

5 CONCLUSIONS

In interior design, space layout is closely related to human behaviour. Different design methods bring different spatial visual effects. With the help of big data-driven and computer-aided CAD technology, this paper studies user behaviour and interior space layout optimization, not only explores the relationship between the two but also completes the automatic generation of interior space layout. Firstly, the user behaviour data is extracted, preprocessed and analyzed. Add the analysis results to the big data drive to further verify the reliability of the results. And the relevant information driven by big data is associated with the spatial layout to explore the interaction between the two. Based on different types of spatial layouts, the paper analyzes the needs of users for open, closed, and mixed spatial functions and verifies whether the actual spatial layout planning meets the requirements according to user behaviors and individual tendencies. The relationship between data and space is used for abstract cluster analysis of users. Finally, the computer-aided CAD system is used to optimize the process of interior space layout. The layout model is selected and divided according to the user's preference using a 3D image presentation instead of the traditional 2D graphic design scheme. The system selects several iterations according to the characteristics of users and finally completes the task of automatic layout planning scheme generation. The results show that the big data-driven analysis of user behaviour can provide a reference for users' individual preferences in indoor space layout and help CAD computer-aided optimization systems. It can not only improve the efficiency of interior space layout but also change the display form of spatial layout.

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REFERENCES

[1] Brown, N.-C.: Design performance and designer preference in an interactive, data-driven conceptual building design scenario, Design Studies, 68(1), 2020, 1-33. https://doi.org/10.1016/j.destud.2020.01.001

[2] Buyukdemircioglu, M.; Kocaman, S.: Reconstruction and efficient visualization of heterogeneous 3D city models, Remote Sensing, 12(13), 2020, 2128. https://doi.org/10.3390/rs12132128

[3] Chatzivasileiadi, A.; Wardhana, N.-M.; Jabi, W.; Aish, R.; Lannon, S.: Characteristics of 3D solid modeling software libraries for non-manifold modeling, Computer-Aided Design and Applications, 16(3), 2019, 496-518. http://dx.doi.org/10.14733/cadaps.2019.496-518

[4] Doungmala, P.; Thai, T.-H.: Investigation into the application of image modeling technology in the field of computer graphics, International Journal for Applied Information Management, 3(2), 2023, 82-90. https://doi.org/10.47738/ijaim.v3i2.53

[5] Du, J.: Application of CAD aided intelligent technology in landscape design, International Journal of Advanced Computer Science and Applications, 13(12), 2022, 1030-1037. https://doi.org/10.14569/IJACSA.2022.01312118

[6] Dubey, R.-K.; Khoo, W.-P.; Morad, M.-G.; Hölscher, C.; Kapadia, M.: AUTOSIGN: A multi-criteria optimization approach to computer aided design of signage layouts in complex buildings, Computers & Graphics, 88(1), 2020, 13-23. https://doi.org/10.1016/j.cag.2020.02.007

[7] Fuchs, D.; Bartz, R.; Kuschmitz, S.; Vietor, T.: Necessary advances in computer-aided design to leverage on additive manufacturing design freedom, International Journal on Interactive Design and Manufacturing (IJIDeM), 16(4), 2022, 1633-1651. https://doi.org/10.1109/ICNETIC59568.2023.00039

[8] Keshavarzi, M.; Rahmani, A.-M.: Genfloor: Interactive generative space layout system via encoded tree graphs, Frontiers of Architectural Research, 10(4), 2021, 771-786. https://doi.org/10.1016/j.foar.2021.07.003

[9] Liu, X.: Three-dimensional visualized urban landscape planning and design based on virtual reality technology, IEEE Access, 8(1), 2020, 149510-149521. https://doi.org/10.1109/ACCESS.2020.3016722

[10] Mourtzis, D.; Angelopoulos, J.; Panopoulos, N.: Personalized PSS design optimization based on digital twin and extended reality, Procedia CIRP, 109(1), 2022, 389-394. https://doi.org/10.1016/j.procir.2022.05.267

[11] Parekh, R.: Automating the design process for smart building technologies, World Journal of Advanced Research and Reviews, 23(2), 2024, 1213-1234. https://doi.org/10.30574/wjarr.2024.23.2.2461

[12] Vyas, S.; Chen, T.-J.; Mohanty, R.-R.; Krishnamurthy, V.-R.: Making-a-scene: a preliminary case study on speech-based 3D shape exploration through scene modeling, Journal of Computing and Information Science in Engineering, 22(6), 2022, 064501. https://doi.org/10.1115/1.4055239

[13] Wang, X.; Liu, A.; Kara, S.: Machine learning for engineering design toward smart customization: A systematic review, Journal of Manufacturing Systems, 65(1), 2022, 391-405. https://doi.org/10.1016/j.jmsy.2022.10.001

[14] Xin, W.; Daping, Q.: Digitalization system of ancient architecture decoration art based on neural network and image features, Journal of Intelligent & Fuzzy Systems, 40(2), 2021, 2589-2600. https://doi.org/10.3233/JIFS-189251
[15] Yang, J.: Teaching optimization of interior design based on three-dimensional computer-aided simulation, Computer-Aided Design and Applications, 18(S4), 2021, 72-83. https://doi.org/10.14733/cadaps.2021.S4.72-83
[16] Zhou, Q.: Research on architectural space design of coastal cities based on virtual reality technology, Journal of Coastal Research, 11(51), 2020, 13. https://doi.org/10.2112/JCR-SI115-005.1