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Research Article

3D Indoor Scene Synthesis System Based on Collaborative Retrieval

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In order to solve the research problem of collaborative retrieval 3D indoor scene synthesis system, an automatic synthesis method of 3D indoor scene is proposed. In the research fields of computer graphics and computer vision, the modeling of various 3D scenes has always been a hot spot and a very valuable research topic for Chinese and foreign scholars. GMM is used to fit the position of the object on the support surface, and the position distribution model is obtained. Firstly, a file is created to store the normalized position of the counted object on the support surface. The number of coordinates represents the number of times the object appears in the scene library. Then, the Gaussian mixture model is used to fit the content of the file to obtain the location distribution model. For the initial indoor scene and the description of small objects to be added to the scene given by the user, select small objects with the help of the material library. Shapenetcorcv2 is the core part of the database, with a total of 55 categories and more than 50000 model instances. The automatic placement of these small objects is realized by using the scene synthesis algorithm, which shows the continuous enrichment of the evolution process of simple scenes to solve various problems of 3D indoor scene modeling. This method not only reflects the design requirements of users but also avoids cumbersome manual operation.

1. Introduction

With the rapid development of computer software and hardware technology, the application field of computer graphics has gradually expanded. Virtual reality, scientific visualization, and computer animation have become the three major research directions of computer graphics in recent years. The so-called virtual reality (VR) refers to the highly realistic virtual space generated by computer. Virtual reality technology (abbreviated as VR) is a new practical technology developed in the 20th century. Virtual reality technology includes computer, electronic information, and simulation technology. With the continuous development of social productivity and science and technology, the demand for VR technology in all walks of life is growing. VR technology has also made great progress and has gradually become a new field of science and technology. Within a certain range, it is highly similar to the real environment in terms of vision, hearing, and touch, so that users can experience as if they were in the real world and have an immersive feeling. Virtual reality is a multidisciplinary integrated technology. Virtual reality also known as spiritual world technology is an advanced computer human-machine interface with immersion, interactivity, and conception as the basic characteristics. It comprehensively utilizes computer graphics, simulation technology, multimedia technology, artificial intelligence technology, computer network technology, parallel processing technology, and multisensor technology; simulate the functions of human sense organs such as vision, hearing, and touch, so that people can be immersed in the virtual realm generated by the computer; and can communicate with them in natural ways such as language and gestures. Real-time interaction creates a human-friendly multidimensional information space. The development of various disciplines has also promoted the progress of virtual reality technology, making it widely used in military, medical, education, science and technology, entertainment, construction, industry, and commerce. 3D modeling technology is the key technology of virtual reality. At present, the modeling methods of objects can be roughly divided into three types:

the first method is to use three-dimensional software for modeling, the second method is to collect information through instruments and equipment for modeling, and the third method is to use image or video for modeling. In many applications of computer games, virtual reality, augmented reality, and hybrid reality, a large number of realistic 3D scenes are needed for users to carry out various interactive activities. Three-dimensional scene is the data basis for the interaction between human and virtual world, and indoor scene is widely used because it can better reflect the interaction between human and virtual scene. Nowadays, the rapid development and increasing popularity of the Internet make the acquisition, aggregation, storage, transmission, processing, and analysis of a large amount of data more and more convenient. After the digital age, information age, and Internet age, mankind has entered the era of big data. Various types of media data are growing rapidly. Although the number of three-dimensional data is less than that of pictures and video data, there are some well-known large-scale three-dimensional model scene databases, such as 3D Warehouse, which makes the acquisition of three-dimensional models more convenient than traditional modeling methods. The massive data resources contained in it provide the necessary data basis for the research of 3D scene analysis. Based on the analysis of existing resources and with the help of computer technology, the automatic generation of 3D scene will greatly improve the efficiency of scene modeling and provide a variety of virtual interactive environments for related applications, as shown in Figure 1.

2. Literature Review

With the improvement of living standards, people began to pay attention to interior home design and unified home decoration style. Ji and others feel that most ordinary users have very limited understanding and mastery of interior design and furniture style matching, and it is difficult to complete the design by themselves [1]. Therefore, usually, many users will hand over the interior design work to special interior designers. Fu and others said that traditional interior design often needs to spend higher labor and time costs and requires effective communication between customers and designers to obtain satisfactory design [2]. Wang and others said that in recent years, the emergence of indoor home intelligent design platform has simplified the design process and reduced the operation difficulty for users. Users can display a satisfactory indoor scene layout through simple drag and drop. After putting out a satisfactory layout, users will be concerned about the overall style of home decoration and the compatibility of furniture [3]. At present, interior home design platforms only classify furniture based on style categories (classical Chinese style, new Chinese style, classical European style, pastoral style, rural style, etc.). Kouadria and others said that users have to manually select appropriate furniture for matching in the same style category. However, even furniture of the same style is not necessarily matching. In the two scenes, all furniture models are modern Chinese style. It can be seen that the scene on the left has more style consistency than the scene on the right [4]. Therefore, if we can analyze the style consistency of the furniture model in the three-dimensional indoor scene and realize the furniture recommendation based on style consistency, we can automatically synthesize the three-dimensional indoor scene with style consistency. Bhangale and Mohanaprasad said that scene synthesis based on style consistency can better and faster help users choose furniture, synthesize indoor scenes that better meet users' needs, and reduce users' time consumption in indoor home design, which is of great significance to the whole home decoration design industry [5]. Zhang and others think that in the process of 3D indoor scene synthesis based on style consistency, the furniture model in the final synthesized scene should not only be the same in the type of home style but also reflect the compatibility and coordination of materials and colors between furniture [6]. However, Dong and others said that in the field of computer graphics and computer vision, the relevant methods of scene synthesis and layout design usually only consider the semantic information of furniture without constraints on the style of synthetic scenes [7]. The scene is a reasonable imagination based on the actual situation of the space, and it is a reasonable experience based on the designer's true feelings in the situation. Whether the analysis and setting of the space scene are successful or not basically determines the style and artistic height of furniture design. Chen and others think that in recent years, with the development of computer graphics and computer vision, style methods based on single model have attracted attention. These methods can obtain the shape characteristics of furniture models under the same style by analyzing the shape characteristics of models [8]. However, these methods often cannot distinguish more detailed shape characteristics under the same style. On the other hand, Wang and others said that the 3D furniture model with style consistency in the same indoor scene not only has similarity in shape but also has consistency in material and texture information to some extent. However, the current 3D model style analysis method does not discuss this information together with shape feature information, so it cannot be directly used for furniture retrieval with style consistency [9]. Therefore, Song and others said that it is still a very challenging problem to design a measurement method of style consistency of 3D furniture model; realize feature extraction including material, texture, and shape; analyze the style similarity of different types of objects; and synthesize indoor scenes on this basis [10].

3. Method

This paper proposes an indoor scene synthesis method based on collaborative retrieval. The process of this method is as follows: after the user decides the layout of the scene and selects the favorite style furniture, the style consistency analysis method is proposed to extract the style of the selected style furniture model and then conduct the corresponding furniture collaborative retrieval combined with the model style features in the model retrieval database and the scene layout information and place the retrieved furniture model in a reasonable position. In order to ensure the

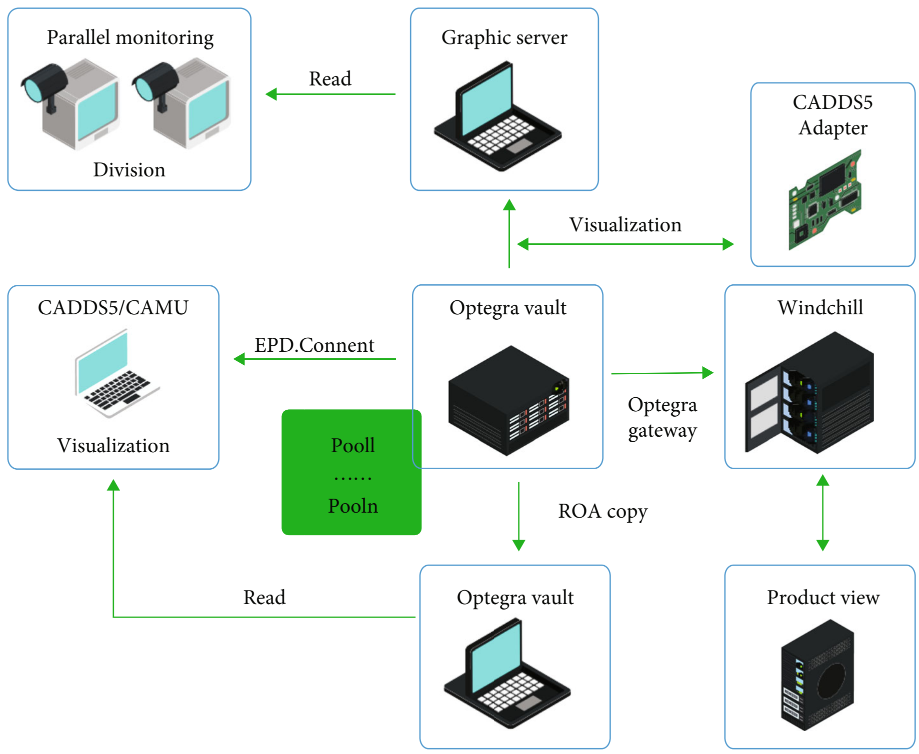

Figure 1: Research on 3D indoor scene synthesis system based on collaborative retrieval.

reasonable and authentic placement of the final furniture model, this chapter uses the furniture model position adjustment method based on constraints. In the process of scene synthesis, the style consistency of the furniture model of the synthetic scene and the consistency of the location and size of the scene furniture model with the layout information of the original scene should be ensured, as shown in Figure 2.

The main goal of style consistency information extraction is to extract the style features of the furniture models in the user selected style furniture and model retrieval database. The 256 dimensional features obtained by the consistency analysis framework are directly used as the style consistency features of each model. Scene layout information extracts the layout information of the scene, including the category and position and size of walls, doors, and each furniture object. This information is used as the limiting condition for user input to constrain the furniture models and their positions in the final synthesized scene [11]. In collaborative retrieval based on style consistency and layout information, after extracting the style consistency information and scene layout information of furniture model, the next step is to retrieve scene furniture. If the best matching retrieval is directly carried out for each furniture object category existing in the scene layout, the consistency between furniture models may be ignored, and it is difficult to achieve satisfactory results. Collaborative retrieval between furniture objects can not only ensure the style consistency of retrieved furniture but also ensure the consistency with the category and shape information of the corresponding furniture model in the layout information of the scene input by the user [12].

In object position adjustment in order to ensure the rationality of the furniture position of the synthetic scene, it is necessary to judge and adjust the position of each object in the scene. After obtaining the candidate furniture data of each furniture node, the combination optimization process based on style consistency features and scene layout information will be carried out. This paper uses formula (1) as a cost function to evaluate the quality of a specific candidate furniture combination and measures the style consistency of the furniture model set C selected from the candidate furniture set, the style consistency between the furniture model set C and the style furniture model provided by the user, and the consistency between the size of the furniture model in C and the size of the corresponding furniture object in the scene layout. $a.w$ and $a.h$ represent the length and width of the surrounding of furniture object a, respectively. Cong, Cong, and Zha are set to 1, 0.5, and 2.0, respectively, in practice, as shown in formulas (1), (2) and (3).

$$F(C) = \lambda_1 \sum_{a,b\epsilon c} d(f_a, f_b) + \lambda_2 \sum_{c\epsilon C} d(f_c, f_{\text{user}}) + \lambda_3 \sum_i d_s(s_i^{\text{user}}, s_i^c), \quad (1)$$

$$d(a, b) = \lambda \|a - b\|^2, \quad (2)$$

$$d_s(a, b) = \max \left(\|a.w - b.w\|^2, \|a.h - b.h\|^2 \right). \quad (3)$$

In order to minimize the best combination of candidate furniture in formula (3), a simple way is to enumerate all possible combinations and directly select the one that can make the largest furniture combination. Since each furniture

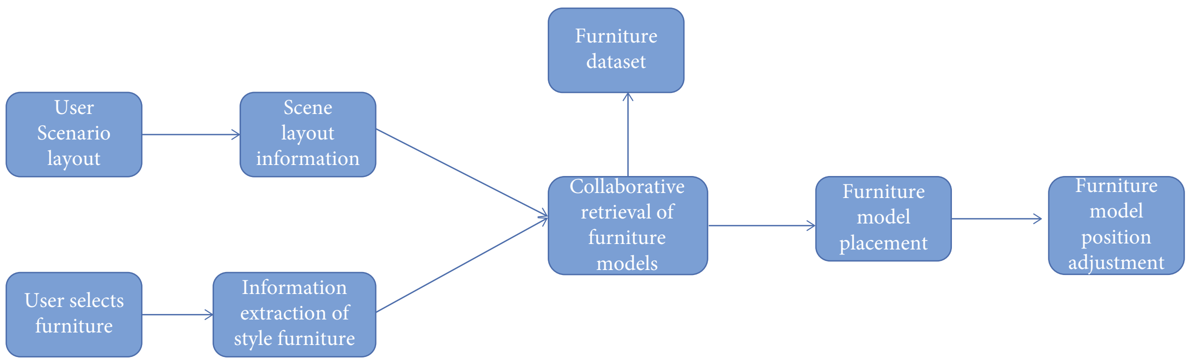

Figure 2: Scene synthesis process based on collaborative retrieval.

selects the first 10 optimal matches as the candidate furniture set, for a scene layout with n furniture nodes, the time complexity of judging all possible combinations is $0(10^N)$, which obviously has a very expensive computational cost [13]. A heuristic algorithm based on cluster search is used to approximate the optimization process. It intuitively explains that if the current combination is optimal, at least one or more subsets of the combination are likely to be optimal. Before adjusting the position, you need to set some constraint information to guide the placement process of each 3D model. In order to ensure that the synthetic scene conforms to the law of the real world, the extracted room contour polygon and the bounding box of each furniture object need to set some hard constraints. These hard constraints are not allowed to occur at any time. Once they occur, it means that the synthetic scene does not meet the physical authenticity. These hard constraints are as follows: overlap rule: when placing an object, the object cannot intersect or overlap with the bounding box of any other object. For two 3D furniture models i and j, this paper calculates the intersection area of two polygons to judge whether the bounding boxes BB_i and BB_j of two objects intersect. If the intersection area of two bounding boxes is O, it means that they do not overlap, as shown in the following formula:

$$C_1(i, j) = \begin{cases} 1, & \text{area}\left(\mathrm{BB}_i \cap \mathrm{BB}_j\right) = 0, \\ 0, & \text{else}. \end{cases} \quad (4)$$

Through wall rule: when placing an object, the object cannot be placed outside the wall or intersect with the wall. For the three-dimensional furniture model i, this paper calculates the intersection area of the bounding box BB_i of the model and the contour polygon P_{wall} composed of the room wall. If the intersection area is equal to the area of the bounding box of the model, it means that the object is placed inside the room, as shown in the following formula:

$$C_2(i, j) = \begin{cases} 1, & \text{area}(\mathrm{BB}_i \cap P_{\text{wall}}) = \text{area}(\mathrm{BB}_i), \\ 0, & \text{else}. \end{cases} \quad (5)$$

Door blocking rule: in real life, in order to ensure that people can enter an indoor scene from the outside. When placing an object, the bounding box of the object cannot overlap with the extended area of the door. In order to judge whether the three-dimensional furniture model I blocks the door J, this paper first extends the door j by 1.2 meters along the interior direction of the room, and the extended area can be represented by a rectangle. Thus, this paper calculates the intersection area between the bounding box BB_i of the model and the rectangular $R_{\text{door}j}$ of the extended area of the door to judge whether there is a door, as shown in formula (5):

$$C_3\left(i, \text{door}_j\right) = \begin{cases} 1, & \text{area}\left(\mathrm{BB}_i \cap R_{\text{door}_j}\right) = 0, \\ 0, & \text{else}. \end{cases} \quad (6)$$

Proximity rule: the distance between each object and adjacent objects should be consistent with the layout information as far as possible. Firstly, we need to define the distance between two objects and describe the specific setting of proximity constraint. For two objects i and j, this paper uses the minimum value d_{ij} of the point distance on the bounding box of two objects as the distance between the two objects. C is the relative distance of objects i and j in the layout provided by the user, and a is the coefficient manually set, which is set to 0.1 in this paper, as shown in the following formula:

$$C_4 = \sum_{i,j} e^{-a\left(d_{ij} - \partial^i_{\text{wall}}\right)}. \quad (7)$$

If one of the objects in the search box is placed against the wall, it should also be placed against the wall. The specific setting of the wall constraint is described. The distance d between the object i and the wall is equal to the minimum value of the distance from the point on the bounding box of the object to the wall polygon. d^i_{wall} is the relative distance between the object 1 and the wall in the layout provided by the user. Compared with the proximity constraint, the influence of the wall constraint is greater. Therefore, it is set as 10 in this paper, as shown in the following formula:

$$C_5 = \sum_{i,j} e^{-\beta\left(d^i_{\mathrm{wall}} - \partial^i_{\mathrm{wall}}\right)}. \quad (8)$$

Based on the discussion of the above constraint information, the position adjustment process can be regarded as the solution process of numerical optimization. Because the layout position provided by the user can be used as a good initial solution, this paper uses the mountain climbing algorithm to solve the local optimal value. First, define the solution goal. According to the previous rule definition, this paper uses the following formula as the optimization goal, as shown in the following formula:

$$C_{\mathrm{all}} = \prod_{i,j} C_1(i,j) \cdot \prod_i C_2(i) \prod_{i,\mathrm{door}j} C_3\left(i, \mathrm{door}_j\right) \cdot C_4 \cdot C_5. \quad (9)$$

In order to verify the effectiveness of the scene synthesis method proposed in this chapter, this section will conduct corresponding experimental analysis on the collaborative retrieval based on style consistency and scene layout information and the location adjustment method based on local optimization mountain climbing algorithm. The corresponding experiments are as follows: collaborative retrieval and top-1 retrieval effect comparison experiment, collaborative retrieval effect comparison experiment with different parameter ratios, scene synthesis effect comparison experiment with or without position adjustment process, and user survey of the comparison between indoor scene synthesized by this method and indoor scene synthesized by experts [14]. Gaussian distribution is a very important continuous probability distribution function in the fields of machine learning, computer, mathematics, physics, and engineering. It describes a random variable distributed around a single value aggregation. At the same time, Gaussian distribution is also the most widely used type of distribution. Gaussian model is used to quantify things with Gaussian distribution and decompose a thing into several models based on Gaussian distribution. It can be divided into a single Gaussian model (SGM) and Gaussian mixture model. The definition of multidimensional Gaussian distribution (normal distribution) probability density function is shown in the following formula:

$$N\left(x, \mu, \sum\right) = \frac{1}{\sqrt{(2\Pi)|\Sigma|}} \exp\left[-\frac{1}{2}(x-\mu)^T \Sigma^{-1} (x-\mu)\right]. \quad (10)$$

Different from the one-dimensional Gaussian distribution, sample x is the n-dimensional sample vector, μ is the expectation of the model, and Σ is the variance of the model. For the single Gaussian model, because it can be clear whether the training sample belongs to the Gaussian model (for example, when training the face skin color model, the skin color part in the face image is segmented to form the training sample set), μ is usually replaced by the mean value of the training sample and Σ by the sample variance. In order to apply Gaussian distribution to pattern classification, it is assumed that the training sample belongs to category A, as shown in the following formula:

$$N\left(\frac{x}{A}\right) = \frac{1}{\sqrt{(2\Pi)|\Sigma|}} \exp\left[-\frac{1}{2}(x-\mu)^T \Sigma^{-1} (x-\mu)\right]. \quad (11)$$

Formula (11) describes the probability value that the sample belongs to category a. Substituting any observation sample x_i into formula (10) can obtain a scalar value $N(x_i, \mu, \sum)$. If the value is greater than the threshold value, it can be determined that the observation sample belongs to category A. When analyzing a three-dimensional indoor scene, one of the key links is to extract and analyze the spatial relationship between objects in the scene, including support relationship and proximity relationship. These are two different spatial relationships, but they have a certain correlation with each other, so priority should be considered in detection. The basis for determining the priority is that after the detection of the spatial relationship with higher priority is completed, the detection results can facilitate the detection of the spatial relationship with lower priority or simplify the algorithm steps and improve the efficiency of the algorithm. In general, the priority of support relationship is higher than that of proximity relationship [15]. Therefore, firstly, the support relationship between objects in the scene is detected. When judging the relationship of objects, the support relationship will be judged first. After the judgment of all supporting relationships is completed, the judgment of proximity relationship can be carried out. In the 3D scene, there will be the relationship between supported and supported objects. This paper detects the relationship by extracting the algorithm of supporting relationship. The flow chart of this algorithm is shown in Figure 3.

The algorithm mainly consists of three steps: preliminary judgment: judge whether two BBB bounding boxes intersect. If the center distance of the BBB bounding box of two objects is not within the preset off value range (set this off value to 4.0), we can directly draw a conclusion: there is no supporting relationship between the two objects. Otherwise, make the next judgment. This step is a preliminary screening process. The purpose is to exclude some object pairs that obviously have no support and supported relationship, so as to save the running time of the algorithm and improve the efficiency of detailed judgment. If the AABB bounding boxes of the two objects intersect, it indicates that the two objects may have a relationship between support and supported. It is necessary to further detect the GOBB bounding box with good tightness to judge whether there is a support relationship between the GOBB bounding boxes of the two objects. If it exists, it can indicate that there is a supporting and supported relationship between the two objects. Otherwise, proceed to the next step of detection [16, 17]. If the AABB bounding boxes of two objects intersect, but the GOBB bounding box has no support and supported relationship, it is necessary to detect the triangular patch level to finally judge whether the two objects have a support relationship. If the triangle of one object is in contact with the

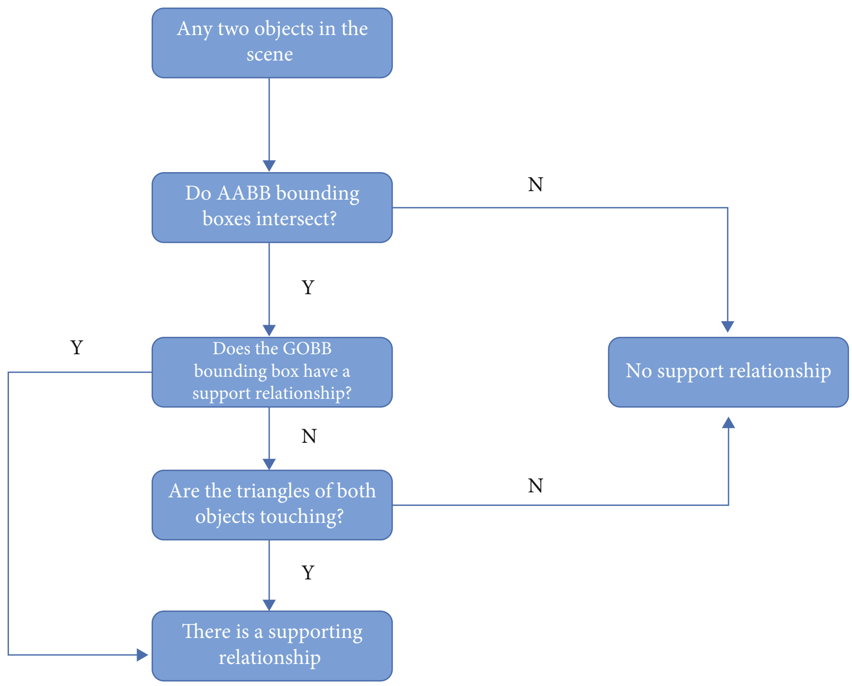

Figure 3: Algorithm flow of extracting support relationship.

triangle of another object, it can be determined that there is a support relationship between the two objects.

4. Experiment and Analysis

Home synthesis system integrates the proposed three-dimensional model analysis method of style consistency with the scene synthesis method based on style consistency retrieval and designs and implements a prototype system for home design. The purpose of this system is to help ordinary users without relevant design experience to quickly carry out indoor home design and meet the requirements of users for style consistency design. The system can not only enable ordinary users to carry out home design but also become an auxiliary tool for home style research by professionals in the home design industry. The system provides relevant data structures and can easily support the expansion of relevant technologies [18]. Today's indoor home design platform can assist users in the actual indoor scene design, but users need to choose the appropriate furniture model for placement. Although the design platform will show some excellent sample rooms for users' reference, a fixed number of sample rooms still cannot meet the diversified user's personalized design needs. It still takes a lot of time for users to migrate directly from house type to template. Taking this as the starting point, based on the research results of style consistency analysis of 3D indoor scenes, a relevant prototype system based on style consistency analysis and 3D scene synthesis will be designed and implemented [19]. The system can not only analyze the style consistency of the current indoor scene but also assist users in the design of indoor scene, realize the style consistency index and recommendation of furniture model, and place the corresponding correct position. While reducing the user interaction time, the system can design and synthesize the indoor scene satisfactory to users. The overall flow chart of the system is shown in Figure 4.

According to the analysis and research on the style consistency of the front three-dimensional indoor scene and the design objectives of the system in this chapter, the main functional modules of the HorneSynthesis system are shown in Table 1.

After determining the process and function of home synthesis system, it is necessary to conduct data analysis for each process and its required functions. The system is written using synthesis.

4.1. Home Security System. The home security system mainly includes home fire prevention, gas prevention, anti-theft, and waterproof leakage. It is composed of sensors, computers, and corresponding control systems. The sensor detects the light, temperature, smell, and other parameters of the home, and if there is a dangerous situation, it will transmit the relevant information to the computer.

4.2. Automatic Control System. The automatic control system is the centralized management of electrical appliances such as air conditioners, washing machines, refrigerators, and cleaners. It consists of two major parts: a home computer and a controller. For example, it can automatically control the air conditioner to automatically adjust the indoor temperature and humidity according to different weather conditions, so that the family can always be in a comfortable environment.

4.3. Home Information System. Household information systems are mainly computer-controlled telephones, televisions, etc., which are connected to the social information

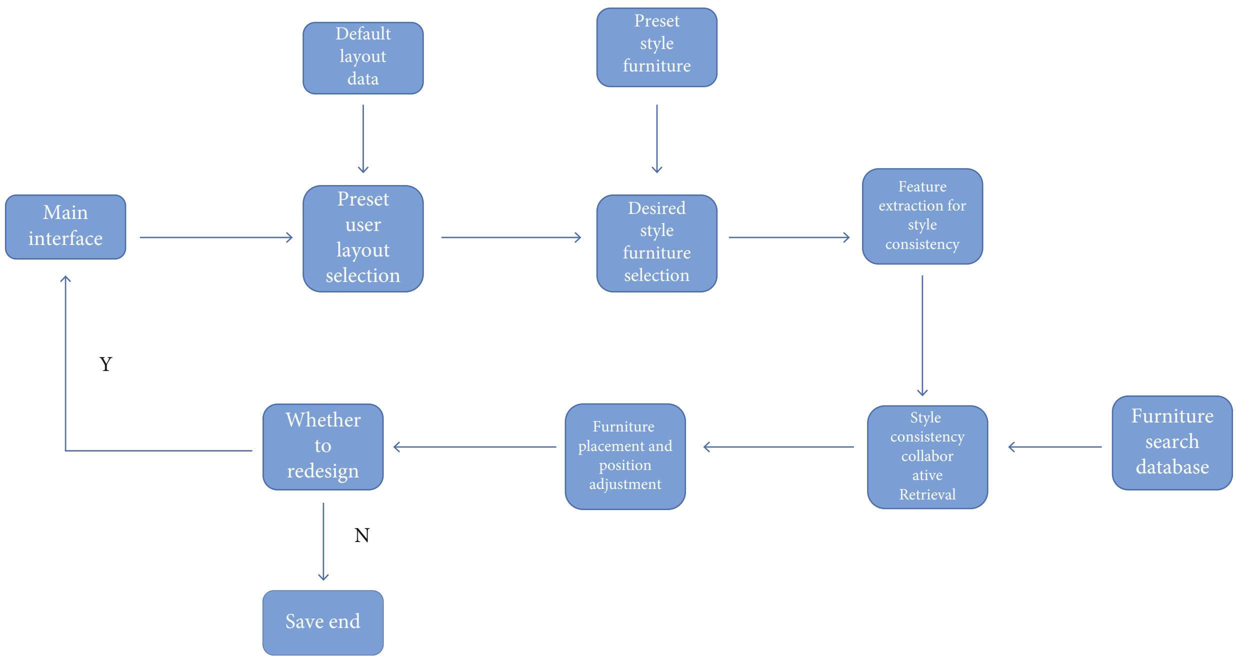

Figure 4: System flow chart.

Table 1: System functions.

Processing process	Specific functions
User information processing	Select preset layout Layout information processing User style furniture selection Feature extraction of user style furniture
Scene synthesis	Furniture retrieval Furniture placement Furniture position adjustment Visual synthetic scene

center through communication lines to obtain various information. The home information system can be used for health management, such as temperature measurement, blood pressure measurement, and pulse measurement, and the home system also realizes home office, truly experiencing the convenience brought by the information age.

The position adjustment class corresponds to the position optimization process proposed in Section 3. Finally, the synthesized scene is rendered by OpenGL. The detailed data structure design is shown in Table 2.

The whole system is divided into four modules: input module, scene analysis module, scene synthesis module, and output module. The description of each module in the algorithm is as follows: input. It refers to the rough scene with only large furniture specified by the user as the initial scene, as well as the type and quantity of objects planned to be put into the scene. In the scene analysis module, it includes two main contents: the analysis of the geometric relationship between objects in the scene and the training of the position distribution model of object placement. For the analysis of geometric relationship, four parts are mainly done: support surface extraction, intersection detection, support relationship and proximity relationship detection, and symbiotic relationship analysis. The function of each part is as follows: support surface extraction: extract the support surface contained by each object in the scene. This part is the basis and support of the whole scene synthesis algorithm. The analysis of intersection relationship, support relationship, proximity relationship, symbiosis relationship, and the training of position distribution model can be completed only after the support surface is extracted [20, 21]. For intersection detection, avoid overlapping objects during placement. The intersection detection algorithm based on bounding box is adopted. In detection of support relationship and proximity relationship, detect the support relationship and proximity relationship between each two objects in the scene to prepare for the analysis of symbiotic relationship, you can try to directly violently return the coordinate information. For example, the yolo detection series yolo contains a foreground probability + 4 coordinates + each

Table 2: System data structure.

Class	Attribute	Attribute property
Layout information class	Layout bounding box	It is used to determine the location of the room layout. The layout information is represented by four point coordinates of a rectangle. The type is list
	Wall information	Save the polygon composed of walls, which is represented by the vertex coordinates of the polygon. The type is list
	Door information	Save the position of each door. Ignore the thickness and height of the door. It is represented by the coordinates of two points. The type is list
	Furniture information	The position, category, size, and orientation information of each furniture in the layout. The type of category information is int and the other types are list
Furniture	Furniture category	Record the category information of furniture. The type is int
	Furniture size	Record the size of the furniture bounding box. The type is list
	Shape feature	Record the shape features of the furniture model for collaborative retrieval. The type is list
	Projection feature	Record the projection features of the furniture model for collaborative retrieval. The type is list
Scene class	Scene model collection	It is used to visualize the display scene
	Scene layout information	Wall, door, and other information used to display the scene
Furniture retrieval	Retrieve candidate sets	The candidate furniture model is calculated during furniture collaborative retrieval, and the type is list
	Optimal retrieval set	The currently calculated optimal candidate retrieval set. The type is list

category probability for each point on the feature map. You can make appropriate magic changes and add four coordinates to return to the associated target boxes, such as the face and human body; of course, this can only be used for simple target associations. The priority of the support relationship is higher than the proximity relationship. In symbiosis analysis, with the help of the data set of three-dimensional scene, the types and frequency of objects that can be supported by various types of supports in the scene are counted. It provides a basis for the algorithm of placing the specified support surface in scene synthesis. For the position distribution training of object placement, firstly, with the help of three-dimensional scene data set, count the position of objects on the same category of supports, normalize the data, and then, fit these data with Gaussian mixture model to train the position distribution model, as shown in Figure 5.

The object random automatic placement algorithm is the first stage of scene synthesis. The goal is to select one of the supports contained in the scene and then randomly select a support plane from the support to randomly place small objects on the plane. The algorithm flow is shown in Figure 6.

(1) The algorithm mainly includes three small algorithms: randomly selecting the support surface, generating candidate placement points, and intersection detection. Firstly, the method of randomly selecting the support plane from the selected supports is introduced. The uniform sampling algorithm of 3D model surface is given. In this algorithm, triangles are randomly selected according to the area of triangles. Inspired by this, we randomly select the support surface according to the area of the support surface. It can be seen that the probability of each plane being selected is proportional to the area of the plane [22]. After accepting the sample, we place it on the support surface based on the rejection. Accept and reject sampling is referred to as reject sampling. The basic idea of this algorithm is as follows: if the function form of target distribution is complex and sampling is difficult. By sampling the distribution of another function that is simple in form and close to the objective function, the invalid data points other than the objective distribution can be discarded, and the rest are effective sampling points [23, 24]. In this paper, the last selected support surface is made into a square according to its longest edge, so that this square contains the whole support surface. Suppose the selected support surface is rectangular, as shown in Figure 7.

It can be seen from the foregoing that the supporting surfaces in the scene are parallel to the xy plane, so the random selection of points on the supporting surface is the random selection of x and y coordinates. The probability of each point being selected on both sides of the square is the same, so the selection of points in the square area conforms to the uniform distribution [1]. After selecting any data point, it is also necessary to detect whether the data point falls within the support surface area. As shown in Figure 7, the support surface area is a rectangular area surrounded by a solid line. If the selected data point is $p(x_1, y_1)$, the data point is within the support surface area, so it is a valid data point. If the selected data point

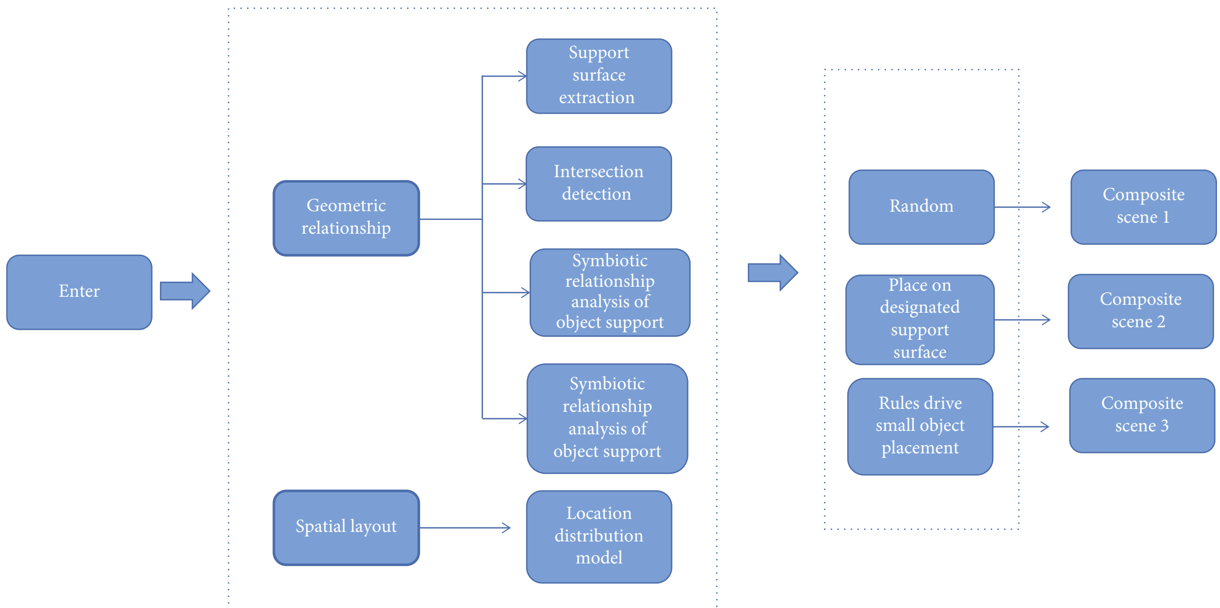

FIGURE 5: User-guided scene synthesis.

is $p(x_2, y_2)$, the data point is outside the support surface area, so it is an invalid data point, which needs to be discarded and recollected [25, 26]. Based on the previous experimental analysis, it can be explained that using shape features and projection features at the same time can more accurately analyze the style consistency of 3D models. However, how can shape features and projection features be effectively combined and how can the dimension of each feature be designed. In this paper, experiments are carried out on different feature dimension combinations in order to analyze the optimal dimension combination scheme. This paper selects different feature dimension combination schemes (128 and 128, 128 and 256, 256 and 128, 256 and 256). Firstly, 20% of the inter template data is reserved for testing, and 100 quads are constructed as the test data. The effect of each combination on the generalization ability of deep learning network is judged by analyzing the loss change curve of the test quads in the training process. The four curves represent the change process of test loss using a specific feature dimension combination, in which SF represents shape feature and PF represents projective feature. It can be seen from the figure that when the shape features and projection features are 128 dimensions, the generalization performance of the network is the best, as shown in Figure 8.

The style analysis method of 3D furniture model based on depth measurement learning is integrated with scene synthesis based on style consistency retrieval, and the corresponding home synthesis prototype system is designed and implemented [27]. From the perspective of software development, this paper introduces the composition module and important data structure of the system and expounds the implementation effect of the main functions of the system through an example. The system can help users without any interior design experience to carry out interior design more effectively. Users need to input a three-dimensional interior scene and the target style furniture object, and the system automatically realizes the scene synthesis of the corresponding style. The system can be used as a tool for furniture style analysis and can also help users quickly synthesize 3D indoor scenes with consistent style.

5. Conclusion

3D scene analysis and synthesis have always been a research hot spot in the field of computer graphics and computer vision. With more and more scene data available, the use of deep learning method can effectively analyze the objects in the scene and extract the common information of objects in a scene. This paper proposes a style consistency analysis method of 3D indoor scene objects, which can extract the style features of furniture objects in 3D indoor scene and use this feature to realize the 3D indoor scene synthesis method based on style consistency retrieval. In this method, the stylistic features of 3D furniture objects are extracted and retrieved together with the scene layout information provided by the user, and then, the position of the placed furniture model is slightly adjusted to meet some position constraints. The work of this paper is mainly reflected in the following three aspects: the style consistency analysis method of 3D model based on metric learning. The style consistency of three-dimensional furniture model means that the furniture model in the same scene should not only be the same in the type of home style but also maintain the compatibility and coordination, reflecting the consistency and aesthetic feeling of color and material. In this paper, the four-tuple depth measurement network based on shape features and projection features is used to analyze the style consistency features of three-dimensional models. This method provides a basis for 3D style consistent scene synthesis. Based on the style consistency feature analysis method, after the user provides the layout information of

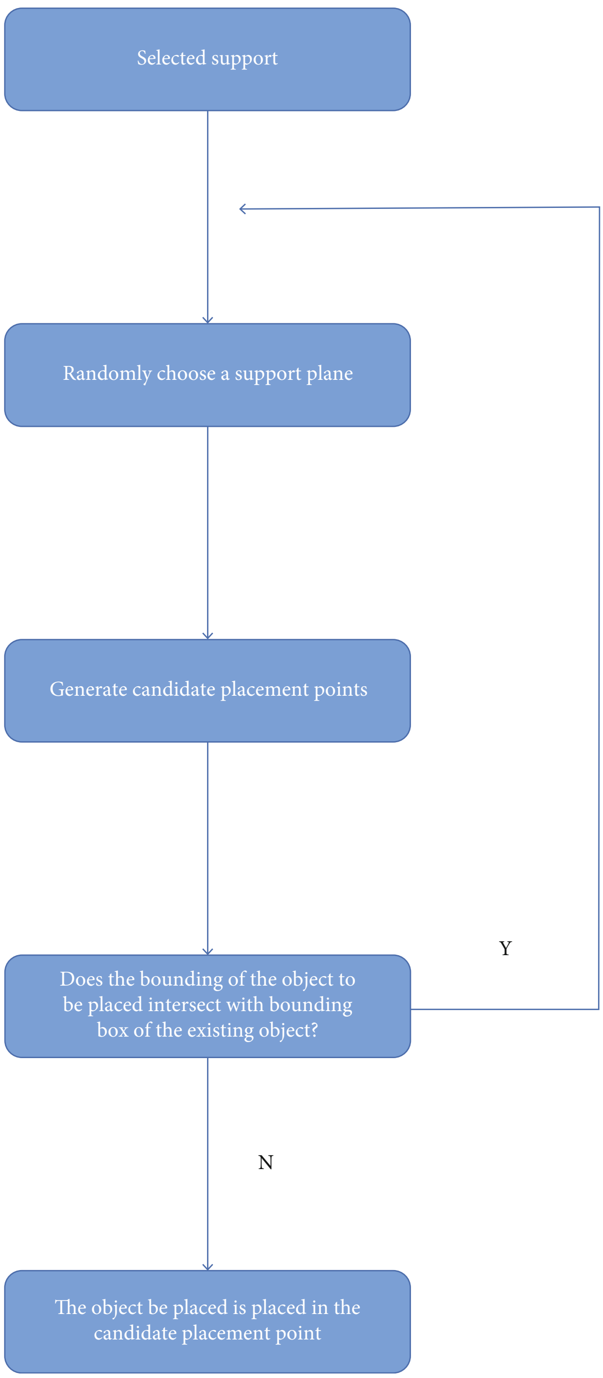

FIGURE 6: Flow chart of random placement algorithm.

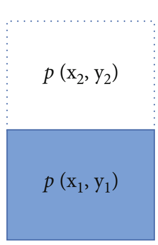

FIGURE 7: Receive reject sampling.

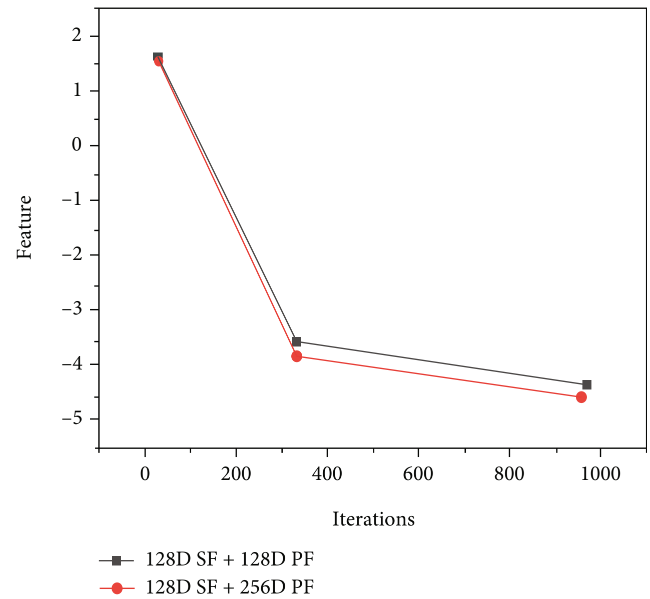

FIGURE 8: Comparative experimental results of different style feature dimensions.

the indoor scene and the furniture of the target style, this paper proposes a 3D indoor scene synthesis method based on style consistency retrieval, which can automatically synthesize the indoor scene with consistent layout information and style consistency provided by the user. Combined with the research contents of the first two parts, this paper integrates the style feature analysis based on style consistency with the scene synthesis method and designs and implements the corresponding home synthesis prototype system. This paper expounds the structure and effect of the system from the perspective of data development.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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