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Research Article

Application of 3D Software Virtual Reality in Interior Designing

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A 3D virtual reality expertise is a dynamic arena of research in current years. Virtual technology is a novel expertise participating in artificial intelligence, image processing, and multisensor knowledge. The formation of situation in 3D virtual reality scheme is the key foundation for the simulation of virtual world scene. Aiming at the main problems that the effect of traditional interior space design is not ideal and cannot achieve practicability. This article proposes an interior space virtual design method based on three-dimensional vision. Initially, the feature of the indoor scene is combined with the set of three points, and finally, the optimal combination of the main and subpoints is obtained through the iterative combination of the main and subpoints of the indoor scene. The information fusion of color background and vision of indoor space is used for indoor comprehensive design. It is proved that the method proposed in this paper can effectively improve the effect and practicability of indoor space design through the simulation experiment with virtual reality platform software.

1. Introduction

At present, virtual technology is widely used in military, construction engineering, education, medicine, and many other fields and brings great economic benefits. Three-dimensional virtual reality technology is an active field of technology research in recent years. Virtual technology is a new technology integrating computer image processing, artificial intelligence technology, and multisensor technology. The creation of an environment in a 3D virtual reality system is the main basis for the simulation of a virtual world scene. To effectively create a relatively realistic virtual environment for users, we must build a real model and virtual scene. However, if the accuracy of the virtual scene and model is relatively high, the calculation process is easy to be too large, which will bring a great burden to the three-dimensional virtual reality system. In particular, for large buildings, some historic site designs, and some more complex scenes, the construction of the scene in the virtual reality system will have an impact on the quality of the model. The amount of data needs to be minimized.

Try to ensure that the designed virtual system can operate effectively under certain conditions. Therefore, for the design of the virtual system, the main problem is how to use the existing technology to build a virtual simulation environment, including the space of the building, the sound and natural conditions of the environment, and other elements. Because the amount of information and data received by human vision and feeling is relatively large and sensitive, so we should formulate a scientific and feasible model, and the real-time dynamic display is very important in a 3D virtual system. A 3D virtual reality is a dynamic research domain that is a novel skill active in artificial intelligence, image processing, and multisensor technologies. The formation of the situation in a 3D virtual reality scheme is the key foundation for the simulation of a virtual world scene. The traditional interior space design is not ideal and lacks efficiency. Therefore, this research proposes an interior space virtual design technique based on 3D.

The major contributions of the proposed research include

(1) To optimize the growth of the virtual indoor scene image, match the feature points of the optimized growth view, and adopt the indoor image color rendering and optimization design based on three-dimensional vision

(2) The traditional virtual interior design method and the virtual interior design based on three-dimensional vision are comprehensively analyzed, and the simulation experiments show that the virtual interior design proposed in this paper has good visual effect and practicability

2. Related Work

At present, 3D virtual technology is widely used in the field of architecture, especially in the field of architectural interior design and decoration. Relevant designers and customers can fully feel the comprehensive layout of the building interior by using virtual technology, decorating the virtual room based on the ideas of customers, and effectively observing the specific effects of the design. Kang L Y et al. modeled the virtual interior space and designed the virtual interior space according to the built model. The shape of the actual indoor landscape is described through the dynamic space, the attribute of the indoor texture representation is analyzed by using the seed point matching method, and a virtual indoor model is built. As the basis of interior design, the model is built from the two aspects of interior decoration and interior architecture, and the dynamic browsing of a virtual interior landscape is controlled to realize the interior virtual design, though the effect of virtual interior design is not ideal because this method adopts the seed point matching method [1].

Yu Haixia proposed the display system of virtual reality interior decoration, comprehensively analyzed the significance and value of interior system design, and deeply studied the main function algorithms of the interior display system. According to the indoor house type map, the indoor landscape modeling is carried out under max, to generate the model file of FBX, and the rendering rendered by unity3D is imported into it. The related functions are developed in unity to realize the interactive function and roaming function of the display system. The virtual interior display system shows the effect of interior design on users from a comprehensive perspective. Residential users can browse the virtual interior and effectively modify the effect of interior design according to their own needs, including changing the style of the floor and the form of furniture placement or changing the color of the wallpaper.

The results of the proposal show that the use of an interior decoration display system can efficiently expand the efficacy of interior design companies and decrease financial expenses, but cannot effectively improve user satisfaction [2]. Liang Yuming et al. adopt VRML technology to design the indoor landscape of the building. The software part adopts the B/s presentation layer and business logic layer. The overall indoor scene is divided into many basic scenes by using the separation of indoor scenes. The modeling function driven by VRML database is used to build the templates of different basic scenes and indoor scenes. On this basis, VRML code is used to generate indoor virtual scenes, change the indoor wall color, and virtual mapping between ground and wall. However, this method has the problem of a poor effect on indoor design [3].

Shi Jingjing et al. proposed an indoor scene design based on three-dimensional laser imaging. The indoor face-changing display in the design adopts three-dimensional laser imaging technology. In the hardware part of the design, in the process of distance testing based on the laser, the laser rangefinder with relatively consistent parameters such as the measured distance and the measurement accuracy is selected. In the design of the software, the detection of dynamic collision must be optimized, the division method of octuple space is used to reasonably separate the imaged indoor space, and the intersection is queried through the indoor scene manager to optimize the colliding objects. The system background manually adds the conditions for judging the indoor scene and selects the indoor color space and colorator to beautify the indoor scene, to complete the design. Through verification, it is proved that this design method can effectively improve the definition of indoor images, but this design method has the problem of the complex process [4].

3. Indoor Space Feature Point Matching in a 3D Virtual Scene

The indoor space feature point matching in a 3D virtual scene is performed using the determination of the best view of indoor space based on growth optimization and virtual feature point matching of indoor space based on factorization.

3.1. Determination of the Best View of Indoor Space Based on Growth Optimization. Firstly, combined with the three-point measurement criterion of indoor space, the coordinates of any point in indoor space are defined. If all views in the indoor space participate in the growth optimization process, not only the image quality will be reduced due to too many images, but also the optimization accuracy of the indoor space image will be very low. Therefore, in the process of determining the view, only the image with high-quality needs to be selected to participate in the optimization process [5]. Select an image opposite to the growth point as the main image. The resolution of the data information provided by it is relatively high, and the amount of information contained in the image is more comprehensive. Then, select a spatial view close to the growing distance. The distance l from the camera to the point p can be expressed as

$$l = P_{w2c} \times Q\left[p_x p_y p_z\right] / f, \tag{1}$$

where P_{w2c} is the transformation matrix between the indoor spatial coordinate system and camera coordinate system; p_x, p_y, and p_z represent the coordinate components of x, y, z of p in indoor spatial coordinates; and f represents the focal length of the camera.

After defining the virtual main drawing of indoor space, select the subdrawing near the main drawing. The main drawing is mainly to improve the accuracy of indoor plane reconstruction [6–8]. The line of sight angle between the newly added image and the existing two images must be moderate. If the included angle is too small, there is a parallax defect, which will affect the results of the virtual indoor space. However, if the included angle is too large, there will be less common information between the views, resulting in poor accuracy of indoor scene matching and failure of matching results. This has a serious impact on the success rate of growth. The newly added image and the existing image form a polar plane, and there cannot be a plane between them, which is conducive to the same characteristics of indoor space scene matching and 3D virtual scene and the direction of camera motion. The above factors consider the scoring of the scene view, select the scene view with advantages, and express the scoring structure of the i picture as

$$s_i = \sum_{u\in A} \exp\left[-(\theta - u)^2/2\sigma^2\right] \times (\varphi/\theta_0), \tag{2}$$

where A represents a set of known scene images, where $u = 20$, θ represents the angle value between the two figures, φ represents the angle between the two scene maps, and the main map to form the two-level plane method, $\theta_0 = 10^\circ$, σ represents the range of viewing angle between the main drawing and the subdrawing, expressed as

$$\sigma = \begin{cases} 5\theta \le 20^\circ \\ 20\theta > 20^\circ \end{cases}. \tag{3}$$

Finally, the perspective of all indoor scene images cannot be more than 80 degrees away from the position in the direction of the P-point, and the selected scene views must ensure high similarity, and the resolution of the image cannot be too low.

After defining the main and subpictures of the indoor scene, carry out optimal growth. In this process, the position and direction of the growth point will be gradually accurate. Selecting the best view with more accurate data can be beneficial to optimization. Therefore, in this process, the images with low similarity can be replaced by one iteration, and the subimages can be replaced according to the principle of not replacing the main image of the scene, so as to ensure that the replaced subimages cannot appear again [8, 9]. After four nodes, if the angle between the last and currently selected scene main image and the growth point φ_o and φ_n, the following conditions must be met:

$$\varphi_o - \varphi_n \ge t_\varphi, t_\varphi = \begin{Bmatrix} 10\varphi_n < 30^\circ \\ 5\varphi_n > 30^\circ \end{Bmatrix}. \tag{4}$$

At this time, the main scene map must be selected again. If the main scene map changes, all the subscenes will be activated and participate in the process of map selection again.

3.2. Virtual Feature Point Matching of Indoor Space Based on Factorization. The feature points of the virtual indoor space are matched after defining the best scenic view. The traditional 3D virtual method needs to calculate the mapping matrix P_j of the scene view, which is expressed in

$$\lambda_j x_j = P_j X_j, \tag{5}$$

where x_j represents the image point of the indoor plane, X_j represents the three-dimensional point corresponding to the image point, and λ_j represents the parameter of depth. However, in the process of practical application, it cannot achieve the shooting effect without error, and some conditions such as the angle and depth between the collected indoor scene images cannot be unified. These defects will affect the effect of three-dimensional virtual.

To solve the above problems, this paper uses the iterative factorization method to match the feature points of the scene image. Using the rotating matrix R, translation vector T, and depth matrix λ, the iterative results replace the solution of the mapping matrix in the traditional way, and the algorithm is applied to the spherical coordinates, which can effectively reduce the error caused by calculating the depth of the two images.

The factorization algorithm is mainly proposed based on the environment of orthographic projection. Based on this idea, many affine and photographic model algorithms are proposed [10, 11]. According to the characteristics of the spherical coordinate system, in the environment of known indoor scene matching points but undetermined camera-related parameters, the parameters of sequential motion of scene images are obtained according to the following algorithm. If the position of the plane movement is expressed as

$$\lambda_j^i x_j^i = \lambda_j^i R_j x_j^i + T_j, \tag{6}$$

where $i = 1, 2, \cdots, n$ represents image feature points, $j = 1, 2, \cdots, m$ represents the number of images, λ represents the scaling parameters corresponding to the feature points, R and T represent the rotation matrix and translation vector, respectively, and R_j and T_j represent the changes caused by the comparison between the j indoor scene image and the first frame image [12, 13]. Multiply both sides of the above formula (6) by $\hat{x}_j^i$ to obtain

$$\hat{x}_j^i \left(R_j x_j^i + T_j/\lambda_j^i \right) = 0, \tag{7}$$

where $\hat{x}$ represents the antisymmetric matrix of x, which can be obtained after sorting formula (7). The matrix form can be represented in

$$a^i \begin{bmatrix} \hat{x}_2^i T_2 \\ \hat{x}_3^i T_3 \\ M \\ \hat{x}_m^i T_m \end{bmatrix} + \begin{bmatrix} \hat{x}_2^i R_2 x_1^i \\ \hat{x}_3^i R_3 x_1^i \\ M \\ \hat{x}_m^i R_m x_1^i \end{bmatrix}, \tag{8}$$

In formula (8), $a_i = 1/\lambda^{i1}$; convert formula (8) into matrix form shown as

$$P_j \begin{bmatrix} T_j \\ R_j \end{bmatrix} = \begin{bmatrix} a^1 \hat{x}_j^1 \hat{x}_j^1 * x_1^{1^T} \\ a^2 \hat{x}_j^2 \hat{x}_j^2 * x_1^{2^T} \\ \text{MM} \\ a^m \hat{x}_j^m \hat{x}_j^2 * x_1^{m^T} \end{bmatrix} \begin{bmatrix} T_j \\ R_j \end{bmatrix} = 0, \quad (9)$$

In the matrix of formula (9), $*$multiply for Kronecker, and the solution for calculating P_j must meet the requirement that the number of indoor scene image feature points $n \geq 6$. The following is the main process of solving R and T. Firstly, the eight-point algorithm is used to calculate R_2 and T_2. Taking the calculation result as the initial value, the following formula can be obtained:

$$a^i = -\frac{\left(\hat{x}_j^i T_2\right)^T \hat{x}_2^i R_2 s_j^i}{\left\| \hat{x}_j^i T_2 \right\|} \quad (10)$$

Obtain the original value of a according to formula (10), and normalize $a_k^i = a^i/a^1$, and then, SVD decompose P_j to obtain $R^{\sim}$ and $T^{\sim}$. At this time, the obtained result is not the standard result, but also decomposes $R^{\sim}$ twice; $R^{\sim}{}_j = U_j S_j V_J^T$ to obtain the best result and to obtain accurate indoor scene operation parameters.

$$T_j = \frac{\operatorname{sign}\left(\det\left(U_j V_j^T\right)\right)}{\sqrt[3]{\det\left(S_j\right)}}, \quad R_j = \operatorname{sign}\left(\det\left(U_j V_j^T\right)\right) U_j V_j^T. \quad (11)$$

The a of the two indoor scene diagrams is not the global solution due to the interference caused by some factors such as noise. Bring the obtained R_j and T_j into formula (12) to obtain the global solution of a^i:

$$a^i = -\frac{\sum_{j=2}^m \left(\hat{x}_j^i T_j\right)^T \hat{x}_j^i R_J x_j^i}{\sum_{j=2}^m \left\| \hat{x}_j^i T_j \right\|^2}. \quad (12)$$

The calculation process of all algorithms needs iterative processing, and the iterative process is stopped when the position error of the feature points in the virtual room is the smallest [14, 15]. After processing by factorization, an accurate and stable set of feature points of a virtual indoor scene can be obtained.

4. Interior Optimization Design Based on 3D Visual Graphics Rendering

The interior optimization design based on 3D visual graphics rendering is carried out using the indoor space graphics rendering and comprehensive design of indoor art form. The detail is provided in the subsections.

4.1. Indoor Space Graphics Rendering. The interior image is designed for 3D rendering from different 3D visual angles combined with the expressiveness of the interior design space. The gray value of the virtual imaging of the interior space is expressed as $C([a, b], R)$. The three-dimensional visual image information is removed and drawn by using the differential binary segmentation method, and the feature matching image is rendered into another surface to obtain the characteristics of the global significance component. The component of the state information of the interior design scene is expressed as

$$\sigma_2(Z; D_X) = \sum_{i>j} \left| d_{jj}(Z) - d_x\left(x_i, x_j\right) \right|, \quad (13)$$

where $d_{jj}(Z)$ represents the function of the boundary volume of indoor scene model elements and $d_x(x_i, x_j)$ represents the color component value of indoor scene state information [16, 17]. Binary segmentation is used for processing, the visual transfer is carried out in the virtual scene, and the virtual reality imaging of indoor space is segmented again. It is concluded that the indoor image segmentation method is as follows:

$$D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y). \quad (14)$$

The data of the interior design graphics sample is mainly stored in the virtual file in the form of a binary file. The recording operation code and length are defined. The function of 3D rendering of the designed background image is expressed as

$$I(u, v) = \left(\frac{1}{2} + \frac{1}{4}\left(\cos\left(\frac{\pi u^2}{R}\right) + \cos\left(\frac{\pi v^2}{R}\right)\right)\right) \times 255, \quad (15)$$

where R, as a normative constant, describes the three-dimensional objects in interior design by using hierarchical attributes and draws the effect drawing according to the specific structure of graphic rendering [18, 19]. Judge the visual range of three-dimensional space, draw a changeable database, and realize the drawing of a graphic model of interior design, to obtain the rendering process of three-dimensional visual graphics of interior design, which is shown in Figure 1.

4.2. Comprehensive Design of Indoor Art Form. Based on rendering the image, the virtual design of indoor space is optimized, and a virtual design method of indoor space based on three-dimensional vision is proposed. The analysis

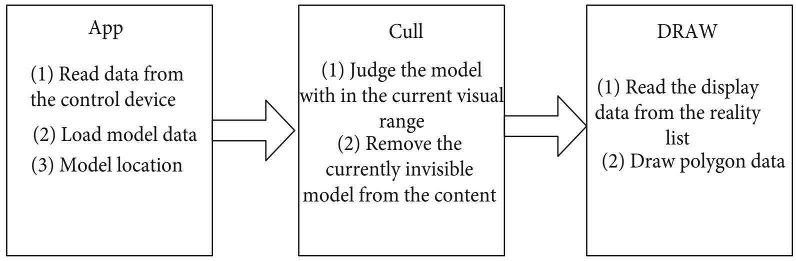

Figure 1: 3D visual graphics rendering process of interior design.

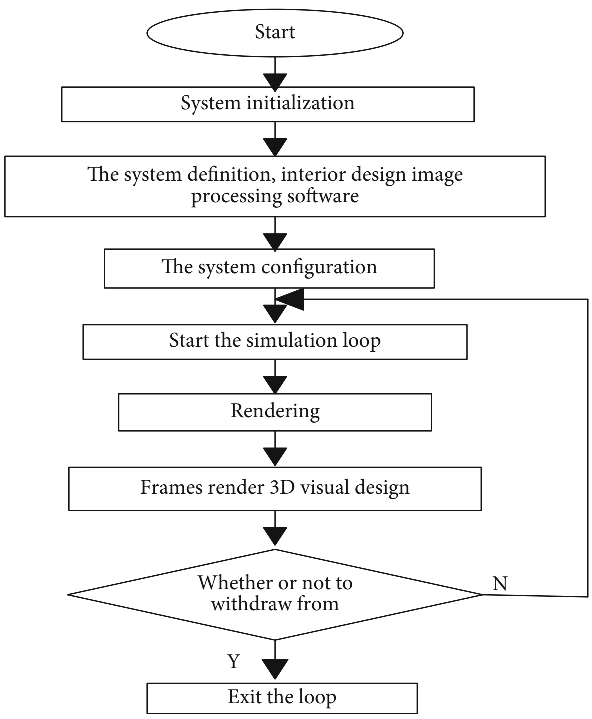

Figure 2: Design flow of interior space virtual design.

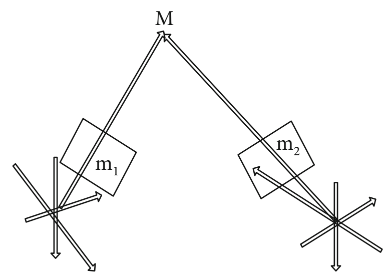

Figure 3: Schematic diagram of 3D virtual interior design.

Table 1: Experimental platform parameters.

The name of the	Parameter settings
Server system	Windows Server 2016
Server requirements	More than 4 GB memory, more than 256 GB hardware capacity
Server	Ggda-25 T5 dedicated server
Server-side database	Oracle 10 g
Client browser	IE 11.0
Client requirements	More than 2 GB memory, more than 156 GB hardware capacity
Test recording tool	Dev test tool

method of three-dimensional vision is used to optimize the indoor collocation, especially the optimal combination of indoor space color, and the visualization equation of indoor decoration color is established using

$$F_d - \frac{d}{dx} F_{d_x} - \frac{d}{dy} F_{d_y} = 0, \tag{16}$$

where F_d represents the derivative of parallax $d(x, y)$ of real-time rendering pixels and d_x represents the data of position characteristics of each pixel. The invariant moment of 3D virtual contour with spatial variation is expressed in the following equation considering the effect of indoor daylighting and lighting:

$$\begin{aligned} y &= \tilde{y} + R_t d, \\ z &= \tilde{z} + R_h d, \end{aligned} \tag{17}$$

where R_T represents the pixel points at the structural edge of interior decoration design and R_h represents the contribution level of interior furniture layout to interior space design. The overall characteristics of interior decoration design are established, and the coefficient of interior design evaluation is expressed as

$$\begin{aligned} \zeta_1 &= PA + A^T P + Q_1 + R_1 + R_2 + K_1 + K_1^T, \\ \zeta_2 &= W_1 - K_1 + M_1 + K_2^T, \\ \zeta_3 &= PB + L_1 + M_1 + K_3^T, \\ \zeta_4 &= -L_1 + K_4^T, \\ \zeta_5 &= -W_1 + K_5^T, \end{aligned} \tag{18}$$

where ζ_1 to ζ_5 represent the coefficients of indoor tone and color configuration, respectively. The interior design is carried out by using the fusion of visual information of space color background. After the fusion of visual information,

Table 2: Experimental parameter settings.

The name of the	Experimental parameters
Data amount per/GB	10-100
System memory/GB	128
Operating frequency/MHz	500
The main CPU frequency/MHz	330

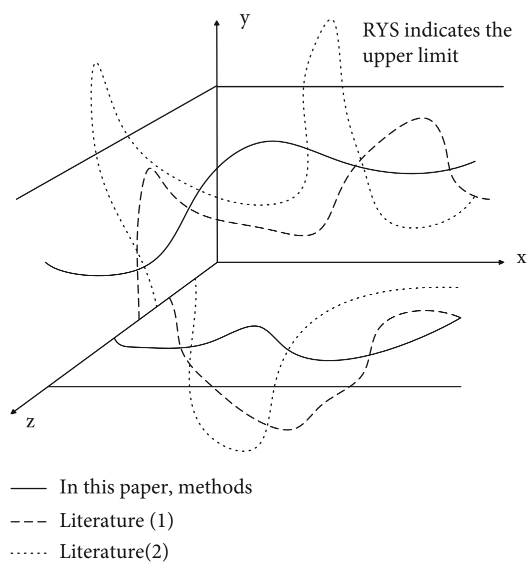

Figure 4: Horizontal comparison results of stereo image design.

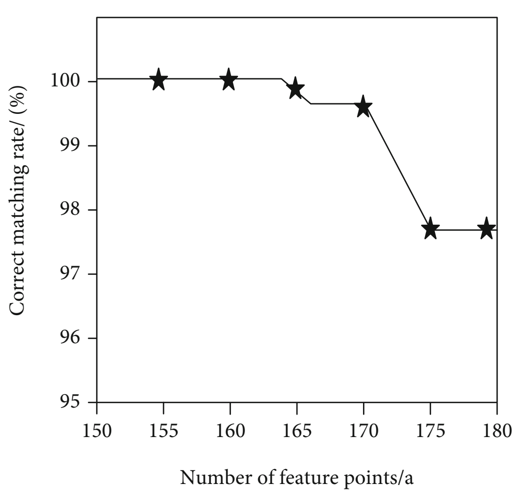

Figure 5: Feature point matching method of indoor scene based on factorization.

the output result of interior design virtual reality image is expressed as

$$\begin{cases} V_i^d(t+1) = W \cdot V_i^d(t) + C_2 \cdot R_2 \cdot \left(G_{\text{best}}^d(t) - P_i^d(t)\right) \\ P_i^d(t+1) = P_i^d(t) + V_i^d(t+1) \end{cases}, \tag{19}$$

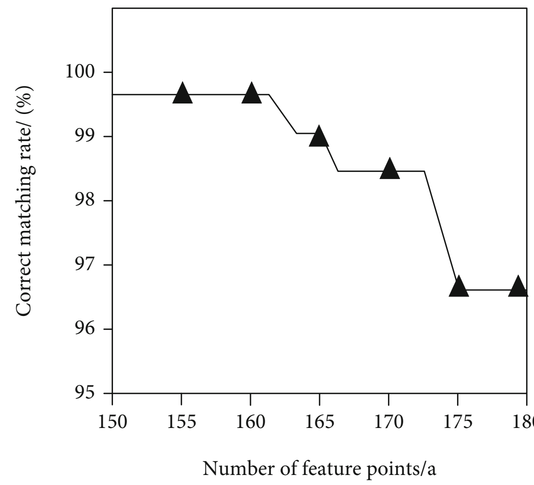

Figure 6: Feature point matching method based on the distance fusion image.

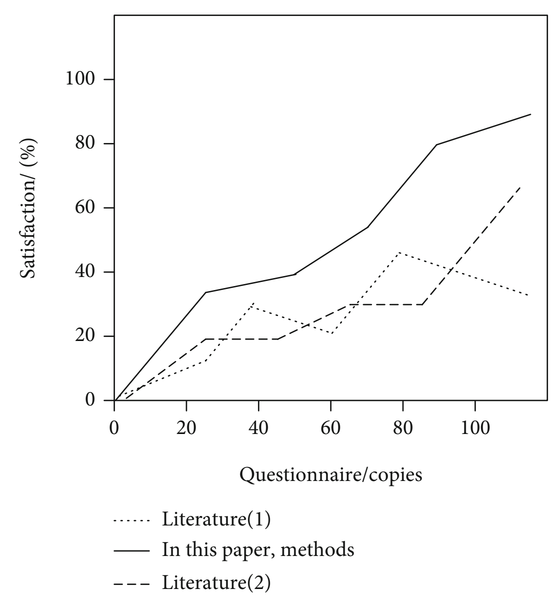

Figure 7: Different methods applied to hotel indoor satisfaction.

where $V_i^d(t)$, $V_i^d(t+1)$, $P_i^d(t)$, and $P_i^d(t+1)$, respectively, represent the coefficients of furniture decoration, lighting, color, and other element feature expression of interior design [20]. Combined with the above analysis, the visual information fusion method of spatial color background is adopted to realize interior design. The flow of interior design is shown in Figure 2.

5. Analysis of Experimental Results

The experiment builds a simulation test platform to verify the proposed method effectiveness. The simulation test platform is designed using facilities including computers, 3D liquid crystal displays, cameras, and other equipment. Figure 3 shows the schematic diagram of the three-dimensional virtual interior design. The parameters of the experimental platform are shown in Table 1, and the specific parameter settings of the experiment are shown in Table 2.

The simulation test platform is also designed to validate the ability of indoor real scene and select an actual indoor scene. The comparison of the proposed method and traditional methods to design 3D virtual scene is provided to verify the effect of different methods to design virtual interior. The level of three-dimensional interior image design of reference [1], reference [2], and the method proposed in this paper are compared, and the comparison results are shown in Figure 4.

According to the analysis of Figure 4, the level of stereoscopic image of indoor scene design method in document [2] is about 46.81%. The level of stereoscopic image design of indoor scene design method in literature [1] is about 64.42%. In this paper, the level of three-dimensional image design of interior design based on three-dimensional vision is about 87.12%. Through comparison, it can be seen that the level of three-dimensional image design of the interior design method based on three-dimensional vision proposed in this paper is significantly higher than that of the interior design in literature [1] and literature [2], which effectively proves the superiority of the interior design method based on three-dimensional vision proposed in this paper.

Figures 5 and 6 show the change curves of the feature matching accuracy of the indoor scene feature point matching method based on factorization and the feature point matching method based on distance fusion image proposed in this paper. With the continuous increase of feature points, the correct matching rate of the two feature points matching gradually decreases through the comparative analysis of Figures 5 and 6. On the other hand, the matching accuracy of the feature point matching method based on proposed factorization is significantly higher than that of the feature point matching method based on distance fusion image. The proposed method can reach 97.5% at the lowest. The lowest feature point matching method based on distance fusion image is 96.5%, which shows that the accuracy of feature point matching proposed in this paper is high.

Using the questionnaire form of the user survey, this paper examines the satisfaction of different users with different methods after the virtual design of the interior of a hotel room is applied in literature [1], literature [2], and the methods proposed in this paper, as shown in Figure 7.

We receive the gradual increase of the number of questionnaires and the satisfaction of the virtual interior design based on proposed 3D vision increases after applying the proposed virtual interior design method to a hotel room with as shown in Figure 7. The literature [1] decreases with the increase of questionnaire scores and then increases with the increase of 40 questionnaire results. However, the satisfaction has not been higher than that of the method proposed in this paper. Although the method proposed in the literature [2] has been steadily improved, the overall satisfaction is still low. Therefore, it is concluded that the three-dimensional virtual design of indoor space proposed in this paper has good color integration and visual beautification effect and has very strong practicability.

6. Conclusions

This paper proposes an interior space virtual design method based on 3D vision. This paper mainly applies 3D virtual reality technology to interior design and puts forward an interior virtual design method based on 3D vision. Firstly, select the most ideal virtual view for optimal growth, match the feature points of the virtual indoor scene based on optimal growth, design the color combination and collocation of the indoor space through the analysis method of three-dimensional vision, use the information integration of the color background of the space for indoor comprehensive design, and finally use the virtual reality platform software for simulation experiment. The practicability of the proposed method is verified. It is proved that the method proposed in this paper can effectively improve the effect and practicability of indoor space design through the simulation experiment with virtual reality platform software.

Data Availability

All the data along with the experimental results are included as part of this work.

Conflicts of Interest

We declare that there is no conflict of interest for publication of this paper.

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