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Research on color optimization and visual experience in art design of housing space

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Abstract At present, insufficient color optimization in the art design of housing space often leads to a less than ideal user visual experience. In view of the above problems, a housing space color optimization model based on virtual reality technology is proposed. Under the support of the principle of housing space color optimization and the theory of composition and layout, the overall image of the housing space scene is started to be collected using a camera acquisition, and the key points of the image in two dimensions are converted into the key points in three dimensions, after which the housing space scene model is constructed. The color of the housing space is matched by the way of cross-section ring blending, so as to achieve a better housing space color scheme design, and complete the light effect rendering processing work of housing space color design. Combining the above theoretical knowledge, the color optimization effect and visual experience of a housing construction project are evaluated and analyzed. The average gradient and image quality index of this paper's method are 25.82 and 0.87 respectively, which are much better than the other two methods, proving the application effect of this paper's method. In addition the average value of visual experience of creative users for color design scheme two is 3.84 points, which is better than scheme one, and scheme two as a whole is a bright hue with high luminance and high purity, which is more in line with the visual experience standard of creative users.

Index Terms architectural projects, housing space, color optimization model, virtual reality technology

I. Introduction

With the improvement of people's quality of life, the design of housing space to meet the basic needs of living at the same time, pay more attention to aesthetics and art. As a design form with deep historical heritage and unique artistic charm, art design not only adds a unique sense of beauty to the housing space, but also reflects the aesthetic taste and cultural connotation of the occupants [1]-[3]. In modern interior design, the application of fine art design has a wide range, from wall hangings, carpet patterns, furniture carvings to the overall decorative style, all of which can be seen in the shadow of fine art design [4
]. It can combine traditional culture with modern aesthetics to create a comfortable and artistic living space for the occupants [5], [6]. At the same time, fine art design complements the personalized needs of interior space design and can create a more unique and personalized interior environment [7], [8]. By integrating personal emotions and values into the interior space design scheme, it can make people feel the closeness of the design, while helping to create an interior space that meets personal taste and style [9]-[11]. In addition, fine art design can also have a high practical value, such as enhancing the durability of furniture through exquisite carving techniques, and utilizing traditional weaving techniques to produce unique household items [12]-[14]. By integrating fine art design into interior design, a living space with personalization, emotion and art can be created, so that people can feel the existence and power of beauty in their daily lives [15], [16].

The housing space art design scheme will affect people's experience of the housing space, and it is generally believed that the visual experience is the first factor to be considered in interior design, and space, light, material, and color are the key parts that affect the visual experience [17]. In terms of spatial layout and interior design, Shen, M. Y. et al. studied the public space layout scheme inside freestanding houses, pointing out that spatial areas connected in different ways can produce different visual connections and form stylized interior space design [18]. Wu, W. and Feng, Y. designed an automatic layout method based on convolutional neural network for spatial area design to meet users' diverse and fashionable cognitive needs for housing space by automatically generating interior layout floor plans [19]. You, Y. et al. introduced visualization and digital media technology into CAD software to generate diagram standardization and design drawing visualization for interior layout design, which enhances the visual presentation of interior design [20].

Light and Shadow Transformations and Interior Design, Ozenen, G. describes the knowledge and qualities associated with artificial and natural light sources and their application in building functional, aesthetically pleasing and sustainable interior spaces [21]. Kong, Z. et al. showed that creating comfortable lighting environments in interior design will effectively enhance the occupants' lighting experience and thus improve the quality of the indoor living environment [22]. Yin, R. Optimization of indoor lighting design using environment-aware algorithms can significantly improve indoor environmental comfort and energy use efficiency by automatically adjusting the lighting state according to environmental factors compared to traditional lighting design using fixed patterns [23].

With regard to decorative materials and interior design, Zeng, J. and Jiang, M. analyzed the functional position and artistic characteristics of decorative materials, which as a design language can reflect certain cultural significance and spiritual connotations, and not only improve the artistry of the indoor environment, but also fully satisfy people's aesthetic needs [24]. Cao, C. showed that it is possible to synthesize the visual representation of interior decorative materials in many ways through big data technology, thus significantly enhancing the artistic characteristics of interior design and reflecting people's artistic intelligence and level [25]. Liu, X. D. et al. analyzed the significance of the influence of textile texture in interior decoration, in addition to the material color, pattern, and emotional aspects of interior design [26].

In terms of color style and interior design, Lin, J. et al. developed a C3 Assignment system for the color design problem of indoor 3D scenes, which can provide diversified suggestions to satisfy the overall and local color design rules to ensure that the user has a comfortable visual experience in the indoor scenes [27]. Guo, S. et al. introduced a progressive color design scheme for indoor scenes based on visual attention, and the proposed proposed view selection method, preference inference model, and creativity support mechanism were presented to satisfy users' personalized color needs under different views [28]. Shan, W. L. et al. explored interior decorative color design based on an improved AlexNet network, which effectively promoted traditional Chinese culture and the international dissemination of Chinese colors by applying Chinese decorative color elements to interior design [29]. Liang, T. et al. used a deep learning model to extract feature data linked to color in interior spaces, and subsequently generated color design solutions with color balance and aesthetic features to meet people's visual and aesthetic needs [30].

Color elements and housing space design complement each other, and the reasonable use and combination of color elements is an important way to show the designer's innovative thinking and design themes [31]. With the development of the times, the traditional architectural housing space design has gradually exposed the problems of insufficient attention to color elements, single form of color elements application, and lack of innovation [32]-[34]. With the rapid development of the global economy and the increasingly close cultural exchanges between countries, people have put forward new requirements for the style of housing space design and the application of color elements, which accelerates the innovation and optimization of the color elements of housing space design to meet the diversified needs of consumers [35]-[37]. Designers need to be based on modern people's consumer psychology and the pursuit of color, innovative color elements content and design methods, to improve the application of color elements to meet consumer demand, and promote the rapid development of the architectural interior design industry [38], [39]. Therefore, it is imperative to innovate the application of color elements in architectural interior design.

In this paper, on the basis of the traditional housing space color design, the introduction of virtual reality technology to optimize it, so that its design works more in line with the current user visual experience needs, as the innovation point of this research. First of all, the color optimization principle in housing space art design is expressed in detail to provide solid theoretical support for the following research work. Under the constraints of the layout of the housing space, virtual reality technology is used to complete the construction of the color optimization model under the concept of housing space art design, and in order to make the color richness of the housing space more realistic, it also carries out light rendering processing. Finally, a housing building is selected as a reference to explore and analyze the color optimization effect and visual experience of the housing.

II. Color optimization and visual experience in housing design

II. A. Principles of color optimization in art design of housing space

II. A. 1) Principle of Integral Unity

Colorful colors seem to be opposed to each other but well ordered in the housing space, we can only make better use of this relationship in order to create a good atmosphere in the interior space. The closer proximity of hue, brightness and purity means that the coordination of colors makes the space have a sense of defiance, but improperly handled, it will make the space look bland, monotonous and empty [40]. Therefore, designers can comply with the principle of overall unity only by contrasting in harmony, where the contrast refers to the contrast between warm and cold, light and dark, and purity of colors.

II. A. 2) The principle of emotional experience

The famous British physicist Isaac Newton decomposed sunlight into six colors of red, orange, yellow, green, blue and violet through a prism, revealing the principle of light color and laying the foundation for the study of color [41]. The color of the living environment can directly affect people's psychological and physiological activities, create an environmental atmosphere, satisfy visual aesthetics, and regulate indoor light. Different colors have different effects on human emotions and psychology. When dealing with the color relationship of the housing space, the emotional appeal of the color should be fully considered. Modern minimalist style indoor space hues are mostly white, forming a brighter overall spatial atmosphere, how to harmoniously match the color has become the key to the design. Relative to the form of the object, the human senses are more sensitive to color perception, people are surrounded by the environmental color at all times, people's emotional fluctuations and spiritual changes are not affected by the color, therefore, the reasonable collocation and use of color, to meet the emotional appeal of the color of the people in the design of housing is extremely important.

II. A. 3) Principle of functional requirements

In the housing space art design, advocating the abandonment of all the redundant elements, emphasizing the unity of technology and art, under the premise of focusing on the use of function, the color palette is particularly important to the creation of the atmosphere of the interior space. Higher brightness colors can create a bright, open atmosphere. Lower brightness of the color and darker light environment, it gives people a “private” atmosphere.

II. B.Layout of the spatial composition of housing

II. B. 1) Spatial function and layout

The core of the housing space design program is first of all a reasonable layout design, in the program planning, first of all, we must consider the views of the owners, according to the owners of the idea and the actual structure of the space for the combination of the use of scientific design methods, to meet the needs of the owners. In the design, all the decorations, furniture and electrical appliances should be placed first to consider the safety, especially the home of the elderly and children, how to do to avoid wires and chemicals is to be carefully considered. To achieve the right proportion, to the comfort of the living room as a starting point, to facilitate human activities, the use of space height, reduce waste, regardless of the size of the room, there should be clear routes of activities, will be the layout of the design of novelty, to give people psychological and emotional satisfaction, give full consideration to temperature and humidity, lighting, noise and other aspects of the factors. Bedroom as the center of the family, need to reasonably arrange the location of living, visual effect and space scale are good, clear function. Choose a reasonable blend of colors, suitable for human physiological needs, distinguish between the primary and secondary colors of the housing space, the variety should not be too much, more appear to be more chaotic, only color matching is reasonable, can bring out the atmosphere of the environment and increase the artistic atmosphere. The choice of furniture depends on the family group activity needs, choose the right style.

Dining room kitchen auxiliary glass sliding door, forming a whole design, cooking the room door closed, the smell of fumes through the hood out the window, in order to ensure the prevention of fumes infested with other spaces at the same time eliminating the sense of closure of the kitchen. After integration with the dining room, the two parts are more closely linked and easier to use, making the space open and active, which is conducive to increasing the sense of comfort. The kitchen adds a social function on top of the original function, which increases the available space for food cooking to a certain extent, and at the same time, dramatically expands the channels of communication with friends and relatives, sharing the fun of cooking and enhancing communication.

II. B. 2) Overall spatial configuration

Vision is the result of the integration of visual physiology, visual experience and sensory functions. In the actual design, it is necessary to give full consideration to the visual integration of the actual experience, and correctly recognize the psychological holistic analysis of Gestalt to grasp the wholeness of the form. Art design needs to be a variety of forms according to the inherent law of re-polished combinations, a bunch of scattered scenery without any sense of art, there is no inherent law, different combinations will change the nature of the formal factors, bringing different overall form effect.

II. C.Optimizing the use of color in housing spaces

II. C. 1) Color composition of housing spaces

Furniture products color here focuses on the living room furniture and home appliances and other products and indoor combined surface, the color of other indoor furnishings co-exist in a space, if the entire housing space environment color harmony is better, the formation of an organic whole, then it will make people produce a strong sense of pleasure. And messy color matching will make the overall living environment space becomes fragmented,

let a person feel irritable, uncomfortable and so on. Home appliances is one of the housing space is very important body, its color affects the home color coordination issues, the same kind of home appliance color selection or placed in different locations, but also able to show a different family atmosphere, to provide a variety of interests. Home appliances need to match the main color of the home space environment from the overall macro-control, can not only consider the color of the home appliances themselves, should consider more of its surrounding environment color relationship, so that their color relationship to become a part of the living tone, and occupies the main role.

Color contrast and color harmony is the main way to achieve the color of home appliances and living environment color unity and coordination. Color contrast refers to a variety of colors in the simultaneous existence of environmental conditions, due to the mutual influence of the characteristics of the prominent or change the situation, as long as the visual sense of the object in front of the color contrast is indicated at the same time. Color contrast is divided into light and dark contrast, color contrast of warm and cold, material texture contrast and so on. Housing space will be more layers, more styles of change, so as to form a different family atmosphere. The use of good contrast, can effectively enhance the overall environment of the housing space in the visual consistency and pleasant, such as white sofas and the ground covered with black and white mats of the contrast can be the atmosphere of the space will be vivid.

Hue of the reconciliation mainly refers to the two sides of the color integration of a way, similar to color matching, so as to form a high degree of unity. If the theme color in the housing space is white, then in terms of lighting and wood flooring also choose close to white accents, it will give a person a kind of simplicity, clean, generous psychological feeling. The overall white color can also be matched with gray carpets, dark windows and doors, etc., the whole will look more peaceful and high-end. For some small furniture, you can use complementary color design, enhance the sense of color contrast, the use of complementary color backing at the same time will have more visual impact, people once a long time to stay in a certain theme color of the environment, will be other with the demand for color, to achieve visual perception balance.

II. C. 2) Housing space color environment

From a psychological point of view, in the human consciousness, the feeling is not alone, but a number of senses and some kind of feeling coexist, and interconnected with each other, people through the senses from the surrounding environment to obtain all kinds of information, each kind of feeling is only a small part of the many environmental information obtained, more than one part of the joint role of the mutual influence, the human being can be harmonized with the environment. Color can cause emotion, which is based on hue, brightness, saturation and other three objective elements outside the derivation of the feeling. For example, Black Foley Ath Bridge, comprehensive black, suicidal people choose this place the probability of a large increase, when it becomes green, the probability of suicide fell by 30%, no coincidence, San Francisco Golden Gate Bridge because the whole body is red, the same suicidal people are many. Although the two are constructed differently, the color is different, but the impact on the suicidal tendency of people is basically the same, visible color in red and black two kinds of people's emotional impact is the biggest, black easy to make people water deep, red easy to produce behind the push feeling, and green will make people's emotions more soothing. So color is very important to the psychological role of people, in the design of housing space needs to focus on.

II. D. Virtual reality-based art design for housing spaces

II. D. 1) Model creation for housing space scenes

The first prerequisite for the art design of housing space is to create and integrate the corresponding overall model of the housing scene, to be able to model the appearance of the housing home furnishings and the overall spatial layout through the model. The following is a detailed description of how the housing space should be modeled, first of all, we need to determine the key points in the two-dimensional space, set the key points in the two-dimensional space as (x, y). Then:

$$x = \overline{x} + \alpha N_1 \tag{1}$$

$$y = \overline{y} + \alpha N_2 \tag{2}$$

where, α is the corresponding description control parameter. N_1 denotes the pattern matrix that describes the overall scene changes in the room. N_2 represents the description matrix of the corresponding texture change. The description control parameter α changes the overall contour of the corresponding scene and the corresponding texture also changes, so as to obtain the coordinates of the key points of different indoor scenes in two-dimensional space. After the conversion is completed, the camera position can be set, Figure 1 shows the schematic diagram of the camera position setting. After the camera position is set, the overall image of the housing space scene is acquired. Taking FIG. 1 as an example, wherein D is defined as the main feature point corresponding to the home

furnishings in the housing space, and the corresponding camera imaging point is positioned at two points D_1 and D_2 at 90° to each other, wherein the straight line O_1D_1 intersects with the straight line O_2D_2, and the intersection point is D. When image acquisition is performed, the z axes of the coordinate system corresponding to the housing space pose coincide with the z axes of the camera, and the x axes of its coordinate system coincide with the x axes corresponding to the camera's coordinate system. Define β as the focal length corresponding to the camera and l as the shooting distance corresponding to the camera. The conversion of key point (x, y) in 2D space to key point (x, y, z) in 3D space can be obtained by the following equation:

$$r_1 = \frac{\beta}{l - x} y \tag{3}$$

$$s_1 = \frac{\beta}{l - x} z \tag{4}$$

$$r_2 = \frac{\beta}{l - (x\cos\alpha + y\sin\alpha)} (y\cos\alpha - x\sin\alpha) \tag{5}$$

$$s_2 = \frac{\beta}{l - (x\cos\alpha + y\sin\alpha)} \tag{6}$$

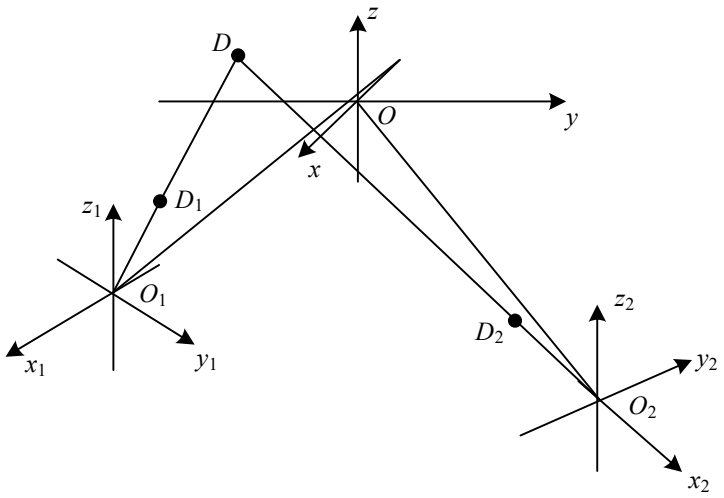


Figure 1: Position setting diagram

II. D. 2) Color optimization and design

After the construction of the housing scene is completed, the color of the housing space is matched with the help of the cross-section ring blending method, and Figure 2 shows the schematic diagram of the cross-section ring blending method.

First, the three points corresponding to the target task are harmonized. Define $O_{a_0b_0}[M_0]$ as the corresponding base color point, then the two reconciled color points corresponding to the base color point are $O_{a_1b_1}[M_1]$ and $O_{a_2b_2}[M_2]$, where $a_0 = a_1 = a_2$, $b_0 = b_1 = b_2$, and $M_0 \neq M_1 \neq M_2$. Then the radius of the color ring corresponding to point $O_{a_0b_0}[M_0]$ can be defined as R, and the radius of the color ring is $x^2 + y^2 = R^2$, and $z = z_0$. After that, calculate the angle between $b = 0$ planes and its angle γ, the formula is as follows:

$$\gamma = \arctan(y_0 / x_0) \tag{7}$$

After obtaining the color ring points in the plane, it is necessary to convert them into three-dimensional space, and the conversion formula is as follows:

$$O'_{ab}[M] = O_{ab}[M] \times z \tag{8}$$

$$O'_{a_1,b_1}[M_1]=\left(-\frac{\sqrt{3}}{2}R,-\frac{1}{2}R,z_0,1\right) \tag{9}$$

$$O'_{a_2,b_2}[M_2]=\left(\frac{\sqrt{3}}{2}R,-\frac{1}{2}R,z_0,1\right) \tag{10}$$

where, z is the corresponding vertex, and if the corresponding vertex $z=3$, the coordinates of the blending point of the color ring corresponding to it are:

$$O_{a_1,b_1}[M_1]=z^{-1}\times O'_{a_1,b_1}[M_1] \tag{11}$$

$$O'_{a_2,b_2}[M_2]=z^{-1}\times O'_{a_2,b_2}[M_2] \tag{12}$$

By the above steps can further match and optimize the housing space color, so as to achieve better housing space color scheme design.

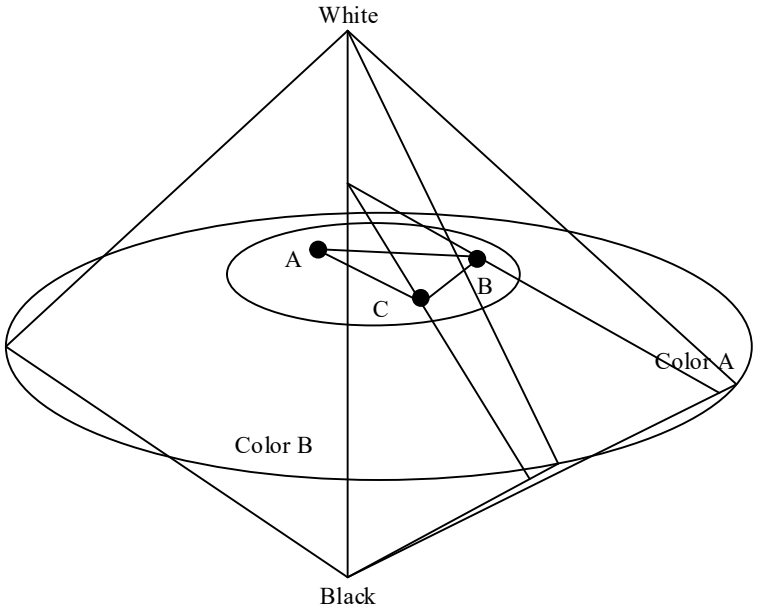


Figure 2: Schematic diagram of annular harmonic mode of cross-section

II. D. 3) Light rendering processing

In the part of light rendering processing, the main light's rendering for the color of housing space is mainly studied [42]. The main light rendering of the overall scene of the housing space is realized by calculating the light refraction, light reflection and its direct radiant brightness corresponding to the main light of the housing space. The equations corresponding to radiant luminance are as follows:

$$\begin{aligned}W(x,\rho)&=W^{\rho}(x,\rho)\\&+\int_{\phi}W\left(\vartheta\left((x,\rho'),\rho'\right)\cos\beta' f_f(x,\rho'),\rho\right)d\rho'\end{aligned} \tag{13}$$

where, $W^{\rho}(x,\rho)$ denotes direct radiation from the same point in the same direction. $W(x,\rho)$ denotes the radiance corresponding to a specific point x in the housing space along the ρ direction. $\int_{\phi}W\left(\vartheta\left((x,\rho'),\rho'\right)\cos\beta' f_c(x,\rho'),\rho\right)d\rho'$ describes the indirect light corresponding to light refraction and light reflection. Define u as the distance from the floodlight light to the plane, k as the radius of the attenuation distance of the distant light, and g as the corresponding display light distance. If there exists a line segment n perpendicular to the light source on the x-axis, and the corresponding number of light sources is m, then the corresponding luminance of the light is obtained according to the following equation:

$$W\left(x_j\right)=\sum_{j=1}^{m}W_j\left(x_j,\rho_j\right) \tag{14}$$

In summary, the simulation effect of indirect light is obtained, and the light feeling of perfect color brightness in the art design of housing space is realized.

III. Exploratory Analysis of Housing Color Optimization and Visual Experience

III. A. Overview of housing construction projects

III. A. 1) Geographical location

The housing construction project is located in a county of a city in a province, adjacent to City A and City B, with obvious location advantages. It is about 100 kilometers away from City A, within two hours' drive, and within 150 kilometers away from City B, within three hours' drive, close to the Beijing-Harbin Expressway, with convenient transportation, and mainly serves housing users from both City A and City B.

III. A. 2) Development orientation

The housing project studied in this paper is dedicated to creating an all-age, all-supportive, family-friendly, healthy and beautiful housing environment, and has created a unique courtyard-style housing model that provides high-quality visual experiences for housing users from City A and City B through high-quality services. The interior facilities of the housing are fully equipped to meet the visual experience needs of the users for cultural activities, social activities, recreation and other visual experiences.

III. B. Exploratory Analysis of Housing Color Optimization

III. B. 1) Experimental environment

The configuration required to run the Interior Color Virtual Model is shown below:

Processor: Inter Pentium 4 or AMD Athlon 64.
Operating system: Windows 7 Home Bas, WindowsXP.
Memory: 2GB DDR3.
Monitor: 1024*768 resolution, 16-bit or 32-bit color monitor.
Hard disk: at least 500G (more hard disk space is recommended).
Installed software: DirectX 9.0, Flash Player.

III. B. 2) Color optimization results of the method in this paper

In this section, through the method of this paper on the design of color in the art design of housing space, first of all, the indoor scene is modeled, taking the living room as an example, to construct the indoor three-dimensional model. The use of the camera for two-dimensional image acquisition, and then the plane graphics into a three-dimensional model, after completing the design of its color, the three-dimensional model rendering. Three-dimensional modeling should be in line with the premise of practical function, to fully consider the spatial relationship between the furniture and the indoor environment in the plane layout. The 3D plane in 3D modeling is the basis for the construction of the indoor 3D scene, the living room space can be determined by polygonal modeling on the 3D plane, the position and scale of the living room sofa, table and chairs can be determined, and the shape of the window wall can be obtained through Boolean calculation, as shown in Figure 3. After obtaining the spatial proportion and scale, other props in the indoor scene need to be detailed.

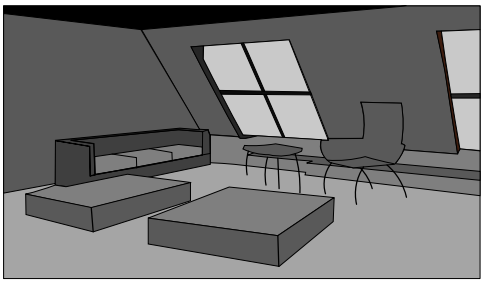


Figure 3: Indoor 3D scene modeling

The edge line of the sofa is selected, and the softness of the sofa is controlled by adjusting the radius of the chamfer and the number of chamfering surfaces. For the props with special shapes in the scene, such as the chair,

we use the tuning point method to roughly adjust the plane shape of the chair in the production process, select the surfaces that need to be extruded, extrude the shape of the armrests of the chair, and combine the scaling tool, rotary tool, moving tool, and comprehensively utilize the stripe point method and the extrusion method to obtain the shape of the chair. After ensuring the structural accuracy of the chair's shape, use the Smooth command to derive the chair's shape. As shown in Figure 4 below, the chair modeling based on the 3D planar surface, using the tuning point method and the extrusion method are shown respectively.

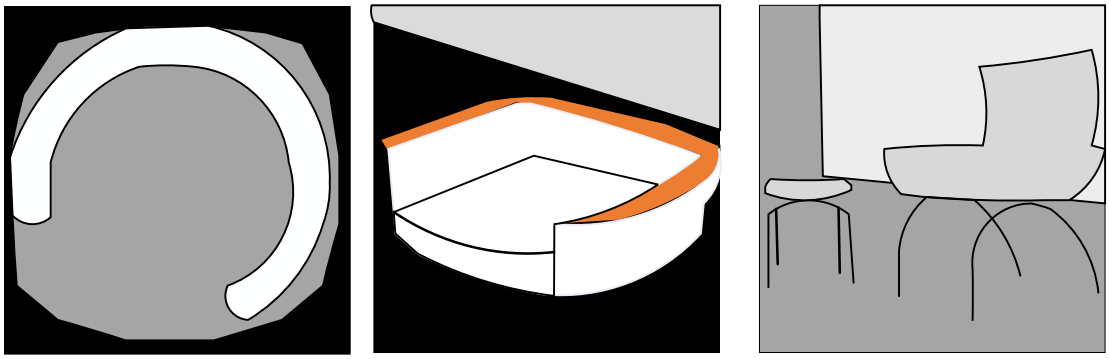


Figure 4: Optimize details

The last step in the construction of the interior scene model is to add embellishments and enrich the details. In the model surface conditions allow, you can add some appropriate embellishments to liven up the picture, in this link, I added oranges, wine glasses, books, fruit plates, windows and other details, and according to the composition needs to adjust the scene within the relevant props placed, the final effect is shown in Figure 5.

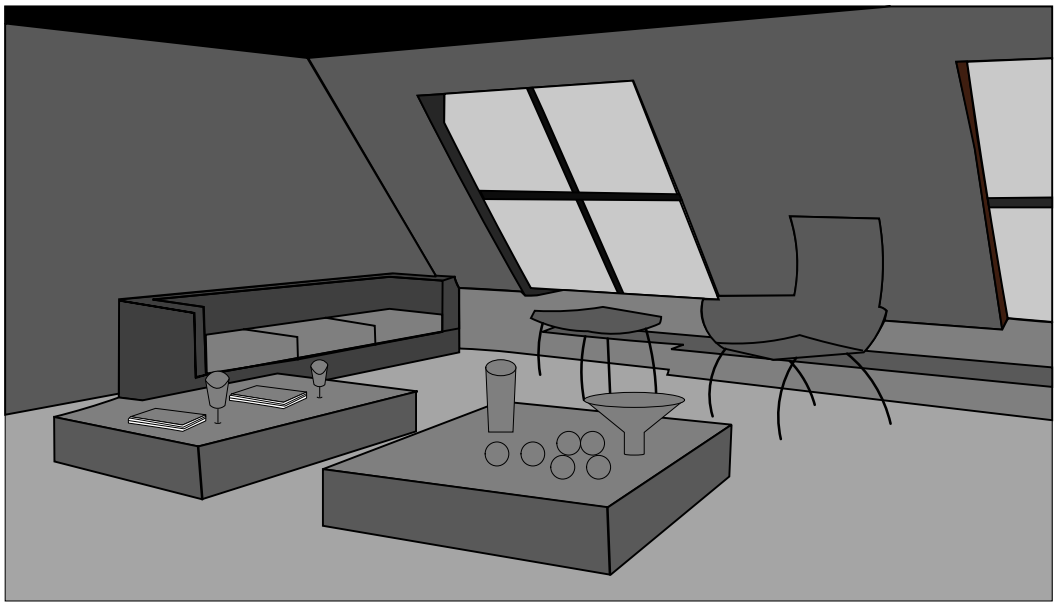


Figure 5: Final effect

In order to facilitate a quick and intuitive color scheme, this session assigns a different material sphere to each of the furniture in the living room. The added materials are shown in Figure 6. In order to improve the speed of operation and reduce the model beam, the material balls are differentiated by color, and no overlaying of material balls is done. Give the created material balls to the living room wall, floor, table, chair, sofa and other related props respectively. Lock the camera, select the part of the scene model that needs to be exported, and export it to a recognizable OBJ format. In order to adjust the environment color scheme as a whole, the model exported in this session is the overall scene model. In addition to the overall model of the scene, combined with the interactive characteristics of the wood system, you also need to export each scene formation separately, and the material of each object needs to be consistent with the overall model of the material. In Key Shot software, import the OBJ

scene file in Maya, adjust the direction and angle of the model, select the appropriate camera lens, and lock the lens.Key Shot software provides a relatively rich material library and lighting environment.Key Shot in the material has been pre-set up the material surface color, gloss, light and dark, texture, transparency, and in the overall scheme of the scene. In terms of color scheme, this case in the color logic on the basis of the material library to achieve the color scheme. Analysis of the interior color design process of this paper's method shows that the method of this paper can effectively achieve interior color optimization, with a strong sense of realism, which helps designers to more intuitively display the design work.

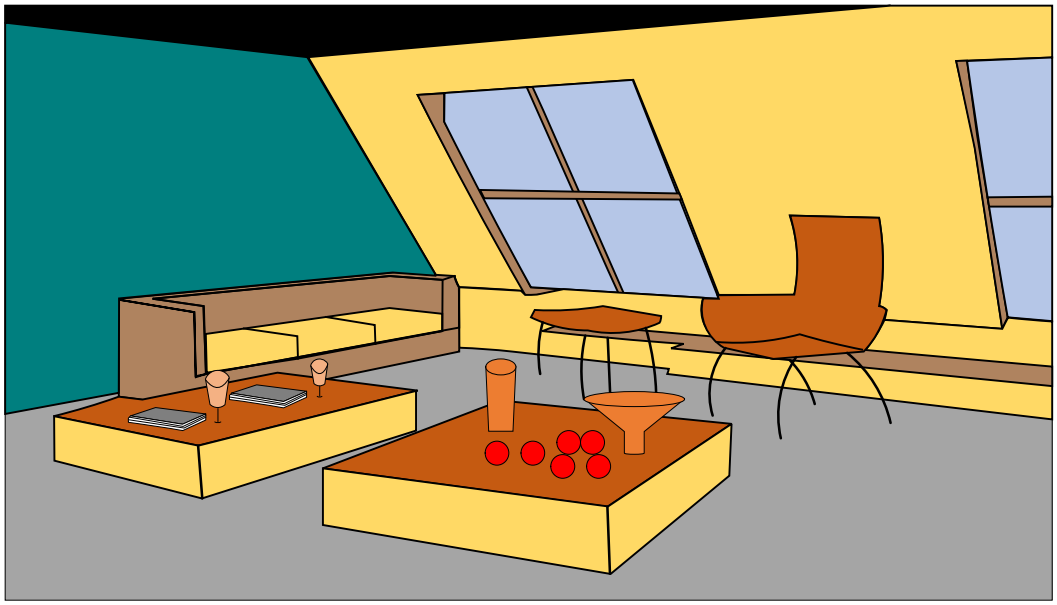


Figure 6: Increase the material

III. B. 3) Comparative testing of optimization results

In order to verify the effectiveness of the color optimization results of this paper's method, 50 designers are selected, so that the designers use this paper's method, CACD method and color conversion relationship method to design the color of the housing space, respectively, and evaluate the quality of the design work by evaluating the gradient and UIQD, and take the average value of the test results of the evaluation indexes as the evaluation results. The average gradient is the embodiment of the image tiny detail contrast and texture change characteristics, the larger the average gradient, the smaller the detail contrast and texture change is considered, the formula is described as follows:

$$\overline{G}=\frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\sqrt{\left(\Delta I_x^2+\Delta I_y^2\right)/2} \tag{15}$$

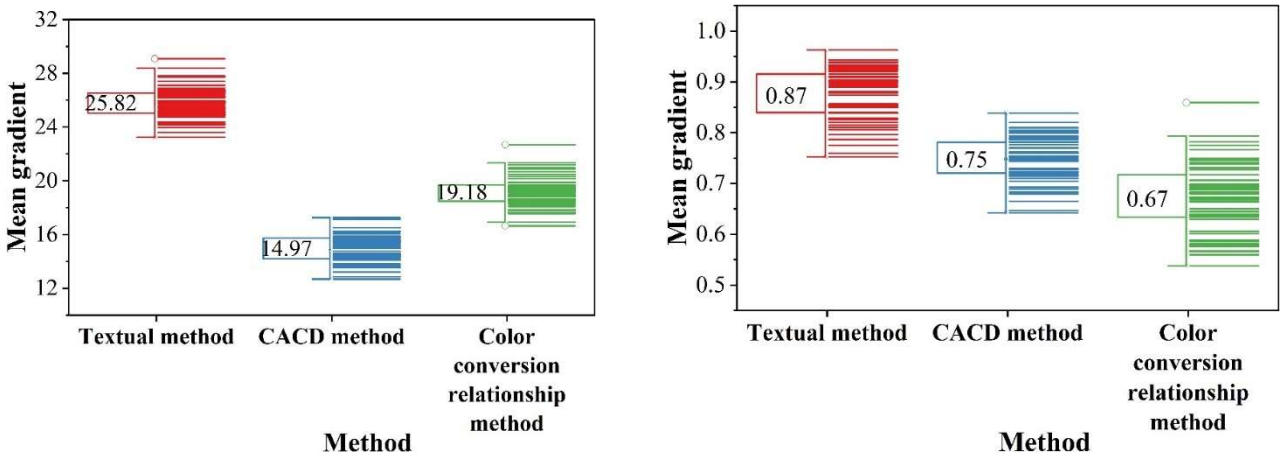
where ΔI_x and ΔI_y represent the difference between x and y directions in turn, and M and N represent the pixels, UIQD is the image quality index, which is a reflection of the visual quality of the human eye, and the higher the value, the higher the visual quality of the human eye is considered to be, and it can be found out by the following equation:

$UIQD$ is the image quality index, which is a reflection of the visual quality of the human eye, and the higher its value, the higher the visual quality of the human eye is considered to be, which can be derived from the following equation:

$$UIQD=\frac{4\sigma_{xy}\mu_x\mu_y}{\left(\sigma_x^2+\sigma_y^2\right)+\left(\mu_x^2+\mu_y^2\right)} \tag{16}$$

where σ_x, σ_y and σ_{xy} represent the gray scale variance and covariance of the image in different directions, respectively, and μ_x and μ_y represent the image color values.

The evaluation results of the three methods of housing space color optimization are shown in Fig. 7, where (a) ~ (b) are the average gradient and image quality index, respectively. Through the housing space color optimization design works designed by the method of this paper, the average gradient and image quality index are significantly higher than the CACD method and the color conversion relationship method, which indicates that the method of this paper is good for housing space color effect, and verifies the effectiveness of the method of this paper.



(a)Mean gradient (b)Image quality index

Figure 7: Evaluation results of indoor color optimization by three methods

III. C. Exploratory Analysis of Visual Experience

Through the exploration and analysis above, the effectiveness of the color optimization model of housing space based on virtual reality technology is confirmed. The next step is to use the above color optimization model to carry out color design for a certain housing, and put forward different color designs for different experience users, which are the housing color design for calm users, the housing color design for focused users, and the housing color design for creative users. On the basis of the three kinds of color design, visual experience exploration and analysis is carried out. The detailed analysis process is as follows:

III. C. 1) Color scheme for peaceful users

In the calm user's housing space color design scheme 1, the wall color using Pantone color No. 601U light yellow paint, the floor and table furniture using light curry and light yellow, curtains and carpets using light pink with light yellow, the overall color design of the interior is high brightness and low purity of the simple tone. In the second color design scheme of the housing space of the calm type users, the wall color uses the light yellow paint of Pantone No. 7499U, the floor and table furniture use light curry and light yellow-green, the curtains and carpets use light purple with light blue, and the overall color design of the interior is a bright tone with high brightness and low purity.

III. C. 2) Color scheme for focused users

In the focused user's housing space color design scheme one, the wall color using Pantone color number for Pantone 304U light blue paint, the ground and furniture table and cabinet were used dark grey and light grey, curtains and carpets gray with light blue, color tone and belong to the color system, tone and belong to a similar tone, the overall color design of the interior is high brightness and low purity of the bright tones. In the focus of the user's housing space color design scheme two, the wallpaper color using beige paint, the ground and furniture tables and cabinets were used curry and light brown, curtains and carpets are used Vp tones of yellow-green, the overall color design of the interior is high brightness and low purity of the bright tones.

III. C. 3) Color schemes for creative users

In color design scheme one of the housing space for creative users, light yellow is used for the floor and wooden furniture, when the carpet and curtains are two-tone color matching, the wall and curtains use the same color tone, and the wall tone is slightly lighter than the curtains, the wall color uses Pantone 127U light yellow paint, the curtains and carpet use B-tone orange with V-tone green, and the two-tone color of the soft furnishings belongs to the medium-difference color scheme. In color scheme two, the wall color uses beige paint, the floor and table cabinet

use light yellow and light curry, the curtains and carpet use V tone of light yellow and B tone of high purity and high brightness of orange.

III. C. 4) Visual Experience Evaluation of Different Design Options

Using the questionnaire survey form based on the semantic difference method, each group of users was evaluated by a return visit, and each group of users was asked to subjectively evaluate the color design scheme of the housing space based on 7 pairs of visual semantics based on "simple-complex", "refreshing-warm", "modern-traditional", "bright-dark", "spacious-crowded", "energetic-steady", "harmonious-abrupt", and the closer to the left visual word was selected 5 points, and the closer to the right visual word was selected 0 points. The critical value of the visual evaluation results is 2.5 points, the mean result is less than 2.5 points, which means that the design solution is more inclined to the left side of the visual, and the mean result is more than 2.5 points, which means that the design solution is more inclined to the left side of the visual. And the more the result is inclined to 0 points, it means that the design scheme is more strong to the right side of the vision. Questionnaire reliability test using SPSS software, get Cronbach's α coefficient = 0.781, scoring data reliability, accept scoring sample reliability.

Figure 8 shows the results of the visual experience evaluation of the two schemes by peaceful users, and it can be seen from the data in the table that the scores of scheme 1 in each group of visual vocabulary exceeded the critical value of 2.55 points, and the average score of the overall visual evaluation of the seven groups was 3.63 points, while the average score of scheme 2 was below 3 points except for the "energetic and stable" visual score. The scores of the other six groups of semantic words were also above 2.55 points, and the average value of the overall visual evaluation of scheme 2 in the seven groups was 3.42 points, indicating that the color design schemes of the two groups met the visual expectations of the users in this group, but scheme 1 was more popular with such people than scheme 2.

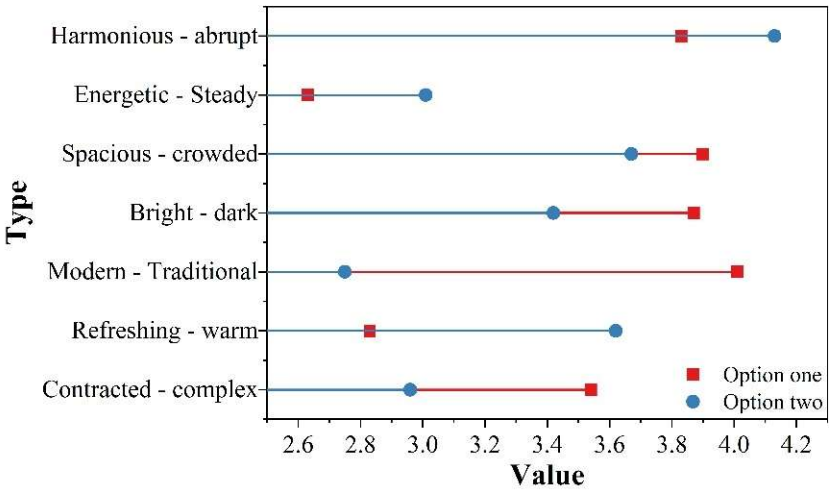


Figure 8: Statistics of visual evaluation results of peaceful users

Similarly, Figure 9 shows the results of the visual evaluation of its two schemes by focused users, and it can be found that the scoring of Scheme 1 in each group of visual vocabulary exceeds the critical value of 2.55 points, and the mean value of the overall visual evaluation of the seven groups is calculated to be 3.43 points, and similarly the mean value of Scheme 2 in the overall visual evaluation of the seven groups can be calculated to be 3.74 points, which indicates that both groups of color design schemes are in line with the visual expectations of this group of users, but Scheme 2 is more popular than Scheme I is more popular with this group.

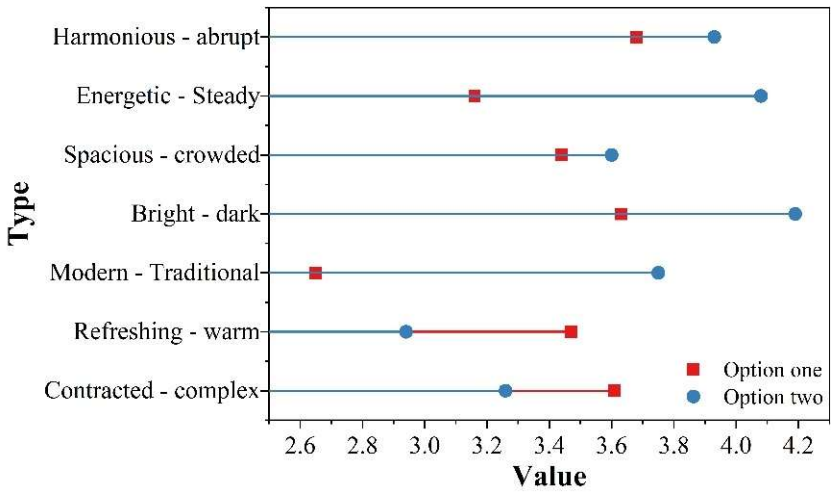


Figure 9: Statistics of visual evaluation results of the solution by focused users

Figure 10 shows the visual evaluation results of the two schemes of creative users, it can be found that the score of scheme 1 in each group of visual vocabulary is above the critical value of 2.55 points, and the average value of the overall visual evaluation of the seven groups is 3.26 points, and the average value of the overall visual evaluation of scheme 2 in the seven groups is 3.84 points, indicating that the color design scheme of scheme 2 meets the visual expectations of the group of users, but the first group scores slightly lower in the dimension of the word "simple-complex". The reason for this may be that the yellow saturation is too high, and the yellow purity of the curtain can be slightly reduced in the later stage to enhance its "simple" vision, but the average score is also more than 2.55 points, indicating that the overall evaluation of the interior color design of the housing space has met expectations.

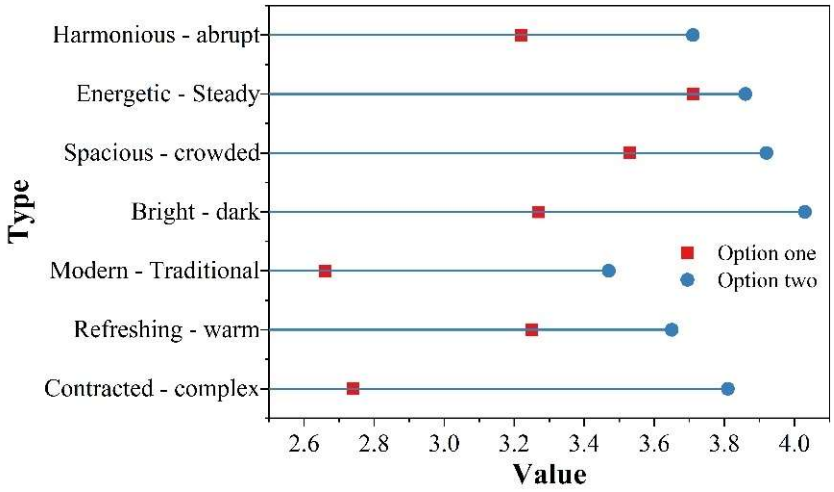


Figure 10: Statistical results of visual evaluation by creative users

Through the above analysis of the visual evaluation experimental results of the housing space color design solutions, it shows that the overall evaluation of each group of design solutions meets the expectations, proving that the method of this paper is effective and feasible, so that the space color design solutions can meet the standards of the user's visual experience.

IV. Conclusion

From the perspective of housing space composition and layout, this paper combines the principle of color optimization with virtual reality technology to jointly construct a color optimization model under the framework of housing space art design. A housing construction project is selected as the research case of this paper, and then with the help of data analysis tools, the color optimization and visual experience of this case are explored and analyzed respectively. Compared with the CACD method and the color transformation relationship method, this

paper's method has a higher priority in the color design of housing space, which proves the effectiveness of the color optimization design scheme for housing supported by virtual reality technology. The analysis of users' visual assessment of different housing color optimization designs is also supplemented. In the color design for calm users, the mean value of users' visual experience of Scheme 1 is 3.63 points, and the mean value of users' visual experience of Scheme 2 is 3.42 points, which can be summarized to show that the scheme better meets the users' visual experience, whereas the visual assessment of the color design for focused users, the visual assessment of the color design for creative users, the visual assessment of the color design for creative users, the visual assessment of the color design for calm users, and the visual assessment of the color design for creative users, are based on the data presented above. Assessment, based on the data above, will not repeat the expression. The research results of this paper can provide reference for the current housing space art design, so that the design works are more suitable for the user's visual experience standards.

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References

[1] Liu, R. (2020). Research on the Application of “Simple Aesthetics” Design Concept in Contemporary Interior Design under the Background of Eastern and Western Culture. Journal of Building Technology, 2(1), 12-19.
[2] Khanzadeh, M. (2024). Beyond Aesthetics: Emotion, Atmosphere, and Cultural References through Color in Interior Architecture. Journal of Academic Social Science Studies, 17(101).
[3] Chen, J., Shao, Z., Zheng, X., Zhang, K., & Yin, J. (2024). Integrating aesthetics and efficiency: AI-driven diffusion models for visually pleasing interior design generation. Scientific Reports, 14(1), 3496.
[4] Moubarak, L. M., & Qassem, E. W. (2018). Creative eco crafts and sustainability of interior design: Schools in Aswan, Egypt as a case study. The Design Journal, 21(6), 835-854.
[5] Mahmood, S. A. (2018). Visual Vision and Sensory Perception and its Relation to Interior Environment Design. International knowledge sharing platform, 61(2), 39-46.
[6] Celadyn, M. (2018). Environmental activation of inner space components in sustainable interior design. Sustainability, 10(6), 1945.
[7] Pasini, M., Brondino, M., Trombin, R., & Filippi, Z. (2021). A participatory interior design approach for a restorative work environment: a research-intervention. Frontiers in psychology, 12, 718446.
[8] Kim, J., & Heo, W. (2021). Interior design with consumers’ perception about art, brand image, and sustainability. Sustainability, 13(8), 4557.
[9] Bettaieb, D. M., Mohammed, W., & Khawaji, S. (2023). Exploring Visual Biophilic Interior Design Features in Homes: An Experimental Study through a Virtual Environment Design. The International Journal of Architectonic, Spatial, and Environmental Design, 18(1), 45.
[10] Malkani, K., & Madhukaillya, R. (2023, January). Need for Including Visual Narratives as a Method of Interior Design Process. In International Conference on Research into Design (pp. 713-723). Singapore: Springer Nature Singapore.
[11] Hassanein, H. (2021). Trends of contemporary art in innovative interior architecture design of cultural spaces. Cities' Identity Through Architecture and Arts, 25-57.
[12] Fan, G., & Guo, C. (2023). Personalized Recommendation Algorithm of Interior Design Style Based on Local Social Network. Journal of Information Processing Systems, 19(5).
[13] Mahmoud, W. R., Ibrahim, A. H., & Salem, M. (2022). A Study on the Impact of the User’s Personality Type on His Interior Design Preferences. International Design Journal, 12(5), 63-70.
[14] Afifi, A. H. M. Y. (2025). Achieving Creative Values in Interior Design Inspired by Folding Techniques. International Design Journal, 15(1), 469-479.
[15] Jin, S., & Hyun, K. H. (2024). Enhancing the Interior Design Process with Crowdsourced Furnishing Pairing Recommendations. Archives of Design Research-Vol, 37(2), 79-101.
[16] Almaz, A. F. H. A. (2017). The role of the digital revolution in developing creativity in the interior architecture. International Design Journal, 7(3), 123-135.
[17] Pylypchuk, O. D. (2023). Development of an innovative means of harmonizing the color scheme of works of fine art and interior environment to create a comfortable space for human existence. Publishing House “Baltija Publishing”.
[18] Shen, M. Y., Yoon, C. S., & Kim, N. H. (2016). The composition types of layout and three-dimensional of the public space (LDK) in small houses in Japan. Korean Institute of Interior Design Journal, 25(2), 92-100.
[19] Wu, W., & Feng, Y. (2022). Interior space design and automatic layout method based on CNN. Mathematical Problems in Engineering, 2022(1), 8006069.
[20] You, Y., Liu, G., & Liu, L. (2022). Art design method of interior space layout based on cad drawing. Computer-Aided Design & Applications, 19, 44-54.
[21] Ozenen, G. (2023). Lighting Sources Used for Interior Design. In Architectural Interior Lighting (pp. 37-49). Cham: Springer Nature Switzerland.
[22] Kong, Z., Utzinger, D. M., Freihoefer, K., & Steege, T. (2018). The impact of interior design on visual discomfort reduction: A field study integrating lighting environments with POE survey. Building and Environment, 138, 135-148.
[23] Yin, R. (2024, May). Visual Characteristics in Interior Lighting Design Based on Environmental Perception Algorithms. In International Conference on Artificial Intelligence for Society (pp. 272-283). Cham: Springer Nature Switzerland.
[24] Zeng, J., & Jiang, M. (2018, June). The Role and Application of Decorative Materials in Interior Design. In 2nd International Conference on Social Sciences, Arts and Humanities (SSAH 2018) (pp. 9-10).

[25] Cao, C. (2021, February). Research on innovative application of artistic characteristics of building decoration materials in interior design based on big data. In Journal of Physics: Conference Series (Vol. 1744, No. 2, p. 022020). IOP Publishing.
[26] Liu, X. D., Yang, B. H., & Huang, G. (2014). The influence and application of textile texture features to interior soft decoration. Applied Mechanics and Materials, 510, 293-296.
[27] Lin, J., Xiao, P., Fu, Y., Shi, Y., Wang, H., Guo, S., ... & Lee, T. Y. (2020). C3 assignment: Camera cubemap color assignment for creative interior design. IEEE Transactions on Visualization and Computer Graphics, 28(8), 2895-2908.
[28] Guo, S., Shi, Y., Xiao, P., Fu, Y., Lin, J., Zeng, W., & Lee, T. Y. (2023). Creative and progressive interior color design with eye-tracked user preference. ACM transactions on computer-human interaction, 30(1), 1-31.
[29] Shan, W. L., Jin, R. M., & Ding, X. Y. (2022). Chinese decorative color based on improved alexnet in interior decoration design. Mathematical Problems in Engineering, 2022(1), 2358905.
[30] Liang, T., Xiao, Z., & Guo, L. (2024). A Deep Learning Model-Based Feature Extraction Method for Architectural Space and Color Connection in Interior Design. Scalable Computing: Practice and Experience, 25(4), 2948-2959.
[31] Enwin, A. D., Ikiriko, T. D., & Jonathan-Ihua, G. O. (2023). The role of colours in interior design of liveable spaces. European Journal of Theoretical and Applied Sciences, 1(4), 242-262.
[32] Wei, J. (2022). The application of modern art color layout in interior design from the perspective of design psychology. Psychiatria Danubina, 34(suppl 4), 732-732.
[33] Park, B. H., & Hyun, K. H. (2022). Analysis of pairings of colors and materials of furnishings in interior design with a data-driven framework. Journal of Computational Design and Engineering, 9(6), 2419-2438.
[34] Güneş, E., & Olguntürk, N. (2020). Color-emotion associations in interiors. Color Research & Application, 45(1), 129-141.
[35] Qian, W. (2018). Analysis of interior space design and visual artistic effect. In 2018 1St International Conference On Education, Art, Management And Social Sciences (EAMSS 2018).
[36] Xu, Y., & Wu, S. (2022). Indoor Color and Space Humanized Design Based on Emotional Needs. Frontiers in Psychology, 13, 926301.
[37] Ćurčić, A., Kekovic, A., Ranđelović, D., & Momcilovic-Petronijevic, A. (2019). Effects of color in interior design. Zbornik radova Građevinskog fakulteta, 35, 867-877.
[38] Elnaggar, H. B. (2022). Illumination and color in interior design of living room. Journal of Design Sciences and Applied Arts, 3(1), 50-63.
[39] Ulusoy, B., & Nilgün, O. (2017). Understanding responses to materials and colors in interiors. Color Research & Application, 42(2), 261-272.
[40] Jian Dong,Lan Qin,Shilong Han,Zhanpeng Wang,Junyue Chen,Xiaochen Liu... & Xiyuan Zhang. (2024). Color Use and Psychological Feeling in Modern Interior Design - Based on Emotional Calculation Perspective. Applied Mathematics and Nonlinear Sciences,9(1),
[41] Chuan Qu,Dongqin Guo,Hui Zhang,Shuaixi Liang,Yuanyuan Li,Shenghai Zhang & Zhengtong Wei. (2024). Theoretical investigation of multiplexed quantum light source in fiber ring cavities with oscillating dispersion. Results in Physics,59,107554-.
[42] Tang Xuefeng. (2021). Research on Interior Design Strategy Based on Optimization of Computer Renderings Production Process. Journal of Physics: Conference Series,1992(3),