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STEREOSCOPIC DISPLAY OF ARCHITECTURAL EXTERIOR DESIGN IMAGES BASED ON VIRTUAL REALITY TECHNOLOGY

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Abstract: The current image stereoscopic display method mainly displays images stereoscopically from the perspective of human left and right eye visual imaging, which not only displays images with distortion and missing details, but also makes it difficult to realize interaction for complex image stereoscopic display. With the goal of improving the above defects, we propose a stereoscopic display method of architectural design images based on virtual reality technology. The images are drawn using DIBR technology and the depth images are processed using Gaussian filtering and so on. Convert the image to 3D virtual model in 3D MAX. After designing the virtual interaction of the image stereoscopic display scene, EON is used to analyze the lighting of the building exterior and realize the stereoscopic display of the image. The simulation experimental data of the stereoscopic display method show that the proposed image stereoscopic display method relatively improves the display effect by about 66.7% and has good adaptability for different gray value images.
Keywords: virtual reality technology; architectural exterior; design images; image presentation; stereoscopic presentation; virtual interaction；

0 Introduction

In the process of architectural design, architects need to design two-dimensional drawings based on customer needs, and professional design drawings can not be understood by non-professionals. At the same time, because the construction period is not only long and irreversible, higher precision of drawing design is required. Architectural appearance design often needs to be adjusted according to functional requirements and customer design requirements, and the adjustment of architectural appearance design images involves many aspects, which can easily increase the difficulty of the work of architectural designers [1]. Therefore, the three-dimensional display of the design image can find the problems in the design and adjust the design image in time. The traditional three-dimensional display of architectural appearance design images mainly uses images from different angles to convert from two-dimensional to three-dimensional, so as to realize three-dimensional display of images. This traditional three-dimensional display method requires multiple plane images from different angles, which has a large workload and a relatively large limitation on the display effect [2]. Although model-based stereo image rendering technology can accurately restore the three-dimensional structure of the object, the calculation process is complex and the rendered image lacks the sense of reality [3]. Generally, it is only suitable for 3D modeling of simple objects, and does not have real time. IBR rendering technology through a series of interpolation processing on a given plane image, so as to draw a variety of virtual images. However, the three-dimensional sense of virtual images displayed by this method is poor, and further improvement is needed [4]. The effect of image display based on stereo vision principle is poor, and it cannot be adjusted at any time [5].

Virtual reality technology uses computer graphics, computer simulation, artificial intelligence, man-machine interface, multimedia, network technology and other technologies. Through the computer simulation of the three-dimensional environment of the real environment on the site, to generate a realistic visual, auditory, tactile integration of a specific range of virtual environment, users can not arrive at the site or in the environment does not exist at all travel and feel the experience of its presence. Virtual reality technology has been widely used in various industries. For example, museums use virtual reality technology and related auxiliary equipment to vividly display cultural relics or historical stories and optimize the visiting experience of visitors. Or the application of virtual reality technology in interior design can let customers intuitively see the more real design effect and improve the quality of design service; In addition, virtual reality technology can also be applied to urban planning and design, and planning schemes can be adjusted in virtual cities to avoid problems in actual urban planning [6]. Many foreign research institutions have achieved fruitful results on how to apply virtual reality technology to the field of architectural design. For example, virtual reality systems designed by using virtual reality devices such as sensors and stereoscopic glasses can facilitate designers to modify the scheme in real time and greatly shorten the architectural design cycle. The walk-through system designed by New York University facilitates users to conduct field design in the interior of virtual building [7-8]. Relevant research institutions in China also use virtual reality technology to realize the large panorama of virtual scene, 3D virtual animation technology, architectural scene reproduction, etc. [9-11]. However, there are still some problems in the application of virtual reality technology in architectural design. For example, the three-dimensional structure of buildings is complex, so it is urgent to simplify the three-dimensional model of buildings. In terms of architectural appearance design, the demonstration of architectural design through virtual reality technology can more intuitively evaluate the advantages and disadvantages of architectural design schemes, and then make the design more and more perfect. It can be seen that the combination of virtual reality technology and architectural design will be a leading research content in the field of architectural design in the future. In order to explore the application of virtual reality technology in the field of architectural design, this paper will study the three-dimensional display of architectural appearance design images based on virtual reality technology, and explore the real and effective assistance and support of virtual reality technology after it enters the field of view design outside buildings.

1 Research on the three-dimensional display method of architectural exterior design images based on virtual reality technology

1.1 Architectural exterior design depth image processing

When designing the exterior of a building, the actual use of the building is taken into consideration, so the DIBR drawing technique is used. In order to reduce the void effect and to filter out the noise in the depth map, the design depth map needs to be pre-processed before converting the image into a 3D model [12]. And the usual preprocessing is Gaussian filtering, which is a smooth filter according to the shape of the Gaussian function to choose the value, is in the image and video processing is more commonly used smoothing filtering method.

Since the human visual system determines that the human eye mainly gets depth information from the parallax in the horizontal direction of the left and right eye images and is not so sensitive to the parallax in the vertical direction, an asymmetric second-order Gaussian filter is used for filtering preprocessing when filtering the depth map so that the filtering intensity in the vertical direction is greater than that in the horizontal direction, which can effectively reduce geometric distortion while attenuating the nulling effect [13].

Second-order Gaussian filter $G(x,y)$.

$$G(x,y)=\frac{1}{\sqrt{2\pi}\sigma_u}\exp\left\{-\frac{x^2}{2\sigma_u^2}\right\}\frac{1}{\sqrt{2\pi}\sigma_v}\exp\left\{-\frac{y^2}{2\sigma_v^2}\right\} \quad (1)$$

Assuming $d(x,y)$ is the depth value of pixel point (x,y) in the depth map, then the depth value $\hat{d}(x,y)$ after Gaussian filtering can be obtained by the following equation [14] :

$$\hat{d}(x,y)=\frac{\sum_{v=-\frac{w}{2}}^{\frac{w}{2}}\left\{\sum_{u=-\frac{w}{2}}^{\frac{w}{2}}\left(d(x-u,y-v)g(u,\sigma_u)g(v,\sigma_v)\right)\right\}}{\sum_{v=-\frac{w}{2}}^{\frac{w}{2}}\sum_{u=-\frac{w}{2}}^{\frac{w}{2}}g(u,\sigma_u)g(v,\sigma_v)} \quad (2)$$

Where, σ_u and σ_v represent the filtering intensity in horizontal and vertical directions respectively. In order to eliminate more noise in the design drawing, the generated design drawing can be filtered by morphological operations such as expansion and corrosion before 3D conversion. For the noise in the design drawing, open operation can be carried out, that is, corrosion first and then expansion. The calculation formula is as follows [15] :

$$A\circ B=(A\Theta B)\oplus B \quad (3)$$

In the above formula, A and B are the architectural appearance design image and image structural element to be processed respectively; $\oplus$ represents image expansion operation; Θ represents the image etching operation. After processing the architectural appearance design images in accordance with the above process, 3DS Max was used to conduct 3D virtual modeling of the corresponding design images.

1.2 Building design image and 3D virtual model conversion

At present, Auto CAD software is mainly used in the architectural appearance design in the construction industry. Therefore, this paper takes the Auto CAD image of architectural appearance design as the research object, and carries out the three-dimensional display research of the design image.

After drawing the image of architectural appearance design, the work of how to transform the two-dimensional image into a three-dimensional architectural model is carried out next. According

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to the requirements of design, complex models and special structures are needed to be built, among which, the detailed contents of the irregular roof modeling and the decorative modeling on the exterior wall of the building in the overall modeling of the building body are as follows [16-17].

First of all, 3D MAX is used for basic modeling of the appearance of the whole building. In the process of modeling, the CAD drawings drawn are imported into 3D MAX software. ==>The two-dimensional lines are stretched into three-dimensional structures by Extrude command, and the facade wall is completed .==>Then the details of the model are processed. Under the Object Type menu of Standard Primitives, click Box to build the structure on the operating surface and add the details of the building's floor level. ==> Use Editable Poly tool to complete the roof construction. Click Selection to edit the Object. Click Selection to edit the selected point and drag the point across the object to complete the roof model editing. After the whole basic appearance model is simulated, the next work is to build the model of each part of the design.

In this project, a certain amount of iron art is used for building decoration. The fluency of the modeling form of iron art will directly affect the viewing effect in the future, so we need to specially adjust the streamline sense of the form in the production. Click Line in the Object Type menu of Splines to edit the curve. Click Modifier after editing the curve, click the drop-down menu Selection, and select Vertex command to handle the details of the dot. After editing the curve, transform 2D line body into 3D model. ==> Click Enable In Renderer and Enable In Viewport In the drop-down menu to transform 2D into 3D model and adjust the parameters under Radial status.

In the process of scene simulation, integrate the architectural appearance parts with the same material parts. Click Group in the menu to Group the integrated models, combine them into an object, and then edit the material. Combined with the detailed information of architectural appearance design image and design requirements, the detailed parameters of the model are adjusted, and the virtual model of architectural appearance image as shown in figure 1 below is finally obtained.

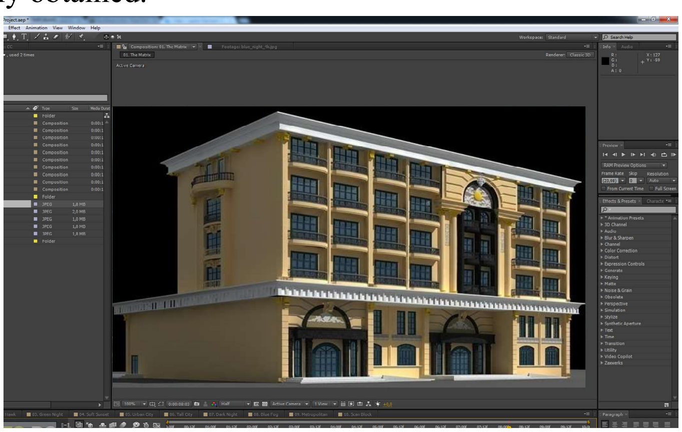

Figure 1 An example of a virtual model of a building appearance image

After the virtual model is established according to the architectural appearance design image, in order to facilitate the multi-angle display and modification, the virtual reality technology is used to design the three-dimensional image display scene virtual interaction.

1.3 Design three-dimensional image display scene virtual interaction design

The three-dimensional picking technology is used to select the object of the architectural appearance design model, which can better operate the model. There are three basic operations for model virtual objects, namely translation, rotation, and scaling.

First, we have to get the model node transformation matrix, and then use the matrix transformation to calculate the new coordinate parameter matrix after translation, so as to realize the translation of the model. If the homogeneous form of the spatial coordinate vector of the model is $\left[x_0, y_0, z_0, 1\right]$, the translated spatial coordinate vector is $\left[x_1, y_1, z_1, 1\right]$, and the translated quantities along each coordinate axis are t_x, t_y, and t_z respectively, then the translation transformation operation formula is [18] :

$$\begin{bmatrix} x_1 \\ y_1 \\ z_1 \\ 1 \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \\ z_0 \\ 1 \end{pmatrix} \quad (4)$$

Using the computer graphics principle, let parameter θ be the specified rotation angle around the x-axis, and let the counterclockwise rotation angle be positive when viewed from the positive direction of the x-axis toward the negative direction, then the chi-squared coordinate form of the rotation transformation matrix equation is

$$\begin{bmatrix} x_1 \\ y_1 \\ z_1 \\ 1 \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \\ z_0 \\ 1 \end{pmatrix} \quad (5)$$

Similarly, we can obtain the transformation matrix for rotation around y-axis and z-axis.

$$\begin{bmatrix} x_1 & y_1 & z_1 & 1 \end{bmatrix}^T = diag\begin{pmatrix} s_x & s_y & s_z & 1 \end{pmatrix}\begin{bmatrix} x_0 & y_0 & z_0 & 1 \end{bmatrix}^T \quad (6)$$

Where s_x, s_y, and s_z are the scaling values (scale change) along the corresponding x, y, and z axes, and are positive real values. To established model, the appearance of the model scale scaling parameters usually takes the same value, that is $s_x = s_y = s_z$. Model objects can also be scaled along a coordinate axis as needed.

Viewpoint transformation is one of the most basic means of interaction in virtual environment. Its essence is to change the definition parameters of the observation space before the graphics engine renders each frame of scene image, so as to achieve the purpose of observing the scene from different positions and angles.

Assume that the viewpoint position of the current frame scene image is $E\left(E_x, E_y, E_z\right)$ and the viewing direction is $\vec{V}\left(V_x, V_y, V_z\right)$. If the translation of the viewpoint position in the world coordinate system at the time of rendering the next scene image is $\Delta\left(\Delta x, \Delta y, \Delta z\right)$. According to the formula below, for the scene image of the next frame, its viewpoint position is [19] :

$$\begin{bmatrix} E'_x \\ E'_y \\ E'_z \\ 1 \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 & \Delta x \\ 0 & 1 & 0 & \Delta y \\ 0 & 0 & 1 & \Delta z \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} E_x \\ E_y \\ E_z \\ 1 \end{bmatrix} \quad (7)$$

Observe the direction vector in the order of $x \to y \to z$ and rotate angles α , β and δ around the three coordinate axes respectively, then the view direction of the next frame scene is:

$$\begin{bmatrix} V'_x \\ V'_y \\ V'_z \\ 1 \end{bmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha & 0 \\ 0 & -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\beta & 0 & -\sin\beta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\beta & 0 & \cos\beta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\delta & \sin\delta & 0 & 0 \\ -\sin\delta & \cos\delta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} V_x \\ V_y \\ V_z \\ 1 \end{bmatrix} \quad (8)$$

According to different rotation order, the order of action of the three transformation matrices in the equation is also different. After designing the virtual interaction of three-dimensional display scene of architectural appearance design images, the 3DS Max model was imported into EON Studio to achieve a more real three-dimensional display of images.

1.4 Virtual three-dimensional display of architectural appearance design image is realized

The virtual reality development platform Eon provides data interfaces for most 3Ds Max systems, making it easy to import assembled 3Ds Max models into the virtual environment. Select a frame function node ==> select.3ds file. Eon Studio uses a conversion program to import the 3D model and insert it into the simulated tree. The EON simulation program is created by adding nodes to the simulation tree, adding node attributes and setting the logical relationship between nodes. Add sound, image, light and other effects to your scene using SOUND, TEXTURE, LIGHT and other nodes. EOC three-dimensional display of architectural design images, in order to make the three-dimensional image more realistic, according to the following process to analyze the lighting of the building appearance.

When simulating the illumination of the model under sunny conditions, the brightness is calculated according to the CIE standard sunny sky brightness distribution function as follows [20] :

$$L_p = L_z \left\{ \frac{\left[0.91 + 10\exp\left(-3\vartheta\right) + 0.45\cos^2\vartheta\right]\left[1 - \exp\left(-0.32/\cos\varepsilon\right)\right]}{\left[0.91 + 10\exp\left(-3Z_0\right) + 0.45\cos^2 Z_0\right]\left[1 - \exp\left(-0.32\right)\right]} \right\} \quad (9)$$

Where, L_p is the brightness of point p in the sky, L_z is the brightness of zenith, ε is the angle between point p and zenith, Z_0 is the zenith angle of the sun, and ϑ is the angle between point p and the sun.

According to the analysis of the lighting of buildings in a completely overcast day, the brightness of the completely overcast sky is the same in different directions at the same height, but from the horizon to the zenith, the brightness is not the same at different heights. Then the brightness change expression is:

$$L_{\varphi} = L_{z}\left(\frac{1+2\sin\varphi}{3}\right) \quad (10)$$

In the formula, L_{φ} refers to the sky brightness at an angle of φ with the ground. After analyzing the illumination of the building under different circumstances, the illumination of the building's appearance is simulated in EON to make the three-dimensional display model more realistic.

Eon Studio provides basic nodes that allow you to perform basic simulation functions, such as changing the light source in the simulated scene, changing the materials of 3D objects, and so on. The following is the illumination analysis of the building by changing the intensity of the light source. First of all, determine the location of the building, altitude, latitude and longitude data information, using the mathematical theory given above for numerical analysis, get the specific parameter value. Next, set up the base node in Eon Studio and add the light node. By inputting the parameter value into the properties of the light source node, the illumination condition of the building appearance model established can be adjusted, and the three-dimensional display virtual model that is closest to the image of the building appearance design can be obtained. So far, the research on three-dimensional display method of architectural appearance design image based on virtual reality technology has been completed.

2 Simulation results

2.1 Simulation process design

In the simulation experiment, the three-dimensional image effect evaluation index was selected as the comparative evaluation parameter, and the three-dimensional display method proposed in this paper (simulation group) was compared with the stereoscopic vision based display method (comparison group 1) and the model-based display method (comparison group 2). The same architectural appearance design images are selected and divided into 10 sub-images of the same area, all of which contain architectural appearance design images of different areas. Three display methods were used to display sub-images, and simulation data were collected according to the detailed requirements of three-dimensional effect evaluation indexes to complete the experimental research.

2.2 Three-dimensional effect evaluation index

Due to the differences in the eyes, observation methods and habits of each observer, there may be different evaluations on the three-dimensional display effect of the same image. For the convenience of comparison, cross entropy and root mean square error are used in this simulation experiment to evaluate the three-dimensional display of the target design image.

According to the basic principles of the two image stereoscopic display methods, the left and right eye views Img_L and Img_R are obtained respectively. The left-eye view Img_L is stereoscopically processed separately to obtain a left-eye view Img'_R with the same size as the right-eye view Img_R, and the evaluation index of the stereoscopic effect of the architectural design image is defined as follows.

(1) Cross entropy

Let X be a random variable with n finite state values, $p_i = P\left\{X = x_i, i = 0,1,\cdots,n-1\right\}$. Cross entropy $I_{[P,Q]}$ is used to measure the difference in the amount of information between two probability distributions $P = \left\{p_0, p_1, \cdots, p_{n-1}\right\}$ and $Q = \left\{q_0, q_1, \cdots, q_{n-1}\right\}$. The formula for calculating cross entropy is as follows.

$$I_{[P,Q]} = \sum_{i=0}^{n-1} p_i \ln \frac{p_i}{q_i} \left(q_i \neq 0\right) \quad (11)$$

Where p_i is the probability statistic of a pixel with a gray value of i in the grayscale image P and $\mathrm{n} = 256$ indicates the number of gray levels. The cross entropy directly reflects the difference in the amount of information between the pixels of two images, and is a key indicator to evaluate the difference between two images. In general, the smaller the cross entropy is, the closer the two images are.

The cross entropy reflects only the overall difference in the amount of information between one image and the other. The situation occurs: the content of the two images is very different, but the cross entropy is relatively small, so it is necessary to refer to the root mean square error of the image.

(2) Root-mean-square error

Let the height and width of the image be M and N (in pixels), respectively, and $\mathrm{Img}_R\left(i, j\right)$ denote the gray value of image Img_R at pixel $\left(i, j\right)$, then the root mean square error.

$$E_{RMS}\left(\mathrm{Img}'_R\left(i,j\right), \mathrm{Img}_R\left(i,j\right)\right) = \sqrt{\frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[\mathrm{Img}'_R\left(i,j\right) - \mathrm{Img}_R\left(i,j\right)\right]^2}{MN}} \quad (12)$$

If the cross-entropy and root-mean-square error between the right-eye view Img'_R obtained after stereoscopic display processing and the right-eye view Img_R obtained by real photography are relatively small, it means that the two views are closer, i.e. the stereoscopic effect of the building exterior design image after stereoscopic display processing is better.

2.3 Experimental data and analysis

The information of the gray value of the image after processing the sub-images in this simulation experiment is counted, and the cross entropy and root mean square error of the processed image are calculated according to equations (11) and (12), and the experimental data in figure 2 and figure 3 below are obtained.

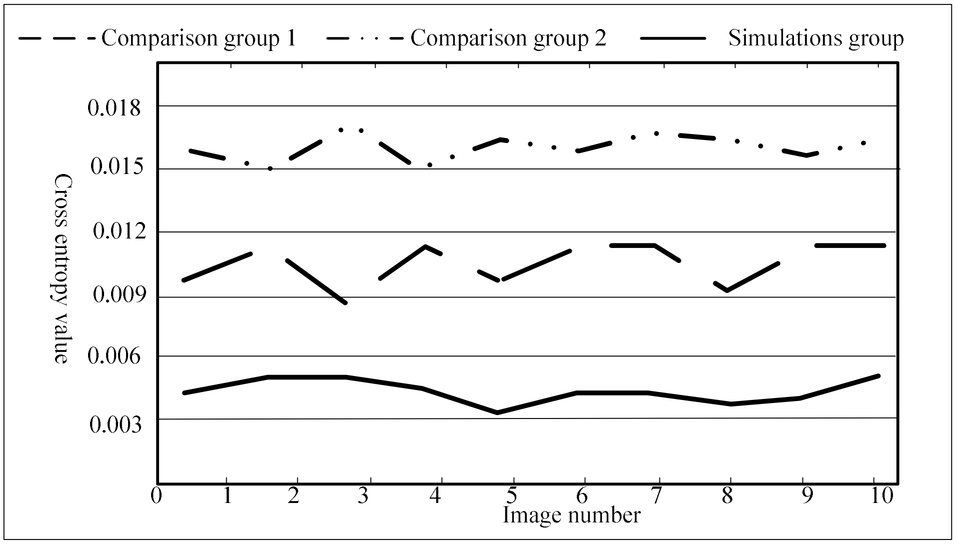

Figure 2 Comparison of cross entropy of processed images

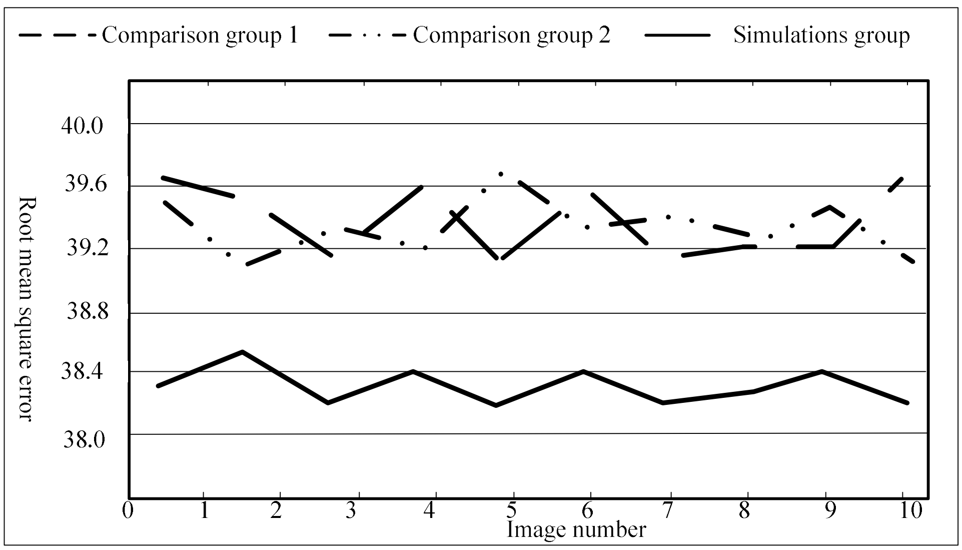

Figure 3 Comparison of root mean square error of processed images

Ideally, the optimal values of cross entropy and root mean square error of the processed image should both be 0, which indicates that the stereoscopic image is almost indistinguishable from the original image. However, in practice, it is not possible to achieve perfect agreement. Therefore, according to figure 2 and figure 3, the cross-entropy and root-mean-square error of the images processed by the simulation group are lower than those of the other two methods, and the average value is about 1/3 of the average value of the two comparison methods.

Conclusion: The virtual reality-based method for stereoscopic display of architectural exterior design images improves the processing effect by about 66.7% and has good applicability for images with different gray values.

3 Conclusion

The application of virtual reality technology to architectural exterior design brings convenience to the control and grasp of external form and internal structure, such as design style matching, decorative material use and configuration of architectural exterior design. Through virtual reality technology to assist in architectural design can better promote the diversity of architectural design information, social culture and the coexistence of historical culture, communication and development. This paper researches the method of three-dimensional display of architectural exterior design images based on virtual reality technology and verifies the feasibility of the method through experiments.

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