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Implementation and Innovation of Computer Graphics in Interactive Art Design

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Abstract The booming development of digital technology has prompted computer graphics to become the driving factor of interactive art design. In this paper, through 3D modeling optimization and geometric modeling technology, we construct a virtual environment interaction model, combining light and shadow mode and VR interaction, etc., to realize the optimization of interactive design. Starting from the image noise, lack of contrast and visualization needs in interactive art design, image smoothing, contrast enhancement and pseudo-color enhancement techniques are used to improve the image quality and enhance the interactive art expression. The method based on computer graphics processing is applied to the actual interactive art design practice to verify the advantages of the method. The results show that the signal-to-noise ratio of the pre-processed images is between 20% and 55%, which is within the range of high-definition standards. In the quantitative comparison, the four index values of NIQE, PIQE, PSNR and SSIM of this paper's method are the lowest among the seven method comparisons. The final score in subjective comparison is 4.2698, which is higher than the comparison methods. The percentage of users who are very satisfied and satisfied with the quality of generated images and interactive realism are 73.62% and 76.21% respectively. The method of this paper can effectively improve the quality of interactive art and enhance the sense of user experience.

Index Terms 3D modeling, geometric modeling, image smoothing, contrast enhancement, pseudo-color enhancement, interactive art

I. Introduction

With the rapid development of modern society, computer technology has also made significant progress, and computer-related technologies are being vigorously promoted and utilized. The scope of application of computers, which are highly efficient electronic appliances, is extremely wide, mainly including mechanical, aerospace, electronics and other aspects of the industry. However, due to the increasing variety of computer software, computers have begun to show great utility in other fields as well. Through the use of CAD, Photoshop and other related auxiliary design software, computers have also begun to play an auxiliary design function in the field of art design [1], [2].

Computer graphic art design can be said to be a combination of computer technology and creative arts, has been applied to a variety of visual arts in the creative process, such as architectural design, film and television production, three-dimensional animation and game art [3]-[6]. In addition, interactive art design based on computer graphics can be achieved through the use of virtual reality technology, the target product as the object of design, give full play to analog simulation technology, the use of graphic design software to achieve the product rendering design [7]-[9]. Computer-aided technology, this new art design means, has a very good prospect for the development of interactive art design is extremely favorable [10], [11]. It can not only promote more diversified forms of interactive art expression, but also can further promote the reform of art design aesthetics and art design thinking [12], [13].

This paper addresses the needs of image quality improvement and interactive experience enhancement in interactive art design, using modeling technology and image processing technology for innovation. 3D modeling is introduced to optimize the design scheme and geometric modeling technology to enhance the efficiency of interactive art design. Starting from image smoothing, contrast enhancement and pseudo-color enhancement, three types of digital image preprocessing techniques are used to improve the image quality of interactive art design. Analyze the image processing effect of this paper's method through simulation experiments. Choose to compare the visual effect of the output image from quantitative comparison and subjective comparison to comprehensively judge the interactive art design level of this paper's method. Collect users' satisfaction with interactive art design, statistically generate image quality satisfaction, and interaction realism satisfaction, and evaluate the value of this paper's method from the user's point of view.

II. Graphic technology support in interactive art design

In this chapter, the potential of computer graphics in interactive art design is systematically analyzed from the perspective of both modeling-related techniques and digital image preprocessing techniques.

II. A. Analysis of modeling-related technologies

II. A. 1) Introduction of 3D modeling to optimize design solutions

In the early stages of interactive art design, computer-aided design (CAD) software and 3D modeling tools are used to construct an accurate model of the environment. This stage should focus on the accuracy of spatial dimensions to ensure that all design elements are correctly placed to scale. The creation of the 3D model provides a solid foundation for subsequent interaction and analysis. On the basis of the preliminary model, material mapping is meticulously added to accurately reproduce the real texture and color of the interactive environment using the texture mapping function of image processing technology. At the same time, the lighting settings are carefully arranged to simulate the interaction between natural light and artificial light, considering the light and shadow changes at different times of the day and the impact of seasonal lighting on the space, so as to optimize the visual comfort and atmosphere creation of the interactive space. After completing the above steps, an interactive virtual environment is created by importing the 3D model into a virtual reality (VR) platform. This not only allows the designer to immersively review and refine the interactive art design, but more importantly, allows the client or project stakeholders to roam freely in the virtual space and interact intuitively, thus providing valuable feedback. Based on this feedback, designers can make timely adjustments to the interactive art design program to ensure that the final results are more in line with user needs and expectations. In this way, computer image processing technology not only greatly improves the accuracy and efficiency of design, but also enhances the intuitiveness and interactivity of design communication, which is an indispensable tool for interactive art design.

II. A. 2) Modeling techniques based on geometric modeling

Geometric modeling technology, also known as geometric modeling technology, which uses computers as well as graphic processing techniques to draw the geometric shape of an object, is a technology that can simulate the static and dynamic processing of an object.

In three-dimensional geometric modeling technology, the geometric elements include the following: points, edges, surfaces, rings, shells, bodies, and voxels. During the long-term development of geometric modeling systems, there have been wireframe models, surface models, solid models, feature models, and so on, which are divided into different ways of storing geometrical shapes in the computer.

Wireframe modeling, which is a form of representing the actual 3D model in terms of vertices and edges, where edges can be lines, quadratic curves, arcs, Spline curves, etc. It uses a vertex table to store geometric information to record the coordinate values of each vertex. It uses a vertex table to store geometric information to record the coordinate values of each vertex, and an edge table to store topological information to record the two vertices that define each edge. The actual model is a three-dimensional image of the vertex and edge tables together. Figure 1 shows the wireframe of a cube, consisting of 8 vertices $(V_1 \sim V_8)$, and 12 edges $(e_1 \sim e_{12})$.

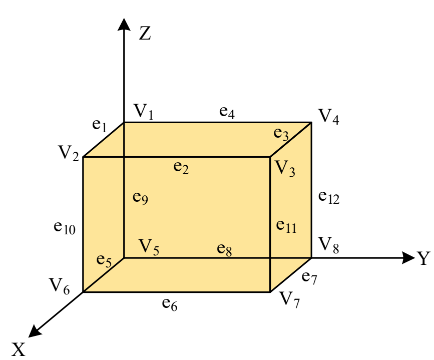

Figure 1: Cube wireframing

II. B. Digital Image Preprocessing Techniques

II. B. 1) Image Smoothing

After smoothing of an image, noise points in the image can be eliminated. Generally, most of the energy in a signal or image is more concentrated in the low and medium frequency bands of the amplitude spectrum, while in the high frequency bands, the information of interest is often overwhelmed by noise. Therefore, using a filter that reduces the amplitude of the high-frequency component reduces the effect of noise. Filters can be categorized into Gaussian, median, and mean filters depending on how they operate.

1) Mean value filter. It can eliminate Gaussian noise and uniform noise very well. Let S_{xy} denote the filter window with center point (x, y) and size $m*n$. The arithmetic mean filter just calculates the mean value of the pixels in the window area and then assigns the mean value to the pixel at the center of the window, the formula (1) is calculated as follows:

$$f(x,y)=\frac{1}{mn}\sum_{(x,y)\in S_{xy}} g\left(x,y\right) \tag{1}$$

where $g(s,t)$ is used to denote the initial image, and $f(x, y)$ is used to denote the image obtained after passing through the mean filter. Based on the above equation (1), the window template of the arithmetic mean filter can be easily obtained, taking the $3*3$ template as an example, the template matrix P is shown in equation (2):

$$P=\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix} \tag{2}$$

2) Gaussian Filter. It is a commonly used linear filter that performs a weighted average of the entire image, that is, the value of each pixel point, is calculated by a weighted average of its own value with the values of other pixels in its neighborhood. Gaussian smoothing filter can well suppress the noise obeying normal distribution, expression (3) is a two-dimensional Gaussian function:

$$G(x,y)=\left(\frac{1}{2\pi\sigma^2}\right)\exp\left[-(x^2+y^2)/2\sigma^2\right] \tag{3}$$

In the above equation σ is the standard deviation and x and y represent the horizontal and vertical coordinates of the pixels of the template.

In image processing, there are two ways to implement Gaussian filtering, one is to use discrete window convolution and the other is to use Fourier transform. The first of these sliding window implementation is the most common, only when the discrete window is large, when the calculation using the sliding window is very large, will go to consider the use of Fourier transform based implementation.

3) Median Filtering. In some cases, the median filter can not only eliminate noise, but also protect the image edges, is a nonlinear method of eliminating noise. It is realized by replacing the value of this point in the digital image with the median value of all points in the region of the point.

A window is a neighborhood of a particular length or shape of a point, and for median filtering of a 2D image, a $3*3$ or $5*5$ window is usually used. The 2D median formula (4) is:

$$g(x,y)=med\left\{f(x-k,y-l),(k,l\in W)\right\} \tag{4}$$

In the above equation, $f(x, y)$ and $g(x, y)$ are the initial image and the image after processing, respectively, and W is the 2D template.

II. B. 2) Contrast Enhancement

Image enhancement technology is a method of processing images that centers on strengthening or enhancing specific features of an image, such as edge information, contour details, and contrast. In this way, useful information in the image can be displayed more sharply, thus significantly enhancing the use value of the image. The problem of unclear flow field structure and the overall darkness of the image really needs to be improved by image processing techniques. In MATLAB software, the imsharpen function is a commonly used image sharpening tool that improves the clarity of an image by enhancing its edges and details. The format of calling this function is as follows:

$$B=imsharpen\left(A,'Amount',amount,'Radius',radius\right) \tag{5}$$

where B is the filtered image, A is the cropped grayscale image, AMOUNT controls the degree of sharpening of the image, which can be adjusted, and $radius=1$ controls the image. After filtering and denoising the image, the quality of the grayscale image is obviously improved by comparing it with the original image.

After the image filtering, call the imadjust function to adjust the brightness of the grayscale image, call the function format:

$$C = imadjust\left(B,\left[low\_inhigh\_in\right],\left[low\_outhigh\_out\right],gamma\right) \quad (6)$$

where, C is the contrast stretched image, B is the sharpened grayscale image, [low_in; high_in] is the grayscale range to be transformed in the original image, [low_out; high_out] is the transformed grayscale range, and the parameter gamma adjusts the slope of the curve, with the default value of 1, i.e., linear mapping, and when gamma is not equal to 1, it is nonlinear Mapping. After the image has been sharpened and brightness adjusted, the noise in the image will be highlighted, resulting in more obvious noise, so it is necessary to use it in combination with the corresponding filtering method in the process of image processing to minimize the impact of filtering.

II. B. 3) Pseudo-color enhancement

In the image processing process, both the grain image and the PLIF image are output as grayscale maps. When the difference between the flow field structure and the background grayscale value is not large, and it is difficult to distinguish the target details, pseudo-color can be used to reflect the spatial position change of the concentration and make it easier to understand. Pseudo-color enhancement technology is based on the original grayscale image, by giving specific colors to different gray value areas, the grayscale image is converted into a color image, this technology is often used to emphasize specific features in the image, and then improve the visualization effect of the image. The main methods of pseudo-color enhancement technique include density segmentation method and spatial domain gray level-color transformation method. Density segmentation is an intuitive means of pseudo-color enhancement, the core idea of which is to divide the gray scale range of a gray scale image into N intervals uniformly or unevenly, and assign a unique color to each interval. Another commonly used pseudo-color enhancement method is the spatial domain gray level-color transformation method. Unlike the density-segmentation method, the spatial-domain gray-level-color transform method is based on the principle of color science, which subdivides the gray range of the original grayscale image into multiple subintervals and transforms each subinterval with independent red, green, and blue (RGB) colors, respectively. Specifically, it generates the corresponding three primary color components $R(x,y)$, $G(x,y)$, and $B(x,y)$, where each component is a function of the original grayscale image at a particular spatial location. These three transformation processes are independent of each other, allowing for fine tuning of each color, thus enabling precise enhancement of image details.

To achieve pseudo-color processing, in this paper we use density segmentation method, which imposes different colors according to the size of the gray values in the image. Through pseudo-color processing we can more easily distinguish and understand the distribution of fluorescent particles in the image as well as the background, which helps to improve the level of interactive art design.

III. Interactive art design practices based on computer graphics

This chapter utilizes the graphic related technical methods designed in the previous paper to conduct simulation experiments on the preprocessing of digital images. Afterwards, the effectiveness of this paper's method is analyzed by comparing the visual effects of the output images. Further, a satisfaction survey on users' interactive art design experience is conducted to assist in judging the application value of this paper's method.

III. A. Digital Image Preprocessing Simulation Experiments

In order to verify the digital image preprocessing level of this paper's method, to ensure that the subsequent output of interactive art images with good quality, this section sets up digital image preprocessing simulation experiments. A set of images from the image data set is imported into the computer, and the method of this paper is used to carry out image smoothing, image noise filtering and image pseudo-color enhancement in three operations. Table 1 shows the technical parameters of the output images after preprocessing. From the technical parameters of the six output images in Table 1, the processed image noise ratio is between 0.76-3.75, the passband value is between 1.28-3.43, the resistive band value is between 0.08-0.16, the convergence coefficient is 1, and the number of channels is between 2-12. According to the preliminary judgment of the image technical parameters, the processed image has higher clarity and more realistic visual effect.

Figure 2 shows the comparison of the image signal-to-noise ratio before and after processing. By analyzing the size of the signal-to-noise ratio of the image before and after processing, the change in the quality of the output image before and after processing is judged. From Fig. 2, it can be seen that the signal-to-noise ratio of the processed image is lower, and the image is within the HD standard range (20%-55%); while the pre-processed image belongs to the multi-noise peak range (55%-100%). In this regard, it can be judged that the clarity of the output image of this paper's method is higher than that of the pre-processing image, and this paper's method has a good digital image processing capability, which can output higher quality and more realistic visual effects and improve the level of interactive art design.

Table 1: Output image technical parameters

Argument	Output image 1	Output image 2	Output image 3	Output image 4	Output image 5	Output image 6
Noise ratio	3.75	3.51	2.69	1.97	1.43	0.76
Passband value	1.28	1.34	1.42	2.36	2.19	3.43
Stopband value	0.12	0.13	0.16	0.13	0.12	0.08
Coefficient of convergence	1	1	1	1	1	1
Channel quantity	2	4	6	8	10	12

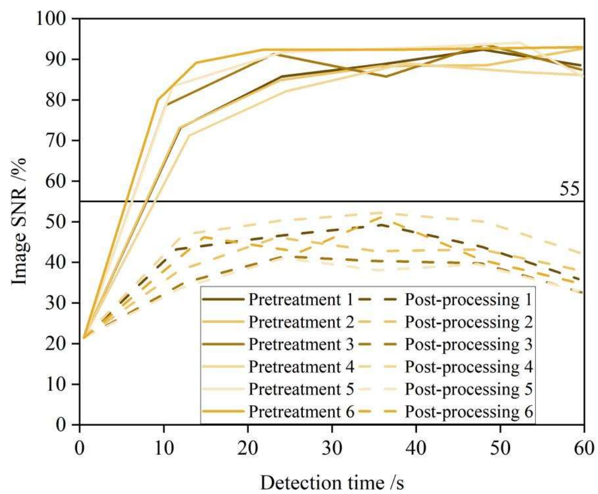

Figure 2: Comparison of signal-to-noise ratio before and after processing

III. B. Comparison of visual effects of output images

In this paper, six types of image enhancement methods are selected as comparison methods and public datasets ExDark, LIME and Tangka datasets are used for image enhancement comparison experiments. The output image visual effects of different methods are compared quantitatively and subjectively. In order to validate the method of this paper in interactive art design output image visual effect advantage.

III. B. 1) Quantitative comparison

Table 2 details the NIQE and PIQE results of different methods on ExDark, LIME, and Tangka datasets.NIQE is a reference-free image quality evaluation metric for assessing the naturalness of an image, with smaller values indicating a more natural image.PIQE is a reference-free image quality evaluation metric based on perceptual features. It utilizes the block structure and noise characteristics of the image to calculate the quality score of the image, and a lower score indicates a higher quality image.

From the data in Table 2, it is obvious that the NIQE values of this paper's method on the three datasets are 9.2371, 11.5474, and 17.5362, respectively, and the PIQE values are 10.2834, 9.4593, and 9.3485, respectively.The NIQE and PIQE values of this paper's method are the lowest among the seven methods. From this, we can conclude the comparison result: the visual effect of the output image of this paper's method is more natural and higher quality.

Table 2: Comparison of NIQE and PIQE results on different data sets

Method	Ex Dark		LIME		Thangka	
	NIQE	PIQE	NIQE	PIQE	NIQE	PIQE
KinD	10.8357	11.9669	16.2569	16.5839	22.5689	30.2186
EnlightenGAN	10.3200	13.4686	15.2399	11.5475	20.7605	16.6252
Zero-DCE	11.3223	12.7898	13.4077	11.6404	19.4011	12.3696
RRDNet	9.9617	11.7507	13.7639	10.7967	18.3514	12.3375
RUAS	9.6839	13.3704	12.7194	14.0554	18.5333	17.2513
SCI	9.6639	13.0427	13.0276	12.6378	18.9600	11.9389
Textual method	9.2371	10.2834	11.5474	9.4593	17.5362	9.3485

In addition, the output images were finely color corrected against real thangka images on the thangka dataset having reference images. In order to further validate the effectiveness of this paper's method, an in-depth comparative analysis of peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM) was conducted between this paper's method and other different methods. Table 3 shows the results of PSNR and SSIM of different methods on the dataset with reference thangkas. Comparative analysis of Table 3 shows that the PSNR and SSIM values of this paper's method are 19.8138 and 0.8739, respectively, which are optimal levels among the compared methods. It indicates that this paper's method has good color correction effect on the referenced Thangka dataset, and the output image quality is higher.

The quantitative comparison results fully prove that this paper's method shows good image enhancement effect on both Tangka dataset as well as public dataset, and can output more realistic and natural high-quality images for interactive art design, which further verifies the validity and practicality of the method.

Table 3: Results of PSNR and SSIM of different methods on Thangka datasets

Method	PSNR	SSIM
KinD	16.1971	0.8401
EnlightenGAN	17.5852	0.8653
Zero-DCE	18.2384	0.8522
RRDNet	17.8926	0.8466
RUAS	15.6797	0.7455
SCI	16.6690	0.8430
Textual method	19.8138	0.8739

III. B. 2) Subjective comparison

After using generalized objective metrics on natural images to judge the visual effects of the output images, this paper designed a dual-incentive subjective experimental evaluation scheme to further compare the visual effects of the images from the direction of subjective evaluation. Three groups of participants of different levels were invited to rate the visual effects of the output images, six participants in each group, Experimental Group 1 was participants who had not been exposed to interactive art and design images, Experimental Group 2 was participants who had some knowledge of interactive art and design images, and Experimental Group 3 was experts in interactive art and design images. The output images were scored and averaged in the following three dimensions: color saturation, line clarity, and exposure. With a score of 5 out of 5, the average score within the group was calculated to obtain the results for each group, and a weighting ratio of 2:3:5 was used to weight the results in order to fully reflect the importance of the opinions of participants from different groups.

Table 4 shows the final experimental results. Higher scores indicate better visual quality of the output image. From the experimental results, it can be seen that the final weighted score of subjective evaluation of this paper's method is 4.2698, while the highest weighted score in the comparative method is 3.9590. By comparison, it is found that the output image of this paper's method. The visual effect of the image has the highest subjective evaluation score. It can be judged that the visual effect of the output image of this paper's method is better.

Table 4: Subjective evaluation result

Method	Experimental group 1	Experimental group 2	Experimental group 3	Weighted average
KinD	3.2161	3.1930	3.1160	3.1591
EnlightenGAN	3.7832	3.8165	3.9166	3.8599
Zero-DCE	3.1005	2.9832	3.0501	3.0401
RRDNet	3.8166	3.9131	4.0434	3.9590
RUAS	3.3065	3.2666	3.1932	3.2379
SCI	3.2432	3.2561	3.1664	3.2087
Textual method	3.9267	4.9868	3.9769	4.2698

III. C. Satisfaction analysis of interactive art design

III. C. 1) Satisfaction with quality of generated images

Through the previous simulation experiments and comparison experimental results, it is found that the method of this paper can output images with more natural and realistic visual effects, so that users can get a better immersion experience of interactive art design. A questionnaire survey is conducted to analyze the user's satisfaction with the interactive art design in terms of 2 aspects: satisfaction with the generated images and satisfaction with the interactive realism, to further study the quality of the interactive art design based on the computer graphics processing method in this paper. The questionnaire is designed with 5 levels, which are very satisfied, satisfied, average, dissatisfied and very dissatisfied. The percentage of users' satisfaction in terms of generated images and interactive realism is counted.

Figure 3 shows the statistical results of user satisfaction with the quality of generated images. Analyzing the statistical results, it is found that the percentage of very satisfied, satisfied, average, dissatisfied, and very dissatisfied in the satisfaction of generated images are 56.89%, 16.73%, 10.38%, 8%, and 8%, respectively. The percentage of very satisfied and satisfied users amounted to 73.62% and the percentage of dissatisfied and very dissatisfied users was only 16%. It is concluded that the users are more satisfied with the quality of the images generated by the method of this paper.

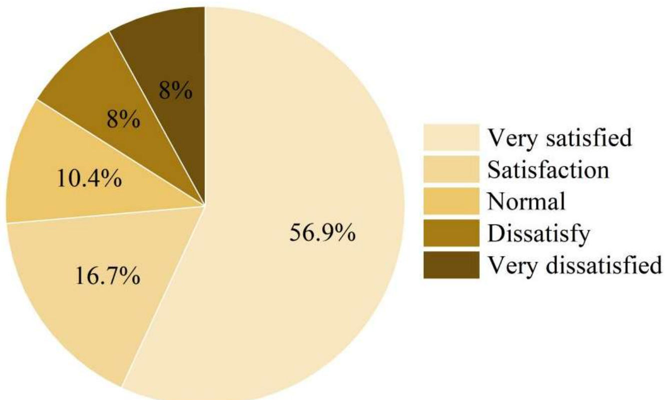

Figure 3: Users' satisfaction with the quality of the generated images

III. C. 2) Interaction realism satisfaction

Figure 4 shows the statistics of users' satisfaction with the realism of interactive art design. From the percentage of each satisfaction option in Figure 4, the percentage of very satisfied is 65.37%, satisfied is 10.84%, average is 13.79%, and dissatisfied and very dissatisfied are each 5.00%. The percentage of very satisfied and satisfied users reaches 76.21%, which is much more than 50%. Accordingly, it is judged that the interactive art design based on computer graphics processing in this paper can well enhance the user's interactive experience and is recognized by most users.

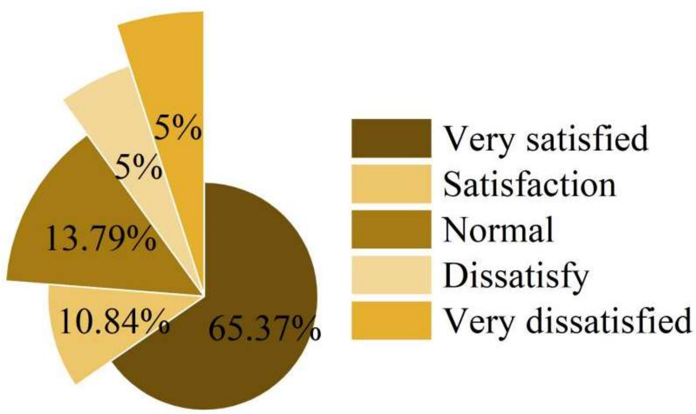

Figure 4: Users' satisfaction with the realism of interactive art design

IV. Conclusion

This paper combines 3D modeling and digital image processing techniques to achieve quality improvement and innovative experience in interactive art design. In the digital image preprocessing simulation experiments, it is found that the signal-to-noise ratio of the preprocessed images is in the range of 20%-55% of the HD standard, and the image quality is better than the 55%-100% multi-noise peak range before processing. In the quantitative comparison, the NIQE values of this paper's method in the three datasets are 9.2371, 11.5474, and 17.5362, and the PIQE values are 10.2834, 9.4593, and 9.3485, respectively, which are lower than the comparison methods. In the Tangka dataset, the PSNR and SSIM values of this paper's method were the highest, 19.8138 and 0.8739, respectively, which were better than the comparison method. In the subjective evaluation, this paper's method scores 4.2698, which is higher than the other six comparison methods. 73.62% of the users are very satisfied and satisfied with the quality of the generated images of this paper's method, and the other 76.21% of the users give very satisfied and satisfied ratings for the interactive realism of this paper's method.

Using the method of this paper can significantly improve the image naturalness of interactive art design, make the image more realistic, and at the same time improve the user's interactive experience. In the future, the efficiency of digital image processing can be further optimized to improve the real-time output effect of the transformed scene, so that users can obtain a more immersive interactive experience.

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