Computer-Aided Design of Fine Art Graphics Based on Virtual Reality Technology

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Abstract. With the increasing development of science and technology, the Internet technology is increasingly updated and iterated, the knowledge system and technical system related to traditional art graphic design are reconstructed. Virtual reality technology has emerged as a revolutionary application in the field of computer-aided art graphic design, creating new possibilities for computer-aided art graphic design. This paper mainly elaborates on the innovation brought by virtual reality technology for computer-aided art graphic design, through the application of virtual reality technology in computer-aided art graphic design as a theoretical compendium, the different roles and differences of virtual reality computer-aided technology in different types of art graphic design, and better conclude the innovation of virtual reality computer-aided technology in art graphic design. To explore more possibilities for the future development of art graphic design.

Keywords: virtual reality; computer-aided; graphic design; multidimensional algorithms
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1 INTRODUCTION

Entering the 21st century, technology manipulates the future era, the development of science and technology has brought about a revolution in virtual reality technology, the high-speed rise of the Internet has brought about a new trend of high-speed processing data, sea quantification of communication information, diversification of communication channels and humanization of audience groups. Virtual reality technology is used in many fields such as art graphic design, industrial manufacturing, entertainment industry, medical industry, museum, real estate industry, and education industry in this era. The combination of technology and art has been bloomed to a greater extent in this era. With the rapid development of the times, the rise of the economic situation, and the increasing rise of the Internet, people's various needs for design comprehensiveness and diversity of entertainment life are getting higher and higher. Traditional graphic design has long been unable to meet the needs of people for life [1]. At this time, art graphic design, which has experienced the baptism and reform of virtual reality technology, has formally come into people's view and is widely used as well as innovative reform.

Modern design takes creativity as a precursor, virtual reality technology as a tool, and new media as a platform to extend the designer's imagination and creative space infinitely, and the way of thinking and technical means of human beings show a tendency of data, and this feature makes the expression form of many modern designs show the characteristics of numerical reason. Data makes the world easier to communicate, and at the same time makes art and design more communal. Designers weaken the national characteristics in the creative process and think about the modern formal vocabulary with the idea of human community, converting forms, colors, and structures into bits and bytes, converting the most indescribable aesthetics [2], and analyzing and deconstructing them in the form of virtual reality. The flat world is essentially a rational world supported by data, and rational design brings data from behind the scenes to the front of the stage as a new trend in future design. The new schema refers to design forms that use virtual reality technology and digital language and present a mathematical and scientific aesthetic as well as a humanistic and technological perceptual experience. The data-based design approach has brought about a large number of modern designs with a mathematical and scientific aesthetic, and this design style forms the new schema. Digital information and new media also continue to call for the emergence of new graphic styles, they build a platform for the emergence of new graphic styles and new visual requirements, digital language and new media have changed the face of design in terms of tools and communication media, innovative formal vocabulary in the mass communication media, and extended from two-dimensional to three-dimensional realm, thus forming the phenomenon of new graphic styles [3].

2 RELATED STUDIES

Through virtual reality technology, designers can "enter" the world of works, breaking the "fourth wall" between designers and works, allowing designers to actively participate in the formation of their unique new forms of expression. Until now, the flourishing of art graphic design is the continuous pursuit of spiritual life under the premise of the progress of human science and technology and the improvement of material living standards. Traditional art graphic design in the current context has become increasingly unable to meet the needs of people's visual experience, people are increasingly inclined to immerse themselves in the world of art, through virtual reality technology and art graphic design combined with the new form of design was born.

Liu et al. [4] provided an in-depth analysis of the development of the virtual reality industry and the application areas of virtual reality. Goe et al. [5] starts with the concept of virtual reality and interaction design and introduces the necessity of virtual reality technology and virtual reality art in the field of design. Jin and Yang [6] argued that one of the important future directions for the development of society is virtual reality and tries to elaborate on this technology to produce changes in all levels and sectors of society. Xia et al. [7] summarized 52 definitions, which are full of technical, philosophical, sociological, and even poetic explorations. Showing how virtual reality has expanded the way humans define themselves and their interaction with the world takes on new forms. Jiang and Zhang [8] provided a detailed description of the script (elements of the script are again visual images, sound), images (elements of cinematography include film, composition, and lighting), sound recording and editing by film production procedures, followed by a detailed explanation of the role and function of the director and the style of some well-known directors. Mohammed and Yaichi [9] explained the visual language of the camera frame in detail, elaborating on picture composition, color, light and shade, and camera movement. Deng et al. [10] systematically and comprehensively introduces the flow and development trend of design history in different regions and countries, such as Egypt, Rome, China and Europe, from the Early Antiquity to the 1980s of the 20th century, providing a certain degree of realistic reference value.

Compared to the rapid development of the entire design industry, there are still relatively few academic studies in the field of design that are more segmented and systematic, especially those that look at actual design through an interdisciplinary perspective. However, interdisciplinarity is an inevitable trend nowadays, as designers need not only the basic skills of design, but also a real understanding of the actual needs of the market to really design valuable works, and the academic community can also bring more innovative results to the whole macro design field through the research in the crossover zone.

3 COMPUTER-AIDED DESIGN OF GRAPHIC DESIGN BASED ON VIRTUAL REALITY TECHNOLOGY

3.1 Computer-Aided Graphic Design Methods Based on Virtual Reality Technology

Modular construction has emerged early in the design form and is carried through to modern design forms, from the megalithic bricks of the Egyptian pyramids to the Dorian style of design of the Parthenon, to masonry design forms, to today's reinforced concrete structures, or glass and steel frame structures. The use of modularity satisfies the design form in the quest for simplicity, speed, and economy of manufacture, and gave multiple facilities for transportation, construction, secondary deconstruction, and reorganization. Modularity has become a design approach from design, transferred to various design disciplines, the module can make the constitutive shape of the body of the block systematically produced, and through the combination of different ways to make the shape presents the characteristics of multiple solutions.

With the intervention of computer technology, modularity has become a new method of creating shapes, and computer-aided art image display is the combination of pixel blocks representing each color together to form various art images that can be presented through the monitor. Especially combined with virtual reality technology, virtual reality technology to complete the design of art graphics in virtual space, can greatly facilitate the designer to solve the problem of hindering the real tools that cannot meet the needs and cannot complete the corresponding works, computer-aided design of art graphics evaluation of the specific process is shown in Figure 1.

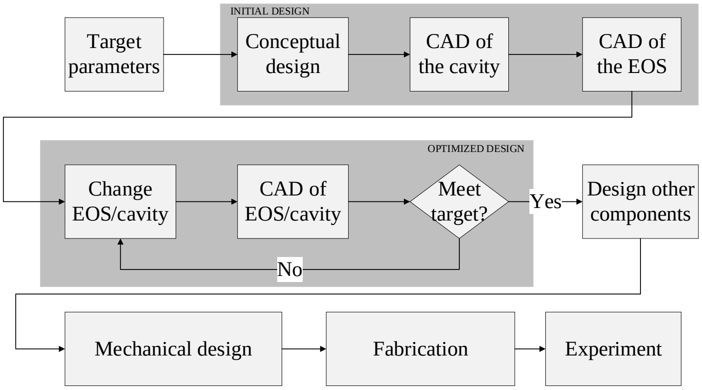

Figure 1: Evaluation of the computer-aided design of graphic arts graphics.

From the virtual to the real, the boundaries of modularity are expanding, and when the computer controls the construction of the module with parameters, the module becomes the key firmware for forming complex geometric shapes, and through its self-deformation and definition, the module can emerge in a new form and present a morphological change with a mathematical aesthetic. The module in the digital age is not just a unit of conformation, but a mimetic body of design elements, which embodies the relationship between modeling and geometry, the module can be replaced by all forms and elements, this modeling allows the computer to realize automatic modeling planning according to the designer's parameter adjustment, the module relies on the change of data to realize the structured adjustment, the designer can thus extract more energy for the design The designer can thus extract more energy for the overall grasp of the idea. In modern design, modules and data modeling often appear together in an integrated manner, where each module is associated in its proper place in the modeling software, where the overall shape is solidified according to the user's needs, where the geometry composed of modules can be structured and manufactured in any possible way, and where the designer's adjustments to the overall shape composed of modules can be achieved using script editing or by real-time simulation and simplification of the geometry to accomplish this. Computer-aided product appearance imagery design techniques generally consist of a combination of design modules such as design analysis, appearance imagery prediction, appearance multi-objective optimization, and optimal appearance solution decision making. In the design process, the quantitative color data of the preliminary color scheme completed by the designer is substituted into the color imagery prediction model, and the color multi-objective imagery value of each preliminary scheme is calculated, and the optimization direction of the preliminary scheme is clarified by comparison with the color design target. In the process of clarifying the optimization direction, different color scheme design ideas are formed according to whether there is a consistent correlation between the key color variables and the multi-target imagery. If there is a consistent correlation, the correlation is used to adjust the key color variables to generate an optimized color scheme. On the contrary, the color multi-imagery preference model is used to complete the evaluation and preference of multiple preliminary product color schemes. After the optimization is completed, determine whether the optimized color scheme meets the color design objectives. Let all the test subjects evaluate the target imagery of the optimal color scheme and observe whether the evaluation result is consistent with the design goal, and iterate again if it is not until the final color scheme with the evaluation result consistent with the design goal is generated.

3.2 Computer-Aided Design Model of Fine Art Graphic Based on Virtual Reality Technology

The role of composition in traditional design works is very great, and a perfect design composition can even make the theme of a design work sublime. However, in virtual reality-based design works, the scene is transformed from a scene constructed by a single picture to a complete large scene, and the scene is presented in a panoramic mode in front of the audience, who can enter the scene through some virtual reality display devices. The composition is no longer fully suitable for the composition of virtual reality-based design scenes. The essence of designing scenes based on virtual reality technology is to show the environment in which the characters live, reflecting the Spatio-temporal relationship between the characters and the background, and to provide realistic and credible scenes for the activities of the characters and the audience through a reasonable layout of the elements to be included in the scenes. The virtual reality technology-based design scene is a three-dimensional virtual world, and this completely independent space requires the creator to have an overall concept at the beginning of the design, so that each independent subspace, scenery, and each perspective in the scene can be taken care of. When designing a scene space based on virtual reality technology, the traditional thinking of designing a scene should not remain, and it should not stick to the flat composition thinking to show the space but should be able to show the virtual scene with the thinking of three-dimensional space, and every angle in the scene can be reasonably arranged. Through the reasonable layout of objects and objects to form a complete picture, so that all the objects in this space form a whole, so that the audience can understand the information that the creator wants to express, such as Figure 2 for the virtual reality-based art graphic design process.

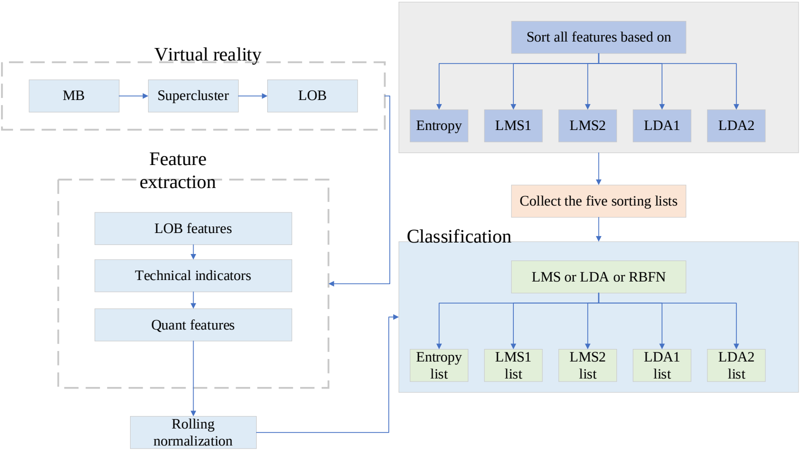

Figure 2: Virtual reality-based art graphic design process.

The "non-linearity" of the design of graphic language dynamics in artistic creation is a reflection of the language of art, an exploration of temporal transformation. The design of graphic language dynamics depends on the design of the time, in which the concept of the timeline is particularly important. The timeline visualizes the invisible time, giving it a vehicle that can be edited. When designing art, the work can be cut, fast-forwarded, or fast rewound at will, and can be recombined according to intent and changed endlessly. With the timeline, we can edit everything that has happened in the past at will, which to some extent breaks down the concept between past and present, making the linear passage of time, "non-linear". The specific process of 2D modeling art image pre-processing is: first the product artwork after binary art image, smoothing process and threshold segmentation, filter out the non-target information in the background of the art image, and then extract the contour boundary features of the product.

This results in a two-dimensional sequence of contour point coordinates consisting of the x and y coordinates of discrete sampling points, starting at a point at the contour boundary and going around the boundary in a clockwise or counterclockwise direction, which describes the shape characteristics of the modeling contour of the sample product, denoted as $(a_1, a_2, ..., a_n)$. The center coordinates of this contour can be further expressed as

$$\mathrm{F}(a_1, a_2, ..., a_n) = \sum_{i=1} \gamma a_i^3 \tag{1}$$

For the subsequent elliptic Fourier transform, the sequence of 2D contour point coordinates is expressed in terms of a complex functional relation as

$$Z(i) = \sum_{i=1}^{n} \kappa X_i + \sum_{i=1}^{n} (X_i - \bar{X})^2 + \mu_X \tag{2}$$

To standardize the different sample data points, the isometric principle is used to standardize the interpolation process in the complex coordinate system. Assume that the number of uniform new interpolation points is A, and the perimeter of the sample morphological boundary contour is

$$sigma(x,y)=\frac{\sigma_y^2+\mu_y+\sum_{i=1}^{n}x_i y_i}{x\cdot e^{i\theta}\cdot\sigma_x} \tag{3}$$

Then the equal arc length sampling spacing is

$$J(W,b)=\frac{1}{m}\sum_{i=1}^{m}J(w,b_i)+\frac{\lambda}{2}\sum(w_{ij})^2 \tag{4}$$

Assume that the new interpolation point lies between the original contour points mz and mz1 and the distance from the original contour point to the starting point is

$$\frac{\partial}{\partial W_{ij}^{\,l}}J(\mathrm{w},\mathrm{b})=\frac{1}{b}\sum_{i=1}^{m}J(w,b;x^i,y^i)+\lambda W_{ij}^{\,l} \tag{5}$$

As a method for exploring the correlation of variables, the principal component analysis represents the original multivariate data through a small number of linearly uncorrelated principal component data based on a linear transformation. Principal component data reveal the intrinsic links between the original data and eliminate their correlation, thereby reducing the dimensionality of the data and simplifying the analysis and processing of high-dimensional oriented data.

The spherical harmonic coefficients achieve formal unification of the heterogeneous data of the triangular mesh model, but their data dimensionality is still high. Since high-dimensional data increases the difficulty of analyzing and processing 3D modeling data, reduces the generalization ability of the algorithm, and is not conducive to the mining of meaningful structures of 3D modeling data, further data reduction, and feature extraction are performed on the spherical harmonic coefficients to obtain more meaningful principal component data of low-dimensional representations. Since there is information loss in the data downscaling process, for this reason, there is a need to find applicable downscaling techniques that can minimize the information loss of spherical harmonic coefficients. Auto Encoder (AE) is an advanced dimensionality reduction technique that extracts low-dimensional depth structural features of high-dimensional data as data representation by using a multilayer neural network with simple nonlinear functions for each layer of the neural network to achieve low-dimensional transformations and feature extraction of high-dimensional data. It can achieve both efficient and accurate linear and nonlinear dimensionality reduction, which provides a feasible method for obtaining principal component data for high-dimensional spherical harmonic coefficients. The self-encoder's network structure is shown in Figure 3.

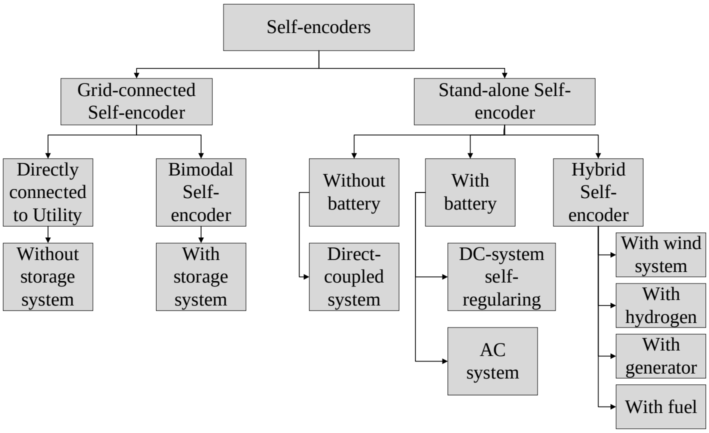

Figure 3: Self-encoder grid structure.

The self-encoder consists of two processes, encoding, and decoding, which are implemented by the encoder and decoder, respectively. Among them, the encoder reduces the input data X into a potential spatial representation X' by the encoding process, which can be represented by the function f(X), and the decoder reconstructs the input data X from X' by the decoding process, which can be represented by the function g(X). Thus, the full process of the self-encoder can be expressed as h(X)->f(X). By completing the solution of the mappings h and f, a potential spatial representation X' with value properties is output by the encoder. As the lowest dimensional vector of the network, X' achieves the purpose of downscaling and feature extraction of the spherical harmonic coefficients that are the input data of the network, and the output of the principal component data is obtained. In the solving process of X', the self-encoder takes the minimization of data reconstruction error as the learning criterion and changes the connection weights between the layers of the network through gradient descent and backpropagation algorithms, to achieve the optimization of the network parameters. Since self-encoders are essentially neural networks, this feature gives them better applicability in dimensionality reduction of high-dimensional complex data compared to linear dimensionality reduction algorithms. Since the only constraint is that its input and output layers have the same dimensionality, in between, any hidden dimensional structure that best encodes high-dimensional data can be created, which provides enough flexibility for dimensionality reduction of high-dimensional spherical harmonic coefficients. At the same time, the structural form of the neural network gives the self-encoder value as a layer structure for building generative models. These features make the self-encoder an effective technique suitable for the processing and generation of quantitative data for the 3D modeling of products.

4 ANALYSIS OF RESULTS

As a technology that uses deep networks, the network structure of CVAE (Cave Automatic Virtual Environment), a based technology virtual reality display system, directly determines its overall performance, so it is important to determine the optimal network structure. Many factors have a significant impact on the determination of its network structure. First, to observe the data distribution in the potential space, CVAE usually sets the dimensionality of the bottleneck layer to 2. After testing, it is found that when the number of hidden layers in the recognition network and the generation network of the model is 3, the computational accuracy and efficiency can be guaranteed at the same time, while increasing the number of hidden layers does not significantly improve the convergence of the model, but increases the computational complexity and time, so the number of hidden layers in both networks of the model is set to 3. Then, the suitable dimensions of the first and second fully connected layers are determined by further simulation tests. To extract the low-dimensional spherical harmonic principal component data to participate in the generation of imagery labels, the appropriate low dimension was first determined for the second fully connected layer located in front of the bottleneck layer. The principal component analysis reveals that sufficient raw data information can be extracted when 4-12 principal components are present, and this dimensional range also helps to reduce the data processing difficulty for 3D modeling imagery label recognition. Therefore, the number of neurons in the second fully connected layer was then tested in that range. The total loss value metric was used to measure the effect of different numbers of second fully connected layer neurons on the overall performance of the CVAE, and thus to determine the specific structure of the CVAE. Figure 4 shows the mean and variance of the total loss value metric for the "high class" imagery label after 30 independent runs with different numbers of neurons in the first and second fully connected layers, respectively. The semi-transparent area around the fold reflects the range of variance.

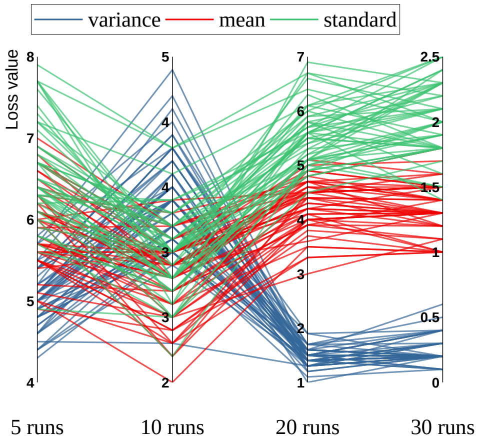

Figure 4: Mean and variance of different structures of the fully connected layer with the number of iterations.

The effect of CVAE on the generation of different target imagery was further observed by combining the sample size and indicator values of each cluster in Figure 5. This reflects that the sample size is an important factor affecting the effect of CVAE generation, and the relatively comprehensive and rich stylistic information enables the model to have better feature mining This reflects that sample size is an important factor affecting the effectiveness of CVAE generation. In addition, although the sample sizes of the "organic" and "unique" clusters are similar, there are differences between them in terms of diversity index and imagery metrics. Compared to the sample shapes in the "organic" cluster, the sample shapes in the "unique" cluster have more differentiated overall stylistic features, but fewer detailed stylistic features. The overall cognitive pattern of stylistic imagery determines that distinctive overall stylistic features are more likely to elicit recognition of image-matching and image difference. According to the definition of diversity index and imagery conformity index, they are both more susceptible to differential overall stylistic features. Therefore, the diversity and imagery conformity of the scenarios generated under the "unique" imagery label is higher. The overall metric values indicate that CVAE has established a good mechanism for generating 3D shapes that match the differential target imagery, and can generate 3D shapes that match the target imagery more accurately; CVAE achieves the distribution fitting of 3D shape data for multiple imagery types at the same time and completes the generation of new 3D shape data that satisfy multiple imagery types. By mastering the distribution of sample 3D modeling data with the same imagery labels, new 3D models matching the target imagery can be generated by random sampling, which increases the possibility of obtaining rich creative 3D modeling solutions and effectively reduces the workload of designers.

A multi-imagery prediction model containing 3 GABP networks was constructed for predicting the computational scores of perceptual imagery for each of the 3 target adjectives. The classical three-layer structure is chosen for each BPNN, with the number of neurons in the input, hidden and output layers being 7, 10, and 1, respectively, and the optimal initial weights and thresholds for the 3 BPNNs are optimized using a genetic algorithm. For the given parameters of the GABP algorithm, Figure 6 shows the prediction errors of the multi-imagery prediction model for each target adjective when the number of iterations is 20,000, and the RMSE values of the multi-imagery prediction model are calculated, reflecting that the RMSE values of the three BPNNs decrease rapidly with the increase of the number of iterations. After 20,000 iterations, the final RMSE values were 455, 534, and 526, respectively, which were within the acceptable error range, indicating that the convergence performance of each network was satisfactory.

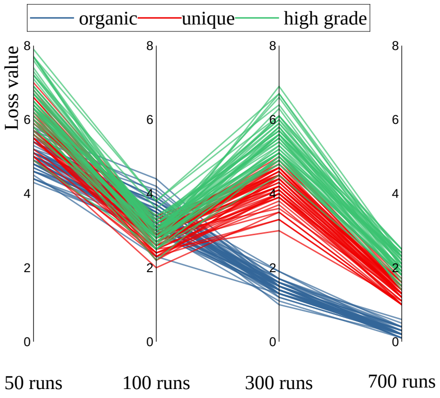

Figure 5: Sample size profile and values of each indicator for each cluster.

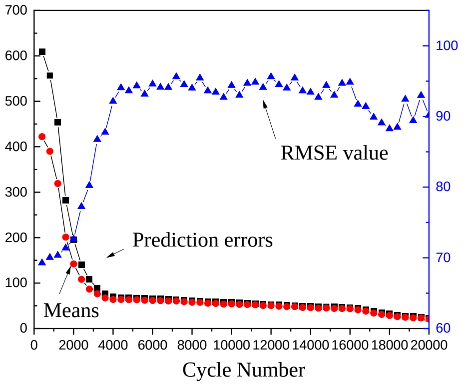

Figure 6: Results of independent sample t-test for posttest scores.

Figure 7 shows the quality evaluation performance of the virtual reality-based computer-aided design quality evaluation method for fine art images on the SIAT-PCQD dataset for all sequences, figures, and object sequences. The proposed method in this paper uses a patch projection representation, the comparison method uses a traditional view projection representation, and the quality prediction uses the same 11 traditional fine art image quality evaluation algorithms for a fair comparison. It can be seen that the average gain of PLCC metric and SROCC metric of the proposed traditional fine art image quality evaluation method based on patch projection is 0.3426 and 0.2368, respectively, and the gain ratio reaches 109.94% and 77.07%, respectively. Compared with the traditional art image quality evaluation method based on view projection, the proposed method has a significant improvement in the correlation on most of the art image quality evaluation metrics, with the improvement ranges of [0.31, 0.54] and [0.27, 0.39] for PLCC and SROCC, respectively. The best performing fine art image quality evaluation metric is IW-SSIM with PLCC and SROCC of 0.8181 and 0.6966, respectively, improving by 0.3883 and 0.2922. The projected fine art image generated according to the proposed method consists of several irregular patches, and the pixels within each patch correspond to 3D spatial points with similar normal vector orientations, and the patches can effectively reflect the human eye's visual perception of the surface details of the point cloud, and thus the proposed method is a substantial improvement on most fine art image quality prediction methods. However, it is noteworthy that the proposed algorithm does not improve the correlation coefficient much on VIF and decreases on IFC. The reason for this is that both IFC and VIF are methods based on natural scene analysis, and the art images formed by patch projection contain many segmented piecewise regions with significant boundary discontinuities, which are significantly different from natural scene art images, and thus the projected art images generated by the proposed method do not improve much when using these types of art image quality evaluation methods for quality prediction. In addition, to verify the effectiveness of quality evaluation using patch-based projection art images. Similarly, the proposed traditional fine art image quality evaluation method based on patch projection has a significant improvement on the 11 fine art image quality evaluation metrics tested, with an average gain of 0.4478 and 0.4596 for PLCC and SROCC, respectively, and a gain ratio of 112.78% and 123.54%, respectively. Considering all correlation metrics, the best performing fine art image quality evaluation methods are RFSIM, SR-SIM, and VSI. the best performing fine art image quality evaluation algorithms have inconsistencies in the dataset and dataset, which may be related to the sequence content of the dataset. the source point clouds of the V-vsenseVVDB dataset are all person point clouds, while the proposed dataset contains both people point clouds and object point clouds. SR-SIM is also one of the best-performing methods for fine art image quality evaluation on the sequence of person point clouds in the SIAT-PCQD dataset.

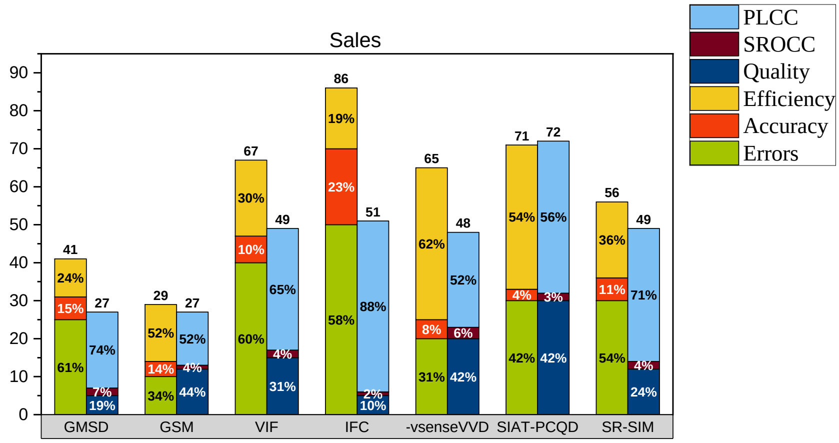

Figure 7: Quality evaluation of multiple computer-aided design algorithms.

5 CONCLUSION

Art graphic design scenes have developed step by step with art graphic design art, from the initial background to an indispensable element of art graphic design narrative, from the initial simple depiction to an indispensable part of today's performance of space-time relationship, which is gradually formed by the continuous exploration and summary of countless creators. The interactivity and immersive viewing experience of virtual reality-based art graphic design have subverted the relationship between the audience and the story, the character, and the scene, and the story and the scene, bringing a brand-new experience to the audience, who are no longer spectators but participants. The audience "enters" the scene of virtual reality-based art and graphic design, which is equivalent to giving the power of camera and time to the designer, and the design changes from a single creation mode dominated by the time to a creative mode with both space and time, which leads to the study of the visual language of the scene of virtual reality-based art and graphic design. The study of visual language becomes crucial. Virtual reality-based art graphic design scenes no longer adhere to the flat composition thinking, but through three-dimensional composition thinking of the elements in the scene for reasonable layout, so that the audience can receive the complete information in the scene under the situation of their continuous movement. Virtual reality-based art graphic design scenes reflect the progress of time through the control of color rhythm while creating different emotions to highlight the occurrence of the plot, and adding the constantly changing light and shadow relative to the audience, with the plot to produce the corresponding scene atmosphere, to achieve the purpose of guiding the audience's free perspective. Through the study of the visual language of the scene based on virtual reality technology, to guide the audience to always focus on the main storyline, to ensure that the audience is in the "free perspective" without the interference of the surrounding scene elements while adding certain interactive means so that the audience can have a diverse experience of the plot. Virtual reality-based art graphic design is an emerging art form, which brings the audience a strong sense of presence based on virtual reality technology and interactive experience, and has great potential for development. Under the condition that the hardware and software are not fully mature now, quality content is one of the driving forces for technical innovation, so that more creators can see the potential of art graphic design based on virtual reality technology, attracting more creators to create and providing more research materials and research topics for art graphic design scenes based on virtual reality technology.

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