Simulation Design of Virtual Packaging Model Based on Visual Transmission

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Abstract. The appearance packaging design of goods mainly uses various visual design elements to form its unique visual image and attract consumers' visual attention. Visual transmission is the direct purpose of visual transmission design, which conveys various visual information to the public through two-dimensional image representation. In this article, under the guidance of visual transmission theory, taking computer-aided design (CAD) of product packaging as an example, combined with the packaging image processing algorithm based on deep learning, a simulation model of visual image of product packaging modeling is established, and then the visual optimization design of product packaging modeling is realized according to the results of edge contour detection and corner detection, so as to improve the visual transmission ability of product packaging modeling. The visual transmission ability of product packaging modeling. With the help of computer-aided means, the quality and efficiency of product packaging design can be greatly improved.

Keywords: Visual Transmission; Packaging Design; CAD; Image Processing
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1 INTRODUCTION

Product development packaging design refers to the packaging design of a product, in order to better showcase its characteristics and advantages, improve its attractiveness and market competitiveness. Packaging design is one of the important links in product development, which can help promote and sell products better. Packaging design needs to consider multiple factors, and packaging design should consider the practicality of the product, such as capacity, portability, and protection. Adem and Közkurt [1] use information technology to prepare teaching content and methods, such as utilizing teaching resources and tools from educational cloud platforms. At the same time, teachers can also use information technology tools such as electronic whiteboards and online courses to enrich classroom teaching content and improve teaching effectiveness. Bakar and Sun [2] refer to the process of designing and optimizing packaging using computer technology. CPD can help packaging designers better understand product characteristics, consumer needs, and market trends, thereby designing more attractive and competitive packaging. CPD can convert three-dimensional modeling into two-dimensional structural graphics, select and apply the generated box structures, or combine and apply the stored parts of various box structures. Indrie et al. [3] innovatively designed, trimmed, and processed various elements of product packaging design, which can be digitized in various aspects such as text, graphics, photos, and layout. They can also perform some special effect processing to complete the design scheme. CPD can convert two-dimensional graphics into three-dimensional visual images through design software, such as modeling with 3DMax, Maya, rhinoceros, or Solidworks software. This can enable customers to have a more intuitive, realistic, and comprehensive understanding of the final packaging effect, in order to provide opinions, make modifications, and adjustments. It can also be used to evaluate the effectiveness of testing packaging design. Liu and Yang [4] conducted process testing on packaging design and optimization using computer technology. It can help packaging designers better understand product characteristics, consumer needs, and market trends, thereby designing more attractive and competitive packaging.

Shih and Sher [5] questioned whether switching behavior would affect the use of CAD modeling and sketching channels in the design process. The study conducted a loud thinking experiment on eight designers. They were asked to use two different methods to design specific artifacts, first not allowing them to switch between media, and second allowing them to switch. Sun et al. [6] explored the field of ceramics, which can help enterprises achieve personalized customization, reduce costs, improve production efficiency, and product quality. The results indicate that 3D printing technology can print ceramic products of different shapes and sizes according to customer needs. This technology can help enterprises achieve personalized customization and meet the needs of consumers. 3D printing technology can reduce intermediate links in the production process and reduce production costs. This is particularly important for ceramic enterprises with smaller production scales. 3D printing technology can achieve automated production and improve production efficiency. This is particularly important for ceramic enterprises with larger production scales. Sydow et al. [7] established three-dimensional models of products and packaging, rendered and animated them accordingly, and visualized them to better showcase the appearance, characteristics, and functions of products and packaging. Computer assisted conceptual design of products and packaging can help designers better understand the design requirements of products and packaging, thus enabling better design. Computer-aided conceptual design of products and packaging can also help enterprises better showcase the characteristics of their products and packaging, improve the attractiveness and competitiveness of their products and packaging. Vasileiadis et al. [8] clarify design goals and requirements, determine the theme and style of the design, and determine the budget and time constraints of the design. Save the file name as a connector, and during the design process, various files need to be saved. Including 3D model files, material files, texture files, etc. Using the Equation Manager, it is easy to manage various design parameters. This includes parameters such as size, position, and color of each part of the model. Wang and Qin [9] chose to use computer-aided design and manufacturing technology to optimize the design of connecting rod molds, which has important engineering practical application value. By optimizing the design and cost calculation of the connecting rod mold, a faster and more accurate solution has been obtained, providing strong support for subsequent mold structure design. The optimization design of connecting rod molds based on computer-aided design and manufacturing technology has shortened the mold development cycle, improved the quality of molds and parts, reduced development costs, and improved product competitiveness. Transmission is generally divided into verbal transmission and non-verbal transmission, and visual transmission of packaging graphics belongs to non-verbal transmission. Packaging technology has experienced three development stages: physical packaging, modern packaging and digital packaging.

2 RELATED WORK

When developing new products, brand designers must understand the needs, preferences, consumption habits, and other information of the target audience through market research. In order to better position the brand and design products. Understand the product characteristics, market positioning, marketing strategies, and other information of competitors in order to better brand positioning and product design. Through user research, understand the needs, preferences, consumption habits, and other information of the target audience, in order to better brand positioning and product design. Wang et al. [10] established a classification system for product related knowledge. Determine a classification system for product related knowledge based on factors such as product functions, characteristics, and application scenarios, such as product categories, product functions, and product characteristics. Determine evaluation indicators for product related knowledge based on the classification system of product related knowledge. Such as the practicality of product functions, the uniqueness of product features, and the applicability of product application scenarios. Establish an evaluation matrix for evaluation indicators. Based on the evaluation indicators of product related knowledge, establish an evaluation matrix of evaluation indicators, such as comparing the practicality of product functions with the uniqueness of product features, and comparing the applicability of product application scenarios with the uniqueness of product features.

Yu and Sinigh [11] analyzed the plane decoration design. For example, the pattern design of packaging boxes, the pattern layout of packaging boxes, and the pattern filling of packaging boxes. The simulation demonstrates that CAD technology can be used for packaging container design and effect simulation display content. Such as the three-dimensional rendering of the packaging box, the unfolding diagram of the packaging box, and the die-cutting diagram of the packaging box. Yun and Leng [12] found that the combination of virtual reality and CAD software can be used to optimize packaging design. CAD software can be used to establish three-dimensional models of packaging, while virtual reality technology can be used to simulate the usage scenarios and effects of packaging, thereby helping designers better carry out packaging design. Combining the development of digital media art, Zhang [13] discussed how to better integrate visual interaction experience with creative design, and analyzed the process, design, and technical points of visual interaction work creation. In addition, an image processing model for human-computer interaction interface visual communication was established, and edge contour feature extraction methods were analyzed to extract its boundary information features. Zhao et al [14] designed a packaging design framework for the main consumer groups of agricultural products. Designers can use CAD software to create a three-dimensional model of packaging, and then use virtual reality technology to simulate the usage scenarios and effects of packaging, such as unfolding, folding, and opening of packaging. Through the simulation of virtual reality technology, designers can better understand the usage and effectiveness of packaging, thereby better carrying out packaging design. In addition, the combination of virtual reality and CAD software can also be used to optimize packaging material selection and process design. Designers can use virtual reality technology to simulate packaging materials and processes, such as the packaging effects of different materials and processes, in order to better select suitable materials and processes and improve the quality and performance of packaging.

In short, the combination of virtual reality and CAD software can be used to optimize packaging design, help designers better design, improve design efficiency and quality.

3 METHODOLOGY

3.1 Visual Image Analysis of Product Packaging Modeling

CAD is a comprehensive system that integrates various technologies, and it closely integrates information technology with application technology. The software system of CAD is composed of system software, data management software, calculation and analysis software, word processing software, graphics software, professional application software and network transmission software. CAD system can be applied to every link of the whole packaging process. The product packaging structure, including the outer packaging carton structure and the form, type and corresponding calculation of the internal buffer structure, also needs as detailed product information as possible. Abstracting the collected product-related information, and then obtaining the corresponding mathematical model. On this basis, the model is built with the help of UG software. The visualization stage of product packaging CAD is shown in Figure 1.

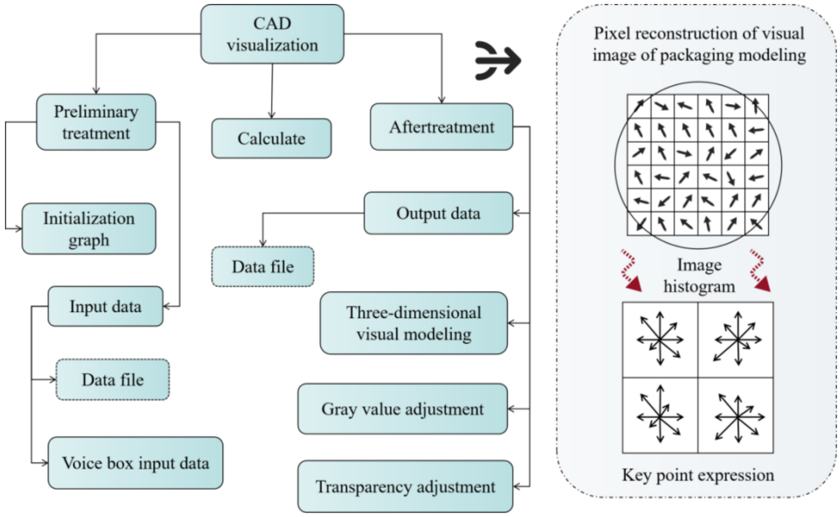

Figure 1: Visualization stage of product packaging CAD.

$$g_{\min} \leq T \leq g_{\max} \tag{1}$$

$$g(x,y)=\begin{cases}1, & f(x,y)\geq T\\ 0, & f(x,y)<T\end{cases} \tag{2}$$

Using image processing method to sample the visual image of product packaging modeling, extracting the edge contour feature quantity of the visual image of product packaging modeling, constructing a three-dimensional visual reconstruction model, carrying out three-dimensional feature analysis and sparse surface feature reconstruction [14]. The scene corresponding to the product needs to be set. At the same time, it is necessary to expand the product packaging structure and make reasonable arrangements for the discharge mode of the contents in the product packaging. The final design effect needs to be displayed in a virtual way. The final result is that the product packaging structure and its contents can be observed in all directions at any angle, any position and various folding angles.

3.2 Virtual Packaging Model Based on Visual Transmission and CAD

Combined with the high-resolution feature reconstruction method, the visual information of product packaging modeling was sampled, and the distributed feature reconstruction model of product packaging modeling vision was established. The gray histogram of visual image of outer packaging modeling was established, and the visual information was reconstructed according to the distribution of pixel feature points in the histogram, and the pixel reconstruction model of visual image of product packaging modeling was obtained. For a packaging image, $p(i)$ is the histogram probability of the image, i is the gray value of the image, $0 \le i \le L$. The histogram potential function is expressed as follows:

$$P_H(k) = \frac{1}{P_{\max}} \sum_{i=0}^{L} \frac{P(i)}{1+\alpha(i-k)^2} \tag{3}$$

$$P_{\max} = \max\left\{\sum_{i=0}^{L} \frac{P(i)}{1+\alpha(i-k)^2}\right\} \tag{4}$$

$$x \in \{0,1,2,3,\ldots,m-1\} \qquad y \in \{0,1,2,3,\ldots,n-1\} \tag{5}$$

$$h(i) = \sum_{x=0}^{m-1}\sum_{y=0}^{n-1} \delta(f(x,y)-i) \qquad i \in \{0,1,2,3,\ldots,G-1\} \tag{6}$$

In the formula, the function $\delta(0)=1$, $\delta(i \neq 0)=0$. $h(i)$ represents the number of pixels whose gray value is i in the image I.

In this article, a simulation design method of product packaging modeling based on CAD is proposed. The visual image of product packaging modeling is sampled by image processing method. Calculate the high-resolution feature distribution value of product packaging modeling vision, reconstruct the three-dimensional feature of product packaging modeling vision by machine vision method, and obtain the active contour distribution of product packaging modeling visual image:

$$P(\phi) = \int \frac{1}{2}(|\nabla \phi| - 1)^2 dx \tag{7}$$

Where: E^{LBF} is the gray item of visual distribution of product packaging modeling; E^{LGF} is the distribution term of edge fuzzy features. Using the method of CAD reconstruction to design visual transmission;

$$\begin{aligned} E^{LBF}(\phi, f_1, f_2) = \lambda_1 \int \left[\int K_\sigma(x-y)|I - f_1(x)|^2 H(\phi) dy\right] dx + \\ \lambda_2 \int \left[\int K_\sigma(x-y)|I - f_2(x)|^2 (1-H(\phi)) dy\right] dx \end{aligned} \tag{8}$$

$$\begin{aligned} E^{LGF}(\phi, f_1^G, f_2^G) = \lambda_1 \int \left[\int K_\sigma(x-y)\left|I^G - f_1^G(x)\right|^2 H(\phi) dy\right] dx + \\ \lambda_2 \int \left[\int K_\sigma(x-y)\left|I^G - f_2^G(x)\right|^2 (1-H(\phi)) dy\right] dx \end{aligned} \tag{9}$$

Where: I^G represents the texture feature of the visual distribution sub-band of product packaging modeling; f_1^G and f_2^G denote gradient modules of regional reconstruction. Wavelet multi-scale decomposition method is used for contour detection and feature point calibration, and three-dimensional sparse surface feature reconstruction of product packaging modeling visual image is carried out.

$$\frac{\partial f}{\partial r} = \frac{\partial f}{\partial x} * \frac{\partial x}{\partial r} + \frac{\partial f}{\partial y} * \frac{\partial y}{\partial r} = f_x \cos\theta + f_y \sin\theta \tag{10}$$

The conditions for $\frac{\partial f}{\partial r}$ to reach the maximum value are:

$$\frac{\partial\left(\frac{\partial f}{\partial r}\right)}{\partial\theta}=0 \tag{11}$$

$$f_x\cos\theta+f_y\sin\theta=0 \tag{12}$$

The following can be obtained:

$$\theta_g=\arctan\left(f_y/f_x\right) or \theta_g+\pi \tag{13}$$

Then the gradient modulus is:

$$g=\left(\frac{\partial f}{\partial r}\right)_{max}=\sqrt{f_x^2+f_y^2} \tag{14}$$

The direction of gray change is:

$$\theta_g=\arctan\left(f_y/f_x\right) \tag{15}$$

In the end, the vectors in each category are replaced by the index numbers of their corresponding codewords, and only the indexes of the codewords are transmitted during transmission. When decoding, only the corresponding codewords need to be found in the codebook according to the received index numbers and used as the reconstructed vectors of the input vectors, thus achieving the effects of data compression and decompression.

4 RESULT ANALYSIS AND DISCUSSION

In order to verify the validity of the virtual packaging model proposed in this article, a picture with low contrast and blurred image in the product packaging of a product is selected for testing. In the test process, the virtual packaging model proposed in this article is compared with the image processing methods of SVM algorithm and BPNN algorithm. Packaging image processing is a reasoning process, which infers the data of unknown parts according to the prior information of known parts in the image. The modeling effect of CAD system is evaluated by the number and accuracy of detected edge pixels, as shown in Table 1. Misjudging points in the table means judging non-edge points as edge points.

	Original image	*Robert*	*Sobel*	*Prewitt*	*LOG*
Edge points	750	594	576	541	575
Detection ratio	-	80.2%	80.1%	77.2%	84.5%
Misjudgment point	-	None	Basically none	Basically none	None

Table 1: Detection effect without noise.

The human eye has the function of filtering all the information in the image and will give priority to the information that the brain thinks is important. Therefore, in the stage of image processing, we should also strengthen the information processing of important parts. Table 2 shows the comparison results of detection effects when Gaussian noise is added. In practice, Gaussian noise is one of the typical noises, so the LOG operator has high practical value.

	Original image	*Robert*	*Sobel*	*Prewitt*	*LOG*
Edge points	750	541	555	522	542
Detection ratio	-	78.8%	80.1%	77.2%	83.6%
Misjudgment point	-	Have	Have	Basically none	Have

Table 2: Detection effect when adding Gaussian noise.

Various packaging structures, shapes, colors, materials, surface textures, and label designs are used to observe product packaging. When time and budget are limited, and it is impossible to actually manufacture multiple packaging samples of a product for comparison, using virtual implementation technology is particularly useful. A combination of techniques can also be used to generate virtual visual packaging on shelves or in a virtual scene in a field environment, so that the designed packaging and how competing products of the same kind emerge on the shelves can be seen. In addition, different lighting can be used for display, so as to evaluate the surface characteristics and other properties of the color materials packaged under various lighting conditions using virtual implementation technology. According to market demand, modern design concepts can be used to mobilize various visual elements such as text symbols, numerical patterns, and accurately and effectively convey packaging information about product characteristics. Therefore, virtual visual packaging can also be directly used to produce printed or television advertisements for the product. Virtual visual packaging can also be used in online sales environments to showcase and market products worldwide through the Internet. The virtual visual packaging displayed on the Internet can not only clearly display the appearance labels and certain properties of formaldehyde products globally with a realistic visual image. And there is no need to worry about the products displayed in the virtual environment being tainted or lost. With the widespread acceptance of television shopping and online shopping, the research and application of virtual visual packaging will undoubtedly win more attention from people.

When designing the packaging of products, the selected patterns should be able to play the role of product reproduction, that is, to understand the relevant characteristics of products through the content of patterns, so as to arouse consumers' interest. This process mainly presents the required product information from an aesthetic point of view. Therefore, it is particularly necessary to integrate human visual characteristics into product packaging design. The image seen by human eyes is formed by the light reflected from the object in the retina. By using Fourier transform, these light can be decomposed into sinusoidal brightness components, and the sinusoidal brightness components change with the change of spatial frequency. The detection ability of human eyes is limited to some extent. For the part with small details of the image, the spatial frequency of its sinusoidal brightness component is higher, which exceeds the lower limit of the detection ability of human eyes. In order to enhance the visibility of this part of the image, modulation is needed. Figure 2 is the gray histogram of the original packaging image. Figure 3 is the gray histogram enhanced by the virtual packaging model in this article.

Traditional methods can extract the characteristic information of packaging images to a certain extent, but at the same time, they also enhance the redundant background information of packaging images. The human eye's ability to perceive the gray-scale deviation of an image is limited to some extent. When the gray-scale difference between image pixels reaches a certain value, the human eye can recognize this change. This value is called the critical visible deviation. When the gray difference of the pixel of the image is lower than the critical visible deviation, its change will not be perceived by people, so the pixel can be replaced by compression.

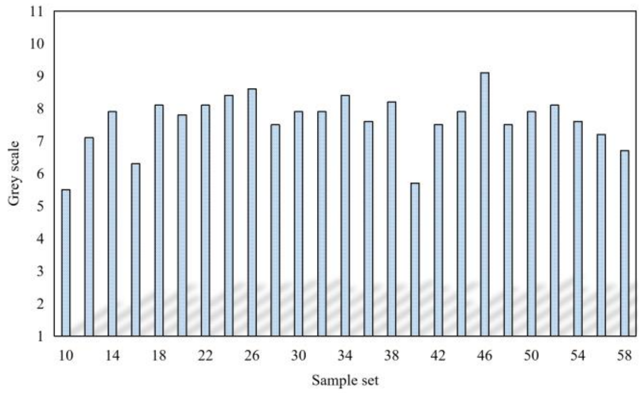

Figure 2: Gray histogram of original packaging image.

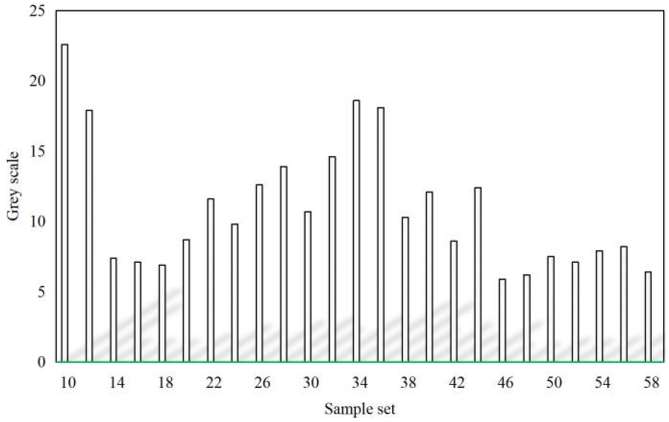

Figure 3: Gray histogram enhanced by digital extraction model.

The segmentation performance of this algorithm is compared with SVM and BPNN respectively. The accuracy of different algorithms is shown in Figure 4. The recalls of different algorithms are shown in Figure 5.

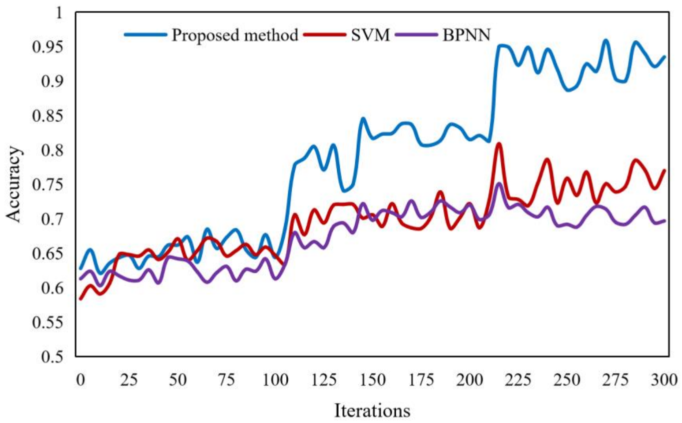

Figure 4: Accuracy of different algorithms.

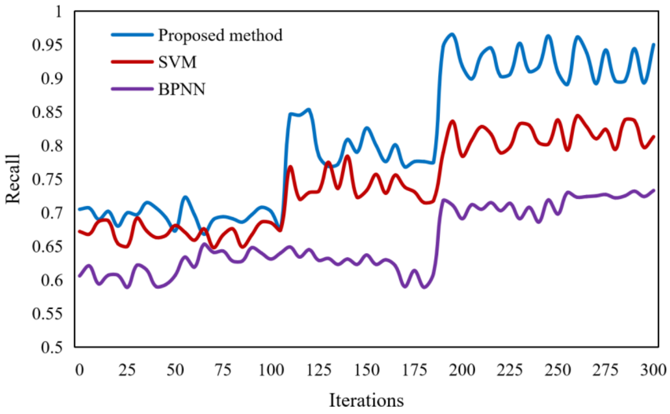

Figure 5: Recall of different algorithms.

Taking the error of product packaging image feature extraction comparison objects, and the test results are shown in Table 3, Table 4 and Table 5.

Number of samples	*Feature extraction error (%)*
50	1.25
100	0.98
150	0.76
200	0.59
250	0.62
300	0.54
350	0.51

Table 3: Product packaging feature extraction error of this method.

Number of samples	*Feature extraction error (%)*
50	4.16
100	3.99
150	3.75
200	3.56
250	3.21
300	2.85
350	2.75

Table 4: Product packaging feature extraction error of SVM.

Number of samples	*Feature extraction error (%)*
50	5.65
100	5.17
150	4.88
200	4.56
250	4.18
300	3.88

350	3.36

Table 5: BPNN product packaging feature extraction error.

The defective pixels in the segmented image are discontinuous in the changes of surface direction, depth and material properties. In order to eliminate the irrelevant information and retain the structural attributes of image defects, this article proposes to treat the defect edge with the maximum and minimum derivatives of image information, and take the direction of the maximum change of information gradient as the edge guidance. The cognitive stage of visual transmission of virtual packaging design is shown in Figure 6.

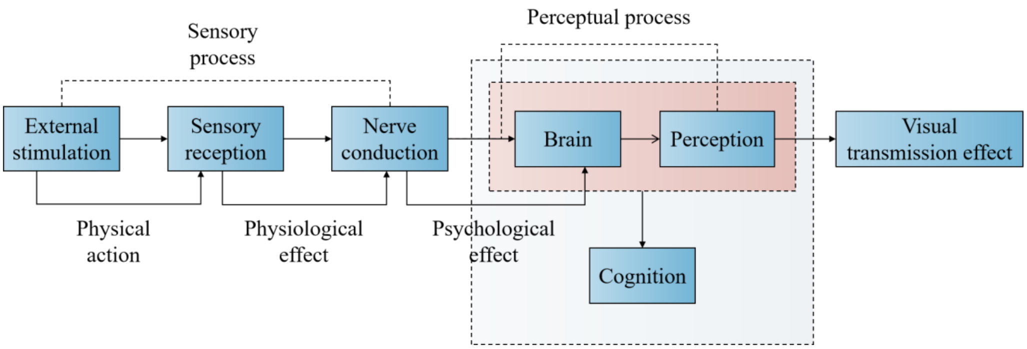

Figure 6: Cognitive stage of visual transmission in virtual packaging design.

When designers get the corresponding design tasks or problems. Figure 7 shows the subjective evaluation test results given by observers on product packaging design.

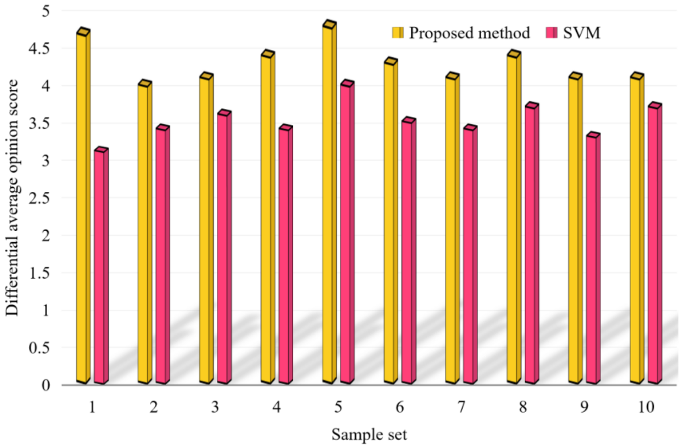

Figure 7: Observer's subjective evaluation of product packaging design.

Subjective evaluation refers to the judgment of the extraction effect of images from the perspective of visual psychology. The test results show that the virtual packaging model in this article can effectively maintain the local structure of packaging images, enhance the contrast and stereo of images, and improve the visual transmission effect of packaging. In packaging graphic design, attention should be paid to increasing the aesthetics of visual information of packaging graphics, which will help attract more people to understand the information that packaging designers want to convey. In today's increasingly fierce competition in the transmission of commodity visual information, it is more necessary to strengthen the aesthetic transmission, which makes the self-designed packaging stand out.

Although the simulation analysis above has not yet been elevated to the level of virtual physical packaging, some of them are only preliminary or simple finite element analysis applications. However, it can be seen that the experiment of using finite element analysis to analyze virtual physical packaging has great application value. Because using this experimental platform can not only save valuable product development time but also save experimental costs. In some cases, the flooding of the experiment may be significant, and it may even be impossible to conduct the experiment. Through this technology, designers can design products that are affordable and meet various customer needs. The degree of agreement between the results of numerical simulation using virtual models with physical properties and finite element analysis methods and the actual situation is closely related to the intrinsic relationship used in the physical model. Whether an appropriate constitutive relationship is used is crucial for the numerical results. For metal packaging materials, good simulation results can usually be obtained by using linear or elastic constitutive relationships. However, for the paper or plastic materials widely used in the packaging industry, using linear or elastic-plastic constitutive relationships sometimes cannot obtain ideal simulation results. This is because paper material is an elastic material, and the relationship between force and deformation is related to the time factor. Moreover, the mechanical properties of paper materials are closely related to their moisture content or the relative humidity of their environment.

5 CONCLUSION

With the help of computer-aided means, the quality and efficiency of design can be greatly improved, and the simulation modeling design of packaging engineering also has a solid foundation. In the whole visual transmission process, information interpretation and visual symbol reception are both complicated processes. In this article, under the guidance of visual transmission theory, taking carton packaging CAD as an example, combined with the packaging image processing algorithm based on deep learning, the simulation model of product packaging modeling visual image, enhance the contrast and stereo of images, and improve the visual transmission effect of packaging. In packaging graphic design, attention should be paid to increasing the aesthetics of visual information of packaging graphics, which will help attract more people to understand the information that packaging designers want to convey. In this article, when designing a digital visual transmission system, we only study it from the visual angle of CAD-aided technology, and we can study it from many angles in the future to improve the shortcomings of this system. For example, we can analyze and design related research strategies from the perspective of software engineering guidance, and we can also design a planned and scientific system to serve the digital visual transmission from the perspective of demand.

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