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Exploration of Multimedia Perception and Virtual Reality Technology Application in Computer Aided Packaging Design

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Abstract. With the help of multimedia technology, packaging design can be integrated with rich elements such as sound, animation, and video, which greatly enhances the sensory appeal and interactivity of packaging. This paper aims to study the innovative use of computer-aided design (CAD) in the packaging field, especially in the combination of multimedia sensing technology and virtual reality (VR) technology. By introducing multimedia sensing technology, this paper realizes efficient identification and classification of packaging patterns. This paper delves into the prospects of employing VR in packaging design, specifically in simulating packaging effects and user interactions within authentic settings. The findings reveal that this approach offers distinct benefits, including boosting design efficiency and elevating user engagement and satisfaction. This study paves the way for the digitalization and intelligent advancement of the packaging design sector, thereby fostering its sustainable progress. Moving forward, we aim to integrate and apply CAD and VR technologies in packaging design further to cater to the growing market needs.

Keywords: Multimedia Perception; Computer-Aided Design; Virtual Reality; Packaging Design
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1 INTRODUCTION

As science and technology continue to evolve, CAD has emerged as a crucial component of contemporary packaging design. The emergence of multimedia perception and VR technology, in particular, has sparked unprecedented advancements in this field. Packaging design now extends beyond its traditional confines of two-dimensional planes, evolving towards more diverse and immersive forms. Traditionally, consumer evaluations of product packaging mainly rely on images, textual descriptions, or physical samples. However, this approach often fails to fully restore the true form and texture of the product, leading to information asymmetry in consumer purchasing decisions. The emergence of multimedia perception virtual reality technology provides a solution to this problem. Branca et al. [1] analyzed consumer evaluations of product packaging in multimedia perception virtual reality. In a multimedia perception virtual reality environment, consumers can immerse themselves in every detail of the product. Through high-definition visual rendering and precise motion capture, the texture, colour, gloss, and even touch of product packaging can be realistically restored. Consumers can freely rotate, enlarge, and shrink product packaging, observe carefully from various angles, and even feel the touch of the packaging by simulating hand movements. This study endeavours to investigate the integration of multimedia perception and VR technology within computer-aided packaging design while also examining their profound impacts on design concepts, methodologies, and the overall user experience. A packaging design that effectively incorporates these elements can elevate a product's value, distinguishing it within a competitive market and capturing the attention of consumers. Brenes et al. [2] explored how to use virtual multimedia perception reality technology to improve packaging design in the market research process. By gaining a deeper understanding of consumer demand, market trends, and competitive trends, companies can develop more precise and effective market strategies. As an important component of a product, packaging design's quality and innovation directly affect the sales and market performance of the product. Therefore, in the process of market research, it is particularly important to conduct in-depth analysis and improvement of packaging design. Through this technology, researchers can construct highly realistic virtual environments that simulate consumer shopping scenes in real life. In this environment, consumers can wear virtual reality devices and experience product packaging design through various senses such as vision, hearing, and touch. Facing the increasingly complex and changeable market demand and consumers' aesthetics, the traditional packaging design method has been stretched. The appearance of CAD provides a powerful tool support for packaging designers.

With the help of multimedia technology, packaging design can be integrated with rich elements such as sound, animation and video, which greatly enhances the sensory appeal and interactivity of packaging. With the support of industrial computers, AR technology can overlay virtual information into the real world in real-time, creating a virtual real workspace for designers. In this space, Cascini et al. [3] freely created, modified and displayed creative products and packaging designs. With the help of AR technology, designers can add dynamic and interactive elements to packaging, allowing consumers to have a richer shopping experience. For example, consumers can enhance their awareness and interest in the product by scanning the AR logo on the packaging to view 3D displays, usage demonstrations, or brand stories of the product. The application of image sensing and processing technology makes the packaging patterns more exquisite and colourful. The combination of audio and video perception technology makes packaging an effective carrier to convey brand stories and product information. Multimedia perception technology integrates multiple sensory information, such as images, sound, and touch, to provide consumers with a more comprehensive and authentic experience. In the virtual reality restaurant scene, consumers can immerse themselves in the atmosphere, decoration, and product details of the restaurant. As an important component of a product, packaging's design, material, and appearance directly affect consumers' purchasing decisions and dining experience. Farias et al. [4] analyzed that the combination of multimedia perception and virtual reality technology provides consumers with a brand-new packaging preference experience. Virtual reality technology can highly restore the realism of packaging. Consumers can see the three-dimensional display of the product in virtual space through devices such as headsets and even observe every detail of the packaging by adjusting the perspective and zooming in and out. This authentic visual experience makes consumers evaluate packaging more objectively and comprehensively. The ingenious application of these multimedia elements not only enhances the artistic value of packaging but also deepens the emotional connection between consumers and products. Augmented reality technology brings consumers a brand new interactive experience by combining elements of virtual and reality. In food delivery packaging, AR technology can display virtual content related to food through the screens of mobile phones and other devices, such as the production process, ingredient sources, nutritional information, etc. The display of these contents not only enhances the fun of packaging but also provides consumers with a more comprehensive and in-depth understanding, thereby improving their overall impression of food. Gu et al. [5] analyzed the application of AR technology in food delivery packaging. AR technology can also add fun and interactivity to the packaging of takeaway food. Consumers can increase the fun of dining by scanning the AR logo on the packaging and watching food-related animations, games, and other content. This interactive experience not only attracts consumers' attention but also enhances their liking for food, thereby reducing the generation of negative reviews.

The introduction of VR technology has brought packaging design into a new dimension. By constructing the virtual packaging prototype, designers can simulate the real-use scene on the computer, and test and optimize all aspects of packaging structure, material and printing. As a powerful computer-aided design software, AutoCAD's 3D modelling function plays an important role in industrial packaging design. Hu [6] explore the application and advantages of AutoCAD 3D modelling function in industrial packaging design. The 3D modelling function of AutoCAD provides strong technical support for industrial packaging design. Designers can quickly create packaging models with complex shapes and structures using AutoCAD software. This software has precise size control and powerful geometric modeling capabilities, allowing designers to accurately define every detail of packaging, ensuring the accuracy and reliability of the design. The 3D modelling function of AutoCAD allows designers to observe and adjust packaging shapes from all angles in a virtual environment. This intuitive operation method helps designers better grasp the proportion, lines, and surface changes of packaging design, thereby creating more beautiful and practical packaging works. VR technology also provides a more realistic display platform for packaging design, enabling consumers to experience the charm of products before shopping.

The integrated utilization of multimedia perception alongside VR technology introduces boundless opportunities for packaging design. Designers can unleash their creativity, transcend traditional design constraints, and craft more personalized, emotionally resonant packaging. 3D personalized human modelling technology refers to the use of computer-aided design software to construct accurate 3D human models based on individual body size and shape data. This technology not only accurately reflects individual physical characteristics but also provides intuitive design references for fashion designers. In the field of clothing packaging, the application of three-dimensional personalized human body modelling technology can help designers better understand the body shape of consumers and thus design clothing and packaging that are more in line with consumer needs. Jia and Tian [7] make targeted adjustments and optimizations to clothing and packaging. Deformation technology can flexibly deform three-dimensional human models through algorithms and computer simulations, making them adaptable to different design requirements. This technology can not only improve the flexibility of design but also greatly shorten the design cycle and improve design efficiency. This innovation encompasses not just the packaging's aesthetics but also its functionality and user experience. For instance, intelligent sensors and interactive technologies enable packaging to perceive consumers' actions and emotions, triggering responsive feedback and adjustments.

A pivotal challenge for researchers lies in harmonizing these cutting-edge technologies with the practical demands of packaging design, achieving a seamless fusion of technology and art. In exploring the application of multimedia perception and VR technology in computer-aided packaging design, this study prioritizes algorithm optimization. It tailors and refines existing algorithms to align with packaging design specifications. Through rigorous experimental validation and performance evaluation, the refined algorithm is seamlessly integrated into the design system. This holistic approach aims to elevate packaging design performance and drive technological advancements in computer-aided design.

The study's innovations and contributions are threefold:

(1) It pioneers the integration of multimedia perception with VR technology in computer-aided packaging design, offering a fresh perspective and overcoming the limitations of traditional methodologies.

(2) The study introduces a novel packaging design paradigm grounded in multimedia perception and VR technology. This approach emphasizes immersion, interactivity, and personalization, redefining design possibilities.

(3) The research outcomes contribute to elevating the overall standard of packaging design, fueling the growth and development of the commodity economy. By enriching the artistic and scientific dimensions of packaging design, these findings also enhance consumers' quality of life and aesthetic appreciation.

In conclusion, this paper initially outlines the significance of computer-aided packaging design in the context of multimedia sensing and VR technology. It then delves into the practical application and integration of these technologies in packaging design, validating their efficacy through experimental analysis. Looking ahead, the paper anticipates future trends and evolutions in this dynamic field.

2 RELATED WORK

The packaging design of feed products has always been an important link, which not only affects the appearance and brand image of the product but also directly affects the preservation, transportation, and sales of the product. Traditional feed packaging design often relies on graphic design and physical models, making it difficult to fully showcase the characteristics and advantages of the product. The intelligent packaging design based on virtual reality technology can break this limitation and bring more vivid and intuitive display effects to feed products. Virtual reality technology can provide a three-dimensional display effect for feed products. Tang [8] uses high-precision 3D modelling and rendering techniques to realistically restore the packaging of feed products in a virtual environment. Consumers can observe the appearance, texture, and details of the product from all angles. This three-dimensional display method not only makes the product more intuitive but also helps consumers better understand the characteristics and advantages of the product. Against the backdrop of continuous development in industrial automation and robotics technology, visual packaging recognition technology for industrial components has become a key link in improving production efficiency and quality. Highlighting view packaging selection, as an important component of this technology, plays a crucial role in ensuring that robots accurately and efficiently identify and process industrial components. Kim et al. [9] explored the prominent view packaging selection problem for visual packaging recognition of industrial components from the perspective of IEEE Robotics and Automation. In the visual packaging recognition process of industrial components, robots need to capture images of the components through cameras and recognize the features and positions of the components through image processing and analysis. Highlighted view packaging selection is the process of selecting the view that best highlights component features and is most conducive to accurate recognition by robots from numerous packaging views.

As an emerging technology, the application of multimedia perception virtual modules in packaging manufacturing design systems has gradually demonstrated its strong potential and value. Ma et al. [10] explored the effectiveness of multimedia perception virtual modules in packaging manufacturing design systems, analyzing how they can improve design efficiency, reduce costs, and enhance user experience. The multimedia perception virtual module can significantly improve design efficiency in packaging manufacturing design systems. The traditional packaging design process often requires multiple physical prototyping and testing, which is not only time-consuming and laborious but also costly. With the help of multimedia perception virtual modules, designers can quickly iterate and optimize in the virtual environment. Real-time adjustment of design schemes reduces the need for physical prototype production, thereby greatly shortening the design cycle. Manavis et al. [11] developed a new computational-based visual brand packaging identification (CbVBI) product design. This innovative design aims to achieve rapid and accurate identification of brand packaging through advanced algorithms and computing technology, thereby promoting progress in multiple aspects such as brand promotion, product traceability, and consumer experience. The foundation of CbVBI product design lies in powerful computer vision algorithms. These algorithms identify the characteristics of brand packaging by capturing and analyzing image information on packagings, such as colour, shape, texture, and identification. Compared with traditional recognition methods, CbVBI product design has higher recognition accuracy and faster processing speed, which can cope with complex and ever-changing packaging design and market environments.

Especially in product packaging design, it plays an important role. Computer-assisted intelligent assembly modelling technology, as a branch of the CAD field, can efficiently capture the intentions of packaging designers. And achieve precise expression of design through product packaging information modelling. Mo et al. [12] explored the application of computer-aided intelligent assembly modelling in capturing packaging design intent and product packaging information modelling. When designing product packaging, various factors such as product characteristics, market demand, and consumer preferences are usually considered. Intelligent assembly modelling technology can understand and extract the designer's design intent by analyzing the designer's input data, operating habits, and design rules. This ability to capture design intent enables computer-aided design systems to be closer to the designer's thinking patterns and achieve more accurate design outputs. The packaging industry is also actively embracing this technology, bringing consumers a brand-new shopping experience by combining AR technology. The Addie model, as a systematic instructional design model, provides an effective guidance framework for developing the application of AR technology in packaging. Nasir and Ali [13] explore how to use the Addie model to develop the application of augmented reality technology in packaging. In the analysis stage, it is necessary to have a deep understanding of the current situation of the packaging industry, consumer demand, and the development trend of AR technology. Determine the potential value and opportunities of AR technology in packaging applications through market research and data analysis. In the design phase, based on the results of the analysis phase, develop a specific plan for the application of AR technology in packaging. This includes determining the scenarios, functions, and interaction methods of AR technology applications. Designers need to fully unleash their creativity by combining AR technology with packaging design to create products that are both practical and attractive.

Packaging design elements, as an important component of product display, play a crucial role in consumer purchasing decisions. Samarraie et al. [14] explored how packaging design elements affect consumer online purchasing decisions, with a particular focus on causal decision models and the application of colour in packaging design. The concept of packaging design elements. Packaging design elements include multiple aspects such as shape, material, colour, pattern, and text. These elements together constitute the external image of the product, conveying the information and value of the product to consumers. In the online shopping environment, consumers are unable to directly contact products, so packaging design elements play an important role in attracting consumer attention, conveying product information, and shaping brand image. Green packaging design emphasizes product packaging design while protecting the environment and conserving resources. It requires designers to fully consider the degradability, recyclability, and environmental impact of packaging materials in the design process in order to achieve packaging reduction, reuse, and recycling. CAD technology, with its powerful design functions and flexibility, provides strong support for green packaging design. In the green concept-based CAD product packaging design, Yu and Sinigh [15] use CAD software for precise 3D modelling and rendering, simulating the actual effect of packaging. This can not only improve design efficiency, reduce the cost and time of physical prototype production, but also fully consider the environmental performance of packaging during the design phase. Analyze the environmental performance of different packaging materials using CAD software and select the material that best fits the green design concept. At the same time, by optimizing the packaging design structure, reducing the use of packaging materials, and reducing the impact of packaging on the environment.

Virtual reality technology, with its unique immersive experience, enables designers to visually observe and adjust their design works in three-dimensional space. In packaging design, designers can use virtual reality technology to import design models from CAD software into a virtual environment for real-time interactive operations. Yun and Leng [16] are able to observe the appearance and structure of packaging from multiple perspectives and can also simulate the performance of packaging in actual usage scenarios, thereby identifying potential problems and optimizing them. Through virtual reality technology, designers can more accurately control the size, shape, and materials of packaging. In a virtual environment, designers can easily adjust various packaging parameters, observe their impact on the overall design, and obtain real-time feedback. Traditional agricultural product packaging design often relies on the experience and intuition of designers, and the design process is relatively cumbersome and inefficient. The introduction of intelligent computer-aided design technology enables designers to achieve more accurate and efficient artistic style appearance design of agricultural product packaging through advanced algorithms and tools. Intelligent computer-aided design technology can automatically analyze and generate packaging design schemes that conform to specific artistic styles based on the characteristics of agricultural products and market demands. Zhao et al. [17] analyzed the relevant parameters and requirements, and the system was able to quickly generate multiple design schemes for selection. This not only greatly shortens the design cycle but also enhances the diversity and innovation of the design. This system can predict packaging styles and design elements that better meet market demand, thereby helping agricultural products stand out in fierce market competition.

3 APPLICATION OF MULTIMEDIA PERCEPTION TECHNOLOGY IN PACKAGING DESIGN

Multimedia perception technology is the product of the combination of modern information technology and artificial intelligence, which covers many fields of knowledge, including computer science, digital signal processing, pattern recognition, cognitive science and so on. The core of this technology is to simulate and extend the human perception system so that computers can understand, analyze and respond to multimedia information like people. Within the framework of multimedia perception technology, computers can capture and process multi-modal information such as text, image, audio and video. Text perception involves natural language processing and text mining technology, which is used to extract and analyze semantic information in texts. Image perception recognizes and understands image content through image processing and computer vision technology; Audio perception mainly uses speech recognition and emotion analysis technology to interpret sound information; Video perception combines image processing, computer vision and dynamic analysis to understand and analyze video content. In packaging design, multimedia perception technology pays special attention to the perceptual processing of images and videos. As the most intuitive visual element in packaging, the image's quality, colour and composition have a direct impact on the attractiveness and brand image of products. Video can show the details and characteristics of packaging dynamically, bringing consumers a more vivid and three-dimensional experience. Through multimedia perception technology, designers can control these visual elements more accurately, thus creating more attractive and personalized packaging designs.

An outstanding packaging design frequently grabs consumers' attention with its delicate imagery, thereby elevating the product's overall aesthetic appeal. The initial phase of packaging design involves image acquisition, where designers utilize digital cameras, scanners, and other tools to digitize physical or handmade patterns. However, these digital images often contain unwanted noise and extraneous information, necessitating preprocessing techniques like denoising, enhancement, and scaling to enhance their visual appeal. Following preprocessing, the refined image undergoes segmentation and recognition. Image segmentation involves distinguishing the focal area from the background, employing methods such as thresholding, edge detection, or region growth. Subsequently, image recognition employs computer vision techniques to categorize these segmented regions, facilitating automatic target detection.

A crucial aspect of image processing and computer vision is the edge detection algorithm, which proficiently identifies edge details in an image, providing a valuable foundation for subsequent segmentation and recognition tasks. In this study, the Canny edge detection algorithm is employed due to its renowned accuracy and resilience against noise. The algorithm's implementation comprises several steps: initially, Gaussian filtering is applied to the input image to eliminate noise and fine textures. Subsequently, the gradient intensity and direction of each pixel are computed. These gradients then undergo non-maximum suppression and dual thresholding to yield precise edge detection results. Finally, hysteresis thresholding is employed to trace, extract, and connect the edges. The process of high-resolution detail reconstruction of commodity packaging mainly includes several key steps. First, use a high-resolution camera or scanner to obtain high-definition images of commodity packaging. Then, the image processing technology is used to improve the quality and highlight the features of these images. Then, with the help of computer vision and graphics algorithms, the details of the packaging are extracted and reconstructed from the image. In this process, the influence of lighting and materials on the reconstruction effect should be considered and adjusted accordingly. Finally, a high-resolution and real commodity packaging model is obtained for various applications. This process needs corresponding hardware and software support and may involve technologies such as cloud computing to improve processing efficiency. Figure 1 shows a process of high-resolution detail reconstruction of commodity packaging.

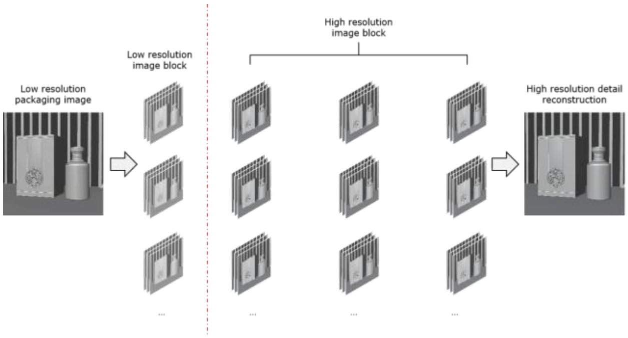

Figure 1: The process of packaging detail reconstruction.

In contrast to grayscale images, colour images offer a richer information set. When it comes to interactive packaging design, the utilization of a colour space model greatly facilitates the extraction of the intended analysis target. Based on the fundamental concept of the three primary colours, any given colour can be defined through a colour equation:

$$F = \alpha\ R\ + \beta\ G\ + \gamma\ B \tag{1}$$

α, β, and γ represent the blending proportions of red, green, and blue, respectively, also known as trichromatic coefficients. After reading the original coloured packaging image, convert it to grayscale and proceed with adjustments accordingly. Refer to Figure 2 for a visualization of the adjusted grayscale image.

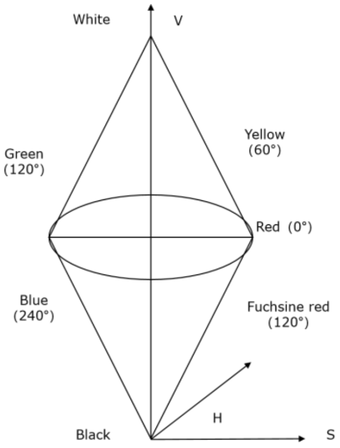

Figure 2: HSV colour model.

Supposing the packaging image has dimensions of $M \times N$ a gray level denoted as M, and a pixel count for gray level i represented by n_i, the frequency of a distinct gray level i would be determined accordingly.

$$p_i = \frac{n_i}{MN} \quad (2)$$

Image pixels can be categorized into two distinct groups, C_0, C_1, based on a threshold value of T. The probabilities associated with these two groups are as follows:

$$w_0 = \sum_{i=0}^{T} p_i,\ w_1 = 1 - w_0 \quad (3)$$

The mean values for the two distinct gray levels are as follows:

$$\mu_0 = \frac{1}{w_0} \sum_{i=0}^{T} i p_i \quad (4)$$

$$\mu_1 = \frac{1}{w_1} \sum_{i=T+1}^{L-1} i p_i \quad (5)$$

The structural element B is utilized to open the image A, resulting in an outcome that can be denoted as $A \cdot B$ and mathematically represented as:

$$A \cdot B = A \oplus B \ \Theta B \quad (6)$$

The closing operation for a commodity packaging image involves an initial expansion of the image A using B, followed by a subsequent corrosion process utilizing the structural element B.

4 APPLICATION OF VR IN PACKAGING DESIGN

4.1 Overview of VR

VR technology is an innovative computer technology. Advanced simulation and rendering can generate a three-dimensional environment that looks real but doesn't actually exist for users. This environment can be not only a copy of the real world but also a product of designers' imagination. Its core is to provide a completely immersive experience so that users feel that they have really entered this virtual world. In terms of technical implementation, VR relies on a series of hardware and software. Hardware devices, such as HMDs, stereo, position trackers, etc., work together to capture the user's actions, sounds, and positions and transform them into interactions in the virtual world. In terms of software, a highly complex graphics rendering engine, physical simulation engine, and user interface are needed to ensure that users can move freely in the virtual world and interact with the environment. With the development of technology, modern VR systems can also integrate a variety of sensors and input devices, such as gesture recognition devices, voice commands, and even brain wave recognition, making the interaction between users and the virtual world more natural and intuitive.

In packaging design, the introduction of VR technology represents a brand-new design concept. It enables designers to simulate the real effect of packaging at the early stage of design and optimize the packaging in a virtual environment. This can not only greatly reduce the cost of physical prototyping but also find and solve potential problems in the early stage of design and improve design efficiency.

4.2 Virtual Prototype Design

Traditional packaging design usually needs to be revised and tested repeatedly on the physical model, which is not only time-consuming and labor-intensive but also expensive. With the introduction of VR technology, designers can create virtual packaging prototypes on computers and test and optimize them in all directions. Through professional VR design software, designers can quickly build a three-dimensional virtual packaging model according to product characteristics and market demand. In this virtual environment, designers can accurately adjust and control the size, shape, material and other aspects of packaging to achieve the best design effect. VR technology also supports real-time rendering and dynamic interaction. Designers can view the modified effect in real time in a virtual environment and collaborate and communicate with team members.

Brightness contrast is quantified as the weighted standard deviation of the fuzzy brightness attribution function, with each image block's weight being determined by the pixel count it contains.

$$CB\ i\ \left[\frac{1}{\sum_{n=1}^{N} R_n} \sum_{n=1}^{N} R_n\ \ B_n\ \ i\ \ \bar{B}_n\ \ i\ \ ^2\right]^{1/2} \tag{7}$$

The weighted mean of the blur brightness of type i can be represented as follows:

$$\bar{B}\ i\ = \frac{1}{\sum_{n=1}^{N} R_n} \sum_{n=1}^{N} R_n B_n\ i \tag{8}$$

To assess the gradient magnitude of each pixel, the inherent variational principle of a windowed total variation, which considers both pixel values and their combinations within a window, is employed. Specifically, for the image I, the windowed total variation at pixel $p\ x,y$ is formulated as:

$$D_x\ p\ = \sum_q g_{p,q} \left| \partial_x I\ _q \right|, D_y\ p\ = \sum_q \sum_q g_{p,q} \left| \partial_y I\ _q \right| \tag{9}$$

Let $q \in R\ p$, where $R\ p$ denotes a rectangle centered at point p. $D_x\ p\ , D_y\ p$ Signifies the total variation of a pixel p in the x,y direction, capturing the absolute spatial disparity within window $R\ q$. Additionally, $g_{p,q}$ serves as a weighting function.

The window scanning and pyramid image sampling of the whole image is to solve the problem of the diversity of the size and position of goods in the image. Window scanning can analyze images point by point, but fixed window sizes may not be suitable for different sizes of goods. Therefore, pyramid image sampling is introduced into the study, and image sets with different resolutions are generated by multi-scale scaling and sampling of images. From high resolution to bottom resolution, the window size is adjusted accordingly to adapt to different sizes of goods. Figure 3 shows this process. By combining window scanning and pyramid sampling, the goods in the image can be identified and located more accurately, which provides strong support for packaging design.

r passband is established for $R^{'}, G^{'}, B^{'}$, centred on the distinctive hue of the pattern. Suppose the numerical ranges for the selected pattern's characteristic colour $R^{'}, G^{'}, B^{'}$ are $R_1^{'} \sim R_2^{'}, G_1^{'} \sim G_2^{'}, B_1^{'} \sim B_2^{'}$, respectively. This study introduces a continuous function, serving as a colour filter, formulated as follows:

$$F\ x,y\ = F_R * F_G * F_B \tag{10}$$

The coordinate value of the point x,y corresponds to the pixel x,y, denoted as $R^{'}, G^{'}, B^{'}$.

Following the filtering process, both the original image's $F\ x,y\ = 1$ pixels and their neighboring points are retained. Subsequently, the contour is extracted and smoothed using a Gaussian function.

$$G_\sigma\ x,y\ = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right) \tag{11}$$

The advantage of virtual prototype design is that it can greatly shorten the cycle from design to market and reduce the development cost. Designers can iterate and optimize many times in the virtual environment until they meet the needs of the market and consumers.

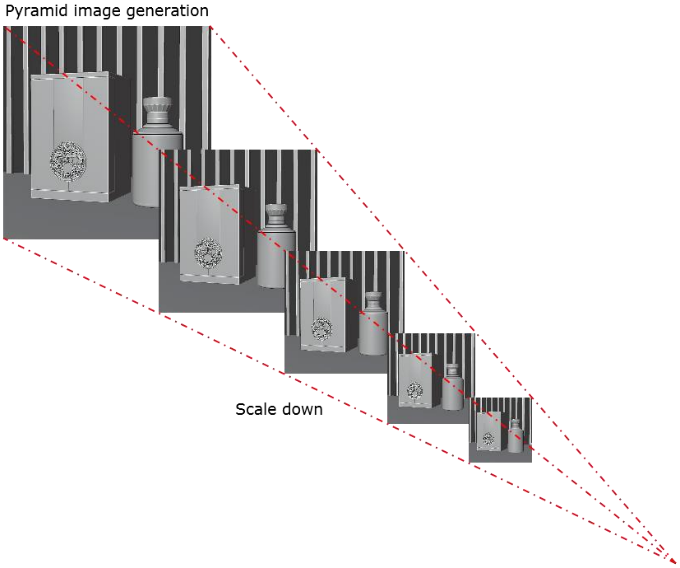

Figure 3: Pyramid sampling.

4.3 Interactive Display

VR technology provides a more realistic and vivid display platform for packaging design. By constructing virtual display scenes, designers can let consumers experience the charm and value of products before buying. In virtual exhibitions, consumers can enter a simulated shopping environment through interactive devices such as helmet displays.

In this environment, they can freely check and compare the packaging design and characteristics of different products and understand the detailed information and usage of products. VR technology also supports a variety of interactive ways, such as gesture recognition, voice control, etc., so that consumers can interact with products more naturally and conveniently.

5 RESULT ANALYSIS AND DISCUSSION

5.1 Result Analysis

In order to comprehensively evaluate the application effect of multimedia perception and VR in computer-aided packaging design, we designed and implemented a series of carefully conceived experiments. The specific software and hardware environment is shown in Table 1.

Project	*Model/Specification*
Operating system	Windows 10 Professional 64-bit
Processor	Intel Core i7-10700K @ 3.80GHz
Internal storage	32GB DDR4 RAM
Display card	NVIDIA GeForce RTX 3070
Save	1TB SSD
VR equipment	Oculus Quest 2

Table 1: Experimental environment.

In the standardized experimental environment, high-performance computer hardware configuration and advanced design software are used. By recording the key indicators of the design process and inviting professional designers and ordinary users to participate in the assessment, it is expected to compare the advantages and disadvantages of different design methods in depth, thus providing a valuable reference for the development of the packaging design industry. Firstly, the detection accuracy of three different methods, including this method, is tested under different offline training sample sets. The results of these experiments are shown in Figure 4, Figure 5 and Figure 6.

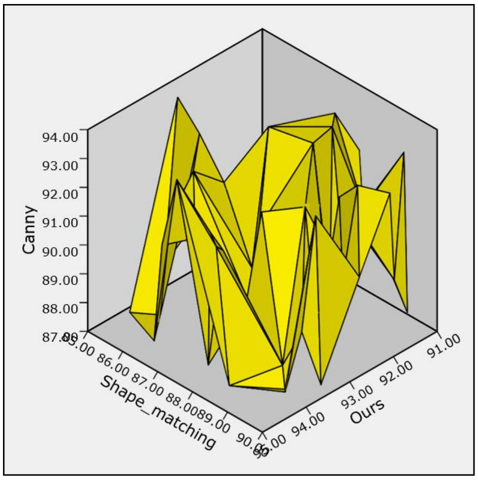

Figure 4: Sorting performance of package 1.

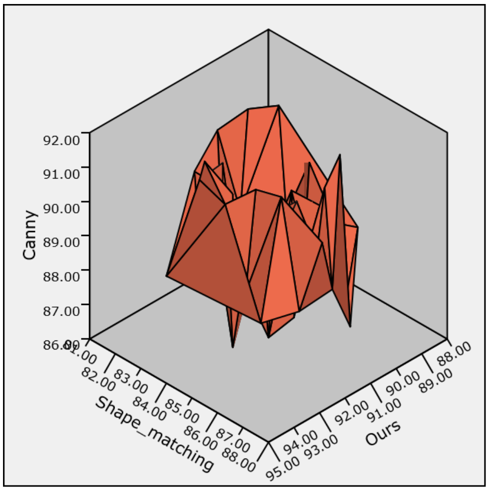

Figure 5: Sorting performance of package 2.

The proposed methodology in this study offers notable enhancements in classifying and detecting the integrity of packaging patterns while preserving crucial information. This advancement is primarily attributed to the algorithm's precise extraction and efficient handling of image features, facilitating the accurate identification of vital details within intricate packaging designs. In comparison to shape-matching techniques, the Canny edge detection algorithm exhibits superior feature depiction capabilities. While shape matching often relies on the overall silhouette of an object, it may struggle to capture nuanced shape variations in complex patterns. Conversely, the Canny algorithm adeptly describes pattern features by detecting edge details in the image.

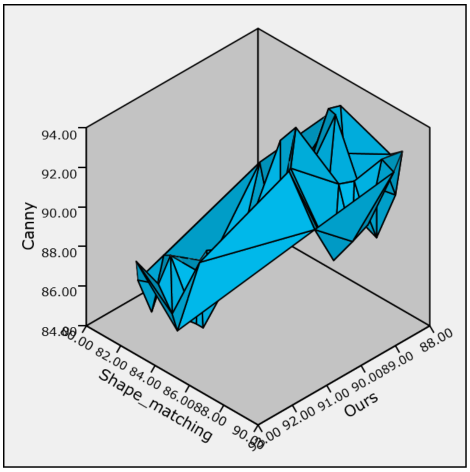

Figure 6: Sorting performance of package 3.

In real-world scenarios, packaging images are susceptible to various factors, such as lighting variations, camera angles, and background distractions, all of which can compromise image quality. However, by incorporating cutting-edge image processing techniques like filtering and enhancement, our method effectively mitigates noise and interference, leading to improved image clarity and, subsequently, enhanced detection accuracy.

As illustrated in Figure 7, a comparative analysis of three distinct packaging design optimization approaches highlights the superiority of our method in preserving intricate details. Detail integrity plays a pivotal role in enhancing the overall aesthetic appeal of products and enhancing the consumer's visual experience. By leveraging advanced image processing algorithms, our approach successfully eliminates image noise while maximizing the retention of original image details.

Figure 7: Optimization effect of packaging design.

Compared with the other two methods, this method pays more attention to the identification and protection of packaging design elements. For example, when dealing with key elements such as patterns and characters on packaging, this method will adopt more elaborate processing strategies to ensure the integrity and clarity of these elements. This targeted processing method makes the optimized packaging image more vivid in the presentation of key elements. In the process of optimization, this method will intelligently adjust the image parameters such as colour, brightness and contrast according to the overall style and theme of packaging design to achieve the best visual effect. This holistic optimization strategy makes the optimized packaging image more harmonious and unified visually, thus improving the overall aesthetic feeling of the product.

6 DISCUSSION

In the realm of packaging design, the integration of multimedia sensing and VR technology has garnered significant interest. This study empirically validates the notable impact of these technologies in elevating design efficiency, refining design strategies, and enriching the user experience. Through a series of experiments comparing the detection precision of three distinct approaches, including the proposed method, across varying offline training datasets, it is evident that our method considerably enhances classification performance and the precision of packaging pattern integrity detection while preserving essential information. Furthermore, when compared to the shape-matching technique, the Canny edge detection algorithm demonstrates superior feature depiction capabilities, thereby further bolstering the accuracy of packaging pattern integrity detection. This result confirms the effectiveness of multimedia sensing technology in packaging image processing. By accurately extracting image features, this method can accurately identify the key information in packaging patterns, which provides strong support for subsequent creative processing and typesetting.

By using high-resolution digital cameras and professional scanning equipment to obtain digital images of packaging materials and then combining them with image processing algorithms for accurate processing, designers can extract key design elements more efficiently. Multimedia perception technology also brings more creative possibilities for packaging design. By denoising, enhancing, segmenting and identifying the image, designers can explore the potential aesthetic feeling and design inspiration in the original image and then create a more unique and attractive packaging design scheme.

By constructing a realistic three-dimensional virtual environment, VR technology provides a brand-new design tool and display platform for designers. The results show that the packaging model created by VR technology can find and correct potential problems in the early stage. By wearing VR glasses or using other interactive devices, consumers can check and understand the packaging of products in detail before shopping so as to make more informed purchase decisions. This immersive shopping experience not only enhances consumers' sense of participation but also establishes closer ties between brands and consumers.

7 CONCLUSIONS

Leveraging multimedia technology in packaging design allows for a seamless blend of diverse elements, such as sound, animation, and video. This integration serves to greatly elevate the sensory appeal and interactivity of packaging, revolutionizing the way it engages with consumers. In this study, we delve into the utilization of multimedia perception technology within packaging design and emphasize the pivotal role of edge detection algorithms in processing packaging images.

Through a series of comparative experiments and subsequent analysis, our findings reveal that the proposed methodology significantly enhances classification performance and boosts the accuracy of packaging pattern integrity detection while preserving crucial information. When benchmarked against alternative approaches, our method exhibits superior feature depiction capabilities and achieves higher detection accuracy.

The incorporation of multimedia perception technology has rejuvenated packaging design, equipping designers with the tools to execute creative and personalized designs more efficiently. By harnessing advanced image processing algorithms, the entire workflow of image acquisition, processing, analysis, and interpretation within packaging design has undergone substantial optimization. This advancement not only elevates the level of intelligence in packaging design but also provides robust support for product quality assurance, brand image establishment, and enhancing the overall consumer shopping experience.

In conclusion, the application of multimedia sensing technology in packaging design holds vast potential and promises a bright future. The insights gained from this study offer valuable theoretical groundwork and practical guidance for the continued innovation and growth of the packaging design industry. We anticipate that these advancements will propel the field toward a more intelligent, personalized, and environmentally friendly future. As technology continues to evolve and market demands shift, multimedia sensing technology is poised to play an even more pivotal role in packaging design, further enhancing its convenience and impact on people's daily lives.

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