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Computer-Aided Design AND APPLICATIONS

Intelligent Analysis and Dynamic Display of Packaging Design Using Computer-Aided Design and Multimedia Technology

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Abstract. With the advancement of computers and intelligent technology, the frequency and scope of the use of high-tech such as computers in various fields of society are also becoming increasingly widespread. The demand for computers in the field of packaging design is gradually increasing, and the packaging design concept implemented based on this intelligent technology has more important value. Most packaging design products not only have requirements for packaging structure but also have certain standards for the visual display of the design appearance. Especially in the face of the current modern social environment, it is necessary to design exterior packaging with a novel structure, complete functions, and exquisite visual images. Based on the above background, we use computer-aided design and multimedia technology to achieve intelligent analysis and overall dynamic display of packaging design. Firstly, in the process of packaging design ideas and design generation, computer-aided design CAD is added to help optimize the design structure and explore the various influences that computer-aided design is affected by. Secondly, when using multimedia technology to complete packaging design displays, virtual reality technology is added to improve the display environment and create a 3D multi-dimensional design concept display system. Finally, based on computer-aided design and 3D digital dynamic display technology, a packaging design automation update system is generated to address the packaging design needs of most products. The research results indicate that packaging design products implemented using computer-aided design and multimedia technology can have a more complete design structure, innovative functions, and higher user feedback evaluations. The aesthetic design of the appearance also better meets the needs of users.

Keywords: Computer-Aided Design; Multimedia Technology; Packaging Design; Intelligent Analysis; Dynamic Display
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1 INTRODUCTION

The graphic packaging design of products plays a very important role in people's lives, and the development of this packaging design can directly affect the overall consumption, economy, and user needs. As an important means of product marketing, packaging design's aesthetics, innovation, and market adaptability are crucial for enhancing product competitiveness. Agarwal et al. [1] analyzed the application of deep learning models based on image transformation in intelligent analysis of packaging design. This provides designers and businesses with a new perspective and tools, which helps to optimize and innovate packaging design. A deep learning model based on image transformation can automatically extract design features, styles, and structural information by learning from a large number of packaging design images. These models use structures such as Convolutional Neural Networks (CNN) to layer by layer abstract and extract features from images, thereby achieving intelligent analysis of packaging design. In the intelligent analysis of packaging design, deep learning models based on image transformation can be applied to multiple aspects. From this, it can be seen that packaging design should be considered from a rational and scientific perspective, and understand the importance of packaging design in social development. In the long-term historical development, the top priority of product packaging design is how to combine packaging design with modern technology while utilizing modern means to meet the needs of design structure, product display, and aesthetic appearance. How to ensure the stable and effective release of these active ingredients during food storage and transportation has always been a research hotspot in the field of food packaging. The emergence of CAD-controlled release technology provides new ideas for solving this problem. Through CAD software, Almasi et al. [2] accurately simulated and predicted key parameters such as permeability, adsorption, and reactivity of packaging materials, thereby optimizing packaging design and ensuring that active ingredients can be released at predetermined rates and quantities. In addition, CAD technology can also customize packaging design based on factors such as food types, storage conditions, and market demand to meet the needs of different consumers. The traditional packaging design concept has a low level of understanding, and most designers believe that packaging design is a product image container composed of multiple flat structures. From the perspective of packaging design, it only includes promotional and display functions. Traditional moulded pulp packaging design often focuses on experience and trial and error, lacking scientific design and optimization methods. Therefore, Bahlau and Lee [3] explored the application of topology optimization and superposition methods in the design of moulded pulp packaging in order to improve the structural performance and material utilization of the packaging. Topology optimization is an advanced structural optimization technique that can find the optimal material distribution within a given design space to meet specific performance requirements. In the design of moulded pulp packaging, topology optimization can help designers determine the optimal distribution and shape of pulp inside the packaging in order to achieve the best cushioning effect and structural strength. Through topology optimization, a more reasonable and efficient pulp distribution scheme can be obtained, thereby improving the compressive and seismic performance of packaging. The promotional function is to make a certain product more in line with the needs of the general public while showcasing its aesthetic appeal. Therefore, packaging design can not only improve the sales efficiency of products but also provide aesthetic guidance for people in the new era, providing spiritual enjoyment and meeting the development needs of different cultures. Packaging, as an important component of a product, often carries the image and cultural value of a brand. CAD multimedia technology can help brands integrate unique cultural elements and stories into packaging design, enhancing brand image and cultural connotation. Consumers are also influenced by the brand image and cultural value conveyed by the packaging when choosing products. When implementing sustainable packaging with CAD multimedia technology, Boz et al. [4] prioritized the use of biodegradable, recyclable, or recyclable materials. These materials are not only environmentally friendly but can also reduce production costs and improve economic benefits. CAD multimedia technology can reduce energy consumption and emissions during the production process and improve production efficiency by simulating and

optimizing the production process. In addition, by implementing the concept of circular economy, waste can be recycled and reused to achieve maximum utilization of resources.

Traditional packaging design often relies on the experience and intuition of designers or collects consumer opinions through questionnaire surveys and on-site observations. However, these methods have certain limitations, such as bias in information transmission and insufficient consumer experience. Brenes et al. [5] analyzed the use of virtual reality in the market research process to improve packaging design. In the process of market research, VR technology can simulate different shopping scenarios, allowing consumers to interact with packaging in a virtual environment. Through this approach, companies can collect more accurate and comprehensive consumer feedback, thereby gaining a deeper understanding of consumer expectations and preferences for packaging. VR technology can also simulate the packaging usage process. Consumers can open the packaging, take out the product, and even experience the effectiveness of the product in a virtual environment. This immersive experience can help designers identify potential issues in packaging design, such as inconvenient openings and unreasonable structure, and make targeted improvements. In addition, continuously improving the ability to master information technology can enable multiple media to work together, making packaging design more ideal and perfect. With the gradual maturity of packaging design concepts and structures, the early stages of mass production are often rigid and lifeless structures. In the increasingly fierce market competition, the importance of product packaging as a bridge between brands and consumers is self-evident. With the development of technology and innovation in design concepts, more and more enterprises are seeking more efficient and accurate methods for product packaging pattern design. In this context, a product packaging pattern design system based on the Kansei engineering and BP neural network has emerged, injecting new vitality into the field of product packaging design. Chen and Cheng [6] integrate emotional factors into product design by delving into and analyzing consumers' emotional cognition in order to create products that can touch people's hearts. In product packaging pattern design, the Kansei project can help designers more accurately grasp consumer aesthetic preferences and emotional needs and design more attractive and personalized packaging patterns. With the rise of media core technologies such as multimedia, information technology and the Internet, the idea of visual communication and packaging design has been fundamentally affected. The form and development form of the packaging design structure have gradually changed, and some special design forms can be simulated with advanced technology. When packaging design collides with modern demand concepts, green and environmentally friendly design makes it safer and more reasonable.

The intelligent packaging system integrates advanced sensors, labels, and communication technology to achieve intelligent control of the food packaging process. These technologies can monitor key parameters such as temperature, humidity, and pressure in real time during the packaging process, ensuring that food is not damaged during the packaging process. At the same time, the intelligent packaging system can automatically adjust the packaging materials, thickness, and sealing according to the characteristics of the food in order to provide the best packaging effect. In terms of food safety, intelligent packaging systems play an irreplaceable role. By integrating RFID tags or QR codes on packaging, intelligent packaging systems can achieve real-time traceability of food information. This can not only quickly locate the production, processing, transportation, and other links of food but also quickly trace the causes of problems and take effective measures to prevent the spread of them. In addition, the intelligent packaging system can also monitor the freshness and shelf life of food through sensors, providing consumers with accurate food status information and avoiding safety issues caused by expired or spoiled food [7]. In the current international market, the structural form of packaging design is still relatively singular, far from meeting the personalized needs of consumers for aesthetics and art. After the improvement of social material conditions and the elevation of levels, people's values and aesthetic views have undergone changes in the process of modernization development. The pursuit of product packaging design by most consumers and the general public has shifted from practicality to diversified appearance requirements. From the dazzling array of packaging products on the market, it can also be seen that designers attach great importance to the appearance and external decoration of packaging of

different sizes. In addition to adding exquisite printing and colourful colour images, there have also been changes in appearance and design. Ordinary two-dimensional graphic design can no longer meet the imaginative design needs of designers. Setting aside the traditional polyhedral structure design scheme, personalized design style makes product packaging design more interesting. It can be seen that utilizing multimedia and new technologies such as computers for intelligent analysis and optimization of multi-packaging design, as well as dynamically transforming the display of design, is an important way to improve the development of the packaging design field.

2 CURRENT STATUS

Georgakarakou et al. [8] found that consumers are more concerned about the environmental attributes, product information, and visual effects of packaging when purchasing organic agricultural products. They tend to choose packaging that uses environmentally friendly materials, has a minimalist design without losing its sense of design, and is transparent in information. At the same time, they also pay more attention to the practicality and convenience of packaging, such as easy opening and portability. Green product packaging often uses biodegradable and recyclable materials, such as paper materials, bio-based plastics, etc., effectively reducing the pollution of packaging waste to the environment. At the same time, these materials also pay more attention to low-carbon and energy-saving in the production process, reducing carbon emissions and meeting the requirements of sustainable development. The design of clothing product packaging has also ushered in a new era of intelligence and efficiency. The collaborative application of CAD (Computer Aided Design) and multimedia algorithms provides strong technical support for multi-link intelligent design of clothing product packaging, greatly improving design efficiency and quality. CAD technology, as the core tool for clothing product packaging design, has advantages such as high accuracy and convenient operation. Through CAD software, Han et al. [9] can easily draw various complex patterns and shapes and quickly adjust the structure and size of packaging to meet the needs of different products. In addition, CAD can also simulate and optimize design results, identify and solve potential problems in advance, and ensure the feasibility and practicality of the design.

The application of artificial intelligence in packaging visual design is mainly reflected in data analysis, automated design, and creative generation. Through deep learning and big data analysis, AI can accurately grasp market trends, consumer preferences, and popular trends of design elements, providing strong data support for designers. The practice of human-machine collaborative creation mode in packaging visual design is the best embodiment of the combination of AI technology and design thinking. In this mode, Huang and Zheng [10] jointly participate in the design process, collaborate and inspire each other. Designers can fully utilize the data support and design suggestions provided by AI while leveraging their creativity and aesthetic abilities to finely adjust and optimize design schemes. AI systems, on the other hand, can continuously improve their design abilities and intelligence levels by learning from designers' creative styles and ideas. The innovation of packaging materials and sensors has become a key force driving industry progress. The emergence of polymer nanocomposite packaging materials and electrical sensors has brought unprecedented changes to the fields of food and agriculture. Idumah et al. [11] reviewed the latest innovations and applications of polymer nanocomposite packaging materials and electrical sensors in the fields of food and agriculture. Polymer nanocomposite packaging materials have been widely used in the fields of food and agriculture due to their excellent performance. By introducing nanomaterials into polymer matrices, the barrier properties, mechanical properties, and thermal stability of packaging materials can be significantly improved. These improvements enable packaging materials to better protect the quality of food and extend its shelf life. Corrugated cardboard, as a common packaging material, has been widely used in agricultural product packaging due to its low cost, environmental friendliness, recyclability, and good cushioning performance. However, in practical applications, the performance of corrugated cardboard under external forces, especially under flattening behaviour, directly affects its packaging effect and service life. Therefore, Park et al. [12] simulated and analyzed the mechanical properties and deformation behaviour of corrugated cardboard under flattening behaviour, which is of great significance for optimizing packaging design

and improving packaging quality. The finite element method, as an effective numerical simulation technique, can accurately simulate the mechanical behaviour of complex structures and materials. In the simulation of the flattening behaviour of corrugated cardboard used in agricultural product packaging, the finite element method can simulate the stress distribution, deformation process, and failure mode of corrugated cardboard under external forces, providing a scientific basis for packaging design.

Product packaging, as an important component of a product, its shape and appearance directly affect consumer purchasing decisions. The traditional packaging design process often relies on the experience and intuition of designers, lacking scientific data support and real-time feedback mechanisms. Based on virtual reality technology, intelligent analysis of assisted modelling can simulate different packaging shapes by constructing a virtual three-dimensional environment and analyzing their performance in the virtual environment through algorithms. Qiu and Zhang [13] observed the visual effects of packaging under different angles and lighting conditions in order to make more accurate and scientific design decisions. Dynamic display design is another important aspect of product packaging design. Traditional display methods are often limited to static images or models, making it difficult to fully showcase the three-dimensional and dynamic effects of packaging. The dynamic display design based on virtual reality technology can simulate real scenes and actions, allowing consumers to personally experience the packaging effect of products in a virtual environment. In the digital age, computer-aided design and multimedia technology have brought unprecedented changes to the field of packaging design. The application of these technologies makes packaging design more precise, efficient, and creative, meeting the needs of consumers for personalization and customization. Rodríguez et al. [14] used Apple as an example to explore how to customize packaging design through computer-aided design and multimedia technology. Computer-aided design (CAD) software provides powerful technical support for the customized design of Apple packaging with its powerful modelling, rendering, and optimization functions. Designers can use CAD software to accurately draw three-dimensional models of packaging, simulate the effects of different materials, colours, and textures, and quickly generate multiple design schemes. In addition, CAD software can also optimize the packaging structure to ensure that it meets the requirements of aesthetics and practicality while protecting the product.

Multi-mode dynamic information encryption technology goes further, as it can dynamically adjust encryption methods and decryption conditions according to different needs and environmental changes. This technology can flexibly respond to various anti-counterfeiting scenarios and improve the anti-counterfeiting effect. Meanwhile, multi-mode dynamic information encryption technology also has high security, ensuring the security and reliability of information even in complex environments. In packaging anti-counterfeiting applications, RGB three-color and multi-mode dynamic information encryption and decryption technology can be combined to form a complete anti-counterfeiting solution. Song et al. [15] used RGB three-colour encryption technology to embed key information into packaging materials, ensuring the concealment and integrity of the information. Then, through multi-mode dynamic information encryption technology, different decryption conditions and methods are set according to actual needs to achieve precise control of information. The application of computer-aided design and multimedia technology in the field of packaging design is becoming increasingly widespread. These technologies not only improve the efficiency and quality of packaging design but also enable designers to delve deeper into the impact of packaging design on consumer willingness to pay. Ton et al. [16] explored how to use computer-aided design and multimedia technology to conduct such surveys and analyzed how packaging design affects the willingness to pay for consumer goods. The application of computer-aided design in packaging design provides designers with powerful design tools. By utilizing techniques such as 3D modelling, rendering, and animation, designers can simulate realistic packaging effects and present consumers with a dynamic and intuitive visual experience. In addition, computer-aided design can also achieve rapid modification and optimization of design schemes, helping designers complete multiple iterations in a short time, thereby improving the pertinence and effectiveness of the design.

The application of computer CAD design and multimedia technology provides strong technical support for the innovation and improvement of agricultural product packaging, further promoting the

enhancement of the market value of agricultural products. Traditional packaging design often relies on the experience of designers and manual drawing, making it difficult to accurately express design concepts and details. CAD design software can accurately draw three-dimensional models of packaging and simulate the effects of different materials, colours, and textures, allowing designers to visually preview and modify design schemes. This not only improves design efficiency but also makes packaging design more precise and in line with market demand. Through image processing technology, agricultural product packaging can present more vivid and attractive patterns and text. Through animation design, packaging can display interesting animation effects during opening or use, increasing consumer curiosity and purchasing desire [17]. With the continuous development of modern agricultural markets and the diversification of consumer demands, agricultural products are no longer just food but commodities that carry rich cultural, ecological, and quality information. In this context, Zhu et al. [18] analyzed agricultural products with multi-layer collective labels and self-packaging, which profoundly affects consumer choices. Self-owned packaging is an important carrier of agricultural product brand image and market competitiveness. Through carefully designed packaging, agricultural products can showcase their unique personality, style, and quality, establishing a closer emotional connection with consumers. At the same time, elements such as patterns, colours, and text on the packaging can also convey the brand's cultural concepts and values, enhancing consumer identification and loyalty to the brand. In the fiercely competitive agricultural market, agricultural products with unique, beautiful, and practical self-packaging often stand out and win the love and trust of more consumers.

3 RESEARCH ON COMPUTER-AIDED DESIGN AND MULTIMEDIA TECHNOLOGY FOR INTELLIGENT ANALYSIS AND DYNAMIC DISPLAY OF PACKAGING DESIGN

3.1 Intelligent Analysis and Research on Packaging Design Using Computer-Aided Design Technology

Through the organization and investigation of theoretical data, as well as the research on the packaging design market, designers have different perspectives on conveying packaging design ideas and forms. Some designers place more emphasis on the colour and structure of product packaging, while others place more emphasis on the reflection of cultural value and corporate image in packaging design. We randomly conducted an in-depth analysis of the outer packaging of a product and found that in addition to its unique appearance, the structure of this packaging is also obtained by cutting corners from hexahedrons. This ordinary corner cutting not only increases the visual size of the packaging but also enhances the expression of lines, thereby creating a more beautiful new shape. Many packaging design styles are unique; in addition to traditional Chinese style, foreign cultural styles are also influenced. Packaging design can reflect both a romantic atmosphere and a minimalist spirit. Therefore, in order to meet the modern demand for packaging design in the market, it is very meaningful to integrate computer-aided design and multimedia technology to optimize design ideas and product production plans. We have counted the number of studies on packaging design in different years and countries in recent years from a large database, as shown in Figure 1.

As shown in Figure 1, with the rapid development of computer technology and modern means, most countries have paid more attention to product packaging design. In addition to the United States and Italy, Japan also attaches great importance to packaging design. After 2008, there has been an unusual increase in the number of studies on packaging design. In our research, we focus on the application of computer-aided design CAD technology in packaging design and analyze its intelligent characteristics. The development of CAD technology can also bring new efficiency and benefits to the field of packaging design. In order to make the appearance, structure, and concept of packaging design more in line with people's needs, the production scale of the manufacturing industry has also undergone changes. The diverse demands of the masses and consumers for products have led to packaging design not only having multiple choices in terms of functionality but also becoming more personalized in appearance.

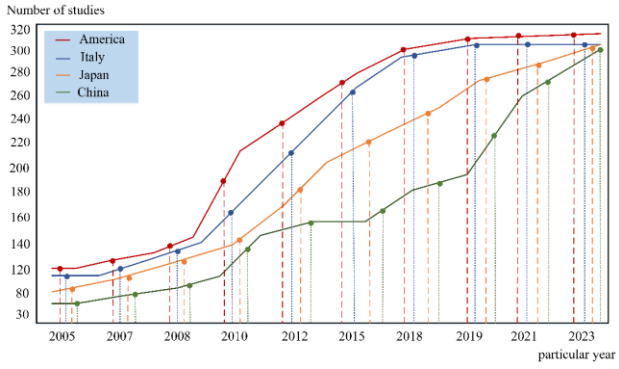

Figure 1: Statistics of research frequency in different countries in recent years.

Firstly, the combination of packaging design and computer-aided design CAD technology is reflected in the designer's ability to integrate and input detailed product data into the computer system. By incorporating decision information from designers into the initial application of computers, designers can change the way appearance art is displayed based on the functional requirements of the product. Determine the ultimate goal of product generation based on various factors such as packaging culture reflection and packaging material selection. We analyzed the importance of packaging design structure, appearance, and function among consumers, as shown in Figure 2:

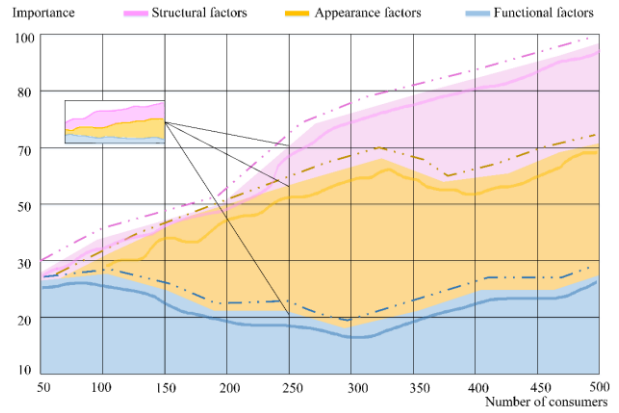

Figure 2: Comparison of factors that consumers value.

From the data graph in Figure 2, it can be seen that the demand for packaging design functions is relatively low, and the rationality of internal structure and aesthetic appearance have a significant impact on consumer choices. We study the conversion process of data information in analysis and build a packaging design model for computer-aided design. Build a three-dimensional scene and achieve information exchange in a computer system. Secondly, data modelling starts from the specific information of packaging design, collects the key node relationships of the same packaging design structure according to the packaging scheme requirements of different products, and builds a structural framework diagram based on the node relationships. The node set formula is as follows:

$$G = (x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n) \tag{1}$$

$$(x_i, y_i) \in G, i = [1, \infty] \tag{2}$$

In the formula, (x_i, y_i) represent the corresponding positions of different relationship nodes in the image, and store similar data information in the set components. After starting to digitize the design drawings, it is also necessary to convert the flattened static images into digitally integrated image pixels. Combining the different styles, images, and structural requirements of packaging design completes the final graphic production. In addition to facing two-dimensional design, packaging design should also comply with dynamic production standards in spatial scenes and selectively layout according to reasonable design schemes. We conduct mathematical calculations on the spatial layout and design the actual positions of design nodes according to quantitative calculation requirements:

$$SP.gry\_mmA = (x_i, y_{i+1}, z_i), (x_{i+1}, y_{i+2}, z_{i+1}), ..., (x_{i+n}, y_{i+2n}, z_{i+n}) \tag{3}$$

$$EN = \begin{bmatrix} (x_i, y_{i+1}, z_i), (x_{i+1}, y_{i+2}, z_{i+1}), ..., (x_{i+n}, y_{i+2n}, z_{i+n}) \\ (x_m, y_{m+1}, z_m), (x_{m+1}, y_{m+2}, z_{m+1}), ..., (x_{m+n}, y_{m+2n}, z_{m+n}) \\ (x_u, y_{u+1}, z_u), (x_{u+1}, y_{u+2}, z_{u+1}), ..., (x_{u+n}, y_{u+2n}, z_{u+n}) \end{bmatrix} \tag{4}$$

In addition to completing spatial layout positioning, the formula also marks the centre point positions of different images. The distance between these similar image information points is:

$$L = \frac{D}{2} - | x - x_i | \tag{5}$$

$$[x_i, y_i, 1] = [x_j, y_j - l_{ij}, 1] \begin{bmatrix} \cos\theta, \sin\theta, 0 \\ -\sin\theta, \cos\theta, 0 \\ f_x, f_y, 1 \end{bmatrix} \tag{6}$$

Calculate the horizontal and vertical values of the entire image layout points and obtain the parameter conversion results of packaging design with the help of computer-aided systems. Using mathematical expressions to prove that this non-planar modelling can generate design drawings that meet the designer's requirements after setting initial parameters. Using a measurement function to determine whether the artistic style in packaging design can automatically appear at the symmetrical centre of the product, the measurement function is expressed as:

$$H(a_n) = \sum_{u=1}^{t-1} | a - a_n^{u-1} | \tag{7}$$

In the formula, $H(a_n)$ the key number represents the centre point. According to the central formula, we can also obtain the formula for generating the transformation matrix:

$$T_x^0 = '1' R_z^i \tag{8}$$

As the solutions generated by computer-aided design are completed within the system, it is crucial to determine the final presentation effect of packaging design. Due to the simple appearance of some packaging designs, it affects customers' pursuit of art and aesthetics. Therefore, more modern multimedia technology helps to further enhance the presentation of packaging design. Meanwhile, due to the different design habits of designers, the appearance design requirements of many products are very special. How to apply computer-aided design more to most of the packaging design requirements is the focus of our research in the future. Combining 3D technology to achieve precise reconstruction of design, multimedia technology is added to enhance surface rendering of packaging appearance and establish a dynamic display system.

3.2 Dynamic Display and Analysis of Packaging Design Schemes Using Multimedia Technology

In traditional packaging design and production, there is a lack of advanced technical support and innovative artistic design styles. Displaying patterns on the packaging surface has become the main choice for presenting most products. In addition to relying on a large amount of computer data support, it is also necessary to strictly control the range of product packaging and size. The

application of computer-aided design CAD technology to accurately calculate data information in design systems, replacing complex and crude operations, maximizing the liberation of designer human resources, and meeting the personalized needs of customers for packaging design. However, some more innovative products have increasingly high requirements for CAD technology, such as obvious defects in the packaging of peripheral products. Therefore, we integrate multimedia technology into packaging design and display, interpreting the corporate image and cultural value of the products. Firstly, packaging design mainly includes stages such as conception, text, images, and colours. Conception is the soul and core of design, which is limited by various factors. Packaging products cannot express comprehensive ideological characteristics and can only express key points. The key content includes product image, meaning, function, background, etc. In the text section, it is the most direct way to convey product information. In the design process, the main body should be highlighted, with a focus on the harmony between the font and the shape. Fonts should not only conform to visual effects but also have a certain degree of subordination, interweaving to form an organic whole. Graphics and colours are the most visually impactful factors in the abstract realm, and they can easily leave a deep impression on consumers. Therefore, in packaging design, we should pay attention to the combination and selection of images and colours.

In order to highlight the presentation effect of packaging design, we have incorporated multimedia technology for transformation. Multimedia is a comprehensive medium of various information, which not only combines text, graphics, sound, and other content, but also utilizes computer technology to complete a series of interactive tasks. The integration of multimedia and product design has changed the singularity of packaging design, allowing for a vivid and intuitive display of a product and allowing consumers to pay more attention to the product itself. We summarize the virtual and real display process of multimedia technology as shown in Figure 3:

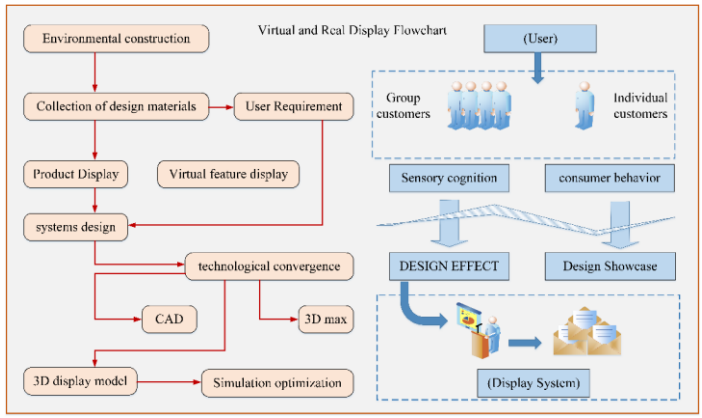

Figure 3: The virtual and real display process of multimedia technology.

From Figure 3, it can be seen that in the display process of the virtual environment, the main emphasis is on the human-computer interaction process, which means that consumers understand the interactivity in the process of product packaging design. In addition, the collection of product information materials and analysis of user needs, as well as the display design of product virtual interfaces, are the main components of multimedia dynamic display. We also found that the artistic features of packaging design include virtuality, interactivity, publicness, and timeliness. Virtual representation in multimedia art construction environments conforms to design concepts but conflicts with authenticity. Interactivity refers to the use of multimedia technology to assist packaging design in forming interactive operational requirements in dynamic displays, where consumers make choices based on their own needs. Publicity is reflected in the need for packaging design to meet the display of the cultural value of goods and have a certain degree of influence.

Timeliness refers to whether the packaging of a product meets current popular needs and the popularity of fashion. We analyzed the impact of these four attributes on consumers of different age groups, as shown in Figure 4:

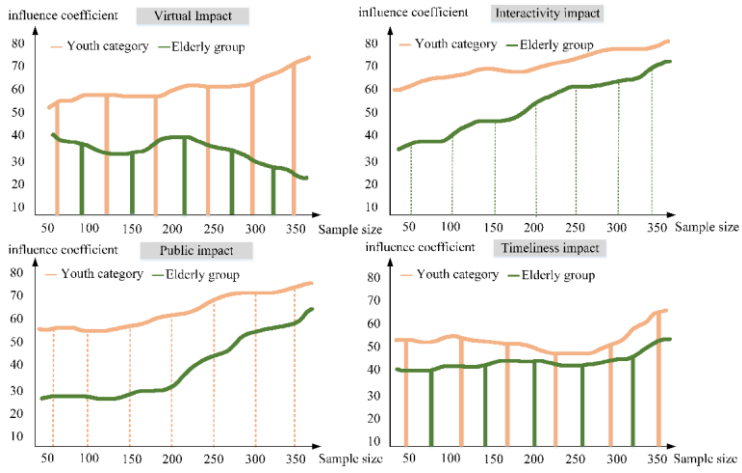

Figure 4: Changes in influence among consumers of different age groups.

As shown in Figure 4, we divide the age group into two stages, youth and elderly, and separately calculate the popularity of packaging design products with different characteristic attributes in these two age groups. It can be seen that design products with interactivity and commonality are popular in both age groups. We add multiple design samples to the dynamic display system of multimedia technology to form a reaction formula matrix:

$$x = \begin{bmatrix} f_1(1,1)...f_1(1,r_1)f_1(2,1)...f_1(m,r_m) \\ f_n(1,1)...f_n(1,r_n)f_n(2,1)...f_n(m,r_m) \end{bmatrix} \tag{9}$$

Establish relevant mathematical models to express the emotional impression rating of consumers towards design displays, as well as the relationship formula between design product sales:

$$y_k = \sum_{i=1}^{m}\sum_{j=1}^{r} r(i,j)b_{ij} + \varepsilon_k \tag{10}$$

Using the least squares method to obtain the error of random multiple sampling, construct the equation expression:

$$R^T Rb = R^T Q^T y \tag{11}$$

$$y = (y_1, y_2, ..., y_m)^T \tag{12}$$

In order to satisfy the solutions of multiple datasets, the formula needs to predict the variable set of the sample. The prediction equation is:

$$y = \sum_{i=1}^{m}\sum_{j=1}^{r} t(i,j)b_{ij} \tag{13}$$

In the equation, b_{ij} represent the impression score corresponding to each sample module and further optimize the model using standard coefficients:

$$y = y + \sum_{i=1}^{m}\sum_{j=1}^{r} t(i,j)b * ij \tag{14}$$

$$b_{ij} = b_{ij} - \frac{1}{n}\sum_{k=1}^{r} n_{ij} b_{nm} \tag{15}$$

Based on the dynamic display effect of packaging design generated by multimedia technology, combined with the above calculation formula, the satisfaction evaluation of consumers towards the designed product can be obtained, which provides assistance for adjusting packaging design schemes and improving design ideas in the future.

4 COMPUTER-AIDED DESIGN AND MULTIMEDIA TECHNOLOGY TO ACHIEVE INTELLIGENT ANALYSIS AND DYNAMIC DISPLAY OF PACKAGING DESIGN RESEARCH RESULTS ANALYSIS

4.1 Analysis of the Results of Intelligent Analysis and Research on Packaging Design Using Computer-Aided Design Technology

The rapid development of computers has enabled them to be applied in various fields of society, and the comprehensive effects they produce also have obvious advantages. The field of packaging design not only focuses on the rationality of packaging structure but also imposes standardized requirements on the appearance design of the packaging. Designing a packaging solution with complete functionality, rich value, and exquisite appearance is the most direct way to increase product sales. Enterprises can highlight their advantages through packaging design, allowing for the presentation of their corporate image and culture. At the same time, based on consumer purchasing choices for different packaging products further improve the direction of product design. In order to further integrate packaging design with computer technology, computer-aided design CAD technology has become the main technology for processing patterns and completing automated design. In addition to using CAD technology as the core design system in our research, we also combined many post-processing software for image processing to assist packaging design in completing appearance beautification tasks. The sample image of the product packaging logo automatically generated using computer-aided design CAD technology is as follows:

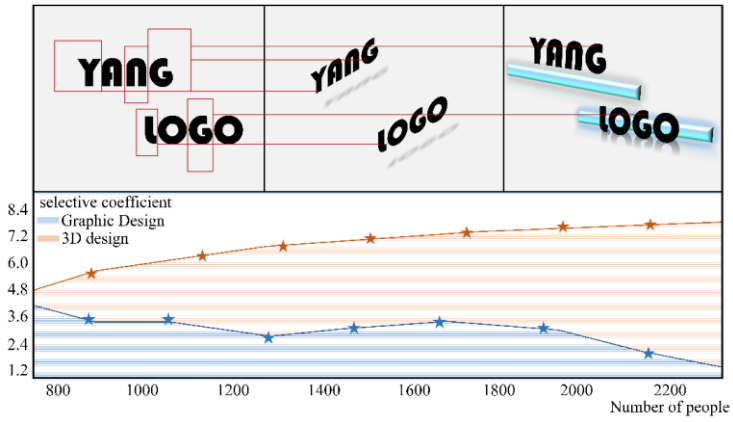

Figure 5: Sample image of automatically generated product packaging logo.

As shown in Figure 5, we have transformed the company's logo image from a two-dimensional graphic design to a three-dimensional dynamic design effect. Based on the results of different people's choices between the two, it can be seen that the packaging scheme of two-dimensional graphic design is significantly better than the three-dimensional effect diagram of computer-aided design. From this, it can be seen that computer-aided technology has great advantages in the intelligence of packaging design. In addition to changing the static flatness of packaging design, it can

also improve the aesthetic appearance of products. In image design and processing, recording colour information, mixing text with images, and generating design schemes are all factors that computer-aided design systems should pay attention to. We input a packaging design concept, add relevant design materials, and explore the comparative effect between computer-aided design systems and manual packaging design, as shown in Figure 6:

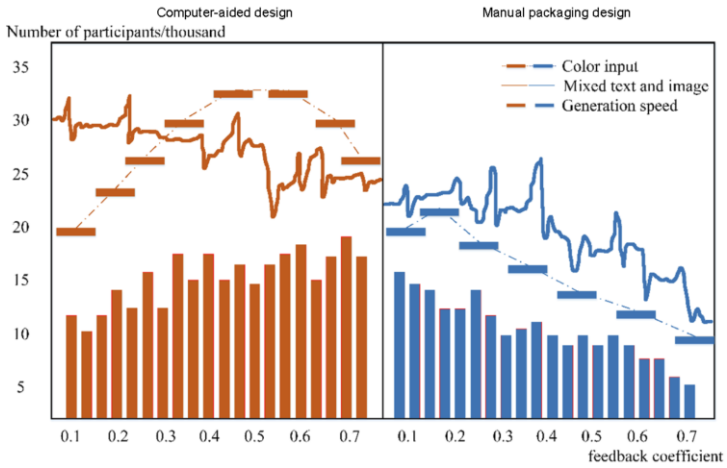

Figure 6: Comparison effect between computer-aided design system and manual packaging design.

From Figure 6, it can be seen that as the feedback coefficient increases from 0.1 to 0.7, the number of participants in the computer-aided design system also increases. However, the number of people involved in manual packaging design by designers continues to decrease, indicating the efficiency of computer-aided design systems and their resistance to feedback coefficient passivation. At the same time, in terms of color information input, text image mixing, and generation speed, computer-aided design systems are significantly superior to the personal operations of designers. As the feedback coefficient increases, the graphic design effect under manual packaging design by designers continues to decrease. Therefore, using computer-aided design systems to generate design drawings is more in line with trends and current aesthetic trends.

In addition, we also randomly surveyed feedback from different groups of people on the two packaging designs. The young audience prefers computer-aided design of packaging patterns, believing that this design style is more innovative and in line with the aesthetic trend of the times. Some middle-aged and elderly people believe that the packaging design hand drawn by designers is more in line with traditional design concepts. However, from the perspective of consumer preferences and sales performance, packaging design solutions implemented with computer-aided design achieve higher performance. We will further analyze the results from the presentation of multimedia technology design schemes in the future.

4.2 Analysis of Research Results on Dynamic Display of Packaging Design Schemes Using Multimedia Technology

Packaging design reflects the current characteristics of the times, and these characteristics also influence the thinking and development of design. Multimedia and other computer technologies have changed people's perception of life and also influenced their aesthetic needs for packaging design. The traditional packaging design thinking is still stuck in the two-dimensional concept, in order to develop it towards a deeper modernization direction. Multimedia virtual reality technology utilizes its advantages in three-dimensional space to form a dynamic display environment for human-computer interaction products. This not only brings inspiration and development space for packaging design but

also presents diverse characteristics and advantages in design schemes, expanding the consumer base and achieving cultural dissemination effects while simplifying design processes and presentation methods. In the virtual interactive design presentation environment, computers meet the complex needs of designers, integrating graphic design and product modelling constraints to form a three-dimensional solid model to express the designer's intentions. The authenticity of the packaging design we presented is completely identical to the actual sample, greatly reducing the occurrence of detail problems in design and production, and also shortening the time for packaging design and product production.

The dynamic key technologies of virtual reality display completed by our multimedia not only require environmental modelling, 3D generation, sensor technology, etc. but also need to be integrated with the corporate culture and image of packaging products. We will divide the dynamic display of packaging design into three sample evaluation results, mainly from the perspectives of artistic factors, structural factors, and image factors in product appearance design, as shown in Figure 7:

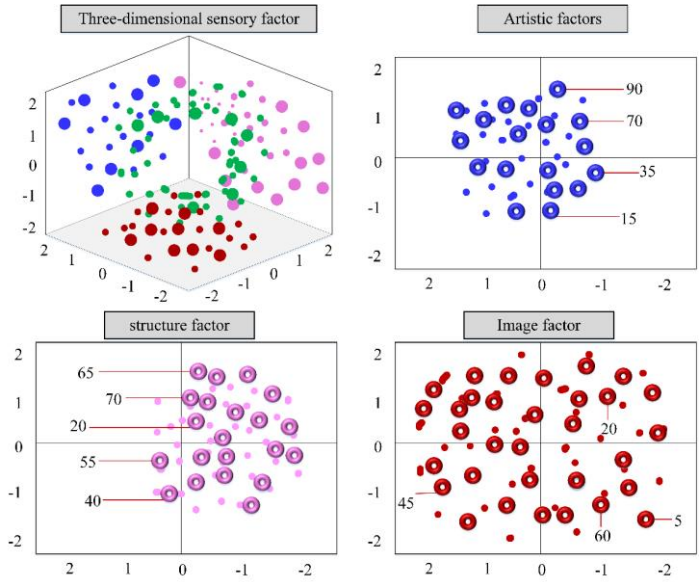

Figure 7: Sample evaluation results from three perspectives.

As shown in Figure 7, the randomly selected consumers have a relatively diverse evaluation of the dynamic display effect presented by multimedia technology. Their feedback on the three evaluation factors varies, and the three-dimensional presentation of the sample reflects that factors such as art, structure, and image are the main components that affect consumer preferences. It can be seen that the dynamic display of packaging design achieved by multimedia technology can more accurately capture consumers' willingness to choose design solutions. This innovative packaging design results in a reduction of visual fatigue for consumers in traditional design patterns.

5 CONCLUSIONS

With the continuous integration of the information age and modern construction needs, computer technology and multimedia technology have brought more changes to people's lives. It not only affects people's living habits but also, to a certain extent, affects their understanding of aesthetics and art. Traditional packaging design is limited to two-dimensional graphic design styles, and the

content involved is only in a single form, such as text, graphics, and lines. As diverse styles gradually influence packaging design concepts, traditional design techniques cannot meet the needs of design development. Therefore, this article uses computer-aided design CAD technology and multimedia technology to achieve intelligent analysis of packaging design and dynamically display and study the final results achieved. The experiment focused on exploring the functionality and advantages of computer-aided design systems and, combined with packaging design requirements, explored the effectiveness of computer-aided technology from multiple aspects such as structure, image, appearance, and function. In our research, we also broke away from the field of two-dimensional planes and incorporated three-dimensional space into packaging design concepts, deepening the integration of packaging design and cultural style. Finally, utilizing multimedia technology to display packaging design results in a virtual reality environment, transforming static packaging design images into dynamic three-dimensional images. Compare the effectiveness of multimedia dynamic display results based on feedback from consumers of different age groups. Research has shown that computer-aided technology and multimedia dynamic display technology can maximize the modern artistic style of packaging design, significantly improving product sales and audience levels.

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REFERENCES

[1] Agarwal, A.; Singh, R.; Vatsa, M.; Ratha, N.: Image transformation-based defense against adversarial perturbation on deep learning models, IEEE Transactions on Dependable and Secure Computing, 18(5), 2020, 2106-2121. https://doi.org/10.1109/TDSC.2020.3027183
[2] Almasi, H.; Jahanbakhsh, O.-M.; Saleh, A.: A review on techniques utilized for design of controlled release food active packaging, Critical Reviews in Food Science and Nutrition, 61(15), 2021, 2601-2621. https://doi.org/10.1080/10408398.2020.1783199
[3] Bahlau, J.; Lee, E.: Designing moulded pulp packaging using topology optimization and superimpose method, Packaging Technology and Science, 35(5), 2022, 415-423. https://doi.org/10.1002/pts.2639
[4] Boz, Z.; Korhonen, V.; Koelsch, S.-C.: Consumer considerations for the implementation of sustainable packaging: A review, Sustainability, 12(6), 2020, 2192. https://doi.org/10.3390/su12062192
[5] Brenes, A.; Marín, R.-G.; López, G.: Improving packaging design using virtual reality in the market research process, Multidisciplinary Digital Publishing Institute Proceedings, 31(1), 2019, 12. https://doi.org/10.3390/proceedings2019031012
[6] Chen, D.; Cheng, P.: Development of design system for product pattern design based on Kansei engineering and BP neural network, International Journal of Clothing Science and Technology, 34(3), 2022, 335-346. https://doi.org/10.1108/IJCST-04-2021-0044
[7] Chen, S.; Brahma, S.; Mackay, J.; Cao, C.; Aliakbarian, B.: The role of smart packaging system in food supply chain, Journal of Food Science, 85(3), 20230, 517-525. https://doi.org/10.1111/1750-3841.15046
[8] Georgakarakou, C.; Riskos, K.; Tsourvakas, G.; Yfantidou, I.: What features of green product packaging are more eye-catching? An eye-tracking exploratory study about organic agricultural products, International Journal of Technology Marketing, 14(2), 2020, 93-124. https://doi.org/10.1504/IJTMKT.2020.110124

[9] Han, C.; Shen, L.; Shaogeng, Z.; Mingming, W.; Ying, T.: Man-algorithm cooperation intelligent design of clothing products in multi links, Fibres & Textiles in Eastern Europe, 30(1 (151)), 2022, 59-66. https://doi.org/10.5604/01.3001.0015.6462
[10] Huang, L.; Zheng, P.: Human-computer collaborative visual design creation assisted by artificial intelligence, ACM Transactions on Asian and Low-Resource Language Information Processing, 22(9), 2023, 1-21. https://doi.org/10.1145/3554735
[11] Idumah, C.-I.; Zurina, M.; Ogbu, J.; Ndem, J.-U.; Igba, E.-C.: A review on innovations in polymeric nanocomposite packaging materials and electrical sensors for food and agriculture, Composite Interfaces, 27(1), 2020, 1-72. https://doi.org/10.1080/09276440.2019.1600972
[12] Park, J.; Park, M.; Choi, D.-S.; Jung, H.-M.; Hwang, S.-W.: Finite element-based simulation for edgewise compression behavior of corrugated paperboard for packaging of agricultural products, Applied Sciences, 10(19), 2020, 6716. https://doi.org/10.3390/app10196716
[13] Qiu, Y.; Zhang, Y.: Aided product modeling design based on virtual reality technology, International Journal of New Developments in Engineering and Society, 5(3), 2021, 10-25. https://doi.org/10.25236/IJNDES.2021.050302
[14] Rodríguez, P.-L.; Mayuet, P.-F.; Gámez, A.-J.: Custom design of packaging through advanced technologies: A case study applied to apples, Materials, 12(3), 2019, 467. https://doi.org/10.3390/ma12030467
[15] Song, H.; Zhang, R.; Zhao, Z.; Wu, X.; Zhang, Y.; Wang, J.; Li, B.: RGB tricolor and multimodal dynamic optical information encryption and decoding for anti-counterfeiting applications, ACS Applied Materials & Interfaces, 14(40), 2022, 45562-45572. https://doi.org/10.1021/acsami.2c12387
[16] Ton, L.-A.-N.; Smith, R.-K.; Sevilla, J.: Symbolically simple: How simple packaging design influences willingness to pay for consumable products. Journal of Marketing, 88(2), 2024, 121-140. https://doi.org/10.1177/00222429231192049
[17] Uzelac, O.; Mijatović, M.-D.; Lukinović, M.: The role of branding agricultural products in better market valorization, Economics of Agriculture, 69(2), 2022, 613-625. https://doi.org/10.5937/ekoPolj2202613U
[18] Zhu, Z.; Shen, Q.; Gao, Z.: Consumer choices in agricultural markets with multitier collective labels and private brands, Agribusiness, 38(4), 2022, 905-922. https://doi.org/10.1002/agr.21747