www.cad-journal.net
Computer-Aided Design AND APPLICATIONS

# Optimization of Emotional Experience in Interactive Packaging Design using Artificial Intelligence

Yipeng Wang[1] and Shilin Zhang[2]

[1]School of Design, Jilin Animation Institute, Changchun, Jilin 130000, China, wangyipeng@jlai.edu.cn
[2]School of Design, Jilin Animation Institute, Changchun, Jilin 130000, China, wdmzjwyp1989@naver.com

Corresponding author: Yipeng Wang, wangyipeng@jlai.edu.cn

**Abstract.** Packaging is a key carrier of goods, brand information and emotional experience, an important information communication bridge between consumers and goods, and an important means to achieve effective marketing. In the deep growth of commodity economy, the function of packaging has changed obviously, not only in protecting products, facilitating storage and transportation, and promoting marketing, including interactive communication and convenient use. The advantages of visual information make its memory more durable than other information carriers, and the information contained in the image itself is more intuitive and vivid, and the rich human emotional semantic information is hidden behind the image characteristics. Focusing on the integration of packaging design and interactive design means and the application of emotional experience in interactive packaging design, this article studies the application of computer-aided design (CAD) technology driven by artificial intelligence (AI) in interactive packaging design to promote the integration of emotional experience and design optimization in interactive packaging design. The music visualization method in this article has a higher score, so it can be considered that the interactive packaging design method combining AI and CAD has achieved a better user experience.

**Keywords:** Artificial Intelligence; Interactive Packaging; Emotional Recognition; Computer Aided Design
**DOI:** https://doi.org/10.14733/cadaps.2024.S7.284-299

## 1 INTRODUCTION

Packaging design is a creative work to convey the internal product information by creating the physical concept of external packaging. In its unique way, packaging design conveys the unique characteristics and functions of the product to customers, thus making the product more suitable for market sales. Driven by artificial intelligence, interactive packaging design can be integrated with emotional experience, thereby improving the design level and user satisfaction of packaging.

Drago et al. [1] use artificial intelligence technology to design personalized packaging based on consumers' preferences and needs, improving their emotional experience. Through artificial intelligence technology, interactive design elements can be added to packaging, such as touch screens, sound prompts, etc., allowing consumers to interact with the packaging, improving their sense of participation and experience. Through artificial intelligence technology, packaging can be designed as a story scene, allowing consumers to experience a complete storyline and improve their emotional experience while opening the packaging. Artificial intelligence technology can design more environmentally friendly and sustainable packaging, such as biodegradable materials and recycling, to enhance consumers' environmental awareness and emotional recognition of packaging. Through artificial intelligence technology, safer and more reliable packaging can be designed, such as anti-counterfeiting signs, anti-theft locks, etc., to enhance consumers' sense of security and trust in packaging. In short, the integration of emotional experiences and design optimization is one of the important directions in interactive packaging design driven by artificial intelligence. By optimizing the design of personalization, interactivity, storytelling, sustainability, and safety, consumers' emotional experience and packaging design level can be improved. The concept of interactive experience is a new concept rising with the growth of economy and society and industrialization, which requires enterprises to interact and communicate effectively with consumers in the stage of operation and development, and to stimulate consumers' enthusiasm for consumption in various ways and improve the attractiveness of products. The applicability of 3D factory simulation software in industrial workplace and process computer-aided Participatory design is very high. This software can provide a real 3D environment, allowing users to simulate actual operations and processes in virtual factories. Through this software, industrial designers and engineers can more easily understand and improve factory design and processes to optimize production efficiency, reduce costs, and reduce errors. 3D factory simulation software can be used to plan and design new factories or improve existing factories. Designers can create and modify factory layouts, equipment, and pipelines in a virtual environment to determine the best design solution. 3D factory simulation software can be used to train operators and maintenance personnel. By simulating actual operations and fault situations, operators can learn how to cope with various situations in a real environment to improve production efficiency and reduce errors. Frutiger et al. [2] by simulating and testing in 3D factory simulation software, engineers can identify and solve potential problems and bottlenecks. They can optimize equipment and processes to improve production efficiency and reduce costs. 3D factory simulation software can promote collaboration and communication among designers, engineers, operators, and other relevant personnel. By working together in a virtual environment, teams can more easily understand and discuss various design and process options to ensure consensus is reached. In a word, 3D factory simulation software has a very high applicability in computer-aided Participatory design of industrial workplaces and processes, which can help industrial designers and engineers better understand and improve factory design and processes, so as to improve production efficiency, reduce costs and reduce errors. Packaging is essentially a unique way to convey to consumers the difference between this product and other items, as well as the product's own personality and functions, so as to make it more suitable for sale and achieve effective consumer perception in the market. Interactive design is mainly based on ergonomics, with the help of the interaction between things, people and things, and people to achieve the purpose of information exchange. The application of interactive packaging design can bring consumers the satisfaction of cultural spiritual needs. Excellent packaging design can build a communication bridge between consumers and products, and consumers can also maintain good psychological experience and behavioral feedback in every link from purchase to opening packaging. The use of artificial intelligence for automated visual information processing and scientific and technological information processing in product design and packaging is an efficient and accurate method. By utilizing computer vision technology, product packaging images can be automatically recognized and processed to extract key features and information of packaging, such as material, structure, color, text, etc. Gavrilov and Lovtsov [3] utilize machine learning technology to mine and classify extracted packaging information, thereby automatically identifying and classifying different types of packaging materials and structures, such as paper packaging, plastic packaging, metal packaging, etc. By utilizing machine learning and data mining techniques, packaging design models can be established to automate packaging design and optimize design parameters, such as packaging size, shape, capacity, etc. Using Natural language processing and data mining technology, scientific and technical information can be automatically processed and analyzed, so as to extract key scientific and technical information, such as technical parameters, material properties, manufacturing processes, etc. In summary, utilizing artificial intelligence for automated visual information processing and scientific and technological information processing in product design and packaging can greatly improve design efficiency and accuracy, while also reducing design costs and shortening design cycles. In practical applications, targeted design and manufacturing need to be carried out based on specific products and market demands.

Metal nanoparticles have a significant impact on the mechanical, barrier, optical, and thermal properties of biodegradable food packaging materials, which can improve the performance of packaging materials, enhance the shelf life and safety of food. However, it should be noted that the application of metal nanoparticles also needs to consider their impact on the human body and environment, and safety and environmental protection assessments need to be conducted. The addition of metal nanoparticles can significantly improve the strength and toughness of biodegradable food packaging materials, making them more wear-resistant and tear resistant. This is mainly because metal nanoparticles form a strengthening interface in the material, which can effectively transfer stress. Jafarzadeh and Jafari [4] found that adding metal nanoparticles can increase the thermal stability and heat resistance of packaging materials, making them less prone to deformation and damage under high temperature conditions. In the stage of interactive packaging design of goods, the cognition and control of consumers, information interaction and emotional experience is an important channel for goods to effectively enhance the aesthetics, application value and consumer experience of interactive packaging design. The growth of the information age is accompanied by the application and popularization of information carriers. Information carriers are not limited to common texts, but a large number of images, sounds and videos, as forms of multimedia information, are increasingly active on major social platforms on the Internet. The advantages of visual information make its memory more durable than other information carriers, and the information contained in the image itself is more intuitive and vivid, and what is hidden behind the image characteristics is rich human emotional semantic information. With the vigorous growth of electronic information industry, the form and interactive form of product packaging design have undergone fundamental changes, and the design that can meet the emotional needs of consumers came into being. Because image features reflect human emotions to different degrees, traditional methods mainly rely on manual construction and selection, and the traditional machine learning model has insufficient ability to classify image emotions, which leads to unsatisfactory effect of image emotion recognition and low prediction accuracy. This article focuses on the integration of packaging design and interactive design means and the application of emotional experience in interactive packaging design, and studies the application of CAD technology driven by AI in interactive packaging design.

Computer-aided engineering (CAE) for automated product packaging design is a method of using computer technology to assist product packaging design. Among them, multi view classification is an effective technology that can automatically classify and identify product packaging, thereby improving design efficiency and accuracy. Multi view classification is an automated classification method based on image processing and machine learning technology. Krahe et al. [5] classify and recognize product packaging by obtaining images from multiple perspectives, processing and extracting features from these images. In the stage of product packaging design, multi view classification can be used to automatically identify and classify different types of packaging materials and structures, thereby helping designers and engineers better select and design packaging solutions that are suitable for the product. Multi view classification can be used to automatically identify and classify different types of packaging materials and structures, thereby helping manufacturers better produce and process packaging materials and structures suitable for their products. In the application stage of product packaging, multi view classification can be used to automatically identify and classify different types of packaging materials and structures, thereby helping consumers better choose and use packaging materials and structures suitable for the product. In summary, multi view classification is an effective technique that can automatically classify and identify product packaging, thereby improving design efficiency and accuracy. In Computer-aided engineering of automated product packaging design, multi view classification can be applied to multiple stages of design, manufacturing and application, providing strong support for product packaging design and manufacturing. KraśNiewska et al. [6] The use of Biopolymer based materials containing silver nanoparticles needs to ensure their safety. The manufacturing and processing of these materials need to be strictly controlled to ensure that the size and shape of nanoparticles and the properties of Biopolymer meet safety standards. In addition, sufficient toxicological research and risk assessment are needed to ensure the safety of these materials for both humans and the environment. In the deep growth of commodity economy, the function of packaging has changed obviously, not only in protecting products, facilitating storage and transportation, and promoting marketing, including interactive communication and convenient use. Effective and appropriate design strategies enable consumers to perceive the attributes and characteristics of products, and produce corresponding experience feelings, which affect consumers' psychology, emotion and thinking, and guide consumers' interaction with products. Due to the rapid growth and application of science and technology, it is no longer a dream to achieve a high-level and high-quality spiritual life. With the gradual improvement of human expectations for the quality of life, new changes have taken place in consumers' values and aesthetic concepts. The successful realization of diversified packaging functions is based on effective design, and the emotional experience of consumers is a key point of modern packaging design. In practice, the whole stage of interactive packaging design should be optimized and improved by effectively integrating emotional experience, so as to promote consumers to better obtain emotional experience, meet their deep-seated consumption needs and improve the effectiveness of interactive packaging design on the basis of maximizing packaging efficiency. In this article, the method of emotional experience fusion and design optimization in interactive packaging design driven by AI is studied, and the following innovations are made:

(1) Based on the ontology of packaging design, this article sorts out the development, types and design criteria of interactive packaging design, a derivative discipline of modern packaging design, studies the application of CAD technology and emotional recognition in interactive packaging design, summarizes the application of user emotional experience concept in packaging design, and analyzes the user experience of interactive packaging.

(2) Considering that transfer learning can transfer all or part of the pre-trained model parameters from a large data set to a small sample data set, and considering that transfer learning can speed up the model training and prevent the model from over-fitting in a small sample data set, this article proposes a packaging image emotion recognition method based on fusion features and transfer learning.

Firstly, this article expounds the basic concept of interactive experience construction in packaging design; Then, combined with emotion recognition and CAD technology, the strategy of emotional experience fusion and design optimization in interactive packaging design is put forward. The effectiveness of this method is verified by simulation experiments. Finally, the contribution and limitations of this article are summarized, and the next research direction is put forward.

## 2 RELATED WORK

Automated High-Level Warehouse (AW) is a common logistics warehousing system used for storing and distributing products. In AW, product packaging and storage allocation are important considerations as they directly affect the operational efficiency and cost of the warehouse. The joint optimization of packaging and storage allocation driven by digital twins is a new method that can optimize the packaging and storage allocation process through digital twin technology. Digital twins are digital models of Physical system collected through sensors and other data sources. This digital model can simulate the behavior of Physical system and be used to optimize the performance of Physical system. In AW, digital twins can be used to simulate the packaging and storage allocation process of products. Leng et al. [7] By simulating the physical characteristics of products, digital twins can determine the optimal packaging materials and dimensions to maximize the load-bearing capacity and efficiency of packaging. In addition, digital twins can also simulate the behavior of packaging during storage and distribution processes to determine the optimal packaging materials and design to minimize the risk of packaging damage and product damage. The use of automated methods to measure packaging visual information is an effective means of product design packaging video mining. Utilize video capture devices such as cameras, video recorders, etc. to capture packaging videos and perform preprocessing such as denoising, correction, segmentation, etc. to obtain clear packaging video data. Li et al. [8] utilized computer vision technology to extract and measure features from packaging videos, such as the shape, size, color, and text of the packaging, in order to obtain visual information about the packaging. Utilize data analysis and mining techniques to automate the processing and mining of extracted packaging visual information, such as clustering analysis and association rule mining, in order to obtain optimization suggestions and decision support for packaging design. Visual communication is an important component of packaging design, conveying product information and brand image through visual elements such as text, images, colors, and textures. In terms of interactive experience, visual communication packaging design should consider the way users interact with the packaging, such as ease of use, reusability, recyclability, etc. Packaging design should be attractive, able to attract consumers' attention and stimulate their purchasing desire. Packaging design should clearly convey product information, including product name, brand, specifications, price, and purpose. The text and images on the packaging should be easy to read and understand to ensure that consumers can quickly and accurately understand product information. Packaging design should be consistent with the brand image to ensure consistency and recognition of the brand image. Li [9] believes that in visual communication packaging design, attention should be paid to user interaction and attractiveness to attract consumers' attention and stimulate their purchasing desire. At the same time, information communication and readability are also very important to ensure that consumers can quickly and accurately understand product information. Finally, packaging design should be consistent with brand image to enhance brand recognition and consumer loyalty. The rapid industrial product packaging design method and its application based on 3D CAD system is a method to realize the rapid design and application of industrial product packaging through Computer-aided design (CAD) technology. This method can greatly improve design efficiency, reduce design costs, and also improve product quality and market competitiveness. Liu [10] uses a 3D CAD system to establish a 3D model of the product, including the product itself, packaging materials, packaging structure, etc. It determines the design tasks and requirements, including product types, target markets, sales channels, and other aspects. By using rapid prototyping technology, the 3D model is transformed into a physical prototype to verify the design and verify the usability of the product. Carry out packaging design in a 3D CAD system, including digital design of packaging structure and digital design of packaging art. Mustafa and Andreescu [11] designed and manufactured nanostructured sensors. Integrate sensors with electronic devices, microprocessors, and communication modules to build an intelligent sensor system. By processing and analyzing sensor data, real-time monitoring of food quality and safety issues can be carried out, and corresponding measures can be taken in a timely manner. Design and manufacture intelligent packaging materials based on the characteristics and requirements of food, such as plastic, paper, film, etc. containing nanomaterials. These packaging materials can protect the quality and safety of food by controlling the transport of substances such as gases, moisture, and microorganisms. Applying intelligent sensors and packaging materials to food packaging and supply chain management can achieve real-time monitoring and protection of food. Through IoT technology and Big data analysis, food production, transportation, sales and consumption can be tracked to improve the reliability and safety of food. In summary, food computer-aided intelligent sensing and packaging applications based on nanotechnology can provide the food industry with more efficient, safer, and environmentally friendly production and sales methods. However, it should be noted that these technologies require strict regulation and standardized production processes to ensure their safety and sustainability. Pauer et al. [12] evaluated the environmental sustainability of smart food packaging and could consider extending its Life-cycle assessment. Intelligent food packaging selects renewable or recycled materials to reduce environmental damage and resource consumption. Optimize production processes to reduce energy consumption and waste generation. Adopting environmentally friendly manufacturing technologies, such as 3D printing, can reduce waste and scrap. Choose environmentally friendly transportation methods, such as low-carbon transportation, to reduce carbon emissions during transportation. Optimize logistics network, reduce transportation distance and time, reduce energy consumption and carbon emissions. Intelligent food packaging can extend the shelf life of food and reduce food waste by providing information on its freshness and quality. At the same time, optimize packaging design to improve its reusability and recyclability. Intelligent food packaging can be designed for recyclability and degradability, making it easy to recycle and dispose of at the end of its lifespan. By extending the Life-cycle assessment of smart food packaging, we can comprehensively assess its environmental sustainability and take corresponding measures to improve its environmental sustainability. In addition, environmental impact assessments can also be considered to assess the environmental impact of smart food packaging in different environments, in order to take corresponding measures to reduce its impact on the environment.

The 3D factory simulation software has high applicability in the computer-aided Participatory design of industrial workplaces and processes. This software can provide a real 3D environment, allowing users to simulate actual operations and processes in virtual factories. Through this software, industrial designers and engineers can more easily understand and improve factory design and processes to optimize production efficiency, reduce costs, and reduce errors. 3D factory simulation software can be used to plan and design new factories or improve existing factories. Designers can create and modify factory layouts, equipment, and pipelines in a virtual environment to determine the best design solution. 3D factory simulation software can be used to train operators and maintenance personnel. By simulating actual operations and fault situations, operators can learn how to cope with various situations in a real environment to improve production efficiency and reduce errors. Pelliccia et al. [13] can identify and solve potential problems and bottlenecks through simulation and testing in 3D factory simulation software. They can optimize equipment and processes to improve production efficiency and reduce costs. At present, there is a lack of effective finite element analysis in the key problems of machine making Oatcake dough. Salahuddin et al. [14] used 3D CAD software to design the concept of a high inclusion dough forming machine. Consider the structure, size, material, Motor system, inclusion detection and elimination system and other aspects of the machine to ensure that the machine can meet production requirements and user experience. Based on the design concept, use 3D CAD software to establish a 3D model of the high inclusion dough forming machine. The model should include all components, fixtures, and positioning devices to ensure the accuracy and manufacturability of the design. Import the 3D model of the high inclusion dough forming machine into finite element analysis software for static and dynamic analysis. Perform 3D printing on the optimized 3D model of the high inclusion dough forming machine for experimental verification. Through experimental verification, the performance and reliability of the machine can be verified, and further optimization and improvement of the design can be achieved. The conceptual design and finite element analysis of a high inclusion dough forming machine using 3D CAD can help designers and engineers better understand and improve the design and performance of the machine, thereby improving production efficiency, reducing costs, and reducing errors. Taillie et al. [15] recorded and compared the purchase behavior of consumers, including the quantity and types of Sweetened beverage and super processed food. Compare the purchasing behavior of the control group and the experimental group, and evaluate the impact of nutritional warning labels on consumer purchasing behavior. After the nutrition warning label was added, the number of consumers in the experimental group who bought Sweetened beverage and super processed food decreased significantly. The experimental group of consumers are more inclined to choose healthier foods and beverages such as low sugar and low salt. Nutrition warning labels have a significant impact on consumers' purchasing behavior and help guide them to make healthier purchasing choices. Adding nutrition warning labels before the packaging of Sweetened beverage and super processed foods can effectively guide consumers to make healthier purchase choices and reduce consumers' intake of unhealthy foods such as high sugar and high salt.

Tripathi and Maktedar [16] identify different varieties by analyzing the appearance characteristics of fruits and vegetables. This technology can help farmers understand the characteristics of different varieties and provide more accurate information for planting and maintenance. Computer vision technology can monitor the growth and health status of plants by analyzing their images. This technology can help farmers discover and solve plant diseases and pests in a timely manner, improving crop yield and quality. Computer vision technology can be used for automated harvesting. By identifying maturity, position, and posture information, the robot is guided to perform precise harvesting, improving harvesting efficiency and accuracy. Computer vision technology can be used for agricultural data analysis to obtain information about crop growth, yield, quality, and other factors through image recognition and analysis, helping farmers make decisions and plans. Van and Lissner [17] analyzed the function of Nutrition facts label in Europe, which are usually used to help consumers make the healthiest choices. These labels typically include nutritional information about the product, such as calories, fat, protein, carbohydrates, fiber, etc. In different European countries, the format and content of Nutrition facts label may be different, but their purpose is to help consumers understand the nutritional value of products. In terms of vision, Nutrition facts label in Europe are usually color coded. This color-coding method allows consumers to quickly identify the nutritional level of the product. For example, some labels use green, yellow, and red to indicate the nutritional level of the product. Green represents health, yellow represents moderate, and red represents unhealthy. In addition, some European countries will use icons or symbols on Nutrition facts label to express the nutritional value of products. These icons or symbols can attract consumers' attention. In general, there are some similarities and differences in the function and vision of Nutrition facts label before packaging in Europe. Their purpose is to help consumers understand the nutritional value of products and make healthier choices. Using Computer-aided design software to design and optimize the passenger cabin can greatly shorten the design time and improve the design efficiency. Yuan and Niu, [18] through parameterized modeling technology, can quickly and accurately establish a three-dimensional model of the passenger cabin, improving the accuracy and efficiency of design. Using artificial intelligence technology for intelligent design can improve the flexibility and diversity of design, and meet different customer needs. By utilizing virtual reality technology, a virtual reality experience of the cabin of an aircraft can be achieved on a computer, improving the realism of the design and customer satisfaction. Considering the environmental friendliness of the cabin design, environmentally friendly materials and processes are used to reduce waste generation and improve the environmental performance of the cabin. By optimizing the above aspects, the design quality and efficiency of passenger aircraft cabins can be greatly improved, customer satisfaction can be improved, and the development of green design in China can also be promoted. Zhao et al. [19] used electrospun fibers to manufacture sensors that can monitor food temperature and humidity, as well as sensors that can detect food spoilage gases. Electrospinning functional materials can be used to manufacture antibacterial agents and prevent bacterial contamination in food packaging. For example, electrospun fibers can be used to produce nanoscale fibers that can kill bacteria, as well as systems that can persistently release antibacterial agents. Electrospinning functional materials can be used to manufacture smart labels for tracking and identifying food packaging. For example, electrospun fibers can be used to create smart labels that can display food information and quality, as well as labels that can identify food sources and batch numbers. In summary, electrospun functional materials have a wide range of applications in intelligent food packaging, providing more intelligent, efficient, safe, and environmentally friendly solutions for food packaging.

# 3 INTEGRATION AND DESIGN OPTIMIZATION OF EMOTIONAL EXPERIENCE IN INTERACTIVE PACKAGING DESIGN

## 3.1 Interactive Packaging Image Feature Extraction and User Emotion Recognition

The packaging structure of traditional products is mainly based on simplicity and convenience, but with the continuous improvement of people's living standards and the change of consumption concepts. At present, in the stage of consumption, consumers' requirements for packaging structure have been improved, and the packaging structure of products is required to be able to change its shape and participate in it effectively. When human beings observe images through their eyes, the visual content will cause emotions. The different psychological induction and emotional ups and downs caused by this, the quantification of visual features and the technology of feature extraction will play an important role in studying the emotional semantics of images. The biggest advantage of interactive packaging design lies in its ease of use. The application of this design style can effectively assist consumers to quickly understand and understand products, and fully convey the design concepts and emotions of designers and manufacturers, thus effectively increasing the vitality of products and narrowing the distance between products and consumers. In the stage of product packaging CAD, if we can properly apply the method of auxiliary structure interaction, design a certain auxiliary activity structure outside the main structure of packaging and establish a three-dimensional structural system, we can innovate the original packaging structure.

With the popularization of deep learning, the attention mechanism is combined with convolutional neural network (CNN), and the main feature areas are determined by quickly scanning the data set, and the attention is concentrated on the areas of interest or the feature positions of important information, ignoring the uninterested areas and irrelevant information, so that the main feature information of the data set can be obtained more quickly and accurately, and the working efficiency of the network model can be improved. As a high-level emotional semantics, it is necessary not only to make the computer understand and recognize the image content, but also to realize effective organization, classification and image management. Establishing the relationship between low-level and high-level semantic features of human perceptual emotion mechanism has become the key to realize image emotion classification and recognition. The user emotion feature recognition model is shown in Figure 1.

Interaction between packaging and human behavior. Users interact with packaging through behavior process, and the way and method of opening packaging, the stage of using packaging and the behavior experience after using it all have great influence on the interaction between packaging and people. The subjectivity and complexity of emotional semantic information lead to fewer image data sets with emotional semantic tags, and the essence of using deep learning method to train models is to learn deep image features in massive data sets, and then obtain emotional semantic information of images. The co-occurrence matrix is determined by combining the joint probability densities of two pixels in different positions in the image. In the co-occurrence matrix, the distribution layout of the bright areas of the image can be shown, and the distribution characteristics of the same or similar brightness can also be reflected. Different features have different effects on emotions, so it is needed to comprehensively consider various features when analyzing the emotions of images. According to the effects of features on human psychology and emotions, we should quantitatively describe and extract relevant features in an appropriate way to describe the emotions expressed in images as comprehensively as possible.

Let the gray value range of the original interactive packaging image $f(x,y)$ be $(g_{\min}, g_{\max})$, choose a suitable threshold $T$, and:

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

Image segmentation with a single threshold can be expressed as:

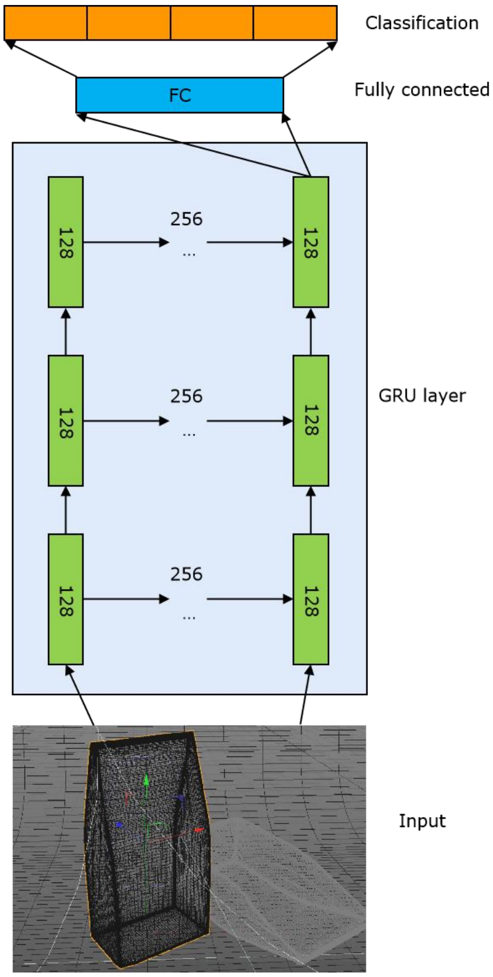


**Figure 1:** User emotional feature recognition model.

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

$g(x,y)$ is a binarized image.

When describing the color information of an image, it is needed to choose a suitable color space besides a suitable feature description method. The most accurate description of the color information of an image is to make statistics on the RGB color space of the image, but the calculation amount of this method is too large. In order to better reflect human visual perception, it is generally needed to select and transform the color space.

Set up an emotional state space set $E=\{e_i|i=1,2,3,\ldots,m\}$ (m represents the number of emotional states). Use the random variable λ to represent the current emotional state, and T to represent the time set. Let $t_i$ be the time point when $\lambda=e_i$, and satisfy $t_i>0$. In this way, the emotional time state space can be expressed as:

$$\begin{pmatrix} E \\ T \end{pmatrix} = \begin{pmatrix} e_1 e_2 & \dots & e_m \\ t_1 t_2 & \dots & t_m \end{pmatrix} \tag{3}$$

Define the mapping matrix of mood and emotion as:

$$L = \left[ e_{pos}, e_{neg} \right] = \begin{bmatrix} 0.40 & -0.40 \\ 0.20 & -0.20 \\ 0.15 & -0.50 \end{bmatrix} \tag{4}$$

Define the mapping relationship between affective variables and mood variables as:

$$E = f\left(M, L\right) = \frac{D}{d_{pos} + d_{neg}} \tag{5}$$

$$D = \left[ d_{pos}, d_{neg} \right], d_i = \left[ \left(M - e_i\right)^T \left(M - e_i\right) \right]^{\frac{1}{2}} \tag{6}$$

Among them, i=1,2, corresponding to positive emotions and negative emotions respectively.

Determining the interactive packaging design based on user experience is an iterative design process, that is, taking the user as the main body of the design, after in-depth study of the user, starting from the user's needs, through repeated user tests and feedback to ensure the realization of the scheme. Finally, through the research and analysis of new technologies, the opportunities and guidance brought by application technologies to interactive packaging design are discussed, and then the processes and methods of interactive packaging design are summarized.

### 3.2 Integration and Optimization of Emotional Experience in Interactive Packaging Design

Senses are the link between people's memories and the bond between emotions. Visual psychology research found that not all areas in an image will attract people's attention and make people have perceptual knowledge. People are usually only interested in part of the information in the image, which is often rich in information and can stimulate the emotional feelings of observers. This part of the region is called the region of interest and is also a significant region in the image. The emotional classification of users based on CNN is shown in Figure 2.

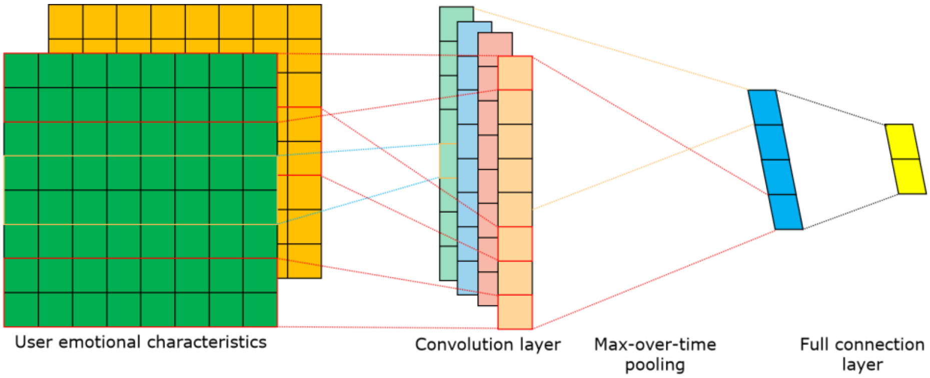


**Figure 2:** CNN is used for emotion classification of users.

This study will make full use of the underlying visual features of packaging images and combine them with the extracted deep semantic features, in which the underlying features are color features and texture features, and the deep emotional semantic features of the images are extracted by CNN with attention mechanism, and the extracted features are fused into the classification network model with simple structure, so as to identify the emotional semantics of packaging images. The emotional renewal equation is established as follows:

$$E_t = E_{t-1} + f\left(M_t, L\right) + \psi\left(A_t, P_t\right) + \phi\left(P_t, E_{t-1}\right) \tag{7}$$

The influence component of affective variables on affective state is defined as $\psi\left(A_t, P_t\right) = \omega_E A_t$, where $\omega_E$ is an affective inducing factor, which is related to personality. $\phi\left(P_t, E_{t-1}\right)$ is the attenuation component of emotion. Modeled on the mood attenuation component is defined as follows:

$$\phi\left(P_t, E_{t-1}\right) = \frac{\beta\left(E_{t-1} - E_0\right)}{1+\beta} \tag{8}$$

Among them, $E_0$ is the emotional calm state, and β is the emotional attenuation factor, which is related to personality.

The proposal of the emotional meta-concept simplifies the stage of judging the emotional orientation of phrases, sentences and texts, and makes the whole reasoning simpler, clearer and clearer. Its definition is as follows:

$$C_e = \left(E_m, N, Q, L_a\right) \tag{9}$$

Among them, $C_e$ is a set of finite emotion elements. $E_m$ is a set of emotional words. $N$ is a set of negative words. $L_a$ is the position where adverbs of degree appear. The essence of batch normalization layer is to normalize the layer input:

$$\hat{x} = \frac{x-\mu}{\sigma} \tag{10}$$

$$y = \gamma\hat{x} + \beta \tag{11}$$

Where $x$ is the input of the batch normalization layer and $y$ is the output of the normalization layer. $\mu$ is the mean value of $x$ in the current training batch, $\sigma$ is the standard deviation of $x$ in the current training batch, $\gamma$ is used for scaling normalized $\hat{x}$, and $\beta$ is used for translation. The size of $\mu$ and $\sigma$ depends on the training data.

## 4 EXPERIMENTAL RESULTS AND ANALYSIS

The opening of packaging is the first link for products to reach consumers. The unique opening method can increase consumers' expectations and associations for products, which is a stage of shape change and emotional experience. In the stage of opening the package, it exerts a subtle influence on consumers' intuitive feelings about the product. In the existing technology, contour extraction is the most commonly used and plays an important role in image processing technology. It is also the cornerstone of shape feature extraction. The contour in the image is completely presented before the shape feature extraction, which greatly promotes the subsequent research. The specific training loss of the algorithm is shown in Figure 3.

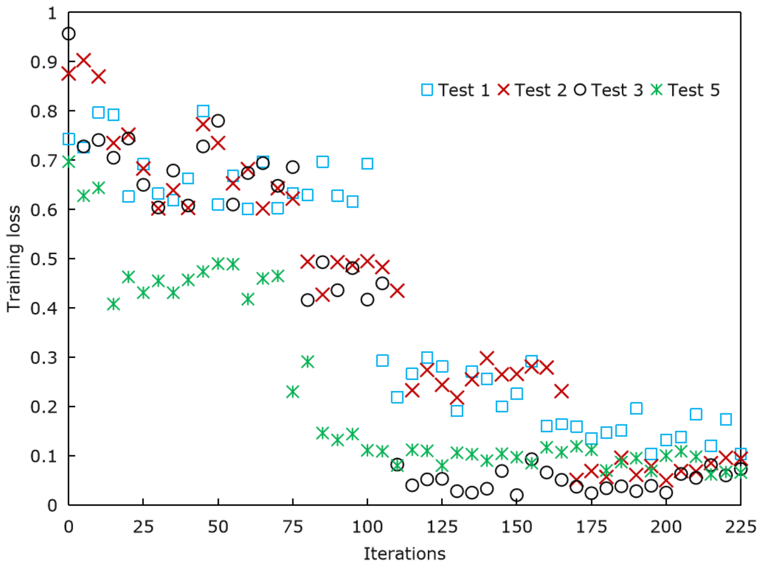


**Figure 3:** Training loss of algorithm.

After about 23 iterations, the algorithm basically reaches convergence. Feature extraction refers to extracting image features in the target domain by using all parameters before the fully connected layer in the pre-training model, and adding new fully connected layer or other classifiers to adapt to the target task. The fine-tuning method can make up for the phenomenon of over-fitting caused by insufficient training of small data sets. By fixing some convolution layer parameters, the universal features of the image are extracted, and other layer parameters are fine-tuned for training the target data set, so as to avoid the defect of long training time caused by retraining the model.

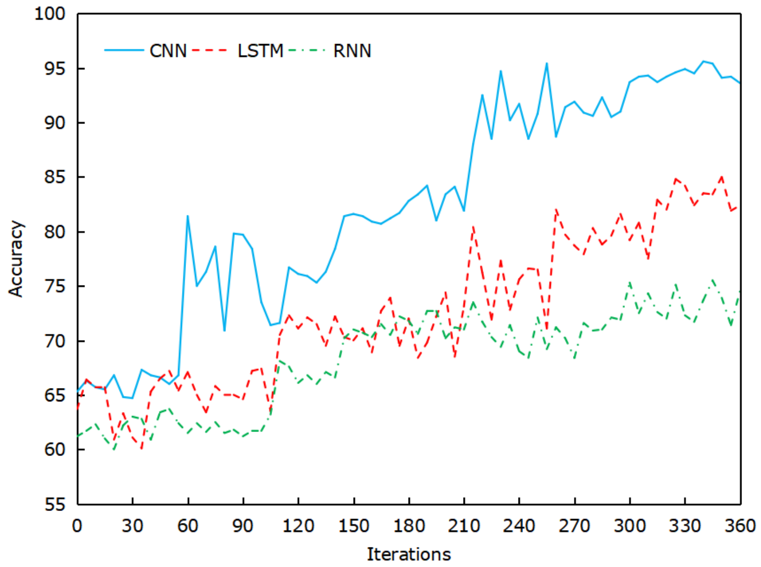


**Figure 4:** Comparison of recognition accuracy of deep learning algorithm.

Repeated optimization strategy is adopted to keep the weight parameters of CNN classification model in a favorable position for emotion classification, so as to continuously improve the emotion classification accuracy of the model. Figure 4 shows the accuracy comparison of the two algorithms in user emotion recognition. Through the analysis of Figure 4, it is found that the correctness of the studied algorithm is more advantageous, which can reach about 95%, and the recognition accuracy is obviously improved compared with the traditional method. By analyzing Figure 5, it can be seen that the traditional method MAE is larger, which is obviously higher than the user emotion recognition method adopted in this study.

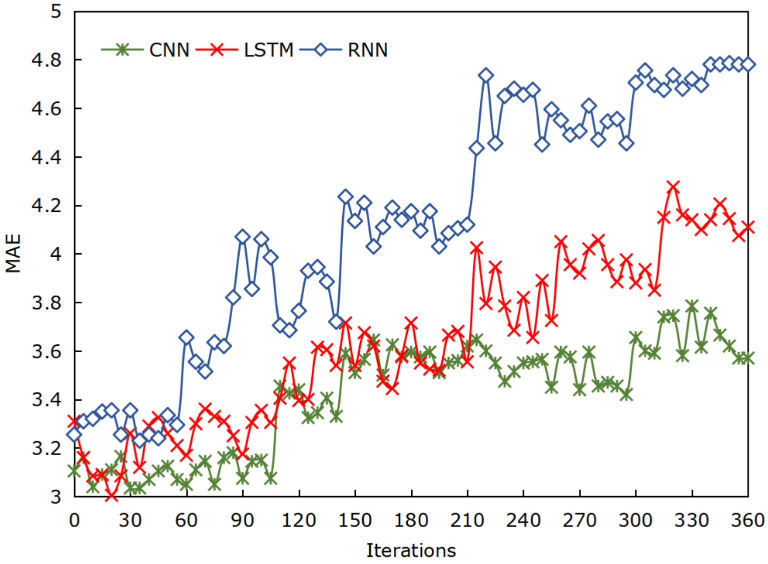


**Figure 5:** MAE comparison.

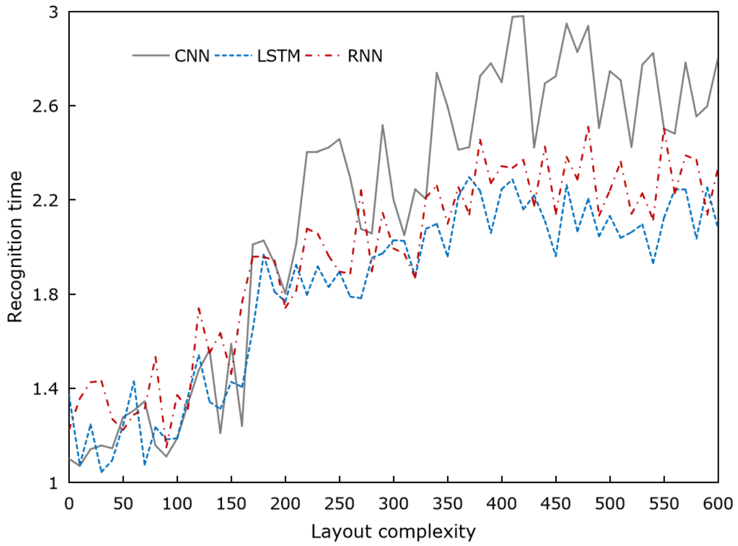


**Figure 6:** Time comparison of emotional feature recognition.

When using transfer learning method to classify and identify image emotions, all or part of the parameters of the pre-trained model can be transferred according to the actual situation, and the model can be fine-tuned by using experimental data sets to improve the accuracy of model classification and prevent over-fitting. The identification time of emotional features of different methods is shown in Figure 6.

In the stage of using packaging, on the basis of ensuring easy use, increasing the participation of consumers, such as innovative opening methods, scene reproduction of three-dimensional pages, introducing new media technologies and other means can effectively improve the communication between packaging and users, and increase their sense of participation through interactive experience. Figure 7 shows the subjective rating given by the observer to the interactive packaging design.

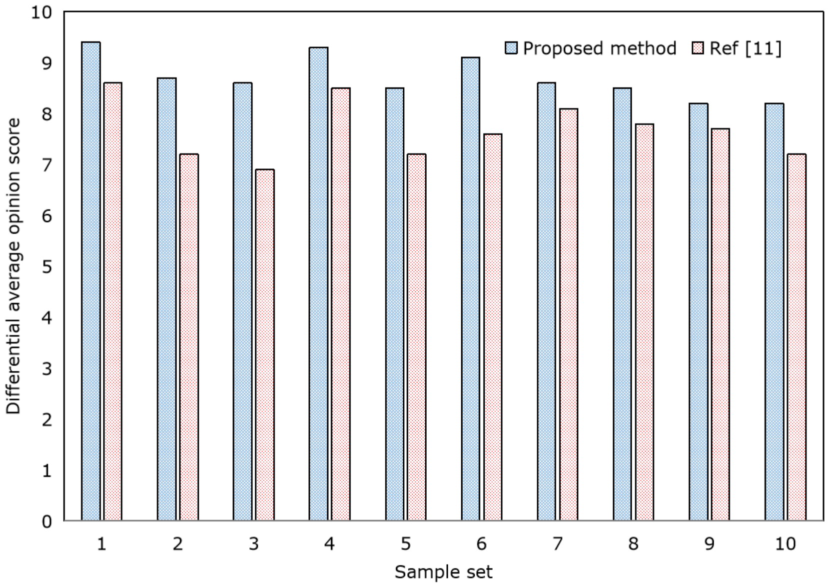


**Figure 7:** Observer's subjective evaluation of interactive packaging design.

The music visualization method in this article has a higher score, so it can be considered that the interactive packaging design method combining AI and CAD has achieved a better user experience. Because the concept of interactive design has been widely recognized and used by designers, interactive packaging design has also joined the tide of development and gradually emerged. The concept of interactive design has been widely used in human-machine interface design, web design, software design and other fields, which has promoted the integration of interactive design into other design fields.

## 5 CONCLUSIONS

Through the analysis and research of AI technology and its application, the CAD method in the AI era is imperceptibly applied in various fields. Intelligent information generation and personalization will be the main features of the next generation product interactive design system. The emotional resonance between man and machine will become the main core of man-machine symbiosis in the future, and it will also be the future of the growth of man-machine interaction design. It is of great practical significance to integrate consumers' emotional experiences at all levels in interactive packaging design. In the stage of integrating theory with practice, we should objectively analyze the problems of product packaging in the current market, explore brand-new ideas, methods and measures, design interactive product packaging with high quality under the guidance of emotional experience integration, and realize the design goal of interactive packaging while enhancing the added value and attractiveness of products. For images, it can not only affect human beings emotionally, but also express human feelings. For individuals, image emotion is subjective. For the emotional cognition of images, human beings have cognitive commonness, so it is also the basis of emotional recognition of images.

How to reduce model training parameters on the basis of improving CNN model and optimizing emotion recognition effect is still a problem to be considered in future experimental research. In the future experimental research, we can try to find other low-level features and deep-level features that can describe the emotional details of the image, and give corresponding weights to different features to achieve the optimal state of model training.

## 6 ACKNOWLEDGEMENT

This work was supported by Jilin Province's Science and Technology Development Plan, Study on the Industrialization Strategy of Cultural and Creative Products Based on Jilin Province's Regional Characteristics.

*Yipeng Wang*, https://orcid.org/0009-0004-7684-1882
*Shilin Zhang*, https://orcid.org/0009-0000-5070-5760

## REFERENCES

[1] Drago, E.; Campardelli, R.; Pettinato, M.; Perego, P.: Innovations in smart packaging concepts for food: An extensive review, Foods, 9(11), 2020, 1628. https://doi.org/10.3390/foods9111628

[2] Frutiger, J.; Cignitti, S.; Abildskov, J.; Woodley, J.; Sin, G.: Computer-aided molecular product-process design under property uncertainties - A Monte Carlo based optimization strategy, Computers & Chemical Engineering, 122(SI), 2019, 247-257. https://doi.org/10.1016/j.compchemeng.2018.08.021

[3] Gavrilov, D.-A.; Lovtsov, D.-A.: Automated visual information processing using artificial intelligence, Scientific and Technical Information Processing, 48(6), 2021, 436-445. https://doi.org/10.3103/S0147688221060034

[4] Jafarzadeh, S.; Jafari, S.-M.: Impact of metal nanoparticles on the mechanical, barrier, optical and thermal properties of biodegradable food packaging materials, Critical Reviews in Food Science and Nutrition, 61(16), 2021, 2640-2658. https://doi.org/10.1080/10408398.2020.1783200

[5] Krahe, C.; Iberl, M.; Jacob, A.; Lanza, G.: AI-based computer aided engineering for automated product design - a first approach with a multi-view-based classification, Procedia CIRP, 86(10), 2019, 104-109. https://doi.org/10.1016/j.procir.2020.01.038

[6] Kraśniewska, K.; Galus, S.; Gniewosz, M.: Biopolymers-based materials containing silver nanoparticles as active packaging for food applications–a review, International Journal of Molecular Sciences, 21(3), 2020, 698. https://doi.org/10.3390/ijms21030698

[7] Leng, J.; Yan, D.; Liu, Q.; Zhang, H.; Zhao, G.; Wei, L.; Chen, X.: Digital twin-driven joint optimisation of packing and storage assignment in large-scale automated high-rise warehouse product-service system, International Journal of Computer Integrated Manufacturing, 34(7-8), 2021, 783-800. https://doi.org/10.1080/0951192X.2019.1667032

[8] Li, X.; Shi, M.; Wang, X.-S.: Video mining: Measuring visual information using automatic methods, International Journal of Research in Marketing, 36(2), 2019, 216-231. https://doi.org/10.1016/j.ijresmar.2019.02.004

[9] Li, Y.: Analysis of visual communication packaging design based on interactive experience, Journal of Physics Conference Series, 1852(2), 2021, 022074. https://doi.org/10.1088/1742-6596/1852/2/022074

[10] Liu, F.: Fast industrial product design method and its application based on 3D CAD system, Computer-Aided Design and Applications, 18(S3), 2020, 118-128. https://doi.org/10.14733/cadaps.2021.S3.118-128
[11] Mustafa, F.; Andreescu, S.: Nanotechnology-based approaches for food sensing and packaging applications, RSC Advances, 10(33), 2020, 19309-19336. https://doi.org/10.1039/D0RA01084G
[12] Pauer, E.; Wohner, B.; Heinrich, V.; Tacker, M.: Assessing the environmental sustainability of food packaging: An extended life cycle assessment including packaging-related food losses and waste and circularity assessment, Sustainability, 11(3), 2019, 925. https://doi.org/10.3390/su11030925
[13] Pelliccia, L.; Bojko, M.; Prielipp, R.; Riedel, R.: Applicability of 3D-factory simulation software for computer-aided participatory design for industrial workplaces and processes, Procedia CIRP, 99(11), 2021, 122-126. https://doi.org/10.1016/j.procir.2021.03.019
[14] Salahuddin, M.-B.-M.; Atikah, A.-F.; Rosnah, S.; Zuhair, M.-N.-M.: Conceptual design and finite element analysis of a high inclusion dough shaping machine using 3D - computer aided design (cad) (solidworks), Materialwissenschaft und Werkstofftechnik, 50(3), 2019, 267-273. https://doi.org/10.1002/mawe.201800205
[15] Taillie, L.-S.; Hall, M.-G.; Popkin, B.-M.; Ng, S.-W.; Murukutla, N.: Experimental studies of front-of-package nutrient warning labels on sugar-sweetened beverages and ultra-processed foods: a scoping review, Nutrients, 12(2), 2020, 569. https://doi.org/10.3390/nu12020569
[16] Tripathi, M.-K.; Maktedar, D.-D.: A role of computer vision in fruits and vegetables among various horticulture products of agriculture fields: A survey, Information Processing in Agriculture, 7(2), 2020, 183-203. https://doi.org/10.1016/j.inpa.2019.07.003
[17] van, B.-D.-L.; Lissner, L.: Differences and similarities between front-of-pack nutrition labels in Europe: a comparison of functional and visual aspects, Nutrients, 11(3), 2019, 626. https://doi.org/10.3390/nu11030626
[18] Yuan, X.; Niu, X.: Optimization of computer aided industrial design system for passenger aircraft cabin, Computer-Aided Design and Applications, 19(1), 2021, 54-64. https://doi.org/10.14733/cadaps.2022.54-64
[19] Zhao, L.; Duan, G.; Zhang, G.; Yang, H.; He, S.; Jiang, S.: Electrospun functional materials toward food packaging applications: A review, Nanomaterials, 10(1), 2020, 150. https://doi.org/10.3390/nano10010150