Application of Case-Based Reasoning in Product Packaging Design System

Yanyan Zhang[1,*] and Shengnan Li[2]

[1]Center for Public Art Education, Xinyang Vocational and Technical College, Xinyang, Henan 464000, China, Zhangyanyan@xyvtc.edu.cn
[2]Center for Public Art Education, Xinyang Vocational and Technical College, Xinyang, Henan 464000, China, lily19337680668@163.com

Corresponding Author: Yanyan Zhang, Zhangyanyan@xyvtc.edu.cn

Abstract. In order to meet the demand of commodity circulation for packaging, a product packaging design CAD system based on CAD technology was designed. The database layer provides packaging, parts, documents and other data to the application layer; In the application layer, 3D visual modeling technology is used to establish the geometric model of packaging materials through packaging material data, and on this basis, the texture information of packaging materials is extracted to complete the 3D visual modeling. In the process of CAD drawing, the transparency and gray value of packaging are adjusted through HO visualization algorithm to improve the flexibility and intuitiveness of product packaging design. The service layer transmits the image drawn by the application layer to the user layer, and provides the services of publishing information, user information registration and authentication; The user layer is responsible for providing information transmission, coordination, classification and retrieval, graphic interaction and other services, and all layers coordinate with each other to complete the product packaging design of visual communication effect. Through experimental analysis, the packaging designed by the system has good visual transmission effect and perspective effect, and CAD drawing time is short and energy consumption is low.

Keywords: Packaging Design, Computer-Aided Design (CAD), Case-Based Reasoning (CBR).
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1 INTRODUCTION

Packaging design is an important part of product design. With the rapid development of science and technology, various products are changing with each passing day, and products are becoming more and more complex [1]. People's requirements for product packaging design are becoming higher and higher. The packaging design of products has increasingly attracted people's attention

[2]. In addition to the traditional requirements that packaging can reliably protect products and facilitate the storage and transportation of products, the aesthetic requirements, ergonomics, environmental protection requirements and economic applicability of product packaging are becoming more and more important [3]. The level of knowledge and ability of product packaging designers is facing serious challenges. The traditional design method has long design cycle, high labor and material consumption, and low design quality, which cannot meet the ever-changing market requirements. The adoption of CDA technology can organically combine the rapidity and accuracy of computers with the logical thinking and comprehensive analysis ability of designers, reduce the workload of designers, improve the design quality, accelerate the design speed and shorten the design and development cycle of products. For the packaging design of military products, it can also save development costs, reduce packaging costs and improve packaging reliability. For different types of products, it is difficult to adopt a unified product description. In order to make the problem description simple and clear, first classify the products, and then determine the product description attributes and packaging requirements. For example, the liquid products can be described by attributes such as value, corrosivity, volatility, flammability and purity [4]. The packaging requirements can be described by attributes such as capacity, storage time and protection grade. The problem description module is used to dynamically select the input interface according to the information input by the user, and guide the user to describe the product and packaging requirements.

Nemat et al. [5] studied the relationship between food packaging attributes and consumer classification behavior. The review emphasized the potential of visual attributes and quality of packaging as a communication channel to encourage consumers to classify food packaging waste. Therefore, the correct design of food packaging will affect the efficiency of waste management system and the quality of recycled products. Rezaei et al. [6] proposed a multi standard decision-making method for selecting sustainable product packaging design, taking into account different participants in the food supply chain. This study extends the focus of sustainable packaging design to the collective of all supply chain participants. The decision-making criteria were determined through literature review, and the current product package alternatives were collected through interviews. Shevel et al. [7] proposed a classification method of engineering object life cycle support automation system, proposed a description structure of design object, and used three description methods: function, mathematics and physics. According to this method, an algorithm for drawing the function description of the life cycle is described, which is based on the unified principle of analysis and synthesis of the system created in the design process. The proposed solution uses the traditional aircraft forming method and takes the application of aircraft replenishment algorithm as an example. To facilitate the use of this architecture, it is recommended to use the design task classification in the form of design cube. The proposed method allows the accurate description of the design object and the subtasks required to create it, which can reduce the time of the project. In recent years, the development of emerging technologies such as active packaging and intelligent packaging has been greatly accelerated, with the focus on letting consumers understand the quality of food. Yousefi et al. [8] will focus on the in-depth summary of the latest technological progress, which may be included in food packaging to ensure food quality, safety or corruption monitoring. These advanced sensing systems are usually aimed at monitoring the gas generation, humidity, temperature and microbial growth in packaged foods. This review also discusses the implementation of portable and easy-to-use handheld devices. We highlight the mechanical and optical properties of current materials and systems, as well as the various limitations associated with each device. The technology discussed here has great application potential in food packaging, and makes us closer to realizing real-time monitoring of food in the whole supply chain. Yun and Leng [9] combine virtual reality technology with CAD software to optimize packaging design, and apply virtual reality to packaging design, which can realize full digitalization of products. It can be predicted that in the future industry, virtual reality technology and its application will be more extensive, and virtual reality will play a more humanized advantage. Product design depends on various design knowledge, including explicit design knowledge and implicit design knowledge. In view of the lack of scalability and flexibility of current design knowledge representation methods, a design knowledge representation framework combining CBR and knowledge graph is proposed. Based on this framework, the design case is represented as a set of knowledge maps. Zhang et al. [10] proposed an ontology model for design case representation. A new method of retrieving design cases from knowledge maps is proposed. This method uses design problem query maps instead of keywords to match similar case examples in knowledge maps.

Economic development has accelerated the transportation and circulation of commodities, and the technology of packaging industry has been developed. In modern packaging technology, computer aided design (CAD) auxiliary technology has always been a graphic design tool with high technology and high capability, and has been widely used in various fields of packaging industry in developed countries at home and abroad. In this system, the user layer is mainly responsible for interactive operation, and the communication service module is responsible for transferring information between the server and the client; The collaborative agent module is mainly responsible for group awareness and cooperation with other functional modules; The packaging retrieval module is connected with the data management module in the application layer in the background to realize the classification retrieval of packaging materials and parts and preview the retrieval results; The CAD graphics module creates a human-computer interactive operating environment, connects the file I/O module and the data management module in the background, converts the I/O of standard files to each other, and stores the package shape in the database.

Case-based reasoning is a new hotspot in the field of artificial intelligence in recent years. It takes analogical reasoning as the theoretical basis and uses the experience of solving similar problems in the past to solve current problems. It avoids the rule extraction process that must be carried out in the development of rule-based expert systems, and makes the solution of problems simple and clear. It has been widely used in many fields and has successfully developed some practical expert systems. The military packaging container design system of the United States searches the existing military packaging containers and designs the packaging of new products according to the special requirements of users. In product packaging design, due to the universal similarity between products, the purpose and requirements of product packaging are often similar. Designers can learn a lot from the experience of similar products and adopt standardized packaging products. With the development of product packaging CAD system, designers can easily use the existing packaging design results to generate new product packaging design schemes through simple modification and adjustment. It can not only reduce the difficulty of design, but also enable packaging designers to share the previous work results, reduce repetitive work and improve work efficiency, which has important practical value.

2 STATE OF THE ART

2.1 Structure of Case-Based Product Packaging Design CAD System

Case-based product packaging design CAD system is composed of five main functional modules: problem description module, retrieval module, case database, case modification module and index module. The system structure is shown in Figure 1.

The case library stores the product packaging design case, which is equivalent to the experience of experts and is the core of the system. Each case includes product description, packaging requirements description, packaging design scheme and corresponding drawings and technical documents. The topic description module is used to assist users to describe the products to be packaged and the packaging requirements. The description method is determined according to the characteristics of different products. The retrieval module is used to find cases similar to the current question description in the case database according to the question description. The case modification module is used to modify the retrieved case according to the difference between the current problem description and the retrieved case description to make it suitable for the current problem. The index module is used to organize the newly generated cases into the case library to realize the system learning. The input of the system is the problem description, and the output of the system is the product packaging design scheme. Figure 2 shows the business income statistics of China's packaging industry segment in 2020.

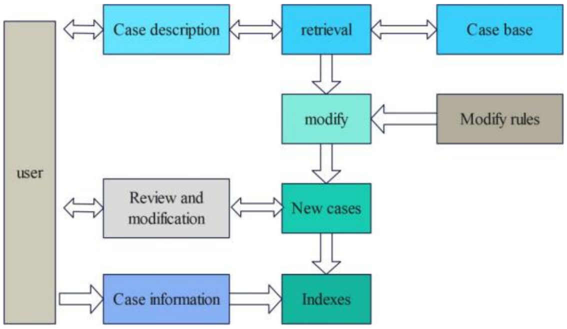

Figure 1: CBR system structure of product packaging design.

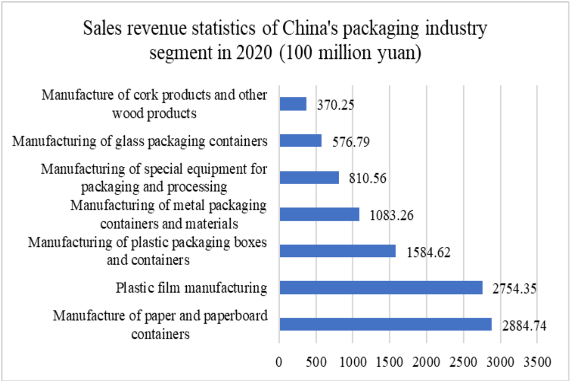

Figure 2: Statistics of operating revenue of China's packaging industry segment in 2020.

2.2 Representation and Organization of Product Packaging Design Cases

In the case, each packaging design scheme is regarded as a case. Each case includes the problem description part of the identification and query case and the conclusion part of the corresponding problem. When selecting the packaging design scheme of the product, we should mainly consider the characteristics of the product and determine the packaging requirements according to the circulation and use of the product. Therefore, the problem description part of the case consists of product description and packaging requirements description, and the conclusion part of the case is that the selected packaging design scheme includes drawings and technical documents.

For different types of products, it is difficult to adopt a unified product description. In order to make the problem description simple and clear, first classify the products, and then determine the product description attributes and packaging requirements. For example, the liquid products can be described by attributes such as value, corrosivity, volatility, flammability and purity. The packaging requirements can be described by attributes such as capacity, storage time and protection grade. The problem description module is used to dynamically select the input interface according to the information input by the user, and guide the user to describe the product and packaging requirements. Figure 3 shows the statistics of major products in China's packaging industry from 2017 to 2020.

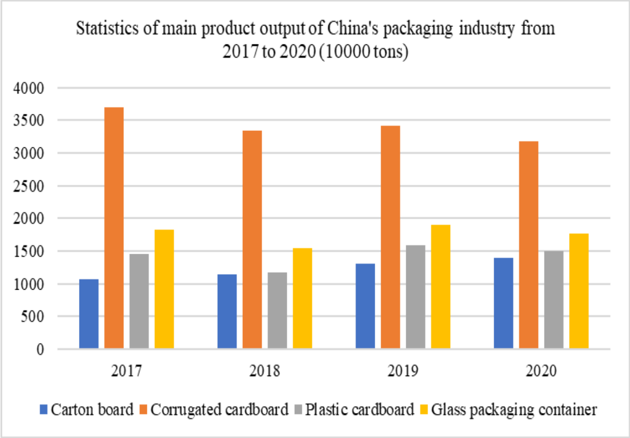

Figure 3: Statistics of main products in China's packaging industry from 2017 to 2020 (10000 tons).

In the case base, a frame structure is used to represent the case, and an independent design scheme is a frame. For standardized packaging products, the name of the packaging product can be used as the name of the framework. For non-standard product packaging cases, the name of the packaged product can be used as the name of the case. The product feature description applicable to standardized packaging or the feature description, packaging requirements, schematic design data, data, etc. of non-standard packaged products are different attributes of the framework. Some attributes may need to be described from multiple aspects.

The cases in the case library are divided into standard packaging design cases and non-standard packaging design cases. Standard packaging design cases are stored according to the type of packaging products, and non-standard packaging design cases are stored according to the type of packaged products.

2.3 Computer Aided Design

The purpose of computer-aided conceptual design is not only to effectively deal with unclear and incomplete design factors, but also to free designers from complicated work, put their main energy into innovative thinking, effectively support the innovative design of products, and more importantly, through the support of computers, it can inspire and stimulate the breadth and depth of innovative thinking of designers, and improve the overall level of innovative design of designers. Therefore, computer-aided conceptual design should be able to meet the special needs of conceptual designers. Through the definition, decomposition, synthesis and screening and determination of product functions, the quality of conceptual design can be effectively improved, design objects can be generated more easily, and a better platform for information exchange and object evaluation can be provided to avoid waste caused by design failure.

In addition, computer-aided conceptual design is actually a human-computer collaborative conceptual design. Through the establishment of a computer support environment based on database and artificial intelligence, it can achieve the close combination of designers' creative thinking and computer automation, achieve real-time or historical collaboration, and give full play to the advantages of designers and computers.

The key of computer-aided conceptual design is to establish a computer model for product conceptual design to express various forms of data, knowledge and information involved in the product as well as corresponding access and operation algorithms, so as to obtain the support of computer environment for conceptual design. Therefore, product model technology is the key technology of computer-aided conceptual design. Conceptual design model is generally divided into product description model, design process model and system model.

Computer-aided conceptual design is a human-computer interactive design process, and the product description model should be able to express both the computer and the designer. For the human brain, the model is mainly sensory, intelligent and visual, while for the computer, the model focuses on calculation and symbol processing, which makes the computer support of conceptual design more difficult, but it is also because this field is challenging that it has attracted the attention of many scholars. The product description model of computer-aided conceptual design can be divided into language, geometric model, graphics, object, knowledge model, multimedia (image 2 voice), etc. according to the degree of computer and designer orientation.

Conceptual design occurs at the early stage of the product life cycle. It is difficult to obtain complete and accurate information and knowledge about requirements, constraints and other aspects at this stage. Conceptual design is very complex. It requires not only knowledge from different aspects such as cost, performance and environment, but also different types of knowledge such as physics, mathematics and experience. Knowledge models are very useful in reasoning. Common knowledge models include frame-based, rule-based, case-based and meta-model. Case-based knowledge model generally includes index and content. The function of index is to easily retrieve cases in the process of reasoning, and the content provides detailed information about problem description, solution and case results. Recently, knowledge model is developing towards the concept of meta-model. Meta-model is a qualitative model used to describe the causal relationship between all concepts of the design object, which reflects the designer's thinking mode about the structure and behavior of the design object.

The closest approach to human thinking and reasoning is visual visualization thinking model, which plays an important role in all stages of design. The freehand drawing scheme is more conducive to speeding up the discussion, comparing different solutions, and observing the scheme from different angles, and finally obtaining a better designed spatial image. The development of speech recognition technology makes the human-computer interface more friendly. Human beings can directly inform the computer of their needs, specifications and requirements for products by voice. Through the speech recognition system, these information will be converted into the form of information that can be understood by the computer, thus making the communication between people and machines easier.

3 METHODOLOGY

3.1 WIE Real BP-AdaBoost Algorithm Design

BP (back propagation) neural network is a multilayer feedforward neural network trained according to the error back propagation algorithm. Its output is:

$$F = (x_1, x_2, ..., x_n) \tag{1}$$

Where the number of training samples is N, and the possibility of class m in the samples is expressed by xm, where m=1,2, N. This paper uses the function "logsig" to compare SVM model with BP neural network, so 0 ≤ xm ≤ 1.

Order:

$$X = \sum_{m=1}^{N} x_m \tag{2}$$

Then the probability output can be expressed as:

$$Y = (y_1, y_2, ..., y_N) \quad (3)$$

$$Y = \frac{x_m}{X} \quad (4)$$

Based on the above, this algorithm is called RealBP-AdaBoost algorithm. In this paper, information entropy is also added to optimize the weighting method of BP-AdaBoost-based classifier, and its formula is expressed as:

$$H(S) = E[-\log P_i] = -\sum_{i=1}^{n} P_i \log P_i \quad (5)$$

Where: n represents the total number of categories of information; Pi represents the probability that the signal is classified into class i.

When the difference in probability of classification is small, the information entropy is large, which shows information uncertainty. At this time, the classifier should be given a smaller weight. In the same way, when the probability of classification varies greatly, the classifier is given a larger weight value. In this paper, the weight coefficient of the ith base classifier of t base classifiers is calculated for the weight of different classifications η Fi can be expressed as:

$$\eta f_i = \frac{\exp(-H_i(x))}{\sum_{i=1}^{n} \exp(-H_i(x)} \quad (6)$$

In order to accurately reflect the classification ability of test samples, this paper defines a weighting coefficient based on the classifier standard. be η When the gi weighting coefficient is in the i-th base classifier, it can be expressed as:

$$\eta g_i = \frac{1 - r_i}{r} \quad (7)$$

Where: ri is the classification error rate of the ith classifier of the sample; η G represents the ability of the classifier; η F represents the classification effect of the same sample. This algorithm is hereinafter referred to as WIERealBP-AdaBoost algorithm. There are two weighting steps. First, the root formula (7) is used to calculate the overall weighting value of the base classifier η Gi, and then calculate the individual weighted value of the sample by the base divider.

$$H_{ij} = \sum_{i=1}^{m} p_{ij} \log p_{ij} \quad (8)$$

$$\eta f_i = \frac{\exp(-H_{ij})}{\sum_{i=1}^{n} \exp(H_{ij})} \quad (9)$$

Where: i=1,2, m; j=1,2,..., n. The weighted information entropy obtained by multiplying formula (7) with formula (8) and (9) can be expressed as:

$$\eta_{ij} = \eta g_i \times \eta f_{ij} \quad (10)$$

To sum up, the overall algorithm process has three steps:

Step1 initialization weight,

$$\eta_i^1 = 1/m, \quad \text{(i=1,2,3,…,m)} \quad (11)$$

number of cycles, t=1,2, L. Where L is the number of training rounds; Using weak learning algorithm, based on sample weight ηti trains the weak classifier lt (x): x → {- 1,1}, then calculates the error rate of lt (x), and obtains

$$\varepsilon_t = \sum_{i=1}^{m} n_i^t (l_i(x_i) \neq y_i) \tag{12}$$

Order:

$$\gamma_t = \varepsilon_t / (1 - \varepsilon_t) \tag{13}$$

$$\beta_t = \frac{1}{2}\log(1/\gamma_t) \tag{14}$$

Adjust the corresponding weight again:

$$\eta_i^{t+1} f_i = \frac{\eta_i^t}{z_t} \begin{cases} e^{\alpha l}, l_t(x) \neq y, \\ e^{-\alpha l}, l_t(x) = y, \end{cases} \tag{15}$$

Where zt is the weight value η Normalization factor of ti;

After the end of Step3 cycle, the final strong classifier is:

$$H(x) = sign(f(x)) \tag{16}$$

So far, the improved AdaBoost algorithm has been built.

3.2 Case Retrieval

The case retrieval process is the process of finding the most similar case in the case database using the input case description information. The retrieval module selects the most important attribute for retrieval according to the description of the case, and selects the best according to the matching degree of the attribute. For the packaging design of products without special requirements, standardized packaging products are preferred. For most product packaging designs, the packaging types available are limited. For example, the inner packaging types of liquid mainly include glass bottles, plastic bottles, plastic bags, metal drums, etc. In order to narrow the search scope and improve the search speed and accuracy, the area of the inspection element can be determined according to the characteristics of the packaged product before retrieval. For example, the most commonly used standardized packaging product type is preferred. When the specified search area cannot get the ideal case, a large area can be expanded according to the specific situation. For example, retrieve non-standard product packaging cases or unusual standard packaging types.

3.3 Case Modification and Index

It is rare that a similar case, whether standard packaging design or non-standard packaging design, is fully applicable to the current needs through case retrieval, and generally needs to be modified. For standard packaging design, at least the packaging mark and relevant technical documents should be modified. For non-standard packaging design, the packaging structure, packaging size, packaging materials, etc. may also be modified. When the similarity of cases is low, it may be necessary to combine the results of different cases. For example, the inner packaging, intermediate packaging, outer packaging and lining structural materials of different cases are combined to form a new design scheme.

The case modification is divided into two parts. One part is that the system automatically modifies the retrieved case according to the case description entered by the user. This process is supported by the modification rules. The other part is the modification and review directly carried out by users. Because product packaging design is a creative activity carried out by users, users' continuous innovation can enable the system to improve the ability to solve problems through learning new cases and improve the level of packaging design. At the same time, case-based reasoning is a kind of uncertainty reasoning. Whether similar cases are suitable for the current problem ultimately needs to be judged by users to ensure the reliability of product packaging design. Therefore, the user's modification and review of the case is an important part of the system operation.

A new case is generated by the system's automatic modification and user modification of the case. After the user's review, the index module codes the case and stores it in the case database to realize the system's learning. In order to ensure the reliability of the system, there should be certain control over the use authority of the system index function to prevent incorrect cases from entering the case database and ensure the credibility of the system work. At the same time, it is also required to input the relevant information of the case designer so that the user can make an appropriate estimate of the credibility of the case.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Experimental Data and Environment

After the smart phone and robot are connected remotely through the LAN, the client carries out the identification and classification task of packaging bottles through the user function interface. In this paper, the robot recognition system uses HSV color space model to make color recognition have good anti-interference. In the experiment of bottle color recognition, after dividing the range of H component, it was verified that the HSV model can distinguish the color of the target well and meet the design requirements.

4.2 Experimental Results and Analysis

Sprite bottles, green tea bottles and surge bottles are used as the targets of shape recognition. In the shape recognition experiment, the classifier collects the characteristic values to calculate the relationship between the recognition accuracy of the feature algorithm and the number of training rounds. The algorithm uses the obtained feature vectors to complete the recognition of the shape of the packaging bottles. The current industrial recognition should be guaranteed to have a good use experience within 1s. For example, Skyline ME7FACE ME face recognition can be put into commercial use within about 500ms. The recognition time of each task in this experiment is only about 5ms, which can be fully applied to industrial production.

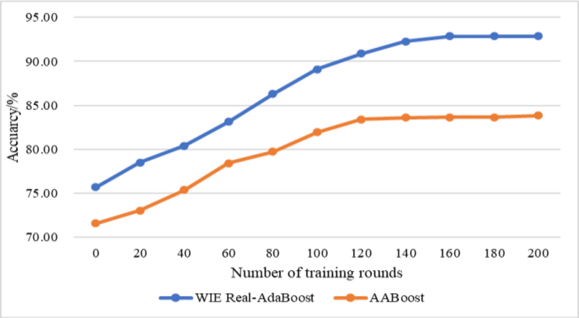

Figure 4: Comparison of the relationship between algorithm recognition accuracy and the number of training rounds.

In terms of recognition accuracy, Figure 4 shows the relationship between the recognition accuracy of AdaBoost and WIE Real BP-AdaBoost algorithms and the number of training rounds. As can be seen from Figure 5, with the increase of the number of training rounds, the accuracy of the two algorithms has been improved, but the improvement of the algorithm in this paper is more obvious under the same number of training rounds. The accuracy difference between the two algorithms is about 4% at the beginning, and reaches the peak after 120 rounds of training. At this time, the accuracy difference between the two algorithms reaches 8%, and then the recognition accuracy of the two algorithms tends to be stable. Finally, the accuracy rate of WIE Real BP-AdaBoost is about 92.86%, which is about 9% higher than that of traditional AdaBoost algorithm, and the practicability is improved. At the same time, there are many prediction points with color difference less than 1; The verification results show that the model has been fully trained, and the prediction accuracy and correlation are also higher. From the analysis of color difference values, it can be seen that the predicted color with color difference less than 1 is completely consistent with the user's expected color, the predicted color with color difference less than 2 is also quite consistent with the user's expected color, and some predicted colors with large color difference are also basically consistent with the expected color. The color difference distribution results in the training set are shown in Figure 5.

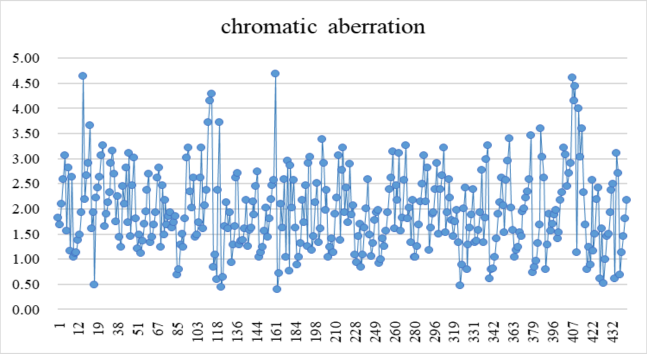

Figure 5: Color difference distribution in training set.

Figure 6 shows the color difference curve between the user's expected color and the model's output color in the model test set. It can be seen that in the test set, the color difference distribution is also relatively reasonable, and most of the predicted color differences are less than 3, that is, the predicted color is consistent with the user's expected color. From the test results, the model has good test performance in the predicted color example.

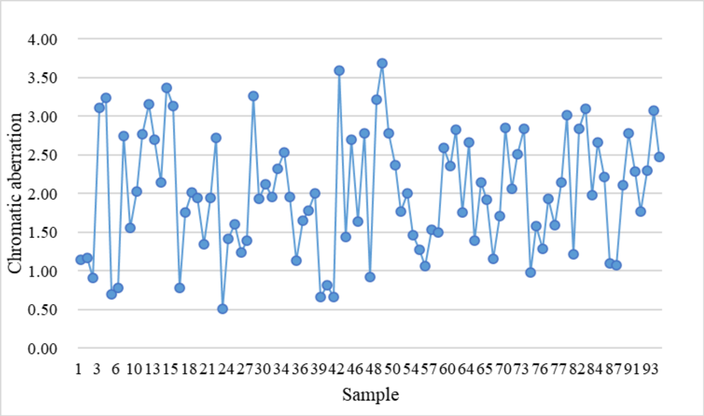

Figure 6: Color difference distribution in test set.

5 CONCLUSION

The development of case-based product packaging design CAD system can enable designers to share design results and avoid repetitive work. At the same time, the development and application of the system will also help to realize the standardization of product packaging and improve the quality of product packaging. The case base that can be established by using various standardized product packaging design cases and constantly enriched during the use of the system can gradually develop the system into a practical tool for product packaging designers. This paper focuses on the identification and classification of packaging bottles, fully proving the feasibility of the fusion of Haar-like feature and WIE Real BP-Adaboost algorithm. Remote control robot is a new direction of industrial development in the future. Using remote robot to identify, classify and recycle garbage is a new idea to solve environmental problems, and is also an important part of rejuvenating the country through science and technology. With the transformation and upgrading of scientific and technological innovation of domestic enterprises, it can also be used in the automatic delivery, identification and sorting of postal express to improve the intelligence of postal express logistics.

Yanyan Zhang, https://orcid.org/0000-0003-4900-7740
Shengnan Li, https://orcid.org/0000-0002-5043-0098

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