Retraction Notice

The Editor-in-Chief and the publisher have retracted this article, which was submitted as part of a guest-edited special section. An investigation uncovered evidence of systematic manipulation of the publication process, including compromised peer review. The Editor and publisher no longer have confidence in the results and conclusions of the article.

RK did not agree with the retraction. HL, CJ, and MS either did not respond directly or could not be reached.

Intelligent packaging design and research based on big data image processing

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Abstract. As people's living standards become higher and higher, people's requirements for commodities and packaging also become higher and higher. The traditional single packaging can no longer meet the consumer demand of the public. The traditional packaging not only wastes resources but also has single functions. Therefore, this paper proposes an intelligent packaging design. This paper aims to study how to research intelligent packaging design based on big data (BD) image processing. This paper proposes the relevant theoretical knowledge of BD image processing, intelligent packaging design, and the importance of both. The experimental results of this paper show that the development of traditional packaging has been constrained in recent years, from the usage rate of about 80% at the beginning to the usage rate of about 20% later. The utilization rate of smart packaging has risen from about 16% at the beginning to the highest utilization rate of about 83%. It can be seen that smart packaging meets people's consumption needs. Smart packaging not only has various styles but also has many more functions than traditional packaging and has become more environmentally friendly, which also greatly reduces environmental pollution. Therefore, it is necessary to analyze the intelligent packaging design based on BD image processing in this paper. © *2022 SPIE and IS&T* [DOI: 10.1117/1.JEI.32.1.011218]

Keywords: big data; image processing; intelligent packaging; median filter algorithm.

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1 Introduction

Big data (BD) is actually a huge amount of data. These huge amounts of data come from data generated at any time around the world. In the era of BD, any tiny data may produce incredible value. In recent years, with the rapid development of computer technology and image processing technology, the computing speed of computers is getting faster and faster. Various efficient image processing algorithms have also appeared, and computer digital image processing technology has been widely used in remote sensing, biomedicine, artificial intelligence, industrial production, automatic control, aerospace, and other related fields.

With the changes brought about by the development of science and technology, traditional packaging is also quietly changing. On the premise of meeting the basic functions of packaging, modern packaging fully reflects the needs of various consumers, showing humanitarian care, and intelligent packaging that expands product functions is gradually appearing. This type of packaging includes advanced design elements such as the latest smart materials, smart technologies, and smart structures, which strengthens the protective function of the packaging and maximizes the special needs and convenience of consumers.

The innovations of this paper are: (1) The theoretical knowledge of BD image processing and intelligent packaging is introduced, and the importance of image processing in intelligent packaging design is analyzed by using BD image processing. (2) This paper expounds on intelligent packaging and image processing. Through experiments, it is found that intelligent packaging design based on BD image processing is more in line with the requirements of the times.

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2 Related Work

With the development of the economy, people's consumption has become higher and higher, followed by the convenience brought by BD. Han et al.[1] found that BD exhibits other unique characteristics, and BD needs more real-time analysis. Therefore, he proposed a systematic tutorial for BD analysis platform to solve the problem. Although he proposed that the arrival of BD has changed people's lives, he did not specify actual cases. Kuang et al.[2] found that diversity and accuracy are two distinct characteristics of BD, and it has always been a huge challenge to effectively represent and process BD with a unified scheme, and he proposed a model. Although he is aware of the problems of BD, he does not explain in detail how to solve this problem. Xue et al.[3] found that to reduce the amount of data collected by IoT, it is necessary to increase the processing speed of BD. For the problem of the high computational complexity of BD, he uses multi-objective optimization particle swarm optimization algorithm to improve, which can effectively improve the reconstruction accuracy of the algorithm. Although the scholar proposed an effective algorithm, he did not have specific experiments to prove the correctness of the algorithm he proposed. Zhang et al.[4] found that BD poses great challenges to traditional computing, and the limitations of cloud computing greatly hinder the vigorous development of cloud computing in the era of BD and the Internet of Things. He provides an overview of BD and a comprehensive survey of how cloud computing and its related technologies address the challenges posed by BD. But the scholar did not describe his findings. Xu et al.[5] found that data mining technology has brought serious threats to the security of personal sensitive information. In recent years, privacy-preserving data mining (PPDM) is an emerging research topic in data mining and has been extensively studied. The current research on PPDM mainly focuses on how to reduce the privacy risks brought by data mining operations. He looks at privacy issues related to data mining from a broader perspective and examines various ways to help protect sensitive information. Although the scholar clearly found that private security is at risk, he did not describe the method he studied. Zhang et al.[6] pointed out that the advancement of information technology has also promoted the development of healthcare technology. However, these new technologies have also made healthcare data more difficult to process. To provide a more convenient healthcare service and environment, he proposed a cyber-physical system based on cloud and BD analysis technology. Although he proposed the system, no experiments were carried out on the system, and there was no concrete data to prove its feasibility. Rathore et al.[7] found that the remote sensing digital world generates massive amounts of real-time data every day, and that information, if collected and aggregated effectively, will have great significance. But extracting useful information in an efficient manner would face significant computational challenges for the system, so he proposed a real-time BD analysis architecture for remote sensing satellite applications. The proposed architecture consists of three main units. But he only mentioned that the architecture has three units and did not give a detailed explanation of the three units. Janssen et al.[8] are looking for ways to use the power of BD to improve white, although in -making, although the impact of BD on decision quality has received little attention. He uses case studies to identify factors that influence BD-based decisions. BD is collected from different sources with different data qualities and processed by various organizational entities, creating a BD chain. The case studies show that leveraging BD is an evolutionary process in which progressive understanding of its potential and the regularization of processes play a crucial role. Although the scholar knew to cite cases, he did not mention what specific cases were.

3 Image Processing Method Based on Big Data

In recent years, with the rapid development of China's industrial economy, the improvement of people's quality of life, and the enhancement of environmental protection awareness. Intelligent packaging has become the most potential form of green packaging due to its advantages of wide source of raw materials, easy molding, and degradable recycling. At the same time of the rapid and stable development of the packaging industry, to meet the needs of diversified industrial design, it fully caters to the market development needs of small batches, individualization, interest, diversification, and short cycle. Computer-aided technology has also been widely used in all walks of life and has become a key technology to improve the product research and development capabilities of various enterprises and enhance their competitiveness.[9]

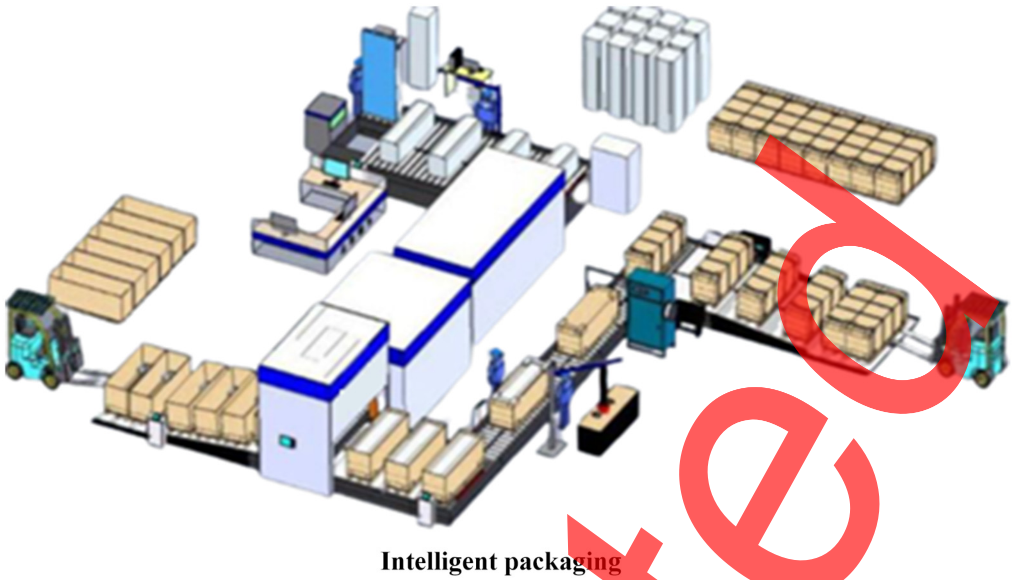

Fig. 1 Intelligent packaging line.

With the development of the economy and technology, especially the rapid development of information technology, the traditional shopping method has changed from supermarkets and shopping malls to online shopping, and this change has caused changes in commodity packaging. In the final analysis, two different shopping directions will bring different degrees of changes in product packaging function, decoration, and promotion.[10] The intelligent packaging pipeline is shown in Fig. 1.

As shown in Fig. 1, smart packaging research not only improves the original packaging form but can also provide another new method for human personalization and humanization, and the practicality it contains is also very important.[11]

Image processing technology is a new computer application field developed with computer technology, network communication technology, and signal processing technology. It aims to improve the visual effect of the image or enhance the object, and uses computer technology and other electronic equipment to process the image.[12] In a broad sense, it is a general term for various technologies related to images, mainly including image analysis, understanding, and computer vision.

3.1 *Representation Model of Digital Images*

Images play a very important role in the process of human perception of the surrounding environment. From the perspective of the five senses of human beings receiving external information, visual information is the most abundant, and the amount of information acquired occupies a considerable proportion.[13] The flow of image processing is shown in Fig. 2.

As shown in Fig. 2, image processing generally refers to digital image processing. Digital image refers to a large two-dimensional array obtained by shooting with industrial cameras, cameras, scanners, and other equipment. The elements of the array are called pixels, and their values are called gray values. According to the performance of the image, it can be divided into analog images and digital images. The images of the surrounding environment seen in daily life are continuous analog images, whereas the images processed by the computer are digital images.[14] From a mathematical point of view, according to the basic principle of chromaticity, a digital image can be defined as a three-dimensional function $f(a, b, z)$, i.e., Eq. (1):

$$f(a, b, z) = \{\text{red}(a, b, z), \text{green}(a, b, z), \text{blue}(a, b, z)\}, \tag{1}$$

where the magnitude of $f(a, b, z)$ represents the intensity of the image at any set of spatial coordinates $f(a, b, z)$.

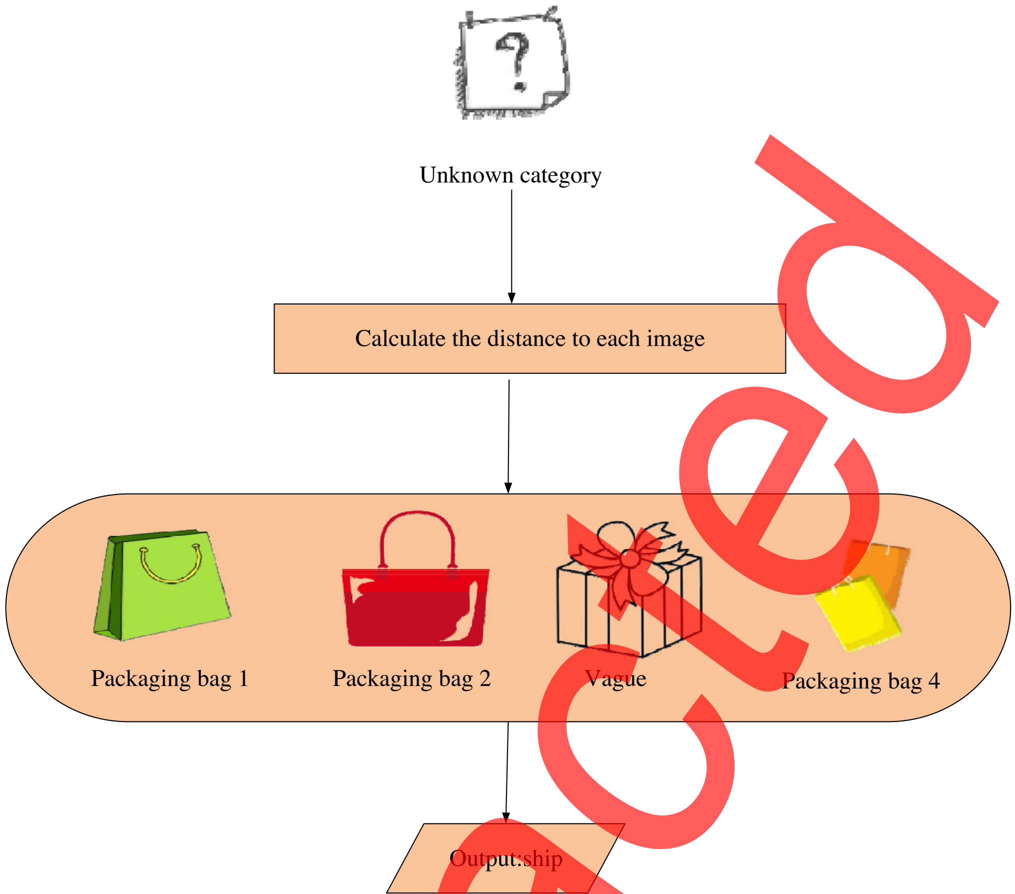

Fig. 2 Flowchart of image processing.

A grayscale digital image is one with only one sampled color per pixel. Such images are usually displayed as grayscale from the darkest black to the brightest white, although in theory, this sampling could be any shade of color, even different colors at different intensities. The above mathematical model is the basic model of color image, whereas the model of gray image is relatively simple. It is a two-dimensional function $f(a,b)$ that represents the image intensity or gray value of any spatial coordinate point (a,b). There are often two processing procedures: sampling and quantization.[15]

If the sampling intervals in the a and b directions are defined as Δa and Δb, respectively, the position of the sampling point is $a = m\Delta a$, i.e., the sampling function as

$$s(a,b) = \sum_{m=-\infty}^{+\infty} \sum_{m=-\infty}^{+\infty} \delta(a - m\Delta a, b - n\Delta b). \tag{2}$$

Sampling an image, if there are M pixels in each row and N pixels in each column, the image size is $M \times N$ pixels so that $f(a,b)$ constitutes an $M \times N$ real number matrix as

$$f(a,b) = \begin{bmatrix} f(0{,}0) & f(0{,}1) & f(0,N-1) \\ f(1{,}0) & f(1{,}1) & f(1,N-1) \\ f(M-1{,}0) & f(M-1{,}1) & f(M-1,N-1) \end{bmatrix}. \tag{3}$$

Sampling refers to replacing the original continuous signal in time with a sequence of signal samples at regular intervals, i.e., discretizing the analog signal in time. The process of converting a continuous signal into a discrete signal is called a sampling process. Among them, each element is a discrete sampling value of image $f(a,b)$, and it can be known from the sampling definition that each pixel can only be represented by a uniquely determined brightness value.

In addition, it is very important to select the sampling point interval when sampling. The image quality after sampling is usually determined by the spatial resolution of the image according to the changes in the original image.[16] The larger the interval, the smaller the sampling interval, and vice versa.

The quantization process is the process of converting the discretized pixel grayscale real value into a single specific data. The binarization required to store a digital image is as shown

$$b = M \times N \times Q. \tag{4}$$

The number of bytes B is

$$B = M \times N \times \frac{Q}{8}. \tag{5}$$

Quantization is mainly used in the conversion from continuous signals to digital signals. Continuous signals become discrete signals after sampling, and discrete signals become digital signals after quantization. The result of sampling and quantization is the actual two-dimensional integer real matrix, and the position of each element in the matrix is determined by the scan order. The actual gray value of each pixel is obtained through a sampling process and then quantized to obtain the gray level of each pixel.[17]

3.2 *Theoretical Algorithms Related to Image Processing*

3.2.1 *Grayscale transformation of images*

Grayscale transformation is the process of changing the image contrast from weak to strong and is a method of emphasizing the image. According to a specific transformation, the grayscale value of each pixel of the original image is changed point by point.[18] The image transformation is generally

$$g(a, b) = T[f(a, b)]. \tag{6}$$

Among them, $f(a, b)$ is the original image to be processed, that is, the image that needs to be enhanced, $g(a, b)$ is the processed image, i.e., the image after grayscale transformation, and T defines an operation that acts on a.[19]

3.2.2 *Linear grayscale transformation*

Assuming that after linear transformation, the grayscale interval of the output image is $[c, d]$, the linear transformation can be expressed as

$$g(a, b) = d - c[f(a, b) - a] + c. \tag{7}$$

Assuming that the grayscale range of the original image is $0 - S$, and the interval of interest is (a, b). To only enhance the information of the region of interest, a piecewise linear grayscale transformation can be adopted. The specific expression is as shown

$$g(a, b) = S - d[f(a, b) - b] + d. \tag{8}$$

By adjusting the slope and inflection point of the polyline, the image is compressed and expanded in segments. In this paper, the principle of differential pressure air leakage detection and the working principle of CCD measurement system is comprehensively used, and an experimental bench for packaging sealing detection is designed, which mainly includes vacuum air system and image acquisition system.[20] The principle of differential pressure detection is to compare the differential pressure between the workpiece and the standard workpiece without leakage so that the system error caused by the unstable air can be offset. The standard tank has good sealing performance, fast heat dissipation, good stability, and is easy to manage (no need to use a workpiece to add a jig to seal).

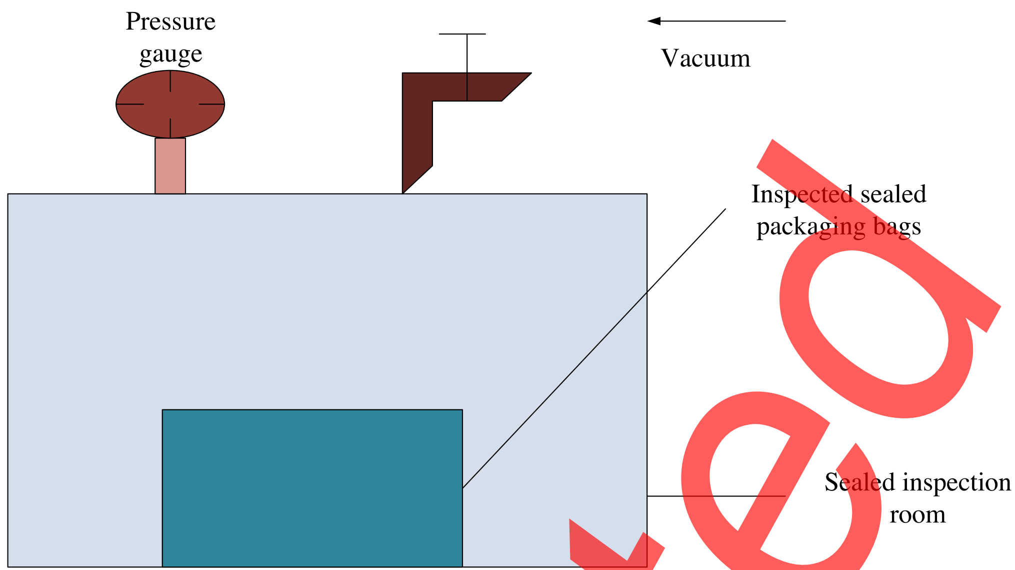

Fig. 3 Schematic diagram of differential pressure air leak detection principle.

The tested sealed package is placed in the sealed testing chamber. After the sealed cavity is evacuated, due to the pressure difference between the inside and outside of the tested sealed package, the sealed package will expand and deform, and the degree of deformation is related to the magnitude of the pressure.[21] The basic detection principle of differential pressure air leakage is shown in Fig. 3.

As shown in Fig. 3, specifically, the package is usually encapsulated under normal pressure. If the package is intact, it will bulge and deform obviously due to the difference in internal and external pressure in a vacuum environment. If the package is leaked and damaged, due to the existence of micropores, the inside and outside of the package are connected, and there is no obvious pressure difference, so the package surface is almost unchanged and remains slightly concave downward.

3.2.3 *Image enhancement*

Enhancing useful information in an image, which can be a distortion process, aims to improve the visual effect of an image for a given image's application. Purposefully emphasize the overall or local characteristics of the image, make the original unclear image clear or emphasize some interesting features. Image enhancement can highlight a specific area of the image and weaken other areas, but the image quality may be reduced, such as by highlighting the outline of the target and increasing the contrast of the image. Therefore, image enhancement improves the intelligibility of the image, which is beneficial to the judgment and recognition of the human eye.

In this paper, the method of grayscale transformation in the space domain, the histogram method, is used to enhance the contrast of the image. A histogram is a function of gray levels that reflects the number or frequency of each gray level in an image. Image processing is divided into spatial domain and transform domain (such as frequency domain processing). The spatial domain refers to the image plane itself, and image domain processing is to directly manipulate the pixels in the image. The histogram is shown as

$$h(r_k) = n_k, \tag{9}$$

where r_k is the k'th grayscale in the interval $[0, G]$, and the normalized histogram is obtained as

$$p(r_k) = \frac{h(r_k)}{n} = \frac{n_k}{n}, \tag{10}$$

where $p(r_k)$ represents the probability of occurrence of gray level r_k.

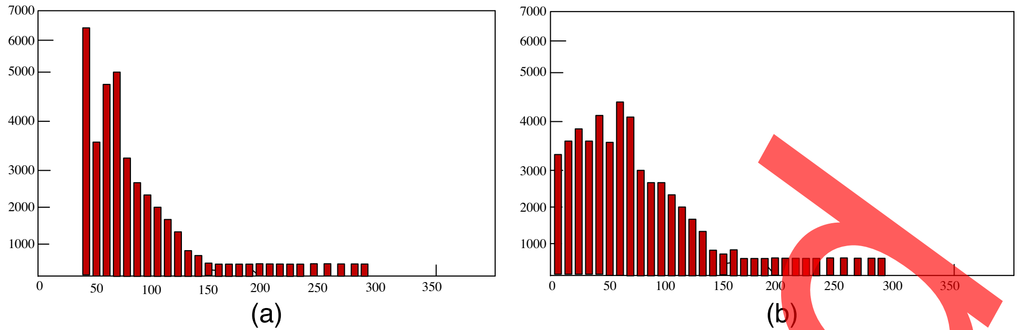

Fig. 4 Histograms before and after image enhancement. (a) Histogram of original image and (b) image enhancement histogram.

The gray value of the image represents the brightness of the gray image, and the histogram of the image enhancement result is shown in Fig. 4.

As shown in Fig. 4, it can be seen from the histogram of the original image of the packaging image in the vacuum state that the gray level is mainly concentrated in the area with relatively small gray value, resulting in a darker image as a whole. To improve the contrast of the image, the part with less gray value distribution is cut off, and the space in the transformed gray scale is extended to the entire gray scale. The gray areas of interest are emphasized, more gray tones are added, and the reflective areas of the package are emphasized, making the result more pronounced.

3.3 *Image Smoothing*

Digital images often have many aspects of noise and interference. Generally speaking, image smoothing always comes at the cost of the lack of some detailed information. Usually, frequency domain filtering is used to process images, and Fourier transform and its inverse transform are used to reduce noise. In addition, spatial filtering can also be used to solve the interference of noise. The smoothing of images can be done not only in the spatial domain but also in the frequency domain. The filtering in the frequency domain is mainly divided into low-pass and high-pass filters. In the frequency domain, the low-frequency part represents the outline, and the high-frequency part represents the details. The median filter is as

$$b_i = \mathrm{Med}\{f_{i-v}, \ldots, f_{i-1}, f_i, f_{i+1}, \ldots, f_{i+v}\}. \tag{11}$$

For median filtering of image $g(a, b)$, the selected filter window is always two-dimensional, which is

$$g(a, b) = \mathrm{med}\{f(i, j)\}. \tag{12}$$

The advantages of median filtering are mainly reflected in noise suppression, and it also has a certain effect on impulse interference, which can suppress random noise and prevent the loss of edge information. For detailed images, some edges are easily mistaken for noise, and median filtering is not suitable.

Then the transfer function of the filter is

$$H(u, v) = \begin{cases} 1, & \left[\left(u - \frac{m}{2}\right)^2 + \left(v - \frac{n}{2}\right)^2\right] \leq D_0 \\ 0, & \left[\left(u - \frac{m}{2}\right)^2 + \left(v - \frac{n}{2}\right)^2\right] > D_0 \end{cases}. \tag{13}$$

Among them, $D_0 \geq 0$ is used to represent the cut-off frequency of the ideal low-pass filter. Although the ideal low-pass filter can remove noise, it also brings some problems. For example, the loss of details makes the edges blur. So, this paper proposes a Butterworth low-pass filter (BLPF). This paper compares the median filter and the Butterworth low-pass filter, as shown in Table 1.

Table 1 Comparison of median filter and Butterworth low-pass filter.

Object of investigation	Noise intensity 0.6		Noise intensity 0.4		Noise intensity 0.2	
	Median filter	BLPF	Median filter	BLPF	Median filter	BLPF
Efficient	54%	67%	53%	70%	57%	78%
Variance	6.1–6.3	9.3–9.5	6.5–6.6	9.6–9.8	6.7–6.9	9.7–9.9

As shown in Table 1, the noise removal efficiency of BLPF is always slightly higher than that of the median filter algorithm, and the experimental data reflects the superiority of this algorithm. The Butterworth low-pass filter can reduce the blurring of edges while suppressing noise. Its N-order transfer function is

$$H(u, v) = \frac{1}{1 + [D(u, v)/D_0]}. \tag{14}$$

The edge of the image processed in the spatial domain is generally clearer, which is beneficial to the extraction of the edge. The degree of blurring depends on the size of the template. Using frequency domain filtering to process the image has a good effect from the perspective of image smoothing.

3.4 *Edge Detection*

The edge refers to a group of pixels around the pixel grayscale image, that is to say, the edge information of the image is the basic feature of the image. The steps of edge detection are shown in Fig. 5.

As shown in Fig. 5, edge detection is a basic problem in image processing and computer vision. The purpose of edge detection is to identify the points with obvious brightness changes in digital images. Significant changes in image properties often reflect significant events and changes in properties. Due to the existence of noise, the gradient value will be biased, and smoothing filtering is needed to remove the influence of noise. However, it should be noted that the stronger the ability to remove noise, the easier the boundary is blurred, and the easier it is to lose details.

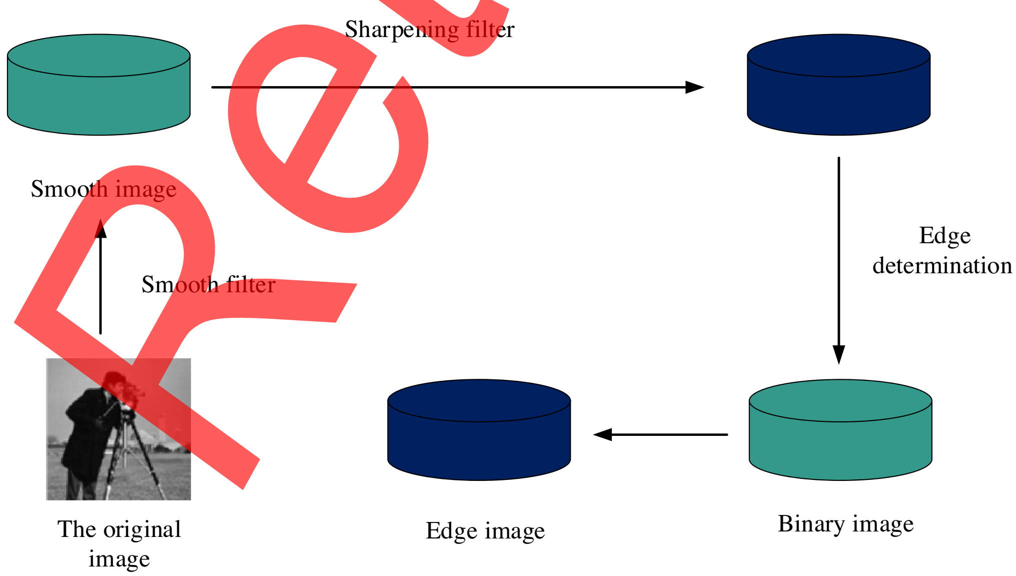

Fig. 5 Steps of edge detection.

Roberts operator is one of the simplest operators, which uses local difference operators to find edge operators. Using the difference between two adjacent pixels on the diagonal to approximate the gradient amplitude to detect the edge, the effect of detecting the vertical edge is better than that of the oblique edge, the positioning accuracy is high, and it is more sensitive to noise. The Roberts edge detection operator is one of the easiest ways to get the first-order partial derivative at (a, b). This operator only uses the neighborhood of the current pixel, which is

$$R(a,b) = \sqrt{(f(a,b) - f(a+1,b+1))^2 + (f(a,b+1) - f(a+2,b)))^2}. \tag{15}$$

The Robert operator is characterized by accurate positioning, sensitivity to noise, and inability to suppress noise well, so it is suitable for images with steep edges and less noise.

Different from the Roberts edge detection operator, the Sobel operator is calculated according to the principle of the existence of extreme values at the edge points. Sobel operator generally refers to the Sobel operator. Sobel operator is an important processing method in the field of computer vision. Mainly used to obtain the first-order gradient of digital images, the common application and physical meaning is edge detection. The algorithm of the Sobel edge detection operator is shown

$$S(a,b) = [f(a-1,b-1) + 2f(a-1,b) + f(a-1,b+1)]. \tag{16}$$

The above edge detection operations are all main edge detection operators. If the obtained first-order derivative function is higher than a certain threshold, the point is determined as an edge point, which will cause too many edges to be detected. Therefore, this paper proposes a second-order edge detection operator. The Laplace operator is a second-order differential operator that operates on a two-dimensional function $f(a,b)$. The second-order derivative of an image $f(a,b)$ at position (a,b) is defined as

$$\Delta^2 f = \frac{\partial^2 f}{\partial a^2} + \frac{\partial^2 f}{\partial b^2}. \tag{17}$$

Differentiation is approximated by difference, so there is

$$\Delta^2 f(a,b) = f(a+1,b) + f(a,b+1) + f(a.b-1) - 4f(a,b). \tag{18}$$

The Laplacian algorithm of the image function is also implemented by the convolution of the template. The basic requirement is that the coefficient corresponding to the central pixel is positive, the coefficient of the adjacent pixel is negative, and the template is zero. In this way, the grayscale shift phenomenon can be excluded. If a bright spot appears in a darker area of the image, the bright spot will become brighter after processing by the Laplacian operator.

The Canny operator converts the edge detection problem into a unit function maximum detection problem. This operator has excellent anti-noise ability and detection accuracy and is also one of the widely used detection operators. The edge points are well located and the located edge must be as close as possible to the true edge. That is, the distance between a point marked as an edge by the detector and the center of the true edge is the smallest. The larger the signal-to-noise ratio, the better the edge effect extracted by the Canny operator. The signal-to-noise ratio SNR is defined as

$$\mathrm{SNR} = \frac{\left| \int_{-w}^{w} G(-a)h(a)\mathrm{d}a \right|}{\sigma\sqrt{\int_{-w}^{w} h^2(a)\mathrm{d}a}}. \tag{19}$$

Among them, $G(a)$ represents the edge function, $h(a)$ represents the filter impulse response of width w, and σ represents the mean square error of Gaussian noise.

The edge positioning accuracy L is defined as

$$L = \frac{\left| \int_{-w}^{w} G(-a)h'(a)\mathrm{d}a \right|}{\sigma \sqrt{\int_{-w}^{w} h'(a)\mathrm{d}a}}, \tag{20}$$

where $G'(a)$ and $h'(a)$ represent the first derivatives of $G(a)$ and $h(a)$, respectively. The larger the L, the higher the positioning accuracy, i.e., the closer the positioning is to the real edge.

3.5 *Classification of Intelligent Packaging*

3.5.1 *Bio-intelligent*

In this information age, multidisciplinary and multifield cross-integrated application has become the mainstream. If the packaging industry can grasp the trend of the times and successfully combine the more mature high-tech in other disciplines with the existing packaging technology, it will be very helpful to improve the overall technical level of the packaging industry. For example, photocatalyst-coated paper is shown in Fig. 6.

As shown in Fig. 6, photocatalysts are a class of substances that are excited to high-energy states by absorbing light, and then transfer energy to reactants to initiate chemical reactions. With the continuous development of China's socialist market economy, China's packaging industry has also made remarkable achievements. However, compared with the world's packaging powerhouses, China's packaging-aided design technology started relatively late, and its technical content is relatively low. Compared with developed countries, there is a big gap. The production methods of some packaging companies still rely on manual calculation, manual drawing, and manual imposition, and the design cycle is long and the cost is high.

3.5.2 *Digital intelligent type*

The goods sold by large warehouse retailers have begun to be equipped with RFID tags. The current social material is increasingly rich, and fast food consumption has become a new trend.

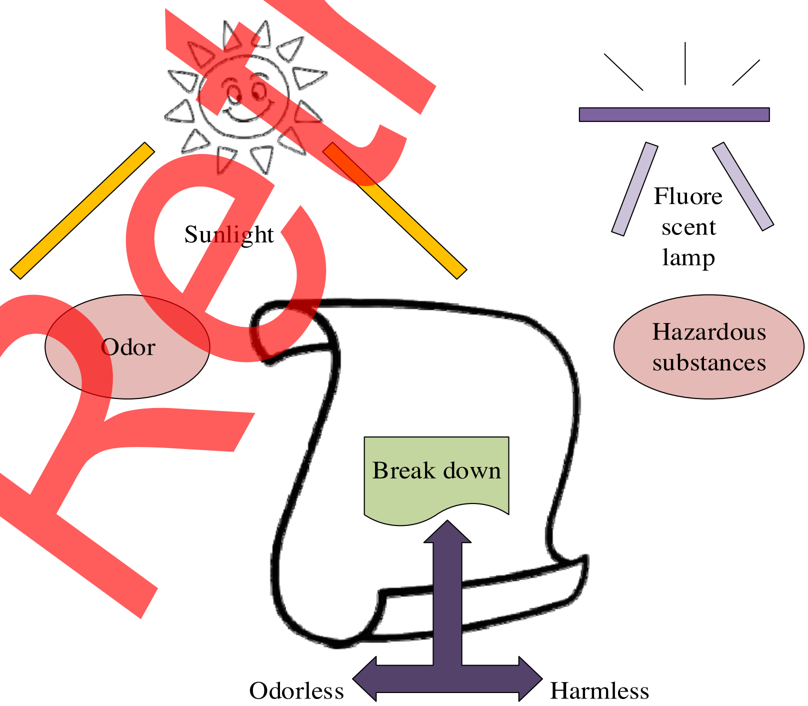

Fig. 6 Application principle of photocatalyst coated paper.

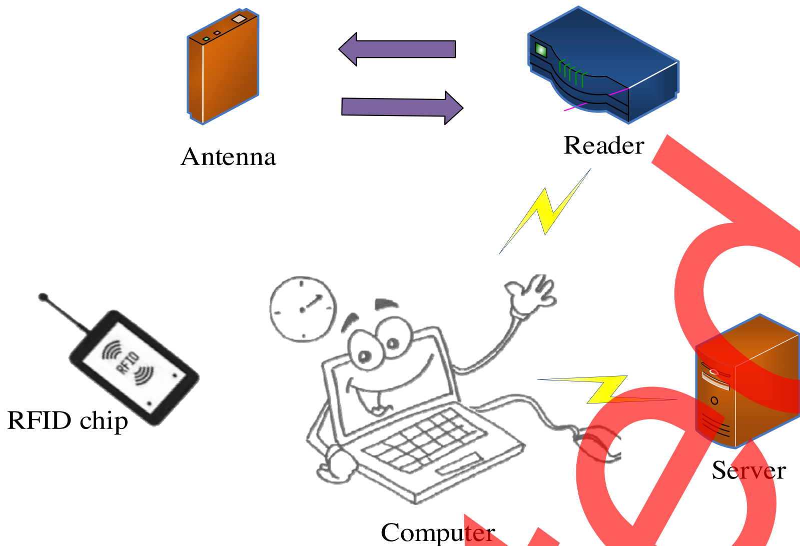

Fig. 7 RFID technology.

Among the many similar products with similar quality, whoever can meet the packaging requirements of the product better and faster and present the best packaging to consumers can win the trust of consumers and become the ultimate winner. RFID technology is shown in Fig. 7.

As shown in Fig. 7, the principle is the noncontact data communication between the reader and the tag to achieve the purpose of identifying the target. The application of RFID is very wide, typical applications are animal chip, car chip antitheft device, access control, parking lot control, production line automation, and material management. RFID technology generally has the characteristics of waterproof, magnetic resistance, high-temperature resistance, and so on, which ensures the stability of the RFID technology in the application. As long as the use of RFID is involved, RFID is beneficial for real-time updating of data, the amount of information stored, work efficiency, and security. RFID can make it easier to update existing data and make work more convenient on the premise of reducing human, material, and financial resources.

4 Experiment and Analysis of Traditional Packaging Design and Intelligent Packaging Design

4.1 *Development of Traditional Packaging Design and Intelligent Packaging Design*

In the era of rapid changes in science and technology, the packaging industry is taking this opportunity to develop rapidly in the direction of networking, informatization, and intelligence. The existing packaging technology can no longer meet the needs of the development of the packaging industry. Research and development of new packaging technology is imminent. At present, intelligent packaging has attracted more and more attention due to its intelligent and humanized technical characteristics, extensive social functions, and huge market development potential.

Due to new consumption concepts and new lifestyles, the packaging of modern goods is substantially enriched. Judging from the existing packaging designs circulating in the market, there are generally several problems: the inability to grasp people's special psychological and physiological habits, the lack of innovative awareness of packaging, and the very single function.

This paper analyzes the development trend of traditional packaging and smart packaging in recent years as shown in Fig. 8.

As shown in Fig. 8, the traditional packaging has no useful value after being opened and can only be discarded. The "single-use" packaging design will not only cause environmental pollution but also increase energy consumption. Packaging design not only needs to accurately

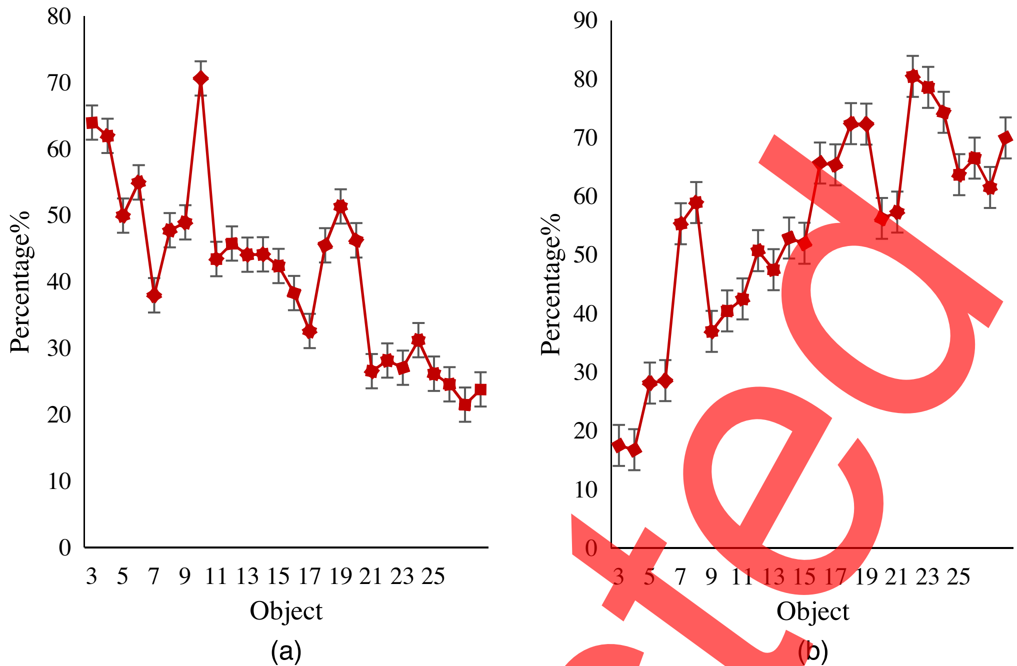

Fig. 8 Trends in traditional packaging and smart packaging. (a) The development trend of traditional packaging and (b) the development trend of smart packaging.

convey information but also needs to have the function of guiding the correct consumption concept.

Now, many companies are trying to use smart packaging, and it is not denied that some manufacturers do not have advanced cognition. Smart packaging hides infinite possibilities, and the application of smart packaging technology is a mainstream tool to solve problems. This paper compares traditional packaging design and smart packaging design, as shown in Tables 2 and 3.

As shown in Tables 2 and 3, smart packaging not only has high convenience but also high safety. Since smart packaging can be used multiple times, it is also environmentally friendly. Combined with the application of BD, the speed of product packaging is getting faster and faster, and the circulation is getting stronger and stronger. This paper analyzes the application fields of intelligent packaging design from 2017 to 2020 as shown in Fig. 9.

As shown in Fig. 9, in recent years, various innovative smart packaging forms have emerged in an endless stream in cutting-edge fields such as food packaging, pharmaceutical packaging, daily packaging, heavy industry, military, and science. Especially with the accelerating pace of life, intelligent packaging is very popular in life, which promotes its development and application.

Table 2 Convenience, safety, environmental protection, and liquidity scores of traditional packaging design.

Packages	Convenience	Safety	Environmentally	Liquidity
Package 1	5.6	5.5	3.9	6.1
Package 2	4.8	5.8	3.2	6.3
Package 3	5.2	5.2	4.0	6.0
Package 4	4.7	4.9	3.4	5.5
Package 5	4.2	5.3	3.7	5.8

Table 3 Convenience, safety, environmental protection, and liquidity scores of smart packaging design.

Packages	Convenience	Safety	Environmentally	Liquidity
Package 1	6.7	8.3	6.3	7.9
Package 2	6.9	8.0	6.8	7.6
Package 3	7.3	7.5	6.6	7.8
Package 4	7.6	7.9	6.2	7.7
Package 5	7.5	8.6	6.5	7.2

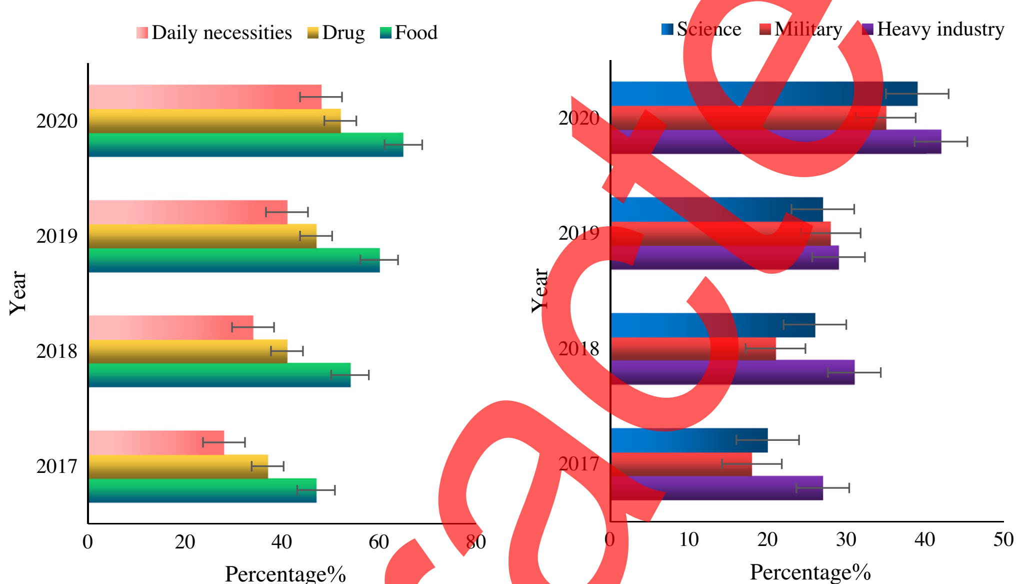

Fig. 9 Application areas of smart packaging design from 2017 to 2020.

4.2 *Principles of Intelligent Packaging Design*

1. The intelligent design of packaging is essentially people-oriented. Therefore, whether to carry out intelligent design should be based on the needs of consumers, not all products are suitable for intelligent packaging design. Intelligent packaging design is a high-end demand due to people's long-term packaging needs, so it must be reasonably implemented and used in the early planning of intelligent packaging design.
2. The investment is minimized. Packaging is an accessory of commodities. In the commodity economy, according to the principles of economics, whether it is in the form of traditional packaging or in an intelligent form, the investment should be minimized as much as possible under the premise of satisfying functions and being easy to use. As a form of packaging, intelligent packaging is still the biggest problem at present.
3. Comprehensive using. The design of intelligent packaging involves knowledge of many disciplines such as science, engineering, and art. It requires designers to have an international vision and broad knowledge, be good at absorbing knowledge from various disciplines, and use them flexibly. At the same time, teamwork should be used to foster strengths and avoid weaknesses.

5 Discussion

This paper discusses how to study a smart packaging design based on BD image processing, describes the theoretical knowledge related to data image processing and smart packaging, and focuses on the importance of smart packaging. A more scientific method of image processing is explored, and the role of BD image processing on intelligent packaging design is discussed through experimental analysis. Finally, it is found that BD image processing can make intelligent packaging design more convenient and practical.

Image smoothing is also studied in this paper, and median filtering and Butterworth low-pass filtering are also studied. Finally, it is found that although median filtering can remove noise and enhance images, it is not suitable for very clear images and will be affected by edge data. However, the Butterworth low-pass filter is not affected by edge data, so its denoising ability is stronger.

From the experimental analysis in this paper, it can be known that the use of BD image processing methods in intelligent packaging design can not only make intelligent packaging design more scientific and environmentally friendly but also improve the efficiency of computing, the image of the packaging becomes clearer.

6 Conclusions

In the era of rapid economic development, people's consumption desire is getting higher and higher, so the packaging of products has become more and more important. Most of the traditional packaging can only be used once, the form is very single, and the style is not fashionable enough. Therefore, based on the development of the times, intelligent packaging began to appear. Based on the design and research of intelligent packaging based on BD image processing, this paper analyzes the concepts of BD image processing and intelligent packaging, and also expounds the importance of intelligent packaging. Smart packaging can not only save energy, but also make people's lives more convenient. In the method part of this paper, a representation model of digital images and a gray value histogram are proposed for BD image processing. These two methods are very important in image processing. Only by finding a suitable image processing method can the intelligent packaging be more perfect. In the experimental part, this paper first analyzes the development of traditional packaging and smart packaging this year. After analysis, it is found that the development of traditional packaging is getting slower and slower, whereas the development of intelligent packaging is getting faster and faster, which proves that intelligent packaging has more advantages than traditional packaging. Then, we compared the characteristics of traditional packaging and smart packaging and found that traditional packaging not only has few styles but also is not environmentally friendly. Finally, this paper expounds the principles that smart packaging needs to follow. Because of the author's knowledge and ability, there are still many shortcomings, so there are still many loopholes in this paper.

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