Colour difference detection method of product packaging based on local enhancement

Hua Song

Department of Art and Design,
Wu'han Polytechnic University,
Wu'han 430048, China
Email: huasong@mls.sinanet.com

Abstract: In order to overcome the problem of high detection absolute error rate and complexity of detection time in traditional methods, this paper proposes a method of colour difference detection based on local enhancement. The projection value of the colour area block of the outer packaging is determined. The threshold segmentation method is used to detect the colour difference of the outer packaging of the product. The difference pixels are extracted by local enhancement method to detect the colour difference of the outer packaging. The results show that the average accuracy of the method is 98.6%, the time of colour difference detection is only 6S, and the absolute error rate of colour difference detection is 0.26%. This method can effectively reduce the complexity of detection time, reduce the absolute error rate of detection, and improve the correct identification rate of colour difference of outer packaging.

Keywords: binarisation energy map; threshold segmentation method; local enhancement; feature extraction.

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Biographical notes: Hua Song graduated from the School of Art and Design, Hubei University of Technology. His research directions are food brand design, service design for visually impaired groups. Among them, 35 papers were published in Chinese core journals and 3 works were retrieved by cpsci-ssh. He obtained 2 patents, presided over 2 projects of Ministry of Education, 2 projects of provincial level and 4 projects of participation.

1 Introduction

The development of science and technology has brought great influence to human life. All kinds of things in life can be solved through the network, resulting in a lot of text information and image information (Guo et al., 2020). Computer technology has been widely used in colour difference detection of industrial products. We will extract the product packaging image, enhance the product packaging image features and detect the colour difference pixels through image processing technology. Improve the production quality and aesthetic level of industrial products. In a certain light, the subtle difference of colour is difficult to recognise by other people's eyes, so the colour difference recognition of industrial products can be realised by computer technology (Fukuda et al., 2019). Relevant scholars have studied this and made some progress.

Su (2020) puts forward a method to detect the colour difference of product packaging based on machine vision. The standard light source D65 is used to get the colour difference of the irradiation product packaging, the high precision colour linear camera is used to get the colour image of the product packaging, and the filtering algorithm is used to remove the colour difference noise of the product packaging image. Based on the RGB colour characteristics, the CIELAB colour space of the product packaging is obtained to detect the colour difference of the product packaging. This method can effectively improve the accuracy of colour classification of product packaging, but the algorithm detection process is more complex. Xie et al. (2020) put forward the research of colour detection method for product packaging based on multi-rotation angle measurement, analyses the colour characteristics of product packaging, determines the distribution law of colour of product packaging, implements colour detection of product packaging through triangulation detection value, this method can improve the accuracy of colour detection of product packaging, but the colour noise removal effect of product packaging is not good. Xing et al. (2029) put forward colour detection of product packaging image based on colour contrast feature, implements boundary segmentation of product packaging image according to SLIC super-pixel segmentation algorithm, constructs HSV space based on the result of segmentation, and uses super-pixel blocks for colour detection of product packaging image. This method can effectively improve the accuracy of colour segmentation of product packaging image, but the accuracy of colour difference detection of product packaging is poor.

In view of the problems of the above methods, a colour difference detection method for product packaging based on local enhancement is proposed. The research ideas of this paper are as follows:

1 Determine the direction projection value of the colour area block of the product packaging, and extract the feature of the product packaging image through binary energy map.
2 According to the obtained packaging image characteristics, the colour difference detection of product packaging is carried out by threshold segmentation method, and the difference pixels are extracted by local enhancement method to realise the colour difference detection of product packaging.
3 Experimental verification, with the correct recognition rate of training samples, the time complexity of the algorithm, and the absolute error rate as the experimental comparison indicators, the proposed method is compared with Su (2020), Xie et al. (2020) and Xing et al. (2019) methods.

2 Feature extraction of product packaging image

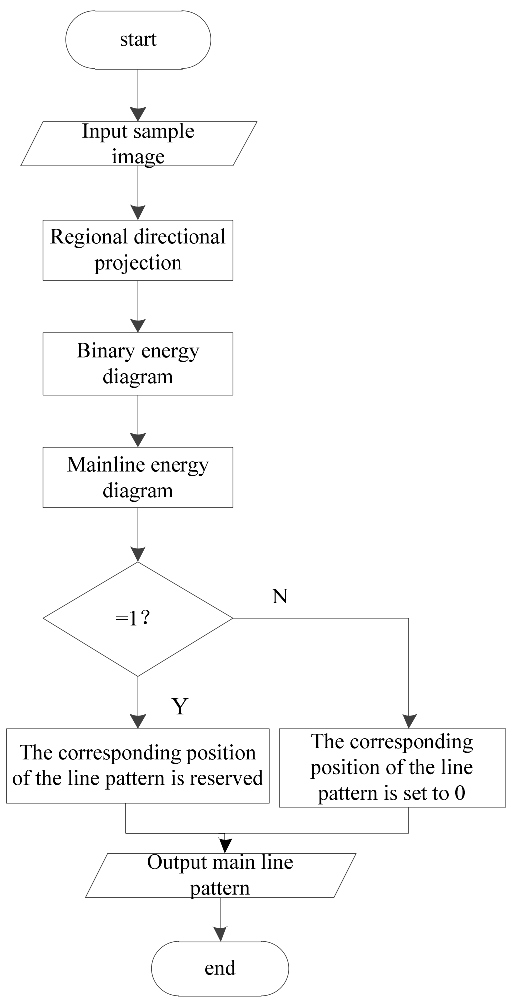
2.1 The direction projection value of product outer package image area block is determined

The size of the product outer package image sample is $m \times m$, and the scale of its region block is $d \times d$ (d is odd, and $3 \leq d \leq 9$). Then, the specific steps of the direction projection value of the product outer packaging image area block are as follows:

Step 1: Select the area block (Nilsson, 2020; Zheng et al., 2019; Li and Cai, 2019) with the scale of $d \times d$ in the upper left corner of the product outer packaging image, and translate it to the right or down 1 pixel each time, then $(m - d + 1) \times (m - d + 1)$ regions will be obtained. Next, the pixel value of each region block is normalised.

Step 2: For each region block, take the vertical direction passing through the centre of the region block as the reference line, and π/dr as the interval Angle (Buckley et al., 2020; Vejar et al., 2019). Rotate counter-clockwise to obtain dr lines with the included angles of π/dr, $2\pi/dr, \ldots, \pi$ respectively. Next, the pixel value of the area block passed by each direction line is recorded, and the sum of all pixel values on the direction line is taken as the projection value of the area block on a certain direction θ (Kolandaisamy et al., 2019), denoised as R_θ. The extraction flow chart of colour features of product outer packaging is shown in Figure 1.

Figure 1 Flowchart of colour feature extraction of product packaging



According to Figure 1, first of all, input the image of product outer package sample, and carry out directional projection in the specified area; Then, the binarisation energy diagram and the main line energy diagram of the outer packaging of the product are calculated (Patruno et al., 2019; Yueru, 2019; Koepele et al., 2020; Heo and Chung, 2020). Determine whether the value of the main line energy diagram is 1, and the judgment result is yes. Keep the line direction diagram at the corresponding position; instead, set the position of the line pattern to 0. Then output the main line direction diagram to realise the direction projection value of the product packaging image.

2.2 Feature extraction of colour image of product packaging

Calculate product packaging colour line direction chart and energy chart. The specific calculation steps are as follows:

First, after obtaining the projection value R_θ of the feature direction of the colour image of the outer package of the product, it is uniformly added into the matrix with *dr* column. At this time, the matrix is designed as $R_{l \times dr}$.

Second, find the minimum value in the matrix $R_{l \times dr}$ and record that the minimum value is *r* and the corresponding column number is *n*.

Third, it is assumed that the line direction and energy values corresponding to this area block are $D(x, y)$, $E(x, y)$ respectively, where x, y are respectively corresponding to the horizontal and vertical coordinates of the colour area block of the product outer packaging image. At this time, the line direction diagram and energy diagram of the product outer packaging image are obtained. The specific expression is as follows:

$$D(x, y) = \begin{cases} n \times \dfrac{\pi}{dr} & \dfrac{d}{2} \le x, y \le m - \dfrac{d}{2} \\ 0 & else \end{cases} \tag{1}$$

$$E(x, y) = \begin{cases} |r| & \dfrac{d}{2} \le x, y \le m - \dfrac{d}{2} \\ 0 & else \end{cases} \tag{2}$$

In the formula, $D(x, y)$ represents the line direction value of the image of the outer package of the product, and $E(x, y)$ represents the energy value of the image of the outer package of the product (Bambil et al., 2020; Ma et al., 2019; Wu et al., 2019). For different area blocks, the line direction and energy values corresponding to different position points (x, y) can be obtained by repeating equations (1) and (2). Then, line direction graph (D) and energy graph (E) are obtained through iteration.

By sorting energy values (Paul et al., 2019), the binary graph E_b of colour energy graph of product packaging can be obtained. Then, the binary rule of colour energy graph of product packaging can be expressed as:

$$E_b(x, y) = \begin{cases} 1 & E(x, y) \ge M \\ 0 & else \end{cases} \tag{3}$$

In the formula, M is the threshold value of the product outer package binary graph. The variance classification method is used to further determine the main line energy graph.

According to the binary diagram (E_b) of the obtained energy diagram, the direction separation diagram (denoted as E_{Ab}, E_{Bb}) is determined. The rule is as follows:

$$E_{Ab}(x,y)=\begin{cases}1 & E_b(x,y)=1\,\&\,0<D(x,y)\leq\dfrac{\pi}{2}\\ 0 & else\end{cases} \tag{4}$$

$$E_{Bb}(x,y)=\begin{cases}1 & E_b(x,y)=1\,\&\,\dfrac{\pi}{2}<D(x,y)\leq\pi\\ 0 & else\end{cases} \tag{5}$$

By binarisation of the energy graph, miscellany lines are removed. Suppose S represents the area of the connected region, and P represents the number of lines in the direction separation graph (Rahmadya et al., 2020). At this time, the calculation formula for the direction separation graph (L_A, L_B) eliminating miscellany lines is obtained:

$$L_A=\begin{cases}0 & S\leq P\\ 1 & else\end{cases} \tag{6}$$

The calculation rule of L_B is consistent with equation (6).

The specific formula of mainline energy graph can be obtained by combining L_A and L_B, i.e.

$$P_L=L_A\cup L_B \tag{7}$$

where, P_L is the mainline energy diagram. Then, extract the main direction features of product packaging. When the pixel value of P_L is 1, the value is reserved, while the other positions are set to 0. If L_d is used to represent the main line direction characteristic diagram, then:

$$L_d(x,y)=\begin{cases}D(x,y) & P_L(x,y)=1\\ 0 & P_L(x,y)=0\end{cases} \tag{8}$$

According to equation (8), the main direction characteristics of product packaging colour of different scales can be obtained.

Firstly, the colour difference of the product packaging is analysed to determine the direction projection value of the colour area block of the product packaging. Secondly, the line pattern and energy map of the colour image of the product packaging are calculated. Finally, the feature extraction of the product packaging image is proposed.

3 The colour difference detection of product packaging based on local enhancement

3.1 Local enhancement of product packaging image

The local feature contrast of product packaging image is enhanced by histogram basic principle, and the desired image of product packaging is obtained by histogram equalisation processing. At this time,

$$s = T(r) = (L-1)\int_0^r p_r(w)\,dw \tag{9}$$

$$G(z) = (L-1)\int_0^z p_z(t)\,dt = s \tag{10}$$

In the formula, $P_r(r)$ represents the probability weight function of the original image of the outer packaging of the product, $P_z(z)$ represents the probability weight function of the expected image of the outer packaging of the product, and T represents the false variable of the expected image of the outer packaging of the product. When $G(z) = T(r)$, z is:

$$z = G^{-1}\left[T(r)\right] = G^{-1}(s) \tag{11}$$

In this paper, the one-dimensional vector transformation function $T(r)$ is obtained according to the input product outer packaging image, and the expected image of product outer packaging is discretised. At this time, the relationship between the transformation function $G(z)$ and the expected image of product outer packaging can be expressed as:

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)G(z) = \frac{(L-1)}{MN}\sum_{j=0}^{k} n_j G(z), k = 0,1,2,\ldots,L-1 \tag{12}$$

$$G(z_q) = (L-1)\sum_{j=0}^{q} p_z(z_i) \tag{13}$$

In the above formula, the total number of pixels in the product outer packaging image is MN, n_j represents the number of pixels of grey value in the product outer packaging image, and r_j represents the local histogram function of the product outer packaging image. There is a given value q value in the discretisation function, then $G(z_q) = s_k$. The one-to-one correspondence is obtained by inverse transformation, and the local enhancement of colour features of product outer package image is realised.

3.2 Product packaging colour difference detection

In order to improve the quality of product packaging, the colour difference of product packaging was detected.

The outer package image of the product after threshold segmentation can be defined as:

$$g(x, y) = \begin{cases} 1, f(x, y) > T \\ 0, f(x, y) \le T \end{cases} \tag{14}$$

In the above formula, $f(x, y)$ represents the original image of the outer packaging of the product, T represents the grey threshold of the outer packaging image of the product, g_{min} represents the minimum grey value of the outer packaging image of the product, and g_{max} represents the maximum grey value of the outer packaging image of the product.

If there are multiple areas with different grey values in the product outer package image, a series of thresholds can be selected, which is called multi-threshold segmentation. The same threshold is selected to segment the two outer package images of products, and whether there is difference in colour between the two images can be judged through the experimental results.

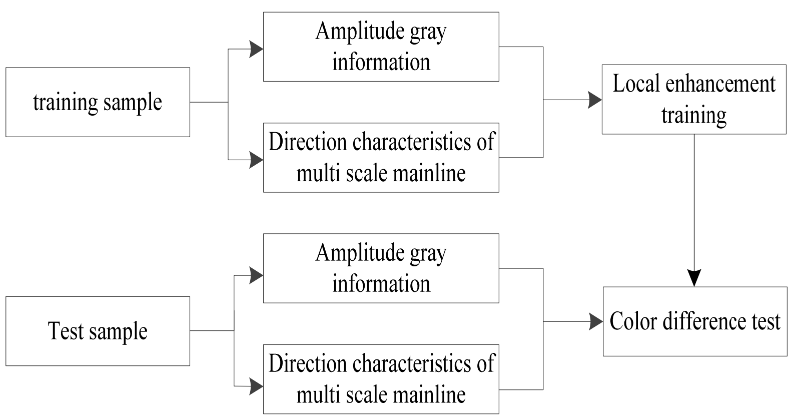
Assuming that the original image $f(x, y)$ of the product packaging is equal to the $h(x, y)$ colour of the product packaging image to be detected, then each of their pixel values is equal, that is:

$$g(x,y) = f(x,y) - h(x,y) = 0 \tag{15}$$

When the number of pixels between two different outer package images of the product is 0, there is no difference in the output of detection results. Assuming that the original image $f(x, y)$ of the outer package of the product to be detected is not equal to the image $h(x, y)$ of the outer package of the product to be detected, the number of pixels of the difference between the two outer package images is not zero. In this case, the pixel point is set to black, and only the pixel points with different pixel values are retained and displayed, thus restoring the difference.

The method in this paper can increase the dimension of useful information in the colour image of product packaging without losing the original amplitude information. The specific detection process of colour difference of product packaging is shown in Figure 2.

Figure 2 Process of colour difference detection of product packaging



Analysis of Figure 2 shows that the process of colour difference detection in product packaging is as follows:

First, get the amplitude grey information and multi-scale main line direction features of the training samples and test samples of the product packaging image. Second, carry out one-dimensional vector transformation of the product packaging image, enter these features into the visual layer of the training network for feature training, and optimise the image colour difference feature by adjusting the parameter values of the product packaging image. Then, the training samples are trained for the local colour characteristics of the product packaging image, and the test samples are directly tested for the colour difference. Finally, feature matching and colour difference detection of product packaging are carried out.

4 Experiment

To verify the validity of colour difference detection in product packaging, 100, 500, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10,000 images were randomly selected as experimental data in the product packaging image database.

4.1 Experimental indicators

On the basis of the above experimental data, a comparative validation experiment is carried out. The experimental scheme is set as follows: to compare the methods mentioned with those of Su (2020), Xie et al. (2020) and Xing et al. (2019), taking the correct recognition rate of training samples, the time complexity of the algorithm, and the absolute error rate as the experimental comparison indicators.

1 *Correct rate of training samples*: Correct rate of training samples of colour samples in product packaging refers to the degree of similarity between training results of different methods and actual results. The higher the correct rate of training samples, the higher the effectiveness of the method.

2 *Time complexity of the algorithm*: The time complexity of the algorithm refers to the time spent in identifying the same amount of sample data, the shorter the time consumed indicates that the lower the time complexity of the algorithm, the higher the recognition efficiency of the algorithm.

3 *Absolute error*: Absolute error refers to the absolute error between the recognition result of different methods and the real result. The expression of absolute error rate (r_e) for the colour difference detection of product packaging is:

$$r_e = \frac{|n - n_0|}{M \times N} \times 100\% \quad (16)$$

where n represents the number of pixels in the colour image of the outer package of the product obtained through the threshold segmentation algorithm, n_0 represents the number of target pixels obtained under the ideal segmentation condition, and $M \times N$ represents the size of the colour image of the outer package of the product to be divided, namely the total number of pixels.

4.2 Correct recognition rate of training samples

In order to verify the correct recognition rate of the training samples for product packaging colour, the methods of Su (2020), Xie et al. (2020) and Xing et al. (2019) and this paper are used to verify the correct recognition rate of the training samples for product packaging colour. The results are shown in Table 1.

Analysis of Table 1 shows that the correct rate of colour difference detection is different under different methods. When the number of pixels of product packaging image is 1000, the correct rate of colour difference detection of product packaging in Su (2020) is 78.6%, the correct rate of colour difference detection of product packaging in Xie et al. (2020) is 82.3%, the correct rate of colour difference detection of product packaging in Xing et al. (2019) is 76.0%, and the correct rate of colour difference detection of product packaging in this paper is 99.6%.When the number of pixels of product packaging image increases to 10,000, the correct rate of colour difference detection of product packaging based on Su (2020) is 64.3%, the correct rate of colour difference detection of product packaging based on Xie et al. (2020) is 67.2%, the correct rate of colour difference detection of product packaging based on Xie et al. (2020) is 69.9%, and the correct rate of colour difference detection of product packaging based on this method is 97.2%. This method always has a high colour difference detection accuracy, and can effectively detect the colour difference of product packaging. This is because this method uses the threshold segmentation method to detect the colour difference of product packaging, and uses the local enhancement method to extract the colour difference pixels, which improves the accuracy of colour difference detection of product packaging.

Table 1 Correct rate of colour sample training for product packaging under different methods

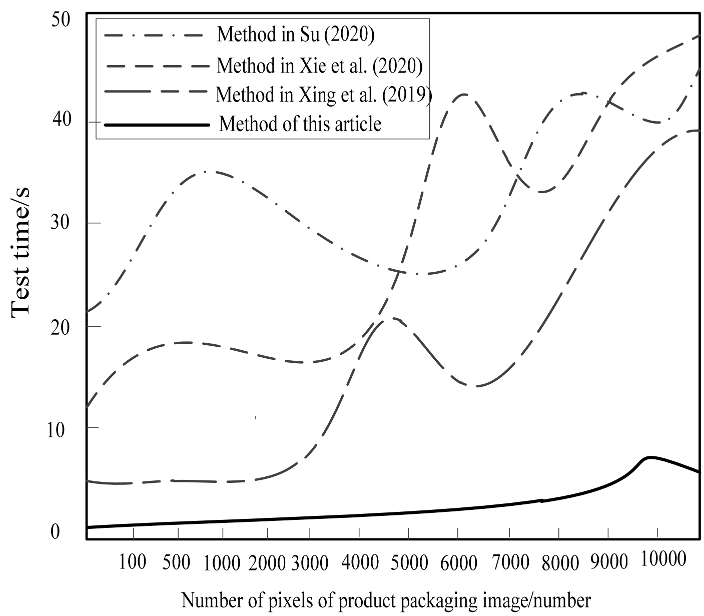
Number of pixels of product packaging image/number	*Correct rate of colour sample training for product packaging/%*			
	Su (2020) method	*Xie et al. (2020) method*	*Xing et al. (2019) method*	*Method of this paper*
100	86.0	82.0	79.0	99.0
500	82.0	79.0	81.0	98.0
1000	78.6	82.3	76.0	99.6
2000	80.5	79.4	78.5	99.5
3000	78.5	76.3	77.8	98.4
5000	76.3	72.6	75.2	99.9
6000	75.4	75.3	78.6	99.6
7000	72.6	76.2	74.2	97.8
8000	68.4	72.9	73.6	98.6
9000	65.8	70.6	78.8	96.8
10,000	64.3	67.2	69.9	97.2
Mean value	75.3	75.8	76.6	98.6

4.3 Time complexity comparison of algorithms

In order to verify the efficiency of this method for detecting colour difference in product packaging, Su (2020), Xie et al. (2020) and Xing et al. (2019) and the time complexity ratio of this method are used to detect colour difference in product packaging. The results are shown in Figure 3.

It can be seen from Figure 3 that when the number of pixels of the product packaging image is 3000, the time for detecting the colour difference of the product packaging with the method of Su (2020) is 29 s, the time for detecting the colour difference of the product packaging with the method of Xie et al. (2020) is 16 s, the time for detecting the colour difference of the product packaging with the method of Xing et al. (2019) is 8 s, and the time for detecting the colour difference of the product packaging with the method of this paper is 1.5 s.When the number of pixels of the product packaging image is 10,000, the time for detecting the colour difference of the product packaging with the method of Su (2020) is 39 s, the time for detecting the colour difference of the product packaging with the method of Xie et al. (2020) is 46 s, the time for detecting the colour difference of the product packaging with the method of Xing et al. (2019) is 38 s, and the time for detecting the colour difference of the product packaging with the method of this paper is 6 s. This method has shorter detection time and higher detection efficiency. This is because this method can determine the direction projection value of product packaging colour area block, and realise product packaging image feature extraction through binary energy map, which effectively reduces the time complexity of product packaging colour difference detection.

Figure 3 Time complexity of colour difference detection in product packaging under different methods



4.4 Absolute error rate

In order to verify the effect of this method on colour difference detection of product packaging, the methods of Su (2020), Xie et al. (2020) and Xing et al. (2019) and this method are used to detect the colour difference of product packaging correctly. The absolute error ratio of the four methods is compared as shown in Table 2.

It can be seen from Table 2 that the absolute error rate of colour difference detection of product packaging is different under different methods. When the product packaging image pixel number is 100, the method of Su (2020) of product packaging colour difference detection absolute error rate is 36%, the method of Xie et al. (2020) of product packaging colour difference detection absolute error rate is 45%, the method of Xing et al. (2019) of product packaging colour difference detection absolute error rate is 33%, the method of product packaging colour difference detection absolute error rate is 0.When the product outer packing to 5000 the number of image pixels, and the method of Su (2020) of product packaging colour difference detection absolute error rate is 30.8%, the method of Xie et al. (2020) of product packaging colour difference detection absolute error rate is 28.9%, the method of Xing et al. (2019) of product packaging colour difference detection absolute error rate is 42.6%, the method of product packaging colour difference detection absolute error rate of 0.07%.The absolute error rate of the method presented in this paper is always lower than that of the other three traditional methods, which can effectively detect the colour difference of the outer package of products.

Table 2 Absolute error rate of colour difference detection in product packaging under different methods

Number of pixels in the image of the outer package of the product/number	*Absolute error rate of colour difference detection in product packaging/%*			
	Su (2020) method	*Xie et al. (2020) method*	*Xing et al. (2019) method*	*Method of this paper*
100	36	45	33	0
500	43	42.5	26	0.2
1000	28.9	38.9	26.5	0.01
2000	25.7	39.6	33.5	0.05
3000	21.6	42.1	38.6	0.11
5000	30.8	28.9	42.6	0.07
6000	18.9	26.7	36.8	0.15
7000	21.6	23.8	32.5	0.21
8000	22.8	22.6	29.7	0.56
9000	28.1	31.7	21.7	0.64
10,000	25.7	30.0	19.7	0.87
Mean value	27.6	33.8	30.9	0.26

5 Conclusion

In this paper, a colour difference detection method of product packaging based on local enhancement is proposed. The image features of product packaging are extracted by binarisation energy graph, the colour difference detection of product packaging is carried out by threshold segmentation method, and the difference pixels are extracted by local enhancement method to realise colour difference detection of product packaging. The following conclusions are drawn through the experiment:

1 The method presented in this paper always has a high accuracy rate of colour difference detection. When the number of pixels in the image of product packaging increases to 10,000, the accuracy rate of colour difference detection of product packaging by the method presented in this paper reaches 97.2%.

2 The detection efficiency of the method presented in this paper is high. When the number of pixels in the image of the outer package of the product is 10,000, the detection time of colour difference of the outer package of the product by the method presented in this paper is only 6 s.

3 The method presented in this paper can effectively and accurately detect the colour difference of product packaging. When the number of pixels of product packaging image increases to 5000, the absolute error rate of colour difference detection of product packaging by this method is only 0.07%.

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