Research on Color Vision Tool Design Based on Detection Algorithms

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Abstract: Accurate identification can quickly determine the state of the target, which is of great significance in both military and industrial production. This article designs several sets of experiments based on detection algorithms to evaluate the applicability and operational efficiency of color detection tools. The experimental results show that, compared with the color detection tool in Cognex DIP, the color detection tool basically meets the design requirements and is equivalent in efficiency to the reference software. It can be applied to military target recognition and industrial applications.

1 INTRODUCTION

In the field of military applications, accurately identifying targets can improve rapid response capabilities, and accurately identifying unexploded ordnance can provide accurate positioning. Therefore, rapid recognition technology has broad application space and significant practical significance in the future. The design of color visual tools mainly includes two aspects: firstly, color feature extraction; The second is the measurement of color difference. In the conventional design field, the hue component (H component) in the color space based on human visual characteristics represents the fundamental color, i.e. the main wavelength of the spectrum. The distribution of the hue histogram represents the overall color distribution of the target (Ma Rui-qing, 2019). When identifying non functional targets or the product coloring is incorrect, it will be reflected on the hue histogram. Therefore, by comparing the difference in hue histograms between the current target image and the template image, it is determined whether the current product coloring is correct (or acceptable), and then the target is identified and distinguished.

2 DESIGN REQUIREMENTS

The design requirements for color visual tools mainly include the following aspects: 1) Color feature selection: Provide at least one color feature for color detection. 2) Color difference measurement: provide at least one color difference measurement method. 3) Applicability: It can be applied to several application scenarios, such as identifying military targets or inspecting the coloring degree of industrial products. 4) Job efficiency: It is equivalent to the reference software in terms of work time scale, at the same level of magnitude. According to the design principles and requirements, develop a basic algorithm for color detection, as shown in Figure 1 (Safdar, 2017).

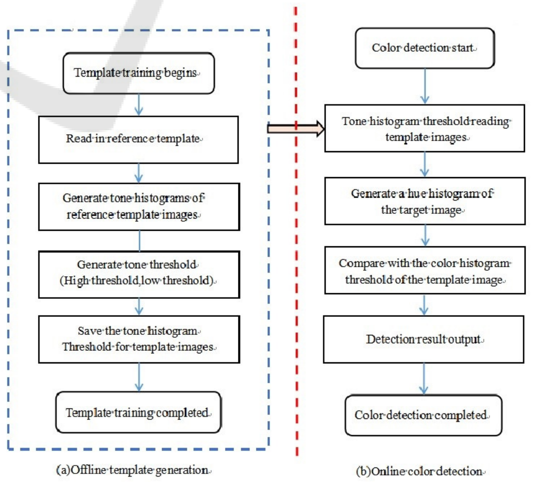

Figure 1: Basic framework diagram of color detection algorithm.

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3 COLOR FEATURE EXTRACTION

Color features mainly refer to the description of the color information of an image (or product), such as how much red it contains and how much blue it contains. Although the RGB color space also contains color information, it is difficult to quantify and the expression is not intuitive enough. The hue components in HSI color space intuitively describe basic color information. The statistical histogram distribution based on hue components represents the overall color distribution of the product, therefore, hue histograms can be used as color features for color detection.

3.1 HSI Color Space

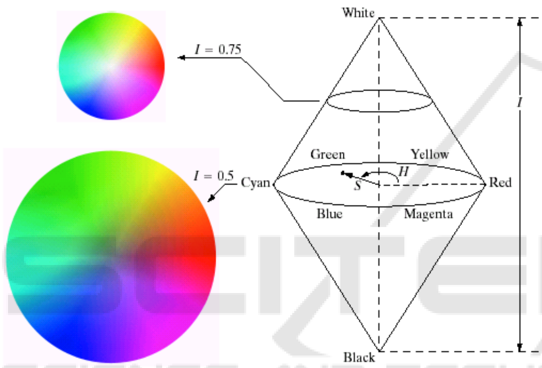


Figure 2: HSI color space.

The HSI color space separates the intensity of colors from color information, which is determined by light intensity, while color information is described by two parameters: hue and saturation. Hue represents the basic color, which is the main wavelength of the spectrum. Saturation is a measure of the purity of a color, representing the amount of mixed white light in the color, which is the ratio of peak height to the entire spectral distribution. The geometric description of the HSI color space is shown in Figure 2, which is a cylindrical coordinate space (Shamey, 2015). The color tone in the figure is described as the angle between the ray formed by the center of the cylinder and the color point to the reference line, with a range of 0°~360°; Saturation is described as the ray distance from the color point to the center of the cylinder; Brightness is expressed as the axial height, and the plane perpendicular to the brightness axis in a cylinder is a first order brightness plane. The mapping relationship between HSI color space and RGB color space is:

$$H = \begin{cases} \theta, if & B \le G \\ 360-\theta, if & B > G \end{cases},$$
$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\} \quad (1)$$

$$S = 1 - \frac{3}{(R+G+B)}\min\{R,G,B\}; \quad (2)$$

$$I = (R+G+B)/3 \quad (3)$$

For the convenience of processing, the range of values for the H, S, and I components is uniformly adjusted to [0,255].

3.2 Tone Histogram and Filtering Processing

The hue histogram of an image is a one-dimensional discrete function

$$h(k) = n_k, k = 0,1,\cdots,255 \quad (4)$$

Among them, $h(k)$ is the image hue histogram, n_k is the sum of the hue values in the image equal to the number of k pixels, and the hue value range of the image is [0,255].

(a) Input RGB image (b) Color tone histogram of input RGB

Figure 3: Hue histogram.

Figure 3 shows a schematic diagram of an image tone histogram. The rectangular area of the image shown in Figure 3 (a) mainly contains two tones, one is blue as the background and the other is green as the target. Figure 3 (b) is a hue histogram of the rectangular area of the image in Figure 3 (a). It can be seen from the graph that the two peaks in the hue histogram correspond exactly to blue and green. Therefore, tone histograms can effectively reflect the content of a certain color in an image.

According to formula (2), when the pixel saturation is very low, that is, the color is close to neutral gray, and its three RGB components are very close, the hue value calculated using formula (1) is easy to shake, and it contains very little color information. Therefore, pixels with saturation below a certain threshold *SatThr* do not participate in the statistics of hue histograms.

From Figure 3 (b), it can be seen that due to the influence of noise, there are usually many small spikes in the tone histogram. To improve the anti noise interference ability of color detection, smooth denoising can be performed on the tone histogram.

Gaussian filter is the most widely used low-pass filter. The mathematical expression of one-dimensional zero mean Gaussian function is:

$$g(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}; \quad (5)$$

Among them, σ is the width control parameter of Gaussian function.

For discrete signals, set the filter width to W, the half width of the filter is $W_h = \mathrm{Int}(\frac{W}{2})$, $Int(\cdot)$is the Rounding Function, then $\sigma = W_h/4$. The formula for constructing filter coefficients is:

$$f(i) = g(i)/a, i = -W_h, -W_h + 1, \ldots, W_h; \quad (6)$$

Among them,$a = \sum_{j=0}^{W_h} g(j)$.

Filtering the tone histogram with a Gaussian filter is essentially a convolution calculation as follows:

$$h'(x) = \sum_{i=-a}^{a} f(i)h(x + i); \quad (7)$$

Among them, $h(x)$ is the hue histogram before filtering, $h'(x)$ is the filtered hue histogram, $f(i)$ is Gaussian filter, $a = -W_h$, $x = 0,1, \cdots ,255$.

For the convolution of equations (7), the boundary filling strategy cannot use the conventional nearest neighbor filling strategy. From the color bars in the tone histogram, it can be seen that the red tones at both ends of the histogram are physically continuous, but are artificially separated during mathematical representation. Therefore, it is necessary to consider this physical characteristic when filling the boundary, and thus equation (7) is improved to:

$$h'(x) = \sum_{i=-a}^{a} f(i)h((x + i + L)\%L); \quad (8)$$

Among them, L is the length of the hue histogram data, % is the modulo operation.

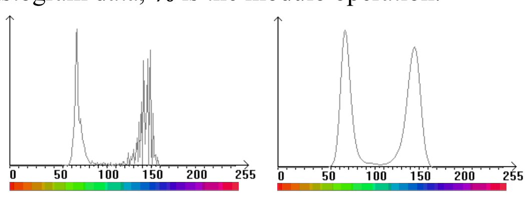


Figure 4: Comparison of tone histograms before and after filtering.

Figure 4 is a comparison diagram of the tone histogram before and after filtering, from which it can be seen that the small peaks in the original tone histogram are well smoothed.

4 COLOR DIFFERENCE MEASUREMENT

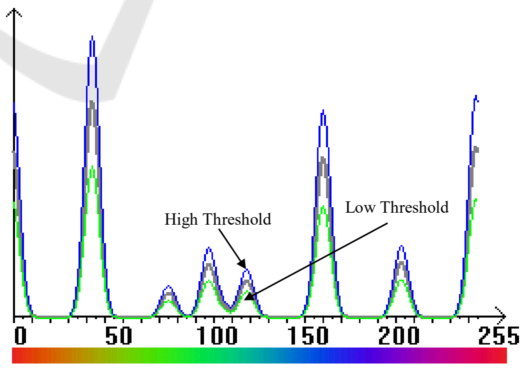
According to the above description, the steps for measuring the difference in tone histograms are:1) generating high and low thresholds for tone histograms based on the tone histograms of the template image; 2) Compare the high and low thresholds of the target image's hue histogram with the template image's hue histogram, and count the number of out of tolerance hues (Xiao,2011).

The threshold of the hue histogram can be determined by the percentage of upper and lower deviations. Set the color tone histogram of the template image is $H_M(k)$; the percentage of upper deviation is P_{up}; the lower deviation percentage is P_{low} ; the high and low threshold of the hue histogram can be determined as:

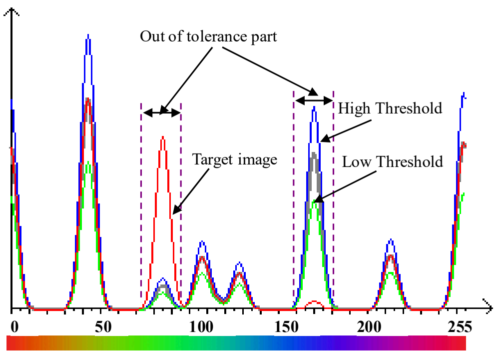
$$HThr_{up}(k) = (1 + P_{\mathrm{up}})H_M(k); \quad (9)$$

$$HThr_{low}(k) = (1 - P_{\mathrm{low}})H_M(k); \quad (10)$$

Among them, $HThr_{up}(k)$ represents high threshold for tone histogram,$HThr_{low}(k)$ represents low threshold for tone histogram.



(a)



(b)

Figure 5: Tone histogram threshold diagram and out of tolerance diagram.

Figure 5 (a) is a schematic diagram of the high and low threshold values of the hue histogram when the percentage deviation between the upper and lower parts is 30. The advantage of calculating the high and low threshold through the percentage of upper and lower deviations is that it takes into account the inherent frequency of a certain color tone in the template image, that is, the allowable deviation of a higher frequency color tone is relatively large, as shown in Figure 5 (a).

Set the hue histogram of the target image as $H_T(k)$, the number of out of tolerance tones can be calculated using the following formula:

$$N = \sum_{k=0}^{L-1} \mathrm{Count}\big(H_T(k) < \mathrm{HThr}_{\mathrm{low}}(k) \;\; OR \;\; H_T(k) > \mathrm{HThr}_{\mathrm{up}}(k)\big); \tag{11}$$

Among them, N represents the number of out of tolerance tones. $\mathrm{Count}(\cdot)$ represents a counting function, 1 is counted when the conditions in parentheses are met, otherwise 0 is counted.

Figure 5 (b) is a schematic diagram of the color tone histogram out of tolerance. From it, it can be seen that the target image has a difference in blue and green tones.

In summary, the overall process of the color detection algorithm is shown in below, which mainly includes:

Step 1. ROI Editing Tool: used to define ROI regions. If there is no ROI region definition, color detection is directly performed on the entire image.

Step 2. Color Space Conversion: Transfer the RGB color space of the image to the HSI color space.

Step 3. Generate Initial Tone Histogram: Generate an initial tone histogram based on H, S components, and saturation thresholds.

Step 4. Initial Tone Histogram filtering: construct a Gaussian filter according to the half width of the filter and filter and smooth the initial tone histogram.

Step 5. Generate Hue Histogram Threshold: Based on the percentage of upper and lower deviations, generate the template image hue histogram high and low thresholds.

Step 6. Measurement of Hue Histogram Difference: Compare the hue histogram of the target image with the high and low threshold of the template image hue histogram, and count the number of out of tolerance hues.

Step 7. Detection Result Judgment: If the number of out of tolerance tones is greater than the given threshold, the image color is judged to be out of tolerance and the out of tolerance tone information (standard value and out of tolerance amount) is returned; Otherwise, it is judged that the image color is not out of tolerance.

5 EXPERIMENTAL DESIGN AND ANALYSIS

5.1 Applicability Evaluation

The applicability mainly refers to the applicability of color detection tools to various applications. Two sets of experiments were designed to evaluate their applicability: 1) detecting typical Demo images in Cognex DIP; 2) Detect offset printing images. The detection parameters of LLV(Luster Light Vision) and Cognex are shown in Table 1.

Table 1: Applicability Evaluation Test Parameters.

LLV		Cognex DIP	
Parameter Type	Parameter value	Parameter Type	Parameter value
ROI	Full graph	ROI	Full graph
saturation threshold	10	saturation threshold	608
Upper deviation percentage	20	Upper deviation percentage	20
Lower deviation percentage	20	Lower deviation percentage	20
Filter half width	14	Smoothing factor	4
Over tone threshold	30	Over tone threshold	30

1)Detect Demo images in Cognex DIP

Figure 6 (a) (b) shows two demo images in Cognex DIP, with Figure 6 (a) as the template image and Figure 6 (b) as the target image.

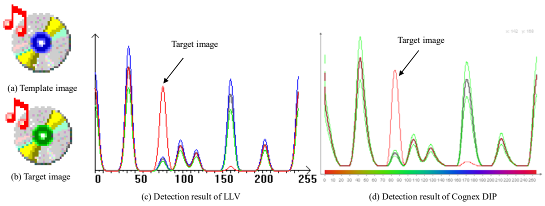


Figure 6: Demo image and two detection results.

Figure 6 (c) (d) shows the detection results of the image in Figure 6 (a) (b), where Figure 6 (c) is a histogram representation of the detection results of LLV, and Figure 6 (d) is a histogram representation of the detection results of Cognex. Comparing these two histogram representations, it can be seen that both detect that the target image has more green and less blue compared to the template image, which is completely consistent with the test image. LLV detected 46 out of tolerance tones, Cognex detected 46 out of tolerance tones, and the number of out of tolerance tones was consistent.

2)Detect Offset Printing Images

Figure 7 shows the offset printing image, where Figure 7 (a) is the template image, Figure 7 (b) is the target image 1, which belongs to the same batch of products as the template image, and Figure 7 (c) is the target image 2, which is not the same batch of products as the template image.

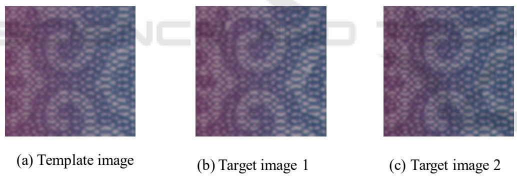


Figure 7: Offset printing image.

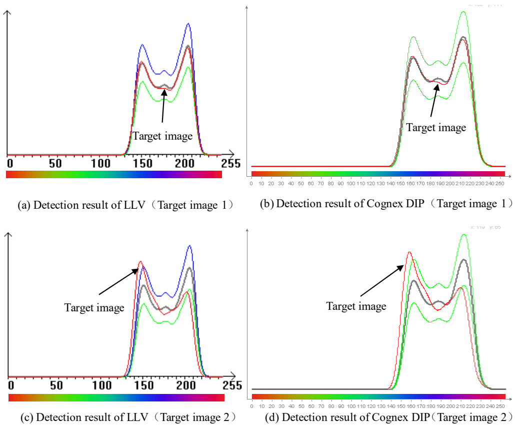


Figure 8: Detection results of offset printing image.

Figures 8 show the detection results of the images in Figures 7. For target image 1, LLV detected 12 out of tolerance tones, while Cognex detected 9 out of tolerance tones; For target image 2, LLV detected 48 out of tolerance tones, while Cognex detected 44 out of tolerance tones. The number of out of tolerance tones is basically the same, and the subtle differences are mainly caused by different histogram filtering strategies, which do not affect the detection results. For target image 1, the detection results are all good; For target image 2, the detection results are all defective products.

3)Efficiency Evaluation

Detection efficiency is also an important focus of color detection tools. Test the efficiency of color detection on the images in Figures 7, which image format is 119×116.

The testing environment is a Pentium 4 CPU with a main frequency of 2.8GHz, 1GB Byte of memory, Windows XP operating system, and the compilation environment is VC6.0 Release version. Table 2 provides a list of the time required for color detection by LLV and Cognex respectively. From it, it can be seen that the time consumption of LLV is equivalent to that of Cognex DIP.

Table 2: Time consumption for color space conversion under different high-order byte bits (ms).

Time consumption list		**LLV**	**Cognex DIP**
Sub item time consumption	Color Space Conversion	4.03	2.37
	Histogram filtering	0.06	
	Histogram comparison and out of tolerance detection	0.01	
Total time consumption		4.10	

6 CONCLUSION

From the aforementioned experiment, the following basic conclusions can be drawn:

Capable of effective color detection of typical demo images and offset images in Cognex DIP;Under equivalent parameter settings, the number of out of tolerance tones detected by LLV is basically the same as the number of out of tolerance tones detected by Cognex DIP. The time consumption of LLV is equivalent to that of Cognex DIP.

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