

Separating Color and Identifying Repeat Pattern Through the Automatic Computerized Analysis System for Printed Fabrics*

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This study proposes a novel analysis system for printed fabrics that can automatically make color separation and identify repeat patterns. The system uses a scanner to obtain red, green and blue (RGB) color images of printed fabrics and then convert them into hue, saturation, intensity (HSI) color images. In order to obtain color separation, a genetic algorithm is used to search for a smaller sub-image with the same color distribution, and then the color separation is conducted by use of the recursive region splitting method. Then carry out another Fuzzy C-means (FCM) calculation on the HSI image using the color clusters (cluster number) and values (cluster centers) obtained from separating the colors of sub-images to quickly classify colors for the pixels. Pixels of different color categories are marked with different gray levels. In this way, a polychromatic pattern image is formed. For identifying repeat patterns, first, a template matching method is applied to discover distributions of same pattern elements. Then, the Hough transform method is used to obtain the cutting positions and dimensions of the repeat patterns in the polychromatic pattern image. Next, the images of the repeat patterns are extracted out from the polychromatic images. Finally, the repeat units of the black pictures are generated based on the color categories and they are expanded to become black pictures that can be used to make plates. According to the experimental results, this system can rapidly and automatically separate colors and identify repeat patterns of images on printed fabrics.

Keywords: color separation, repeat patterns, Hough transform, template matching, printed fabrics

1. INTRODUCTION

Printed fabrics are high value-added textiles that have richer colors and more variations than other kinds of textiles. Color patterns on printed fabrics are created by printing patterns repeatedly with different color plates and through color register. In manufacturing or analyzing fabrics, how to separate color and identify the repeat patterns are the most important. In conventional printing processes, color separation, identification of repeat patterns, painting of black pictures, and plate making are all conducted manually requiring large amounts of labor. Currently, the computer-aided separation system used for fabrics is to conduct a color reduction on color images of fabrics, and the color cor-

Received January 13, 2006; revised May 1, 2006; accepted June 21, 2006.

Communicated by H. Y. Mark Liao.

* The authors gratefully acknowledge the support for the project provided by National Science Council of Taiwan, R.O.C., under project No. NSC 93-2216-E-011-019.

rection is carried manually out on the computer; that is, the color and pattern correction is managed on incorrect pixels in the images and the black pictures used for printing are generated according to color categories [1, 2]. Although this computer-aided separation system saves time over conventional manual operations, it can only provide this advantage of the supplementary separation, and it cannot achieve completely automation since it is not able to identify repeat patterns. Thus, a computer visual system for printed fabrics would be a substantial aid to this industry.

The printed color patterns are created only with a small number of colors. It is the yarn structure on the textile surface that makes the distribution of color complicated. Moreover, since the pattern elements that constitute repeated patterns are larger in size and rather limited in number, they form patterns of a low number of repetition times. To comply with the machinery that prints horizontally and vertically, the repeated patterns for printed textiles must be rectangle-shape. In terms of reference literature, none is found on the subject on printed color patterns. However, there are studies on autocorrelation, Fourier transform, or co-occurrence matrices to detecting periodic pattern [3-5], which are related to the repeated patterns. Autocorrelation, among them, is more suitable for analyzing patterns with a low number of repetition times. However, this method produces rhombus-shaped repeated patterns, making it difficult both to produce repeated patterns that have a fixed cutting point and to further analyze pattern elements that constitute the repeated patterns [6]. Recently, our research has focused on color separation and identification of repeat patterns on printed fabrics, and for the color separation, an unsupervised color clustering was conducted on the RGB image of printed fabrics [7]. In order to enhance the accuracy and efficiency of color separation, a recursive region splitting method was used in the HSI image of printed fabrics to carry out an unsupervised color separation as well [8]. Nonetheless, this method is still incapable of dealing with the color separation problem in large-area printed images in a proper way. In the research on repeat-pattern, a genetic algorithm was used in RGB image of printed fabrics to search for the rectangular images of repeat patterns. But since there were no fixed types obtained from the repeat patterns undertaken, no further analysis was possible on their composition and structure [9]. Subsequently, the method used was that after RGB images are separated, an unsupervised classification would be conducted over pattern elements, and then from the fabric's pattern images, distributions of the same pattern elements were identified. Finally, a Hough transform method was utilized to carry out a cutting of repeat patterns [10]. Nonetheless, this method fails to properly deal with the category problem in pattern elements that occur after rotation and when the shape features are too close.

This study moves one step further by proposing an automatic computer analysis system for printed fabrics, combining color separation with repeat-pattern identification. This system features the ability to quickly obtain the colors clusters and color values by separating colors using the recursive region splitting method on smaller sub-images of the same color distribution for color inquiry. In terms of the function of identifying repeated patterns, this system runs another FCM calculation on large-area printed images to quickly separate colors, overcoming the difficulty of long and complicated calculations that are required for unsupervised color separation on large-area color images. Moreover, to simplify the process of identifying the same pattern elements and to lock up the locations thereof, this study adopts the template-matching method to quickly locate pattern elements that have exactly the same colors, shapes, and orientation for cutting

repeated patterns. Hence, the main structure of this study is to use a scanner to obtain RGB images of fabrics and pre-processes the images by a median filter, then convert them into HSI images. In color separation, a genetic algorithm is first utilized to derive a smaller sub-image with identical color distribution from the original image. Then, a recursive region splitting method is carried out for separation to enhance the precision of color separation. Finally, color clusters (cluster number) and values (cluster centers) are obtained. To identify repeat patterns, the template-matching method is used to identify the pattern elements distribution with identical color, shape, and orientation. After that, a Hough transform is used to derive a straight line that connects the centers of identical pattern elements to achieve cutting of repeat patterns. Finally, a repeat unit of black pictures is generated according to color categories and then expanded to become black pictures used for plate making.

2. RESEARCH METHODS

2.1 HSI Color Space

The most frequently used color image is the hardware-oriented RGB color space, which is directly obtained by a scanner. It would be difficult for users to distinguish or describe which color is represented by a certain set of RGB since the color sensation of human eyes is presented to define the color value in HSI color space. However, this space can be obtained by converting from the RGB color space, and the relevant formula is as follows [11]:

$$\begin{aligned} I &= (R + G + B)/3, \\ S &= 1 - \min(R, G, B)/I, \\ H &= \cos^{-1} \left[\frac{(R - G) + (R - B)}{2\sqrt{(R - G)^2 + (R - B)(G - B)}} \right], \end{aligned} \quad (1)$$

if $B > G$ then $H = 360^\circ - H$.

The distance (d) between two points in HSI color space is defined as follows:

$$d = \sqrt{(I_1 - I_2)^2 + (S_1 \cos(H_1) - S_2 \cos(H_2))^2 + (S_1 \sin(H_1) - S_2 \sin(H_2))^2}. \quad (2)$$

2.2 Genetic Algorithm

Genetic algorithms are stochastic search algorithms that mimic the process of natural selection and genetics. A basic genetic algorithm makes use of three genetic operators: selection, crossover, and mutation. The selection operator is based on the survival-of-the-fittest strategy, but the key idea is to select better individuals of those remaining in the population. A commonly used strategy to select pairs of individuals is the roulette-wheel selection. The crossover operator involves the swapping of genetic material (bit values) between the two parent strings. In single-point crossover, a bit position along the two strings is selected at random and the two parent strings exchange their genetic material.

The mutation operator alters one or more bit values at randomly selected locations in casually selected strings. This introduces variability into the population, and provides a mechanism to escape from local optima [12].

2.3 Fuzzy C-Means (FCM) Clustering Method

The FCM algorithm was originally introduced by Jim Bezdek [13], in order to optimize the following objective function:

$$J = \sum_{i=1}^c \sum_{j=1}^n u_{ij}^m d_{ij}^2 \quad (3)$$

where c is the number of clusters, $u_{ij} \in [0, 1]$ expresses the membership degree of the data point x_j belonging to the i th cluster, $d_{ij} = \|w_i - x_j\|$ is the Euclidean distance between i th cluster center (w_i) and j th data point (x_j), and $m \in (1, \infty)$ is a weighting exponent which influences the fuzziness of the clusters [14].

2.4 Template Matching

In template matching, the template is shifted over all possible locations (x, y) in pattern image and a similarity measurement is used to compute between the template and pattern image [15]. A higher position in similarity indicates that the color patterns at that position are more similar to the template. Similarity measurement of each position is indicated in the similarity coefficients, the calculation of which is explained in the following equation:

$$\text{Similarity coefficient at the } (x, y) \text{ position} = \frac{\text{the number of same color pixels between the template and pattern image at the } (x, y) \text{ position}}{\text{the total pixels on the template}} \quad (4)$$

2.5 Hough Transform

The Hough transform is an algorithm that will take a collection of points and find all the lines on which these points lie [16, 17]. In a polar representation of a straight line is given by:

$$\rho = r \cos \theta + c \sin \theta. \quad (5)$$

In row and column (r, c) -based image space, we can define that line by ρ , the distance from the origin to the line along a perpendicular to the line, and θ , the angle between the r -axis and the ρ -line. Now, for each pair of values of ρ and θ we have defined a particular line in (r, c) -based image space. The (ρ, θ) parameter space is divided into a specific number of blocks. Each block corresponds to a line in (r, c) parameter space. If we expect only a single line, we restrict peak detection to the maximum peak in (ρ, θ) parameter space. If we want all significant lines, we set a threshold for the peak accumulation.

3. EXPERIMENTAL METHODS

The software MATLAB[®] [18] is used to develop this system. The experimental materials are a three-color printed fabric and a two-color printed fabric. Explanations on steps of the experiment flowcharts in this study, as shown in Fig. 1, are as follows.

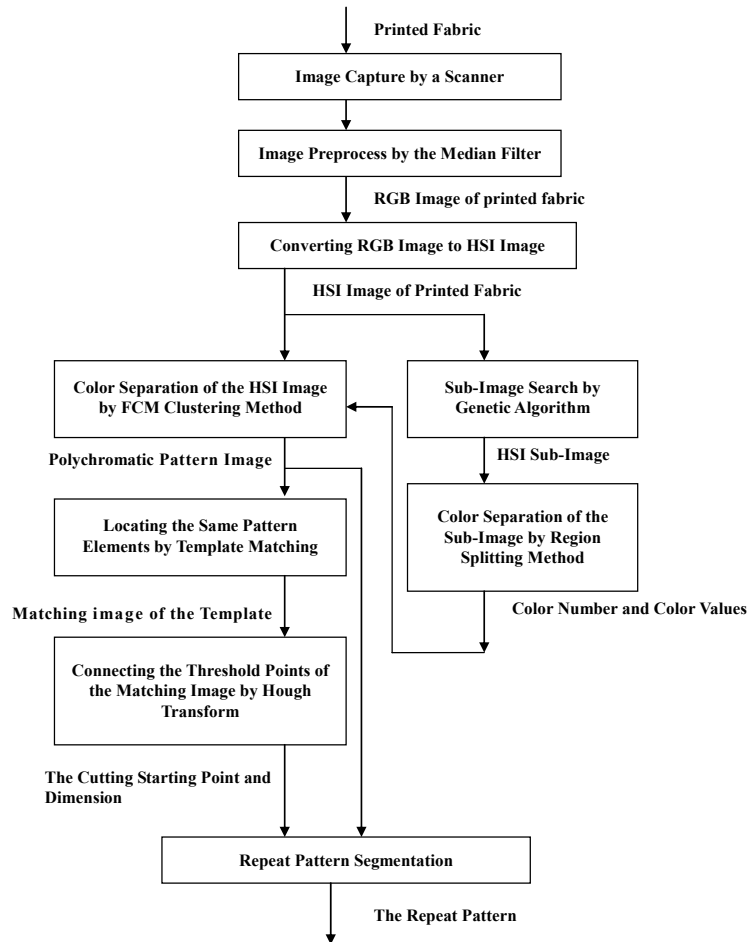


Fig. 1. The experiment flowchart.

3.1 Image Capture by a Scanner

The size of fabrics are 7in × 7in. An EPSON scanner 2400 PHOTO with resolution of 125 dpi is used to digitize the image of printed fabric in RGB mode.

3.2 Image Preprocess by the Median Filter

In order to reduce the color differentiation caused by undulated weaving structure

on the fabric's appearance, the 3×3 median filters are applied to preprocess the RGB images. The median filtering is accomplished by sorting color values of the pixels within the mask and selecting the pixel with the medium value [19].

3.3 Converting RGB Image to HSI Image

The Eq. (1) can be used to transform the RGB color space to HSI color space. Hue (H) has a range of values between 0° to 360° with red at 0° , saturation (S) is a ratio that ranges from 0 to 1; and intensity (I) also ranges between 0 and 1.

3.4 Sub-Image Search by Genetic Algorithm

To substantially reduce the tedious algorithm calculation, the genetic algorithm is used to automatically search for smaller sub-image that can be used to replace the image color of the original printed fabrics for carrying out the subsequent color separation algorithm to obtain the color clusters (cluster number) and values (cluster centers). Stated below is the genetic algorithm process:

- (1) Set the initial parameter for genetic algorithm: The total species of each generation is 40 counts and the genetic composition of each species is (X, Y, DX, DY) , where (X, Y) are the coordinates of sub-image. In addition, the genetic number is coded by 9-bit length, while (DX, DY) represent the size of sub-image and the genetic number is coded by 7-bit length. To prevent the size of the searched image being too small and reducing the correctness of color separation, the width and height of the smallest sub-image are limited to over 200 pixels.
- (2) To search for the sub-image having the same color distribution as the original image, the histogram intersection proposed by Swain and Ballard [20] is used to carry out the color similarity measure for the sub-image and the original image. To obtain this histogram, the HSI color space is segmented into 113 distinct colors, or [(12 hues * 3 saturations) * 3 layers + 5 grays], for further number coding. The histogram intersection between the sub-image and the original one will be defined as follows:

$$S = \frac{\sum_{j=1}^n \min(H(I_Q, j), H(I_D, j))}{\sum_{j=1}^n H(I_D, j)} \quad (6)$$

where:

S : Color similarity.

$H(I_Q, j)$: Number j bar value of sub-image (I_Q) in the histogram.

$H(I_D, j)$: Number j bar value of original image (I_D) in the histogram.

n : Total color counts.

- (3) The color similarity (S) is calculated by Eq. (6). The range of color similarity values are between 0 and 1. As the value approaches 1, the similarity becomes higher. The

area ratio (P) is derived by dividing the area of the original image with the area of the sub-image. Eq. (7) is used to calculate the fitness function (E) of each species, which is derived by color similarity (S) and area ratio (P).

$$\text{IF } (S > 0.995) \text{ THEN } E = S + P \text{ ELSE } E = S \quad (7)$$

- (4) In Eq. (8), the roulette-wheel selection is used to calculate the count of each species that can be reproduced to the next generation.

$$N_i = \frac{f_i}{\sum f_i} \times N \quad (8)$$

Where:

N_i : Number i species count to be reproduced.

f_i : Fitness function value of Number i species.

N : Total count of each species generation.

$\sum f_i$: Fitness function value for total of the entire species.

- (5) The crossover between species is conducted by single-point crossover method to produce the next generation.
- (6) Two species are randomly selected from such generation family for performing the genetic mutation of one bit.
- (7) Record the best species genetic combination of this generation, *i.e.* (X, Y, DX, DY) values.
- (8) Repeat steps 1 to 7 until the area ratio (P) over 4, then obtain the optimal (X, Y, DX, DY) values.

3.5 Color Separation of the Sub-Image by Region Splitting Method

To enhance the precision of color separation, the region splitting method is used for color separation. The image is segmented into two sub-regions in a recursive manner until the homogeneity of each sub-region has reached the threshold value and the region cannot be segmented any further [21, 22]. In practice, the FCM algorithm with two clusters is adopted to automatically segment the region into two sub-images. The procedure can be described as follows:

- (1) Take the entire image as an individual region.
- (2) Split the region into two sub-regions by means of the FCM method with two clusters. The FCM method will be conducted by the following steps:
 1. Set the cluster number as $C = 2$; the weighting exponent, $m = 1.5$; the terminative precision, $\varepsilon = 0.000001$; and counter, $t = 1$.
 2. Initialize the fuzzy C -partition.
 3. Update the centers matrix (W), using

$$w_i = \frac{\sum_{j=1}^n (u_{ij}^*)^m x_j}{\sum_{j=1}^n (u_{ij}^*)^m}, \text{ for } 1 \leq i \leq c. \quad (9)$$

4. Update the memberships degree matrix (U), using

$$u_{ij} = \left[\sum_{k=1}^c \frac{\|x_j - w_i\|^{2/(m-1)}}{\|x_j - w_k\|^{2/(m-1)}} \right]^{-1}. \quad (10)$$

5. If $|U^{(t+1)} - U^{(t)}| \leq \varepsilon$ then stop, otherwise $t = t + 1$ go to step 3.

- (3) In the two sub-regions thus obtained, the morphological operations will be operated for the erosion and dilation, respectively, with the 2×2 pixels structuring element in order to eliminate the isolated points.
- (4) Acquire the color statistical value of these two sub-regions, including the mean value and standard deviation of intensity (M_I, S_I), the mean value and standard deviation of saturation (M_S, S_S), and the mean value and standard deviation of hue (M_H, S_H).
- (5) Conduct homogeneity test for these two sub-regions respectively to determine if further segmentation is required, and this test shall include the inspection of 2 lines of mean and deviation homogeneity criteria, as described below:

IF $[M_S \geq 0.1]$ and $[S_H < 10^\circ]$ THEN stop ELSE split. (11a)

IF $[M_I < 0.15 \text{ or } M_I > 0.85 \text{ or } M_S < 0.1]$ and $[S_I < 0.1]$ THEN stop ELSE split. (11b)

- (6) Repeat steps 2 to 5 until the color homogeneity of all sub-regions has exceeded the designed threshold value, *i.e.* no more sub-regions can be segmented.

3.6 Color Separation of the HSI Image by FCM Clustering Method

Run another FCM calculation on the HSI image using color clusters (cluster number) and color values (cluster centers) obtained from the previous step to quickly obtain the color categories for the pixels. Pixels of different color categories are then marked with different gray levels to facilitate differentiation. In this way, a polychromatic pattern image is formed.

3.7 Locating the Same Pattern Elements by Template Matching

The repeat pattern consists of a set of pattern elements, and it is continuously duplicated for a complete print pattern. If the distributions of pattern elements with identical color, shape, and orientation can be identified, the repeat patterns in a complete printed pattern can be obtained. To do that, first, set the color that covers the greatest measure of area on the polychromatic pattern image as the background color. That leaves all other

color categories with front-ground colors, *i.e.* color categories of the pattern elements. Stated below is the template-matching algorithm process:

- (1) From the polychromatic pattern image, select the largest independent pattern element as the template.
- (2) Conduct the similarity coefficient calculation for the template and the polychromatic pattern image by Eq. (4).
- (3) Using 0.9 as the threshold value, then locate the pattern element that is similar to the template image to derive the threshold points.

3.8 Connecting the Threshold Points on the Matching Image by Hough Transform

If the distribution of the same pattern elements can be found out, and the corresponding vertical and horizontal distance whenever this repeat pattern element can be measured, then the size of the repeat pattern can be acquired. Because the lines we are looking for are straight lines structure that are horizontal and vertical in the direction of the same pattern elements, we use the Hough transform to obtain plus/minus 5° of horizontal and vertical lines. The algorithm of this Hough transform consists of 4 steps:

- (1) The parameters for calculation are to set 0.1° for the angle increment ($\Delta\theta$) and 1 pixel for distance increment ($\Delta\rho$).
- (2) For each threshold point (r, c), input the values for r and c into the line Eq. (5). Then, for each value of θ ($+5^\circ \sim -5^\circ$) and ($85^\circ \sim 95^\circ$), solve for ρ and record the corresponding (ρ, θ) pairs in the quantized space.
- (3) The straight lines that connect pattern elements can be obtained at (ρ, θ) parameter space with mean value as its threshold.
- (4) Reconstruct the straight lines where the pattern element centers lies.

3.9 Repeat Patterns Segmentation

The cutting position for both HSI image and polychromatic pattern image are the coordinate points derived by intersecting the first horizontal line and the first vertical line in the previous step. The average distance between the horizontal and vertical lines, which connect the same pattern elements, is the height and width of the repeat pattern.

4. RESULTS AND DISCUSSION

Fig. 2 shows the HSI image obtained after scanning and preprocessing the three-color printed fabric, and the size is 875×875 pixels. Fig. 3 shows the sub-image searched by genetic algorithm having same color distribution as Fig. 2 and the size is 649×201 pixels, which the area ratio (P) is 5.9. In other words, this sub-image consists of 16.9% measure of area in the original image. This greatly reduces the calculation time in the successive algorithm for color separation. Shown in Fig. 4 (a), the image in Fig. 3 is split into two sub-regions, represented by sub-region A_1 and sub-region A_2 respectively. The sub-region A_1 has successfully segment red regions from Fig. 3. Table 1 shows that further

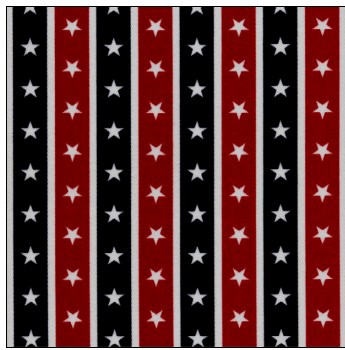


Fig. 2. HSI image of the three-color printed fabric.



Fig. 3. Sub-image having same color distribution as the Fig. 2.

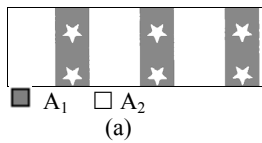


Fig. 4. (a) Binary color separation result of the Fig. 3; (b) Binary color separation result of the Fig. 4 (a).

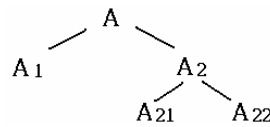
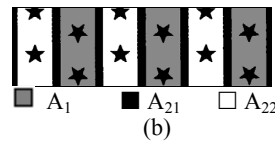


Fig. 5. The binary tree structure of the color separation.

segmentation would be required for sub-regions A_2 , since the color homogeneity is below the threshold value. Fig. 4 (b) shows the result of further split computation for sub-region A_2 , represented by sub-region A_{21} and sub-region A_{22} respectively, which has successfully segment the white and black regions from Fig. 3. Furthermore, Table 1 also indicates that the color homogeneity of these two color groups has exceeded the threshold value and so further segmentation would no longer be required. The entire splitting process is indicated in Fig. 5.

Fig. 6 (a) is a polychromatic pattern image derived from a re-categorization of pixels in Fig. 2 by using the FCM algorithm with 3 color values in Table 1 as the clustering centers. Moreover, since correct color clusters (cluster number) and values (cluster centers) have been obtained, the FCM algorithm only needs to be run once to separate colors, saving a lot of time for calculation. Compared to Fig. 2, Fig. 6 (a) accurately marks clusters of each pixels and generated the polychromatic pattern image. Fig. 6 (b) is made by eliminating incomplete pattern elements on the image edge and choosing the biggest one as the template from independent pattern elements in Fig. 6 (a). Fig. 7 (a) is a result from matching the template with the polychromatic pattern image. As the figure reveals, it is clear that the template matching method is effective in differentiating star-shaped patterns similar to the templates and the rotary star-shaped patterns. The white spots in Fig. 7 (b) have been extracted from Fig. 7 (a) with 0.9 as the threshold value of the similarity

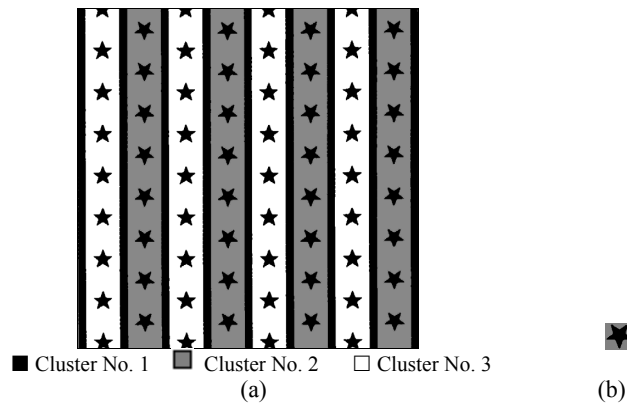


Fig. 6. (a) The polychromatic pattern image of the Fig. 2; (b) The template image.

Table 1. Statistic values of each sub-region.

| Sub-Region | Cluster No. | M_H | M_S | M_I | S_H | S_S | S_I | Area (%) |
|-----------------|-------------|--------|-------|-------|--------|-------|-------|----------|
| A ₁ | 2 | 358.1° | 0.87 | 0.25 | 5.2° | 0.07 | 0.03 | 35 |
| A ₂ | – | 214.3° | 0.17 | 0.44 | 108.3° | 0.13 | 0.41 | – |
| A ₂₁ | 1 | 166.2° | 0.03 | 0.89 | 147.8° | 0.07 | 0.08 | 29 |
| A ₂₂ | 3 | 253.3° | 0.27 | 0.09 | 5.1° | 0.05 | 0.04 | 36 |

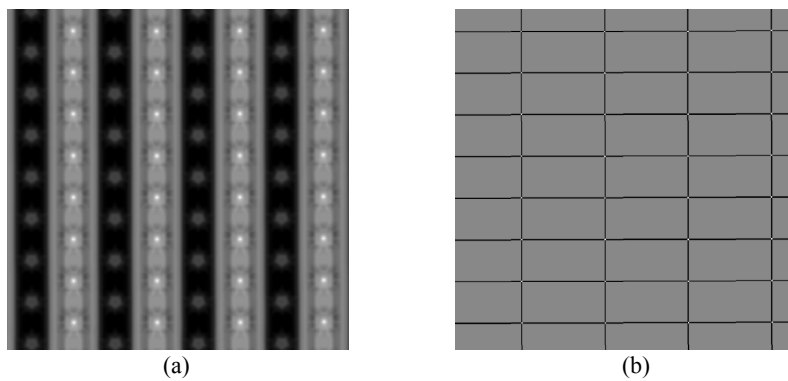


Fig. 7. (a) The image of template matching; (b) The image with vertical and horizontal connecting lines and the threshold points.

coefficient. These white spots represent the locus of same pattern elements with the template, and the black straight lines are obtained by connecting these white spots horizontally and vertically by means of the Hough transform method. In Fig. 7 (b) the average space of the vertical lines is 213 pixels, which represents the width of repeat patterns; and the average space of the horizontal lines is 107 pixels, which represents the height of repeat patterns Fig. 8 (a) is a repeat color image extracted from Fig. 2, while Fig. 8 (b) is the repeat pattern image extracted from Fig. 6 (a). The cutting position for both is the coordinate point (168, 56) derived by intersecting the first horizontal line and the first



Fig. 8. (a) Repeat image of the Fig. 2; (b) Repeat pattern of the Fig. 6 (a).



Fig. 9. (a) The repeat unit of black pictures of color cluster 3.

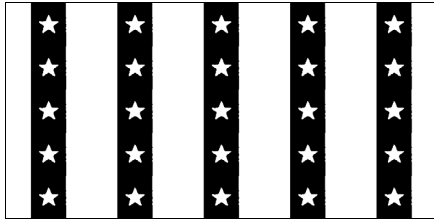


Fig. 9. (b) The black picture for plate making that has been enlarged five times in length and width.



Fig. 10. (a) The repeat unit of black picture of color cluster 2.

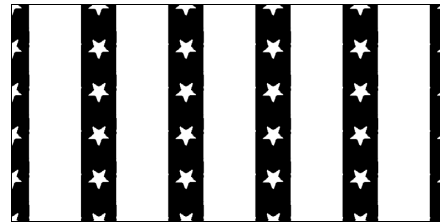


Fig. 10. (b) The black picture for plate making that has been enlarged five times in length and width.

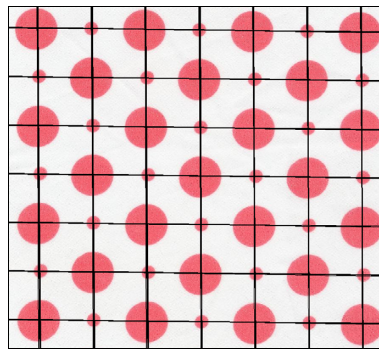


Fig. 11. The image of two-color printed fabric with the connecting line.

vertical line, with the cutting width and height being 213×107 pixels. Since printed fabrics are usually printed on white fabric, the sample fabrics in this study needed for plate making are color cluster 2 and color cluster 3 in Fig. 6 (a). Fig. 9 (a) is a black picture made by extracting color cluster 3 from Fig. 8 (b), with the black pixels representing color cluster 3 pixels. Fig. 9 (b) is an enlarged image from Fig. 9 (a) that can be used for plate making. Fig. 10 (a) is a black picture made by extracting color cluster 2 from Fig. 8 (b), with the black pixels representing color cluster 2 pixels. Fig. 10 (b) is an enlarged image from Fig. 10 (a) that can be used for making the plate.

Since the edge of printed fabric indicates the vertical direction of printed patterns, the images do not tilt too much in scanning. However, it is still possible for slight tilt to appear the moment when the cloth being placed. Hence, the Hough transform algorithm in this study is set to launch a search within an angle range of $\pm 5^\circ$ on horizontal and ver-

tical lines to identify repeated rectangle-shape patterns. As shown in Fig. 11, there are patterns arranged in the rhombus-shaped order and the two-color printing that is slightly tilted. The black lines in the figure link the center points of the same pattern elements obtained using the abovementioned method. This proves that the method adopted in this study functions is able to produce the needed rectangle-shape repeated patterns even with different pattern arrangements and to cope with slightly tilted images.

5. CONCLUSIONS

According to the above results, this system can rapidly and successfully complete color separation and identification of repeat patterns for printed fabrics images. This study can simultaneously or singly meet the requirements of color analysis and pattern analysis on printed color images.

When only the color analysis is required, this study obtains the sub-images of the same color distribution by means of genetic algorithm. Since the sub-images are small in measure of area, the method of unsupervised color separation can be adopted to obtain the number of color and color values quickly. In this way, the color variation in small-area images will be smaller than those in large-area images to overcome the difficulty in color separation, improve accuracy in color separation, and greatly reduce calculation time.

To identify repeated patterns, colors in large-area printed color images must be separated first. A quick way to do so is by taking the number of color and color values obtained in the abovementioned color analysis as the cluster number and clustering centers to do the FCM Algorithm calculation once only on large-area images. In this way, the difficulty in carrying out time-consuming recursive calculations on large-area color images will be conquered. Because each pixel in the printed color images has been categorized, the pixel value of each category will also be marked with gray levels to form gray scale images (polychromatic pattern image) and to facilitate the follow-up pattern analysis. This method is easier than conducting repeated pattern analysis directly on color images, while producing more accurate results. In terms of identification of repeated patterns, this study adopts template-matching method to locate the center points of pattern elements that have the same colors, shapes, and orientation. This method differs from others in that it directly replaces black-and-white image (monochromatic pattern image) template matching with gray-scale image (polychromatic pattern image) template matching, thus simplifying the procedure of template-matching method. Moreover, this method has a higher degree of tolerance on shape variation of pattern elements. Not only does it reduce the difficulty in categorizing and identifying pattern elements, but it also distinguishes pattern elements that are rotary. Finally, Hough transform is adopted for drawing horizontal lines and vertical lines that link up the center points of the same pattern elements. By doing so, the height, width, and the coordinate point necessary for cutting rectangle-shape repeated patterns could be obtained. By using Hough transform to detect the ($+ 5^\circ \sim - 5^\circ$) and ($85^\circ \sim 95^\circ$) straight lines, even if the images are slightly tilted or that the center points of some elements are not correctly cut, the horizontal lines and vertical lines can still be drawn by linking the center points of the same pattern elements.

Finally, because black pictures for plate making can be generated, this system's practicability is enhanced. This system may also be further combine with automatic manufacturing equipment to further increase the level of automation for printed fabrics processes.

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