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Yarn-Dyed Fabric Image Retrieval Using Colour Moments and the Perceptual Hash Algorithm

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Abstract
Due to the variety of yarn colours and arrangement, it is a challenging problem to retrieve a yarn-dyed fabric image. In this paper, yarn-dyed fabric samples are captured by the DigiEye system first, and then pattern images of the fabric images captured are simulated by pattern design software based on extracted structure parameters of the yarn-dyed fabric. For the simulated pattern image, an effective algorithm is proposed to retrieve these kinds of images by combining the colour moments method and perceptual hash algorithm. Then the pattern images retrieved are mapped back to the yarn-dyed fabric image so as to realise the yarn-dyed fabric image retrieval. In the algorithm proposed, the colour moments method is adopted to extract the colour features, and the perceptual hash algorithm is utilised to calculate the spatial features of the simulated pattern images. Then the two kinds of image features are used to compute the similarity between the input original image and each target image based on the Euclidean distance and Hamming distance. Relevant images can be retrieved in dependence on the similarity value, which is determined by calculating the optimum weighted value of the colour features' similarity and spatial features' similarity. In order to measure the retrieval efficiency of the method proposed, the accuracy rate and retrieval rate of image retrieval were computed in experiments using a PATTERN image database with 300 images. The experimental results show that the average accuracy rate of the method proposed is 85.30% and the retrieval rate – 53.51% when the weighted value of the colour feature similarity is fixed at 0.45 and the spatial feature similarity is 0.55. It is shown that the method presented is effective to retrieve pattern images of yarn-dyed fabric.

Key words: *yarn-dyed fabric, image retrieval, colour moments, perceptual hash algorithm, Hamming distance.*

Introduction

In recent years, with the development of multimedia information processing technology, the trend of utilising advanced multimedia processing methods in real world problems is beginning to emerge [1, 2]. As one of the key techniques, image retrieval, which focuses on finding images from a large image set to meet users' needs, has received considerable attention in research and industry [3-5].

Yarn-dyed fabric, which is interwoven with dyed warp yarn and dyed weft yarn in a periodic arrangement, consists of yarn-dyed plaid fabric and striped fabric. Due to the variety of yarn colours and arrangement, yarn-dyed fabrics are more and more colourful. With the higher demands on clothing appearance, yarn-dyed fabrics are playing an increasingly important role in the textile market. As a result, all kinds of yarn-dyed fabrics are being developed by textile factories. However, as the types of yarn-dyed fabric increase, product management and retrieval are getting more complex and tedious. Therefore, an effective fabric retrieval method can greatly improve a factory's production efficiency and bring huge economic benefits to a factory. The traditional methods of obtaining yarn-dyed fabric can be categorised into two groups: 1) The manual method, in which actual fabric samples, which are labeled and classified by a manual, are stored in a warehouse. And then a required relevant fabric can be found by a human based on the label and category. However, this method requires to preserve a large number of product samples. It not only takes up a lot of space but also the colour of samples may fade as time goes by. Furthermore, it is time-consuming work; 2) Keywords-based image retrieval. In this method, fabric images, which are described by some keywords, are saved in a database. Then the fabric image required can be obtained by inputting some relevant words. Although this method can retrieve some similar fabrics, single keyword searching cannot meet complex fabric image retrieval requirements.

In order to establish an effective and accurate image retrieval system for fabric, many image retrieval algorithms have been proposed based on image content. Low-level features, for example, colour, texture, shape and space relationship, etc. are always utilised to retrieve an image from existing research projects. Jing etc. [6] proposed a printed fabric image retrieval algorithm based on colour moments and the gist feature description method. In their works, image features were extracted by the two methods first, and then the similarity between query image features and the feature database was computed from the Euclidean distance. The experimental results indicated that the algorithm proposed was more effective and accurate than other hybrid schemes for printed fabric images in terms of precision and recall. However, this algorithm cannot be used for retrieving a yarn-dyed fabric image because of the gist features of yarn-dyed fabric images are too similar to each other. Thus, it is difficult to retrieve a yarn-dyed fabric image according to this method. Zhang etc. [7] presented a method of lace fabric image retrieval based on the multi-scale and rotating invariant LBP. In their study, the Multi-Scale and Rotation Invariant Local Binary Pattern (MRI-LBP) feature was extracted based on the texture of the lace image. However, the texture features of a yarn-dyed fabric image are not obvious because the repetition of texture is too strong [8], which leads to the texture feature of the ordinary pixel being difficult to extract from the yarn-dyed fabric image. Zand etc. [9] proposed an approach that used the Gabor wavelet and curvelet transforms to classify and retrieve a texture image. A fitting method was applied

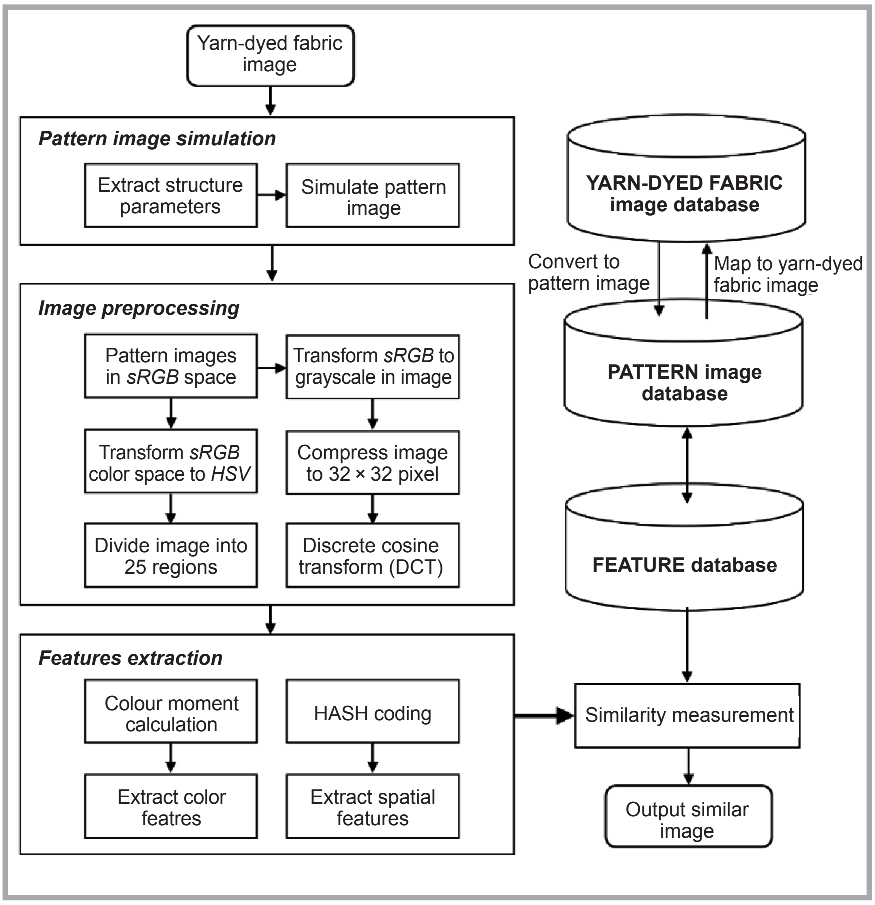

Figure 1. *Flow chart of yarn-dyed fabric image retrieval.*

to encode sub-band information in polynomial coefficients to create a texture feature vector with the maximum power of discrimination. In their research, a fabric image as part of a texture image was also retrieved. Although the experiments demonstrate the effectiveness of the approach proposed, their method requires high image resolution, and the retrieval rate of the method proposed is not high.

Currently, there is no report on image retrieval for yarn-dyed fabric images. Due to the complexity of a yarn-dyed fabric image, it is hard to obtain a good retrieval result by using a real yarn-dyed fabric image. In this paper, an indirect and effective method is proposed to retrieve a yarn-dyed fabric image. Yarn-dyed fabric samples were captured by the DigiEye system first, and then pattern images of the fabric images captured were simulated by pattern design software based on extracted structure parameters of the yarn-dyed fabric. For the simulated pattern image, the colour moments method and perceptual hash algorithm are presented to retrieve these kinds of images. Subsequently, the pattern images retrieved are mapped back to the yarn-dyed fabric image so as to realise the yarn-dyed fabric image retrieval. A flow chart of yarn-dyed fabric image retrieval is shown in ***Figure 1***. In the algorithm proposed, in order to extract the colour features, the simulated pattern images are converted from sRGB colour space to HSV colour space first, then the HSV image is divided into 25 regions, and the colour moments of each region are calculated. In order to extract the spatial features, the sRGB images are transformed into grayscale images first, and then the grayscale images, which are compressed to 32 × 32 pixel, undergo discrete cosine transformation (DCT). The 8 × 8 pixel area of the upper left corner of the resultant images are used to calculate the HASH coding, which represents the spatial features. All the features of the simulated pattern images preserved in the PATTERN image database are extracted and saved in the FEATURE database. As shown in ***Figure 1***, there is a one-to-one correspondence between the YARN-DYED FABRIC image database and PATTERN image database. Finally, the colour feature similarity, spatial feature similarity, accuracy rate, and retrieval rate of image retrieval are computed in experiments to evaluate the retrieval efficiency of the method proposed.

Research methods

Colour space transform

The choices of colour space may have significant influences on the result of image retrieval. There are many kinds of colour space, including sRGB, YCbCr, YUV, HSV, CIE L*a*b*, and CIE L*u*v*. Although sRGB, YCbCr, and YUV colour spaces are commonly used in raw data and coding standards, they are not close to human perceptions [10]. Moreover, CIE colour spaces are perceptually uniform but inconvenient since they require complicated computations. HSV (Hue, Saturation, Value) [11], which is shown to have better results for image retrieval than sRGB colour space, is capable of emphasising human visual perception in hues and has an easily invertible transformation from sRGB [12-13]. Thus, the pattern images of the yarn-dyed fabric are converted from sRGB colour space to HSV colour space first in this paper. The conversion formula is defined as [6]:

$$\begin{cases} V = \max\left(sR, sG, sB\right) \\ S = \begin{cases} \dfrac{V - \min\left(sR, sG, sB\right)}{V} & if\ V \neq 0 \\ 0 & otherwise \end{cases} \\ H = \begin{cases} \dfrac{60(sG - sB)}{V - \min\left(sR, sG, sB\right)} & if\ V = sR \\ \dfrac{120 + 60(sB - sR)}{V - \min\left(sR, sG, sB\right)} & if\ V = sG \\ \dfrac{240 + 60(sR - sG)}{V - \min\left(sR, sG, sB\right)} & if\ V = sB \end{cases} \\ H = H + 360 \quad if\ H < 0 \end{cases} \tag{1}$$

Where, H, S, and V represent the hue, saturation, and brightness in the HSV colour space, respectively, and sR, sG & sB the values of the red, green and blue components in the original image, respectively.

Colour moments

For yarn-dyed fabrics, colour is undoubtedly one of the most important features. It is also one of the most prominent and expressive visual features in colour image retrieval and recognition. On the other hand, the colour feature is not dependent on the size, orientation, viewing angle, translation, rotation, etc. of the image itself and has strong robustness relative to the underlying features, such as texture and shape [14]. Many methods can describe the colour feature, for which the colour histogram has the advantages of speed and not being sensitive to image changes, such as translation, rotation, etc. [15,16]. The colour moment is a very simple and effective method for colour characterisation. It includes the mean (first moment), standard deviation (second moment) and skewness (third moment) of colours. Compared with the histogram, the colour moment method has a lower feature vector dimension. Moreover, colour information is mainly distributed in the low-end moments. Therefore, the first moment, second moment and third moment can be used to express the colour distribution of the pattern image of yarn-dyed fabric. These can be defined as follows [17]:

$$\mu_{m,j} = \frac{1}{N}\sum_{i=1}^{N} P_{i,j} \qquad j = H,S,V$$
$$\sigma_{m,j} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(P_{i,j}-\mu_{i,j}\right)^2\right]^{\frac{1}{2}} \tag{2}$$
$$\zeta_{m,j} = \left[\frac{1}{N}\sum_{i=1}^{N}\left(P_{i,j}-\sigma_{i,j}\right)^3\right]^{\frac{1}{3}}$$

Where, $\mu_{m,j}$, $\sigma_{m,j}$ & $\zeta_{m,j}$ represent the first moment, second moment, and third moment, respectively. and $P_{i,j}$ the probability of the jth colour channel in the mth block matrix of the image. N is the number of pixels in each block matrix. m ($m = 1, 2,\ldots, T$. $T = 25$ in this paper) is the sequence number of the block matrix in the pattern image.

For each pattern image of the yarn-dyed fabric, after feature extraction of the colour moments above, K ($K = T\times 3\times 3$) components can be obtained from the colour feature vector F_{CM}, which can be obtained from ***Equation (3)***.

$$F_{CM} = \begin{bmatrix} \mu_{1,H} & \mu_{1,S} & \mu_{1,V} \\ \sigma_{1,H} & \sigma_{1,S} & \sigma_{1,V} \\ \zeta_{1,H} & \zeta_{1,S} & \zeta_{1,V} \\ \vdots & \vdots & \vdots \\ \mu_{T,H} & \mu_{T,S} & \mu_{T,V} \\ \sigma_{T,H} & \sigma_{T,S} & \sigma_{T,V} \\ \zeta_{T,H} & \zeta_{T,S} & \zeta_{T,V} \end{bmatrix} \tag{3}$$

Perceptual hash algorithm (pHash)

The Mean hash algorithm (aHash) and Perceptual hash algorithm (pHash) are two commonly used hash algorithms. Compared to aHash, pHash is more robust because aHash is very strongly affected by the mean of the grayscale image. For example, gamma correction or histogram equalisation of the image will affect the mean value, which influences the final hash value.

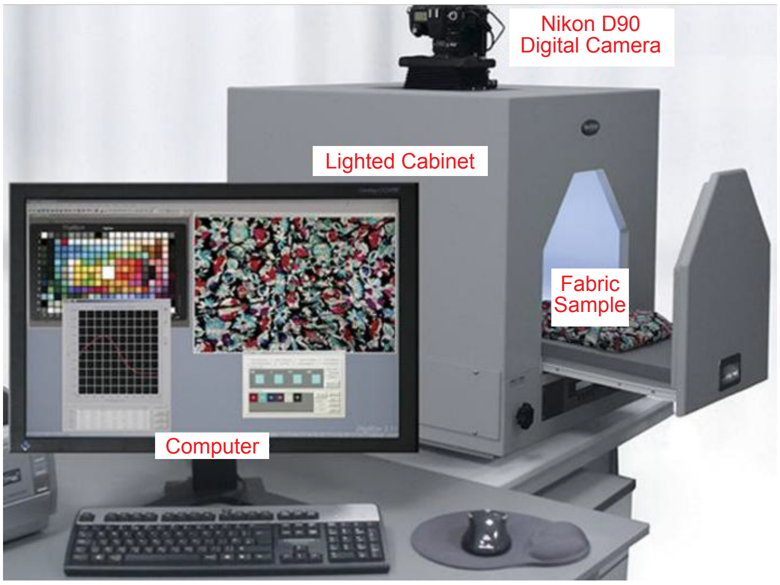

Figure 2. *DigiEye system for image acquisition.*

In the pHash algorithm, the discrete cosine transform (DCT) is applied to obtain the low frequency components of the image. DCT is a kind of image compression algorithm which transforms the image from the pixel domain to the frequency domain. Transformation formulas for the image are depicted in the following equations [18]:

$$F(u,v) = \alpha_u \alpha_v \sum_{x=0}^{H-1}\sum_{y=0}^{W-1} f(x,y) \cdot \cos\frac{\pi(2x+1)u}{2H}\cos\frac{\pi(2y+1)v}{2W} \tag{4}$$

$$\alpha_u = \begin{cases} \frac{1}{\sqrt{H}} & u=0 \\ \sqrt{\frac{2}{H}} & 1\le u\le H \end{cases} \quad u\in[0,H-1] \tag{5}$$

$$\alpha_v = \begin{cases} \frac{1}{\sqrt{W}} & v=0 \\ \sqrt{\frac{2}{W}} & 1\le v\le W \end{cases} \quad v\in[0,W-1] \tag{6}$$

Where, $F(u, v)$ represents the output image frequency coefficient matrix. $f(x, y)$ the input grayscale image, and H & W are the height and width of the image.

In order to obtain the HASH coding, normally the integrated steps of pHash are described as follows[19-20]:

(i) Compress image. pHash starts with a small picture until it is more than 8*8, with 32*32 being the best. The aim is to simplify the calculation of DCT rather than reduce the frequency.

(ii) Convert to grayscale image and compute DCT. The colour image is transformed into a grayscale image, and DCT is utilised to obtain a DCT coefficient matrix of 32*32.

(iii) Reduce DCT. The 8*8 matrix in the upper left corner of the DCT coefficient matrix, which represents the lowest frequency in the image, is applied to extract the frequency coefficient.

(iv) Calculate the hash value. In the DCT 8*8 matrix, if the DCT values are larger than the mean value, the values are set as 1, and conversely set as 0. Then the 0 and 1 values constitute a 64 bit integer called HASH coding, which is the fingerprint of the input image.

Experimental details

Image database

In this paper, 300 yarn-dyed fabric samples, which are from an actual factory, are captured by the DigiEye system [21], and a YARN-DYED FABRIC image database is formed. The DigiEye system (Verivide, UK), which shown in ***Figure 2***, consists of a lighted cabinet, calibrated Nikon D90 digital camera, and computer. It can not only capture the

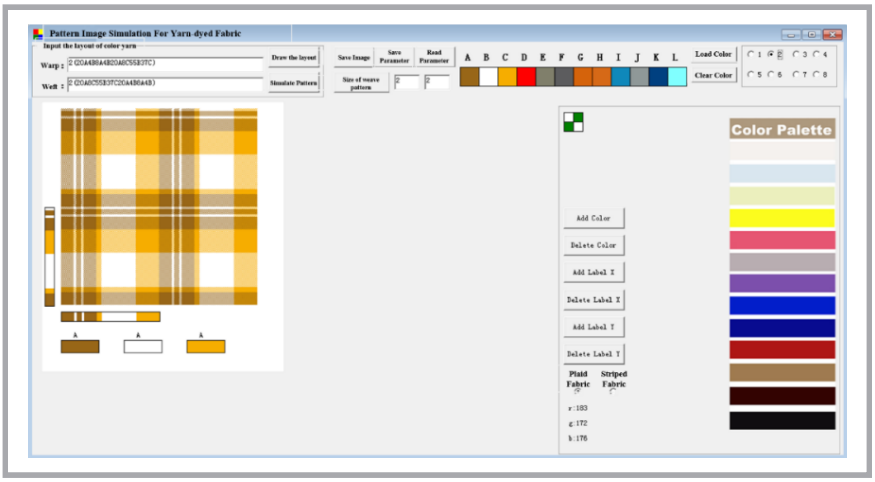

Figure 3. *Interface of pattern image simulation for yarn-dyed fabric.*

image faster and more conveniently than a scanner, but it can also get more accurate colour values.

The yarn-dyed fabric images captured are processed using image processing methods based on previous works [22-25]. Structure parameters of the yarn-dyed fabric, which consist of the yarn colour, the layout of the colour yarn, and the weave pattern, have been determined from these previous works. Then these structure parameters are used to design and simulate the pattern image of the yarn-dyed fabric using pattern design software. The design interface of the software is shown in ***Figure 3***. By using this software, the pattern images of all the yarn-dyed fabric images stored in the YARN-DYED FABRIC image database are simulated based on the following steps:

Step 1: Select the yarn colour (warp and weft yarn), yarn count and weave pattern according to the extraction results of structure parameters from the yarn-dyed fabric's original image.

Step 2: Design yarn arrangement coding according to the layout of colour yarn obtained.

Step 3: Simulate the pattern images of all the yarn-dyed fabric images, and save them in the PATTERN image database.

In the experiment, MATLAB2014b is applied to retrieve the pattern image of yarn-dyed fabric. The processor is a second generation Intel Core i5-2450M dual-core 2.5 GHz, which has an 8 GB RAM running memory. The yarn-dyed fabric images which are stored and represented by sRGB colour space are divided into two categories based on their content, namely, yarn-dyed plaid fabric and striped fabric. Two kinds of captured yarn-dyed fabric images and their corresponding pattern images are shown in ***Figure 4***.

Colour feature extraction

In order to extract the colour features, the pattern images of the yarn-dyed fabric are converted from sRGB colour space to HSV colour space first, and then the HSV image is divided into 25 regions,

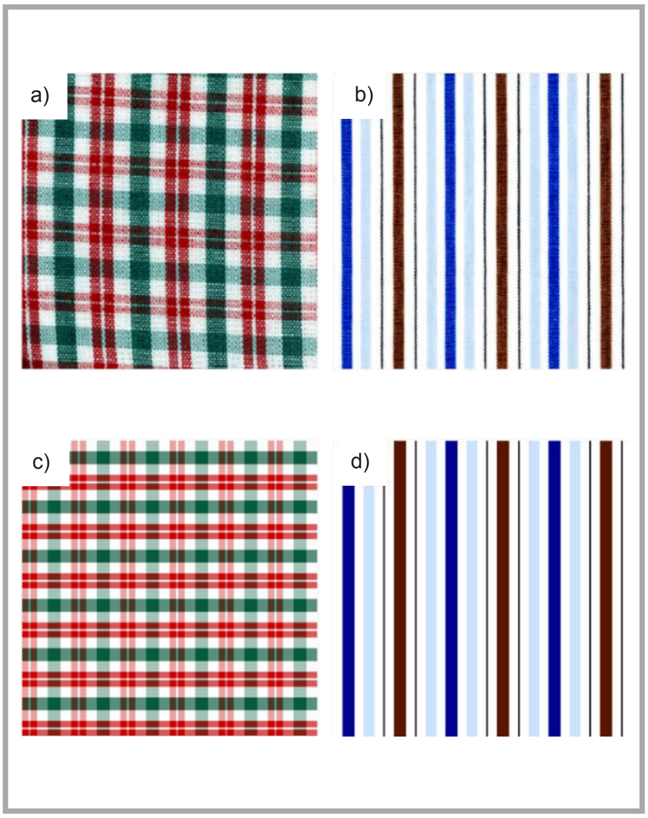

Figure 4. *Two yarn-dyed fabric images and their corresponding pattern images: a) yarn-dyed plaid fabric image, b) yarn-dyed striped fabric image, c) pattern image of image a), d) pattern image of image b).*

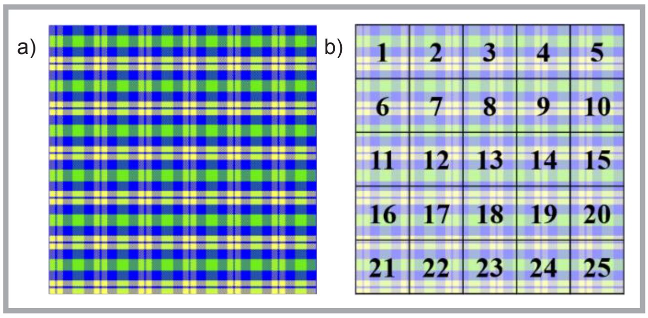

Figure 5. *Schematic diagram of HSV: a) image and b) its 25 regions.*

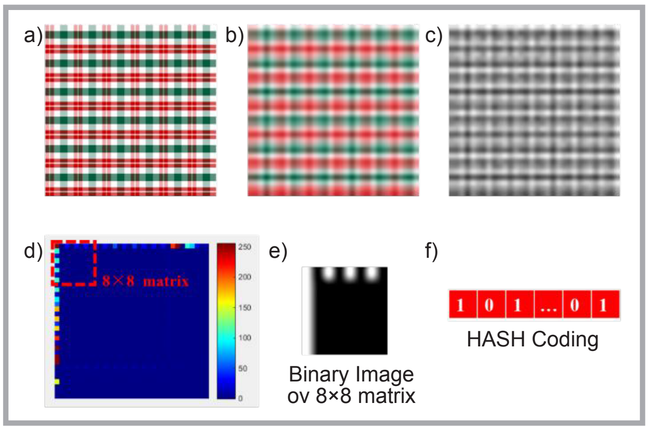

Figure 6. *Extraction procedures and results of the spatial feature: a) the original pattern image, b) compressed image of 32×32 pixels, c) grayscale image of b), d) rendered image after DCT for image c), e) binary image of 8×8 matrix, f) 64 bit HASH coding.*

and the colour moments of each region are calculated. Take ***Figure 4.c*** as an example. A schematic diagram of the HSV image and its 25 regions are shown in ***Figure 5***. The colour moments of 25 regions, shown in ***Figure 5. b***, are calculated and saved in the F_{CM} matrix based on ***Equation (3)***.

Spatial feature extraction

In this part, the integrated steps of pHash, as described in *Perceptual hash algorithm (pHash)* chapter are carried out for extracting the spatial feature of the pattern image. The extraction procedures and results based on ***Figure 4.c*** are shown in ***Figure 6***.

As can be seen from ***Figure 6***, the spatial features of the pattern image are represented by the 64 bit HASH coding. Combining the F_{CM} matrix and HASH coding (denoted as F_{HC} matrix), the colour and spatial features of all the pattern images stored in the PATTERN image database are extracted, and the two feature vectors are saved in the FEATURE database.

Similarity evaluation

The similarity between the images can be measured based on the image feature vectors. The similarity between the different eigenvectors needs to be found by different measurement methods according to the characteristics of the eigenvector itself. In this paper, the similarity degree (SD_{total}) is defined as:

$$SD_{total} = w_1 SD_{CM} + w_2 SD_{HC} \tag{7}$$

Where, SD_{CM} and SD_{HC} represent the colour moment (colour feature) similarity and HASH coding (spatial feature) similarity, respectively. w_1 & w_2 are the weight of two similarities, which are determined experimentally.

For the extracted colour feature, the Euclidean distance is used to measure the similarity between the two F_{CM} matrices of the input image and image database. The similarity degree of the colour feature (SD_{CM}) measurement can be defined as follows [6] ***Equations (8)-(10)***.

Where, F_{CM}^{Input} is the colour moment vector of the input pattern image, and $F_{CM}^{Database}$ the colour moment vector of the image in the retrieval database (PATTERN image database). E_{CM} is the total Euclidean distance in the H, S, and V directions, and ω_H, ω_S & ω_V represent the weights of the each component in the HSV colour model, respectively. It has been indicated that the calculation of SD_{CM} can obtain good result when $\omega_H = 0.25$, $\omega_S = 0.3$ & $\omega_V = 0.25$ [6]. e_j is the Euclidean distance calculated for each colour channel j. $\mu_{m,j}^{Input}$, $\mu_{m,j}^{Database}$, $\sigma_{m,j}^{Input}$, $\sigma_{m,j}^{Database}$, $\zeta_{m,j}^{Input}$ & $\zeta_{m,j}^{Databse}$ represent the mean, standard deviation and skewness of the mth region of the input images and database images in each colour channel j, respectively.

For the HASH coding, the similarity cannot be calculated from the Euclidean distance. For this kind of coding, in this paper the Hamming distance [26] is adopted to calculate the similarity degree of the spatial feature (SD_{HC}) between two F_{HC} vectors as follows:

$$SD_{HC} = \frac{L - \left(\#\left(F_{HC}^{Input} \neq F_{HC}^{Database}\right)\right)}{L} \tag{11}$$

Where, L is the total number of elements in the HASH code (in this paper, $L = 64$). F_{HC}^{Input} and $F_{HC}^{Database}$ are the HASH coding of the input pattern image and database image, respectively, and the symbol $\#(F_{HC}^{Input} \neq F_{HC}^{Database})$ represents the number of different elements between two kinds of F_{HC} matrices.

Retrieval performance evaluation

The accuracy and retrieval rate are the most widely used evaluation criteria for evaluating the performance of image retrieval. The accuracy rate (AR) measures the ability of the retrieval system to retrieve only models that are relevant, which is the ratio of the number of relevant images retrieved from the database to the total number of images retrieved from the database. The retrieval rate (RR) measures the ability of the system to retrieve all models that are relevant, which is the ratio of relevant images retrieved from the database to the total number of relevant images in the database. Formulas for the above-defined are as follows:

$$AR = \frac{s}{s+k} \tag{12}$$

$$RR = \frac{s}{s+v} \tag{13}$$

Where, s is the number of relevant images retrieved from the database. k the number of uncorrelated images retrieved from the database. and v is the number of relevant images which are not retrieved from the image database.

Results and discussion

Different weight values

In order to find an optimum pair of weight values between the colour feature similarity and spatial feature similarity, 300 pattern images simulated based on 300 yarn-dyed fabric images are retrieved one by one. The weight value of colour feature similarity w_1 is set from 0 to 1 in steps of 0.05, and the weight value of spatial feature similarity w_2 is set from 1 to 0 in steps of -0.05. AR and RR are calculated for different weight values. The mean of AR and RR of 300 query results for different weight values are shown in ***Table 1*** and ***Figure 7***.

From ***Table 1*** and ***Figure 7***, it can be seen that the AR and RR value firstly increases and then decreases with an increment of w_1 and decrement of w_2. The peak values of AR and RR curves are equal to 0.8530 and 0.5351, respectively, when $w_1 = 0.45$ and $w_2 = 0.55$. Therefore, in this work, the optimal weight values $w_1 = 0.45$ and $w_2 = 0.55$ are applied to retrieve the pattern image.

Image retrieval results

In order to display the results of image retrieval for the pattern image of yarn-dyed fabric, a GUI interface is built based on MATLAB. Four examples are given in ***Figure 8*** retrieved for randomly selected images as a query to verify the feasibility of the image retrieval method proposed. In these figures, CMPH represents the image retrieval method proposed in this paper.

In the figures above, the top 12 images retrieved by the algorithm proposed are displayed according to the values of SD_{total}

$$SD_{CM}\left(F_{CM}^{Input}, F_{CM}^{Database}\right) = \frac{1}{1 + E_{CM}\left(F_{CM}^{Input}, F_{CM}^{Database}\right)} \tag{8}$$

$$E_{CM}\left(F_{CM}^{Input}, F_{CM}^{Database}\right) = \omega_H e_H + \omega_S e_S + \omega_V e_V \tag{9}$$

$$e_j = \sum_{m=1}^{25}\left(\sqrt{\left(\mu_{m,j}^{Input} - \mu_{m,j}^{Database}\right) + \left(\sigma_{m,j}^{Input} - \sigma_{m,j}^{Database}\right) + \left(\zeta_{m,j}^{Input} - \zeta_{m,j}^{Database}\right)}\right) \quad j = H, S, V \tag{10}$$

Equations (8), (9) *and* ***(10).***

__Table 1.__ Mean of AR and RR of 300 query results for different weight values.

Weight Value (w_1, w_2)	AR	RR	Weight Value (w_1, w_2)	AR	RR
(0, 1)	0.418	0.341	(0.55, 0.45)	0.772	0.491
(0.05, 0.95)	0.695	0.436	(0.60, 0.40)	0.756	0.484
(0.10, 0.90)	0.701	0.440	(0.65, 0.35)	0.732	0.481
(0.15, 0.85)	0.715	0.452	(0.70, 0.30)	0.715	0.476
(0.20, 0.80)	0.739	0.467	(0.75, 0.25)	0.712	0.471
(0.25, 0.75)	0.765	0.481	(0.80, 0.20)	0.712	0.462
(0.30, 0.70)	0.795	0.491	(0.85, 0.15)	0.712	0.461
(0.35, 0.65)	0.812	0.503	(0.90, 0.10)	0.712	0.435
(0.40, 0.60)	0.831	0.505	(0.95, 0.05)	0.714	0.421
(045, 0.55)	0.853	0.535	(1, 0)	0.60	0.25
(0.50 0.50)	0.812	0.532			

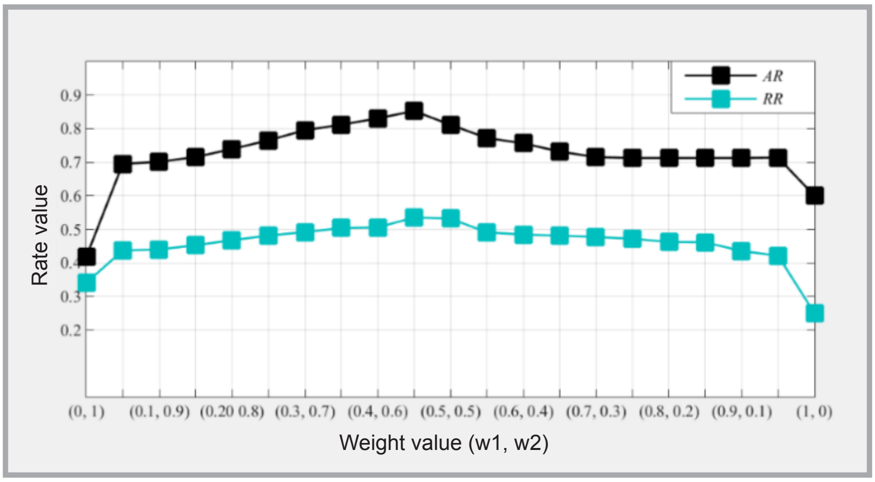

__Figure 7.__ Average AR and RR for different weight values.

from left to right and top to bottom in the GUI interface. From the figures, it can be seen that the retrieval results obtained by using the method proposed seem to consistent with the practical situation. The top 5 images, which have a similar colour and yarn layout, are retrieved first, and then the retieved images with similar spatial features or similar colour features are shown.

Contrast with other methods

To test the retrieval effect of different algorithms on the pattern image, the CH method (image retrieval based on a colour histogram), SURF method [27] (image retrieval based on SURF), and HASH method (image retrieval based on aHash) are selected to compare with the method proposed. An example is given in ***Figure 9*** of retrieval using the four image retrieval methods. As shown in the figure, image retrieval results for the same input image are different using the four methods. ***Figure 9.a*** shows the result of using the CH method based on the statistical characteristics of the image colour. Due to the method losing colour spatial distribution information, the image retrieval results are very different. ***Figure 9.b*** shows the results of using the SURF operator to retrieve a pattern image, which

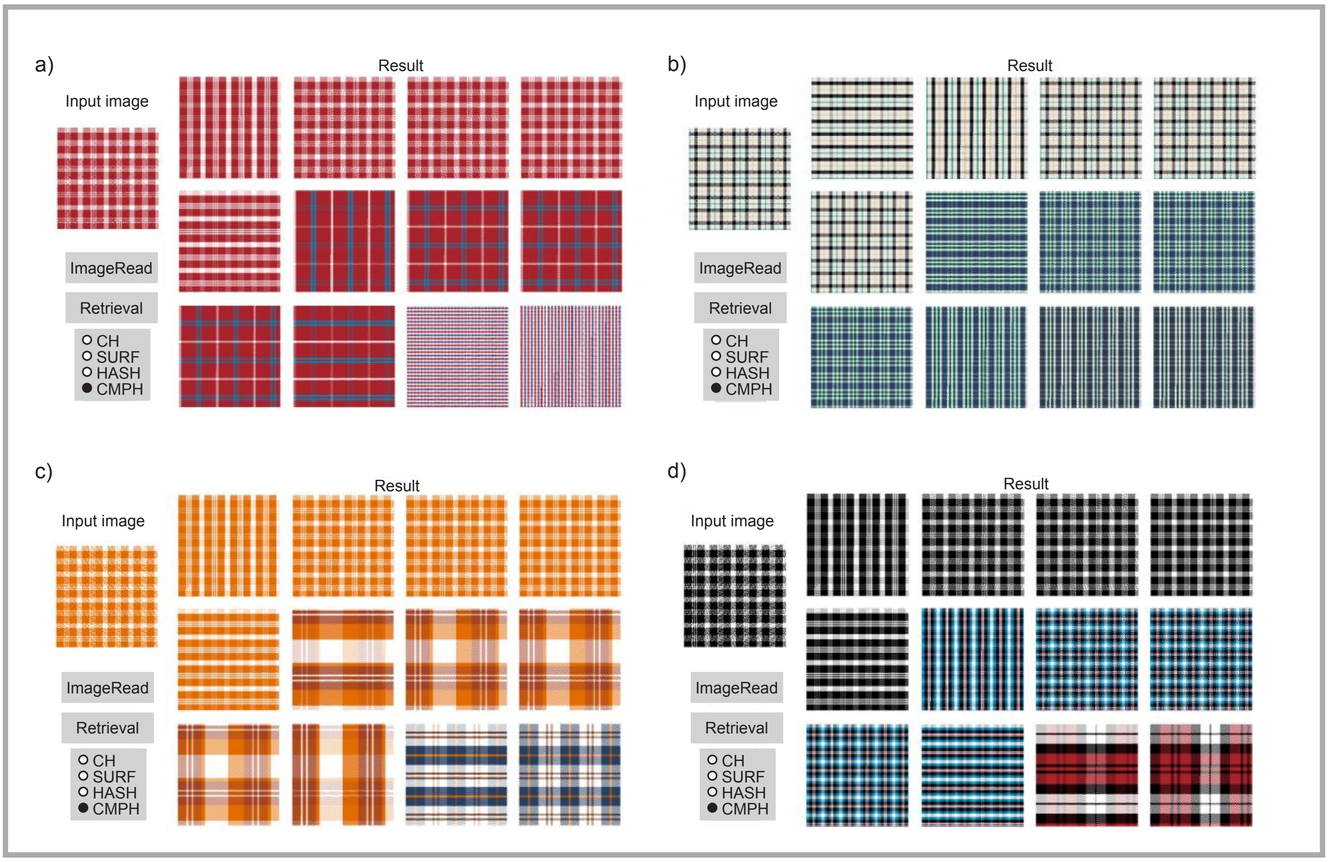

__Figure 8.__ Four examples of image retrieval results: a) example 1, b) example 2, c) example 3, d) example 4.

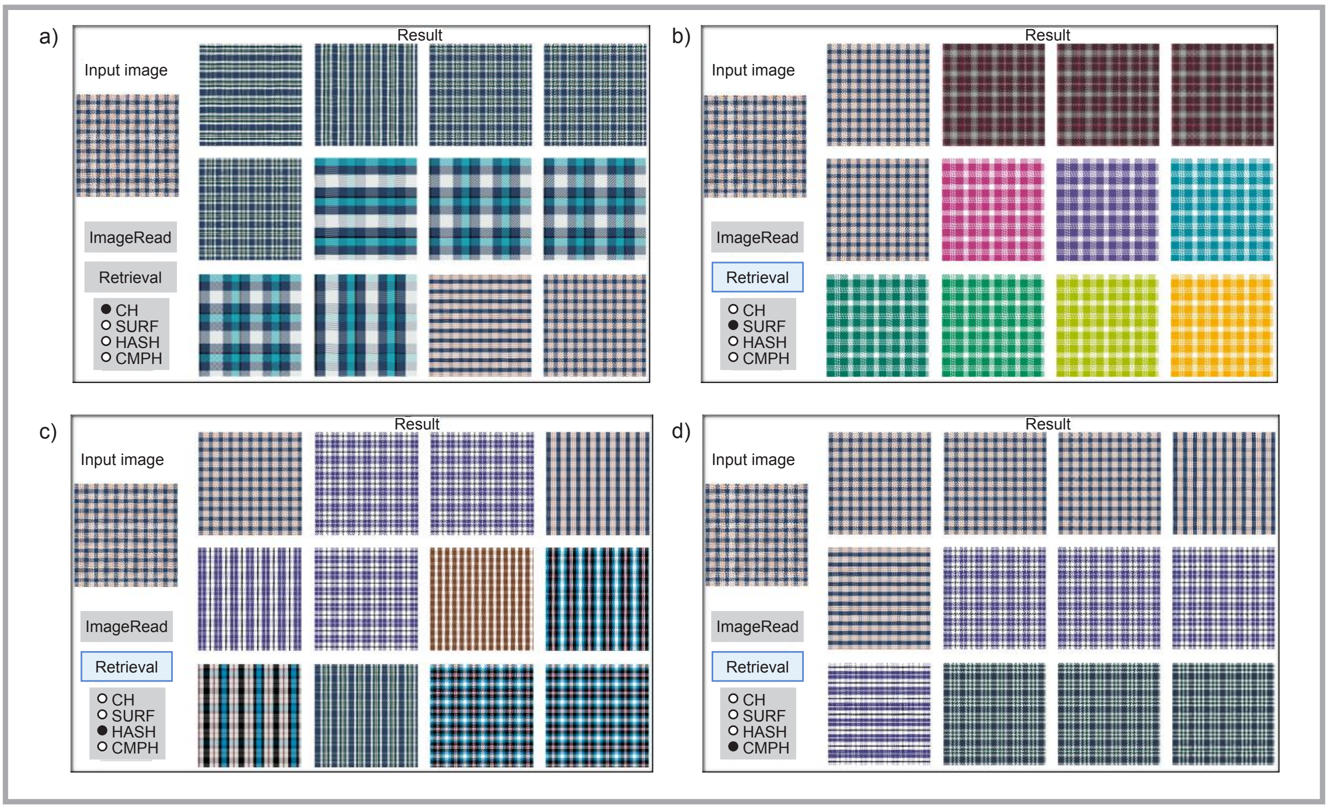

Figure 9. *Pattern image retrieval results of four methods: a) CH, b) SURF, c) HASH & d) CMPH (proposed).*

extracts the feature points of the image. Unlike other images, the feature points in the pattern image are not many, and most of them are repetitive. Therefore, many unexpected results appear in the matching process. ***Figure 9.c*** shows the results of the aHash algorithm. Although this method is very simple and the retrieval efficiency is very fast, it is highly susceptible to the mean value, which results in the retrieval result not being accurate.

To compare the retrieval effect objectively, each of the 300 images in the PATTERN image database is retrieved using the four methods. The average *AR*, *RR* and retrieval time (*RT*) of each method is calculated, shown in ***Table 2*** and ***Figure 10***.

From ***Table 2*** and ***Figure 10***, it can be seen that the method proposed in this paper has obvious advantages over the other three methods either in accuracy and the retrieval rate . In addition to the efective comparison given in ***Table 2***, the time taken for pattern image retrieval is 0.561, 0.598, 1.193, and 1.563 seconds, respectively, for the four image retrieval methods. Although the average retrieval time of the method proposed is more than for the other methods, the retrieval performance of the method proposed is better than for the others, and the retrieval time is not too long. The results of experiments show that the algorithm proposed is accurate and effective.

Conclusions

In this paper, an indirect method is proposed to retrieve a yarn-dyed fabric image to greatly improve a factory's production efficiency. Yarn-dyed fabric samples are captured by the DigiEye system first, and then pattern images of the captured fabrics are simulated by yarn-dyed fabric pattern design software based on the structure parameters of the yarn-dyed fabric. For the simulated pattern image, an effective algorithm is proposed to retrieve these kinds of images by combining the colour moment method and perceptual hash algorithm. Then the pattern images retrieved are mapped back to the

Table 2. *Average AR, RR and retrieval time of four methods.*

Methods	Average *AR* (%)	Average *RR* (%)	Average *RT* (s)
CH	0.6542	0.4421	0.561
SURF	0.5076	0.3522	0.598
HASH	0.6433	0.3833	1.193
Proposed	0.8530	0.5351	1.563

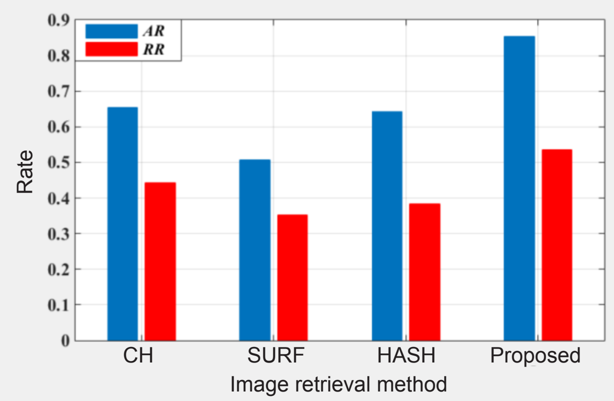

Figure 10. *Average AR and RR of different algorithms.*

yarn-dyed fabric image so as to realise the yarn-dyed fabric image retrieval.

In the algorithm proposed, the colour moment method is adopted to extract the colour features, and the perceptual hash algorithm is utilised to calculate the spatial features of the simulated pattern image. The Euclidean distance and Hamming distance are used to compute the similarity. The experimental results show that the average accuracy rate of the method proposed is 85.30% for the PATTERN image database, which is better than other methods. It is shown that the method presented is effective for retrieving pattern images of yarn-dyed fabric.

However, this paper mainly focuses on the image retrieval of a pattern image, which is simulated based on the structure parameters of the yarn-dyed fabric image. Although the method proposed is an indirect method for retrieving a yarn-dyed fabric image, it can not only avoid the image noise problems brought about by the direct method but it can also improve the retrieval accuracy. The direct method of retrieving a yarn-dyed fabric is to use the original fabric images captured by a camera. However, the cleanliness of the fabric itself, the shooting environment and the colour uniformity of yarn can have an immense impact on the results retrieved. The indirect method proposed, which uses a simulated fabric image, can avoid the problems above. By using the method proposed, the fabric surface is clear and the yarn colour shows uniformity. Therefore, it is easier to get better retrieval results. In the future, a more complete framework will be presented for pattern image retrieval. Meanwhile, direct image retrieval for a yarn-dyed fabric will be investigated in order to compare with the method proposed.

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References

1. Li T, Yan S, Mei T, Hua XS, Kweon IS. Image decomposition with multilabel context: algorithms and applications. *IEEE Transactions on Image Processing* 2011; 20: 2301-2314.
2. Li T, Mei T, Kweon IS, Hua XS. Contextual Bag-of-Words for Visual Categorization. *IEEE Transactions on Circuits & Systems for Video Technology* 2011; 21: 381-392.
3. Joshi KD, Bhavsar SN, Sanghvi RC. Image retrieval system using intuitive descriptors. *Procedia Technology* 2014; 14: 535-542.
4. Yan CL. Accurate image retrieval algorithm based on color and texture feature. *Journal of Multimedia* 2013; 8: 277-283.
4. Zaied M, Salwa S, Jemai O, Amar CB. A novel approach for face recognition based on fast learning algorithm and wavelet network theory. *International Journal of Wavelets Multiresolution & Information Processing* 2011; 19: 923-945.
5. Jing J, Li Q, Li P, Zhang L. A new method of printed fabric image retrieval based on colour moments and gist feature description. *Textile Research Journal* 2016; 86: 1137-1150.
6. Zhang L, Liu X, Lu Z, Liu F, Hong R. Lace fabric image retrieval based on multi-scale and rotation invariant LBP. *International Conference on Internet Multimedia Computing and Service* 2015. p. 74.
7. Zhang J, Xin B, Shen C, Fang H, Cao Y. Novel colour clustering method for interlaced multi-colored dyed yarn woven fabrics. *FIBRES & TEXTILES in Eastern Europe* 2015; 23, 3(111): 107-114. DOI: 10.5604/12303666.1152535.
8. Zand M, Doraisamy S, Halin AA, Mustaffa MR. Texture classification and discrimination for region-based image retrieval. *Journal of Visual Communication & Image Representation* 2015; 26: 305-316.
9. Chen TW, Chen YL, Chien SY. Fast image segmentation based on K-Means clustering with histograms in HSV color space. *Multimedia Signal Processing*, *2008 IEEE, Workshop on* 2008, p.322-325.
10. Smith JR. Color for Image Retrieval. In: Castelli V, Bergman LD, editors. Image Databases: Search and Retrieval of Digital Imagery. John Wiley & Sons, Inc., 2002. p. 285-311.
11. Sural S, Qian G, Pramanik S. Segmentation and histogram generation using the HSV colour space for image retrieval. *International Conference on Image Processing* 2002, p. 589- 592..
12. Chen W, Shi YQ, Xuan G. Identifying computer grahics using HSV color model and statistical moments of characteristic functions. *IEEE International Conference on Multimedia and Expo*. July 2007, p. 1123-1126.
13. Huang ZC, Chan PPK, Ng WWY, Yeung DS. Content-based image retrieval using color moment and Gabor texture feature. *International Conference on Machine Learning and Cybernetics* 2010; 9: 719-724.
14. Brunelli R, Mich O. Histograms Analysis for Image Retrieval. *Pattern Recognition* 2001; 34: 1625-1637.
15. Flickner M, Sawhney H, Niblack W, et al. Query by image and video content: The QBIC system. *IEEE Computer* 1995; 28: 23-32.
16. Maheshwary P, Srivastava N. Prototype system for retrieval of remote sensing images based on color moment and gray level co-occurrence matrix. *International Journal of Computer Science Issues* 2009; 3: 20-23.
17. Chen WH, Smith C, Fralick S. A fast computational algorithm for the discrete cosine transform. *IEEE Transactions on Communications* 2003; 25: 1004-1009.
18. Fan F, Gao G, Li J. Visual object tracking based on perceptual hash algorithm. *International Computer Conference on Wavelet Active Media Technology and Information Processing. IEEE* 2016. p. 233-236.
19. Wen ZK, Zhu WZ, Liu PF, Du YH, Zhang M, Gao, J. H. A Robust and Discriminative Image Perceptual Hash Algorithm. F*ourth International Conference on Genetic and Evolutionary Computing*. IEEE Computer Society 2010. p.709-712.
20. Matusiak M, Walawska A, Sybilska W. Comparison of spectrophotometric and digieye colour measurements of woven fabrics. *Tekstil Ve Konfeksiyon* 2017; 27: 53-59.
21. Pan R, Zhang J, Li ZJ, Gao WD, Xu BG, Li W. Applying image analysis for automatic density measurement of high-tightness woven fabrics. *FIBRES & TEXTILES in Eastern Europe* 2016; 24, 2(116): 66-72. DOI: 10.5604/12303666.1191429.
22. Zhang J, Pan R, Gao W, Zhu D. Automatic detection of layout of color yarns of yarn dyed fabric. part 1: single-system -mélange color fabrics. *Color Research & Application* 2014; 40: 626-636.
23. Zhang J, Pan R, Gao W, Xu B, Li W. Automatic detection of layout of color yarns of yarn dyed fabric. part 2: region segmentation of double-system-mélange color fabric. *Color Research & Application* 2016; 41: 626-635.
24. Zhang J, Pan R, Gao W, Xu B, Li W. Automatic detection of layout of color yarns of yarn dyed fabric. part 3: double system mélange color fabrics. *Color Research & Application* 2016; 40: 626-636.
25. Mceliece RJ. The Theory of Information and Coding (Second Ediation), CUP; 2002.
26. Velmurugan K, Baboo SS. Content-Based Image Retrieval using SURF and Colour Moments. *Global Journal of Computer Science & Technology* 2011; 11: 1-4.

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