(REFEREED RESEARCH)

DETERMINATION OF STRUCTURAL PARAMETERS OF SINGLE–COLORED WOVEN FABRICS BY USING IMAGE PROCESSING METHOD

TEK RENKLİ DOKUMA KUMAŞLARIN YAPISAL PARAMETRELERİNİN GÖRÜNTÜ İŞLEME YÖNTEMİ İLE BELİRLENMESİ

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ABSTRACT

Determination of fabric structure parameters is the first process in all textile factories, especially weaving mills. The analysis of woven fabrics is one of the most important, indispensable, and time-consuming processes that require care and precision. For this reason, any errors made in the analysis of fabric may cause the losses which may be extremely difficult to compensate for the factory. Almost all mistakes in the processes of the fabric analysis are human-induced. And also, minimizing human-induced errors is very important for enterprises to decrease their time and financial loss. In this study, thanks to image processing method, it has been aimed to determine the fabric structures, warp and weft densities from structural parameters of single-color woven fabrics. In order to determine these parameters, algorithms have been developed, and applied to the different woven fabrics.

Keywords: Fabric, Staple fiber, Image processing, Structure, Woven.

ÖZET

Kumaş yapı parametrelerinin belirlenmesi dokuma işletmelerinde ilk işlemdir. Dokuma kumaşların analizi zaman alıcı dikkat ve hassasiyet gerektiren en önemli işlemlerden biridir. Bu nedenle, kumaş analizinde yapılacak herhangi bir hata işletmeler için giderilmesi son derece güç olabilecek kayıplara neden olabilir. Kumaş analizinde oluşan tüm hatalar insan kaynaklıdır. İnsan kaynaklı hataların minimize edilmesi işletmelerin zaman ve mali kayıpları nı azaltmak için çok önemlidir. Bu çalışmada tek renkli dokuma kumaşların atkı ve çözgü sıklıkları ve kumaş örgüleri, görüntü işleme metodu ile belirlenmiştir. Bu parametreleri belirleyebilmek için algoritmalar geliştirilmiş ve farklı farklı dokuma kumaşlara uygulanmıştır.

Anahtar Kelimeler: Kumaş, Kesikli lif, Görüntü işleme, Yapı, Dokuma.

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1. INTRODUCTION

Every image can be defined as a function of two-dimensional light intensity. This is the x and y Cartesian Coordinates of ʆ (x, y) function. The numerical value of (x, y) point gives the value of its brightness or the gray level of that point. A numerical image is a matrix. Each element of this matrix, called as pixel, shows the gray level value that refer to a point in the image. The indices of the matrix shows the coordinates of the examined point in the same image (1).

The color spaces are mathematical models which representing and defining all the colors. Color spaces are designed in 3D. According to the first law of Grassmann, three independent variables are required to determine a color in the Colormeter Science. The places of colors in the color space are determined by those variables. Each color space has the color standards peculiar to itself. Each color space may be converted to the other color space by means of linear or nonlinear methods. Different color spaces are used by different color imaging and processing devices. For instance, while scanners, television and computer monitors use the RGB color space, printers and plotters use the CMY (K) color space (2).

The RGB color space is based on Cartesian coordinate system. All colors are in the unit cube or on the edges of the unit cube. The diagonal of unit cube is gray-scale axis. Figure 1 shows RGB image space, schematically.

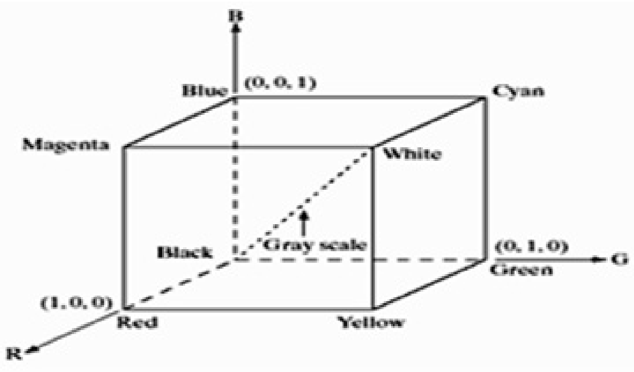


Figure 1. Showing of the RGB color space in the Cartesian coordinate system (2).

Color value of any component in the RGB color space can be expressed in the following formulas (3).

$$Color = 65536 \times B + 255 \times G + R \quad \text{Eq. 1}$$

$$R = Color \ Mod \ 256 \quad \text{Eq. 2}$$

$$G = (Color \ / \ 256) \ Mod \ 256 \quad \text{Eq. 3}$$

$$B = Color \ / \ 65536 \quad \text{Eq. 4}$$

In order to obtain the desired values from the available image, the improvements or smoothing operations are necessary in the image processing. The procedures of image improvements are given below.

1. ***Conversion to gray scale:*** The values of red, green and blue components of colors are calculated with the help of the 2, 3 and 4 equations by reading the color value of each pixel in the image. New color value of pixel is given through taking arithmetic mean of calculated values.(3,5)

$$R_N = G_N = B_N = \frac{R + G + B}{3} \quad \text{Eq. 5}$$

The second phrase used to calculate the pixel value of gray scale is given by Eq. 6.

$$R_N = 0{,}299 \times R + 0{,}587 \times G + 0{,}114 \times B \quad \text{Eq. 6}$$

2. ***Histogram:*** Histogram is the graphics that has shown the numbers of total pixels in the same color on the original image corresponding to each color value in the image converted to the gray scale. It is important to determine the structure of the transactions applied on images. While creating gray scale histogram of the image, the arithmetic mean, standard deviation, and median values of colors are also calculated to obtain more detailed information about the structure of the image (3).

3. ***Histogram synchronization:*** In this process, clearer image is obtained from original image by increasing differences between brightness levels of gray-scale image. This is the process that the minimum and maximum brightness values of gray-scale image spread between black (0) and white (255) values. Histogram synchronization process stages are shown below.

   a. The histogram of the image has been determined.

$$SF = \frac{SR}{AR} \quad \text{Eq. 7}$$

$$SR = AR + Round \ [SF * (255 - GD)] \quad \text{Eq. 8}$$

$$NBV = Round \ [SF * (OBV - AR_{min})] \quad \text{Eq. 9}$$

   b. The cumulative histogram has been obtained from histogram. Cumulative histogram is a graph containing the sum of each original value and his predecessors'.

   c. Cumulative histogram values have been multiplied by the new maximum color values on the image, then divided by the numbers of the total points, and so they have been normalized.

   d. After normalized histogram values and real color values on the image are updated, the histogram synchronization process is completed.

4. ***Noise Reduction:*** Sharpness of the image may be reduced after some transformation processes are applied to the image. In this situation, various operations are applied on the image in order to improve the image and reduce noise. Median method can be applied to reduce the noise of the image. In this method, color values of neighboring pixels are ordered ascending in the certain image, and middle value is accepted as new value of the pixel (3).

5. ***Changing the brightness of the image:*** As you can see Eq. 10 and Schema 1, the brightness value of gray-scale image can be changed thanks to increasing or reducing brightness value of each point on the image, equally (3,5).

$$R_N = f(x, y) \pm a \quad \text{Eq. 10}$$

$$\begin{matrix} 50 & 126 & 115 \\ 89 & 103 & 186 \\ 47 & 95 & 149 \end{matrix} \quad a = 10 \quad \begin{matrix} 60 & 136 & 125 \\ 99 & 113 & 196 \\ 57 & 105 & 159 \end{matrix}$$

Schema 1. Increased brightness value of each pixel in the image (+ 10)

If the pixel brightness value exceeds to 255 in the increasing process, the pixel color value is accepted as 255, or if any value is negative in the reducing process, then color value is taken as zero.

Image processing is promising, and also new concept in the textile industry. And also in this process, appropriate computer software has to be used. In this study, yarn densities and pattern structure of the single color weave fabrics have been determined by using image processing method.

1. MATERIALS AND METHODS

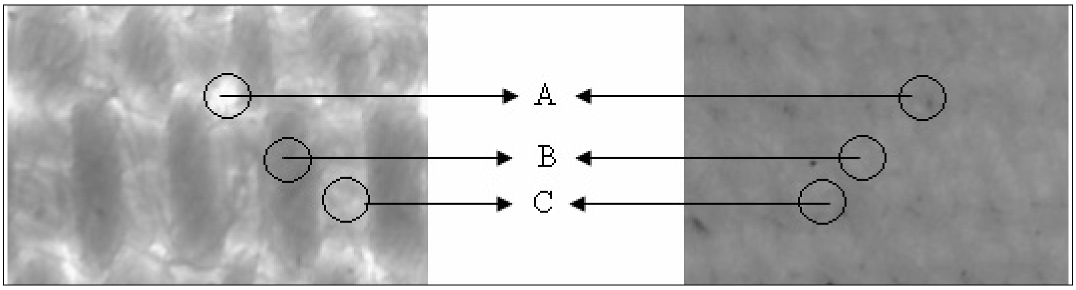
100 % cotton fabrics were used in this study, and their characteristics were given in Table 1. Images of fabrics were taken by digital microscope using an AM30 13T DINO LITE camera with 200 magnifications. Firstly, fabrics were illuminated to increase their visibility and lighting direction was determined by pre-treatments.

As shown Figure 2, while the lines were clearer in fabrics illuminated from below. Therefore, images were taken by lighting from the bottom of samples.

To prevent images from being affected by environmental lights, circumference of the microscope was closed and the images were recorded as “bmp”. To determine fabric construction from fabric images, such as warp/weft densities and weaving plan, appropriate computer program was written in Microsoft Visual Basic 6.0 Programming Language. A mechanism used for taking images of fabric was schematized in Figure 3.

Table 1. Fabric Properties

No	Weave	Density (yarn/cm)		Yarn Count (Nm)	
		Warp	Weft	Warp	Weft
1	Plain	48	32	68/1	68/1
2	Plain	22	18	34/1	34/1
3	2/1 Rip	40	30	34/1	27/1
4	2/1 Rip	41	32	34/1	27/1
5	2/1 Rip	42	28	34/1	27/1
6	3/1 Rip	40	32	34/1	27/1
7	3/1 Rip	40	33	34/1	27/1
8	3/1 Rip	40	31	34/1	27/1
9	3/1 Rip	40	30	34/1	27/1
10	2/1 Twill	42	30	34/1	27/1
11	2/1 Twill	41	25	34/1	27/1
12	2/1 Twill	43	17	27/1	20/1
13	2/1 Twill	40	23	34/1	27/1
14	2/1 Twill	16,5	13	17/2	17/2
15	Rip	40	20	30/1	30/1
16	Basket 2/2	40	22	34/1	34/1



(a) (b)

Figure 2. Image of fabrics lighted from the two different directions (a: From bottom, b: From top)

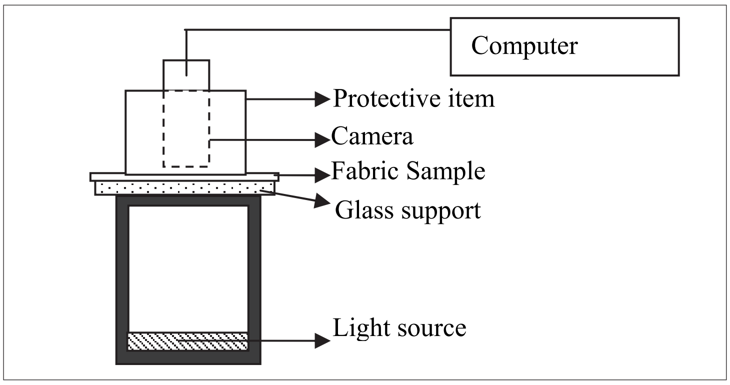


Figure 3. The schematic view of the mechanism used for receipt of fabric images

Obtaining desired values from real images

For process of taken images of the fabric following operations were performed on the same fabric.

a. Gray-scale conversion

b. Determination of the arithmetic average, standard deviation, minimum and maximum color values.

c. If necessary, the implementation of the geometric transformation process.

d. Histogram equalization process of the obtained values.

e. Removing of image noise (median filter).

f. Determination of yarns and space regions between yarns in the image.

- g. Sharpening of the different brightness regions in the image (Difference filter).
- h. Determination of warp and weft yarn areas; calculation of arithmetic mean, rows and columns.
- i. Determination of fabric construction (4).
- j. Determination of density and drawing (4).

Gray-scale conversion

The algorithm of gray-scale conversion process was given in Figure 4. Images were converted to the gray-scale with this algorithm, and then the arithmetic mean, standard deviation, the lowest and highest brightness values were determined.

Histogram Equalization

The histogram equalization, its algorithm was given in Figure 5, was achieved by using the arithmetic mean, standard deviation, maximum/minimum color values, range of color values, used for conversion to gray-scale (5).

In the Figure 6, image converted to gray-scale is on the left, image after histogram equalization is on the right (Sample fabric No:1). As a result of the operation, yarns on the fabric surface appeared darker than the others and light leaking regions. While minimum and maximum brightness value, arithmetic mean and standard deviation were calculated 147, 255, 196.04 and 23.66 after conversion to gray-scale, these values were determined as 0, 255, 117.98 and 56.35 after the histogram equalization process, respectively. Each of both cases show that image contrast increased.

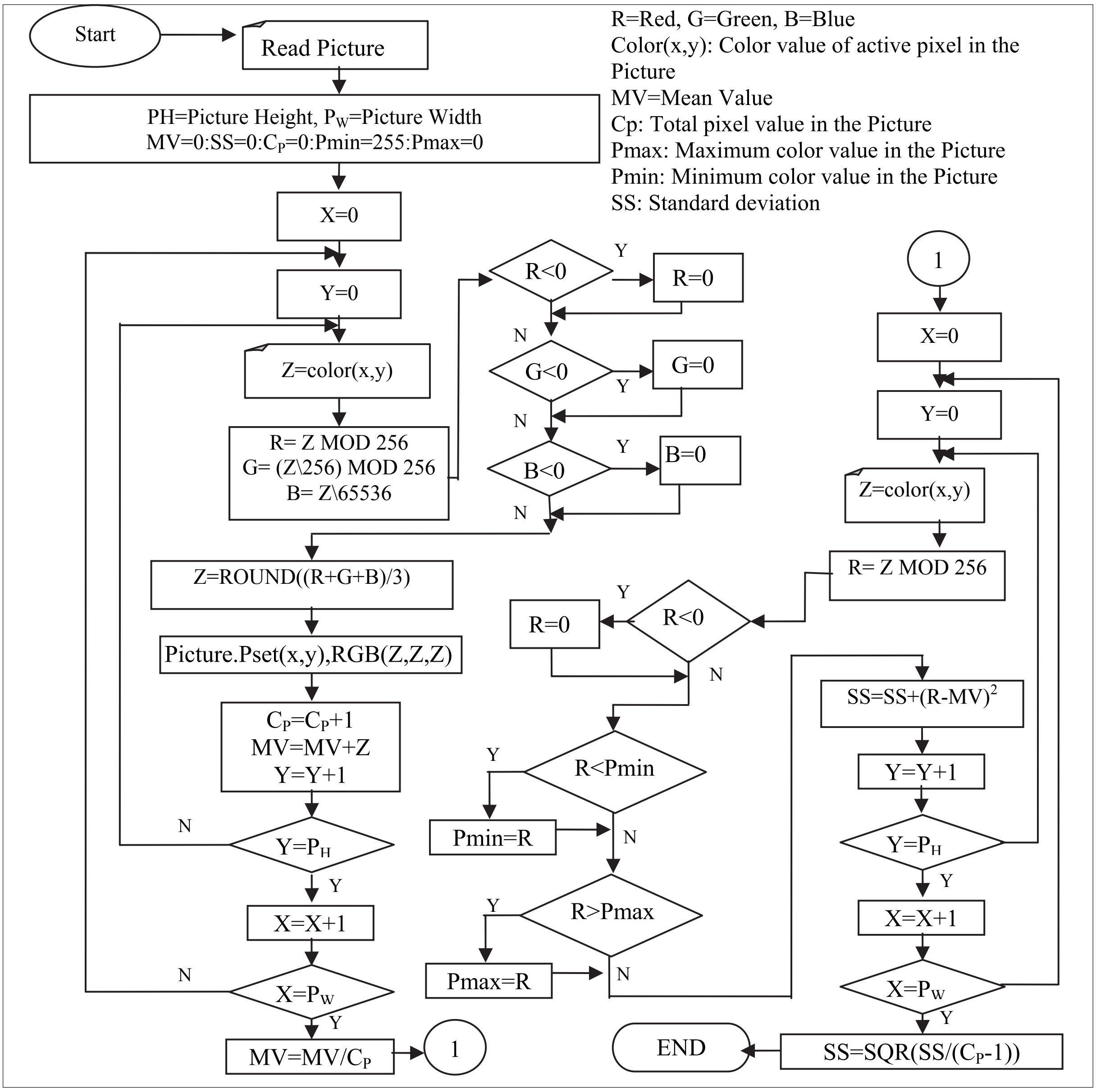


Figure 4. The algorithm used for gray-scale conversion of images

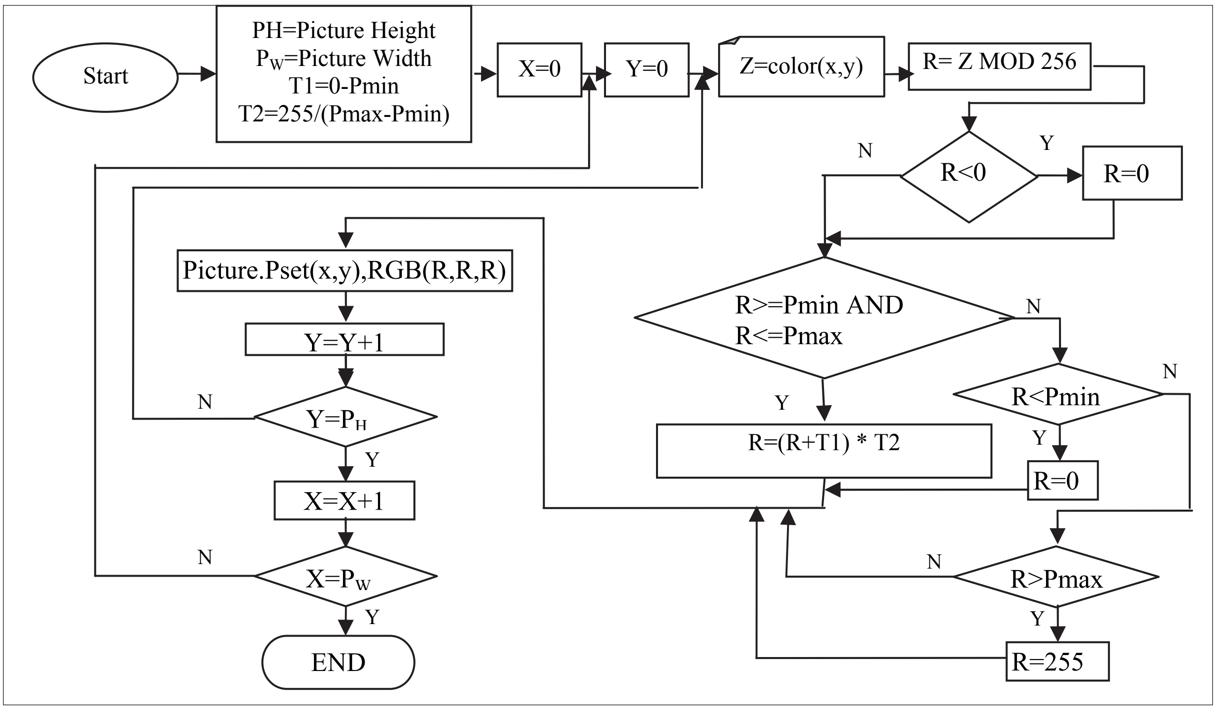


Figure 5. Histogram equalization algorithm

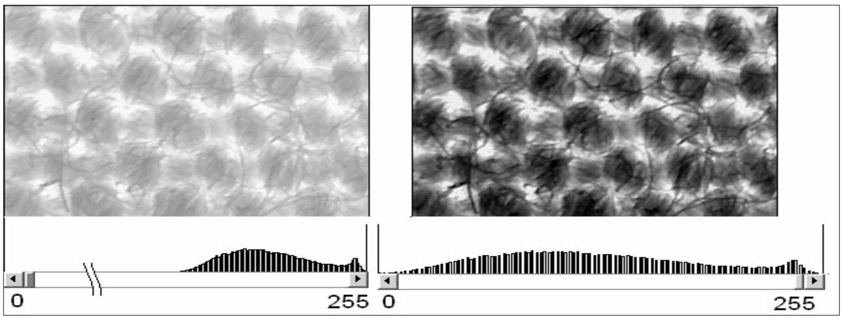


Figure 6. Status of the image before (left) and after (right) from histogram equalization

If the samples are not properly placed while their images were being taken, warp and weft yarns constructing the fabric can't be parallel in the vertical and horizontal axes. Color values obtained from these kinds of sample images can be incorrect if the images are placed in wrong directions. For this reason, ***geometric rotation*** is made in order to ensure that warp and weft yarns are parallel to the vertical and horizontal axes before starting image process. Images of samples after and before geometric rotation were given in Figure 7.

Noise reducing process

After histogram equalization process, noise in images can be reduced with median or low pass filters. Median brightness value of the series is accepted as active pixel by these filters. 3x3, 5x5 and 7x7 sizes as kernel filters can be selected for filter processes (Schema 2). The more the filter size grows, the more brightness value of any pixel is affected by the brightness value of neighboring pixel. As the space value of a yarn is low, brightness value of pixel on the yarn may be affected from brightness value of space between yarns. To minimize this inconvenience, 3x3 filters has been chosen.

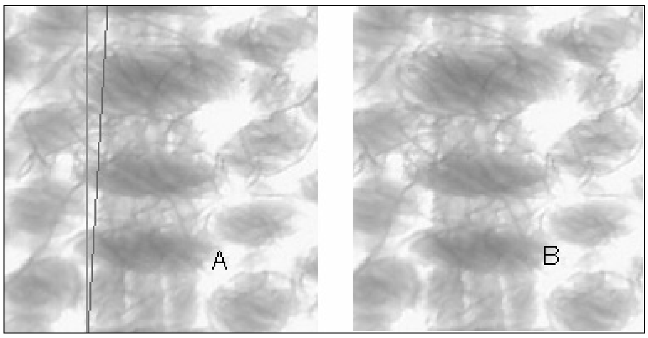


Figure 7. Images of sample before (A) and after (B) geometric rotation process

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \times \frac{1}{9} \qquad \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix} \times \frac{1}{10} \qquad \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \times \frac{1}{16}$$

$$A \qquad\qquad B \qquad\qquad C$$

Schema 2. Different low pass filter types: A: Mean, B: Filter which the central pixel is two times more impact compared to in the neighboring pixels, C: Gauss filter

Median filtering is another noise reduction filter. Active pixel (center pixel) is equally affected by the brightness value of the neighboring pixels. The brightness value of the active pixel is determined by the median of brightness values of 9 pixels. Figure 8 shows the median filtering method algorithm.

To eliminate small distortions, which may occur in the image, the noise must be removed from the image. Although low-pass filter (Fig. 7) and the median filter have reduced noise in the image, noise is completely irreparable.

In particular fabrics produced from staple fibers (natural and synthetic staple), fiber ends on the surface will cause a noisy and distorted image. They can cause fall of arithmetic mean of brightness values in the image and obtaining incorrect results. A different filter was used for cleaning of fiber ends from images in the linking areas which have the lightest leaking.

Determination of yarn densities from fabric image

Determination of the location and number of yarns is important in terms of determination of density of yarns and weaving report. To determine yarn density and location, arithmetic mean of each pixel rows and columns of image was calculated, and graphs were plotted separately in the weft and warp direction. While whitish areas in the images represented the gap between yarns, yarns were accepted as blackish areas in the images.

Process of determining the boundaries of the warp and weft yarn algorithm is in Figure 9. Algorithm of operation was based on determination of arithmetic means of brightness values of each row and column, separately and drawing of according to average values. In the Figure 10, after determining the boundaries of the warp and weft yarn, respectively, arithmetic means of all the pixels in the image, arithmetic means of each row (A, B, C, D) and column (1, 2, 3, 4, 5, 6) forming yarns and each region (A1, A2, etc.) were calculated.

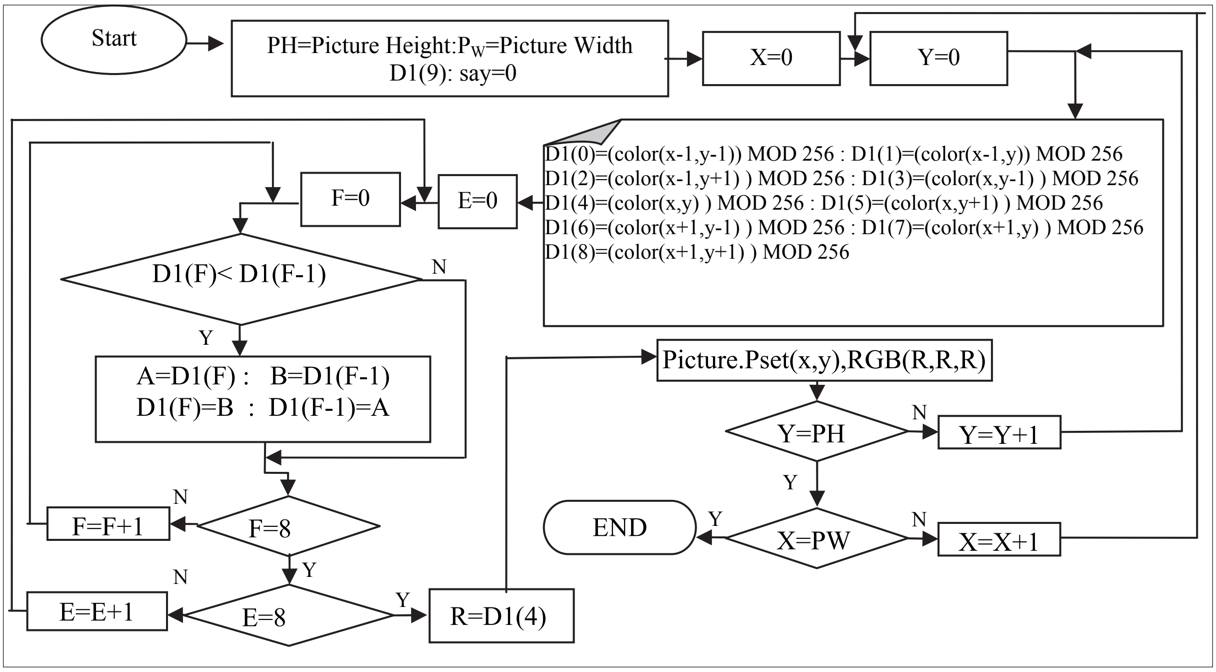


Figure 8. The algorithm of median filtering process

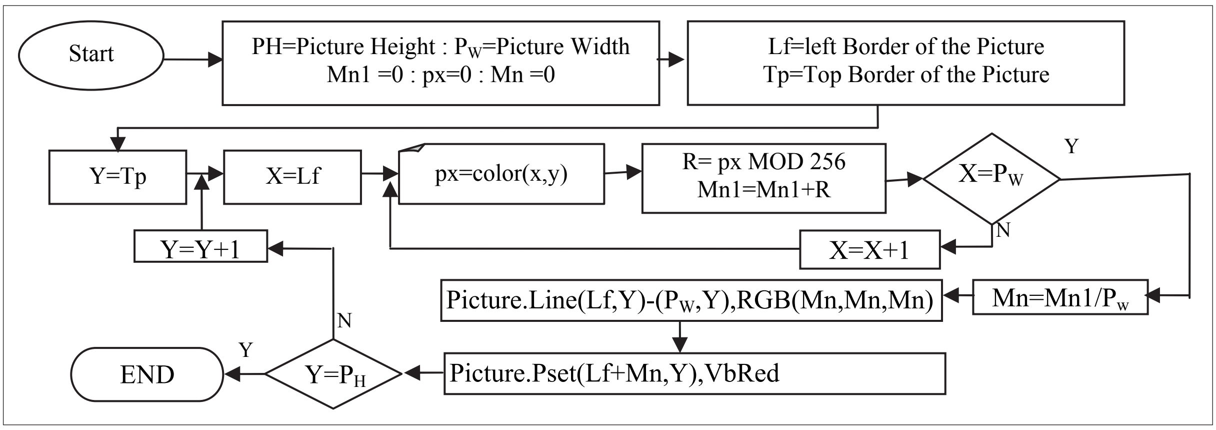
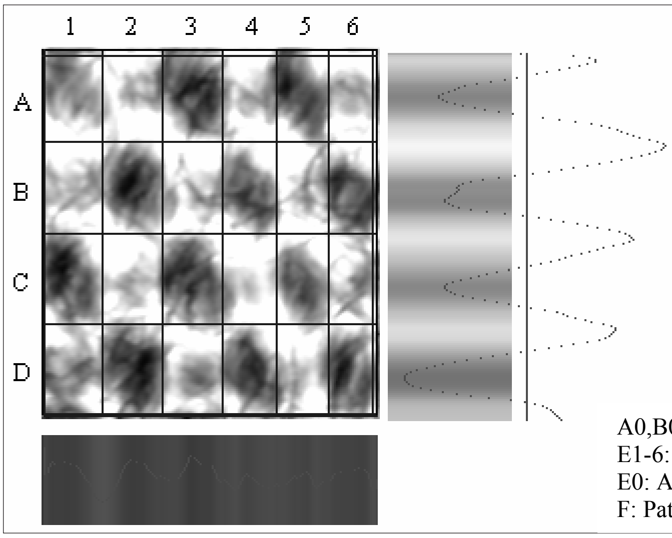


Figure 9. Algorithm of determination process of the boundaries of the warp and weft yarns



	0	1	2	3	4	5	6
A	186	184	226	134	215	146	222
B	187	219	146	226	166	222	151
C	183	139	229	139	234	173	211
D	168	184	125	209	151	218	139
E	180	204	176	173	184	183	190

F

0	255	0	255	0	255
255	0	255	0	255	0
0	255	0	255	0	255
255	0	255	0	255	0

A0,B0,C0,D0: Mean values of the rows
E1-6: Mean values of the columns
E0: Arithmetic mean of the overall picture.
F: Pattern report (255= Empty, 0=Full)

Figure 10. Determination of construction and arithmetic mean of image (Sample 2)

Each arithmetic mean of A1-D6 regions was separately compared with its row, column and the overall average. In the process, order of precedence was means of rows, columns and overall average. If average of the region (A1, etc.) is higher than average of its row, 255 will be given that region; if not, then 0 will be given. In the event of equality, it is compared to column of average. In Figure 10-F, fabric construction was shown. It was found that once the samples determined construction and densities of yarns depending on determining process of yarn boundaries. Calculation of weft or warp yarn density formulas was given in Eq. 10.

$$Is = CS - 1$$

$$S_C = \frac{10 \times I_s \times BO \times R_x}{(SC_x - IC_x) \times E_x} \qquad S_A = \frac{10 \times I_s \times BO \times R_y}{(SC_y - IC_y) \times E_y} \quad \text{Eq. 10}$$

2. RESULTS

Figure 11 shows brightness graphs of warp and weft yarns of (No:1). Because every weft and warp yarn is connected to each other, open areas in the graph of weft yarns (1) are indicated by especially transmitted light from gaps between weft yarns. In the brightness graph of warp yarns, regions similar to open areas in the weft are shown in the graph as No:3. In warp yarns graph, boundaries of yarn are not as clear as in weft yarns.

As shown in Figure 11, brightness increased from top to bottom in the graph. Brightness values change due to the fact that illumination is not equal for all parts of the sample and yarns order in irregular places.

Determination of warp and weft yarns is shown at 3/1 warp rips sample in Figure 12. In the same figure, right-hand chart, and the bottom chart are plotted for determination of weft and warp yarn boundaries, respectively. While regions with the highest average of brightness values are shown as B points, the other points (A) are regions which weft yarns are very close due to its construction.

The peak points have showed boundaries of weft yarns in the right side of graph. In the graph showing brightness of warp yarns, D points show regions having intense warp yarns, and also C points show regions having the highest transmission of light between warp yarns.

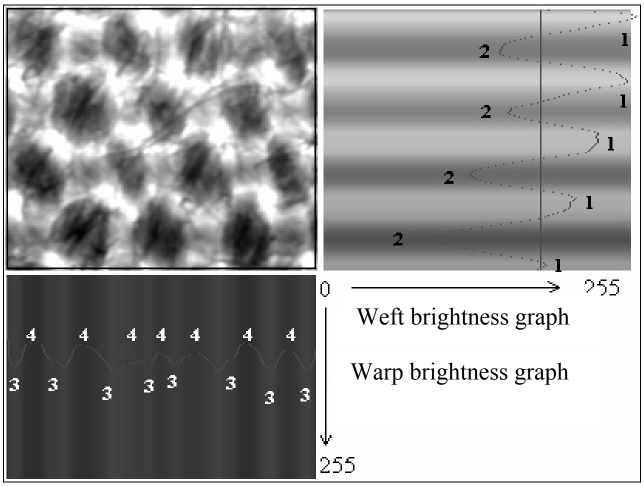


Figure 11. Determination of weft and warp yarns areas plain woven fabric (Sample 1)

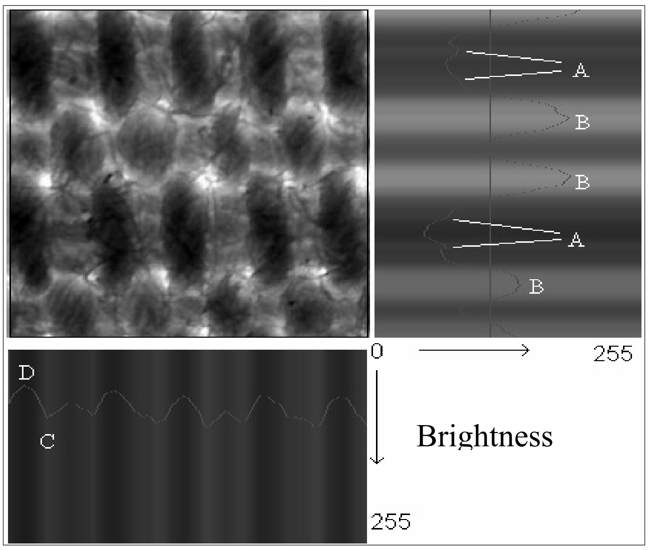


Figure 12. Determination of warp and weft yarns areas for sample 7

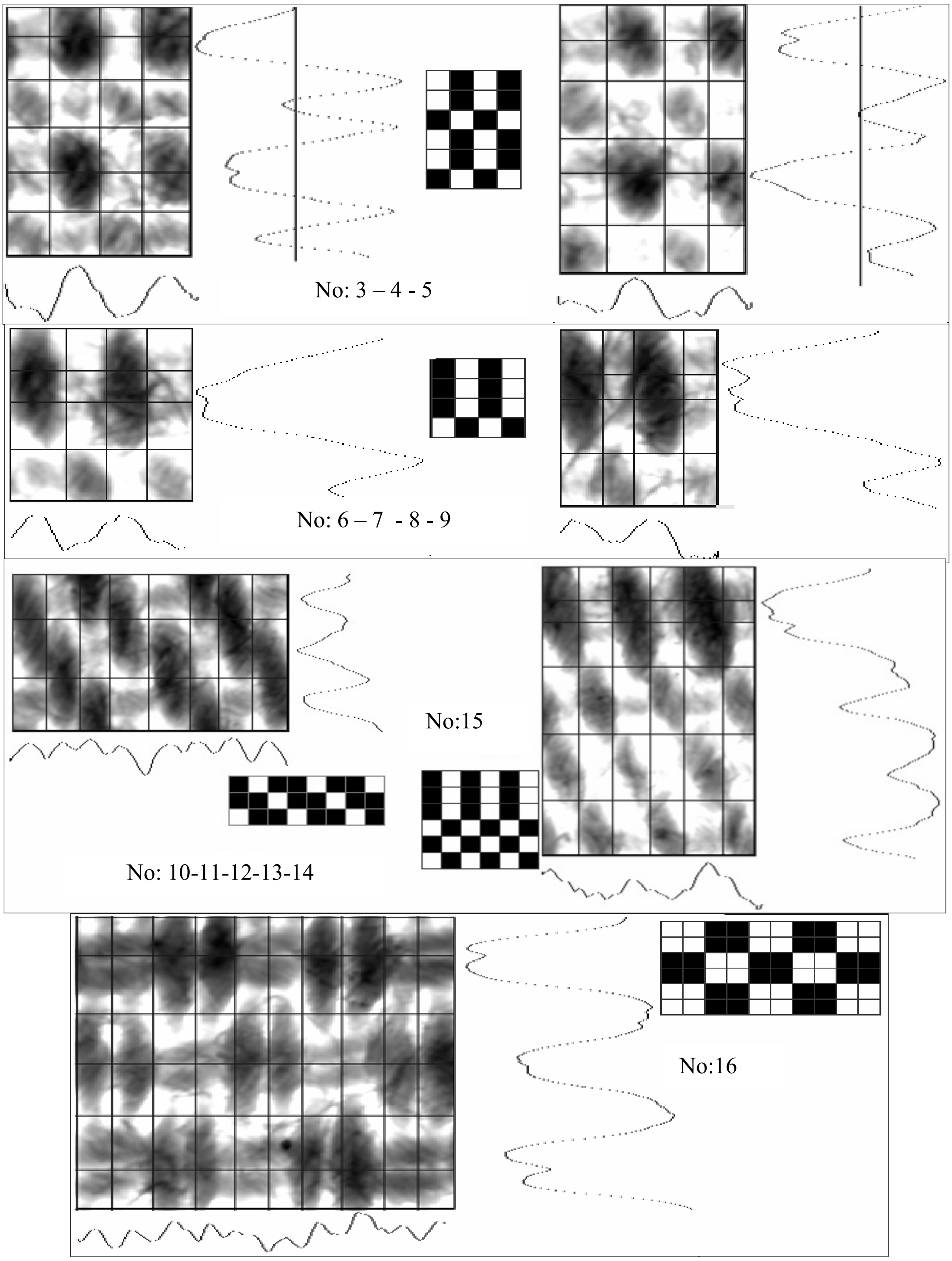


Figure 13. Fabric constructions obtained from different fabric images

Figure 13 shows construction parameters for different samples. It was observed that differentiation between peaks structures obtained from yarns depended on fabric constructions in the brightness graphs of weft yarns

Analyzing weave peaks

Plain weave peaks: Plain weave peaks are shown in Figure 14. In the plain woven fabrics, it is not possible that weft yarns can be closer to each other due to intersections between all yarns. Each weft yarn has approximately equal space. Therefore, as shown in Figure 14, peaks are smooth. The minimum points, one point (A) or with a value of more than one point occur on the same brightness (B).

As shown Figure 14, warp yarns peaks have more irregular structure than weft yarns. Warp density is higher than weft density in the very large part of woven fabrics. Irregularity of warp yarns is valid for all woven construction.

Rips and Panama weaves: Rips and panama weaves are shown in Figure 15. As we have seen, diagrams of rips and panama weaves are similar to plain structure. Unlike plain weave, warp yarns, weft yarns or both warp and weft yarns are found in more than one thread depending on woven constructions.

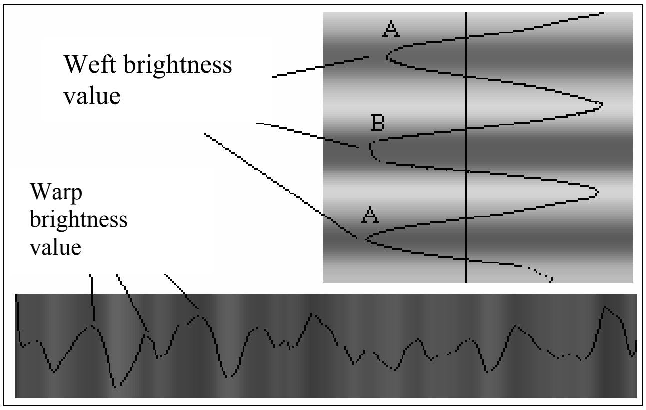


Figure 14. Brightness diagrams of warp and weft yarns and peak structure in the plain fabric

In the regions having yarns groups, yarns in the same groups settle more and more close to each other. Because of this structure resulting from settlement, less light passes through the grouped yarns.

Peak structures, as seen in Figure 15, are the characteristic structure in the brightness diagrams for rips and panama fabrics. Brightness difference between two weft yarns groups in the panama is less than that of rips. Because of the location of warp yarns, there is much more distance between one weft in the rip and three weft groups. One weft yarn seems brighter than the other three weft yarns due to the light passing from the distance.

If number of yarn groups is closer to each other, brightness peak values are also closer to each other. And also theoretical peak value can be obtained as seen in Figure 15 (on the right side).

Twill structure: Yarn groups similar to rips and panama structures' are not obtained for the twill structures. The distance between the weft yarns is regular and approximately equal to each other. Therefore, peaks of weft yarn in the twill fabrics are more similar to peaks of plain woven fabrics than panama or rips woven fabrics.

Determination of densities of fabrics

Density values of fabrics were obtained from both directly on fabrics and imaging process, and these values were shown in Table 2. Some deviations between imaging process and directly measuring method were shown. Average deviation for densities of weft and warp yarns was 0.8 % and 2.06 %, respectively (See Figure 16).

Table 2. Densities values (with directly measuring and imaging process)

No	Weave	Raw-material	Warp Density (yarn/cm)		Weft Density (yarn/cm)	
			D_{1-d}	D_{1-i}	D_{2-d}	D_{2-i}
1	Plain	%100 Cotton	48	49.389	32	32.918
2	Plain	%100 Cotton	22	22.710	18	18.440
3	2/1 Rip	%100 Cotton	40	40.494	30	31.408
4	2/1 Rip	%100 Cotton	41	41.480	32	31.010
5	2/1 Rip	%100 Cotton	42	42.030	28	28.417
6	3/1 Rip	%100 Cotton	40	40.241	32	32.675
7	3/1 Rip	%100 Cotton	40	38.950	33	32.258
8	3/1 Rip	%100 Cotton	40	40.279	31	31.716
9	3/1 Rip	%100 Cotton	40	40.739	30	29.643
10	2/1 Twill	%100 Cotton	42	42.902	30	30.923
11	2/1 Twill	%100 Cotton	41	41.917	25	25.551
12	2/1 Twill	%100 Cotton	43	42.706	17	18.089
13	2/1 Twill	%100 Cotton	40	40.522	23	23.622
14	2/1 Twill	%100 Cotton	16.5	16.252	13	13.500
15	Rip_Top	%100 Cotton	40	40.070	20	21.210
16	Basket 2/2	%100 Cotton	40	40.080	22	21.689

D_{1-d}: Warp density measured with directly; D_{1-i}: Warp density measured with imaging process; D_{2-d}: Weft density measured with directly; D_{2-i}: Weft density measured with imaging process

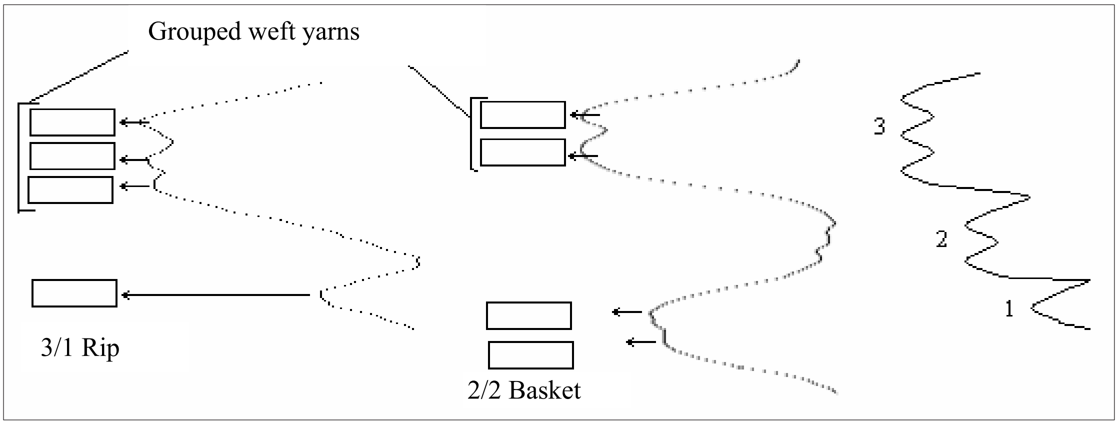
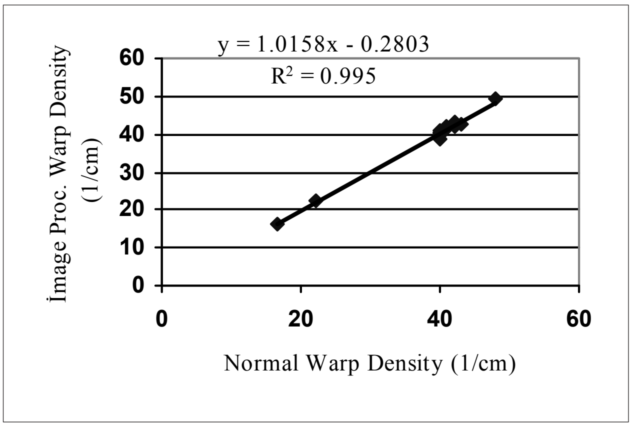


Figure 15. Weft brightness diagrams and peak structure for Rips and panama



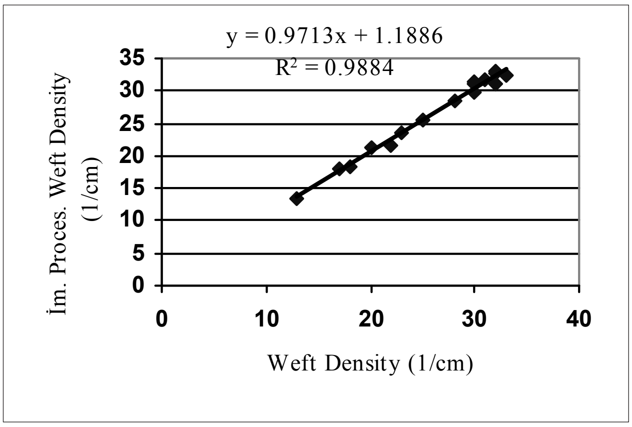


Figure 16. Comparison to results of warp and weft densities

On the other hand, results of measuring are very similar in the same method. Practically, determination of the decimal values of densities is too hard especially, in directly measuring method. Because of difference between these densities, measuring methods are resulted from decimals of density values.

3. CONCLUSION

According to the results of the study, the warp and weft density parameters in the single-color woven fabrics can be determined with computer programs by using appropriate software and camera. It has been determined that the image processing method is more suitable method for obtaining construction parameters and also density of yarn. Besides, the image processing is time saving in the woven mills because it has minimized human errors in the analysis process and analysis process can be completed in very short time. Finally it can be said that the using of color image processing for determination of construction parameters has some practical advantages in terms of textile producers such as time saving, manual labor, cost, laboratory-business compliance, minimum error. It is believed that image processing for calculation of production parameters in textiles gives new opportunities for low-cost preparation in textile production.

Symbol	Unit	Description
R	-	Red component of pixel color value
G	-	Green component of pixel color value
B	-	Blue component of pixel color value
R_N		Gray scale value of pixel
SF	-	Stretch factor
SR	-	Stretched color values range
AR	-	Actual distribution range of colors in the picture
AR_{min}	-	The minimum value of the real range
EPD	-	Ex-brightness value
F (x.y)	-	Pixel color of certain point in the picture
CS	-	Number of border lines
Is	-	Number of yarn
S_c	yarn/cm	Density of weft yarns
BO		Magnification
Rx	Pixel	Number of pixel in the transverse direction of picture
Ry	Pixel	Number of pixel in the longitudinal direction of picture
Ex	Pixel	Number of pixel in the transverse direction of screen (horizontal resolution)
Ey	Pixel	Number of pixel in the longitudinal direction of screen (vertical resolution)
Icx	Pixel	Starting point x value of the first guide line
SCx	Pixel	Starting point x value of the last guide line
Icy	Pixel	Starting point y value of the first guide line
Scy	Pixel	Starting point y value of the last guide line

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