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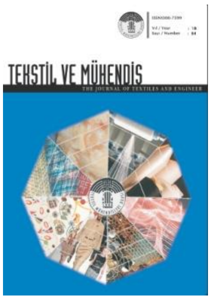

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Automatic Measurement of Shrinkage Rate in Denim Fabrics After Washing

Yıkama Sonrası Denim Kumaşlarındaki Çekme Oranının Otomatik Ölçümü

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Araştırma Makalesi / Research Article

AUTOMATIC MEASUREMENT OF SHRINKAGE RATE IN DENIM FABRICS AFTER WASHING

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ABSTRACT: In a large-scale garment facility, an average of 300-350 fabric rolls (150 meters each) is washed daily. Measuring the changes in fabric sizes with the washing process, transferring them to the fabric follow-up form, and saving the follow-up forms to the system at the end of the day are performed manually. In these processes where 6-7 personnel are involved, different quality control errors occur due to incorrect measurement or writing. In this study, a new system based on a computer vision system that can automatically calculate the shrinkage occurring in the fabric during the washing process and transfer it to the system is proposed. The proposed system consists of data collection and processing stages. In data collection, colored fabric images obtained with a CCD camera before and after washing are recorded with the help of a prepared cabinet. The processing phase includes the steps of removing the lens effect from the images, filtering, line detection by Hough transform, and computing the draw. As a result of experiments on six different fabric types, it has been observed that there is a %0.5-0.33 difference (within tolerance) between manual measurement of the shrinkage value and measured using the proposed system.

Keywords*:* Denim fabric, shrinkage, washing, image processing, computer vision

YIKAMA SONRASI DENİM KUMAŞLARINDAKİ ÇEKME ORANININ OTOMATİK ÖLÇÜMÜ

ÖZET: Büyük ölçekli bir konfeksiyon işletmesinde, günlük ortalama 300-350 kumaş rulosu yıkanmaktadır. Yıkama işlemiyle kumaş ebatlarında meydana gelen değişikliklerin ölçülmesi, kumaş takip formuna aktarılması ve gün sonunda takip formlarının sisteme kaydedilmesi işlemleri manuel gerçekleşmektedir. 6-7 personelin görev aldığı bu işlemlerde yanlış ölçüm veya yazım nedeniyle farklı kalite kontrol hataları meydana gelmektedir. Bu çalışmada, yıkama sürecinde kumaşta meydana gelen çekmeyi otomatik olarak hesaplayıp sisteme aktarabilen bilgisayarlı görü sistemine dayalı yeni bir sistem önerilmektedir. Önerilen sistem veri toplama ve işleme aşamalarından oluşur. Veri toplamada, hazırlanan bir kabin yardımıyla yıkama öncesi ve sonrası CCD kamerayla elde edilen renkli kumaş görüntüleri kaydedilir. İşleme aşaması, görüntülerdeki lens etkisinin kaldırılması, filtreleme, hough dönüşümüyle çizgi tespiti ve çekmenin hesaplanması aşamalarını içerir. Altı farklı kumaş türü üzerinde yapılan deneyler sonucunda, çekme değerinin manuel ölçülmesiyle önerilen sistem kullanılarak ölçülmesi arasında %0.5-0.33 fark (tolerans dahilinde) olduğu gözlemlemiştir.,

***Anahtar Kelimeler*:** Denim kumaş, çekme, yıkama, görüntü işleme, bilgisayar görüsü

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1. INTRODUCTION

The production speed increases day by day in apparel clothing companies and this increase creates diversity in terms of buyers. The increasing amount of production drives people to be selective in purchasing the best quality, cheapest, most different, and newest product. Increases in demand in recent years, decreasing profitability in the apparel sector, and increasing competition in quality; show that there is a need for more initiatives for upper-class products that can make a difference with their alternative features. According to this requirement, the sector is moving towards a structure where the quality factor is decisive, high-class, high-quality, fashion, brand, and knowledge-based products are produced and sold. This situation pushes businesses to develop new technologies and increase their quality values with the integration of conventional systems. To achieve this, many apparel companies make use of technology in production and quality units and try to actively use computer vision systems [1, 2].

Denim fabrics, which have continuously improved since the 19th century and are one of the leading trends in fashion design, are now an indispensable part of fashion. The increase in the demand of young masses for denim products is an important reason for famous fashion brands to turn to denim fabric [3].

There are many types of denim fabric. At the beginning of the 19th century, mostly "open-end" yarn was used for denim manufacturing, and in time, carded ring yarn in warp and weft replaced it to provide a softer denim quality. Denim fabrics with various properties can be produced with the varying raw materials used [4].

In addition to the weaving structure and yarn diversity of the denim fabric, one of the important processes for denim products is the washing operation. The washing process is the process of washing the sewn denim clothing in special washing machines according to certain recipes and techniques, removing the sizes on it and giving it different color and touch. Jeans washing technology has turned to the aim of creating new color tones and effects with the influence of consumer demands and fashion. The main feature of blue jeans is that they are dyed with an indigo dye that gets lighter as they are washed [5].

Washing consists of very difficult and requires experience. The formulas that emerged after researches and experiments on this subject provide different colors and effects from washed fabrics. The washing process causes changes in the appearance of the denim fabric and affects the physical properties of the fabric [6] [7]. Denim fabrics are passed through several physical property tests before they are turned into a final garment product. These tests can be listed as shrinkage [8], tensile/tear strength [9], pilling, wrinkle resistance, elasticity, and permanent elongation, potency, and weight. One or more of the tests specified on the fabric to be manufactured must be made [10].

It is seen that computer vision and image processing techniques that provide objective results are used more and more day by day to solve textile problems [16]. In this study, only the shrinkage test is focused on the physical tests performed on the fabric in apparel businesses. Due to the organization of the study, first the classical shrinkage test and then the proposed computer vision system is mentioned. Finally, the comparison of the advantages and disadvantages of both systems is mentioned in a way and the results obtained are shared.

2. CLASSIC SHRINKAGE MEASUREMENT

The change in the dimensions of the fabric due to processes such as washing, drying, and ironing is called shrinkage. The process of determining the shrinkage value in the fabric is called the "shrinkage test" [3]. There are different fabric shrinkage rates that can be determined by using different textile test methods that calculate fabric shrinkage standarts [15]. AATCC 135, AATCC 150, ISO 6330, and CAN/CGSB 58 are a few of the most recognized international organizations that provide fabric shrinkage tests and the most popular textile test methods used to calculate shrinkage rate on fabrics. For example, while washing the fabric is performed three times in the AATCC 135 test method, it is performed once in the AATCC 150 (detailed below) [17].

Figure 1. Taking the width and length measurements of the fabric in the shrinkage test and entering the values into the fabric tracking form} (Left) Width (Right) Length

2.1. TEST PROCEDURE

The shrinkage test (see Figure 1) is performed in three steps:

Step 1) The fabric to be tested is laid on the table with the reverse side on top. A drawing template of 50cmx50cm is placed on the fabric parallel to the edge and at a distance of 20cm. Marking is done with a pencil on the marking area on the mold. After the mold is removed, the ball number is written on the inside of the marked area and the fabric is cut so that it remains 20cm from the other edge.

Step 2) The edge of the marked fabric is overlocked. Then it is sewn from the reverse and the edges of the fabric are joined together. The fabric is ready for washing and is shipped to the washing section. In the washing section, the fabric-specific washing process is carried out, hanging in the direction of the warp threads, dried, and sent back again.

Step 3) The joined edges are cut off with scissors and the fabric is ironed. Then, the fabric is conditioned for 30 minutes and the width and length tensile values of the fabric are measured with a metal shrinkage measuring ruler. The average of the measurement values made in the width and length of the fabric is calculated and written on the follow-up form.

The following points should be taken into account when taking measurements:

- Measurement is made perpendicular to the fabric edge, excluding the edge area.
- The fabric should be spread evenly, there should be no creases, no folds, it should be laid without tension.
- Measurement should be made in the middle of the fabric parts, not the ends.

2.2. DISADVANTAGES

In the classical shrinkage test approach, taking measurements from the width and length regions, calculating the average values, recording the values in the tracking form, and transferring the data in the tracking forms to the computer system are completely done manually. In any of these processes, erroneous results may occur due to misspellings. This situation brings along many quality errors, especially measurement problems in subsequent processes and processes. In addition, making these operations manually causes the operating costs to increase as it creates the need for personnel [17].

For example, at Baykan Denim [11], a garment company, 50,000 meters of denim fabric is used every day to turn it into a final garment product. This amount corresponds to approximately 330 rolls of fabric. A classical shrinkage test is performed on each roll fabric. 8 personnel responsible for the shrinkage test work in the enterprise. Overwork and human-induced errors prevent businesses from taking quick action and producing quality products. This situation negatively affects the competitiveness of the enterprises in the market.

3. PROPOSED SYSTEM: AUTOMATIC SHRINKAGE MEASUREMENT

The proposed system includes the use of computer vision techniques. Thus, the length and width of the fabric can be measured automatically and the values can be transferred to the system instantly. The advantages listed below are obtained when compared to the classical system:

- Reducing workload and increasing productivity: Considering that an average of 300 fabric rolls are tested per day and each test process takes an average of 10 minutes, it is seen that the total time spent corresponds to 3000 minutes = 50 hours = 6.25 personnel/day. A testing process with the proposed system takes about 10 seconds. Thus, it is seen that the time spent per day in the factory is 3000 seconds = 50 minutes = 0.9 hours.
- Elimination of worker-induced errors (measurement, calculation, note-taking, and computer transfer)
- Minimizing the time lost during measurements and narrowing the production process

The proposed system consists of an imaging cabinet and software that processes images obtained from the cabin.

Figure 2. Imaging Cabinet

3.1. Imaging cabinet

A special-purpose cabinet has been prepared to obtain standard images from the fabrics to be tested (see Figure 2). The interior wall color of this cabinet with dimensions of 1.5mx1.1mx1m is painted matt gray. The operator lays the fabric to be tested into the cabin from the front surface. The imaging device (camera and lens) is located in the middle of the cabin ceiling. The imaging device can deserve on a bar perpendicular to the Z-axis. After determining the optimal distance to the fabric, fixation was made and precise adjustment in image clarity was made with the lens. In the imaging device, an ELP 8MP camera and a lens of 8mm focal length are used. D65 standard lighting source has been used in the cabin.

3.2. The developed software

The steps of the proposed method for calculating shrinkage values are shown in Figure 3. Accordingly, the software includes four basic steps: remove lens distortion, filters (adaptive and color)/ enhancement, hough line detection, and shrinkage measurements.

3.2.1. Removing lens distortion

The distance of the imaging device to the laid fabric was set at 50 cm. In this way, 50cmx50cm dimensions on the floor can be seen. However, distortions occur due to lenses in obtaining wide-angle images. For this reason, the distortion effect caused by the lens has been eliminated in the first stage of the software. Camera calibration is required to eliminate the lens distortion effect. The Multi-Plane Calibration method was used in this study [12]. This method can calculate the $[M]_{2x4}$ matrix containing the internal and external parameters of the camera using images of a particular plane (usually checkerboard) from different angles (see Figure 4).

The values of this matrix with 12 unknowns are calculated by the equations shown in Eq.1.

$$\begin{bmatrix} X_1 & Y_1 & Z_1 & 1 & 0 & 0 & 0 & 0 & -u_1X_1 & -u_1Y_1 \\ -u_1Z_1 & -u_1 \\ 0 & 0 & 0 & 0 & X_1 & Y_1 & Z_1 & 1 & -v_1X_1 & -v_1Y_1 \\ -v_1Z_1 & -v_1 \\ \dots \\ X_{128} & Y_{128} & Z_{128} & 1 & 0 & 0 & 0 & 0 & -u_1X_{128} & -u_1Y_{128} \\ -u_1Z_{128} & -u_1 \\ 0 & 0 & 0 & 0 & X_{128} & Y_{128} & Z_{128} & 1 & -v_1X_{128} & -v_1Y_{128} \\ -v_1Z_{128} & -v_1 \end{bmatrix} \begin{bmatrix} m_{00} \\ m_{01} \\ m_{02} \\ m_{03} \\ m_{10} \\ m_{11} \\ m_{12} \\ m_{13} \\ m_{20} \\ m_{21} \\ m_{22} \\ m_{23} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ \dots \\ 0 \end{bmatrix} \quad (2)$$

$$\mathrm{u_i(m_{20}X_i + m_{22}Y_im_{22}Z_i + m_{23}) = m_{00}X_i + m_{01}Y_im_{02}Z_i + m_{03}}$$
$$\mathrm{v_i(m_{20}X_i + m_{22}Y_im_{22}Z_i + m_{23}) = m_{10}X_i + m_{11}Y_im_{12}Z_i + m_{13}} \quad (1)$$

The m_{ij} variables in the equation refer to the cell values in matrix M. The X, Y, and Z parameters show the point coordinates on the plane, u and v parameters show the values of these coordinates on the image plane. The two equations in Eq.2. belong to a reference point on the checkerboard. Since there are 8x8 squares in the checkerboard, 64 reference points are obtained, resulting in an equation ($Ax = b$) with 128 equations:

After solving the obtained equation system as shown in Eq. 3, the calibration matrix is obtained:

$$x = (A^T A)^{-1} A^T b \quad (3)$$

Figure 5 shows how the lens distortion effect in a sample fabric image is removed. Figure 5 (left) shows how the 50cm^2 sized square shape drawn on the fabric is curved. The image was corrected with the calibration matrix obtained. Figure 5 (right) shows the corrected image.

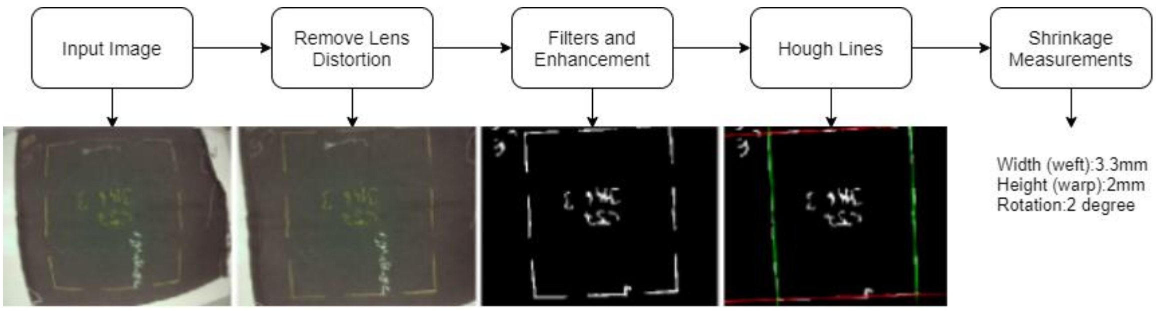

Figure 3. The stages of the software developed for calculating shrinkage values

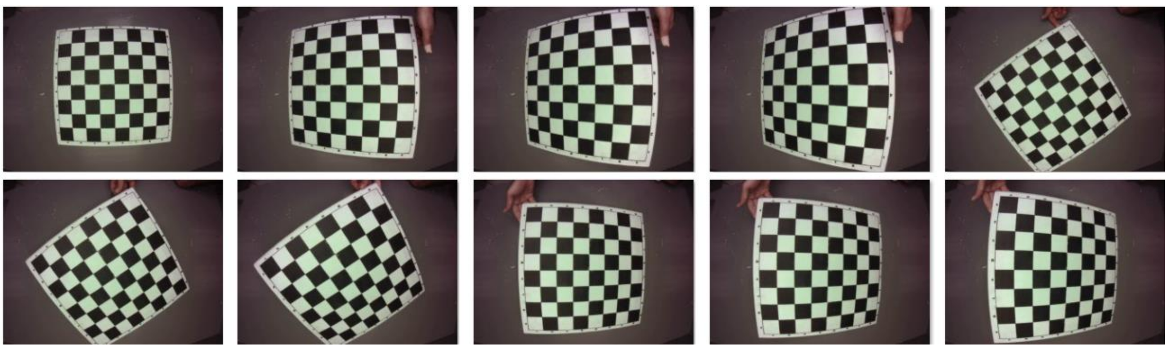

Figure 4. Multi-Plane Calibration Method

Figure 5. Removing Lens Distortion (Left) Original, (Right) Corrected

3.2.2. Filters and enhancements

In this section, filtering and making clear the straight lines drawn on the fabric are included. For this, a three-step process has been carried out. In the first stage, the adaptive filter result was obtained. In the second step, the color filter result was obtained and combined with the adaptive filter. In the third stage, the merging/ strengthening of the broken or broken lines in the combined filter result was achieved [13].

The adaptive filter is used to convert the color input image to a black and white form. Accordingly, each pixel in the image is evaluated together with the average value of the pixels in the 5x5 neighborhood. The average value is used softened by the conversion sensitivity coefficient (set at 0.4 in this study). Thus, if the pixel value is below averagex0.4, the conversion is 0, if it is above 1.

The color filter ensures that only pixels of the desired color range remain in the image. Before applying this filter, the image in RGB color space is converted to HSV space (H: color, S: saturation, V: intensity). The color range of the item marked on the fabric is expressed in Eq.3. The conversion is performed so that the pixels that meet the requirement in Eq.4 are 1, the others 0.

$$Binary\ \ Image = \begin{cases} 1 & H > 0.08\ \&\ H < 0.35\ \&\ S > 0.2\ \&\ V > 0.35 \\ 0 & otherwise \end{cases} \tag{4}$$

For a pixel to be on the frame, both filter results must be positive otherwise, the pixel is considered to belong to an object other than the square. Therefore, both filter results are combined with the "AND" operator which process somehow guarantees that the pixel found is on the straight line.

When the filter combination result is examined, it is seen that there are cut, broken, or weak lines. This situation makes square lines difficult to detect and sometimes causes lines not to be captured. Therefore, a morphological enhancing operation was carried out to join the cut lines and strengthen the weak lines. In the first stage, a 20-pixel long and line-shaped mask was prepared. After that its derivatives were obtained by rotating the prepared mask at -10, 0, 10, 80, 90, 100 angles. The reason for determining the angles in this way is that only square lines (horizontal and vertical) are to be strengthened. In the last step, the morphological closing operation was performed on the image with the prepared masks, and the results obtained were combined with the "Or" operator. Fig.6 shows the results of the filter and line reinforcement operations. When the results are examined carefully, it is seen that the cuts in the horizontal and vertical lines of the square have disappeared.

3.2.3. Hough lines

Hough transform is used to determine the positions of geometric structures such as lines, circles, and ellipses that can be mathematically expressed with equations in the image [14]. Hough moves the image from the spatial coordinate system to the space of geometric parameters. For example, if the lines in the image are captured, it performs a conversion from the spatial coordinates x and y to the θ and d parameter space in the polar representation of the line. As a result of the transformation, the H accumulator matrix is obtained.

$$\mathrm{x}\cos\theta - \mathrm{y}\sin\theta = \mathrm{d} \tag{5}$$

d refers to the distance of the pixel to the origin, θ refers to the angle with the horizontal axis. Pixels belonging to the same line correspond to the same cell in the H matrix. Therefore, the more pixels the line has, the greater the cell value in the H matrix. After transformation, the four highest cell values (four sides of the square) in the H matrix are kept and the other cells are zeroed and the reverse transformation is done. Thus, the four longest lines on the image are detected (see Figure 7).

3.2.4. Shrinkage Measurement

At this stage, it is tested whether the four longest lines detected by the Hough method belong to the square or not, and the lines that are positive for the test result are converted into (mm) by calculating the pixel length. Finally, it is calculated how far the horizontal and vertical edge lengths deviate from 50 cm, which is accepted as a reference.

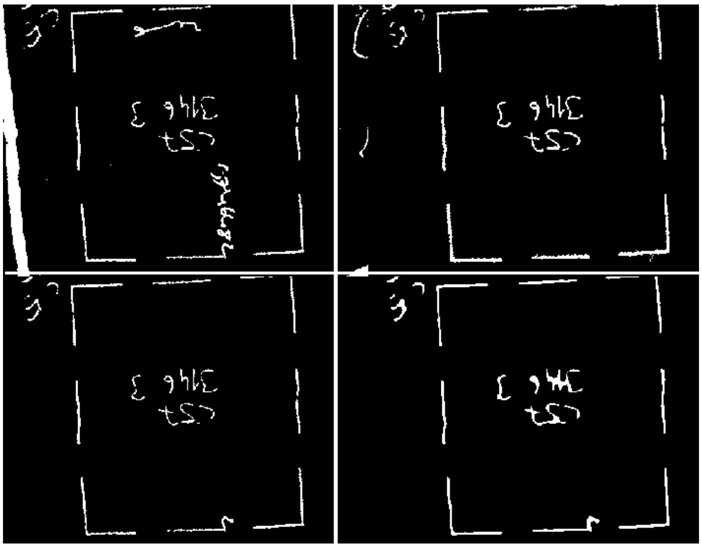

Figure 6. Filter Results. (Top left) Adaptive, (Top right) Color, (Bottom left) Adaptive&Color, (Bottom right) Improved Adaptive& Color

Two different tests were applied to determine whether the detected horizontal and vertical lines belong to the square or not. While evaluating the difference between the angle values in the first test, the average value of the angles was used in the second test. Horizontal and vertical lines are tested among themselves. Accordingly, the angle difference of the horizontal and vertical lines can be at most 10 for the detected lines to belong to the square. If the difference value exceeds 10, the line detection process is considered to have failed and an error message is generated. The second test is about laying it properly on the ground. Accordingly, the angle made by the square with the horizontal cannot exceed 45 degrees. Otherwise, the result is that the fabric is not laid properly on the floor and the error message is reflected. When both tests are passed successfully, the lengths of the horizontal and vertical lines in pixels are calculated. For this, the conversion from the parameter space to the spatial area is provided and the Euclidean distance between the start/end points is calculated. In the last stage, the distance values calculated in pixels are converted into mm and the differences are calculated with 500mm (50cm).

Table 1 lists the shrinkage test results on six different fabric types (5 of each). Both manual measurements were made on each fabric and the shrinkage values were calculated by the proposed automatic system. When the experimental study results are examined, it has been determined that there is a difference of %0,5-0,33 between manual measurement and system measurement. It has been evaluated that this difference is within tolerances and the proposed system can be used in the enterprise.

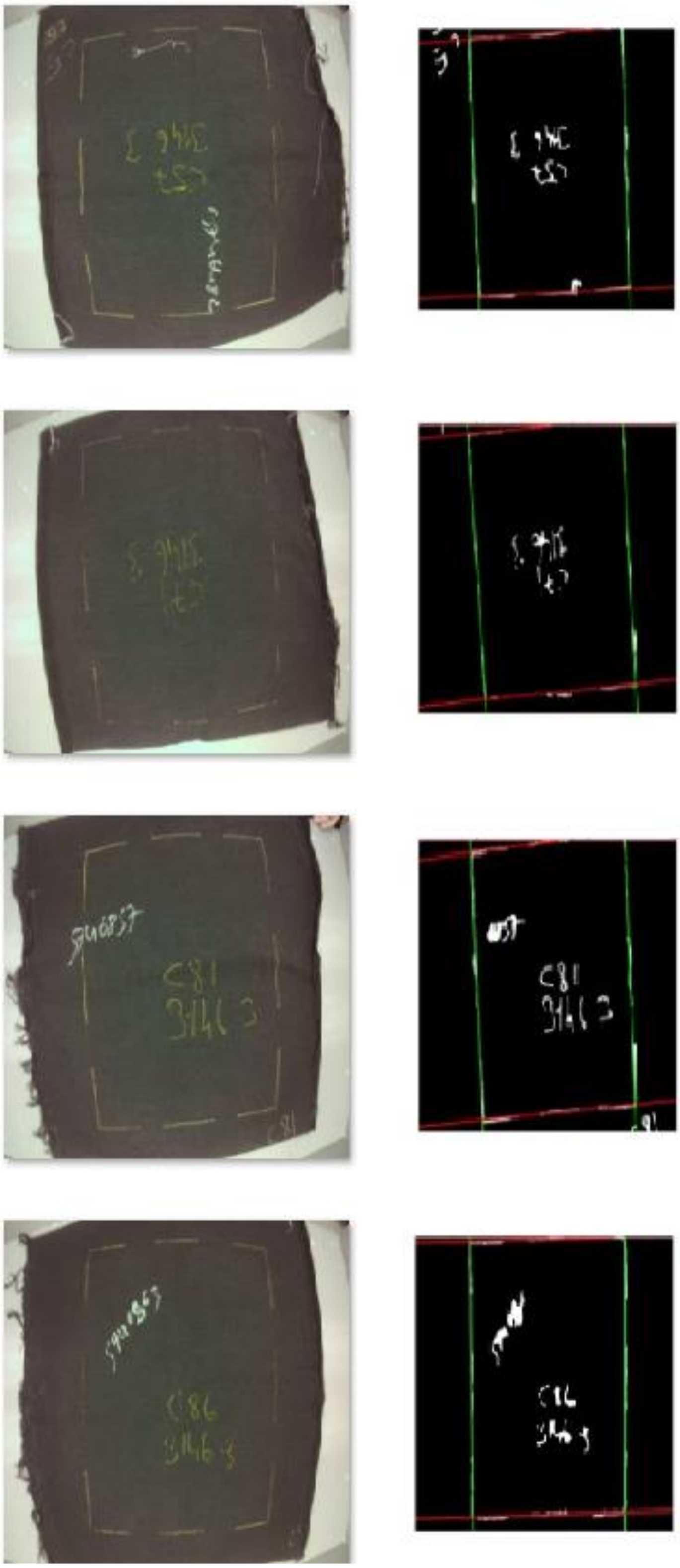

Figure 7. Detecting Square Lines} (Left) Original, (Right) Hough Lines

Table 1. Shrinkage test results on six different fabric types

No	Manuel		Proposed System		Fabric Type
	Width	Angle	Width	Angle	
1	-20	-4	-19.900	-3,92	A1
2	-19,6	-4	-19.502	-3,92	A2
3	-19,6	-3	-19.502	-2,94	A3
4	-19,6	-4,6	-19.502	-4,508	A4
5	-18,6	-5	-18.507	-4,9	A5
6	-3,4	-6	-3.383	-5,88	B1
7	-2,2	-5,8	-2.189	-5,684	B2
8	-3	-5	-2.985	-4,9	B3
9	-3	-5	-2.985	-4,9	B4
10	-2.6	-6	-2.587	-5,88	B5
11	-3,6	-6	-3.582	-5,88	C1
12	-3	-6,2	-2.985	-6,076	C2
13	-3	-6	-2.985	-5,88	C3
14	-3,2	-6	-3.184	-5,88	C4
15	-3	-6,4	-2.985	-6,272	C5
16	-23	-0,6	-22.885	-0,588	D1
17	-23	-0,2	-22.885	-0,196	D2
18	-23	-0,2	-22.885	-0,196	D3
19	-23	0	-22.885	0	D4
20	-23,8	-0,2	-23.681	-0,196	D5
21	-22,6	-4,2	-22.487	-4,116	E1
22	-25	-6,2	-24.875	-6,076	E2
23	-24,8	-6	-24.676	-5,88	E3
24	-23,8	-6	-23.681	-5,88	E4
25	-24	-6	-23.880	-5,88	E5
26	-3	-3,6	-2.985	-3,528	F1
27	-3	-2,6	-2.985	-2,548	F2
28	-3	-1	-2.985	-0,98	F3
29	-3	-1,6	-2.985	-1,568	F4
30	-3	-1,6	2.985	-1,568	F5

4. CONCLUSION

In this study, a computer vision-based approach is presented that can quickly and accurately calculate the shrinkage values of different types of denim fabrics after washing. This approach, which is an alternative to manual measurement, is based on obtaining standard fabric images with a viewing cabinet and calculating the shrinkage values in the images using a proposed method. Shrinkage values are calculated by the difference of the measurements of a square drawn on the fabric before and after washing. The shrinkage test process includes drawing the shape on the fabric before washing, taking measurements on the horizontal and vertical edges of the shape after washing, calculating the average shrinkage values, recording the values in the follow-up form, and transferring them to the computer. Performing these steps manually causes many erroneous values to be transferred to the system due to human error and complicates quality control processes. In addition, the manual measurement process is costly to the enterprise due to personnel expenses.

Although the proposed autonomous system is easy to install and operate, its cost to operate is low. Six different fabric types were used in the experimental studies of this system, which prevents human errors. When the obtained results were evaluated, it was determined that there was a %0.5-0.33 difference between manual measurement and automatic measurement of the proposed system. It is evaluated that this difference is within tolerances and the proposed system can be used in the enterprise.

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