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A Machine Vision Solution for Industrial Application of Abrage Inspection and Diameter Measurement on Yarn Bobbins

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ABSTRACT

The abrage fault inspection and bobbin diameter measurement are very important processes in yarn manufacturing industry. These processes are performed manually, and so they are difficult, low efficient, time-consuming processes. The abrage faults are seen as colour or shade difference on the dyed fabric. This happens when the bobbins including abrage are converted to the fabric form, mistakes in colour differences are seen after dyeing process. An automatic machine vision system was developed for detecting abrage fault, and bobbin diameter from yarn bobbin cross-section view. Image processing software was developed and applied on different sizes of bobbin samples including different types of abrage fault. The success of vision system was statistically evaluated by detecting the bobbin abrage faults with 95.83% accuracy. In addition, the bobbin diameters obtained from the developed image processing algorithm were statistically analysed and the correlation coefficient (R^2=0.99) was calculated.

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KEYWORDS

Bilinear interpolation, local thresholding, machine vision system, yarn faults, bobbin diameter

1. INTRODUCTION

In recent years, Industry 4.0, image processing applications, machine vision systems and artificial intelligence applications are extended as Textile 4.0 as in other sectors. Machine vision systems are becoming more common to perform objective evaluations automatically with less errors and in shorter time. Machine vision is used in textile sector while manufacturing high quality products with minimum defects. The machine vision systems and different image processing approaches can be used for determination of fiber, yarn, and fabric characteristics. New developments of industry 4.0 in terms of machine vision systems are also noticed in textile manufacturing sectors covering spinning, weaving, finishing, and clothing. These new technology systems are adapted to manufacturing line instead of manually controlled or human evaluated processes.

The fibers have different dyeability properties and different light reflectance characteristics. Accidental mixing of raw materials used in different stages of yarn production (blending or winding) results in a fault called “Abrage”. This fault is detected on the bobbin after the yarn production and on the fabric before the ready-made process. Currently, its control is performed manually with the human eye both on the yarn package and the fabric under the UV light (Figure 1). The yarn bobbins are placed in a creel prior to packing. They are then transported to a special room illuminated by UV light, where the bobbins are individually controlled. According to the research and analyses on yarn bobbin abrage control process in different firms, it is revealed that in an enterprise with an average daily production capacity of 15 tons of yarn, approximately 7500 bobbins are controlled in a day requiring 4 workers at least. Thus, the workers can inspect only 40% of the abrage faults and so this type of manual quality control process results higher labor costs with lower efficiency. This process is undoubtedly time consuming and tiring. When the number of bobbins to be checked daily is considered, the risk of overlooked bobbin gets higher. When the bobbins are overlooked, the production efficiency can decrease by at least 60%.

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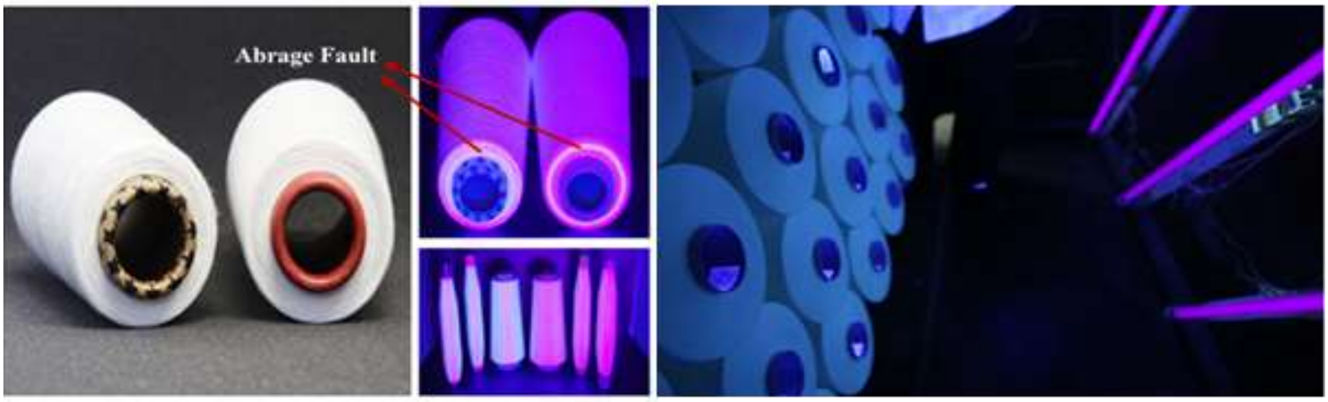

Figure 1. Abrage view under UV light [1, 2]

The yarn bobbin diameter measurement is also an important parameter for yarn packaging process. Normally, the diameter of the bobbins produced in the spinning mills is measured manually at certain intervals. This process is a significant value to perform packaging plan and to evaluate the efficiency of the winding process. It provides reliable inference about the yarn weight on bobbin, packaging tension and winding quality. If there is a problem in the winding stage, which is the last stage of the yarn production line, the diameter of the winding bobbins will be different or vice versa.

According to the literature research, it was seen that the most used method for determining circular objects in image processing is Hough transformation [3-5]. Circular objects in an image frame were distinguished from the complex background and highlighted. On the other hand, it was stated that the diameter values of the objects determined by Hough Transform can also be found. Since the yarn bobbin has a rounded appearance, Hough transformer was the most convenient way to determine the bobbin diameter. According to the literature research to segment the defective region in the image, the thresholding method plays a major role in binarization stage. Looking at the published scientific research about thresholding, histogram shape, measurement space clustering, entropy, object attributes, spatial correlation, and local gray-level surface methods are categorized according to the information they are exploiting by thresholding. Thresholding is an efficient way to distinguish objects from their surroundings thus this process produces a binary image with one state representing the foreground objects, such as written text, a defective part of a substance, and so on [6, 7].

Many studies are conducted on the detection of foreign matter in the fibers using image processing techniques [8-16]. Studies on image processing applications to yarn characteristics are mostly about the determination of yarn hairiness, yarn unevenness and yarn defects (thick place, thin place and neps) [17-26]. Apart from these, very few studies have dealt with the subject of abrage fault on the yarn package. Silvestre et al. conducted a study to determine the abrage faults caused by the mixing the different types of fibers on the yarn spool (cops). Yarn samples were raw yarn and dyed yarn. The detection of fault in HSV color space has given better results in the study. The proposed system ultimately showed 100% detection of faulty yarn packages in the product with an error margin of 0.5%. The defective parts of the bobbin are detected by using the different reflectance properties of the fibers the under the UV light [27]. In Çelik's study [28], a prototype of vision inspection system was designed for abrage fault detection. The vision system components were lightening unit, High Density (HD) web camera, a cabin and PC. A user interface was prepared for applying the fault detection algorithm on the yarn bobbin samples by using MATLAB®. The abrage faults of different bobbin samples were detected and labeled successfully. This study was performed to set up a prototype system for a start study. As a result of study performed by Çelik [28], it was decided that the system hardware components should be revised, and system should be rearranged with more professional hardware parts for industrial applications. After the necessary hardware component changes were achieved and system revision were completed, Gültekin et al. [29] presented a machine vision system for automatic inspection of yarn bobbin and fabric abrage defect. The prototype system is introduced, and properties of its components are investigated. The optimum image acquisition parameters that are useful for abrage inspection were also determined. In another study performed by Gültekin et al. [30], an image processing algorithm based on pixel intensity transform and morphological operations were developed, and it was applied on different bobbin and fabric samples including abrage fault. The success of the given machine vision system was discussed. However, this study is conducted to develop a more effective and sensitive image processing algorithm in terms of abrage defect segmentation and bobbin diameter measurement by using same machine vision hardware. The method and algorithm used in this study has been improved. With developed algorithm in this study, it is attempted that more robust and proper to industrial application system will be developed.

The most important contribution of this study is the establishment of a machine vision system and the proposal of a user-interfaced image processing algorithm to automatically control abrage faults and measure the bobbin diameter. Both two important inspections are achieved with a single system and single user-interface. The outputs of the machine vision system can be adapted to yarn packaging unit. So, the yarn bobbins can be automatically sorted according to their size and the yarn bobbins including abrage fault can be automatically removed. In the current yarn packaging system, the bobbins moving on the conveyor belt are taken one by one by the robot arm and placed on the pallets. With the developed machine vision system, which can be adapted to the robot arm, the diameter of the bobbins and the abrage fault will be detected automatically. In the packaging unit, which is the last stage of the yarn production line, the surface images of the yarn bobbins will be taken with the machine vision system that will be mounted on a robot arm. Then the bobbin diameter calculation and surface scanning process will be performed on the images taken, and if defect is detected, the faulty bobbins will be transported to another department by means of a robot arm. To highlight the originality of this work to show the difference of algortihm steps between current design and previous study, which was published earlier, Gültekin et al. [29] introduced the system components by discussing the design of the developed machine vision system and the materials used in detail. Later, in another study [30], the same authors explained the camera settings and lighting unit of the machine vision system. They developed and carried out preliminary studies with a simple algorithm. The biggest difference of this submitted article from the other two previous studies is the applied image processing algorithm. In contrary to the previous studies [29, 30], the circular image of the yarn bobbin cross-section is cropped and converted to linear formation by using "Polar to Cartesian Transform" technique in proposed method. So, the proposed algorithm detects the abrage fault in a more detailed and more sensitive way. Thanks to the machine vision system developed, the faults in the yarn bobbin and bobbin diameter can be performed precisely and reliably. Thus, it will be possible to increase the production efficiency of yarn manufacturers by 60%. In the meantime, the profit margin of the manufacturers will increase due to the decrease in worker incentives and the decrease in the rate of advertising caused by faulty bobbins.

2. MATERIAL AND METHOD

2.1 Material

The abrage bobbin samples are collected as three groups: blend abrage, cops abrage and abrage free ones. The blend abrage was produced by deliberately blending different fibers during fiber opening. Cops abrage samples were produced by feeding different cops to the same bobbin winding machine in a controlled manner. On the other hand, the abrage fault can occur at different location of the bobbin cross-section. In the content of this study, all possible abrage fault occurrence types were considered, and 36 different yarn bobbin samples were produced. Different fiber materials: USA cotton, domestic cotton, Tencel and polyester were used in the production of abrage bobbins. The bobbin abrages were produced at three different places of bobbin cross-section: at the beginning of the bobbin, in the middle of the bobbin and at the end of the bobbin with different sizes. Totally, 36 different yarn bobbin samples were produced by KİPAŞ Mensucat R&D Center, Kahramanmaraş, Turkey.

2.2 Method

To create an efficient and fully automatic system for the abrage fault detection and bobbin diameter measurement under industrial application condition, the inspection should be achieved while the bobbins are also automatically transferred through the process zone. However, such a system must be built on an industrial yarn production mill and the real-time trials must be made under the manufacturing condition. Since this type of application is difficult and, requires long time, high effort, and high construction cost, it was seen easier and effective to develop a robust inspection algorithm with prototype system consists of industrial hardware components. After the required success is obtained, the machine vision system can be adapted to industrial application and necessary modifications for real-time inspection can be carried out quickly.

In this study, MATLAB® software program was used for preparing user interface and image processing algorithm. Since such a vision inspection system consists of image acquisition and processing parts, first the components of the image acquisition system were introduced and then the image processing algorithms were explained.

2.2.1 Description of vision inspection system

A prototype vision inspection system was developed to acquire and analyze the image frame of the yarn bobbin samples. According to the experience-based knowledge received from the yarn industry, 95% of the abrage fault in the yarn bobbin was encountered on the bobbin surface, and so it was stated that it will be sufficient to inspect only the upper cross-section of the yarn bobbin. The prototype machine vision system was designed in accordance with these criteria. The system consists of a lightening unit, a camera system, a cabin, and a computer (Figure 2). The BASLER acA1920-40uc area scan camera with the Sony IMX249 CMOS sensor delivers 41 frames per second at 2.3 MP resolution, and the sensor size of camera is 11.3 mm x 7.1 mm was used. A top-lightening unit consisting of 12 LED UV fluorescent lamps and positioned around the camera system. The dimensions of the cabin are given as 80 cm x 80 cm x 85 cm to provide easy location of bobbin samples. The cabin was painted in matt black color to provide a homogeneous illumination and eliminating reflection inside the cabin. The camera was placed to the top of the cabin by using a properly designed attachment frame. A suitable apparatus was designed for positioning the bobbin samples at the bottom of the system. The distance of the bobbin sample to camera lens is to be arranged. This is necessary so that the camera field of view can be adjusted according to the bobbin size. A screw system was used to adjust the camera distance. The other adjustments related to camera and algorithm performance were achieved via computer. High image quality is essential for the system response, the parameters in the camera software interface (Pylon5) were analyzed. The related camera parameters: Light Source Pre-set, Gain, Gamma and Exposure time etc. have been adjusted until the required image frame was obtained. Determined camera parameters were set during inspection tests. In this study, the gain was set to 30, gamma was set to 2, and exposure time was set to 5000. These values can vary according to different light intensity. Therefore, these parameters must be changed in different application areas. The optimum values of these parameters were determined by trial-and-error method in different applications.

Before adapting the proposed system to yarn production line for real-time inspection, the hardware of the system; industrial camera properties, lighting conditions and cabin design, which are the most important equipment of the system, were completed. As it will be difficult to test such a smart quality control system directly on the production line, firstly, experiments were carried out on a prototype structure.

2.2.2 Abrage detection algorithm

When an operation is performed for an object in any image, it is desired that the applied filter or operation should affect only the target object in the image size. This process can only be possible when the image frame completely consists of the target object. Considering the visual evaluation of the yarn bobbin in the image frame, a circular area is occupied within a rectangular image frame with a size of M×N. When the image frame of yarn bobbin cross-section view is seen in the machine vision system, the yarn bobbin has shades of gray, while the areas outside the circular bobbin area are seen as completely black. During processing of image frame with any filter, a neighborhood operation is performed. The value of any given pixel in the output image is determined by applying an algorithm to the values of the pixels about the corresponding input pixel. Filtering is valid for whole image matrix. Because of the filtering restrictions, the area covered by yarn bobbin cross-section surface should be extracted from the image frame.

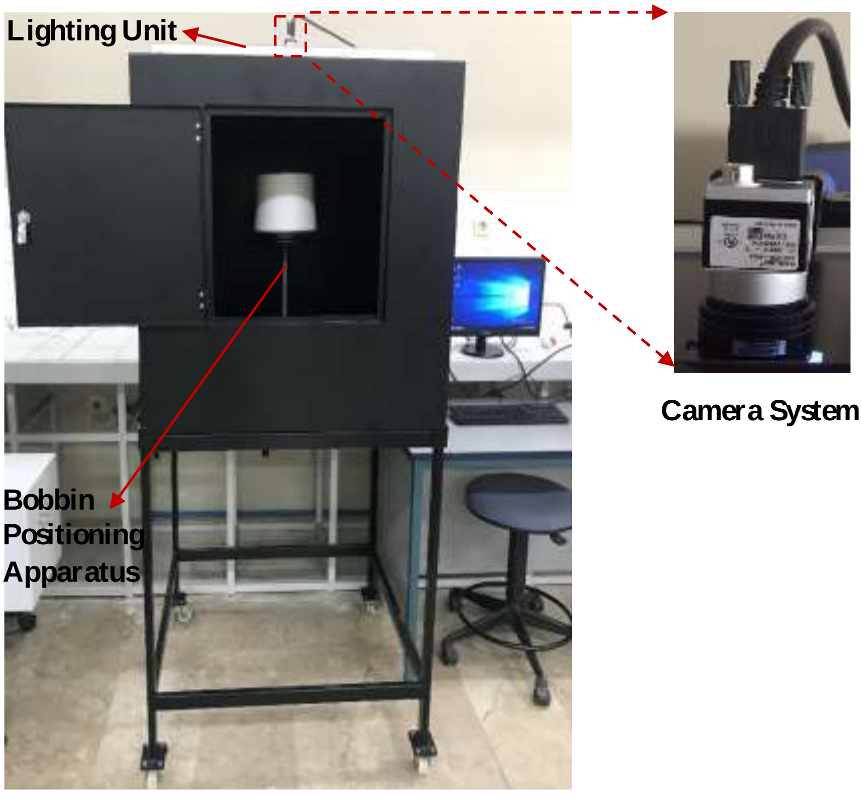

Figure 2. A prototype bobbin inspection cabin design

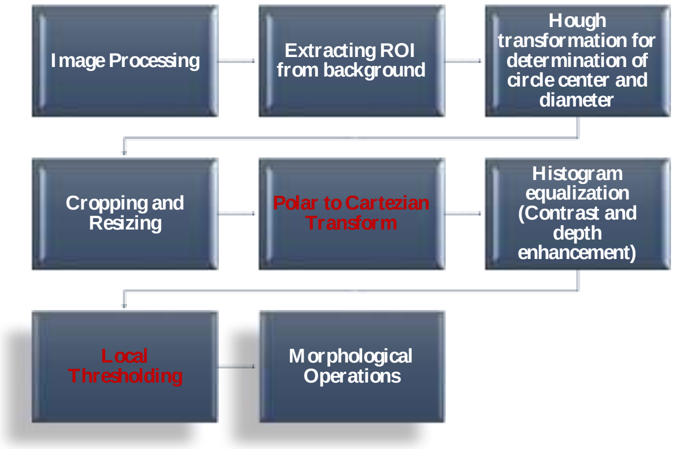

Figure 3. Steps of the algorithm

The flow chart of the algorithm developed for diameter measurement and abrage detection is given in the Figure 3. Before this object extraction operation, some preprocessing phases were achieved. All color images were taken from the machine vision system were converted to gray format. The images in gray format were converted to binary form, where the bobbin was completely white, and the rest was black. The Hough transformation approach was used to calculate the center of the bobbin where the boundaries were defined by drawing its contour (Figure 4). The inner (r_{in}) and outer (r_{out}) radiuses of the bobbin was determined via Hough transform (Figure 4).

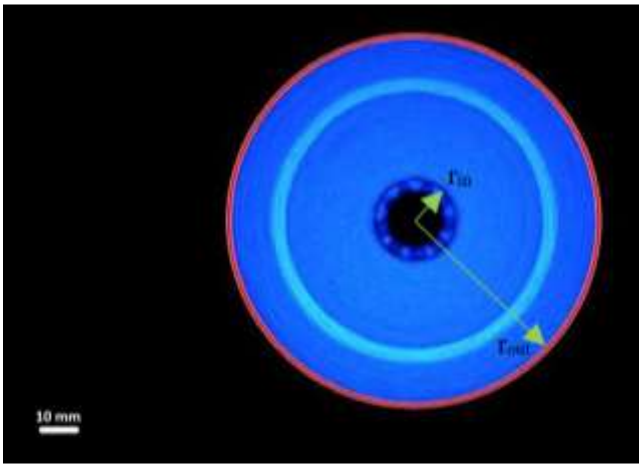

Figure 4. Bobbin diameter boundary image with Hough transformation

2.2.3 Polar to Cartesian transform

The method for this problem is based on the transformation of object polar coordinate into a cartesian coordinate system by bilinear interpolation. The Cartesian coordinates (x, y) in two dimensions describe the direction of a point P in the plane. Polar coordinates are another two-dimensional coordinate scheme. Polar coordinates specify the direction of a point P in the plane by its distance r from the origin and the angle (θ) formed by the line segment from the origin to P instead of signed distances along the two coordinate axes. Calculation of a point's cartesian coordinates using polar coordinates (r, θ) by constructing the right triangle shown in (Figure 5). The hypotenuse is a line section that runs from the origin to the point and is r in length. The side of the triangle adjacent to the angle, $x = r \cos \theta$ is the projection of this line section on the x-axis (Figure 5(a)). The other side determines the y-component, $y = r \sin \theta$ (Figure 5(a)).

The polar coordinates can be transformed to area map (Figure 5(b)). The transformation from polar (r, θ) plane (left in Figure 5(a)) to cartesian coordinates (x, y) plane (right in Figure 5(b)) with $(x,y)= T(r, \theta) = (r \cos \theta, r \sin \theta)$ maps a rectangular. As seen in Figure 5(b), the yellow dot on the right panel corresponds to the rectangular area on the left panel. Each small curvy rectangular cell of the polar plane is also mapped to small rectangular cells of the cartesian plane. As seen from this simulation (Figure 5), it can be proved that area between the inner and outer diameters of the yarn bobbin can be transformed to rectangular area [31].

The boundaries of the bobbin with the inner and outer diameters were determined by Hough transformation (Figure 6(a)). The image was segmented according to the boundaries of an object whose diameter was already known (Figure 6(b)). Thus, the region occupied by yarn bobbin was cut out from the image frame. Then interpolation was performed on the segmented image. In this conversion, M is the number of pixels from the minimum r to the maximum r along the radius. Eventually, the output image was an M×N image with M points along the r-axis, and N points along θ-axis. An object in the form of a circle was extracted and then it is transformed into a rectangular image frame (Figure 6(c)).

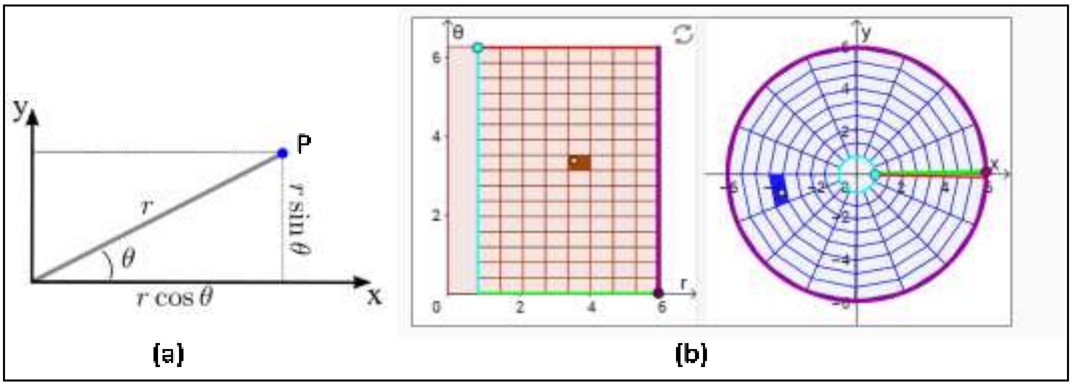

Figure 5. Schematic representation of area transformation of polar coordinates map [31]

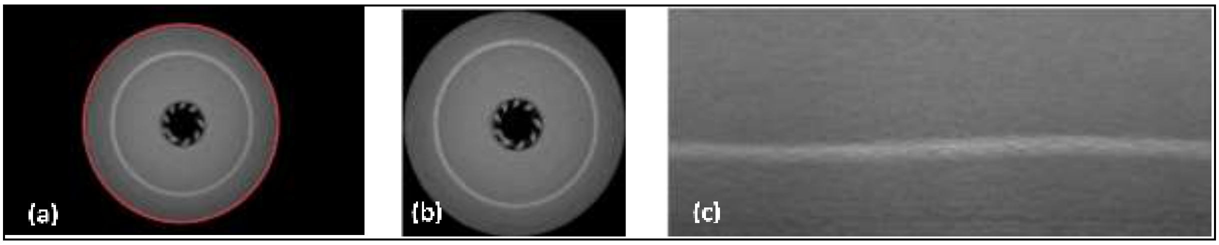

Figure 6. (a) Plotted bobbin boundary, (b) Image cropped according to bobbin outer boundary, (c) Bobbin cross-section extracted and transformed into rectangular image frame

2.2.4 Adaptive thresholding based on local statistics

Adaptive thresholding should be preferred in cases where the ghosting in the image caused by the lighting source is high. The adaptive thresholding approach based on computing threshold pixel intensity value of each local pixel (x, y) from the pixel values of (x, y) neighbors in m×n size (Figure 7).

Let $S_{x,y}$ demonstrate the set of coordinates of a neighborhood centered on a gray image. Neighborhood processing generates a corresponding pixel at the same coordinates in an output (processed) binary image. This specified operation comprises the pixels in the input image with coordinates in $S_{x,y}$. The defined procedure is to calculate the average value of pixels in a rectangular neighborhood of size M×N based on the specified point (x, y). Binary image is obtained sliding the N×M thresholding window along the gray image frame and so the specific threshold value of each pixel is obtained according to the center (x, y) coordinate pixel and corresponding neighbor pixels [32].

As the basic approach for local thresholding, the standard deviations and means of the pixels adjacent to each point in an image are used. Since these two values define the local contrast and the average intensity, they are very useful in calculating local threshold. Although this process appears to be a laborious task, the modern algorithms and the hardware allow fast neighbor processing with common functions, logical and arithmetic operations.

Let σ_{xy} and m_{xy} indicate *the standard deviation* and *mean value* of the set of pixels contained in a neighborhood centered at the coordinate (x, y) in an image. The format of local thresholds (T_{xy}) is given as follows Equation (1):

$$T_{xy} = a\sigma_{xy} + bm_G \quad (1)$$

where m_G is the global image mean, a and b represent nonnegative constants. The segmented image $g(x, y)$ is computed as Equation (2):

$$g(x,y) = \begin{cases} 1 \ if \ f(x,y) > T_{xy} \\ 0 \ if \ f(x,y) \leq T_{xy} \end{cases} \quad (2)$$

where $f(x, y)$ represents the input image. This equation is evaluated and applied at all pixel locations.

Thresholding can be categorized into global and local thresholding. In images with uniform contrast distribution of background and foreground like yarn bobbin images, global thresholding is more appropriate. Therefore, in this study, global thresholding was used with the standard deviation and average pixel values obtained from the entire image frame according to Equation 1. The optimum values of a and b constants in Equation 1 have been obtained because of different trying, as made in many image processing studies.

3. RESULTS AND DISCUSSION

3.1 Results of Local Thresholding Algorithm

Abrage fault detection application was achieved by using Local Thresholding Algorithm. The results of the local thresholding method are given in Figure 8.

Since the pixel intensity values of faultless region was different from abrage region, the defective region was distinguished from the average and standard deviation calculated from the neighbor relations of each pixel give high accurate results.

The success rate was determined by applying the algorithm to all bobbin samples. Once the model is developed, the next phase is to calculate the performance of the developed model using confusion matrix criteria.

Confusion Matrix is a tool to determine the performance of classifier. It contains information about actual and predicted classifications. The below table shows confusion matrix of two-class, positive and negative classifier [33]. The terms in Table 1 are.

True Positive (TP) is the number of correct predictions that an example is positive which means positive class correctly identified as positive.

False Negative (FN) is the number of incorrect predictions that an example is negative which means positive class incorrectly identified as negative.

False Positive (FP) is the number of incorrect predictions that an example is positive which means negative class incorrectly identified as positive.

True Negative (TN) is the number of correct predictions that an example is negative which means negative class correctly identified as negative.

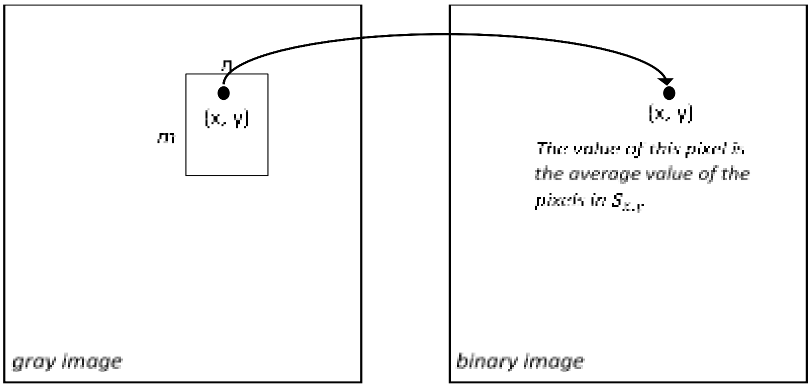

Figure 7. Local averaging using neighborhood processing

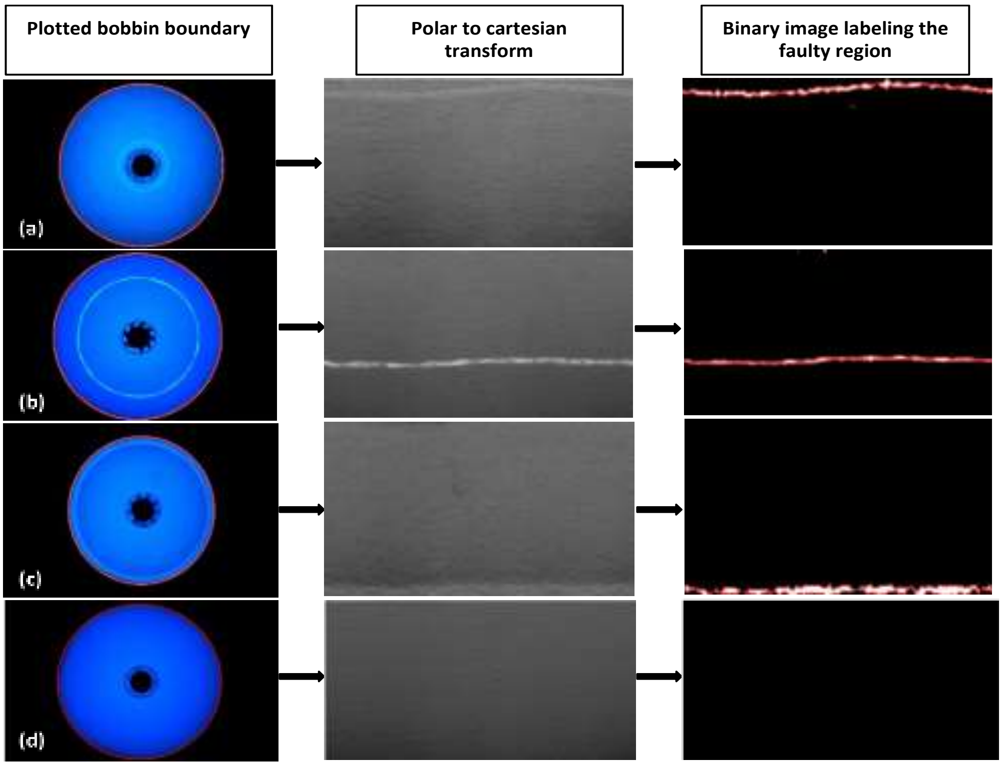

Figure 8. Algorithm results prepared by Local Thresholding method (a) abrage at the beginning of the bobbin, (b) abrage in the middle of the bobbin, (c) abrage at the end of the bobbin, (d) faultless bobbin

Table 1. Confusion matrix with advanced classification metrics

		Predicted Class		
		Positive	**Negative**	
Actual Class	**Positive**	True Positive (TP)	False Negative (FN)	**Sensitivity** $\frac{TP}{(TP+FN)}$
	Negative	False Positive (FP)	True Negative (TN)	**Specificity** $\frac{TN}{(TN+FP)}$
		Precision $\frac{TP}{(TP+FP)}$	**Negative Predictive Value** $\frac{TN}{(TN+FN)}$	**Accuracy** $\frac{TP+TN}{(TP+TN+FP+FN)}$

Sensitivity is also referred as "True Positive Rate" or "Recall". It is a measure of positive examples labeled as positive by classifier required to be higher. Specificity is also known as "True Negative Rate". There should be high specificity. Precision is ratio of total number of correctly classified positive examples and the total number of predicted positive examples. It shows correctness achieved in positive prediction. Accuracy is the proportion of the total true predictions to all predictions. Figure 9 shows confusion matrix of yarn bobbins. The bobbin samples were evaluated manually under UV light via human eye and compared with the results of the image processing algorithm. The comparison results were categorized according to confusion matrix. The image processing algorithm results were evaluated in four classes as: (1) at the beginning of the bobbin, (2) in the middle of the bobbin, (3) at the end of the bobbin, and (4) faultless bobbins, respectively.

After creating a confusion matrix chart from the true labels and the predicted labels, the true positive rates and false positive rates in the row summary were displayed as sensitivity and specificity. Also, column summary displayed the positive predictive rates and false predictive rates as precision and negative predictive value.

Finally, the success rates, which called sensitivity, were obtained as; 100% at the beginning of the bobbin abrage (1), 91.7% at the middle of the bobbin abrage (2), 91.7% at the end of the bobbin abrage (3), in 100% abrage-free bobbins (4). An average accuracy of 95.83% were achieved. This ratio is a very good result for determining the abrage error in the yarn package. When the abrage fault, which are evaluated manually in the UV light room by the experienced employees, the success rate obtained from the machine vision system is evaluated as acceptable level.

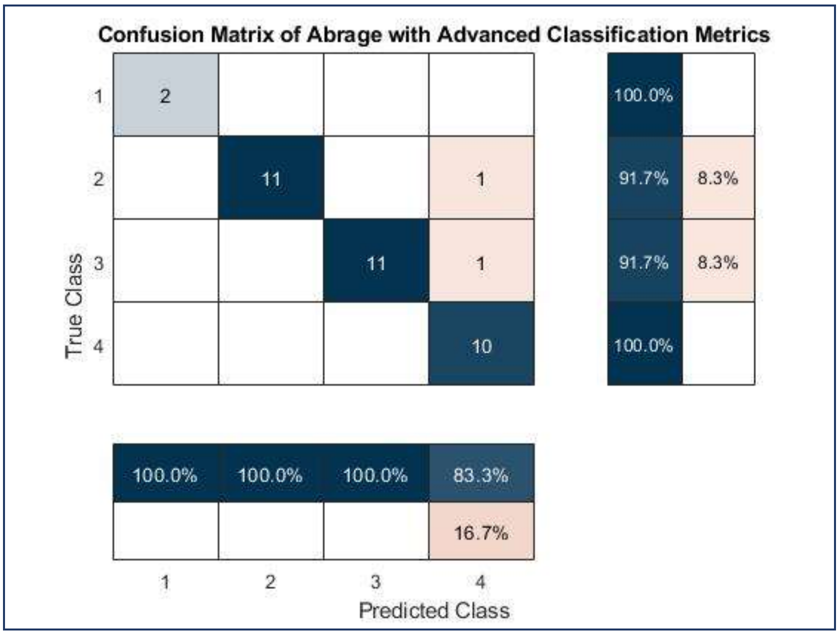

Figure 9. Confusion matrix of yarn abrage classification according to fault class

3.2 Bobbin Diameter Measurement Results

The bobbin measurement verification was performed using 25 bobbin samples. Bobbin diameter was measured manually with calipers as the actual results. The same bobbins were placed in the machine vision system and the diameter values were then determined. Since the diameter measurement made with image processing algorithm is in pixel unit, it must be transformed to mm unit. A calibration process is performed to determine the size of each pixel in mm. Thus, the diameter of each bobbin was obtained by multiplying the pixel size with the measured number of pixels in diameter. The accuracy of the bobbin diameter measurement via machine vision system was determined by using the mean absolute percentage error (MAPE) statistical model (Equation (3)) that is calculated from Hough transformation results of developed image processing algorithm (Figure 4) and the actual diameter measurement results. The bobbin diameter results of both methods and corresponding MAPE values are presented in Table 2.

$$MAPE = \frac{\sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{y_i} \right| x100}{n} \quad (3)$$

Table 2. Actual and predicted bobbin diameter results

Number of Samples	Actual Measurements (mm)	MATLAB IP Measurements (mm)	MAPE
1	188	189.46	0.78
2	191	190.00	0.52
3	189	190.14	0.60
4	208	209.54	0.74
5	199	200.12	0.56
6	211	210.67	0.16
7	211	212.90	0.90
8	210	209.91	0.04
9	211	212.18	0.56
10	211	212.72	0.82
11	212	212.69	0.33
12	209	210.53	0.73
13	207	208.09	0.53
14	190	190.37	0.20
15	206	205.96	0.02
16	195	196.91	0.98
17	213	213.20	0.10
18	211	212.50	0.71
19	186	187,00	0,54
20	208	207.67	0.16
21	205	205.09	0.04
22	202	202.82	0.41
23	199	200.55	0.78
24	196	197.44	0.74
25	216	217.88	0.87
Average	**203.36**	**204.34**	**0.51**

According to Table 2, the lowest and highest error percentage values were obtained as 0.04% and 0.98%, respectively. The mean absolute percentage error of the results was calculated as 0.51%. The linear regression analysis is made between the actual and image processing measurement results and displayed in Figure 10. It can be clearly seen that there is high correlation between two value sets and so the actual and the image processing results are progressing on the same trend (Figure 10(a)). The regression coefficient between actual and image processing values was calculated as R^2= 0.9921 (Figure 10(a)). In the residual graph (Figure 10(b)), each point indicates the yarn bobbin diameter measurement, where the measurements made by the image processing algorithm are on the x-axis and the accuracy of the measurements is on the y-axis. The distance from the line at 0 is how bad the image processing measurement was performed for that value. So, the residual is the bit that subtracting the image processing value from the actual value.

3.3 Abrage Fault Inspection System User Interface

The Image Processing and Image Acquisition Toolboxes in MATLAB program were used in the user interface preparation stage. The prepared GUI (Figure 11) has buttons such as "Start Camera", "Capture Image", "Exposure Time", "Image Processing" and "Exit" with its functions separately. The relevant codes are inserted to the working extension of the interface. The camera is started via the interface. An option is then provided where you can set the Exposure Time manually. The "Exposure Time" option provides the adjustment of the lightening duration according to the yellowness of the fibers on the yarn bobbin. Therefore, the pixel intensity values can be adjusted for different products. Otherwise, it is not appropriate to use a fixed Exposure Time value for all fiber types. The Capture Image button is used to get a yarn bobbin cross-section image frame. After all these adjustments, the abrage detection process is started with the Image Processing button. When image processing is performed, the image of inspected bobbin, the histogram graph of the image, binary transform of the image was represented on related axes of user interface. Besides to all these fault detections, the bobbin diameter is also given to the user in mm. If abrage fault exist in the inspected image, the percentage of the abrage fault to the total bobbin cross-section area is calculated and presented to the user. If any abrage fault is detected, the bobbin sample is named as "Abrage Found" and saved. If the detected sample has not got abrage fault, it is displayed as "Faultless".

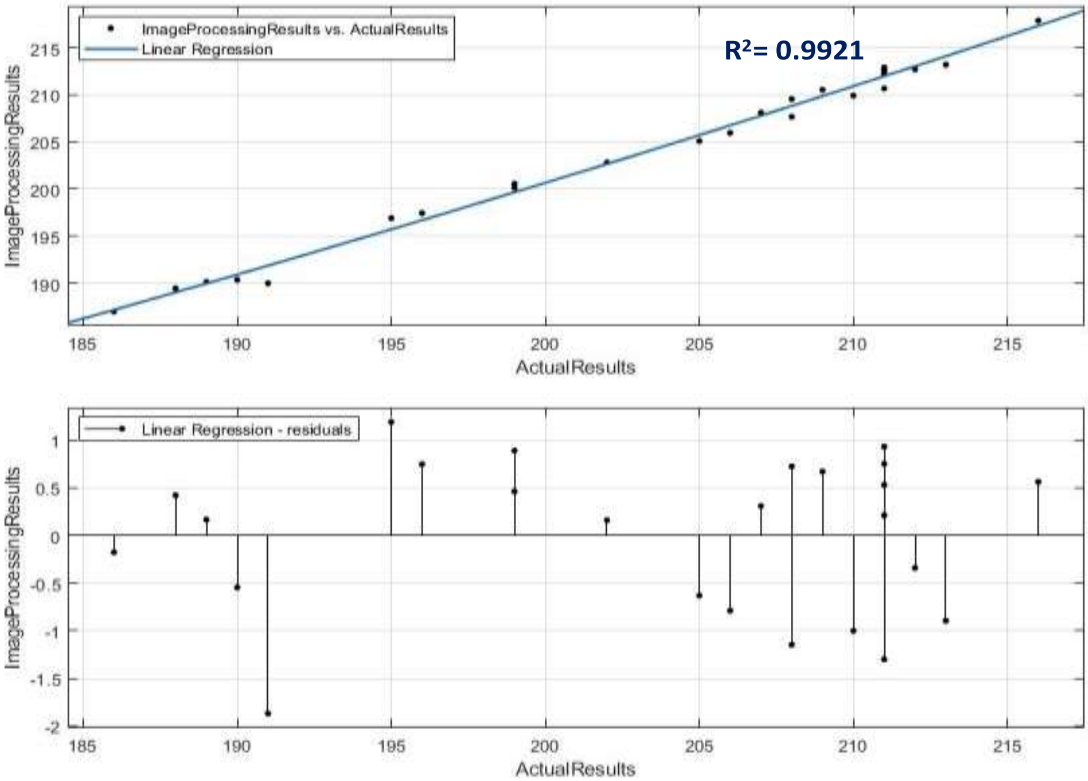

Figure 10. Q–Q plot of the actual and image processing measured bobbin diameter values (a) correlation graph, (b) residual graph of each measurement

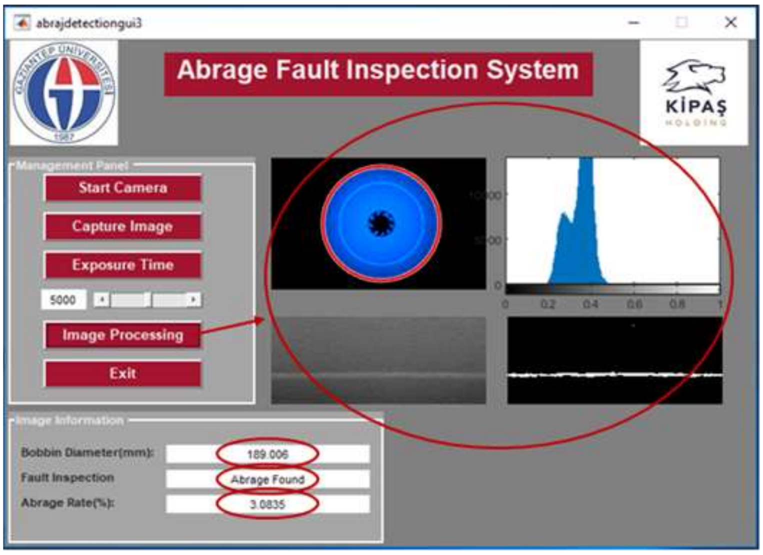

Figure 11. Abrage fault inspection system- User Interface

4. CONCLUSION

A machine vision system was proposed for bobbin abrage fault detection and bobbin diameter measurement. Thirty-six yarn bobbin samples were inspected with a success rate of 95.83%. This ratio is quite high for a spinning mill even it has full automation line. The system can easily be improved by building necessary hardware and software and so it will be possible to access the system remotely and acquire the number of abrage and fault free bobbins in real-time. In addition, since the automatic measurement of the yarn bobbin diameter is very important in terms of determining the packaging tension and the winding quality of the winding machine, the automatic measurement of the bobbin diameter was achieved with a high success rate of R^2= 0.9921.

The study is performed as a part of a research project involving an industrial application. The machine vision system was created by using the correct illumination system and high-resolution camera. The operation duration of the machine vision system that is the time required for abrage inspection and bobbin diameter measurement was determined as 10 seconds. The conveyor band that is used for yarn bobbin transformation is driven with approximately 15 rev/min motor speed. The developed machine vision system and image processing algorithm can be adapted easily on the yarn bobbin conveyor band currently used in the spinning mill and run successfully.

The proposed system can be replaced with the manual inspection process. It can be estimated that production efficiency can be increased by at least 60% by saving labor costs with the proposed machine vision system. The developed image processing approach technique can be used to achieve the current time-consuming quality control process automatically, sensitively and in shorter time.

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