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IMAGE PROCESSING APPROACH FOR FOREIGN MATERIAL DETECTION IN COTTON BUNDLE

PAMUK DEMETİNDE YABANCI MADDE TESPİTİ İÇİN GÖRÜNTÜ İŞLEME YAKLAŞIMI

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IMAGE PROCESSING APPROACH FOR FOREIGN MATERIAL DETECTION IN COTTON BUNDLE

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***ABSTRACT*:** The image processing philosophy is mainly determined by the complexity of the image and provides the necessary information to be derived from the image. In the textile industry, the image processing technique focuses on the determination of the geometric properties of the fibers such as cross-sectional shape, diameter, length, fineness, and curl while the studies on the yarn characteristics mostly focus on the determination of yarn hairiness, yarn unevenness and yarn defects (thick place, thin place and neps). In this study, previous studies about image processing approaches that are applied for fiber characteristics were investigated. A case study was conducted to automatically determine the visible foreign matter in the waste cotton bundle that can be used for recycled cotton yarn production. It was revealed that the image processing methods can be successfully applied for foreign fiber and matter detection in cotton bundle. As a result, it is emphasized that the waste cotton properties can be specified with a sensitive and accurate approach via image processing technique, objective and numerical determination can be obtained instead of visual evaluation based on experience.

Keywords: Image processing, visible foreign matter, waste cotton, fiber characteristic

PAMUK DEMETİNDE YABANCI MADDE TESPİTİ İÇİN GÖRÜNTÜ İŞLEME YAKLAŞIMI

***ÖZ*:** Görüntü işleme felsefesi esas olarak görüntünün karmaşıklığına göre belirlenir ve görüntüden elde edilecek gerekli bilgilerin toplanmasını sağlar. Tekstil sektöründe görüntü işleme tekniği liflerin kesit şekli, çapı, uzunluğu, inceliği, kıvrımı gibi geometrik özelliklerinin belirlenmesine odaklanırken, iplik özellikleri üzerine yapılan çalışmalar çoğunlukla iplik tüylülüğü, iplik düzgünsüzlüğü ve iplik kusurları (kalın yer, ince yer ve neps) belirlenmesine odaklanmaktadır. Bu çalışmada lif özelliklerine yönelik uygulanan görüntü işleme yaklaşımları ile ilgili daha önce yapılan çalışmalar incelenmiştir. Geri dönüştürülmüş pamuk ipliği üretiminde kullanılabilecek atık pamuk demeti içindeki görünür yabancı maddenin otomatik olarak belirlenmesi amacıyla bir ön çalışma yapılmıştır. Pamuk demetlerinde yabancı lif ve madde tespitinde görüntü işleme yöntemlerinin başarıyla uygulanabileceği ortaya çıkmıştır. Sonuç olarak atık pamuğun özelliklerinin görüntü işleme tekniği ile hassas ve doğru bir yaklaşımla belirlenebileceği, tecrübeye dayalı görsel değerlendirme yerine objektif ve sayısal tespitin elde edilebileceği vurgulanmıştır.

Anahtar Kelimeler: Görüntü işleme, görülebilir yabancı madde, atık pamuk, lif karakteristiği

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This study was presented at "International Congress on Sustainability and Technological Developments in Textiles (TESTEG October 13-15, 2023)". Peer review procedure of the journal was also carried out for the selected papers before publication.

1. INTRODUCTION

Raw cotton must be sorted to eliminate any foreign fibers and particles before it can be spun into cotton yarn. Foreign materials like polypropylene (PP) or polyethylene (PE) fibers are frequently light and translucent, making it challenging to identify them using traditional foreign fiber separators. Although, the foreign particles have different color, contrast, and structure, it is difficult to detect and separate them from cotton. Even at extremely low levels, impurities from foreign fibers in cotton can cause the fabric to become discolored and lose value when they are used to make finished cotton products. This can result in significant financial loss for cotton textile companies (Shofner et al., 1986).

During the manufacturing process, raw cotton may blend with a range of foreign fibers that comes from package. The quality of cotton products has been negatively impacted by foreign fiber. The variety, low percentage, and widespread dispersion of these foreign fibers make physical examination for foreign fibers both costly and useless. In the production line, it may be more effective and efficient to use an automated method for inspecting foreign fibers.

The use of machine vision, CT X-rays, infrared and ultraviolet radiation, multi-band image fusion, and other methods for detecting foreign fiber have all been examined by researchers. Several methods, including ultrasonic-based inspection, sensor-based inspection, and machine-vision-based inspection, have been developed to implement automated inspection and removal of foreign matters in cotton (Chen et al., 2010). Machine vision technology is especially used for the detection and identification of foreign fibers in the visible spectrum (Ji et al., 2010).

Over the past 20 years, several academic institutions and research centers have concentrated on the detection of foreign fibers. Currently, it is common practice to use image processing techniques to extract morphological characteristics of foreign fibers, such as their shape and color. Du et al. used a Hitachi UH4150 UV/Vis/NIR spectrophotometer to assess the reflectance of the five foreign fibers' spectra (Figure 1). The 780–2360 nm spectral scanning band range was used. The sample was scanned every 1 nm. It scanned at a rate of 1200 nm/min. To prepare the spectroscopic data, Savitzky-Golay smoothing was applied, and LightGBM-ANOVA was used to identify the best wavelengths. Using a 1D convolutional neural network (1D-CNN), spectral properties from preprocessed data were obtained. Then classification models were created using the Temporal Convolutional Neural Network (TCN), Long-Short Term Memory (LSTM), Gated Recurrent Unit (GRU), Recurrent Neural Network (RNN), and 1D-CNN (Du et al., 2023).

Three distinct forms of multi-class SVM were built by Li et al. to categorize the visual properties of foreign fibers (Li, Yang, and Wang 2010). Live images were first captured by a machine vision system (Figure 2), which was followed by image processing algorithms in this study. Then, feature vectors were assembled using the obtained color, shape, and texture properties of each foreign fiber. The construction of three different types of multi-class support vector machines, including one-against-all decision-tree based MSVM, one-against-one voting based MSVM, and one-against-one directed acyclic graph based MSVM, was then completed. The MSVMs were finally validated using leave-one-out cross validation utilizing the retrieved feature vectors as input. The outcomes show that the one against one vote based MSVM and the one against one directed acyclic graph MSVM are capable of satisfying the accuracy criteria of the classification of foreign fibers, with the mean accuracy being 93.57% and 92.34%, respectively.

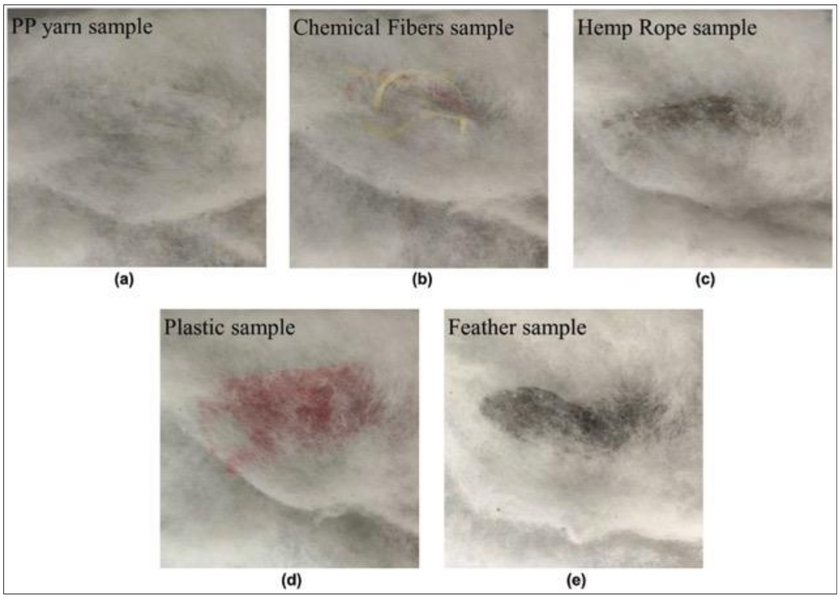

Figure 1. Foreign fibers experiment samples:(a) PP Yarn; (b) Chemical Fibers;(c) Hemp Rope; (d) Plastic; (e) Feather (Du et al., 2023)

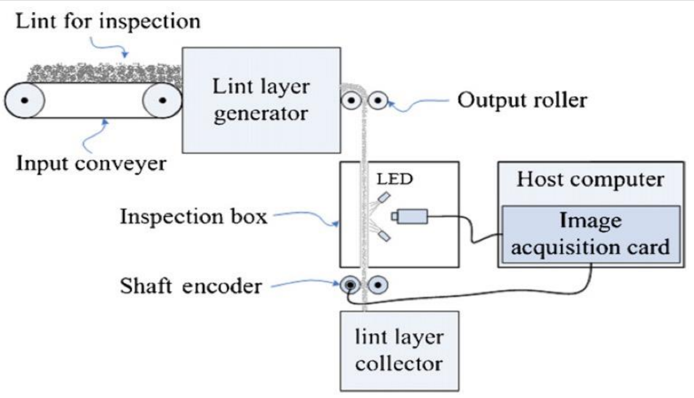

Figure 2. Outline of the machine vision system (Li, Yang, and Wang 2010)

Using visual characteristics, Ji et al. (2010) coupled decision trees and SVM to identify foreign materials. The real output from China's textile factories is used to construct a method for detecting foreign materials. Image acquisition and image recognition comprise the entire system. Figure 3 shows the subsystem diagram for image acquisition. Using high-speed 3CCD color line scan technology and extremely bright LED lighting, a Canadian DALSA camera captures colorful images. Research finds foreign materials with colors distinct from cotton. Black plastic, blue fabric, red silk, brown hemp rope, black hair, and red polypropylene yarn are the six types of foreign materials that were used for the experiment. The primary morphological characteristics of foreign materials including length, breadth, aspect ratio, area, perimeter, roundness, and duty cycle, were determined. According to the experimental findings, the support vector machine-based identification algorithm can successfully identify various types of foreign materials at rates more than 92%.

Du et al. categorized foreign fiber using cluster analysis and a color feature model (Du et al. 2017). In this investigation, hair, wool, hemp rope, and feather were the four types of foreign fiber that were taken into consideration. Ten samples with different lengths and areas were taken for each category. The cotton was fully opened after a certain amount of pure cotton was chosen; a layer of homogeneous cotton was produced. The samples of foreign fiber are sequentially inserted into the cotton layer throughout the opening process, and an image of the foreign fiber is captured. Figure 4 displays the experimental equipment. The foreign matter detection and cleaning 60AT4 used in the experiment was made by the Daheng imaging company. The result of the cluster analysis technique for evaluating the foreign fiber identification rate can reach 85%.

Zhao et al. investigated whether classifier's feature set best matched that of the foreign fibers (Zhao et al. 2018). Five classifiers were employed in the study to analyze the dataset of foreign fibers in cotton and to determine which feature set best matched the classifiers. The best feature sets of foreign fibers in cotton that correlate to certain classifiers were found using the four filter feature selection procedures. A total of 75 characteristics, comprising 41 texture features, 7 shape features, and 27 color features, were obtained from foreign fiber items. The feature vector of 75 dimensions is made up of these retrieved features. In Figure 5, these characteristics were given. The experimental findings demonstrate that the extreme learning machine and kernel support vector machines work exceptionally well for the identification of foreign fibers, with classification accuracy of 93.61% and 93.17%, respectively, utilizing the chosen corresponding feature set of 42 and 52 features.

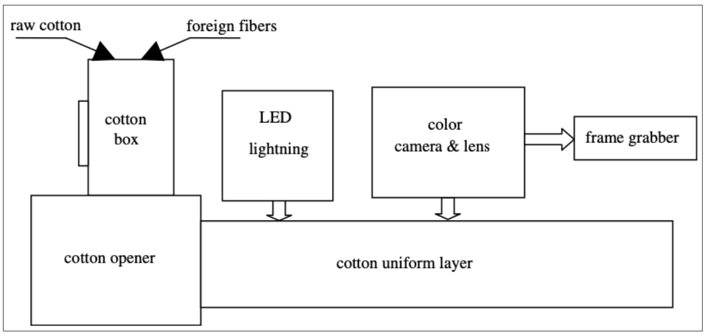

Figure 3. The image acquisition subsystem diagram (Ji et al. 2010)

Figure 4. Experimental equipment (Du et al. 2017)

Xiaoyun et al. identified the type of foreign fibers in seed cotton pictures using the Faster RCNN deep learning algorithm (Xiaoyun et al. 2018). To identify the type of foreign fibers using an integrated system with a Field Programmable Gate Array (FPGA) Digital Signal Processor (DSP), Wei et al. constructed a Convolutional Neural Network (CNN) model. This article suggests an embedded system based on a DSP and a FPGA that can identify and eliminate foreign fibers found in cotton (Figure 6). Huge samples of real and fake foreign fibers were gathered to test this technology thoroughly. A CNN model is created based on these samples to confirm the categorization of the suspected targets from the detection subsystem, increasing the detection accuracy. The system computes the statistics of the color histogram and gradient, as well as the summation threshold based on the probability parameter. The color difference and gradient data were then counted in the opposite direction of the maximum value, and the actual segmentation threshold of the color difference and gradient data could be obtained when the closest summation threshold was reached, as shown in Figure 7. A model with the optimal performance and computation balance is discovered by testing a number of model designs. The model is successful, as evidenced by the high success rate up to 96% in the validation set (Wei et al. 2019).

No.	Color feature	No.	Texture feature	No.	Texture feature	No.	Shape feature
1	RGB mean		Gray-level Co-occurrence Matrix:	52	Entropy	69	Area
2	R mean	28	Contrast	53	Inertia	70	Euler number
3	G mean	29	Entropy	54	Inverse difference	71	Form factor
4	B mean	30	Homogeneity		Gray-smooth co-occurrence matrix:	72	Eccentricity
5	RGB variance	31	Energy	55	Contrast	73	Solidity
6	R variance	32	Cluster shade	56	Entropy	74	Rectangularity
7	G variance	33	Cluster prominent	57	Inverse difference	75	Sphericity
8	B variance	34	Correlation	58	Energy		
9	RGB third-order moment		Gray correlation:	59	Cluster shade		
10	R third-order moment	35	Contrast	60	Cluster prominent		
11	G third-order moments	36	Entropy		Gray-level differences:		
12	B third-order moments	37	Homogeneity	61	Contrast(d=1 pixel)		
13	Gray mean	38	energy	62	The second moment(d=1 pixel)		
14	Gray variance	39	Cluster shade	63	Entropy(d=1 pixel)		
15	Gray third-order moment	40	Cluster prominent	64	Average(d=1 pixel)		
16	HSV mean	41	Correlation	65	Contrast(d=2 pixel)		
17	H mean		Gray-gradient Co-occurrence matrix:	66	The second moment(d=2 pixel)		
18	S mean	42	Small gradient strengths	67	Entropy(d=2 pixel)		
19	V mean	43	A large gradient strengths	68	Average(d=2 pixel)		
20	HSV variance	44	Gray distribution inhomogeneity				
21	H variance	45	Gradient distribution inhomogeneity				
22	S variance	46	Energy				
23	V variance	47	Average gray				
24	HSV third-order moment	48	Average gradient				
25	H third-order moment	49	Gray variance				
26	S third-order moment	50	Gradient variance				
27	V third-order moments	51	Correlation				

Figure 5. The color, texture, and shape features (Zhao et al. 2018)

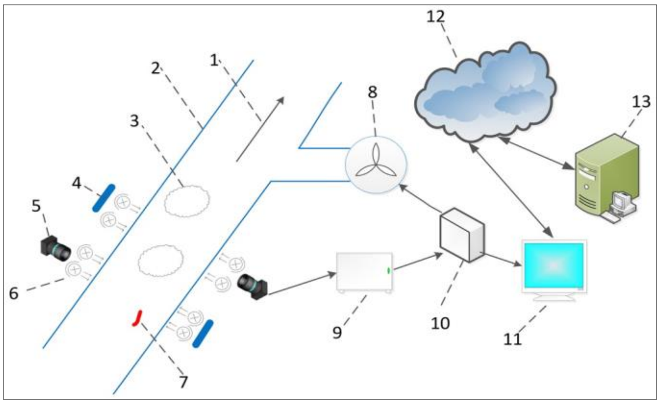

Figure 6. Structure diagram of foreign fiber cleaning machine. (1) Flow direction, (2) cotton pipe, (3) cotton, (4) background board, (5) the imaging unit, (6) tube, (7) foreign fiber, (8) removal fan, (9) processing subsystem, (10) classification subsystem, (11) industry personal computer, (12) Internet, and (13) cloud server. (Wei et al. 2019)

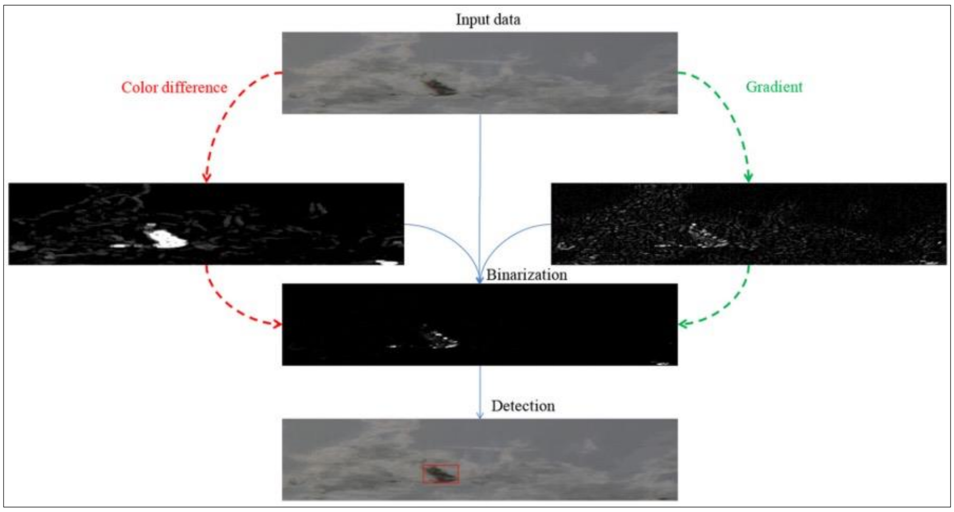

Figure 7. Example with target data (Wei et al. 2019)

Wei et al. suggested a deep learning-based approach for evaluating the foreign fiber content. It was based on the foreign fiber cleaning machine. In order to create the mask image collection of foreign fibers, a significant number of images of foreign fibers were first gathered from various manufacturing lines and annotated. Second, tests comparing deep learning-based image segmentation algorithms revealed that U-Net performed better on evaluations of various segment metrics. U-Net is currently being enhanced to enable real-time segmentation of images containing foreign fibers (Wei et al. 2020).

In our study, image processing technique was used to analyze impurities (dust, garbage, synthetic material, etc.) in the waste cotton sample under UV light. A closed cabinet was designed to benefit from the different light reflecting properties of foreign materials in the waste cotton bundle. An image processing algorithm has been developed to analyze image frames taken with a digital camera. As a result, it has been seen that foreign material inspection in waste cotton can be done more objectively and reliably with such a machine vision system.

2. MATERIALS AND METHODS

In this study, a prototype system was constructed for synthetic fiber detection in cotton sample. The system consists of UV fluorescent lights, white light for trash analysis, a cabinet and HD web camera (Figure 8). The image frames were taken by placing the camera and lights vertically above the cotton bundle.

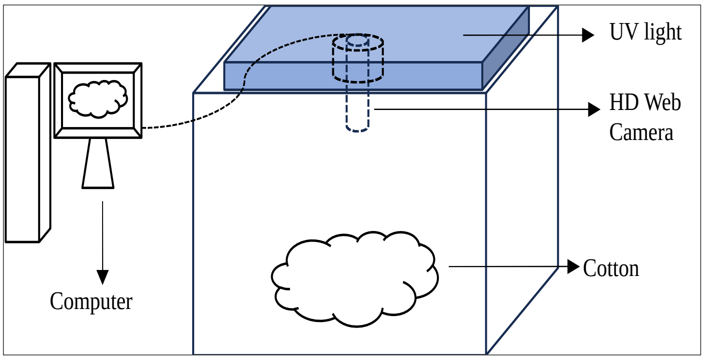

Figure 8. Prototype system design

2.1 Foreign Mater Detection Algorithm

In the process of image analyze, the qualities of the image have a significant impact on the desired outcome. Image quality is influenced by a number of variables, including camera resolution, motion blur, illumination, and compression while the images are being stored. In order to enhance the camera-taken images, different noise-cleaning and image-enhancement filters are used once the digital images have been transmitted to a computer environment (Gonzales & Woods, 2004). As a result, before the foreign object detection in the waste cotton sample, noise cleaning and enhancement filters were applied to the image frames.

Image processing algorithm was created for foreign fiber detection using MATLAB 2020a. RGB images were initially transformed from grayscale images. The noise was then removed using a Wiener filter (Chen, 2006). To make the boundaries of the suspended image of the cotton sample more distinct from the ground texture, a contrast deepening filter was used. The images were transformed to binary format, which consists of 0 (black) and 1 (white) value, after all of these prior processes. The binary image's identified object boundaries were made apparent and the image's pattern lines were removed using opening and closing morphological procedures.

3. RESULT AND DISCUSSION

Foreign material and synthetic fiber detection in cotton bundle sample are shown in Figure 9 and Figure 10 respectively. The proposed machine vision system was successful to detect foreign materials and synthetic fiber in the waste cotton sample. As stated in the literature, it has been observed that image analysis can be performed much faster and more precisely thanks to the high-resolution industrial cameras and proper lens. The prototype system can be adapted to a test device and the cotton contamination can be analyzed via image processing techniques.

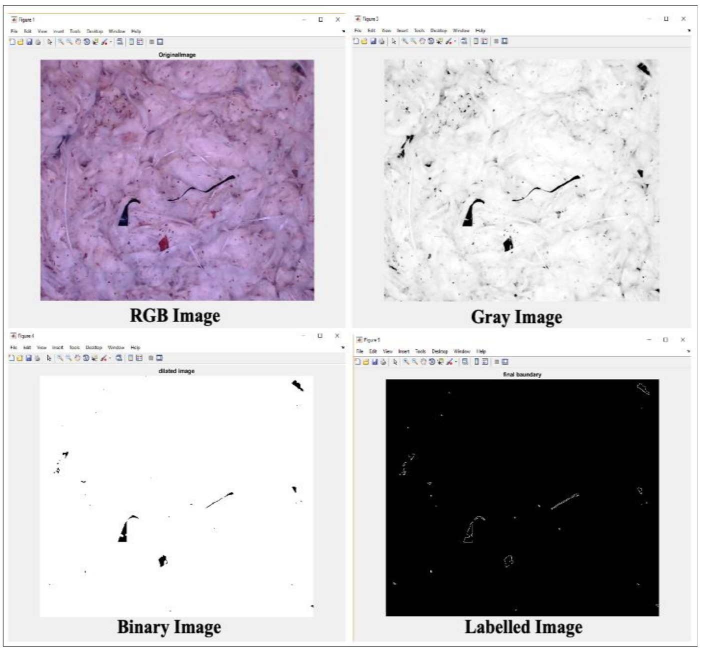

Figure 9. Detection of foreign material in waste cotton bundle

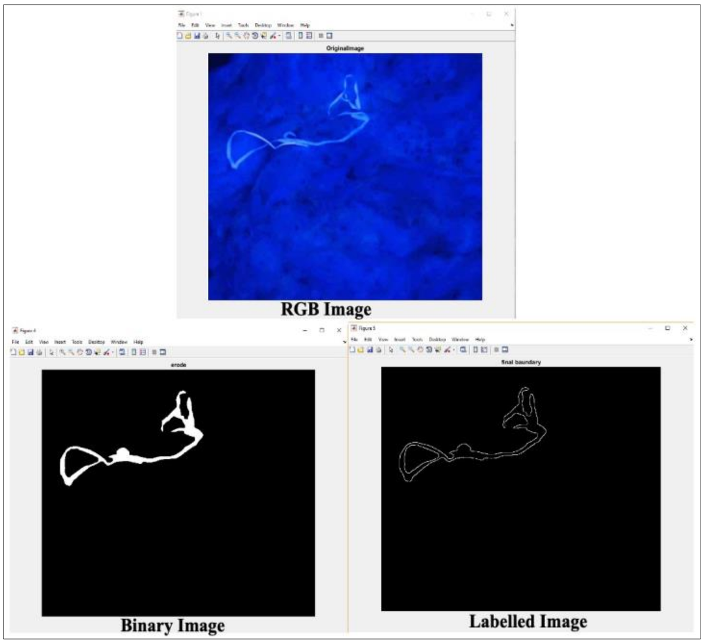

Figure 10. Detection of synthetic fiber in waste cotton bundle

4. CONCLUSION

Foreign materials in cotton may lower the quality of yarn and fabric and possibly cause some items to be completely returned. Pollution increases production wait times, damages machine parts by adhering to them, increases cost of labour, increases workload, lowers product quality and price, and decreases yarn and fabric manufacturing efficiency. Particularly when foreign fibers (especially synthetic fibers like polypropylene and polyester) remaining in the cotton bundle are transferred into the completed product without being cleaned, it causes significant economic losses since it results in abrage after dyeing.

In order to obtain sustainable textile products, recycle fiber should be used with a proper ratio in the production. Pre-consumer and post-consumer recycle cotton is used for yarn production. The contamination in the recycle cotton is higher than virgin cotton. Since all machine adjustments are made according to fiber properties, the quality of the recycle cotton in terms of mean fiber length, foreign material ratio and contamination ratio must be analyzed sensitively before yarn production. In the present technology, it is difficult analyze the quality and contamination of recycle cotton. So, an innovation project was conducted to design and develop a test device for analyzing recycle cotton quality. The foreign materials inside the recycle cotton sample will be inspected via machine vision systems.

In this study, a case study was conducted to detect synthetic fibers and foreign matter in the waste cotton bundle of a spinning mill for a start. Machine vision system and image processing algorithm was developed for this aim. The synthetic fiber and foreign materials were detected and marked by using developed image processing algorithm.

Industry 4.0 and artificial intelligence technologies now provide significant advantages in production, which is why they are taking place quickly in the textile industry. The previously used operations may be completed in less time and with higher precision thanks to the image processing approach, which also determines the foreign matter detection in the cotton sample and gives an objective assessment of the quality control tests. Machine vision systems and image processing methods may be successfully applied in industrial settings. Therefore, this current approach was advised for factors including reducing user mistakes, archiving images, and especially significantly reducing testing time.

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