

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/256426336>

Developing an Algorithm for Defect detection of Denim Fabric: Gabor Filter Method

Article in *Tekstil ve Konfeksiyon* · January 2013

CITATIONS

0

READS

348

1 author:



Lale Canan Dülger

Izmir University of Economics

72 PUBLICATIONS 507 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Intelligent Fabric Defect Detection System [View project](#)



Haptic technology [View project](#)

DEVELOPING AN ALGORITHM FOR DEFECT DETECTION OF DENİM FABRIC: GABOR FILTER METHOD

DENİM KUMAŞIN HATA DENETİMİ İÇİN BİR ALGORİTMA GELİŞTİRİLMESİ: GABOR FİLTRE YÖNTEMİ

H. İbrahim ÇELİK¹, L. Canan DÜLGER², Mehmet TOPALBEKİROĞLU¹

¹Gaziantep University, Department of Textile Engineering, Gaziantep, Turkey

²Gaziantep University, Department of Mechanical Engineering, Gaziantep, Turkey

Received: 08.02.2013

Accepted: 29.03.2013

ABSTRACT

In this study, an algorithm is developed by using Gabor filtering and double thresholding methods for fabric defect detection automatically. The defective area of the fabric image is accentuated, and the defect-free texture is attenuated as result of convolution operation with the Gabor filter. The image is then converted into binary form for by using double thresholding method. The noises are removed and the defective area is determined clearly by using dilation and erosion morphological operations. The boundary of the defect is labeled. A fabric defect image database consists of five defect types; warp lacking, weft lacking, hole, soiled yarn and knot is formed. The database includes 30 different images for each type of defect and defect-free fabric samples. Thus, the algorithm is applied over 180 fabric images. All defective areas are detected with high success rates. The performance of the algorithm is given statistically.

Key Words: Gabor filter, Fabric defect inspection, Image processing, Quality control, Denim fabric.

ÖZET

Bu çalışmada, kumaş hata denetiminin otomatik olarak gerçekleştirilebilmesi için Gabor filtresi ve çift eşikleme metotları kullanarak bir algoritma geliştirilmektedir. Gabor filtresi ile yapılan konvolüsyon işlemi sonucunda kumaş görüntüsündeki hatalı alan vurgulanırken hatasız doku sönmektedir. Görüntü daha sonra çift eşikleme metodu kullanılarak ikili (binary) forma dönüştürülmektedir. Genişletme ve aşındırma morfolojik işlemleri kullanılarak gürültüler yok edilmekte ve hatalı alan belirgin bir şekilde ortaya çıkarılmaktadır. Hatanın sınırları işaretlenmektedir. Çözüğü kaçığı, atkı kaçığı, delik, lekeli iplik ve düğüm gibi beş hata tipinden oluşan bir kumaş hata görüntüsü veritabanı oluşturulmuştur. Veritabanı her bir hata tipi ve hatasız kumaş numunesi için 30 farklı görüntü içermektedir. Böylece, algoritma 180 kumaş görüntüsüne uygulanmıştır, tüm hatalı alanlar yüksek başarı oranları ile tespit edilmiştir. Sonuçta kullanılan, algoritmanın başarısı istatistiksel olarak değerlendirilmiştir.

Anahtar Kelimeler: Gabor filtresi, Kumaş hata denetimi, Görüntü analizi, Kalite kontrol, Denim kumaş.

Corresponding Author: H. İbrahim Çelik, hcelik@gantep.edu.tr, Tel: +90 342 317 27 14, Fax: +90 342 317 27 06

1. INTRODUCTION

The fabric has a regular pattern and texture properties along the weft and warp direction. The regions that deform the regular pattern and cause the change on the appearance and physical properties of the fabric are called as 'defect'. The defects may be evaluated as 'major' and 'minor' types. Some of them are encountered commonly and some of them are seen rarely. The defects encountered within production must be detected and

corrected at early stages of the production process. The fabric inspection operation is achieved by passing the fabric over an illuminated surface and scanning with human eyes resulting in a time consuming and tiring process. The quality control person losses his/her concentration or his/her eyes gets tired after a while. He/she cannot deal with fabric wider than 2 meters. The inspection speed of a fabric even woven with an efficiency of 97% is about 30 m/min. There is a growing need for automated fabric

defect inspection system in the textile industry. Many attempts are made to replace the traditional human inspection by automated visual systems;

Karayiannis A. Y. et al have presented a pilot system for defect detection and classification of web textile fabric in real-time (1). The method that was based on double thresholding, binary filtering, binary labeling, multi-resolution decomposition via the wavelet transform, and the statistical texture feature extraction was presented.

Adaptive wavelet filters have been designed for the detection of five kinds of fabric defects by Zhi X. Y. et al (2). Adaptive wavelet filter had only one vanishing moment and equivalent to multi-scale edge detector. Serdaroğlu A. et al have combined Wavelet Transformation (WT) and Independent Component Analysis (ICA) methods for fabric defect detection (3). Applying Wavelet Analysis (WA) prior to ICA has increased the defect detection rate compared to the use of WT or ICA alone. Liu G. S. and Qu P. G. have used WT and Back Propagation Neural Network (BPNN) together to detect and classify the fabric defects (4). Defect classification rates of wavelet transforms with 1, 2 and 3 resolution levels were compared. Mak K. L., and Peng P. have used Gabor Wavelet Network (GWN) for texture feature extraction and defect detection (5, 6). The defect detection scheme consisted of one real-valued Gabor Filter (GF) and Gaussian smoothing filter. The performance of the scheme was evaluated both on-line and off-line tests. The on-line defect detection was achieved by using a designed prototype system. Han R. and Zhang L. have proposed a fabric defect detection method based on Gabor filter (7). In the proposed method consists of one even symmetric Gabor filter and one odd symmetric Gabor filter derived from the optimal Gabor filter. Parameters of the optimal Gabor filter were obtained by applying Genetic Algorithm (GA). It was determined that even symmetric Gabor filter was good at detecting blob-shaped fabric defects (like knot) and odd symmetric Gabor filter performs well in detecting edge-shaped fabric defects (like miss pick). Huang C. C. and Chen C. I. have presented a method combining Fuzzy Logic (FL) and a Back-Propagation (BP) learning algorithm with Neural Networks (NN) (8). Nine categories were classified, normal fabrics and eight kinds of fabric defects: missing end, missing pick, double ends, double picks, hole, light filling bar, cobweb, and oil stain. Kumar A. has presented an approach for the segmentation of local textile defects using Feed-Forward Neural Network (FFNN) and fast web inspection method using linear NN (9). Jianli L. and Baoqi Z. have detected and classified four types of fabric defect; warp lacking, weft lacking, oil stain and hole (10). The defective areas are segmented by using Wavelet Thresholding Method (WTM).

The texture features of the fabric samples were extracted by using Haralick method from Gray Level Co-occurrence Matrices (GLCM) of the sample images and used as input for NN training. Kuo C. J. and Lee C. J. have classified four types of defects by training a three layer BPNN (11). After thresholding operation, maximum length, maximum width, and gray level of the detected region were extracted as inputs for NN. It was stated that the classification was achieved with high recognition for all types of defects. Saeidi et al. have been implemented a computer vision-based fabric inspection system on a circular knitting machine (12). The defect detection was performed off-line by using three methods; Fourier Transform (FT), Wavelet Transform (WT) and the Gabor Transforms (GT). The overall success rates of three methods were obtained as 15.71%, 52.3% and 78.4% respectively. The GT method was then applied on-line with overall success rate of 96.57%. Marmaralı and Torun have presented an on-line defect detection system for circular knitting machines (13). Imaginary Gabor Function (IGF) was used for defect detection. It was stated that the developed system can stop the knitting machine after the system reaches a predetermined faulty image quantity.

In this study, an algorithm for fabric defect detection is developed by using Gabor filter method. It is applied for an undyed raw denim fabric. Five types of defects; hole, warp lacking, weft lacking, soiled yarn and knot are detected. The performance of the algorithm is evaluated statistically in off-line application.

2. MATERIAL AND METHOD

2.1 Material

Denim clothing has an important place in the ready-made clothing export. It has a ratio of 30.7 % in the woven fabric ready-made clothing export of the Turkey (14). So, the material used for defect detection is selected as denim. A fabric defect database is formed including defect-free fabric and five commonly occurring defects; warp lacking, weft lacking, hole, soiled yarn and knot. Thirty different samples are formed for each defect type and defect-free fabric. One hundred eighty fabric samples are provided on total.

The sizes of the fabric samples are prepared as 5.5 cm X 23.5 cm. The image frames of the database are acquired by means of a scanner with a resolution of 200 dpi. The sample material used is cotton/polyester undyed raw denim fabric. The fabric pattern configuration is 3/1 twill. The warp yarn is 100% cotton 10/1 Ne_c and the weft yarn is 100% polyester 697 dtex. The warp sett and the weft sett of the fabric are 28 ends/cm and 22 picks/cm respectively. It is woven on Picanol Gammax rapier weaving machines with production speed of 450 rpm and production efficiency of 87%. The algorithm is not applied for other types of fabrics such as plain, sateen or indigo dyed denim yet.

2.2 Method

When the fabric defect detection applications are investigated, three main approaches are proposed; '*statistical*', '*spectral*' and '*model-based*' (15). Since the spectral approach is suitable for the defect detection of uniform textured images and the successful results are obtained by using this approach, it is most commonly preferred for fabric defect detection applications. The spectral approach includes the following methods; Discrete Fourier Transform (DFT), Optical Fourier Transform (OFT), Windowed Fourier Transform (WFT), Optimized Fir Filters (OFF), Gabor Filters (GF), Wavelet Transform (WT).

The algorithm is developed by using MATLAB® program. It is built by using Gabor filter, noise removing filter and morphological operations (Figure 1). The Gabor filters are band-pass filters with tunable center frequency, orientation and bandwidth (16). A 2-D Gabor function is a complex exponential modulated by a Gaussian function, which can form a complete but non-orthogonal basis set. These functions allow us to represent a signal in spatial and frequency domain simultaneously. In fabric defect detection applications, Gabor filter is used to extract the basic texture features of the fabric under investigation from a non-defective fabric sample. These texture features are then used as prior knowledge for the design of the optimal Gabor filters. The fabric image is convolved with optimal Gabor filter and so, the background texture information is attenuated and the defect

regions are accentuated. Different Gabor filter types are proposed in literature (17-19). The Gabor filter consists of real and imaginary parts. The real part of the Gabor filter is used in this study is as equation 1 (20, 21).

"standard deviation (σ)" (20, 21). Here, λ is the wavelength of the cosine factor of the Gabor filter, its value is

specified in pixels. θ specifies the orientation of the normal to the parallel stripes of a Gabor function specified in degrees. When θ has zero value, Gabor function determines the details perpendicular to the x axis. φ is the phase offset specified in degrees. The valid values are between -180° and 180° . γ is aspect ratio or it may be

defined as 'spatial aspect ratio'. This parameter specifies the ellipticity of the support of the Gabor function. σ denotes the standard deviation of Gabor function. All this parameters are determined experimentally by using defect-free fabric sample as a template.

$$g_{\lambda,\theta,\sigma,\gamma,\varphi}(x,y) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right) \cos\left(2\pi \frac{x'}{\lambda} + \varphi\right) \quad (1)$$

where;

$$x' = x\cos(\theta) + y\sin(\theta) \text{ and } y' = y\cos(\theta) - x\sin(\theta) \quad (2)$$

The Gabor filter involves some parameters that have to be optimized according to the applications; "wavelength (λ)", "orientation (θ)", "phase offset (φ)", "aspect ratio (γ)", and

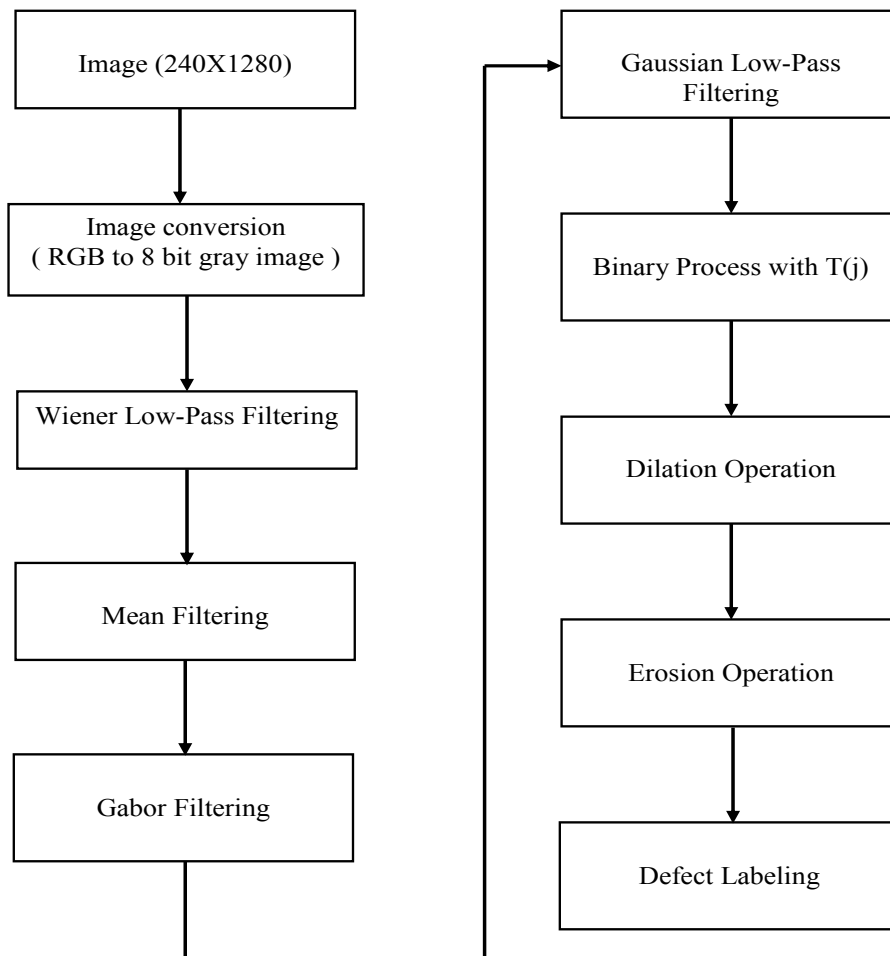


Figure 1. Flowchart of Gabor filter algorithm

The image frames captured from the scanner have a size of 240 X 1280 pixels. The image frame is converted to 8 bit gray level format. Pixel values do not reflect the true intensities of the real scene because of noise resulting from errors in the image acquisition process. The noises are occurred because of illumination change, fabric structure and impurities in the fabric. They are removed by using Wiener low-pass filter and mean filter (Figure 1). The window size is selected as 3 X 3 for both Wiener and mean value filters. The noise removed image is convolved with Gabor filter. Thus, the defective area is accentuated and the regular fabric texture is attenuated. In order to make the image smooth, the image is then convolved with Gaussian operator.

The filtered image is converted into the binary form. Thus, the defective area is identified and clarified. The binarization process is achieved by using double thresholding method. Two thresholding values; upper and lower thresholds are determined by using the defect-free fabric image. These values are calculated (equation 3) by using the average and the standard deviation values of a defect-free image frame (22, 23).

T_1 is the upper limit, T_2 is the lower limit of the double thresholding processes, and 'w' is the weighting factor. It is determined experimentally between 2-4. The binarization process is carried out using equation 4 (5, 22, 24).

If the pixel value of the detected image is between T_1 and T_2 , the gray value is allocated as 0. Otherwise, it is set as 1 because of the high defect probability. In the binary image, the value of 0 means no defect, and 1 means that the cell has a defect or noise. The binary image is applied to dilation operation. The spaces between the defective regions are closed and they are interconnected. The remaining noises are then removed via the erosion operation. Finally the defective area is labeled.

3. RESULTS AND DISCUSSION

Gabor filter algorithm is applied for five defective fabrics given in Figure 2.(a), (c), (e), (g), (i) and the results given in Figure 2.(b), (d), (f), (h) and (j) are obtained respectively. The algorithm is applied over 180 database images. The success rates of each defect type are determined in terms of True Detection (TD), False Detection (FD), Misdetecion (MD) and Overall

Detection (OD). When the white areas of the binary image overlap the areas of the corresponding defects or when no white area appears in the binary output image if the sample image contains no defect, it is defined as TD. When the white areas of the binary image do not overlap the corresponding defects or when the white areas appear in the binary image although the captured image contains no defect, it is recorded as FD. When the white areas do not appear in the binary image although the captured input frame contains defects, it is recorded as MD. OD is the sum of TD and FD (7). The detection performance of the algorithm is given in Table 1. Except the defect-free and knot defect samples, all defective fabric images are detected with TD rate of 100% (Figure 3). Any MD detection is not obtained for all samples. False detections are obtained only for 6 image frames among 180 database images.

$$T_{1,2} = \text{mean}[a(l, j)] \pm w \cdot \text{std}[a(l, j)] \quad (3)$$

$$L(l, j) = \begin{cases} 0, & T_1 < a(l, j) < T_2 \\ 1, & a(l, j) < T_1 \text{ or } a(l, j) > T_2 \end{cases} \quad (4)$$

Table 1. Performance of the algorithm

	Image Frame Type					
	Defect-free	Warp Lacking	Weft Lacking	Hole	Soiled Yarn	Knot
Number of Frames	30	30	30	30	30	30
TD	26	30	30	30	30	28
FD	4	0	0	0	0	2
MD	0	0	0	0	0	0
OD	30	30	30	30	30	30
TD rate (%)	86.7	100.0	100.0	100.0	100.0	93.3
FD rate (%)	13.3	0.0	0.0	0.0	0.0	6.7
MD rate (%)	0.0	0.0	0.0	0.0	0.0	0.0
OD rate (%)	100.0	100.0	100.0	100.0	100.0	100.0

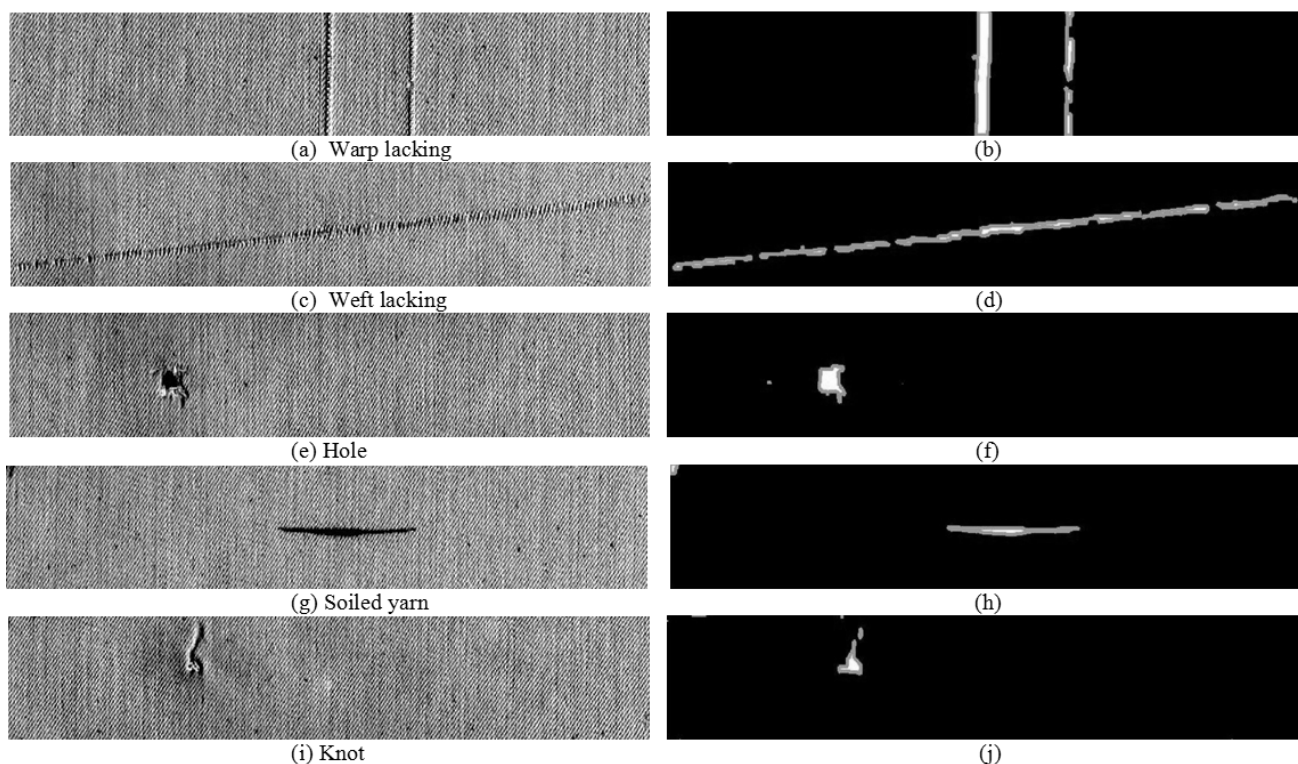


Figure 2. The defects warp lacking, weft lacking, hole, soiled yarn and knot are (a), (c), (e), (g), (i) and the segmentation results are (b), (d), (f), (h) and (j) respectively

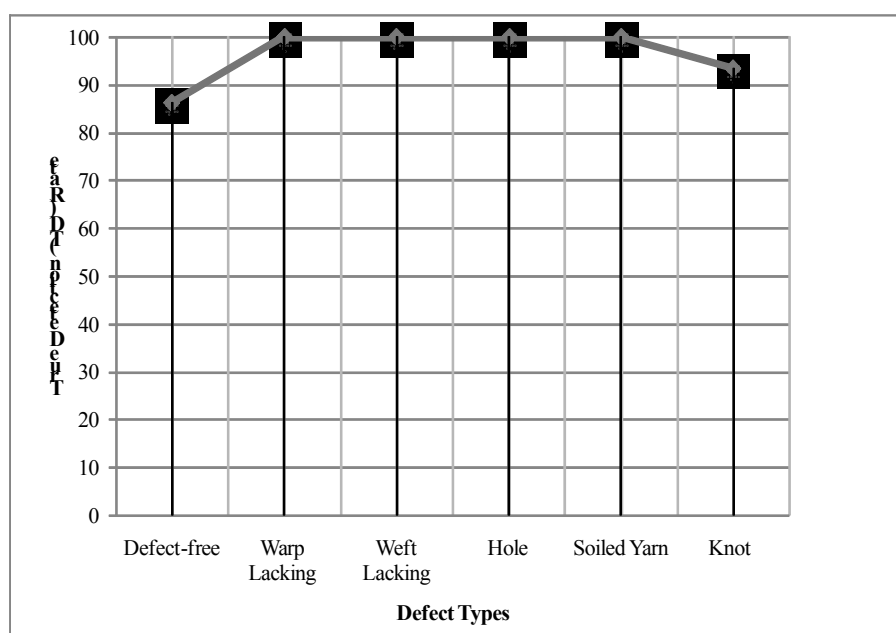


Figure 3. TD rates of each defect type

4. CONCLUSION

A defect detection algorithm is developed for undyed raw denim fabric in this study. The algorithm is applied off-line over 180 fabric database images. The images of the database are acquired by scanning the fabric samples with a resolution of 200 dpi.

The database consists of defect-free fabrics and five types of defects; warp lacking, weft lacking, hole, soiled yarn and knot. The defective and defect-free images are detected with an OD of 100%. The boundaries of the defective areas are labeled successfully. False detections are only

obtained for knot defect and defect-free samples. FD obtained for knot defects are not caused from the algorithm. They are simply caused from the fabric scanning difficulty. Because of the knots on the fabric surfaces, the fabric samples cannot be laid smoothly and scanned uniformly.

Since the algorithm is sensitive to the wrinkles and the fabric surface roughness and it can detect fabric parts involving rough and wrinkle areas as if they have defect. The fabric sample is an undyed raw fabric and it has some impurities. Although, they are removed by using noise removing filters and morphological operations, some big ones may be also detected as soiled yarn defect. So, the FD obtained for defect-free samples are

caused by wrinkles and some big cotton impurities.

The algorithm is tested off-line. High TD rates are obtained for all five defect types, it will be applied real-time on the fabric inspection machine. The studies on real-time applications are still continuing in Gaziantep University Textile & Mechanical Engineering Departments. In the real-time application, the number of defect types will be increased and the detected

defects will be classified by using Artificial Neural Network (ANN) method.

ACKNOWLEDGEMENTS

This study is financially supported by Gaziantep University Scientific Research Projects Management Unit with the project number of MF.10.12.

REFERENCES

1. Karayiannis Y. A., Stojanovic R., Mitropoulos P., 1999, "Defect detection and classification on web textile fabric using multiresolution decomposition and neural networks", *The 6th IEEE International Conference on Electronics, Circuits and Systems, Pafos*, 2, pp:765-768.
2. Zhi Y. X., Pang G.K.H. and Yung H. C. N., 2001, "Fabric defect detection using adaptive wavelet", *IEEE International Conference on Acoustics, Speech, and Signal Processing*, pp:3697-3700.
3. Serdaroglu A., Ertuzun A. and Ercil A., 2005, "Defect detection in textile fabric images using wavelet transforms and independent component analysis", *Pattern Recognition and Image Analysis*, 16, 1, pp: 61-64.
4. Liu G. S. and Qu P. G., 2008, "Inspection of fabric defects based on wavelet analysis and BP neural network", *Proceedings of the 2008 International Conference on Wavelet Analysis and Pattern Recognition, Hong Kong*, pp: 232-236.
5. Mak K. L. and Peng P., 2006, "Detecting defects in textile fabrics with optimal gabor filters", *World Academy of Science, Engineering and Technology*, 13, pp: 75-80.
6. Mak K.L. and Peng P., 2008, "An automated inspection system for textile fabrics based on Gabor filters", *Robotics and Computer-Integrated Manufacturing*, 24, pp:359-369.
7. Han R. and Zhang L., 2009, "Fabric defect detection method based on Gabor filter mask", *Global Congress on Intelligent Systems, Xiamen, China*, pp:184-188.
8. Huang C. C. and Chen C. I., 2001, "Neural-fuzzy classification for fabric defects", *Textile Research Journal*, 71(3), pp:220-224.
9. Kumar A., 2003, "Neural network based detection of local textile defects", *Pattern Recognition*, 36, pp:1645-1659.
10. Jianli L. and Baoqi Z., 2007, "Identification of fabric defects based on discrete wavelet transform and back-propagation neural network", *Journal of the Textile Institute*, 98:4, pp:355-362.
11. Kuo C. J. and Lee C. J., 2003, "A back-propagation neural network for recognizing fabric defects", *Textile Research Journal*, 73(2), pp:147-151.
12. Saeidi R. G., Latifi M., Najari S. S. and Saeidi A. G., 2005, "Computer vision-aided fabric inspection system for on-circular knitting machine", *Textile Research Journal*, 75(6), pp:492-497.
13. Torun T. K. and Marmarali A., 2011, "Online fault detection system for circular knitting machines", *Tekstil ve Konfeksiyon*, 21(2), pp:164-170.
14. İTKİB, Genel Sekreterliği AR&GE ve Mevzuat Şubesi. 2011. Hazırgiyim ve Konfeksiyon Sektörü 2011 Ocak-Haziran İhracat Performans Değerlendirmesi. http://www.itkib.org.tr/ihracat/DisTicaretBilgileri/raporlar/dosyalar/2011/konfeksiyon_performans_raporu_haziran_2011.pdf. 17.11.2012.
15. Kumar A., 2008, "Computer-vision-based fabric defect detection: a survey", *IEEE Transactions on Industrial Electronics*, 55, 1, pp:348-363.
16. Levine M. 2000. Texture segmentation using Gabor filter. Image Processing & Communication Course Technical Report. http://www.cs.huji.ac.il/~simonp/papers/ip_project.pdf. 15.11.2012.
17. Jain A.K., Farrokhnia F., 1991, "Unsupervised texture segmentation using Gabor filters", *Pattern Recognition*, 24(12), pp:1167-1186.
18. Porat M. and Zeevi Y.Y., 1988, "The generalized Gabor scheme of image representation in biological and machine vision", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 10, pp:452- 468.
19. Bovik A.C., Clark M., Geisler W.S., 1990, "Multichannel texture analysis using localized spatial filters", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 12, 1, pp:55-73.
20. Grigorescu S.E., Petkov N., Kruizinga P., 2002, "Comparison of texture features based on Gabor filters", *IEEE Transactions on Image Processing*, 11, 1, pp:1160-1167.
21. Petkov N and Wieling M.B., 2008, "Gabor for image processing and computer vision", http://matlabserver.cs.rug.nl/edgedetectionweb/web/edgedetection_params.html, 15.11.2012.
22. Cho C. S., Chung B. M. and Moo-Jin P., 2005, "Development of real-time vision-based fabric inspection system", *IEEE Transactions on Industrial Electronics*, 52, pp:1073-1079.
23. Stojanovic R., Mitropoulos P., Koulamas C., Karayiannis Y., Koubias S. and Papadopoulos G., 2001, "Real-time vision-based system for textile fabric inspection", *Real-Time Imaging*, 7, pp:507-518.
24. Mak K. L., Peng P., Lau H.Y.K., 2005, "A real-time computer vision system for detecting defects in textile fabrics", *IEEE International Conference on Industrial Technology, Hong Kong, China*, pp: 469-474.