Mansoura Engineering Journal, (MEJ), Vol. 34, No. 1, March 2009. T. 1

Applications of Image Analysis and Artificial Neural Network Techniques for Fabric Pilling Evaluation

تطبيقات تقنيات تحليل الصور والخلايا العصبية الصناعية لتقييم خاصية التوبير للأقمشة

Mounir Hassan
Dept. of Textiles Engineering, Mansoura University, Mansoura, Egypt

الملخص:

فى هذا البحث تم إيجاد منظومة بالحاسب تقوم على تحليل الصور مع استخدام الخلايا العصبية لتقييم خاصية التوبير للأقمشة. للحصول على صور جيدة لصور التوبير على الأقمشة تم إتباع نظام خاص للإضاءة والتصوير. تم تحليل الصور مع الأخذ فى الاعتبار التركيز على التوبير الحادث للأقمشة وإهمال ارضية القماش للحصول على الخصائص الأساسية التي تصف عدد وحجم الوبرة ودرجة تركيز الوبرة على سطح القماش. تم إدخال الصور القياسية المأخوذة من النظام القياسي *ASTM* على الخلايا العصبية لعمل التمرين والتعرف على هذه الخصائص وتحديد درجة التوبير طبقاً لنظام *ASTM* والمتدرج من 1 إلى 5 (حيث 1 توبير عالي جداً و 5 لا يوجد توبير). تم إدخال هذه الخصائص الأساسية للتوبير الفعلي الحادث على الأقمشة على الخلايا العصبية لعمل التمرين والتعرف على هذه الخصائص وتحديد درجة التوبير الفعلية للأقمشة طبقاً لنظام *ASTM* والمتدرج من 1 إلى 5. هذه الطريقة استطاعت تحديد مستويات التوبير بدقة عالية وبدون أخطاء مما يجعلها وسيلة مثلى لتقييم تلك الخاصية الهامة للأقمشة.

Abstract

The main aim of this contribution is description of image analysis approach combined with artificial neural networks to describe the fabric pilling features. For obtaining the fabric pills features the especially prepared digital images are used. These images are processed by the image analysis tools to achieve the aim of extraction of pills and computation of their basic features. The fabric Pills feature vector is then used in trained Artificial Neural Network (ANN) for grading the level of pill formation according to the ASTM.

Key words: Fabric pilling, Image Analysis, Artificial Neural Network, ASTM Standard.

Accepted March 31, 2009.

1- INTRODUCTION

Fabric pilling is commonly tested in the laboratory by using specific machines to generate pills. These machines are usually supplied with standard consistant photographs of samples with different degrees of pilling. Experts with long training and experience assign a degree of pilling by looking at the sample processed by the machine. However, a common draw- back of these subjective methods based on estimations by experts is their inconsistency and the inaccuracy of the rating results.

After rubbing of a fabric it is possible to assess the amount of pilling quantitatively either by counting the number of pills or by removing and weighing them. However, pills observed in worn garments vary in size and appearance as well as in number. The appearance depends on the presence of lint in the pills or the degree of color contrast with the ground fabric. These factors are not evaluated if the pilling is rated solely on the number or size of pills. Furthermore the development of pills is often accompanied by other surface changes such as the development of fuzz which affect: the overall acceptability of a fabric. It is therefore desirable that fabrics tested in the laboratory are assessed subjectively with regard to their acceptability and not rated solely on the number of pills developed.

Counting the pills and/or weighing them as a measure of pilling is very time consuming and there is also the difficulty of deciding which surface disturbances form pills. The more usual way of evaluation is to assess the pilling subjectively by comparing it with either standard samples or with photographs of them or by the use of a written scale of severity. Most scales are divided into five grades and run from grade 5, no pilling, to grade 1, very severe pilling.

The main aim of this contribution is using of image analysis approach for replacement of the subjective grading by an objective way. The artificial neural network is used for extraction of pilling features. Pills feature vector is then used in trained Artificial Neural Network (ANN) for grading according to the ASTM.

In this paper Fabric Pilling Evaluation technique (FPE) has been developed for a complex treatment of pilling images created on the base of this approach is used for objective pilling evaluation of huge number of samples.

2- PILLING PHENOMENA

Pilling is a condition that arises in wear due to the formation of little 'pills' of entangled fiber clinging to the fabric surface giving it an unsightly appearance. Pills are formed by a rubbing action on protruding fibers, which are present on the fabric surface. Pilling was originally a fault found mainly in knitted woolen goods made from soft twisted yarns. The introduction of man-made fibers into clothing has forced its seriousness. The explanation for this is that these fibers are stronger than wool so that the pills remain attached to the fabric surface rather than breaking away as would be the case with wool [1].

The initial effect of abrasion on the surface of a fabric is the formation of fuzz as a result of two processes, the brushing up of free fiber ends not enclosed within the yarn structure and the conversion of fiber loops into free fiber ends by the pulling out of one of the two ends of the loop.

It was found that the fuzz formation must reach a critical height, which is dependent on fiber characteristics, before pill formation can occur. The greater the breaking strength and the lower the bending stiffness of the fibers, the more likely they are to be pulled out of the fabric structure producing long protruding fibers. Fiber with low breaking strength and high bending stiffness will tend to break before being pulled fully out of the structure leading to shorter protruding fibers.

The next stage is the entanglement of the loose fibers and the formation of them into a roughly spherical pile of fibers, which is held to the surface by anchor fibers. As the pill undergoes further rubbing, the anchor fibers can be pulled further out of the structure or fatigued and eventually fractured depending on the fiber properties and how tightly they are held by the structure. In the case of low-strength fibers the pills will easily be detached from the fabric but with fabrics made from high-strength fibers the pills will tend to remain in place. This factor is responsible for the increase in the propensity for fabrics to pill with the introduction of synthetic fibers.

Low twist factors and loose fabric structures such as knitwear have a rapid fiber pull-out rate and long staple length resulting in the development of numerous large pills. The life of these pills depends on the balance between the rate of fiber fatigue and the rate of roll-up. Pill density can increase steadily, reach a plateau or pass through a maximum and decrease with time depending on the relative rates of pill formation and pill detachment. The pill density is also governed by the number of loose fiber ends on the surface and this may set an upper limit to the number of pills that will potentially develop. This has important implications for the length of a pilling test because if the test is carried on too long the pill density may have passed its maximum. Fibers with reduced flex life will increase the rate of pill wear-off.

Because the fibers that make up the pills come from the yarns in the fabric any changes, which hold the fibers more firmly in the yarns, will reduce the amount of pilling. The use of higher twist in the yarn, reduced yarn hairiness, longer fibers, increased inter-fiber friction, increased linear density of the fiber, brushing and cropping of the fabric surface to remove loose fiber ends, a high number of threads per unit length and special chemical treatments to reduce fiber migration will reduce the tendency to pill. The presence of softeners or fiber lubricants on a fabric will increase pilling. Fabrics made from blended fibers often have a greater tendency to pill as it has been found that the finer fibers in a blend preferentially migrate towards the yarn exterior due to the difference in properties [1].

The amount of pilling that appears on a specific fabric in actual wear will vary with the individual wearer and the general conditions of use. Consequently garments made from the same fabric will show a wide range of pilling after wear which is much greater than that shown by replicate fabric specimens subjected to controlled laboratory tests. The Pilling of Sweatshirts that are a 50/50 blend of polyester and cotton were studied [2].

Finishes and fabric surface changes may exert a large effect on pilling. Therefore, with some fabrics, it may be desirable to test before as well as after laundering or dry cleaning or both.

3- RANDOM TUMBLE PILLING TEST

In this test, fabric specimens are subjected to a random rubbing motion produced by tumbling specimens in a cylindrical test chamber lined with a mildly abrasive material. In order to form pills that resemble those produced in actual wear in appearance and structure, small amounts of grey cotton lint are added to each test chamber with the specimens.

Three samples each 105 mm square are cut at an angle of 45° to the length of the fabric. The edges of the fabric samples are sealed by a suitable rubber adhesive to stop them fraying. All three samples are then placed in one test chamber, which has been fitted with a fresh cork liner, and 25 mg of the cotton lint is added. The machine is run for 30 min periods during which time the samples are tumbled by an impeller in the center of the chamber. After each 30 min cycle the fabric is assessed and the chamber cleaned out and loaded with a fresh supply of lint. The number and timing of the cycles depend on the type of fabric being tested and would be laid down in the relevant specification. Figure 1 shows the chambers of a random tumble-pilling tester.

Figure 1: The random tumble-pilling tester

In order to assess the amount of pilling on the fabrics they are placed in a suitable viewing cabinet, which illuminates the pilled surface with light at a low angle so throwing the pills into relief. The fabric samples were assessed by comparing them with a set of photographic standards (ASTM "American Society for Testing and Materials") [2], the rating being a subjective one using the following scale:

5- No pilling 4- Slight pilling

3- Moderate pilling 2- Severe pilling

1- Very severe pilling

4- PILLS IDENTIFICATION

Computer-vision technology provides one of the best solutions for the objective evaluation of pilling [4-8]. Researchers in various institutions have been exploring image-analysis techniques that are effective for pill identification and characterization. A typical set-up of an image-analysis system for pilling evaluation includes a CCD camera, a frame grabber, a computer, and the analysis software. Suitable hardware is generally available on the market, but the analysis software often requires a great deal of customization or new development. A pilling-evaluation program needs to include at least two procedures: pill identification and feature measurement.

The simple computation; algorithms involved in pill identification in a solid-color fabric follow a common principle that pills are brighter than their surrounding areas and can therefore be differentiated by selecting a proper threshold.

Image processing techniques have been widely used for characterizing and inspecting textured materials in general, thus including textiles. An interesting study of pilling evaluation by digital image analysis was carried out by Konda et al. [3]. Images of the real samples were captured under near-tangential illumination, which gave images with good pill-to-background contrast that were then compared with standard images. The original image was binarized by applying a double threshold. The first threshold was determined by discriminate analysis and the second threshold was established to include only pills bigger than a given minimum. Although threshold selection was sometimes imprecise, it was a big step forward on conventional visual testing by experts and provided some basis for a deeper study.

A fully automatic method was developed for pilling evaluation by digital analysis that estimates the total area of the sample covered by pills. The analysis procedure sequentially combines operations in both the spatial and frequency domains to properly segment pills from the textured background of the web. The analysis of the set of standard images enables us to approach empirically the underlying relationship between the total area of pilling and the degree of pilling attributed to the standard samples. In addition, this automatic method is compared in this work to human observers assisted by computer.

5- Artificial Neural Networks (ANN).

Artificial Neural Networks (ANN) are widely used in many applications such as pattern recognition, non-linear system identification, adaptive signal processing، etc. Artificial Neural Networks have also been applied to different textile problems such as classifying patterns or defects in textile textures, and predicting fabric parameters [9-15].

6- PILLING EVALUATION

After acquiring the fabric image, it will be processed in progressive steps to enable the system from extracting some important features, which indicate the status of the fabric pilling. The system process the image in the following manner:

1- Image acquisition through digital CCD camera directly to the computer image file.

2- Converting the image type to be put in binary form, using the appropriate threshold which distinguishes the pills from the image background which is the fabric itself.

3- Extracting the image feature vector, that will be used in the process of training the Artificial Neural Network (ANN).

This system is schematically described on the fig. 2

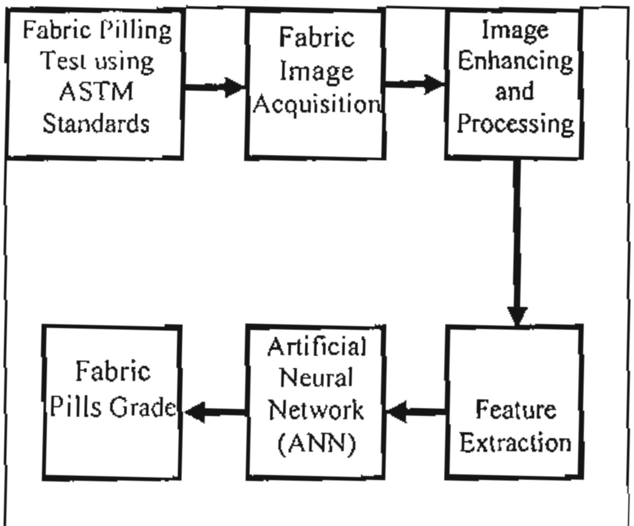

Figure 2: System for pilling evaluation

The following image features were selected:

a) Number of pills

The first feature that will be used to train the Artificial Neural Network (ANN) is the total number of pills in the processed fabric image.

This feature gives an indication to the severity of fabric pilling.

b) Average area

The area of pills is another important factor influencing pilling appearance. The proposed system locates each pill and calculates its area, which will be stored in a separate vector. Thus, for each image we can obtain mean, standard deviation, maximum and minimum areas of the pills. in this study, average area was chosen to train the ANN.

c) Area ratio

Area ratio is equal to the ratio of the total area of pills to the image area.

$$A_{ave} = \frac{\sum_{i=1}^{n} A_i}{L * W}$$

where A_i is the area of the i-th pill in pixels, n is number of pills in the image, L is the image length in pixels, W is the image width in pixels.

d) Pilling density

The proposed system divides the original image to blocks with equal size and counts the pills located in each block and calculates the average number of pills per block that indicates the pilling density for the fabric.

To count the pills, we have to identify the centers of each pill. The underlying notion used by the system to identify the coordinates of mass center for each pill is to divide each pill into its constituent pixels and allocating the center coordinates of each pixel. The mass center coordinates can be calculated from the following relation:

$$X_{mk} = \frac{\sum_{i=1}^{n} A_i * X_i}{\sum_{i=1}^{n} A_i}$$

$$Y_{mk} = \frac{\sum_{i=1}^{n} A_i * Y_i}{\sum_{i=1}^{n} A_i}$$

where; n equals the number of pixels in the k^{th} pill in the image (see fig. 3).

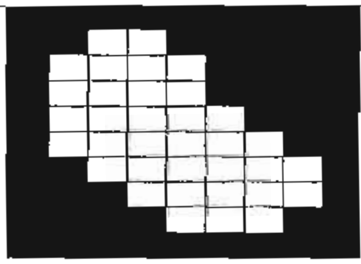

Figure 3: Pill expressed in pixels

After identifying the center of each pill the system counts the pills whose centers located in the predefined block and then calculates the average of these counts to indicate pilling density.

7- ANN TRAINING

For each of the ASTM standard pilled fabrics, an image is acquired and processed with the appropriate threshold to get the binary image. For each image the system calculates the number of pills in the image, the average area of the pills in the image, the area ratio and the pilling density. These features were extracted with different threshold levels to obtain a variety of values of each image features that enable us from training the Artificial Neural Network (ANN).

The ANN were constructed with input-hidden-output layers, the network has four inputs, six neurons in the hidden layer with sigmoid function as a transfer function and one output neuron in the output layer with linear transfer function (see fig. 4).

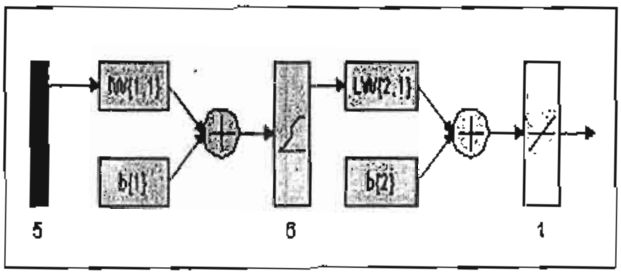

Figure 4: ANN system for pilling evaluation

The training set consists of 20 varieties of the four features data as inputs and 20 equivalent grades as output. The training has 100,000 training epochs based on back propagation training algorithm with training rate of 0.5. The resulted error curve, which indicates the performance of the system, is shown in Fig. 5.

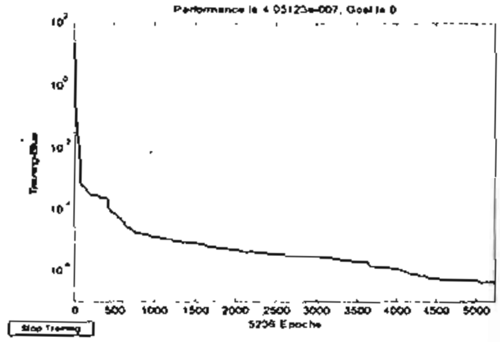

Figure 5: ANN error curve

8- SYSTEM FPE

The software system FPE for pilling evaluation based on the scheme described on fig. 2 was created. The main window of this system is shown on the fig. 6-a, 6-b.

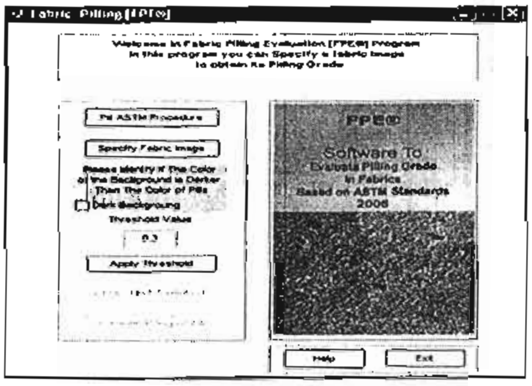

Figure 6-a: System FPE® for ASTM Images

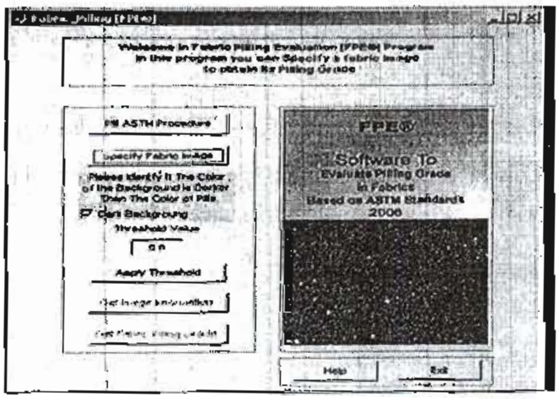

Figure 6-b: System FPE® for Real Fabric Images

Typical output from system TPE is given on the fig. 7.

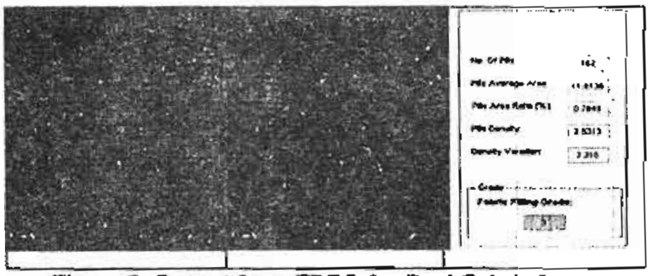

Figure 7: Output from FPE® for Real Fabric Images

9- CONCLUSION

The use of image analysis combined with trained Artificial Neural Network (ANN) for grading according to the ASTM is powerful tool for replacing subjective decision by the objective manner. The new software FPE for complex treatment of pilling images created on the base of this approach can be used for routine objective pilling evaluation in practice.

10- References

1. Saville, B.P. © Physical Testing of Textiles, Woodhead Publishing, 1999.
2. ASTM D3514 - 09 Standard Test Method for Pilling Resistance and Other Related Surface Changes of Textile Fabrics:
3. Alston P.V., 'Pilling of Sweatshirts That Are a 50/50 Blend of Polyester and Cotton', Textile Research Journal, 64(10), 592-596, 1994.
4. Konda, L. C. Xin, M. Takadera, Y. Okoshi, and K. Toriumi, "Evaluation of pilling by computer image analysis" *J. Text. Mach. Soc. Jpn.* 36 (3), 96–107, 1990
5. Abril H.S., Milla'n, M.S., Torres Y. and Navarro R., "Automatic method based on image analysis for pilling evaluation in fabrics", *Opt. Eng.* 37 (11), 2937–2947, 1998.
6. H. C. Abril, M. S. Milla'n, and Y. Torres, "Objective automatic assessment of pilling in fabrics by image analysis" *Opt. Eng.* 39 (06), 1477–1488, 2000.
7. Binjie Xin, Jinlian Hu and Haojin Y An, "Objective Evaluation of Fabric Pilling Using Image Analysis Techniques" *Textile Res. J.* 72(12), 1057-1064, 2002.
8. X. Chen and X.B. Huang, "Evaluating Fabric Pilling with Light-Projected Image Analysis", Textile Research Journal.; 74: 977-981, 2004.
9. Tsai I.S., Lin C., Lin J., "Applying an Artificial Neural Network to Pattern Recognition in Fabric Defects", Textile Research Journal, 65(3), 123-130, 1995.
10. Barrett, G.R., Clapp, T.G., Titus, K.J., "On-line fabric classification technique using a wavelet-based neural network approach", *Textile Research Journal*, Vol. 66 No.8, pp.521-., 1996.
11. Chen P., Liang T., Yau H., Sun, W., Wang, N., Lin, H., Lian, R., "Classifying Textile Faults with a Back-Propagation Network using Power Spectra", Textile Research Journal, 68(2), 121-126, 1998.
12. Tilocca A., Borzone P., Carosio S., Durante A., "Detecting Fabric Defects with a Neural Network Using Two Kinds of Optical Patterns", Textile Research Journal, 72(6), 545-550, 2002.
13. Chattopadhyay, R., Guha, A., "Artificial neural networks: applications to textile", *Textile Progress*, Vol. 35 No.1, 2003.
14. Beltran, R., Wang, L., Wang, X., "Predicting the pilling propensity of fabrics through artificial neural network modelling", *Textile Research Journal*, Vol. 75 No.7, pp.557-, 2005.
15. Nuray Uçar, Seniz Ertuğrul, "Prediction of Fuzz Fibers on Fabric Surfaceby Using Neural Network and Regression Analysis", FIBRES & TEXTILES in Eastern Europe, Vol. 15, No. 2 (61), April / June, 2007.