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Detecting and Measuring Fabric Pills Using Digital Image Analysis

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Abstract**—**In this paper a novel method was presented for evaluating the fabric pills using digital image processing techniques. This work provides a novel technique for detecting pills and also measuring their heights, surfaces and volumes. Surely, measuring the intensity of defects by human vision is an inaccurate method for quality control; as a result, this problem became a motivation for employing digital image processing techniques for detection of defects of fabric surface. In the former works, the systems were just limited to measuring of the surface of defects, but in the presented method the height and the volume of defects were also measured, which leads to a more accurate quality control. An algorithm was developed to first, find pills and then measure their average intensity by using three criteria of height, surface and volume. The results showed a meaningful relation between the number of rotations and the quality of pilled fabrics.

Keywords**—**3D analysis, computer vision, fabric, pile, surface evaluation

I. INTRODUCTION

GENERALLY, quality of a fabric is estimated by three criteria of physical properties, appearance and defects. Most of the defects in a fabric are related to physical properties of the fabric. Consisted in this relation, occurrence of pilling defects in fabrics is related to the physical properties of fiber, yarn twist and fabric structure. Evaluating the pilling defects; we can assess these properties of fibers, yarns and fabrics and also the probability of problem occurrence in production line. As a result, using a reliable method for detection and measurement of these defects might lead to evaluate the quality of products and correctness of the working machines. In the ASTM (D3511 and D3512) pilling resistance test methods, an observer is guided to assess the pilling appearance of a tested specimen based on a combined impression of the density, pill size and degree of color contrast around pilled areas. A frequent complaint about the visual evaluation method is its inconsistency and inaccuracy. Until recently, the inspection of fabric was made by operators on an inspection table with a maximum accuracy of only 80%. Existing methods of inspection of fabric vary from mill to mill. The inspectors view each fabric as it is drawn across the inspection table. This task of visual examination is extremely exhausting, and after a while, the sight can not be focused, and the chance of missing defects in the fabric becomes greater. More reliable and subjective methods for pilling evaluation are desirable for the textile industry. Computer vision technology provides one of the best solutions for the objective evaluation of pilling. Researchers in various institutions have been exploring image analysis techniques effective for pill identification and characterization [1, 2, 3]. To present a comparative method for judging the pilling intensity and controlling the quality researchers introduce different approaches. image-processing-based methods were developed for pilling evaluation which combined operations in both the frequency and the spatial domains in order to segment the pills better from the textured web background. Z. Fazekas, J. Komuves et al. located pill regions in the non-periodic image by using template matching technique and extracting by using threshold in the image. Density, size and contrast are the important properties of pills that describe the degree of pilling and are used as independent variables in the grading equations of pilling [4].

Bugao Xu used template matching technique for extracting pills from fabric surface [5]. The limitation in this approach was that one had to ensure that all imaging conditions were always constant and that the non-defective fabric samples were all identical. Moreover, dust particles, lint, and lightning conditions on the template sample may introduce false defects. In another research, Abouelela, M. Abbas et al. employ statistical features such as mean, variance and median to detect defects [6]. In that research due to the method of utilized algorithm only large defects such as starting marks, reed marks, knots, etc. could be extracted and system is unable to detect minute defects like pills. In several other research programs, digital image processing is used to determine pill size, number, total area and the mean area of pills on a fabric surface[7,8].

In this research an algorithm was suggested and programmed by MatLab and its Image Processing toolbox. In this algorithm, using the 2D image, a 3D model of the fabric surface is made. The 3D model allows measuring of two other criteria besides surface area: height and volume.

II. Material and Method

The fabric takes a long time to be pilled in normal application. To evaluate the pilling occurrence, a number of testing machines have been designed to simulate the pilling that is occurred in normal wear. Fabrics are abraded by tumbling, brushing, or rubbing specimens with abrasive materials in machines, and then are compared with visual standards, which may be actual fabrics or photographs of fabrics, to determine the degree of pilling on a scale ranging from degree of 5 which means no pilling to grade of 1 means very severe pilling [9, 10]. This approach for evaluation of fabric pilling is not accurate and depends on the inspector in each factory which might results in difference in the abrading and pilling standard of fabric. For this research 100% cotton fabric was produced and used in the experiments. Pills were generated in the Martindale abrading machine. Different numbers of rotation in the standard mode of pill generating were used to be evaluated in the written program. For this use, number of rotation of 500, 1000, 1500 and 2000 were applied to the fabric. These fabrics were scanned by an optic scanner with a resolution of 600 DPI. Finally these pictures were used as the input of the program. A scanned surface of fabric was shown in the Fig.1.

Fig. 1. Scanned surface of pilled fabric

The most important part of research is detecting pills and unevenness in the fabric by using image processing techniques. To detect pills a quite new technique was used; first the images were converted to the double format to enable the mathematical calculations on it. Then a wiener filter was used to decrease the noises in the image. Wiener filtering is one of the earliest and best approaches to linear image restoration. This method works by considering the images and noises as random processes and minimizing the mean square error between image and its differential. Following that step; the detection is started by finding corners in the image. It can be defined as the intersection of two edges; a corner can also be defined as a point for which there are two dominant and different edge directions in a local neighborhood of the point. An interest point for detecting is a point in an image which has a well-defined position and can be robustly detected. This means that an interest point can be a corner but it can also be, for example, an isolated point of local intensity maximum or minimum, line endings, or a point on a curve where the curvature is locally maximal. As a consequence, if only corners are to be detected it is necessary to do a local analysis of detected interest points to determine which of them are real corners. Harris corner detector was used for this approach. Harris corner detector finds corners by considering the differential of the corner score with respect to direction directly, instead of using shifted patches [11].

These detected corners are actually the crossing points of weft yarns and warp yarns. The point is that when the fibers entangle outside the yarn and fabric structures the pilling is happening, as a consequence these entangled fibers cause the disturbance in the visual pattern of crossing points. As it is shown in the Fig.2 pills cause perturbation in the structure of woven yarns. As a result, the points which are distinctly the crossing points of a warp yarn and a weft yarn, and not disordered by the pills and other unevenness origins as a corner can be detected. After applying corner detector, to separate the defected areas from the background of fabric; first a histogram equalization technique was used, this technique expand the gray scales of image into the 256 layers. This makes the image more distinguishable and visually more meaningful. Then a threshold applied to the histogram equalized picture. The threshold value was set according to the histogram of gray scale equalized image, and set for all images about 0.1. The remaining of threshold is those areas which are not detected as a corner. But most of these areas are small areas which are neither a defect nor a corner. In fact these are the body of yarns or the small spaces between two parallel yarns. These areas should be eliminated from the detection matrix. Since these areas are slight we can use the size as criteria for deciding whether a detected spot is a defect. In consequence, the detected areas whose squares were less than 400 pixels were eliminated from the final result. The result of applying the threshold and omitting slight areas is the defected areas matrix (Fig.3). Assessing these areas led to quality control of fabric and finding a standard for the pile density and abrasion resistance.

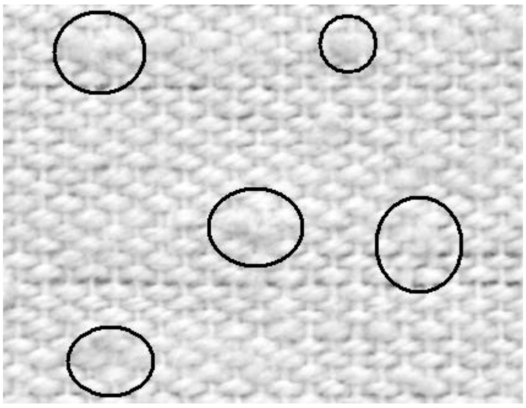

Fig. 2. Magnified surface of fabric and where the ovals are showing, are the piled areas

Fig. 3 is the result of defect detection algorithm applied on the shown image in the Fig 2.

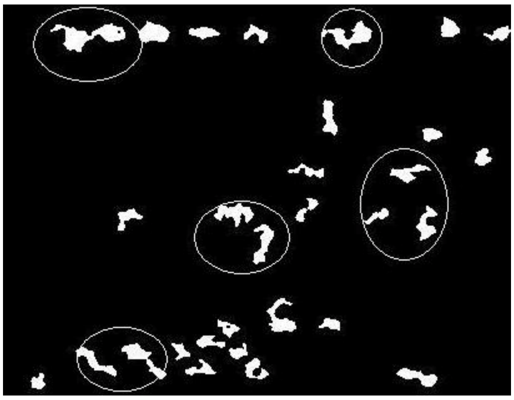

Fig. 3. Result of the algorithm on the image of Fig.2

The result of detection algorithm is a matrix whose elements have the value of zero in the fine areas and have the value of 1 in the defected areas. As it is shown in Fig.3 black areas are the zero-valued elements and the white areas have the value of one. This matrix was multiplied by the original image, and the result is a matrix which has the value of zero in the fine areas and the original value of fabric image in the defected areas. The final matrix is a key to 3D modeling of fabric surface. The 3D model is simulated by using the intensity values of elements. The brightest point has the maximum value of intensity in the image and should be considered as the point in the fabric which has the maximum height. Accordingly the zero elements in matrix have the minimum value in the fabric. The lowest point in the fabric is on the background surface of the fabric and its height is equal to thickness of fabric. The thickness of the fabric was measured by the micrometer. The highest point in the fabric is the summit height of the highest pile. This height is measured by scanning from the side of the fabric and counting the vertical pixels of the highest pile. Then the height was calculated by multiplying the number of pixels of height in the DPI of image. This calculated height plus the thickness of the fabric is the highest point in the fabric. The zero elements considered as the points with the 0.83 mm height in the fabric and the maximum element has 2.015 mm height in the fabric. Lastly, a linear relationship considered between the value of the elements and the height of fabric in that point. The higher the point is, the closer it is to the illumination. Consequently, it absorbs more lights and appears more brightly in the image than the points with lower height. To figure this function the gray level of the darkest point in the processed image considered as the points with 0.83 mm height. And the gray level of brightest point considered as the points with the 2.015 mm height. As the images acquired in the 256 levels of gray scale, formula 1 describes this function.

$$H(i,j) = 0.83 + \frac{1.185}{255} I(i,j) \qquad (1)$$

Where the *H(i, j)* describes the height of points and *I(i,j)* describes the illumination of points. Using this function we could simulate the fabric surface. The simulated surface of fabric was shown in the Fig.4.

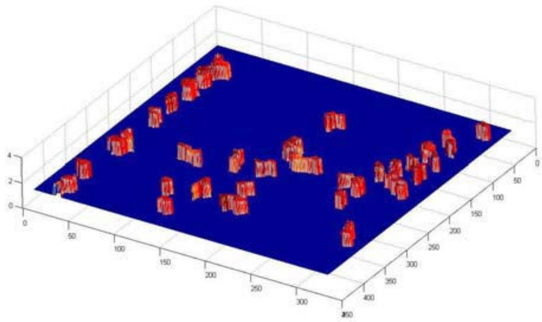

Fig. 4. Simulated surface of fabric

In this surface, pills have been completely extracted from the fabric texture background and it is enabling us to measure the height and volume of pills.

III. Results

To evaluate and compare the different fabrics with the algorithm, a criterion was defined in the algorithm using all of the three measured criteria. First, the volume of piles was calculated in the fabric, which is total values of elements in the *H(i,j)* matrix. Second, the total surface of piles was measured. This criteria measured by summing up the defected detected matrix (Fig.3). Third, the mean height of piles was measured by dividing the criteria of volume by the total surface. A criterion was described in the formula 2 as a standard for the quality of fabric and intensity of piles.

$$\text{Index} = ((vol/(V+vol))+(sur/S)+(H/(th+maxh)))/3 \qquad (2)$$

In this Index, *vol* is the total volume of piles, V is the total volume of fabric without piles, *sur* is the total surface of piles, S is the surface of fabric, H is the mean height of piles, *th* is the thickness of fabric, and *maxh* is the maximum height of piles in the fabric. This standard always is between 0 and 1 for easier assessing.

In order to detect the pilled areas, the previously-mentioned algorithm was applied to the images but the resulting values were too similar and the fabric quality could not be evaluated. To solve this problem a new standard was defined according to formula 3. This standard was entirely distributed between 0 and 1 and makes it possible easily to judge between qualities of different types of fabric.

$$\text{new index} = \frac{index_i - \min(index)}{\max(index) - \min(index)} \qquad (3)$$

In this new index, $index_i$ is the initial calculated index, min(*index*) is the minimum of index and max(*index*) is the maximum of index in all the calculated indices. The results of this index were shown in Table I for the abraded fabrics for different numbers of rotation.

TABLE I
RESULTS OF QUALITY STANDARDS MEASURED BY THE PROGRAM

Rotation	Sample I	Sample II	Sample III
500	0.38396	0.00	0.79220
1000	0.35344	0.38397	0.65502
1500	0.78117	0.79331	0.52703
2000	1.00	0.83891	0.69511

These numbers show the quality of fabric linearly, when the standard is closer to 1 it shows that it has more piles and lower quality.

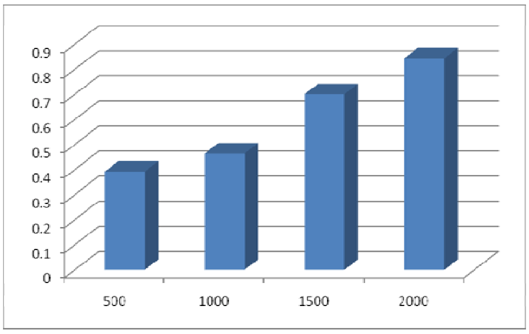

Fig.5 The Horizontal axis is the number of rotations and the vertical axis is the average quality standard

Clearly, when the rotation of abrading machine increases the number of piles grows on the surface of fabric. Fig.5 shows this fact by averaging the quality standards of samples in a specific number of rotations.

In Fig.5 it was shown clearly, that increase in the number of rotation results in growth in the piles. And this standard can be fair and reliable to assess fiber and fabric quality in the industries, laboratories and also could be used as a standard for measuring abrading resistance of fabrics instead of human vision.

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