Orientation Angles Quantification for Commingled Fibre/Polypropylene Engineering Fabric Using Partly-Computerized Edge-Detection Image Processing Technique

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الملخص:

التباين في زوايا اتجاهات النسيج الهندسي الممزوج من الياف الزجاج والبوليلروبيلين تم قياسها باستخدام طريقة تصويرية مبتكرة تعتمد على اكتشاف الحدود. وهذه الطريقة مرتكزة على اساسيات رياضية وعددية. هذه الطريقة اثبتت بعض المزايا مقارنة الطريقة اليدوية وذلك لما اظهرته من انقاص في الوقت والجهد وزيادة في الدقة.

Abstract:

Orientation angles changeability of glass/polypropylene commingled engineering fabric has been measured using numerical edge detection method. This method based on mathematical and numerical background. Accordingly, this method presents advantage over the labor-intensive method in terms of time and efforts decreasing and accuracy increasing.

1. Introduction:

The labour-intensive image examination process of measuring orientation angles variability of engineering fabric discussed in author paper [1] is a very time overwhelming method due to the labour-intensive process of manual drawing efforts in addition imageJ [2] software efforts of measuring shear angles of every fabric unit cell. Consequently, a computerised method or partly computerised method which reduce labour-intensive efforts and time is essential. In this predisposition, Skordos and Sutcliffe [3] carried out an image processing work on woven roving engineering carbon fabric to measure the changeability in yarns direction paths. They used an image processing technique based on the basics of Fourier convert scheme. Another research in this way performed by Gan, et al. [4].

They employed a computerised technique to examine changeability in yarns direction, yarns' sizes and gaps of different types of fibre-reinforced matrix. The simple fundamentals of their method is converting the photo of engineering fabric from colour to gray, hence considering each yarn' crossover as a black concentrated point. The position and coordinates of those points were determined using restricted configuration method. The present scientific technical article concerned with determining partly-computably the statistical variables of the changeability of the orientation angles of a given engineering fabrics and textile composite materials. The purpose of these effort is for reducing labour-intensive and time as well as increasing correctness. 'PatCompImPro' computer software was implemented in Matlab for measuring the statistical variables of the changeability in yarns' orientation angles to be as s raw data for further numerical or finite element analysis of textile or fabric forming or structural performance examination of composite laminates or mechanical properties of textile or fabric composite.

2. Material and Method:

The partly-computerised name is an indication of that; the recent method consist of two steps the first step could be a labor-intensive or computerized and the second and last step is a computerized. The first step is determining the position of crossed yarns and the second step is determining the coordinates of each fabric unit cell yarns crossovers. The labor-intensive in the first step is a hand drawing grid tracking yarns with desired grid's degree or painting a spot on yarns' crossover on fabric image imported to Painter software [5]. However, this step can be changed to be a computerized by ordering from fabric suppliers a particular purpose fabric with different warp and wefts colors i.e. the warps are dark and the wefts are bright or verse versa. On the other hand, the second step is a computerized step in all cases where a coordinates of each yarns' crossover were determined using one of number of edge detection techniques implemented in Matlab.

The weave structural configuration of engineering fabric ease the process of detecting yarns' crossover as different color regions using edge detecting techniques [6-8].

3. Theory and Numerical Analysis

Images can be in gray or colour scale. The substantial constitutive of any gray or colour image is pixel. Every image consists of limited number of pixels depends on image's scale and quality. Pixels are saved numerically as numbers for example (0-255) for gray scale image and also for colour images but (0-255) for green, (0-255) red and (0-255) blue.

Defining perimeters in images based on a method takes in account the first and second derivative. Taken pixels first derivative crossover an image is the way of determining perimeters. Each image has intensity function I, perimeters detected by taken the first derivative of the intensity function I (see equation 1 and 2) [11].

$$\nabla I = \nabla f(x, y) \tag{1}$$

$$\nabla I = \begin{bmatrix} \dfrac{\partial I}{\partial x} \\ \dfrac{\partial I}{\partial y} \end{bmatrix} \tag{2}$$

$\dfrac{\partial I}{\partial x}$ and $\dfrac{\partial I}{\partial y}$ are the partial deferential equations of the intensity function in the directions of x and y axes respectively. The absolute value of the intensity function gradient is as illustrated in the following equation 3.

$$|\nabla I| = |\nabla f(x, y)| = \sqrt{\left(\frac{\partial f(x, y)}{\partial x} i_x\right)^2 + \left(\frac{\partial f(x, y)}{\partial y} i_y\right)^2} \tag{3}$$

The straightforward edge detection method among several methods is the operation developed by Robert in 2002 [12] which adopted an edge detection technique based on local intensity function gradient. A matrix of four components (kernel) defining the brightness and darkness of every pixel and consequences of pixel state on neighbour pixels produce a reasonable edge detection results [13,14].

$$\frac{\partial f(x,y)}{\partial x} = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \quad (4)$$

$$\frac{\partial f(x,y)}{\partial y} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad (5)$$

Another image detection method was developed for grey scale by Prewitt [15-17]. Prewitt replaced the 2x2 convolution kernels with 3x3 convolution kernels.

$$\frac{\partial f(x,y)}{\partial x} = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad (6)$$

$$\frac{\partial f(x,y)}{\partial y} = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad (7)$$

For higher gray scale edge detecting Sobel developed another edge detection method. The advantage of this method it can detect edges that existed in both direction (horizontal and vertical direction) [15-17].

$$\frac{\partial f(x,y)}{\partial x} = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (8)$$

$$\frac{\partial f(x,y)}{\partial y} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad (9)$$

4. Method:

The methodology of characterising orientation angles changeability inherent in engineering fabric or textile composite using the partly-programmed image handing out technique divided into steps. The first step could be carried out physically by hand using marker pen by drawing grid or points on given engineering fabric (see Figure 1) or ordering a fabric with different warp and weft colour as explained previously in the introduction of this paper

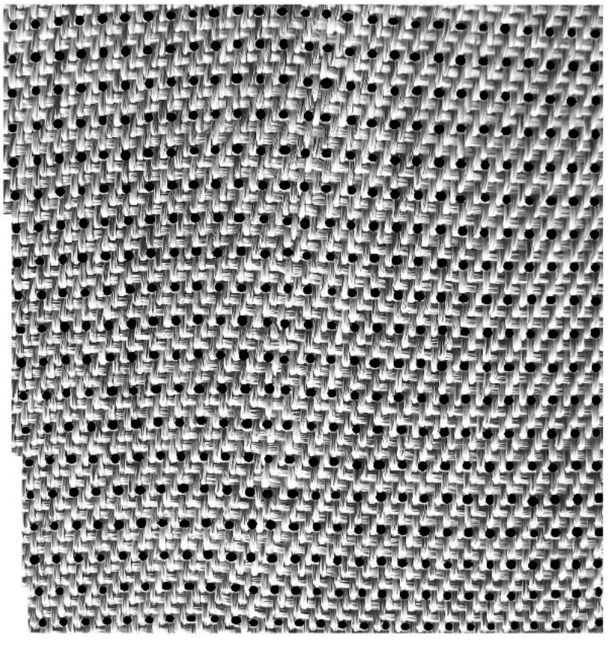

Figure 1: Painting spots on the crossover of warps and wefts with desired grid degree.

Once the drawing grid or points is performed on the given fabric, a colour photo of the given fabric is taken and imputed to Matlab with tif image format. Gray and colour images converted to matrices consisted of numbers. Gray image consists of one matrix (0-225) whereas colour image consists of three matrices (0-225) for three colours green, red and blue. After imputing the colour image to Matlab, converting the colour image to gray image by using ***rgb2gray*** subroutine already stored in Matlab Library. Although the image converted to gray image, but there are still some unclear features and unwanted edges which need to be cleared to obtain just a black spots on a white background. This has been done by increasing the brightness to a desired level by changing the gray scale of intensity matrix I with suitable factor (see Figure 2). Figure 2 shows black spots after increasing the brightness to a desired level.

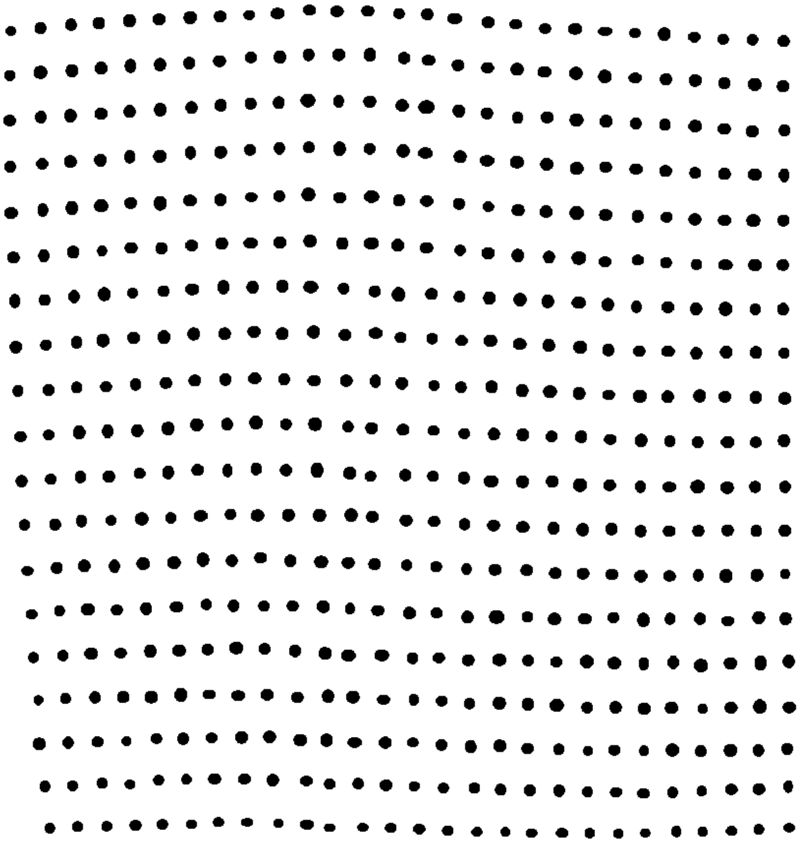

Figure 2: Black spots as a result of increasing the brightness of the image.

Detection black spots were carried out using Roberts edge detection method implemented as Matlab subroutine in Matlab library. This method introduced first time by Bovik [18] in his research paper. Detecting edges using this method has been carried out by applying the kernels (4) and (5) (see equations 4,5). Edges in the given image are detected after applying equations (4) and (5) as a number of coordinates in each single spot. Considering an edge detection process to be successfully defined once the characteristic features of the image edges are obvious and apparent with brilliant visualization as well as clear background with almost no image noise [18].

The black spots appear as circles or rounded 2D shapes. The perimeter around each circle are small connected points (see Figure 3). The coordinates of each small point on the perimeters are determined using a Matlab subroutine implemented already in Matlab library (bwboundaries).

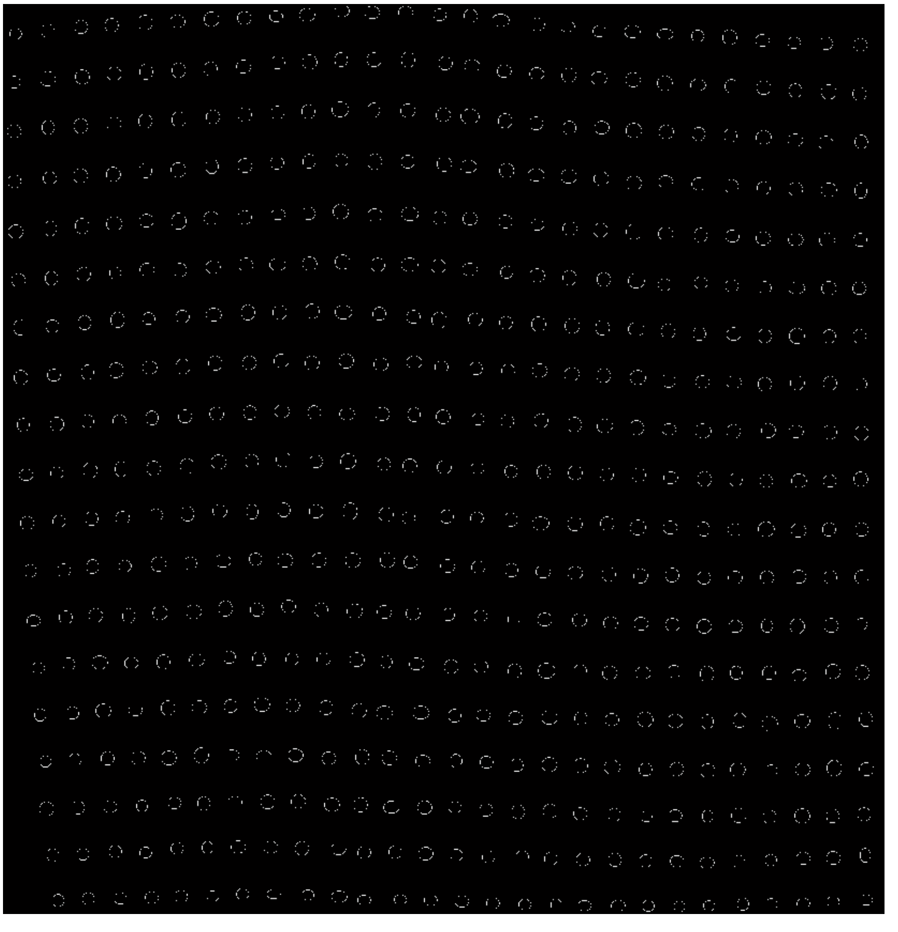

Figure 3: Detected edges of the black spots as small connected points and determining coordinates of those small points

In order to generate one node in each detected edges of the black spots, averaging the coordinates of the small connected points on each individual perimeter was carried out. To this extend, node matrix contains x,y and z coordinates has been created and stored. Generating quadrilateral finite elements were carried out using a simple polar searching technique implemented in 'PatCompImPro' (see Figure 4). For further use in numerical orientation angles e.g. Varifab [1] statistical information as the mean and standard deviation of the given image is calculated and stored. The flow chart of the programming stages of 'PatCompImPro' are illustrated in Figure 5.

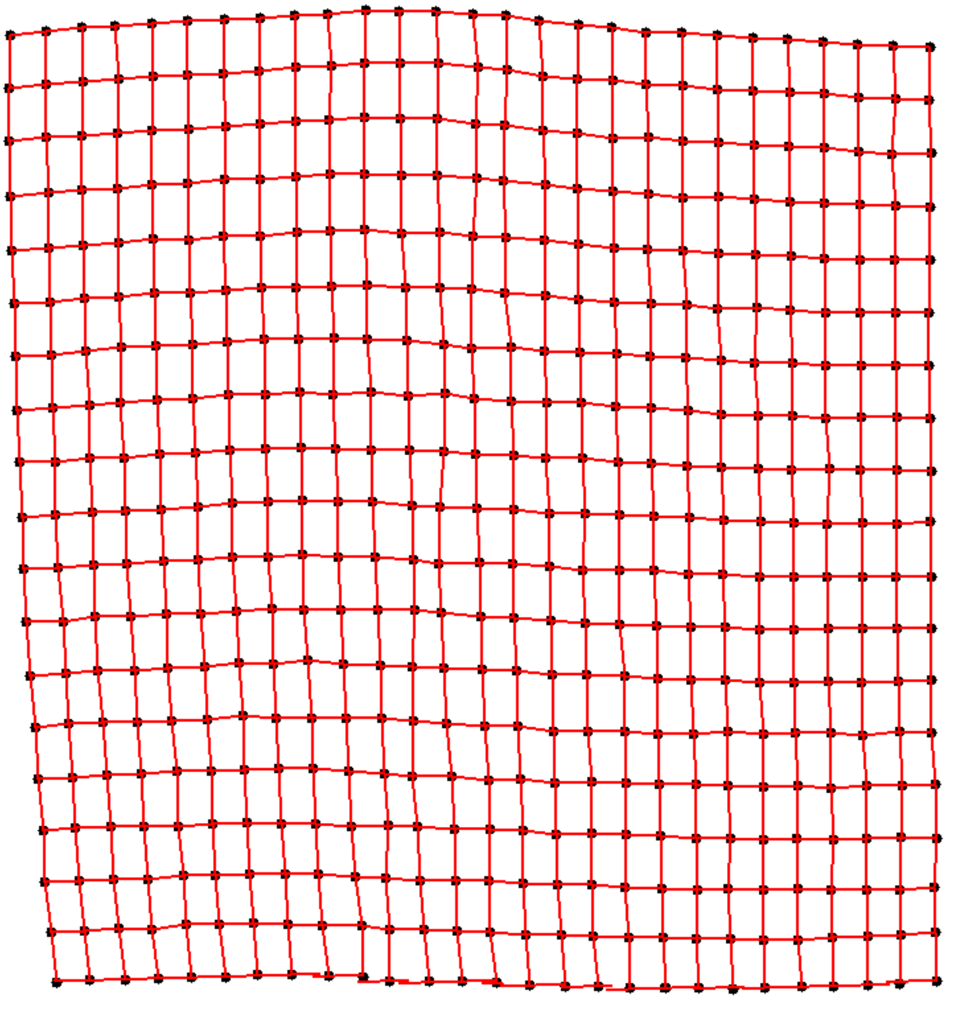

Figure 4: The connectivity of the quadrilateral finite element generated from the nodes obtained from edge detection method

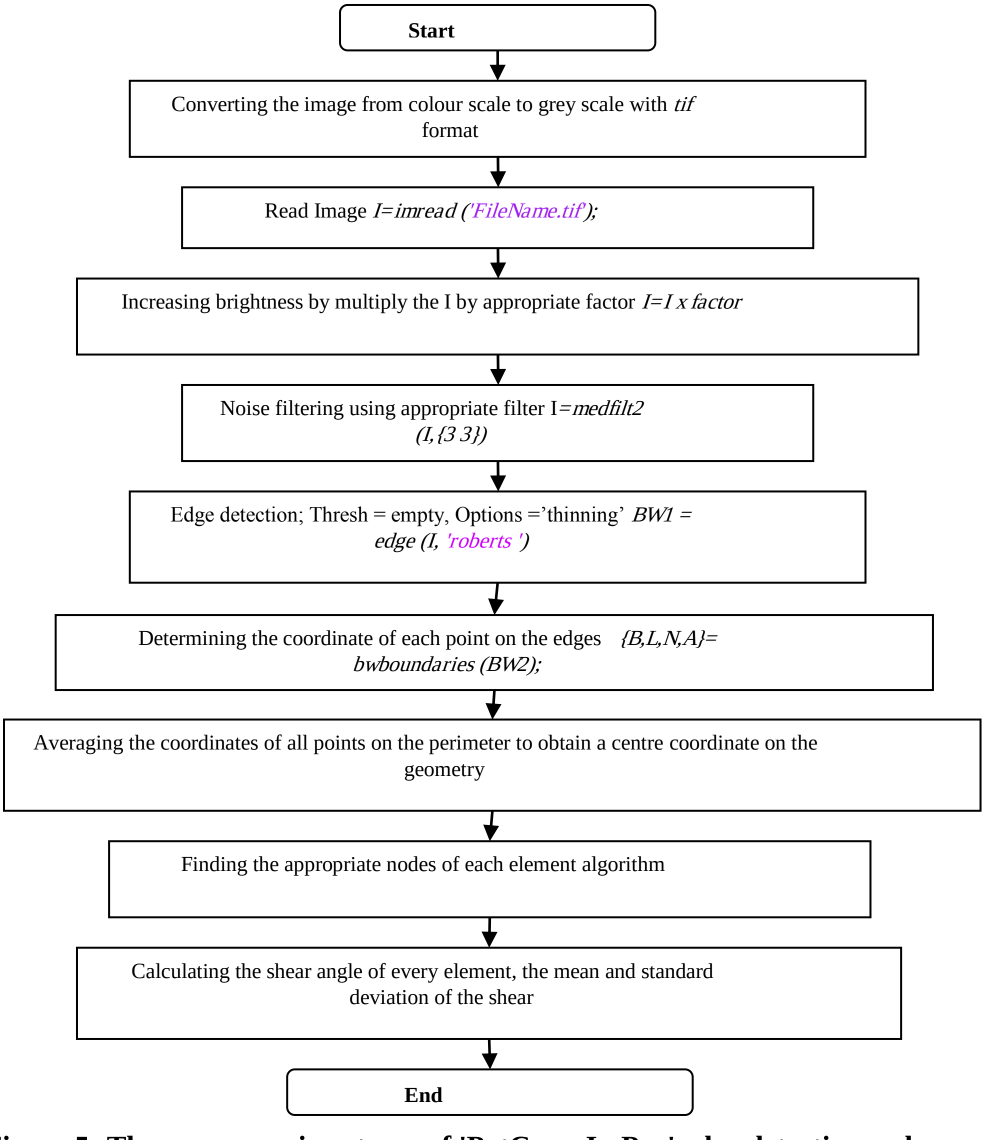

Figure 5: The programming stages of 'PatCompImPro' edge detection code

5. Results and Discussion:

In the way of 'PatCompImPro' code validation, numerical and labour-intensive work on square 30x30 cm of glass/polypropylene commingled twill weave engineering fabric to measure the inherent orientation angles variability has been carried out. The statistical variable as mean and standard deviation of the inherent orientation angles of the fabric sheet were produced once by the numerical method using 'PatCompImPro' code and the other once using hand drawing grid or black spots on yarns crossover and then measuring the shear angles by imageJ [2] software. A comparison between the two mentioned methods was taken place as illustrated in the histogram in Figure 6. Without any little doubt, numerical method of determining the statistical variables of the orientation angles of the commingled fabric using 'PatCompImPro' introduced number of advantages on the counterpart method such as reducing time, reducing efforts and increasing accuracy. The huge differences between the two method as can be easily noticed in the two curves (Figure 6) shows how much differences between the two method where the labor-intensive lacks of accuracy since it is tedious and need focusing on the screen which can be stressful and depends on human skills and sight.

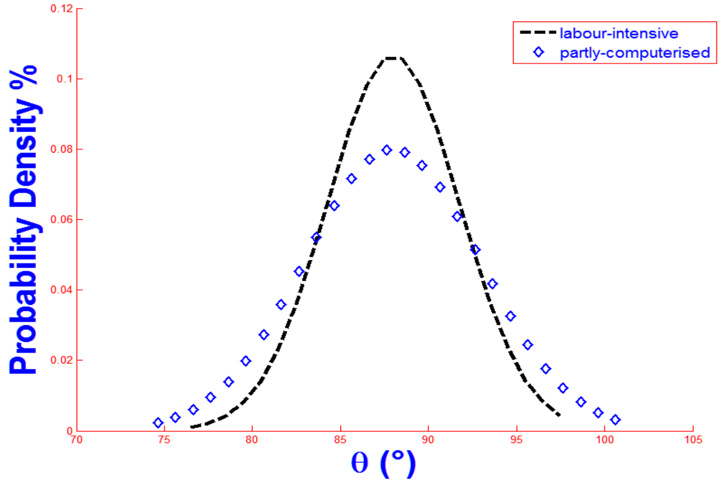

Figure 6: Comparison between the measurement of orientation angles of commingled fabric using labour-intensive and partly-computerised methods

6. Conclusions:

New inventive method of measuring the statistical variable for orientation angles of commingled fabric has been developed using edge detection numerical foundations. This method can be applied to any type of engineering fabric such as plain weave, twill weave and satin weave or commingled fabric and textile unidirectional composite. In addition, the results shows the benefits of using the numerical method where a huge differences takes place between the numerical and labour-intensive method. Moreover, numerical method decrease the processing time and efforts.

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