Yarn Parameterization and Fabrics Prediction Using Image Processing

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Abstract

This paper presents the main characteristics and functionalities of a system based on image processing techniques applied to quality assessment of yarns. In Textile Industry we used image processing to determine yarn mass parameters as well as yarn production characteristics. A low cost solution based on a web-pc camera plus the optics of a low cost analogue microscope and a software tool based on IMAQ Vision from LabVIEW was designed. Several tests were performed and compared with other methodologies of yarn parameterization validating the proposed solution. With the results one can support that this can be an alternative solution to the traditional yarn testers, with several advantages (among others, low cost, weight, volume, easy maintenance and reduced hardware). Moreover, this yarn parameterization can be used to assess the quality of the fabrics resultant.

Keywords

Yarn; Mass; Diameter; Hairiness; Image Processing; Faults; Fabrics

Introduction

The yarn mass parameters are essential for the quality of fabrics. These include the yarn diameter, mass and hairiness. The most used commercial equipment for measuring these parameters is developed by Uster [1-3]. Although, they present several drawbacks associated with cost, portability, accuracy, resolution, and complexity, among others.

To overcome these problems, we are developing a technological solution using image processing capable of determining the yarn mass parameters and the yarn production characteristics allowing a new level of yarn parameterization. These characteristics can be used to predict the quality of the fabrics resultant from the yarn parameterized using artificial intelligence.

The image acquisition is performed using a web-pc camera plus the optics of a low cost analogue microscope with a maximum amplification of 40X (Fig. 1). A custom software tool developed with the IMAQ Vision form LabVIEW is then used [4].

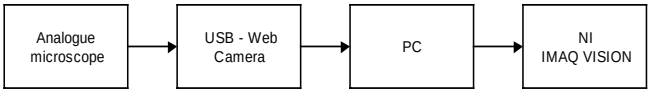

FIG. 1 DESIGNED SYSTEM FLOWCHART

This paper is organized as follows: Section 2 presents the module of determination of mass parameters, Section 3 presents the module of yarn production characteristics, Section 4 shows theoretical concepts of fancy yarns and prediction models and Section 5, the conclusion and future work developments.

Mass Parameters Determination with Image Processing

This section presents the description of the yarn mass parameters determination (hairiness, diameter and faults) as well as the algorithms developed with LAbVIEW, from National Instruments to characterize them. Some results are also presented.

Hairiness

Image Procssing (IP) based applications have been used in the textile industry since 1964 [5], although they have not been converted to viable quality control methods [6]. Several algorithms are currently under development to characterize the yarn hairiness (Fig. 2) with IP, in particular to detect and characterize the protruding fibres length [3, 7-9].

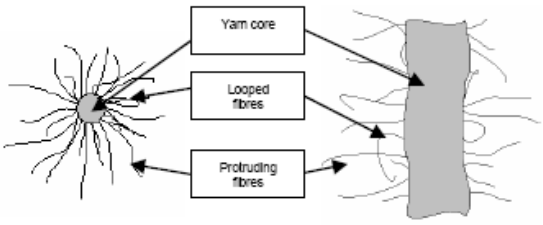

FIG. 2 IDENTIFICATION OF YARN CORE AND YARN HAIRINESS (LOOPED FIBRES AND PROTRUDING FIBRES) [7]

Still, it is necessary to develop algorithms to detect and characterize loop fibres length and to clearly distinguish between protruding fibres and loop fibres when they are interlaced.

Yarn Hairiness Determination Software Application

The algorithm presented in Fig. 3 is used for yarn hairiness determination [10, 11].

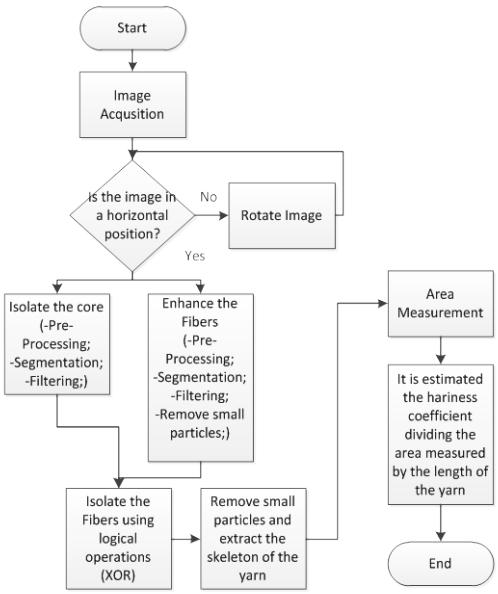

FIG. 3 ALGORITHM USED TO MEASURE THE YARN HAIRINESS INDEX

The previous algorithm was applied to the image of Fig. 4 giving rise to the image shown in Fig. 5.

FIG. 4 ORIGINAL SAMPLE IMAGE ACQUIRED

Results Obtained in the Hairiness Determination

Five yarns with different linear masses (16.4 g/km to 98g/km) were analyzed (Fig. 6) and the algorithm presented in Fig. 3 was applied [10, 11].

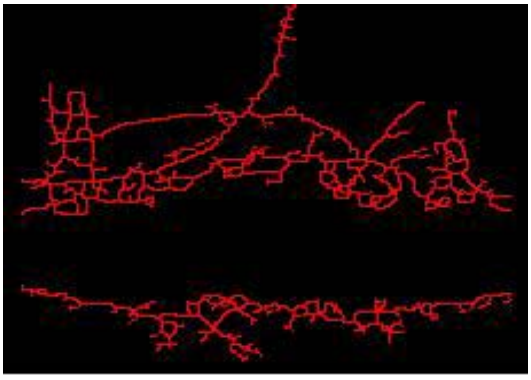

FIG. 5 RESULTANT IMAGE USED TO CHARACTERIZE THE HAIRINESS OF THE YARN SHOWN IN FIG. 4

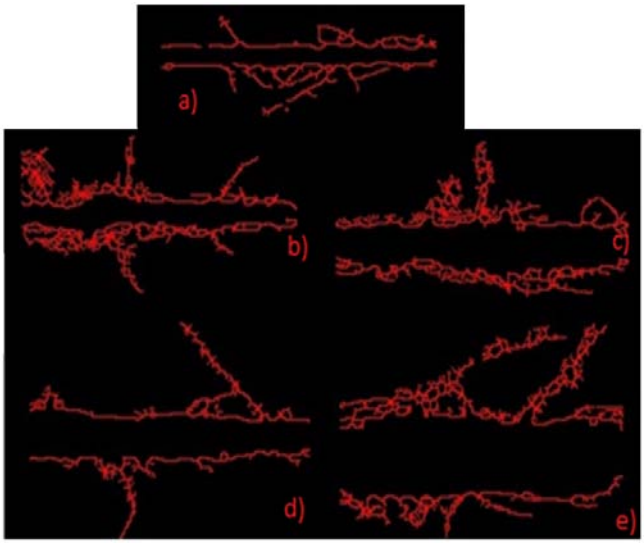

FIG. 6 RESULTS OBTAINED FOR A)16.4 G/KM YARN, B)19.68 G/KM YARN, C)29.5 G/KM YARN, D)36.9 G/KM YARN, E)98 G/KM YARN

Table I presents the results obtained from the average experimental values for different positions of the same yarn. The coefficient of hairiness (H) is given by the ratio between the hairiness length and the length of yarn analyzed. The yarn with a linear mass of 16.4 g/km presented the lowest hairiness index (4.31) whereas the yarn with a linear mass of 98 g/km presented the highest hairiness index (7.15).

TABLE 1 RESULTS OF HAIRINESS

Sample Number	Linear Mass (g/km)	H(m/m)
1	16.4	4.31
2	19.68	6.69
3	29.5	6.64
4	36.9	4.56
5	98	7.15

Diameter and Irregularities

Yarn diameter characterization with IP can be easily achieved with algorithms already applied to the determination of the yarn core [9, 12]. But algorithms to measure the exact length of yarn faults (thin places, thick places and neps) [1] (Fig. 7) still need to be developed.

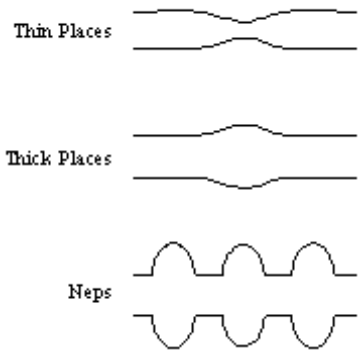

FIG. 7 IDENTIFICATION OF YARN IRREGULARITIES [1] (THIN PLACES - A DECREASE IN THE MASS DURING A SHORT LENGTH (4 MM); THICK PLACES - AN INCREASE IN THE MASS, USUALLY LOWER THAN 100 % OF SENSITIVITY, AND LASTING MORE THAN 4 MM; NEPS - HUGE AMOUNT OF YARN MASS (EQUAL OR SUPERIOR TO 100 % OF SENSITIVITY) IN A SHORT LENGTH (TYPICALLY FROM 1 MM TO 4 MM))

Diameter and Yarn Faults Software Application

The algorithm applied for measuring diameter is presented in Fig. 8 [10, 11].

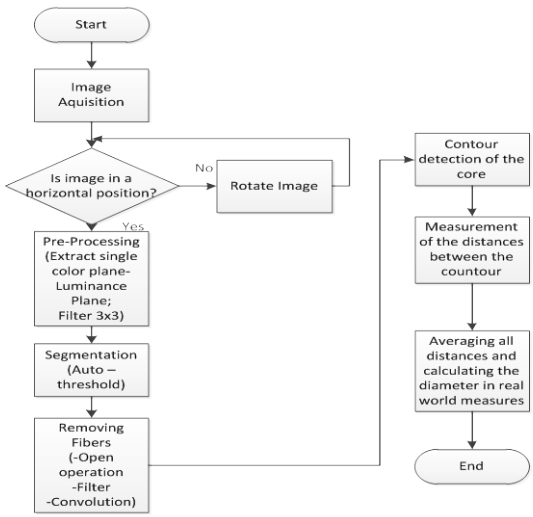

FIG. 8 DIAMETER ALGORITHM

Considering the image presented in Fig. 10 a) as reference, the previous algorithm was applied to obtain the image presented in Fig. 9.

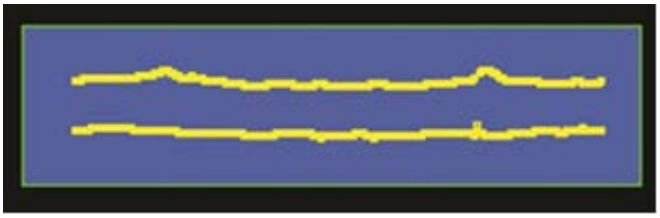

FIG. 9 IMAGE RESULTANT FROM THE APPLICATION OF THE ALGORITHM TO FIG. 10 A)

Results Obtained in Diameter Determination

The algorithm described in Fig. 8 was applied to four sample images with different linear masses (22 g/km, 50 g/km, 55 g/km and 16.40 g/km) (figure 10) [10, 11]. Fig. 11 presents the images obtained after the application of the image processing techniques to characterize the yarn diameter. Table 2 presents the results in pixels (diameter in pixel – dp) and in real world units (mm) after conversion (diameter experimental – de), which also shown for comparison are the values predicted by the theoretical relationship (d(mm)=0.060*sqrt(Tex)) between the yarn's linear mass and the diameter (theoretical diameter - dt) for the respective linear masses [4].

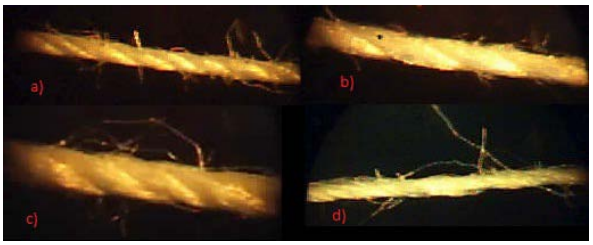

FIG. 10 ACQUIRED IMAGES A) 22 G/KM YARN, B) 50 G/KM YARN, C) 55 G/KM YARN, D) 16.40 G/KM YARN

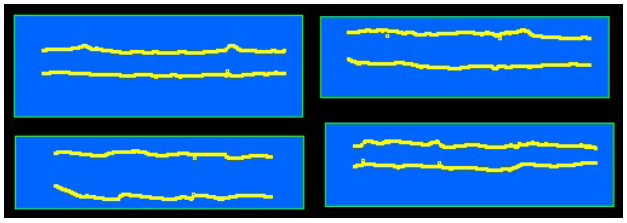

FIG. 11 APPLICATION OF THE TECHNIQUES OF IMAGE PROCESSING TO QUANTIFY YARN DIAMETER TO THE IMAGES OF FIGURE 10

TABLE 2 RESULTS OF THE DIAMETER DETERMINATION

Sample nº	Linear Mass (g/km)	dp (pixels)	dt (mm)	de (mm)	SD (mm)
1	22	19.65	0.2814	0.2690	0.0086
2	50	26.11	0.4242	0.3576	0.0471
3	55	32.78	0.4449	0.4490	0.0028
4	16.40	17.71	0.2429	0.2426	0.0002

Yarn Faults Software Application

The algorithm applied for measuring yarn faults is presented in Fig. 12 [10, 11].

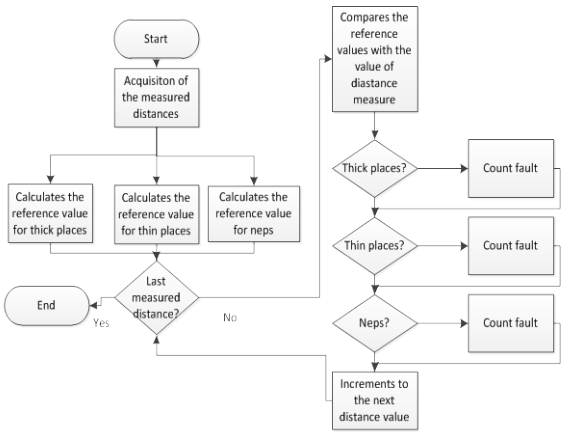

FIG. 12 ALGORITHM USED TO DETECT YARN FAULTS

Results Obtained in the Analysis of the Yarn Faults

This study was performed through the theoretical correlation between mass and diameter, allowing the identification of thin places, thick places and neps when comparing the distances detected between the edges, to their average value. These measurements are then be used to detect the frequency of each of these types of yarn faults. A yarn with linear mass of 19.68 g/km was considered (figure 13) and the algorithm presented in figure 21 was applied [10, 11].

Table 3 shows the results for the 19.68 g/km yarn measured at 10 different points. The data shows that sample 7 has the greater number of thick places, and thin places were detected in only two samples and no neps were detected.

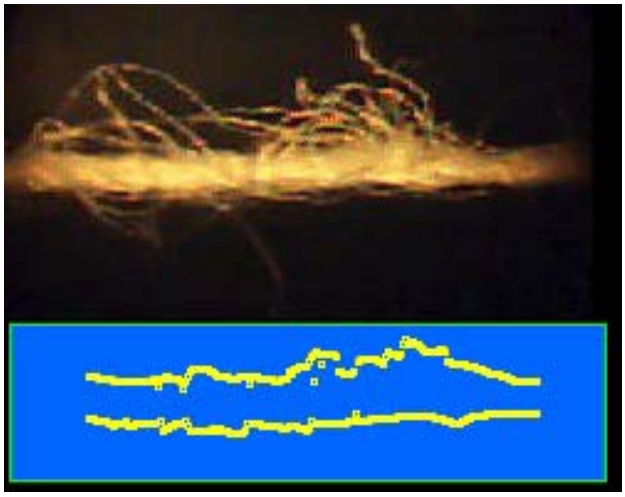

FIG. 13 EXAMPLE OF YARN WITH FAULTS

TABLE 3 YARN FAULTS

Sample Number	Thick places	Thin places	Neps
1	0	0	0
2	0	0	0
3	2	0	0
4	0	0	0
5	0	0	0
6	2	1	0
7	4	1	0
8	0	0	0
9	0	0	0
10	2	0	0

Yarn Linear Mass (Count)

It is possible to obtain the yarn linear mass based on the diameter, porosity and density [3, 13-15]. Some studies are being taken to allow this determination considering the use of IP algorithms and methods.

Yarn Production Characteristics Determination with Image Processing

This section presents the description of the yarn production characteristics as well as the functions applied in the software algorithm used for their determination. Some results are also presented [3, 4].

Yarn Production Characteristics

IP can also be used to determine the yarn production characteristics (snarls length – twist step, number of cables, fibres orientation, cables orientation), where no commercial solution can be found. Studies to determine and measure yarn snarls (Fig. 14), as well as other characteristics are being taken [3, 4, 16].

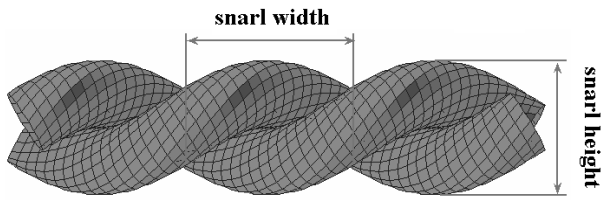

FIG. 14 IDENTIFICATION OF YARN SNARLS – TWIST STEP [21]

Fig. 15 and Fig. 16 present, respectively, a picture of a 55 g/km 100 % cotton yarn and the results of the application of image processing tools to Fig. 15 [3, 4]. The applied algorithm considered a sequence of functions from the National Instruments IMAQ Vision, namely contrast adjust, gamma adjust, removal of the

luminance plane over the hue saturation luminance colour space, inter variance auto threshold, hole filling, erosion, convex hull, small objects removal and particle analysis [4].

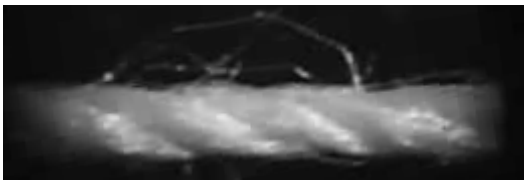

FIG. 15 INITIAL IMAGE [4]

FIG. 16 FINAL IMAGE [4]

The particles obtained in the final images, associated with the application of the algorithm, enable the determination of the yarn production characteristics based on the algorithm presented in [3, 4].

Table 4, as an example, presents for each particle of Fig. 16, the first horizontal pixel, the orientation angle and the area.

TABLE 4 RESULTS OBTAINED FOR THE 22.00 G/KM YARN

Particles	First Horizontal Pixel	Orientation (º)	Area (pixels)
1	73	154.5	377
2	116	158.0	292
3	181	174.6	120

Based on Table 4 and the application of the algorithm presented in [3, 4], the results of the production characteristics for the yarn shown in Fig. 15 are:

- Fibres twist orientation: clockwise;
- Twist orientation of the folded yarn: anti-clockwise;
- Number of cables: more than 1 cable (folded yarn);
- Twist step of the folded yarn (snarls width): 0.70 mm.

It is also our intention to develop an algorithm that is able to determine the exact number of cables in a multi cable yarn.

Fabrics Prediction

Using the yarn parameterization obtained with IP (yarn diameter, yarn hairiness, yarn mass, yarn faults and yarn production characteristics) it will also be possible to develop an artificial intelligence based solution to allow obtaining accurate prediction virtual fabric models of the structures resultant [17, 18] potentiating a better Textile Industry performance.

Conclusion and Future Work

The main goal of this paper is to describe a technological solution to automatically characterize yarns properties and predict the visual appearance in fabrics, using primarily Image Processing (IP) and artificial intelligence based techniques.

Regarding the results obtained for each of the parameterizations performed (yarn production characteristics, yarn diameter and imperfections and yarn hairiness determination) it can be concluded that the reliability of the image processing system option is competitive with traditional systems based on capacitive and optical sensors. Apart from other benefits, its low cost, portability and reduced maintenance give proper indicators in order to justify its adoption for offline yarn analysis systems.

Future work will consider artificial intelligence algorithms to improve the detection and to enable a distinction between the loop and protruding fibers. Furthermore it would be particularly interesting to extend the developed methodologies to the characterization of different types of yarns, such as fancy yarns.

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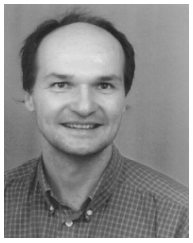
Nuno M. Gonçalves received his MSc in industrial electronics engineering and computers in the option of telecommunications and industrial informatics, in 2010 in Minho University, Portugal. He is preparing his PhD application in industrial electronics, which in the area of image processing. He is currently working as researcher in Minho University, Portugal. His main fields of interest are image processing, data acquisition and signal processing.

Filomena O. Soares received her degree in Chemical Engineering in 1986 at Porto University, Portugal. In 1997, she obtained her PhD in Chemical Engineering at the same University. Since 1992 she has worked in the Industrial Electronics Department Minho University and she has developed her research work in R&D Algoritmi Centre. Her main scientific interests are in the areas of System Modeling and Control, with application to bioprocesses and in Biomedical Engineering Science, and how robots can foster the communication with autistic children. Recently, she is interested in new teaching/learning methodologies, in particular blended-learning.

Rosa M. Vasconcelos received her degree in textile engineering, in 1984 at Minho University, Portugal. In 1993 she obtained her PhD in Engineering - Textile Technology and Chemistry on the specialty of Textile Technology, in Minho University. Since 2005 she has worked as associate professor, in the Textile Engineering Department of Minho University. Her fields of interest are textile processes and industrial automation.



Michael S. Belsley obtained his PhD degree in physics from the University of Colorado at Boulder in 1986. He then worked at the California State University in Long Beach, Oxford University and the University of Oregon before coming to Minho University in Braga Portugal where he has lectured as an associate professor of physics since 1992. His main fields of interest are ultrafast laser spectroscopy and nonlinear optics.