TEXTILE YARN ANALYSIS FOR DEFECT RECTIFICATION THROUGH SOFT-COMPUTING APPROACH

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Abstract—Textile Industry is one of the major revenue generating industry in India. Defect rate minimization of a product plays a very important role in the improvisation of the yield and financial growth especially in the yarn manufacturing process. It is highly emphasized here because of the mass production in the manufacturing process whereby a minor defect leads to large financial and production loss. As the yarn is the most preliminary product in the textile industry, it holds the utmost importance in the industry. The estimation of the yarn quality parameters is not an easy task as it requires expensive instruments and skilled manpower that are highly unaffordable by the small and medium scale entrepreneurs. Henceforth, the proposed work concentrates on the development of a cost effective module for the yarn analysis which is carried out through the imaging methods. The parameters such as the yarn hairiness index, uniformity, hairiness index variation are estimated through the segmentation and feature extraction methods. The current requirement of the industry which is the automatic characterization of yarn parameters that has been designed in our system through soft computing approach using fuzzy expert system.

Keywords—Yarn Hairiness Index, Uniformity, Segmentation, Feature Extraction, Automatic Characterization, Fuzzy Expert System

1. INTRODUCTION

The textile industry in India traditionally, after agriculture, is the only industry that is generated huge employment of both skilled and unskilled labour. The textile industry continues to be the second largest employment generating sector in India. It offers direct employment to over 35 million people in the country. The share of textile exports was 11.04% during April-July 2010, as per the Ministry of Textiles, India. The raw material may be natural or synthetic where the natural sources include cotton fibers, bamboo fibers, etc., and the synthetic fibers include the polyesters, nylon, etc.

The end product of the textile industry which comes across several process is the apparel. The flow of the textile process the products are shown in the Fig.1. It is inferred from the flow that the yarn is the most preliminary product which comes under the spinning sector. Hence, the textile processors give utmost importance to the yarn quality. Also, it is predictive to test the yarn quality thoroughly before weaving or knitting as it ensures the quality of the fabric.

In general, the yarn is continuous strand of textile fibers, filaments or material in a form suitable for knitting, weaving or otherwise intertwining to form a textile fabric. There may be enormous types of yarn which are the spun yarn, zero twist yarn, filament yarn, etc., based on the fiber packaging model around the axis.

There are several factors that influence the yarn quality namely the types of fibers, yarn twist, yarn count, blending ratio and the technology of production. The proposed work estimated the yarn parameters through imaging methodology and carries out auto characterization through fuzzy expert system. The system carries out three stages of task namely acquisition of the images, analysis of the images and the classification or characterization of the images. Classification stage explains the guideline parameters for decision making in order to predict the yarn faults at the manufacturing stage.

The paper is organized as follows. Section 2 explains the existing works related yarn quality estimation while the section 3 explains about the overall concept of the paper and also deals with the acquisition of images. Section 4 describes the image processing and parameterization methods while the section 5 describes about the automatic characterization works. Finally, the section 6 contains the conclusion and discussion on the performance of the system.

Fig. 1. Flow of Textile Process and its Products

The commonly analyzed parameters in a textile yarn and their explanations are as follows:
Count Variation (CV) : Variation in the yarn diameter along the length of the yarn beyond an acceptable range.

Unevenness (U) : Mass variation per unit length (cm). This fault is expressed as U%.

Frequently occurring faults: These are faults that occur in the range of 10 to 5000 times per 1000m of the yarn which are divided into three groups namely,

1. Thin Places: Cross Sectional size -30% to 60% of normal yarn with fault length of 4 to 25mm.
2. Thick Places: Cross Sectional size +30% to +100% of normal yarn with fault length of 4 to 25mm.
3. Neps: Cross Sectional size of +140% to +400% of normal yarn with default length of 1mm. Neps are defined as small tight balls of entangled fibers on linear textile strands.
4. Hairiness: Characterizes the amount of free fibers (fiber loops) protrudes from the compact yarn body towards the outer yarn surface (fabric, knitting, etc.,). The following Fig. 2. shows the hairs protruding in the microscopic view of a textile yarn.

![Fig. 2. Hairs in the microscopic view of a yarn](image)

2. EXISTING METHODS

The preliminary method of yarn parameterization is through the analysis by its appearance. This method is carried out by wrapping the yarn with a black board of a predefined size or in black chart so that one can visualize its appearance for any defects. This method is also known as the visual passing method. Since this method is high manual, the accuracy is very low and the prediction does not prove to be reliable. However, this method is still existing in modern days as preliminary analysis at certain cases.

The cutting and weighing method is predominantly carried in present industrial procedure for estimating the strength and count of the yarn. This method is the most predominant method in spinning industry. Here, the yarn is wrapped in a machine called lea tester where it is wrapped for around 740 yards and it is weighed in a calibrated weighing scale.

Then comes the electronic capacitance testers and hairiness testers where enormous length of yarn is fed through the sensors which in turn computes the indices of the protruding hairs in the fibers and the variation index of the diameter called the uniformity. These instruments costs around few lakhs to few crores. Hence, these instruments are highly preferred only by large scale manufacturers while the small and medium scale manufacturers are literally unaffordable.

To overcome these economic affordability issues, we have designed a system which computes the yarn parameters through a unique user-friendly system which is the imaging methodology. Here, the images of the samples of specific length are captured by a high resolution microscopic camera and are fed to the imaging system. The model and functionality of the system are discussed in the following part of this paper.

3. OVERVIEW OF THE IMPLEMENTED SYSTEM

The overall system of the textile yarn image parameterization and decision making includes various processing blocks through which the yarn image has to pass through as input and renders the output in the form of required parameters which in turn renders an output suggestion as a remedial measure to make a defect free produce.

A. Stages of the implemented system

The following Fig. 3. shows the stages that an imaging system to estimate and characterize the textile yarn is as follows:

![Fig. 3. Stages of the system](image)

B. Block diagram of the system

The following Fig. 4. shows the overall functioning concept of the imaging system.

![Fig. 4. Over view of the system](image)
During the measurements, the yarn under the investigation is placed on the background sheet in front of the USB microscopic camera. The illumination is provided by a light bulb or can be placed in an illuminated room. This ensures uniform illumination of the yarn. Additionally, no reflection from the illumination source appears, as the black material absorbs the light. This ensures uniform intensity distribution in the background area. The USB camera acquires images of consecutive sections of the yarn while it is moved by the rollers. It is also possible to move the yarn manually and obtain the image of the yarn without motion for the research purposes.

The captured yarn image is saved in the PC for further applications. The yarn images are then used for the processing and then the parameters are estimated. Finally, the decisions for corrective actions are made through fuzzy logic which are then tabulated for analysis.

4. IMAGE PROCESSING AND PARAMETERIZATION

In the considered application, image processing algorithms aim at extracting the yarn core and single fibers protruding from the background. They also provide input data for image analysis (i.e., yarn properties) that are to be performed in further steps. Processing of yarn image is performed in four main steps. Firstly, the yarn core is extracted. Next, the image is enhanced and then yarn is segmented. Finally, the single fibers that are looped and protruding are separated from the yarn core.

Prior to the processing of the image, the appropriate selection of the image processing tool and the quality of the image acquired is mandatory.

A. Image Acquisition

The image acquisition gains the utmost importance in the processing field. Planar still images of yarns whose hairiness were magnified several are considered in this work. The images were acquired with 8 bit resolution and are stored as monochromatic images of spatial resolution M X N equal to 480 X 640 pixels. The exemplary image of a cotton yarn is shown in the below Fig. 5.

B. Image Analysis

The yarn image has to be preprocessed efficiently in order to find the parameters accurately. Prior to the preprocessing steps are the image analysis methodologies which analyses if the image is suitable for the preprocessing and makes according steps. The captured image is expected to have certain aspects related to the position, background illumination levels, presence of the object at the foremost, etc.,

C. Yarn Core Segmentation

For the yarn core segmentation from the fuzzy fibers, an efficient algorithm proposed by Boykov and Jolly is applied. This method divides an image into sub regions through the computation of global optimum among all the segmentations besides the hard constraints imposed for the object and the background. This is performed on the basis of graph based yarn image representation where the image is given as weight undirected graph with nodes representing pixels and weights representing edge capacities. There are two types of edges in the graph: n-links connecting neighboring pixels and t-links connecting pixels with two terminals i.e., source S (representing objects) while the sink T represents background. This method retains the original shape of the core without averaging the variations in its diameter thereby serving a great purpose for the estimation of the uniformity of the yarn. Fig. 6 shows the concept of graph-cut segmentation.
**D. Image Preprocessing**

The input image after the extraction of the yarn core, it is used again for yarn segmentation. Due to the imperfections in the image acquisition system, there may be high noise level in the background of the considered images. It negatively influences the subsequent stages of image processing. Therefore, the background noise should be removed before the main processing while significant image regions belonging to the fibers at the same time. In order to do so, the following steps are applied to the image in a sequence:

- Median filter to reduce the noise and to preserve the fiber regions in the image
- Unsharp the image
- Reduce the background noise in comparison to the reference pattern.
- Application of windowing technique.

**E. Yarn Segmentation**

The yarn segmentation is performed on the enhanced image through the application of a high pass filter to the image where it is convolved with a mask \( p \). As a result, all values above 0 are set to 1 while the others are set to 0. In this method, the extracted fibers are disjoint and well-defined while fibers segmented by the thresholding methods are often discontinuous and merged into one region.

**F. Fibers Extraction**

The final processing step, the protruding and looped fibers are separated from the yarn. It is done by subtracting the core obtained in the first processing step from the image.

**G. Yarn Parameterization**

The parameters of the yarn that has been estimated are as follows:

- Yarn Length: Difference between the very first white pixel in the first left column and the very last white column in the first right column of the image.
- Yarn Diameter: The segmented yarn image in \( n \) equal sections for measuring the edge differences of the upper and lower portion results in calculation of diameter in diameter in pixels. The mean and coefficient of the yarn diameter variation (CV\%) of the consecutive images of the test sample are calculated. The non-uniformity in the yarn diameter leads to the unevenness and hairiness in the yarn.

- Yarn Hairiness Index: The hairiness of the yarn is determined by the Hair Area Index (H_a) and Hair Length Index (H_L). Hair Area Index is the unit less parameter defined as the ratio of summation of the total area of the single fibers \( S_f \) and total area of the core \( S_c \).

\[
H.A.I = \frac{S_f}{S_c} \quad (1)
\]

Hair Length Index is the unit less parameter defined as the ratio between the total length of the released fibers \( L_f \) and the total length of the core \( L_c \). Among the two terms, the hair area index is the most predominant factor that affects the yarn quality.

- Uniformity Characters: The uniformity characters based on the estimated parameters into the three cases of yarn faults namely the thick places, thin places and the neps along the horizontal axis of the yarn are shown in the following Fig. 7 while the Fig. 8 shows the hairs extracted from the yarn core.

**H. Fuzzy Expert System**

The present day machines of a small and medium scale manufacturer in the textile industry lack in the analysis algorithms for an automatic characterization of textile yarn parameters. This system looks ahead of the present day requirements and provides the corrective measure for the purpose of fault rectification through fuzzy logic algorithm. Table. 1 shows the member variables of a fuzzy expert system and their ranges and the Fig. 9 shows the rule viewer of the fuzzy expert system as follows:
TABLE 1 MEMBERSHIP VARIABLE OF AN FIS

<table>
<thead>
<tr>
<th>MEMBER VARIABLE</th>
<th>RANGE</th>
<th>MF1 &amp; RANGE</th>
<th>MF2 &amp; RANGE</th>
<th>MF3 &amp; RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSP</td>
<td>1800-3200</td>
<td>Poor</td>
<td>Average</td>
<td>Good</td>
</tr>
<tr>
<td>COUNT INPUT</td>
<td>8-12</td>
<td>Ne 20s</td>
<td>Ne 30s</td>
<td>Ne 40s</td>
</tr>
<tr>
<td>CV%</td>
<td>0.5-2.5</td>
<td>Good</td>
<td>Average</td>
<td>Poor</td>
</tr>
<tr>
<td>Machine Settings</td>
<td>1-2</td>
<td>Increase TPI &amp; Speed</td>
<td>Reduce TPI &amp; Speed</td>
<td>Check Draft Settings &amp; RH &amp; TPI</td>
</tr>
</tbody>
</table>

Finally, the calibrated and estimated parameters for each trial along with consolidated report are written as "*.xls" file in different sheets.

5. CONCLUSION

In the textile field, the image processing of the yarn to find its parameters has made a great impact on the importance of the quality aspects due to its high efficiency, reduced cost and portability. In this work, the processing of the yarn image using efficient filtration and segmentation methods has made the estimation of the yarn parameters for plain yarns such as the yarn CV, Hairiness Index and Uniformity to a maximum accuracy level to the standard methods with the fuzzy expert system. This method is highly suitable for the small and medium scale enterprises due to the cost reduction of around 10 times that of the commercially available systems. This developed system has been implemented for a pilot study of it working in a spinning mill.

In future, we have proposed a system for the analysis of various fancy yarns parameters and also to automate it with more parameters thereby reducing the requirement of skilled staff.

REFERENCES