A comparative case study between Image Processing functions in MATLAB and graph analysis techniques to determine TPI value in doubled yarns.

Noman Haleem[1]

***Abstract*— The purpose of the research is to demonstrate a problem solving approach for a typical case study entitled "Determination of twist per inch value in doubled yarns using digital image processing techniques". Twist per inch value (TPI) is an important factor in spinning the yarns as this parameter mainly affects certain characteristics of yarn, fabric and garment. There are some conventional methods of determining TPI value of yarn but they are purely mechanical in nature and destroy the yarn specimen that is checked for TPI value. A novel approach with experimental evidences is introduced in this study of applying digital image processing functions to determine TPI value of yarns without causing destruction in the mechanical properties of the sample. The digital images of yarn samples are captured by a specialized sensitive camera and analyzed by image processing software to determine the desired parameter i.e. TPI value. During the analysis some limitations in MATLAB image processing toolbox are noticed regarding the pattern recognition in yarn image due to its nonlinear and random structure, but after analyzing the pixel-intensity values graph of the grayscale image an algorithm based on intelligent settings inspired by human vision system has been designed to solve the particular problem.**

***Index Terms*— CAIA (Computer aided image analysis), doubled yarns, image processing, TPI (Twist per Inch)**

I. INTRODUCTION

TPI (twist per inch) value is an important parameter that has direct influence on the certain properties of yarn. It mainly affects the yarn strength [1], yarn feel, moisture absorbency, dye uptake, and even garment serviceability [2], [3] in terms of pilling, snagging and etc. The conventional testers used for determining the TPI value of yarn are destructive in nature that results in the hard waste or yarn loss. Another major limitation of such kind of testers is their inability to online test the TPI value on spinning frame or auto winders because they require a specific length of yarn mounted in the tester clamps to check the sample [4]. So, it was required to produce such a system that should be able to check the TPI value of the given yarn sample without destroying the specimen and it must have an ability of testing the yarn online so that the twist irregularity in yarns can be reduced by online correction mechanisms. In order to achieve the above mentioned tasks an innovative idea of implementing image processing techniques to determine TPI value of yarn was derived [5]. Image processing is a widely known technical computing art that is being used in various processes to determine certain variables also in textiles [6]. A pattern of alternating bright and dark places in the yarn is recognized by yarn surface, structure and texture analysis. A software in graphical user interface is designed to calculate the desired parameter based on the specific pattern recognition of yarn. MATLAB 7.0.4 with image processing toolbox support is used to design the graphical user interface.

1. Noman Haleem is with the Yarn Manufacturing Department, National Textile University, Faisalabad, Pakistan, (phone: 92-333-6735396; email: nomanhaleem@ymail.com).

II. PATTERN RECOGNITION

The main objective in determining the TPI value by image processing functions is the analysis of the yarn image and defining an algorithm by which the software would be able to make the relevant computations in order to make particular feature estimation from given data. The doubled yarn structure is shown in Fig. 1

Fig. 1, The sample of one inch length of yarn is exposed by a sensitive imaging device in a specified setup of constant illumination.

It is obvious in the above figure that a specific pattern of the dark and bright regions or clusters occurs through out the length of yarn but they are unevenly distributed and certain dark and bright areas are fused into each other randomly. The reason of formation of bright and dark regions on the yarn surface is due to the reflection of light from the yarn structure, the randomness of structure is responsible for reflecting a series of bright and dark regions and it is viewable in coarser counts of yarn with naked eye even [7]. The philosophy of determining the TPI value with help of dark and bright regions in the yarn texture lies in the logic that the total number of either bright or dark regions in one inch length of yarn is equal to double of TPI value of yarn.

$$\text{TPI value} = \frac{\text{Total number of bright regions in one inch length of yarn}}{2}$$

In fact this phenomenon is based on human vision system by which humans are able to see and count twists in yarns with naked eye. If there is no color variation or alternating dark and bright places in the yarn humans can never be able to observe twists in the yarn with naked eye. The phenomenon of alternating dark and bright regions is illustrated in Fig. 2.

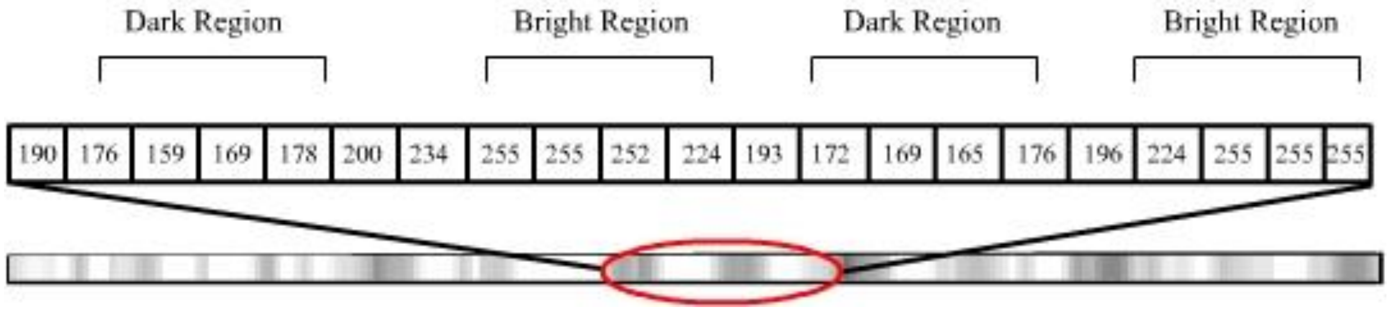

Fig. 2, Rectangular cropped area of yarn image visualizing the dark and bright patterns in the yarn texture by means of grayscale image intensity values ranging from 0-255.

III. ALGORITHM DESIGNING

It is desired to calculate the total number of consecutive bright regions in the area of interest in the image so that the TPI value can be determined. In order to analyze the structure of yarn a graph between the total number of pixels in linear form and intensity of pixels in the area of interest is shown in Fig. 3.

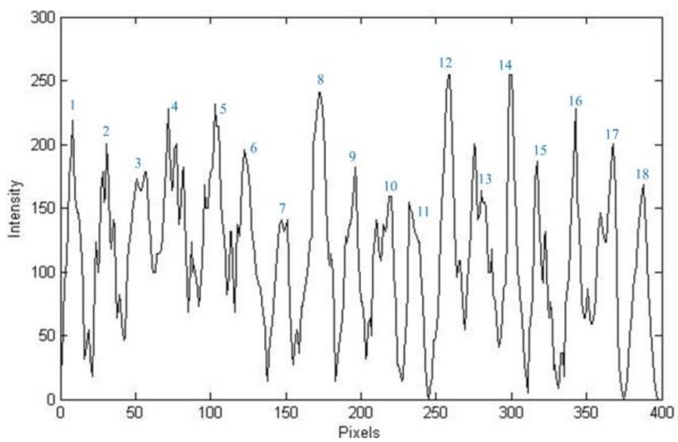

Fig. 3, The graph shows linear relation between intensity values and pixels of the cropped image area. The peaks of the graph are represented by numbers.

A typical pattern of intensity fluctuations can be observed in the above shown graph in form of maxima or minima or more commonly in form of peaks and valleys of data. The interesting fact is, the total number of peaks in the graph represents the total number of bright regions in the area of interest and similarly the dark areas in the graph are represented by the valleys in the graph. It is more convenient to say that there is a specific pattern exists in the digital image of yarn that can also be logically proved by pixel-intensity plotting. The degree of randomness in yarn structure can be estimated by the variation in the amplitude, peaks and valleys of the intensity graph. The graph is not showing such a compatible pattern so that the total number of peaks can be calculated by means of an algorithm and an automated generalized system can be designed for it, which should be valid for all yarn samples testing.

First of all the most common possible approach for solving this particular problem can be designing such a filter that extracts the pixels from the image in a given range of intensity values. For this selection, the function ROIFILT is used in the following syntax.

Roicolor (A, lower limit, upper limit);

Where A is the matrix containing the image pixels information, the lower and upper limits are limits of intensity range. It should be mentioned that the programming plate form in this study is MATLAB 7.0.4. The pixels between the upper and lower limit are selected by applying this function. Suppose for instance, an arbitrary range of intensity is defined to the function i.e. 150-255 as this range includes almost all the peaks of the graph in it, in other words it covers the bright regions in terms of pixels. The selected area is shown with help of gray shade in the graph shown in Fig. 4

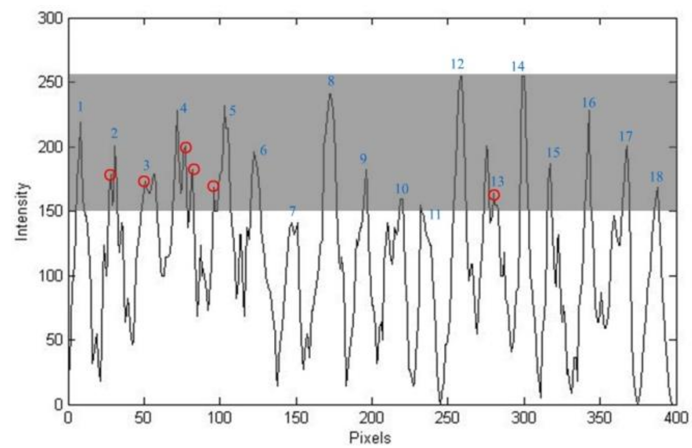

Fig. 4, Pixels selection by using intensity range filter to count total number of peaks in the graph

In above shown graph, peak number 7 is not included in the selected area, and some variations can also be noted down near peak number 13. If the lower limit of the intensity range is increased in order to cover the peak number 7 in the range, the fake peaks will also be added to the selection as original ones. Due to randomness in the structure two peaks will be considered instead of one at the peak number 13 due to small fake peak in the neighbor of original peak. Although the total number of peaks will remain same due to one missing peak from the range (i.e. peak 7) and one fake peak (i.e. small peak near 13) added in the range but this algorithm is not the ultimate solution of the problem, because it may give the correct results in case of testing the particular image of yarn, but it cannot be implemented as a generalized algorithm for processing yarn images of different counts and twist levels, also it will fluctuate the results in a wide range.

Another logical approach for algorithm design to solve of the problem of counting peaks can be the maxima location function integrated in image processing toolbox. The function is used in the following syntax.

Imregionalmax (A)

Where A is a matrix of pixel values of the grayscale image, this function divides the image array into small clusters according to their color distribution. The pixels with maximum intensity value in a specific cluster are selected by this function. Those selected pixels represent the regional maxima of that particular cluster [8]

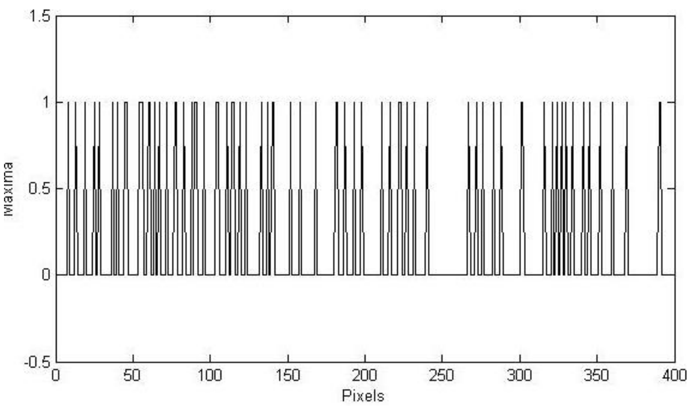

Fig. 5, Pixels having value 1 are representing a peak and remain represent a valley based on the classification made by imregionalmax.

The total bright regions in this specific image of yarn are 18 so the number of peaks should also be equal to the bright regions but the implementation of above mentioned function is showing diversification from the actual results. The pixels having a value 1 are denoting a peak in the graph shown in Fig. 5. Application of this function shows 70 peaks (or pixels) in the image that are much more than required results, this variation in results is due to fake peaks and randomness in the structure of yarn, it can also be some non uniformity in the illumination while image was captured. Some fake peaks that can be clearly visualized are shown in the Fig. 4 by small red circles.

Hence, it is not possible to solve this particular problem with the help of conventional image processing operations particularly the ones integrated in MATLAB due to randomness in the yarn structure. A logically strong algorithm is required to solve the described issue of counting the bright segments or clusters from the area of interest.

Graph analysis techniques is basically a phenomenon in which the solution of a problem or analysis of some particular information is made by analyzing the trends in the graph of the provided data in order to recognize a valid and generalized pattern. The graph of the relevant cropped image area is already shown in Fig. 3. If the graph is observed thoroughly it can be noticed that the peaks of the graphs repeat themselves after a specific number of pixels, no matter what the amplitude of the peaks is or whatever is the variation between two relevant peak structures, normally the peaks are repeated in a specific pattern. The algorithm that is found to be an ultimate solution for this problem is based on the pattern recognition of this peaks repetition in a particular manner. As it is already mentioned that the structure of yarn is very much random and highly unpredictable so it is possible to have some problems in accuracy issues but they will be rare. The algorithm designed to solve this problem is based on graph analysis techniques in combination with various integrated functions of MATLAB and image processing toolbox. The logical approach of this novel algorithm is the selection of all regional maxima in the image including the fake ones. Then application of a designed filter on the selected peaks eliminates the undesired or fake peaks. The strategy to distinguish the fake peaks from real ones is determined by graph analysis techniques. The algorithm is based on the fact that the real peaks which represent a bright region in the yarn structure, must involve such a pixel whose intensity should be the universal maxima in the group of a specified number of pixels. A universal maximum means that the pixel intensity is the highest in the predefined range of pixels in the small cluster taken from digital image of yarn. Let's take a look at the following graph that is representing a small cluster taken from the area of interest close to peak number 4.

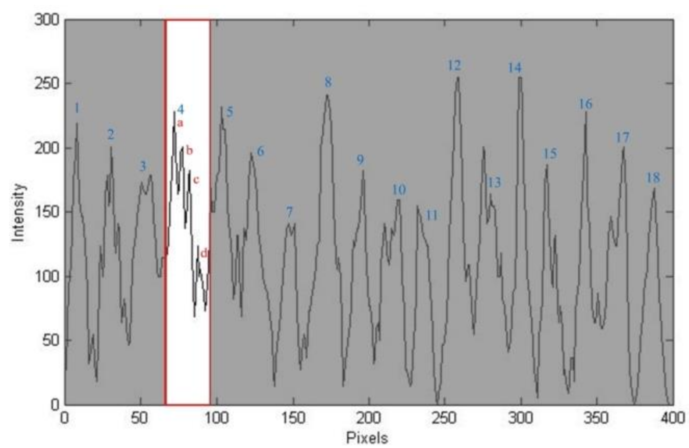

Fig. 6, Analysis of a small cluster taken from the cropped image area in order to distinguish the real and fake peaks.

There are initially 4 peaks in this very small region consisting on almost 30 pixels next to each other. The peaks are denoted by *a*, *b*, *c* and *d* having the intensity values of 228, 200, 182 and 123 respectively. When the peaks would be selected by using the image processing function of local maxima these 4 peaks would be selected from this region highlighted in above graph and they will represent a single bright region. when the results would be compiled from this small cluster of pixels it will show 4 bright regions in it that means there are 2 twists present in this cluster, but as we know this cluster is only representing a single bright region that means there is only ½ twist in this area. This will cause deviation from actual results. The accurate results can only be achieved if the software considers all these 4 peaks representing a single bright region or it must ignore three fake peaks out of it. This is only possible if the fake peaks are separated from the real peaks and the counting should be real peaks oriented and as shown in the above graph the real peak is one which is having a maximum intensity value locally in the cluster i.e. peak ‘a’ having an intensity value of 255. The designed filter for solving this problem basically works on predefined rules. Suppose we got a peak at a pixel position ‘n’ in the area of interest, the peak will be verified for its realness from its neighborhood pixels in a way that a range would be introduced by using a relevant pixel ‘n’ that represents the peak. Suppose we introduce a range of 5 pixels on left and 5 on right of the pixel ‘n’, the total pixels selected will be ranging from ‘n-5’ to ‘n+5’. This range will involve a total of 11 pixels in verifying a single peak that either it is real or fake. If among the selected 11 pixels the intensity value of the pixel ‘n’ is the higher most it will be representing the real peak else it will be fake and its origination is due to randomness of yarn structure or bad illumination effects not because of special pattern in yarn structure. Following are the ranges determined for peaks a, b, c, d and it is logically proved that using this algorithm for finding the actual peaks can lead to the accurate results.

Pixels	*Intensity Values*			
	a	b	c	d
n-5	118	**228**	**200**	**182**
n-4	128	196	168	146
n-3	150	164	137	91
n-2	182	168	155	68
n-1	205	196	178	87
n	**228**	200	182	123
n+1	196	168	146	100
n+2	164	137	91	105
n+3	168	155	68	100
n+4	196	178	87	87
n+5	200	182	123	83

Table 1, Table shows the intensity values of the pixels that are selected in the given range, the bold figure in the columns represent the maximum value in the range while ‘n’ represents the peak pixels selected from the given area.

After defining the range and making a series of pixel intensities the next task is to sort out the highest value among the series. This can be done by using a simple function of matrix analysis

$$\mathbf{A = Max(C)}$$

Where ‘C’ is the series of pixel intensities in form of a matrix having dimension of [1 x 11] and ‘A’ is the variable

If the max value in the series of 11 pixels is the intensity value of pixel that represents the peak i.e. ‘n’ then the peak will be considered as the real peak else it would be marked as the fake peak and will not be considered in the calculations. All the peaks that have been verified for their realness are grouped in a separate matrix array in order to distinguish them from fake peaks. All the selected peaks are denoted by their relevant pixel dimensions, total number of pixels in the array is calculated and this will represent the total number of bright regions throughout the length of 1 inch yarn. Twist per inch value can be derived from total number of bright [9].

IV. Results and Discussion

Three different counts of doubled yarns are tested by using the particular software that is designed using MATLAB 7.0.4 based on the above described algorithm. The results found are quite encouraging and very close to the real values. The results given in the following chart shows the TPI values calculated by the human vision inspired algorithm based image processing software named IQARFTM (Image quantitative analyzer and region of interest processor for twist measurement) in comparison with the conventional testing mechanisms and manual testing of twist per inch by human operator. These particular results show the study on count of 10 plied yarn.

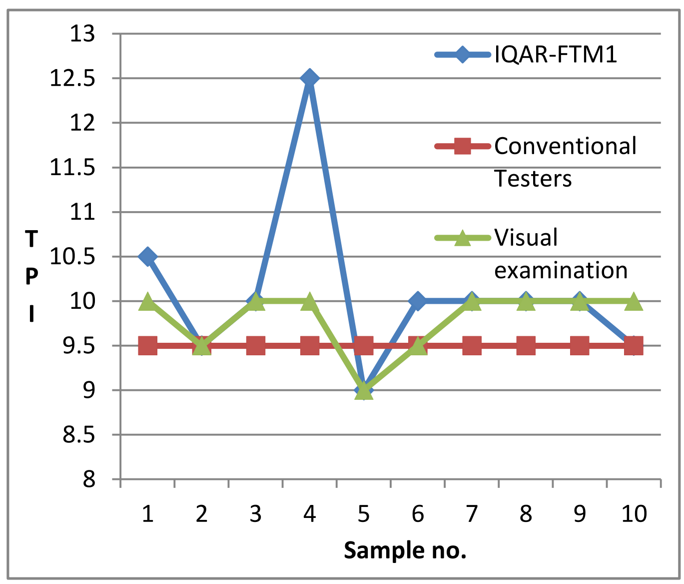

Fig. 8, The TPI values of 10 plied yarn as measured by the conventional and novel methods.

The data plotted in graphs represents the results of TPI value calculated by using the image processing functions, the visual analysis of the graph and the results calculated from the conventional instruments already used in the testing laboratories. An overview of the 10 samples is given that is based on the comparison of TPI results obtained from three different origins. It is obvious that the results found by applying image processing operations on the yarn image are quite close to the results of conventional testing mechanisms. As well as the accuracy of the algorithm functionality can be judged by making a comparison with visual examination results, as this system is inspired by human vision. Although the software doesn’t compromise on accuracy issues but it provides a testing speed of 1-2 sec for a single test of 1 inch specimen of yarn. While in case of testing the sample with conventional methods, almost 3-4 minutes are required in order to test a single specimen.

V. FUTURE PROSPECTS

The future plan is to apply the image processing operations on the single yarns, so that a new method can be introduced to check the TPI value of yarn with greater flexibility and reliability of testing the sample without wasting the yarn.

The design of the hardware used for capturing the images of the yarn sample is still in black and white, and it is intended to construct a textile testing instrument based on the imaging hardware setup to use it on commercial scale that can be used in laboratories for offline testing and on machines for online testing purposes.

VI. REFERENCES

[1] J. Simpson and L.A. Fiori, "How Yarn Twist Affects Yarn Uniformity and Imperfections," *Textile Research Journal*, vol. 45, pp. 136-137, Feb. 1975.

[2] R. Steele, "The Effect of Yarn Twist on Fabric Crease Recovery," *Textile Research Journal*, vol. 26, pp. 739-744, Oct. 1956.

[3] I.C. Sharma, Narender Kumar Gupta, B.R. Agarwal, and N.R. Patnaik, "The Effect of Twist Factor and Stitch Length of Open-End Spun Cotton Yarn on Properties of Rib Knitted Fabrics," *Textile Research Journal*, vol. 57, pp. 73-81, Feb. 1987.

[4] E. R. Schwarz, "Twist Measurements in Single Yarns'," *Textile Research Journal*, vol. 8, pp. 157-164, March.1938. (insert the month in it and also confirm the edition)

[5] N. Haleem, "Determination of Twist per Inch Value in Doubled Yarns Using Digital Image Processing Techniques," to be presented in *2nd Int'l Conf.Textile and Clothing* (ICTC 09), Textile Institute UK, March, 2009.

[6] M. Cybluska, "Assessing Yarn Structure with Image Analysis Methods 1," *Textile Research Journal*, vol. 69, pp. 369-373, May. 1999.

[7] H. D. Young and R.A. Freedman, *University Physics with Modern Physics*, 10th ed. USA: Addison-Wesley Publishing Company, 2000.

[8] Soille, P., *Morphological Image Analysis: Principles and Applications*, Springer-Verlag, 1999, pp. 170-171.

[9] Mathworks, "Matlab image processing toolbox online Documentation," Available: **http://www.mathworks.com/access/helpdesk/help/toolbox/images** **[Accessed: May 16, 2008].**