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A New Method to Evaluate the Appearance of Cotton Yarn Using Image Processing and Fuzzy Inference System Supported with Graphical User Interface

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Abstract

The evaluation of the spun yarn appearance is very important to determine its quality. In this paper, based on standard images of ASTM (D 2255) a new method was designed to classify the cotton yarn by using digital image processing and fuzzy inference system (FIS). As a result, all yarns are subjected to the same method of evaluation and thus ensure that the same result will be obtained to classify the yarn objectivity. Regardless of who does the experiment or the laboratory in which the classification is performed? Also, the search was provided with a GUI to facilitate the investment the algorithm of this research without previous knowledge about the used techniques. Thus, save time and effort in the classification processing.

Keywords: Appearance; Cotton yarn; Evaluation; Fuzzy inference system (FIS); Graphical user interface (GUI); Image processing

Introduction

Specifications and final applications of yarns are affected by their structure and appearance. The quality of final products reflects the quality of yarns. So the evaluation of yarn surface appearance is an important routine in assessing yarn quality in textile industry. The appearance of yarn not only significantly affects its commercial value but also directly influences the characteristics of end products [1].

There is a standard method in ASTM (D-2255) for grading cotton yarns appearance. In this method, Yarns to be examined are wrapped onto a matt black surface in equally spaced turns so as to avoid any optical illusions of irregularity. The blackboards are then examined under good lighting conditions using uniform non-directional light [2]. According to ASTM (D-2255), a yarn sample on a black board compare the board with a series of photographic standards representing the grades A (best), B, C and D (worst). The Requirements for Preparations of Specimens are listed in Table 1.

Traditionally, the inspection is carried out by direct observation in which a skilled specialist visually compares the wound yarn sample with the grade labeled photographic standard and then judges the quality of the yarn sample according to the standard definition [3]. Mouèková and Jirásková made an objective evaluation of yarn appearance to evaluate the surface unevenness of yarn [4]. They converted the yarn board appearance into a grey-scale image and then evaluated fluctuations in degrees of greyness between square fields in the image by semivariogram. Nevel et al., proposed an electronic system to read the diameter of a single yarn when it moved over a CCD camera [5].

Seriesa	Range of Yarn Numbers		Wraps	
	Single Cotton Count	Tex	per in.	per cm
1	1 to 12	590 to 50+	20	8
2	12+ to 24	50 to 25+	22	9
3	24+ to 36	25 to 16+	26	10
4	36+'s to 50	16 to 12+	32	13
5	50+ to 75+	12 to 8+	38	15
6	75+ to 135	8 to 4+	48	19

Table 1: Requirements for Preparations of Specimens ASTM (D-2255).

The length of the yarn was then split into a number of shorter lengths so it could be displayed electronically side-by-side to assist in manual grading. Rong and Slater developed a microcomputer system for yarn unevenness analysis [5]. The analogue signal of the yarn diameters was converted into digital signal and then analyzed in terms of statistical parameters of unevenness. Semnani et al., proposed a computerized grading method, to grade a yarn appearance based on an image yarn board [6]. They use image analysis and an artificial intelligence technique. This method enabled the identification of yarn faults and the classification of yarn appearance directly from a yarn image captured from a standard yarn board. On the other hand, other researchers used techniques such as saliency map analysis, wavelet transform and artificial neural network to extract the full yarn surface characteristic features [3]. Then they classified and graded yarn surface qualities based on digital features. Semnani et al., used image analysis and artificial neural network to develop a new method for grading various types of yarn for appearance [7,8]. The images of standard yarn boards were analyzed by image analysis and four different faults factors were defined and measured for each series of yarn counts. For each series of yarn counts, a neural network with one layer was trained by measured fault factors of standard boards. The trained neural networks were used for grading various types of yarns.

On the other hand, Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false". Fuzzy logic based on natural language and it can be a very powerful tool for dealing quickly and efficiently with imprecision and nonlinearity [9]. The heart

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of a fuzzy system is a knowledge base consisting of the so-called fuzzy IF-THEN rules. A fuzzy IF-THEN rule is an IF-THEN statement in which some words are characterized by continuous membership functions. It should be introduced the concept of linguistic variables and proposed to use fuzzy IF-THEN rules to formulate human knowledge [10].

The above researches classify the yarn appearance grade as fuzzy value so-called linguistic variable (A, B, C, A+… etc.). So, there is a probability of giving different yarn samples the same grade of appearance because of the limited grades. In this paper, the classification depends on fuzzy inference system (FIS). So, each yarn will classify as a percentage between two successive grades. By using this method, each yarn will take its own appearance grade and the evaluation will be more reality and accuracy.

Methods and Methodology

Theoretical principle

When conventional method based on ASTM (D-2255) is used, many yarn sample images would be graded as the same grade. Figure 1 is designed to clear this idea, where first yarn sample image (im1) and second yarn sample image (im2) take the same grade i.e. (A) grade.

In this paper, the yarn appearance classification depends on fuzzy inference system (FIS). The FIS method will give each sample image a special grade as shown in Figure 2. The first yarn sample image (im1) takes a grade as percentage between (A and B) grades according to its memberships μ_A (im1) and μ_B (im1) to each fuzzy set, whereas the second yarn sample image (im2) will take a grade as percentage between (A and B) grades according to its memberships μ_A (im2) and μ_B (im2) to each fuzzy set. So, each yarn sample takes its own grade.

Fuzzy sets creation

To build the suggested FIS, fuzzy sets should be created. This paper will demonstrate how to differentiate between standard images from the same series in term of image analysis. As shown in Figure 3, the yarn which has higher quality has less thick places and neps. So it has fewer white pixels than black pixels. On the other hand, the yarn which has lower quality has more thick places and neps. So, it has more white pixels than black pixels. Consequently, the number of white pixels will increase from grade A, to grade B, to grade C, to grade D respectively. The black pixels are vice versa with the white pixels. The sum of black pixels and white pixels is always constant representing the number of the binary image pixels as shown in Equation (1).

Black pixels + white pixels= binary image pixels= Constant (1)

All standard images have been acquired using a commercial scanner as colored photos with two resolutions (300 dpi & 150 dpi) (Figure 3). After that, image processing has been done using MATLAB®. The number of white pixels for images and its average are listed in Table 2. The average value will be used to build fuzzy inference system.

Figure 4 shows an example about how to create fuzzy sets according to ‘colored average’ in Table 2. In this example the white pixels in the second series is selected. The rest of FIS series could be built like this example. It’s enough to select white pixels (without black pixels) to set FIS because there is a relationship between the number of white& black pixels as shown in Equation 1.

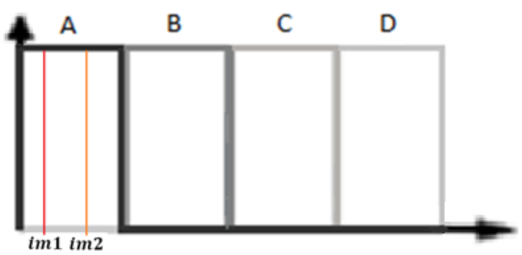

Figure 1: Classification using conventional method.

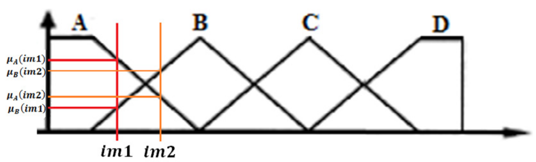

Figure 2: Classification using FIS method (suggested).

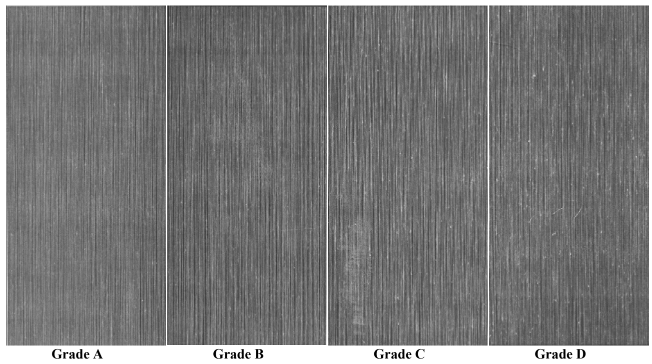

Figure 3: Series 3 of cotton yarn appearance standards ASTM (D-2255).

FIS series	yarn count range	grade	colored		colored average
			1 (150 dpi)	2 (300 dpi)	Average 1 and 2
First_series	590 to 50+ tex	A	455689	451003	453346
		B	471965	465965	468965
		C	563398	555277	559338
		D	679876	681822	680849
Second_ series	50 to 25+ tex	A	323377	323889	323633
		B	382002	370502	376252
		C	413845	416355	415100
		D	474956	462125	468540
Third_series	25 to 16+ tex	A	326279	324311	325295
		B	372424	368781	370603
		C	399668	395000	397334
		D	418115	412922	415519
Fourth_ series	16 to 12+ tex	A	365182	350997	358090
		B	429167	420497	424832
		C	514710	513115	513913
		D	536590	541349	538970
Fifth_series	12 to 8+ tex	A	313433	307654	310544
		B	327074	330252	328663
		C	329227	357939	343583
		D	384195	388177	386186
Sixth_series	8 to 4+	A	305236	310748	307992
		B	327715	336849	332282
		C	360486	378446	369466
		D	397614	401348	399481

Table 2: The number of white pixel for all standard images.

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FIS design

The fuzzy sets will be used to build the fuzzy inference system (FIS) to classify the yarn appearance. FIS contains inputs, output, and IF-THEN rules. The inputs contain white pixels of images. The output is a grade of yarn appearance. The fuzzy IF-THEN rule is: IF the number of white pixels is (A), THEN the yarn appearance grade is (A). The fuzzy rule base is built by Mamdani-style inference which is the most commonly seen fuzzy methodology [9]. This fuzzy inference is a type of in which the fuzzy sets from the consequent of each rule are combined through the aggregation operator and the resulting fuzzy set is defuzzified to yield the output of the system [11,12]. Figure 5 shows the block configuration of the requested system.

There are six FISs each one for one series of yarn count which is listed in Table 2 from first series to sixth series. Figure 6 shows the input of FIS for second series. Figure 7 shows the output of FIS for second series.

Results and Discussion

To deal easily with grading yarn appearance by FIS and image processing, a simple graphical interface (GUI) has been created. After that, ten new yarn samples were produced. Each two samples have same count (49.2, 98.4, 29.5, 11.8, or 5.9 tex) with different appearance. Then FIS method has been applied to classify the yarn appearance. For example, the two yarns with count (49.2 tex) were warped into black board. The manual classification for these yarns by using ASTM (D-2255) standard image was (grade A) for both yarn samples. To classify by using FIS method, the two samples should be scanned to acquire digital images. After that, the images were processed by using the GUI.

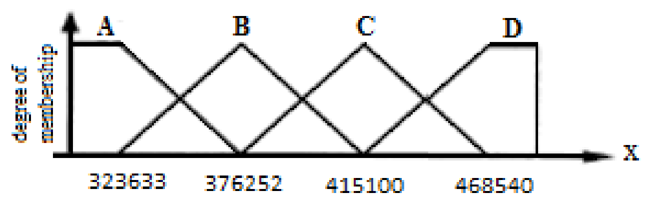

Figure 4: An example of membership functions for white pixels in the second series.

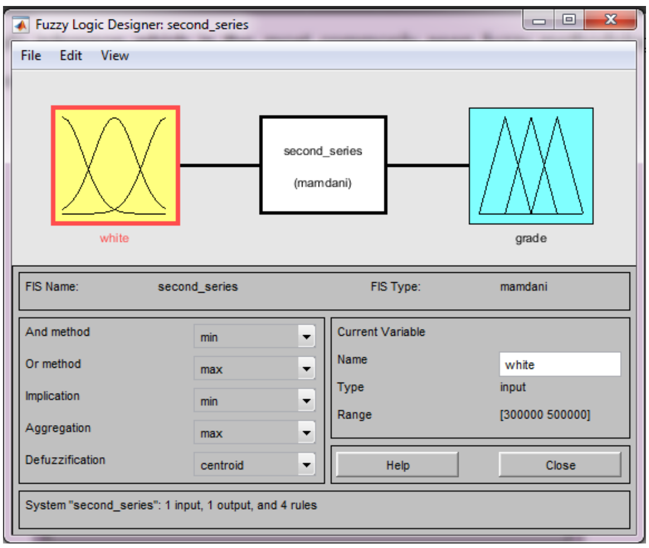

Figure 5: The configure of FIS built by MATLAB.

So, the white and black pixels were counted as shown in Figures 8 and 9 (each figure for one sample). In Figure 8 the number of white pixels was (323889). After pressing (Classification) button, the suitable FIS series will be called according to the count yarn in Table 2. Then the yarn appearance grade will be evaluated as a percentage between two successive images. So, the classification will be (66.5% A + 33.5% B). By using the same way of classification, Figure 9 has (323377) white pixels. So, the classification will be (67.6% A + 32.4% B). It means that, by using the FIS method, the yarn classification would be differing from yarn to another. The above method was applied on the rest sample yarn boards. The results listed in Table 3.

It could be noted that by using the FIS method, the evaluation results of yarn appearance will be more delicate and accuracy than the manual method. The manual classification gives the same result for the images which belong to the same range of white pixels. While the FIS method will give an exceptional grading for each yarn image. All of that prove The Theoretical Principle section (Figures 8 and 9).

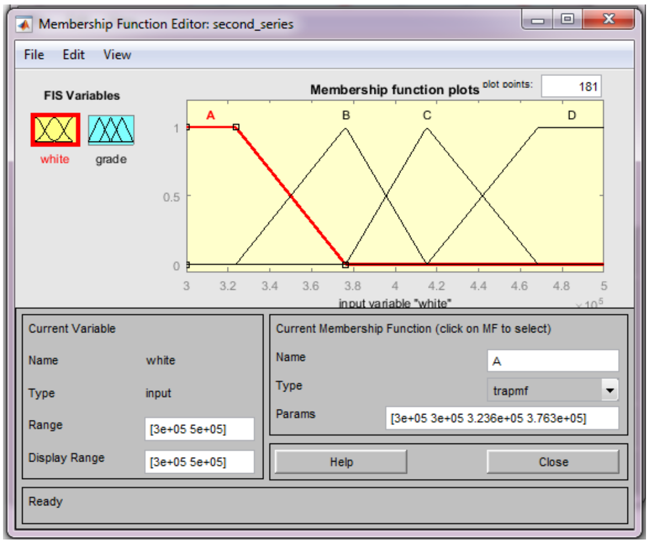

Figure 6: Fuzzy Sets of the input of FIS.

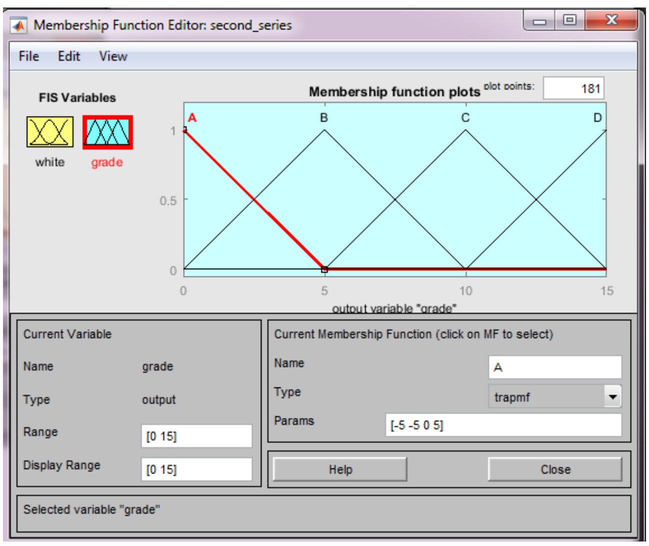

Figure 7: Fuzzy Sets of the output of FIS.

Sample No.	Yarn count (tex)	Manual classification	FIS classification
1	49.2	A	66.5% A + 33.5 % B
2		A	67.6% A + 32.4 % B
3	98.4	C+	33.3% D + 66.7% C
4		C+	3.17% B + 96.83% C
5	29.5	C	45.3% B + 54.7% C
6		C+	0.15% B + 99.85% C
7	11.8	A	47.85% A + 52.15% B
8		A	67.65% A + 32.35% B
9	5.9	B+	0.5% A + 99.5% B
10		B	43% B + 57% C

Table 3: The comparison between manual method and FIS methods.

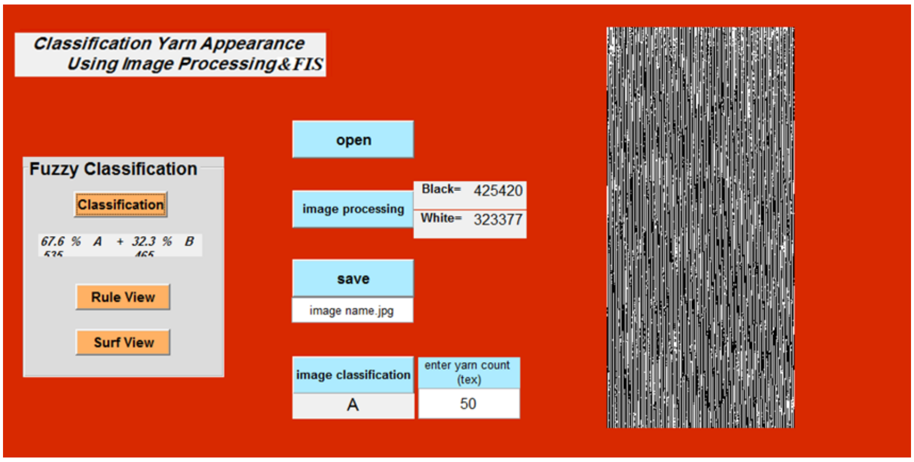

Figure 8: Classification the yarn appearance using FIS.

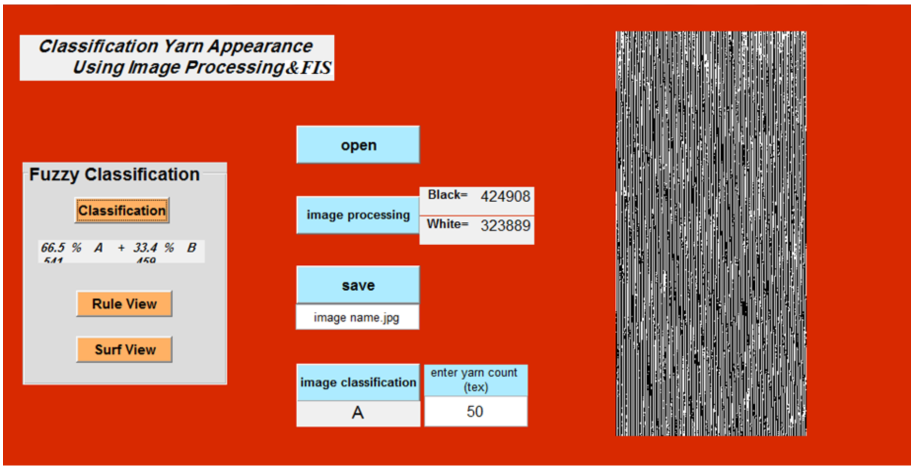

Figure 9: Graphical user interface for whole purpose of this research.

Conclusions

This paper used the FIS method to evaluate the cotton yarn appearance. The FIS method showed more realistic results than conventional manual method, because it gives the grade appearance as a percentage of grading degree not as a natural grading (A, B, C.., etc.). FIS has been architected after processing the standard images. There are six series of standard images. So, there are six series of FIS. The range of each series depends on yarn count.

To deal easily with this method, a simple GUI was created. The GUI provides the ability to evaluate the yarn appearance after processing a sample image and entering the yarn count. The yarn count will be used to select the FIS series. Above that, the GUI was provided with a (Rule View) and (Surf View) which will give an additional information about the yarn sample. By using this method, the yarn sample will obtain the same classification regardless of the specialist or the laboratory. All of that will release a new version for commercial relationship. Another consequence of this paper is the possibility of using FISs to resolve the problems faced by researchers and producers in the textile field.

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