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Using Fuzzy Logic System (FLS) for Cotton Yarn Quality Assessment and Grading Classification Method

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Abstract: *This paper concerned on using of fuzzy logic system (FLS), for assessing and grading of cotton yarn surface quality based on the generated binary image pixel values of the yarn wound blackboard image. Fuzzy logic has toolbox in MATLAB and it is a good measuring frame to handle the problem of uncertainty, vague or unclear things in the image information. In this studying, FLS for cotton image classification is applied to identify homogeneous groups of data points and to select some parts from the other in a given dataset and assigning it to a class. By applying fuzzy rules and mathematical formulas, the calculated degree of membership of the input value (binary image white pixels of sample) used to decide the grade of yarn quality either good or bad, based on their relative similarities with the standard one. The yarn quality grading and classification can be accomplished by a process of grouping pixels into a set of classes based on their relative similarities with regard to certain properties.*

Key Words*: Pixels, Fuzzy logic system, Cotton yarn grading appearance, Membership function, Fuzzy rule, Tex.*

1. INTRODUCTION:

The term “Fuzzy Logic” has been developed in 1965 and it is based on the knowledge of "partial truth", which means truth values between "absolutely true" and "absolutely false". Fuzzy Logic offers a structure to model ambiguity, and the perception process of human decision. It is based on linguistic variables and through a set of fuzzy logic rules an inference system is built which is the basis of the fuzzy computation [1]. In MATLAB, Fuzzy logic has a toolbox which used to solve uncertainty or vague problems during image processing and classification. This fuzzy logic has a set and its elements have different degree of membership that the values always assigned between 1 and 0. A Fuzzy logic System (FLS) is to map an input space to an output space by using a fuzzy set. It tries to formalize the reasoning process of human language by means of fuzzy logic (by building fuzzy IF-THEN rules and by using linguistic variables such as adjectives and adverbs).

FLS for image classification is applied to identify homogeneous groups of data points and to select some parts from the other in a given dataset and assigning it to a class. The image classification can be accomplished as a process of grouping pixels into a set of classes based on their relative similarities with regard to certain properties.

This project mainly concerned on using of FLS image classification, for yarn surface quality assessing and grading based on the binary image pixel values of the yarn sample. Then by applying fuzzy rules and mathematical formulas of fuzzy membership function, the calculated degree of membership of the input value (binary image white pixels of sample) is used to decide the grade of yarn quality either its good or bad, based on their relative similarities with the standard one.

Evidently the cotton yarn sample image processing phase should be developed in GUI toolbox with the aim to get the most suitable features (pixel values) from the image to use as input value for yarn quality grading based on the fuzzification, fuzzy rules and defuzzification process. In MATLAB yarn image processing, from the generated binary image number of black and white pixel values, we take the white and applied in the formulated fuzzy rules and membership functions in FLS. Because the white pixel values indicates only the yarn surface in the yarn carrying blackboard and it is a combination of yarn cure (non-defect area) and surface defects. For this investigation, we received the prepared yarn sample image by email from Kombolcha Textile Industry which found in Ethiopian Country. In the figure below are the received yarn samples that we used for experiment in this investigation.

(a) (b) (c) (d)

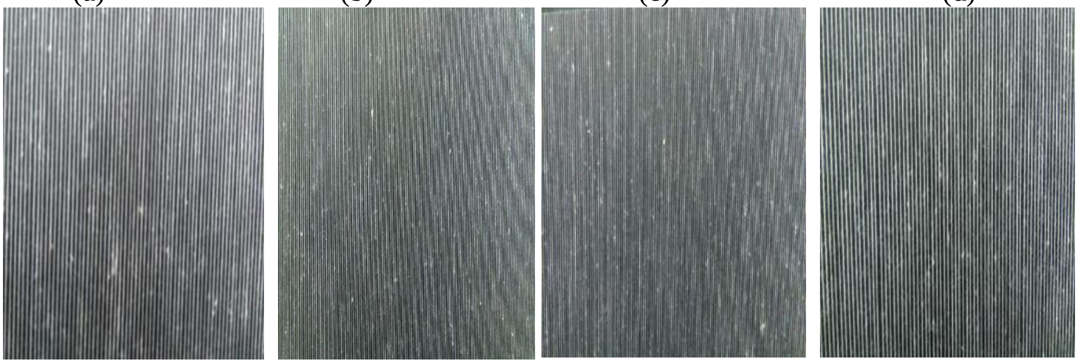

Figure 1.1 Cotton yarn samples for applying in this investigation (Tex); (a) 42, (b) 37, (c) 34, and (d) 29.4

Based on the ASTM standard (D-2255) method, totally there are six series of yarn count ranges in the world textile yarn manufacturing industry. Each series has a four graded standard photographs that the yarn manufacture uses it as a standard quality reference to compare and evaluate their product by visual observing. And according to the investigation of [5], they have been analysed and gave a fixed pixel number for each standard photographs.

This project deals by taking the standard ASTM yarn count series range of 50 to 25+ Tex, and its generated pixel values in MATLAB image processing to construct the membership function (MF) of the FLS, because the yarn sample for this experiment belongs in this count range and its parameters are listed in the table below.

Table 1: ASTM (D-2255) STANDARD IMAGE PIXEL VALUES OF SECOND SERIES YARN COUNT [5].

Series	Sample cotton yarn count	ASTM standard photograph values of 2nd series count	
		Image grade	Standard image white pixels
Second series	Range from 50 to 25+ Tex	A	323505
		B	376252
		C	415100
		D	468541

As shown in the above table, first grade image (grade A), has best yarn quality which means less thick, thin place and neps. While the last grade 'D', due to its higher number of thick places and neps, it's the worst in quality and has larger pixel number. As a result when we go to from grade A, to grade D, the number of white pixels becomes increase and black pixels are decrease, while from grade D, to grade A, the vice versa is true.

Generally, the white pixels of the binary image describes the quality of the yarn surface, because it is the combination of pure (core) yarn surface and different surface defects. That means the fewer pixels describes the higher yarn quality (less thick place and neps) and it has, while higher pixels describes low yarn quality (more thick place and neps).

2. REVIEW ON RELATED PAPERS :

According to the standard method of ASTM (D-2255-02), cotton yarn appearance standard were first adopted in 1938 and revised in1964, with series III being revised again in 1975. Traditionally the inspection is carried out directly by visual comparison of the wound yarn sample (blackboard wrappings of yarns) with the grade labelled photographic standards (grade A, B, C and D) and based on the assessment of regularity, freedom from imperfections, foreign matter, neppiness and lack of hairiness [2].

Researchers have developed an artificial intelligence and computer vision evaluation method for yarn quality testing and grade classification. In this investigation the quality classification was done through the integrated digital system which integrates the whole image processing algorithms. To classify the yarn quality and grade in artificial neural network, authors have been used eighteen yarn features and statistical results of USTER yarn evenness tester [3].

Authors have been used a statistical function of semivariogram method for evaluation of yarn surface unevenness. To accomplish their investigation, they used image processing algorithms in matlab software such as image acquiring, and grey scale image conversion. Then based on the standard yarn board (CSN8 0704), the fluctuation in the degree of greyness between the square field image has evaluated by semivariogram. The greyness degree were constructed from the standard yarn board by dividing the grey image into square field of selected size [4].

2.1 Theoretical principle

Theoretically, as described in the figure below (fig1. a), the conventional method of yarn quality testing and grading evaluation is based on the ASTM (D2255) method, and the yarn quality checker sometimes give same grade for which has different yarn surface appearance of the same yarn count. And also when sometimes the grade falls between the two consecutive grades, they give a plus sign after the letter based on their perception.

In this project, the yarn quality and grading classification will be analysed by using fuzzy logic system. Fuzzy logic has toolbox in MATLAB and it is a good measuring frame to handle the problem of uncertainty, vague or unclear things in the image information. In FLS toolbox, there are different menu parameters such as FIS editor, IF-THEN rule editor, membership function editor and others that used for image classification by using linguistic variables and mathematical membership functions [6].

As shown in the figure below (fig1. b), the first image yarn sample (im1) will expressed in percentage between two standard grades (grade A and B) according to its degree of membership, i.e. µA(im1) and µB(im1) to each fuzzy set, whereas the grade of the second yarn image (im2) will expressed in percentage between (A and B) grades, which means according to membership of µA(im2) and µB(im2) to each fuzzy set.

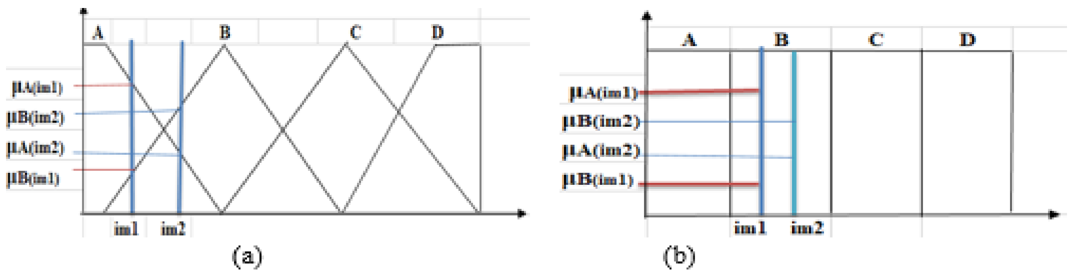

Figure 1.2 A) Yarn grade conventional classification, and B) classification by using FLS.

After image processing and generating the pixel values for each yarn samples, the yarn appearance grading will be analysed in fuzzy logic system based on the number of white pixels of the yarn binary image.

2. OBJECTIVES:

The objective of this paper, mainly concerned on cotton yarn appearance grading and classification in percentage based on the analysed binary image white pixel values of yarn sample with the help of MATLAB image processing. In addition to this, it's possible to avoid the errors which occurred by human perception and decision of visual assessment yarn quality grading system.

3. STATEMENT OF THE PROBLEM:

In textile yarn manufacturing industry, the cotton yarn surface evaluation (unevenness testing) and quality grade classification by human visual assessment is one of the challenging tasks. In conventional way of yarn surface grading, based on ASTM (D-2255) method, quality evaluators sometimes give same grade even if the samples have different yarn surface appearance for the same yarn count. This project is proposed for yarn quality grade classification in percentage by using the generated white pixel values as input parameters of fuzzy set membership function in fuzzy logic system.

4. METHODS AND MATERIALS:

In this paper, to analyse the cotton yarn appearance grading and classification the following are the basic steps which used to build a FLS design and fuzzy logic membership function.

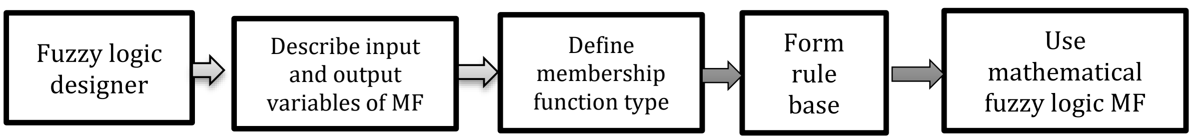

Figure 4.1 Diagram to construct FLS and membership function for yarn grade classification.

As shown in the above diagram, to perform yarn quality grading by using fuzzy logic, three stages must be occur. First fuzzification which is used to modify the membership values of a specific data set or image pixel values. After the image data are transformed to the membership function using fuzzification, appropriate fuzzy techniques

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modify the membership values. This can be a fuzzy rule-based approach, or a fuzzy integration approach and finally defuzzification, which to get the output crisp value from linguistic variables and rules.

The including materials that we used for this investigation are, cotton yarn sample, digital camera, black plate and MATLAB software for yarn carried black plate image processing and analysing. Those materials are listed below.

(a) (b) (c)

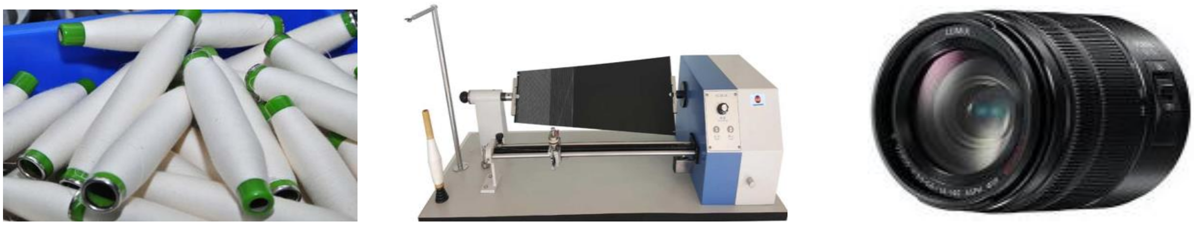

Figure 4.2 Materials for studying (a) Yarn bobbin , (b) Black plate, (c) Digital camera

4.1 FLS Codes for Yarn Quality Grading:

Input variables: white pixels and it's ranging from (parameter values): $3.0*10^5$ to $5.0*10^5$. Number of membership functions is four (depends on the four graded image of standard yarn). This includes the following:

A= trapmf (white pixel, [3.0, 3.0, 3.235, 3.763]$*10^5$)
B= trimf (white pixel, [3.235, 3.763, 4.151]$*10^5$)
C= trimf (white pixel, [3.763, 4.151, 4.685]$*10^5$)
D= trapmf (white pixel, [4.151, 4.685, 5.0, 5.0]$*10^5$)

Output variables: Grade and it's ranging from 3e+05 to 5e+05. Number of membership functions is four and it includes the following MF with its parameters:

Excellent: trapmf (grade, [3.0, 3.0, 3.235, 3.763]$*10^5$)
Good: trimf (grade, [3.235, 3.763, 4.151]$*10^5$)
Fair: trimf (grade, [3.763, 4.151, 4.685]$*10^5$)
Poor: trapmf (grade, [4.151, 4.685, 5.0, 5.0]$*10^5$])

4.2 Basic Steps for Fuzzy Logic Membership Function

The following are the basic steps which used to build a FLS designer for yarn appearance and grading classification:

1. Open Fuzzy Logic Designer and Identify input and output variables including with their descriptions. In the MATLAB command line, type fuzzy to open the fuzzy logic designer. Then to construct fuzzy membership function, decide and identify the input and output variables with their descriptions. In this project, a single input variable which is white pixel value and single output variable which is grade are used, to create the membership function of FLS for yarn quality grading classification. This project uses mamdani type of fuzzy inference system to construct fuzzy logic membership function and to accomplish the yarn grading classification.

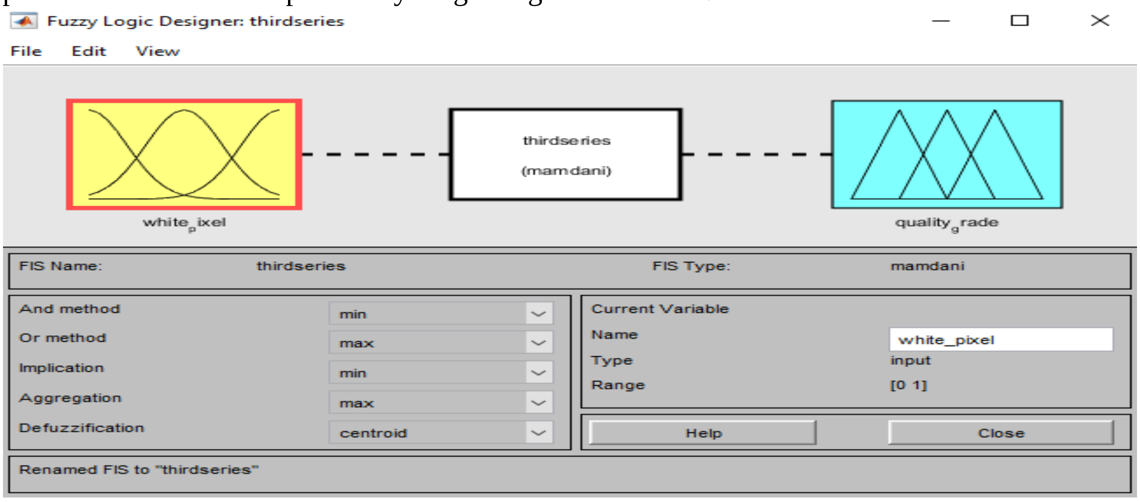

Figure 4.3 The initial fuzzy logic designer which contains the input and output MF variables

2. Define the membership function type for each input and output variables. Here for yarn grading and evaluation we choice a trigonometric and trapezoidal shape of membership function. Membership functions define how each point in the input space is mapped to a membership value between 0 and 1.

To create a fuzzy logic membership function, first select and identify the parameters (interval values) for input and output variables which used as a crisp value fuzzy set. In this project, we used from 50 to 25+ Tex yarn count range of four graded standard photograph pixel values to form input variable membership function, because the yarn samples belong in this count range. The input variable four membership functions universe of discourse is ranging from 3e+05 to 5e+05, because the standard yarn image pixel values belongs between this range.

Table 2: INPUT VARIABLE AND PARAMETERS FOR CONSTRACTING FLS MEMBERSHIP FUNCTION

Linguistic variable	Parameters (intervals) which ranging for each fuzzy set variable
A	3e +05, 3e+05, 3.235e+05, 3.763e+05
B	3.235e+05, 3.763e+05, 4.151e+05
C	3.763e+05, 4.151e+05, 4.685e+05
D	4.151e+05, 4.685e+05, 5e+05, 5e+05

In fuzzy logic system membership function for both input and output variables the horizontal x-axis range describes the white pixel value (quantity) of the second series yarn count and the vertical y-axis indicates the degree of membership of the yarn sample which drops in one or two of the given four fuzzy sets based on its generated pixel number.

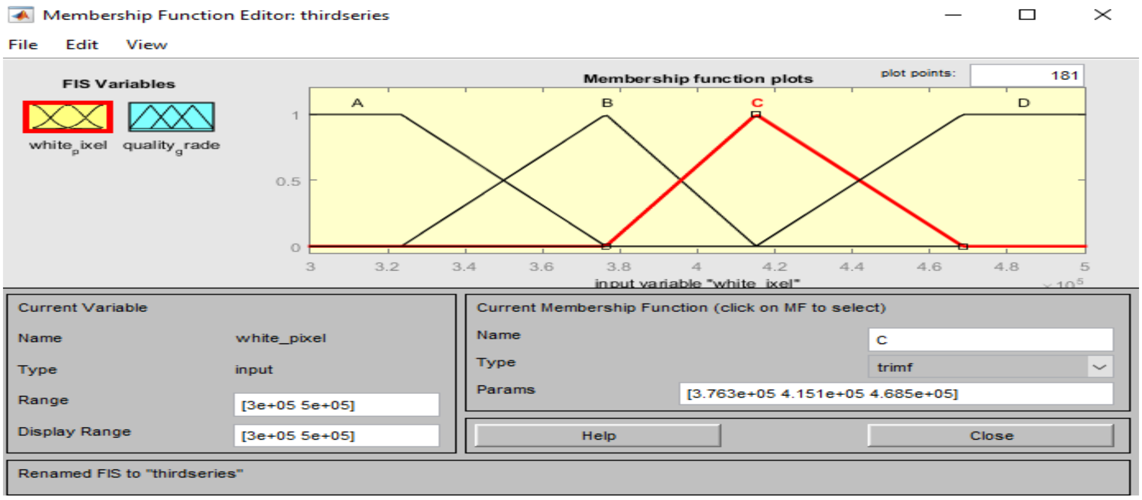

Figure 4.4 The single input variables of MF for yarn grading and classification

The output variable of quality grade, has four linguistics and its universe of discourse is ranging same length like that of input variable in order to have equal width and same shape membership function. The output variable is described as below figure.

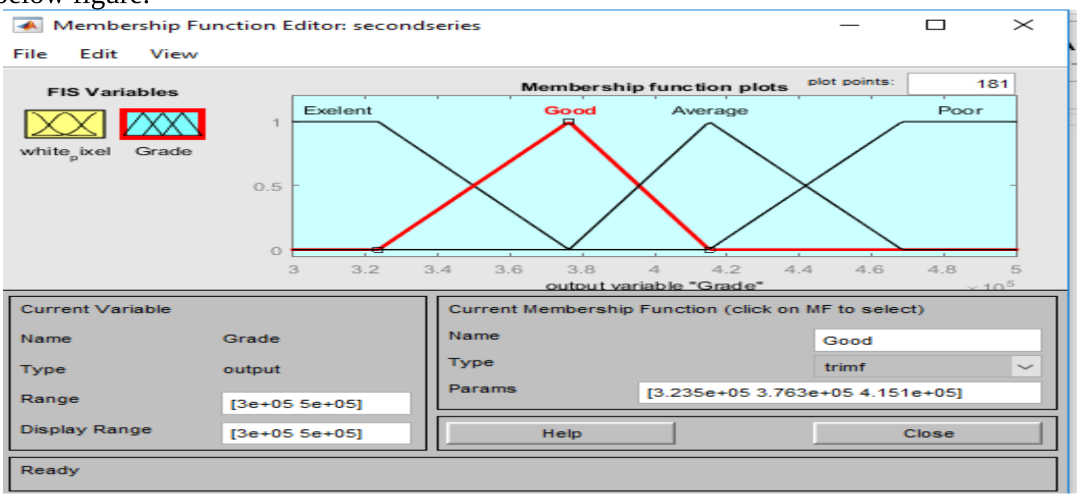

Figure 4.5 Single output variables of MF for yarn grading and classification

3. Form rule base. That means create rules by using the Rule Editor that define the logical relationship between the input and the output variables. Basically, based on the descriptions of the input and output variables defined with the Fuzzy Logic Designer, the Rule Editor allows to construct the rule statement. Here to study this project, we form four rules as shown in the bellow figure.

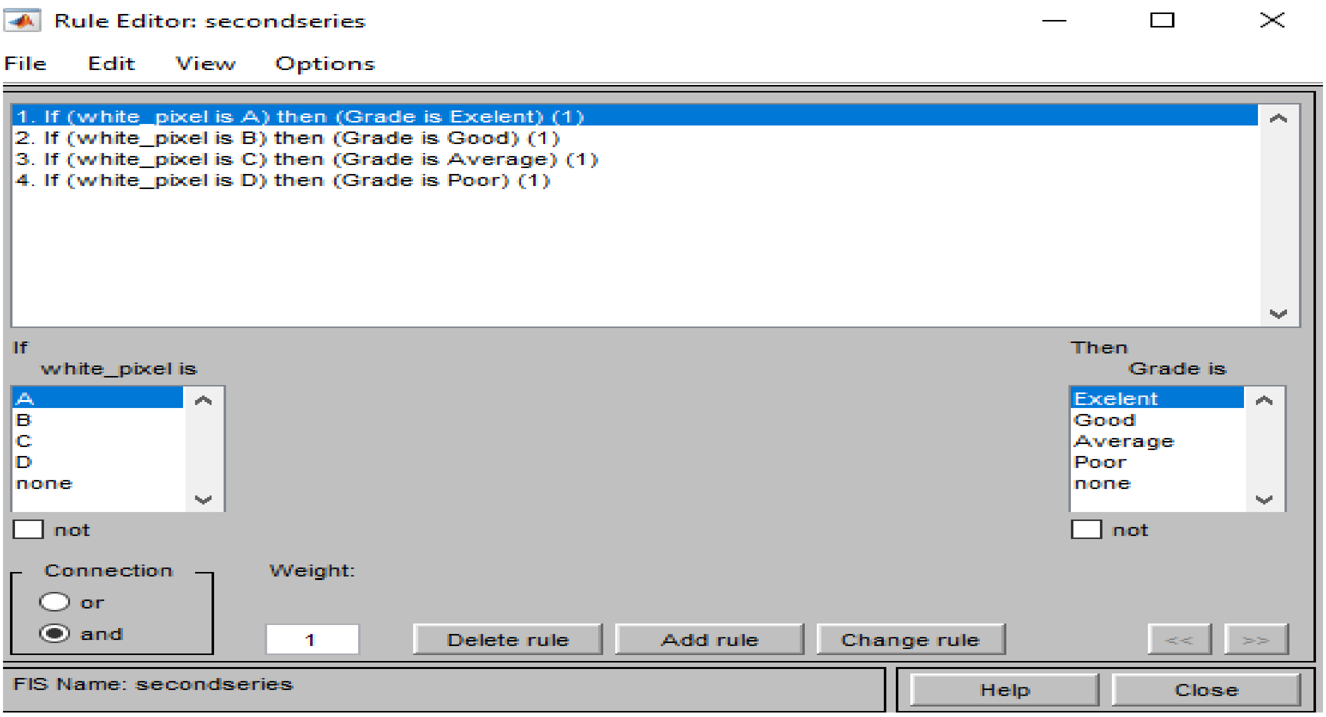

Figure 4.6 If-then rules of input white pixel and output grade in FLS

After the system defined and completed the fuzzy sets variables, membership functions and rules becomes main applicable to calculate the output value and degree of membership.

4. Importing to the GUI Tools. At the time of saving the constructed fuzzy system to a file, it is saving in FIS file representation of that system with the file suffix .fis. This text file can be edited, and modified based on the requirement. At the time of saving fuzzy system to the MATLAB workspace, it is forming a variable (whose name you choose) that acts as a MATLAB structure for the FIS system.

5. RESULT AND DISCUSSION:

After yarn image processing and analysing in the developed MATLAB graphical user interface, the output of binary image pixel values (white and black pixels) of the yarn sample are listed in below table.

Table 3: WHITE AND BLACK PIXEL VALUES OF THE BINARY IMAGE FOR EACH YARN COUNT SAMPLE

Sample No.	Count (tex)	Binary image pixel values	
		White pixel	Black pixel
1	42	335740	220930
2	37	368286	204657
3	34	322296	237652
4	29.4	380340	298630

After defining the input and output variables, and their membership functions to classify the sample quality grade for each cotton yarn count in FLS, by taking the white pixels we can get the output crisp values either by writing MATLAB program in the formed graphical user interface, or by using rule viewer toolbox. In this work, the fuzzy logic rule viewer easily shows how each rules are combined together in order to get the final crisp value by defuzzification process.

The rule viewer displays a road map of the whole fuzzy control process. From this the number of rows describes the number of rules and the number of columns describes the number of variables for both input and output [6]. The figure below is the developed rule viewer in this project for both yarn image pixel input variable and grade quality output variable. As shown in the left bottom side of input area by changing the pixel numbers simply it's possible to gate the aggregated rules of output values in right corner side.

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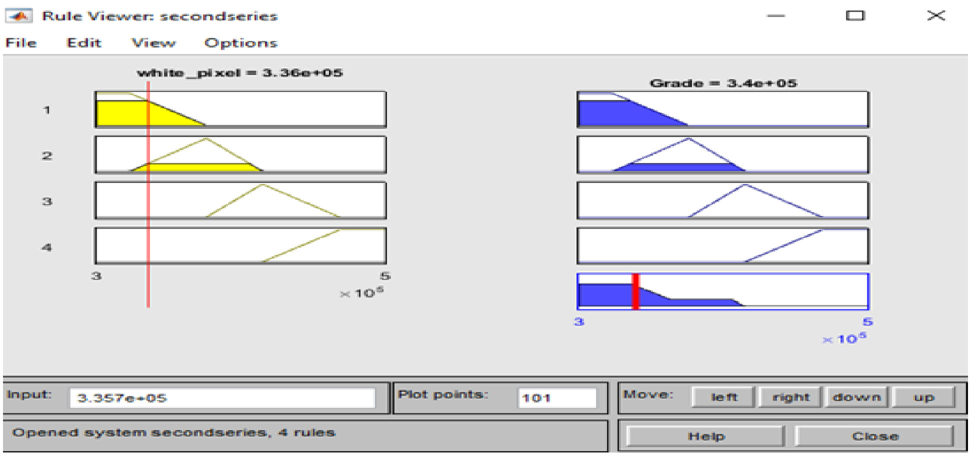

Figure 5.1 Rule viewer of the input white pixel and output quality grade variables

By taking the analysed pixel values of each yarn count sample from table3, and by inserting in the rule viewer individually the combined rules output crisp value becomes as follows in the table.

Table 4: YARN SAMPLE PIXEL AND UTPUT VARIABLE CRISP VALUES

Count (tex)	Sample pixel value	Rule viewer aggregated output
42	335740	339583
37	368286	366414
34	380340	378906
29.4	322296	326734

The yarn quality evaluation and grading system will takes place by grouping the output of yarn binary image pixels in a fuzzy set of classes based on their relative similarities of the standards and by calculating the degree of membership, which defines the truth value of the yarn in the given fuzzy set. The degree of membership in a fuzzy set can be defined by a mathematical function which is called membership function (MF). MF is a curve that defines how each point in the input space is mapped to a membership value (degree of membership) between 1 and 0 or it is a graphical representation of each input values, and ts denoted by miw (µ). In MF, the input space sometimes termed to as the fuzzy set width or universe of discourse [6].

In this project to deal the yarn surface quality grading, as shown in the formed input and output variable of the FLCS, the selected membership functions are triangular (trimf) and trapezoidal (trapmf), and mathematically to calculate the degree of membership of input pixel value, we applied the following mathematical expressions.

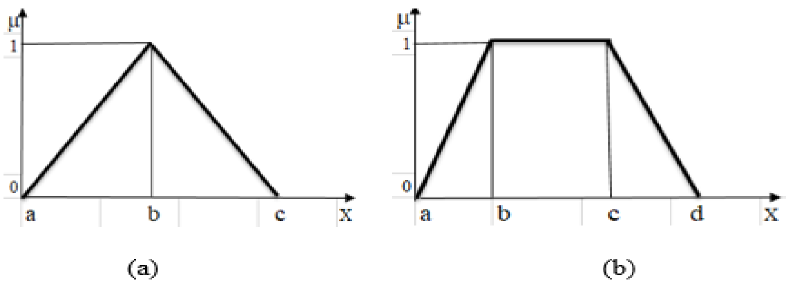

Figure 5.2 Membership function of (a) triangular, and (b) trapezoidal

$$\mu(x;\ a, b, c) = \begin{cases} 0, & x<a \ \&\ x>c \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \end{cases} \qquad \mu(x;\ a, b, c, d) = \begin{cases} 0, & x<a \ \&\ x>d \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{c-x}{c-b}, & b \le x \le c \end{cases}$$

Equation **1**. Membership function equation of (1) triangular, and (2) trapezoidal [7].

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From the above figures of triangular and trapezoidal membership functions,the horizontal x-axis parameters (a, b, c, and d) indicates the crisp value which used as a primary fuzzy set to crate the required membership function both for input and output variables and instead of these variable we used the standard of four graded image pixel values, whereas the vertical line range between 0 and 1 is describes the truth value (degree of membership) of the input value of the yarn image pixels that generated in MATLAB yarn image processing.

After this we are going to calculate the degree of membership of the output crisp value based on the above mathematical formula and finally by converting to percentage we go to decide and classify the yarn grade as the description is given in the output variable of MF like (excellent, good, average and poor). Then from the above table yarn count of 42tex aggregated value 335740 is belongs between excellent and good of output membership function as shown in the figure below.

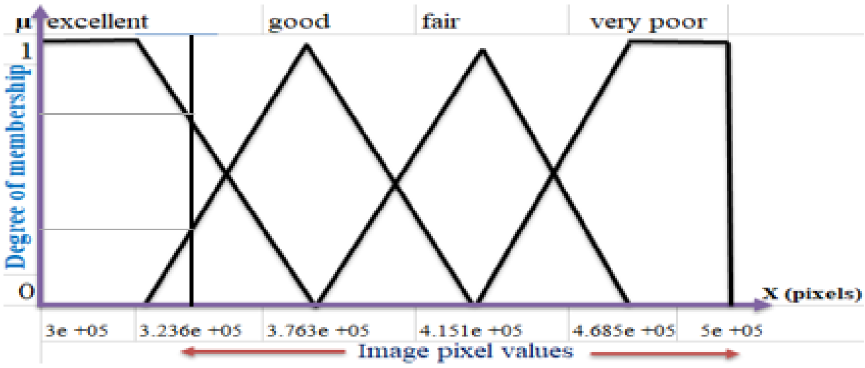

Figure 5.3 Output variable (grade) membership function

From this figure, the two intersection points of the line describes the truth value of the yarn sample that can be evaluated as excellent and good surface description by classifying in percentage. The fuzzy set 'excellent' has a trapezoidal MF and the fuzzy set 'good' has triangular MF. Therefore based on the given function formula, it can be calculated as follows.

$$\mu_{excellent}(339583) = \frac{(376252-339583)}{(376252-323505)} = 0.6952 \text{ (degree of membership in excellent boundary)}$$

$$\mu_{good}(339583) = \frac{339583-323505}{376252-323505} = 0.3048 \text{ (degree of membership in good boundary)}$$

These calculation output normally describes the truth value based on the given trapezoidal and triangular membership function, which means the tested yarn sample grade, 69.52% is excellent and 30.48% is good.

Similarly based on this calculation method, the rest yarn count sample truth value becomes; yarn count (37tex) has 18.65% excellent and 81.34% good surface appearance, yarn count (34tex) has 93.17% good and 6.83% average, yarn sample (29.4tex) has 93.88% excellent and 6.12% good surface appearance. Finally, this quality description and classification result can be conclude in table as follows.

Finally, the cotton yarn appearance evaluation and classification result can be summarized as shown in table below. In this investigation the selected adjective words, that we used to describe the yarn appearance and grade classification which includes (excellent, good, fair, and very poor) will replaced the standard letters (A, B, C, and D) respectively. Because, in yarn manufacturing industry mostly, quality evaluators used these adjective words instead of letters to assess the yarn surface appearance.

Table5: YARN QUALITY GRADING AND CLASSIFICATION RESULT IN BOTH MANUALLY AND IN FLS

Sample No.	Count in (tex)	Cotton yarn appearance assessment result in visual observation and by using FLS calculation	
		In visual observation	Quality evaluation and classification by using FLS membership function
1	42	A	69.52% excellent & 30.48% good
2	37	B+	18.65% excellent & 81.14% good
3	34	C	6.83% average & 97.17% good
4	29.4	A	6.12% good & 93.88% excellent

The above result and discussion of this work is accomplished by using MATLAB image processing for generation of pixel values, and a fuzzy logic system membership function for cotton yarn quality evaluation and appearance grading classification, instead of using the manual method which required two or three evaluators for final quality decision after observing the surface appearance. This studying shows accurate result than the traditional methods, because this work accomplished by converting the whole yarn surface area into quantitative value (pixels) and it gives the result in percentage instead using '+' sign of human perception.

6. CONCLUSION:

This studying, applied the fuzzy logic system (FLS) to assess and grade the quality of the cotton yarn surface based on the analysed pixel values of the yarn wound blackboard in MATLAB image processing. In yarn manufacturing textile industry, many methods are available to determine the yarn evenness, many of them are tedious and depend on the operator for this result, while others those less subjective and of high speed, are probability expensive and required high cost for maintenance during damaging time because of their more sensitive and easily damageable parts. Therefore, this project proposed a simple method to evaluate yarn appearance and based on mathematical equation of fuzzy logic membership function and it is possible to get accurate grade result by removing the manual testing method limitation.

7. RECOMMENDATION :

From this investigation, it can be seen that the cotton yarn appearance evaluation and grading system is accomplished by using fuzzy logic system and membership function equations based on the generated pixel values in MATLAB yarn image processing. Internationally, according to the ASTM (D-2255) standard method, mostly the cotton yarn manufacturing industries used traditional blackboard yarn appearance method for comforting customer acceptance, but this way of appearance evaluation needs two or three evaluators to decide the quality grade, time consuming, and difficult to assess the yarn surface defects by comparing with the standard photograph. This studying recommended that for all cotton yarn manufacturing company, instead of traditional method, applying of fuzzy logic system and membership function equations it can be get accurate yarn quality grading result.

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