Using a Fuzzy System to Determine the Uniformity of Dyed Fabrics

S. Gorji Kandi[i], M. Amani Tehran[ii]

ABSTRACT

Visual assessment is traditionally used to evaluate the uniformity of color in dyed fabrics. By considering that visual assessment is a time-consuming process and there are usually inconsistency between subject's viewpoints, a machine vision method as substitution is preferable. In this paper, we suggest a computational method using computer vision technique and a fuzzy system to evaluate color levelness of dyed fabrics. In this way, after capturing proper images of dyed fabrics, a low pass filter in frequency domain is applied to eliminate the texture of the fabric images. Then the difference between each pixel value and the mean value of the whole image is computed and the image is quantized into four gray levels depending on the magnitude of difference values. The area portion of each gray level is used to classify the uniformity of dyed fabrics in terms of, excellent, good, moderate and low degree of levelness. Finally, a fuzzy system is developed to determine the total levelness of the dyed fabric as an index. The accuracy of the proposed index was verified by comparing the visual assessments of 11 dyed samples with the obtained index. The results show an acceptable agreement.

KEYWORDS

Levelness, Dyed fabric, Fuzzy system, Image analysis .

1. INTRODUCTION

Fabric appearance is regarded as one the most essential textile attributes in textile industries. Some features affect the appearance of the fabrics. One of the most important features is the color uniformity of dyed fabrics. The shade uniformity appearance of the fabric is an important criterion for the consumers. The colorants, auxiliaries and dying process are controlled to have a uniform shade in dying fabrics. However, some problems can lead to produce non-uniform sites.

Textile manufacturing industries are concerned with the appearance of color uniformity in terms of levelness or uniform shade in dyed fabrics [1]. It is necessary to have a color quality control part after dyeing process to distinguish the non-uniform sites in dyed fabrics and estimate the degree of levelness. Traditionally, the dyed fabrics are graded based on their uniformity appearance by expert persons and there is no well-known computational method. Despite the importance of dyed uniformity measurements, there are a limited references in this subject [1-4]. These studies performed some digital image analysis techniques but for special fabrics and colorants and in limited case.

It is noted that sometimes unevenly colored textile are preferable for example in the case of garments, which are water-washed or stone-washed, there is a study related to this subject that proposed the standard deviation of K/S values in different places of the fabric to determine the degree of levelness [5]. However, spectrophotometric information does not usually available especially for an online quality control.

By considering that visual assessments are a time-consuming process and there are usually inconsistency between subject's viewpoints, it is desirable to have a computational method. Although digital image analysis has been usually used for textile quality control, as mentioned, it has not been wildly employed for evaluating the color uniformity of dyed fabrics. In this study, we use image analysis techniques and a fuzzy system to evaluate the color uniformity of dyed fabrics.

2. METHOD

After dying process, the uniformity of the color of dyed fabric defines the levelness of dying process. Sites on the fabrics surface whose colors are far from the mean value of color of the dyed fabric are classified as undesirable areas that cause unlevelness. It is clear that the degree of unlevelness is not the same for all of the defect parts and it is dependent on the distance between the colors of each

i S. Gorji Kandi is with the Department of Textile Engineering, Amirkabir University of Technology, Tehran, Iran (e-mail: gorji_s@aut.ac.ir).
ii M. Amani Tehran is with the Department of Textile Engineering, Amirkabir University of Technology, Tehran, Iran (e-mail: amani@aut.ac.ir).

part from the mean of color of the fabric. For example, the points with no dye absorption produce much more defect in human perception as same as the spots which are so darker than the real color of the fabric. By considering this fact, we classified the unlevelness of the fabric into four groups. The parts of the fabric that are uniformity dyed assigned in the first group and vice versa, the points with a high difference with the real color of the fabric put in the last group. In addition, there are two other groups between these extreme groups. Then based on the coverage percentage of each group, the total levelness of the dyed fabric is defined by an index.

To perform it, a Canonscan LIDE30 scanner was used for capturing proper image of each fabric. The scanning resolution was 300 DPI and all other parameters set on its normal for picture capturing. It is noted that, testing a range of DPI resolutions showed that 300 DPI is adequate to distinguish the defect sites. The obtained color images then transform to gray scale images to avoid complicated computation. By considering that the most color defect in the case of uniformity of dying process exists in lightness direction, performing the algorithm on gray scale image could be have acceptable accuracy. To eliminate the texture from the image, we use a low pass filter in frequency domain. The filter cuts off the high frequency components of the Fourier transform that are at a distance grater than a specified distance (D_0) from the origin of the transform [6].

$$H(u,v) = \begin{cases} 1 & if D(u,v) \le D_0 \\ 0 & if D(u,v) > D_0 \end{cases} \quad (1)$$

where $D(u,v)$ is the distance from point (u,v) to the center of frequency rectangule. If the image is of size $M \times N$, the center of frequency rectangle is at $(u,v) = (M/2, N/2)$ and the distance from any point (u,v) to the center of Fourier transform is given by:

$$D(u,v) = [(u - M/2)^2 + (v - N/2)^2]^{1/2} \quad (2)$$

It is expected that the texture points, to be the points with high frequency so they can be eliminated by this process. D_0 can be optimized based on the image texture characteristic. Considering that the image noises are the points with high frequency too, by applying this filter the probably noise of the images can be simultaneously eliminated.

After that, the difference of each pixel value from the mean of the pixel values of the image is calculated by equation (3).

$$\Delta(i,j) = I(i,j) - \bar{I}$$
$$\bar{I} = \frac{\sum_i \sum_j I(i,j)}{N \times M} \quad (3)$$

where, $I(i,j)$ is the pixel value at (i,j) point of the image, $\bar{I}$ is the mean value of the image, N and M are the length and width of the image per pixel.

The image is quantized into four gray levels based on the computed difference of each pixel with the following rules:

$$\begin{cases} if \Delta(i,j) < \varepsilon_1 then, I(i,j) = GrayVal.1 \\ if \varepsilon_1 \le \Delta(i,j) < \varepsilon_2 then, I(i,j) = GrayVal.2 \\ if \varepsilon_2 \le \Delta(i,j) < \varepsilon_3 then, I(i,j) = GrayVal.3 \\ if \Delta(i,j) \ge \varepsilon_3 then, I(i,j) = GrayVal.4 \end{cases} \quad (4)$$

where ε_1 is an acceptable color difference, ε_2 and ε_3 instance for level one and two of unlevelness, respectively. The number of points in each group is divided into the total number of image points to obtain the coverage percentage of each unlevelness sites to be expressed in terms of, excellent (*EL*), good (*GL*), moderate (*ML*) and low (*LL*) degree of levelness.

$$\begin{cases} EL = \frac{No.(GrayVal\ .1)}{N \times M} \\ GL = \frac{No.(GrayVal\ .2)}{N \times M} \\ ML = \frac{No.(GrayVal\ .3)}{N \times M} \\ LL = \frac{No.(GrayVal\ .4)}{N \times M} \end{cases} \quad (5)$$

$$EL + GL + ML + LL = 1 \quad (6)$$

Since one of these variables can be obtained from the others using equation (6), only three independent variables would remain. By considering that the first expression (*EL*) specifies the sites with acceptable levelness, the last three values (*GL*, *ML*, and *LL*) are used to examine the degree of unlevelness.

Finally, a fuzzy model was developed to produce the total levelness of the fabric as an index. This fuzzy system was designed with the aid of fuzzy toolbox of Matlab software [7] as follows:

i) The inputs and outputs of the design have to be determined. The inputs of the model consist of:

1) The degree of good levelness (*GL*)
2) The degree of moderate levelness (*ML*)
3) The degree of low levelness (*LL*)

Each input variable divided into four levels consists of very low, low, mid and high by Gaussian membership function. Figure (1) shows the membership functions for *GL* input variable. The corresponding output parameter is the index of levelness defined into five levels consists of reject, low, good, very good and excellent again by Gaussian membership function. Figure (2) shows the membership functions for output variable.

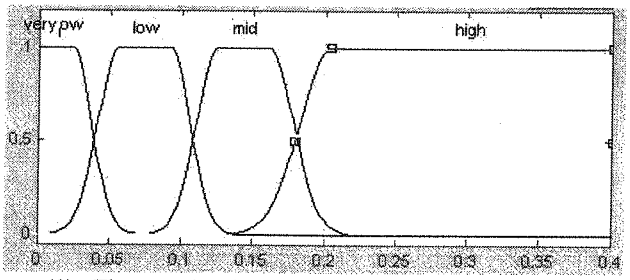

Figure (1): The membership functions of the good levelness (*GL*) input variable.

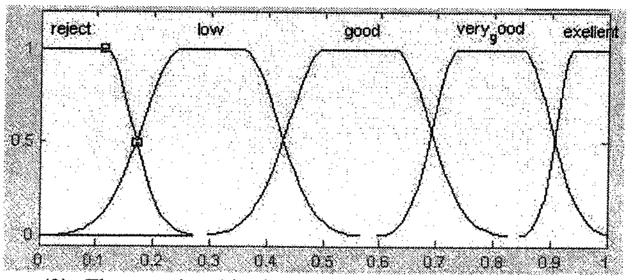

Figure (2): The membership functions of the levelness index as output variable.

ii) The rules, are formulated using a series of if-then statements, combined with AND/OR operators. Such as:

IF *GL* is very low, AND *ML* is very low and *LL* is very low THEN the levelness is Excellent.

IF *GL* is low, AND *ML* is very low and *LL* is very low THEN the levelness is Very Good.

IF *GL* is very low, AND *ML* is low and *LL* is low, THEN the levelness is Good.

IF *GL* is very low, AND *ML* is high AND *LL* is very low THEN the Levelness is Low.

IF *LL* is high, THEN the levelness is Reject.

With three inputs, each having four membership functions, there are a combination of 64 rules. However, using the minimum or maximum criterion, some rules are combined and finally a total of 36 rules were remained. The output of this system is an index between 0-1, which express the degree of levelness. To obtain acceptable results we optimized the range of the input variables, the membership functions and the rules based on visual assessment of levelness of dyed fabrics.

To evaluate the accuracy of this method, we used 11 dyed cotton and nylon fabrics with different degree of levelness from different industrial color samples. The color characteristics of the fabrics are given in Table (1). Ten observers were requested to sort the samples into seven levels from reject to excellent degree of levelness. In parallel, the levelness index of each of the sample was computed by the proposed method. At the end, the degree of correlation between the visual assessment and the computational method was evaluated.

TABLE 1

THE COLOR CHARACTERISTICS OF THE 11 EVALUATED FABRIC SAMPLES IN CIELa*b* COLOR SPACE.

	L^*	a^*	b^*
1	24.54	26.27	4.69
2	38.88	49.88	10.91
3	33.90	48.88	13.94
4	67.83	32.94	77.27
5	21.65	11.76	-34.74
6	24.59	25.19	4.03
7	68.92	31.89	76.08
8	68.05	34.16	78.94
9	34.91	48.01	13.09
10	26.15	8.80	-39.36
11	25.02	25.02	3.33

3. RESULT

As an example, Figure (3) shows that how the proposed technique is able to distinguish the unlevelness parts of the fabric. This figure shows the initial color image of the fabric, the gray scale one, the image after eliminating the texture from it and the final quantized image with four area levels. It is illustrated that the undyed part of the fabric would be white in quantized image. Vice versa, the points that dyed well are black in this picture. Two other levels in between, indicate the part with level one and two of unlevelness.

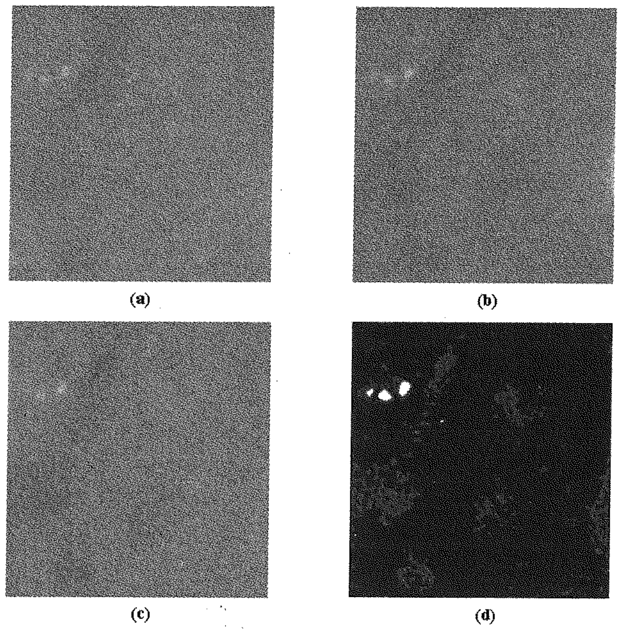

Figure (3): (a): Color image of the fabric; (b): the gray scale image (c): the gray scale image after eliminating texture; (d): the quantized image.

Table (2) shows the visual assessment of levelness for 11 dyed samples. As it shows for all of the samples, the standard deviation is smaller than one unit. The mean value of group numbers that were assigned to each sample by the observers was used as a visual index. Table (3) shows the results of levelness index that was computed for each sample by the proposed method. To be able to have a comparison between the visual index and the computed one, we scale the entire visual index to the range of 0-1 by dividing them to 7, and Figure (4) indicates the results of correlation between the visual and computed index. As it was illustrated, the computed levelness index has a good correlation with visual assessment by a R^2 of 0.92. It shows that this method is able to determine the degree of levelness of dyed fabrics with an acceptable accuracy in comparison to visual assessment.

TABLE 2
THE RESULTS OF SORTING 11 DYED SAMPLES BASED ON THEIR LEVELNESS (FROM THE WORST TO THE BEST) INTO SEVEN GROUPS BY 10 OBSERVERS.

	1	2	3	4	5	6	7	8	9	10	Mean	*std*
1	1	1	1	1	1	1	1	1	1	1	**1**	*0*
2	2	1	1	1	1	1	1	2	1	1	**1.2**	*0.18*
3	2	4	3	3	2	3	2	3	2	3	**2.7**	*0.46*
4	3	4	2	2	3	2	3	2	3	3	**2.7**	*0.46*
5	4	3	4	4	3	3	4	4	4	4	**3.7**	*0.23*
6	4	6	5	3	5	4	5	4	4	4	**4.4**	*0.71*
7	5	3	4	5	4	4	4	5	6	5	**4.5**	*0.72*
8	5	5	5	4	5	5	5	5	3	5	**4.7**	*0.46*
9	6	5	6	5	4	5	6	6	5	6	**5.4**	*0.49*
10	6	6	6	6	6	6	6	6	5	6	**5.9**	*0.1*
11	7	7	7	7	7	7	7	7	7	7	**7**	*0*

TABLE 3
THE COMPUTED LEVELNESS INDEX FOR THE 11 DYED SAMPLES BY THE PROPOSED METHOD.

	Levelness Index
1	**0.2991**
2	**0.2998**
3	**0.5773**
4	**0.5623**
5	**0.7842**
6	**0.7688**
7	**0.8589**
8	**0.8006**
9	**0.9457**
10	**0.9283**
11	**0.9489**

4. CONCLUSION

The color uniformity in terms of levelness in dyed fabrics is an important factor in textile manufacturing industries. Traditionally, the dyed fabrics are graded based on their uniformity appearance by expert persons and there is no general computational method to do it. In this study, we applied image analysis techniques and a fuzzy system to evaluate the color uniformity of dyed fabrics. After capturing proper images of dyed fabrics, the obtained color images transformed to gray scale images to avoid of complicated computation. Then a low pass filtering technique was applied to eliminate the texture from the fabric images. After that, the image was quantized into four gray levels based on the calculated differences between each pixel value and the mean value of the whole image. The area portion of each gray level was used to classify the uniformity of dyed fabrics as expressions of, excellent, good, moderate and low degree of levelness. Finally, a fuzzy system was developed to determine the total levelness of the fabric as an index. Comparing the visual assessments of uniformity of some dyed samples with the proposed index indicated an acceptable agreement by a R^2 value of 0.92. In addition, the obtained quantized image is able to show the unlevelness parts of the dyed fabric considering the intensity of unlevelness.

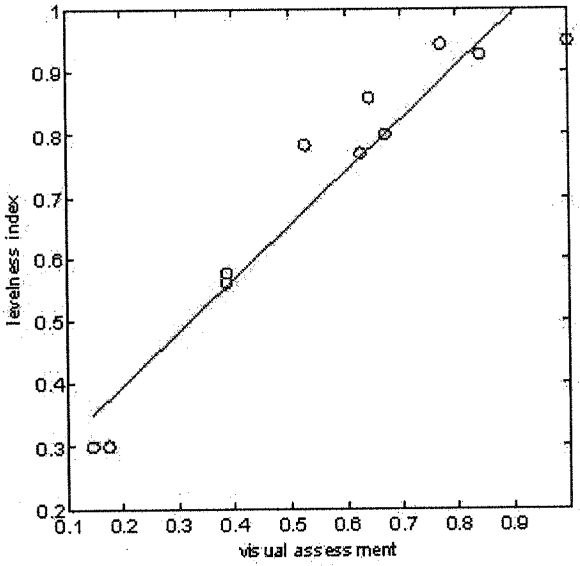

Figure 4. The computed levelness index against the results of visual assessment. The R^2 value is 0.92.

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