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Düzgünlük-Düzgünsüzlük İndeksinin Tarayıcı Verileri Kullanılarak Belirlenmesi

Determination of Levelness-Unlevelness Index Using Scanner Data

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DETERMINATION OF LEVELNESS-UNLEVELNESS INDEX USING SCANNER DATA

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ABSTRACT: In this study, two new criteria are suggested to assess the unlevelness of fabrics with different degrees and patterns of unevennesses by analyzing of data obtained by imagining of fabrics with scanner. The basic statistical properties of matrices of grabbed images, i.e. the singular values extracted by singular value decomposition technique and the two dimensional standard deviations are introduced as the unlevelness indices. The results are compared with those reported by visual assessment of observers as well as numerical outcomes of quantitative method employing the spectral K/S values calculated from reflectance spectra of samples by spectrophotometer.

Key words: Unlevelness, scanner, singular value decomposition, two dimensional standard deviation

DÜZGÜNLÜK-DÜZGÜNSÜZLÜK İNDEKSİNİN TARAYICI VERİLERİ KULLANILARAK BELİRLENMESİ

ÖZET: Bu çalışmada, değişik derecelerde ve desenlerde faklılıklara sahip kumaşların düzgünsüzlüğünü değerlendirmek için iki yeni kriter önerilmiştir. Bu amaçla kumaşların tarayıcı ile görüntülenmesi sonucu elde edilen verilerin analizi kullanılmıştır. Türetilmiş görüntülerin matrislerinin temel istatistiksel özellikleri, örneğin tekil değer ayrıştırma tekniği ile çıkartılmış tekil değerler ve iki boyutlu standart sapmalar, düzgünsüzlük indeksi olarak tanımlanmışlardır. Sonuçlar, hem gözlemcilerin görsel değerlendirme raporları hem de örneklerin spektrofotometre ile elde edilen yansıma tayflarından hesaplanan spektral K/S değerlerini veren kantitatif metot çıktıları ile karşılaştırılmıştır.

Anahtar kelimeler: Düzgünsüzlük, tarayıcı, tekil değer ayrıştırma, iki boyutlu standart sapma

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1. INTRODUCTION

While the production of uniformly colored textiles is normally followed in the classical dyeing processes, the interest for tightly fashion connected unlevel colored textiles is continuously increasing on the market. The fantasy unlevel dyed yarns and the intended uneven colored fabrics are some examples of these types of textile material. Different techniques have been designed to provide such uneven products. The methods could be categorized by the stage that the unevenness is applied; hence the uniformity would be decreased by the pre-dyeing, in-dyeing and after-dyeing treatments. Simply, the levelness of dyeing can be controlled by changing the uniform accessibility of material to dye liquor. For example, tying of yarns and fabrics prior to dyeing leads to unlevel dyeing results. The uniformity of dyeing procedure could be also changed by intentional changing of parameters in dyeing procedure e.g. unsuitable liquor circulation and/or unsuitable auxiliaries in wrong time and sequences. Obviously, the uniformity of level dyed materials can be partially destroyed by some after-coloration finishing treatments. Water-washed, acid-washed, enzyme-washed, stone and sand-washed are some popular techniques that stain the level colored fabrics. The spottiness is also available through the bleaching of even colored fabrics after dyeing processing.

Within the uneven textile products, denim plays the most important role. For years, the partially faded denim has been the most commercially attractive uneven products. It seems that, the production, control and evaluation of uneven dyed denim is still an attractive topic in textile research. While some objective methods were developed to assess this product, the techniques and the results are too subjective and the methods report different results for similar patterns.

Within the last two decades, some instrumental methods were introduced to overcome to the problem of visual evaluation and get more reliable results [1-3]. The method employed the spectrophotometric properties of fabrics and used some simple statistical features of captured data to quantitatively show the degree of unlevelness or oppositely demonstrate the degree of evenness.

Chong and his coworkers [1] introduced a quantitative term called relative unlevelness index (RUI) by the reflectance spectra of different points of desired sample. The suggested method calculated the standard deviation of the reflectances of eight randomly selected points of sample as shown by Equation1.

$$S_\lambda = \sqrt{\frac{\sum_{i=1}^{n}\left(R_{\lambda,i} - \bar{R}_\lambda\right)^2}{n-1}} \qquad (1)$$

where n is the number of measurements, i.e. 8, and $R_{\lambda,i}$ is the reflectance of the the i[th] measurement at wavelength λ $\bar{R}_\lambda$ shows the mean of reflectance spectra at desired wavelength. The summation of the standard deviations of all wavelengths in the visible spectrum was introduced as RUI_u that indicates to uncorrected relative unlevelness index.

$$RUI_u = \sum_{\lambda=400}^{700} S_\lambda \qquad (2)$$

Since the value of calculated RUI_u depends to the overall level of reflectance of sample, they improved the RUI_u index by normalizing of the factor to the level of reflectance and called it as corrected relative unlevelness index, RUI_c as shown by Equations 3 and 4:

$$C_\lambda = \frac{S_\lambda}{R_\lambda} \qquad (3)$$

$$RUI_c = \sum_{\lambda=400}^{700} C_\lambda \qquad (4)$$

The index was modified to establish better correlation between the visual and instrumental assessments by incorporation of the spectral responsivity of standard observer in phtopic condition i.e. V_λ

$$RUI = \sum_{\lambda=400}^{700} C_\lambda V_\lambda \qquad (5)$$

The RUI was introduced as the relative unlevelness index.

Yang and Li [2] used similar logic and introduced their U index to show the unlevelness of coloration. Instead the reflectance spectra, they employed the K/S function of reflectance and aranged their formula accordingly.

$$S_{\lambda,r} = \sqrt{\frac{\sum_{i=1}^{n}\left[\frac{(K/S)_{\lambda,i}}{(K/S)_{\lambda,mean}} - 1\right]^2}{n-1}} \qquad (6)$$

The $S_{\lambda,r}$ is the relative value of sample standard deviation and n shows the measurement point. $(K/S)_{\lambda,mean}$ indicates to the mean of $(K/S)_\lambda$ Same as RUI, due to different sensitivities of human observer to visible spectrum, the $S_{\lambda,r}$ was then weighted by V_λ and the result was named as unlevelness factor. Equation 7 shows the suggested formula.

$$U\left(\frac{K}{S}\right) = \sum_{\lambda=400}^{700} S_{\lambda,r} V_{\lambda} \quad (7)$$

Recently, a term called "surface irregularity function" was introduced by Gunay [4]. The method employed an image capturing system using a standard light box and a digital camera. The captured image was portioned into different grid sizes and the coefficient of variations at different grid sizes was computed. Finally, the surface irregularity index was reported by plotting of coefficient variations against the grid size. In fact, the between-area variances of different grid sizes of gray scale image were calculated by this method and showed by $CB(A_k)$ as shown in Equation 8.

$$CB(A_k) = \frac{100}{\bar{F}_k}\sqrt{\frac{1}{m_k n_k}\sum_{i=1}^{m_k}\sum_{j=1}^{n_k}\left[F_{i,j} - \bar{F}_k\right]^2} \quad (8)$$

where A_k is the area size, m_k and n_k are the number of segments in the x and y directions, $F_{i,j}$ shows the lightness value of gray scale image of the cell in row i and column j. $\bar{F}_k$ shows the mean of lightness values at the proposed cell. Obviously, as the sizes of unit areas increase, the variances within unit areas increase while, the coefficient of variations between areas i.e. $CB(A_k)$ decreases. The method was employed on fabrics with different leveling properties and good correlation was claimed between the suggested technique and those obtained by visual evaluation.

2. SUGGESTED METHODOLOGIES

Two new criteria were employed to assess the unlevelness of fabrics with different degrees of levelness. Both methods use the basic statistical properties of images of fabrics and analyze the corresponding matrices accordingly. In fact, two dimensional standard deviations and the singular values decomposition methods were used to categorize the unevenness of images of fabrics captured by scanner.

2.1. Using two dimensional standard deviations

The standard deviation of a matrix shows the distribution of elements around the mean point. In fact, this simple statistical operation shows how the elements are dispersed around the mean of matrix. For the image, the low standard deviation indicates that the data points tend to be very close to mean and benefit from similar values, i.e. a solid image is formed. On the other hand, the high standard deviation shows that the data are spread out over a large range of values and a type of unevenness could be possible. This method simply was used to evaluate the degree of unlevelness within the fabrics by computing the two dimensional standard deviation of the corresponding gray scale images as shown by Equation 9.

$$U_{STD2} = \sqrt{\frac{1}{m \times n}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(F_{i,j} - \bar{F}\right)^2} \quad (9)$$

Where $F_{i,j}$ shows the lightness value as the matrix element of of ith raw of the jth column and $\bar{F}$ is the mean of lightness matrix m×n.

2.2. Employing the singular value decomposition technique

The singular value decomposition of an m×n matrix M is a factorization of the form shown by Equation 10.

$$M = U\Sigma V^* \quad (10)$$

where U and V^* are m×m and n×n unitary matrices and Σ is an m×n diagonal matrix. The diagonal entries $\Sigma_{i,i}$ of Σ are known as the singular values of M and the non-zero singular values of Σ are the square roots of the non-zero eigenvalues of M^*M or MM^* matrices. Σ shows the importance of different columns of matrices U and V. The variation of Σ indicates the details of proposed image. For simple image, minimum variation is expected while the decreasing rate is more noticeable for complex images. It is expected that the uniform images benefit from slower decreasing rate in comparison to the uneven samples. Figure 1 shows the first four singular values of images of three fabrics with different degrees of unlevelness, i.e. solid, medium levelness and significantly uneven samples. As the figure shows, samples are distinguished from each other based on the degrees of unevenness.

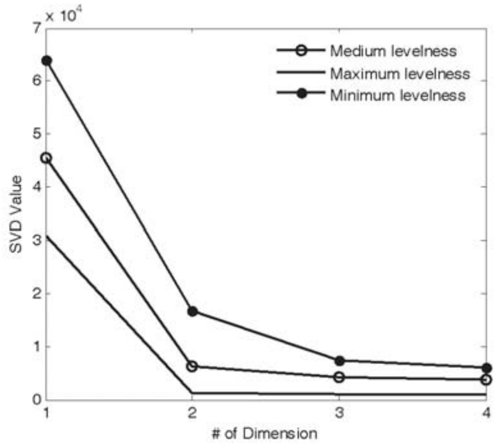

Figure 1. The first four singular values of images obtained from fabrics with different degrees of unlevelness.

To follow the idea in the instrumental assessment of unlevelness, the decrement slops of the singular values of images were computed by dividing of the second to the first singular values, as shown by Equation 11.

$$s_i = \frac{\Sigma_{2,i}}{\Sigma_{1,i}} \quad (11)$$

s_i shows the slop of the i^{th} images and the $\Sigma_{1,i}$ and $\Sigma_{2,i}$ indicate to first and second singular values of proposed image. Then, the S was formed as a vector containing the s value of n sample as $S = [s_i]_{i=1}^{n}$ To adjust the index comparable with other methods, Equation 12 was employed to fix the outputs between 0 (for the most uniform sample) and 1 (for the most uneven specimen).

$$U_{SVD} = \frac{S - \min(S)}{\max(S - \min(S))} \qquad (12)$$

where, the U_{SVD} shows the unlevelness index obtained by SVD and the min(S) and max(S) respectively show the minimum and the maximum values of vector S.

3. MATERIALS AND METHODS

3.1. Preparation of samples

By controlling the classical dyeing procedure, 12 colored samples were produced with different degrees of levelness. A blue direct dye form former Ciba Specialty Chemicals company named Solophenyl Blue AB was used to take the advantages of simple dyeing procedure of cotton with this class of dyestuff as well as providing colored samples with hues close to the blue denim fabric. The sizes of dyed samples were limited to 14×19 cm and the instrumental and visual evaluations were restricted to this size of sample. One extra sample was also provided by the fully controlled dyeing process and considered as uniform reference.

3.2. Sample measurements

Samples were scanned by using a CanoScan 4400 F as conventional scanner in market. The employed resolution was 100 dot per inch (dpi). All images were converted to grayscale image and are shown in Figure 2. The converted grayscale images were saved as 2 dimensional matrices for further mathematical operations. To compare the results with classical method, the reflectance spectra of samples were also measured in 12 different randomly selected points of each fabric. Samples were measured using a Gretag Macbeth Color Eye 7000A spectrophotometer with the sampling geometry of d/8. The spectral range was from 400 to 700 nm at 10 nm intervals.

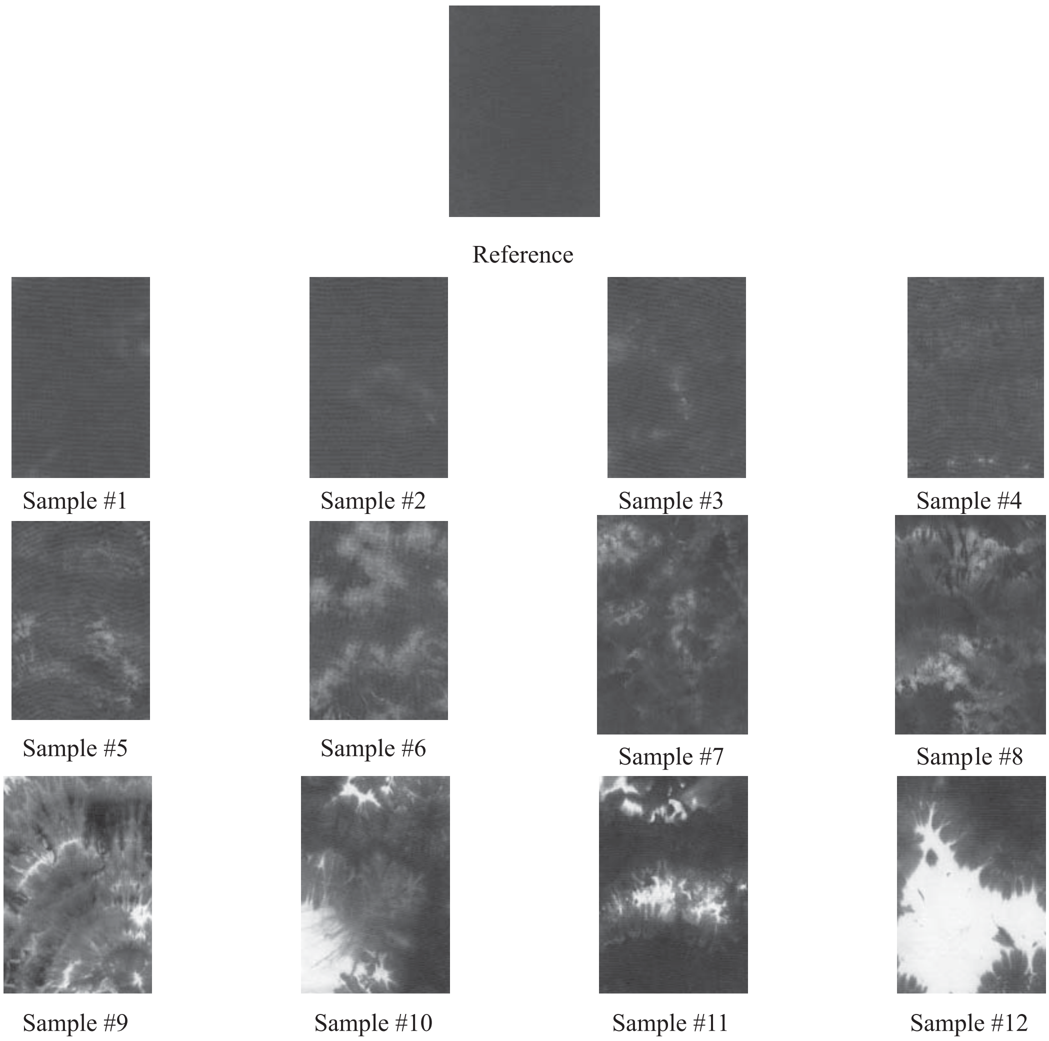

Figure 2. Gray scale images of samples with different degrees of unlevelness.

3.3. Visual assessment of unlevelness

All the visual evaluations were performed under a VeriVide light cabinet using a D65 light simulator. The viewing geometry was 0 / 45 and twenty five amateur observers were asked to arrange the samples according to the relative unevenness of samples to the reference sample and order them accordingly. The normal color vision of the observers was checked prior to the evaluation sequence by means of an Ishihara test. Besides, the observers took part in a short training program to become familiar with the concepts of the rank-ordering method. In order to avoid any presupposition, samples were randomly presented to the observers one by one and they were asked to find the position of the sample within the existing samples based on the closeness/farness from reference sample. In this way, the order gradually grew and samples were ordered according to the perceived unevenness of each observer. The resultant data consisted of average of the number of ratings assigned to each sample.

4. RESULT AND DISCUSSIONS

Equations 7, 9 and 12 were used to calculate the instrumental unlevelness factors by different methods. The validity of methods was checked by those obtained by visual evaluation of unevenness. Figure 3 shows the calculated unlevelness factors by different instrumental methods in comparison to the visual assessment. To make the comparison possible, results are normalized between 0 and 1. The correlation coefficients between the results of desired instrumental methods and the visual rank ordering technique were determined and are reported in Table 1. Besides, the differences between the desired methods and the visual evaluation were also computed by mean of the sum of absolute value (SAV) of differences between the assigned rating by different instrumental methods and the visual assessment and are shown as index of acceptability of method in Table 1.

According to Figure 3 and Table 1, the index obtained by SVD shows better correlation coefficient with visual assessment in comparison to other techniques and the result is confirmed by the smaller residual between these two methods. Both criteria, i.e. correlation coefficient and the SAV also confirm the priority of U_{STD2} over the $U_{(K/S)}$.

It should be emphasized that, due to the wide range of unevenness of unlevel samples, results of visual evaluation for highly unlevel specimen are not decisive and the observers were not certain in their decisions about such fabrics. The problem was originated from the fact that the reference fabric was adequately uniform while no reference was introduced as unlevel sample. In other words, the employed rank ordering method was open-ended visual experiment.

Table 1. The correlation coefficient and the sum of absolute value (SAV) of differences between visual and different instrumental methods.

Employed method	Correlation coefficient	SAV
U_{SVD} (using Equation 12)	0.8709	1.9718
U_{STD2} (using Equation 9)	0.8563	3.2256
$U_{(K/S)}$ (using Equation 7)	0.8391	3.2782

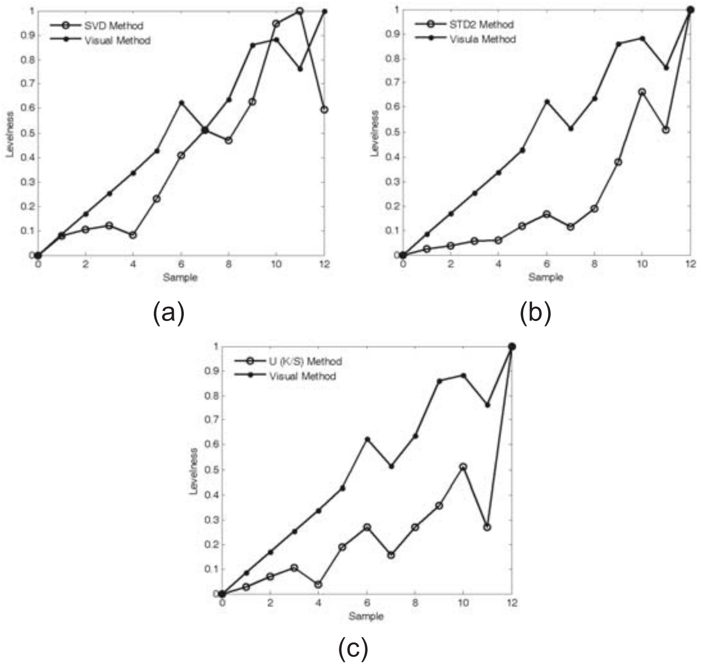

Figure 3. Visual rating versus levelness obtained by different methods, (a): singular value decomposition, (b): two dimensional standard deviation and (c): the weighted K/S method. Sample #o shows the reference sample.

5. CONCLUSION

Two new criteria i.e. U_{SVD} and U_{STD2} were introduced for quantitative evaluation of levelness/unlevelness of dyed fabrics with different degrees of unlevelness with various patterns. The first index employed the grayscale data of images of fabrics grabbed by scanner and analysis the complexity of unevenness of fabrics by determination of the singular value decomposition of created matrices. The second index calculated the two dimensional standard deviations of proposed matrices and compute an unlevelness factor accordingly. The performances of proposed techniques were compared with results of visual evaluations of samples as well as the $U_{(K/S)}$ index introduced as uniformity index. Both methods showed some types of priority over the previous quantitative method in comparison to visual assessments.

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