ASSESSING OF FABRIC APPEARANCE CHANGES USING IMAGE PROCESSING TECHNICQUES

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Abstract This paper describes the use of image processing to measure lightness changes of fabric appearance. The lightness changes due to dyeing, washing and exposure to light treatments are studied. These properties are measured by using the changes in the intensity levels of the fabrics image and the L* obtained by a spectrophotometer. For each case, analysis of variance (ANOVA) is carried out and the correlation between the intensity level and L* is computed. This study also investigates the use of angular power spectrum (APS) to quantify the variation in fabric surface protrusion due to washing.

Key Words Image processing, Fourier Transforms, Angular Power Spectrum (APS), Gray Level, Spectrophotometer, Color Fastness, Colorimetry, Analysis of Variance (ANOVA), Protruding Yarn Density, Lightness (L*), Fabric Appearance

چکیده در این مقاله به مطالعه و بحث در مورد «کاربردپردازش تصویری برای اندازه گیری تغییرات روشنایی سطح پارچه» پرداخته شده است. بدین منظور، تغییرات روشنایی منسوجات ناشی از عملیات رنگرزی، شستشو، و قرارگرفتن در معرض نور بررسی شده اند و با توجه به تغییرات شدت تصویر سطح خاکستری پارچه و L* بدست آمده توسط اسپکتروفتومتر اندازه گیری گردیده اند. در ادامه مطالعه، آنالیز واریانس برای هریک از عملیات فوق استخراج گردید. همبستگی بین شدت سطح خاکستری و L* محاسبه شد و تغییرات ایجاد شده در تراکم برآمدگیهای سطح پارچه در نتیجه عملیات شستشو با استفاده از طیف زاویه ای توان - مشخص گردید.

INTRODUCTION

When a fabric is subjected to appearance measurement, there are many factors that may influence its visual characteristics, including fabric structure, fabric production machinery, spinning technology of yarn production, material, protruding yarn density, and color fastness to light and wash. The periodic nature of the fabric surface permits the use of image processing techniques in Fourier transform analysis to consider fabric appearance. The application of image processing techniques to carpet appearance measurement has been established in the literature [1]. Wood [2] used Fourier and associated transforms to characteris carpet patterns. In a recent paper, fabric appearance changes, i.e., directionality and protruding yarn density as a function of weft density using an angular Fourier power spectrum was discussed [3]. It has also been shown that, the protruding yarn changes with wear [3]. However, little has been published about the fabric appearance changes. The aim of this study was to determine lightness changes of the fabric appearance due to dyeing, washing and exposure to light treatments based measurement of gray level intensity and L*. Then, the protruding yarn density changes under washing was evaluated using angular power spectrum.

THEORY

Texture may be defined as the global properties of an image with respect to the repeating units that compose it [1]. The overall appearance is evaluated by examining the mean and standard deviation of image intensities.

Overall Appearance

Intensity levels measured with a digitizer with an 8-bit resolution lie of 1-256, where black is represented by 1 and white is represented by 256. **z** was set as a random variable denoting a discrete image intensity, and $p(z_i)$, together with $i=1,2,3,\ldots,L$ as a corresponding histogram, where **L** is the number of distinct intensity levels. The nth central moment of **z** about the mean is defined as [4]

$$\mu_n(z) = \sum_{i=1}^{L} (z_i - m)^n p(z_i) \quad (1)$$

where **m** is the mean value of **z**

$$m = \sum_{i=1}^{L} z_i p(z_i) \quad (2)$$

The second moment which is also called the variance is important in texture. A feature that can be used to quantify uniformity is the coefficient of variance(CV%) given by

$$CV\% = (S/m) \times 100 \quad (3)$$

where S is the standard deviation.

Figure 1 shows a typical histogram of the surface appearance intensity of MJS fabric. The intensity level of samples after dyeing, washing and lighting treatments was measured and the results were expressed in terms of the intensity.

Angular Power Spectrum

The applicability of using the angular power spectrum (APS) which was first suggested by Weszka et al.[5], is discussed by Ravandi [3]. The magnitude and wavelength of a prominent angular power spectrum peak provide measures of protruding yarn density and directionality of fabric surface, respectively. The APS ($A(\theta)$) may be defined as

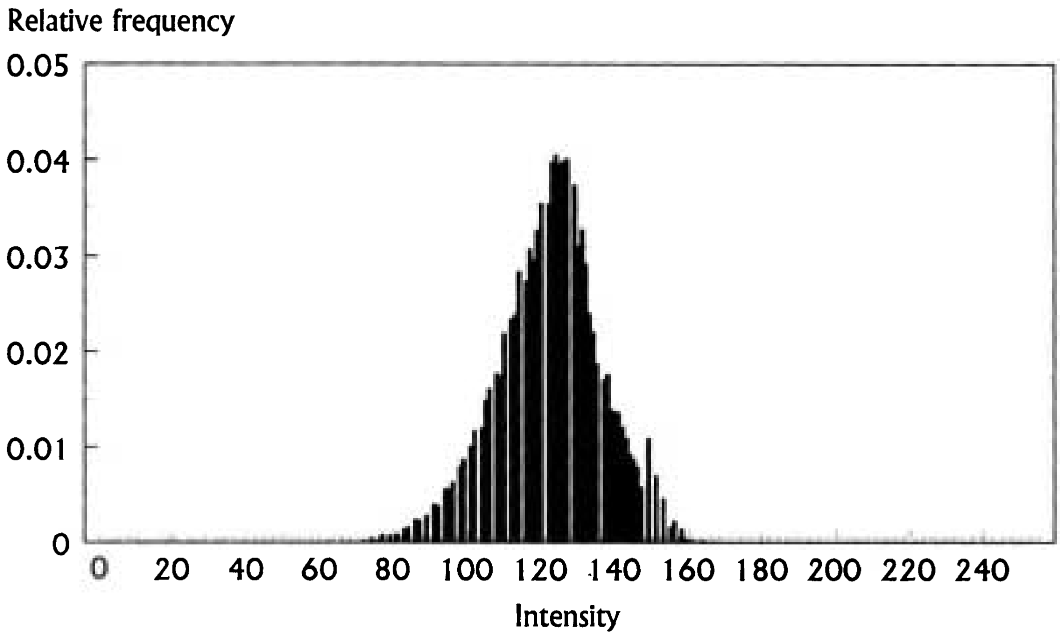


Figure 1. Histogram of fabric surface intensity

$$A(\theta) = \Sigma p_r(\theta) \quad (4)$$

where **p** is a two-dimensional power spectrum for an N×N image picture, and **r** varied from 1 to **R** and θ varied from 0 to 2π are the variables in the polar coordinated system. **R** is typically chosen as N/2. In this work **N** = 256 pixels.

Colorimetry

The lightness of samples after dyeing, washing and exposure to light treatments was measured by a spectrophotometer and the results were expressed in terms of the CIE **L* a* b*** color coordinate system. In this system **L*** stands for lightness component, **a*** for red-green component and **b*** for blue-yellow component. The chroma value is denoted by $c^* = (a^{*2} + b^{*2})^{1/2}$.

Measurement of fabric surface intensity might be readily derived from the monochrome images of the samples. Color alteration in fabrics due to washing and exposure to light treatments was believed to be essentially a lightness change. It was shown that the other components (**a*,b***) contributed more to the aesthetics than to the physics of a sample [6].

Statistical Analysis

The filling yarn does not have uniform properties and structure. Its diameter is not constant and its surface hairiness is not the same throughout its length. These variations may affect the fabric surface intensity and the abosrption of the dye. Analysis of variance (ANOVA) [7] was undertaken for the fabric surface intensity after dyeing, washing and exposure to lighting treatments. The ANOVA test compared the means of treatments which affected the fabric surface intensities in the experiments under consideration. Table 1 shows the average intensity level, CV% of intensity level and **L*** values for different fabrics after dyeing. **F** values indicated that there were differences among the yarn absorption of dye due to changes in different spinning systems. The level of confidence was 0.05 throughout this work.

EXPERIMENT

The video camera and lighting arrangements cause light variation and would influence the results. In this study, to optimize conditions for image acquisition and minimize the light variation, the image scanner Gt-8000 was used to capture images.

The captured area of fabric was 16×16 mm at a resolution of 256×256 pixels (400 dots per inch). Images were monochromatic with 256 gray levels, and at least four images were stored for each sample.

Five plain-woven fabrics with constant yarn densities of 16 and 25 thd/cm for weft and warp yarns

TABLE 1. The Results of Image Analysis Method and Colorimetry for Dyed Samples.

Sample	MJS	Core-Spun	Open-end	Carded	Combed	F Value
Intensity	123.19	126.9	126.1	124.52	125.77	20.23> 3.06
CV% Of Inten.	12.01	14.1	12.26	11.54	11.84	
L*	58.21	59.6	58.24	58.12	58.88	

were investigated, respectively. The warp yarn was cotton/polyester (50/50) with a linear density of 26/1 tex. The difference between the 5 fabrics was that the weft yarns with a linear density of 28/1 tex were commercial cotton yarns produced using 5 different systems namely, combed, carded, air-jet (Murata jet spinning: MJS), open - ended and core-spun. The fabrics were coded with these spinning system name i.e. MJS. Bleached fabrics, dyed by Direct scarlet 4BS (C.I Direct Red 23), were used for the test.

RESUTLS AND DISCUSSION

Color Fastness to Wash

Washing was conducted by a computerised wash fastness instrument (Polymath from Data Color), which was programmed for 30 minutes at 60±2°C. Mechanical washing in water using domestic detergent and also sodium powders was carried out. The hardness of the water, used throughout washing, was 24° French. Assessment of alteration of samples was done according to the ISO 105-A02 standard method. In addition, the lightness **L*** and the average intensity levels of the samples before and after washing treatments were measured. The fastness to wash of the five sets of fabrics used in this work was also assessed by seven experienced judgers, using sets of ISO reference fabrics as a guide. The grades ranges from 1 (extreme change) to 5 (no change). The overall results of the assessment between the judges were very close and these results are given in Table 2. Alteration indicated that there were differences among the fabrics in terms of color fastness to wash due to different spinning systems and weft yarn structure.

Color Fastness to Light

The color fastness of the samples after 8 hours of exposure to light (D65) using Suntest from Hanaus

TABLE 2. The Results of Color Fastness to Wash.

Sample	Color Fastness	ΔL*	Δint
MJS	4 - 5	2.01	-0.13
Core-spun	3 - 4	1.75	1.24
Open-end	3 - 4	0.49	1.54
Carded	4	0.02	3.89
Combed	3 - 4	0.02	3.54

group was measured based on a standard method (ISO 105-A02). Similarly, the lightness L* and the average intensity levels of the samples before and after exposure to light were measured. The subjective assessment was derived by experts as mentioned in the previous section. The grades ranged from 1 to 8. Table 3 summariezes the results and shows the differences between the color fastness of the samples.

Image Analysis Results

In Tables 4 and 5, the intensity level, CV% of intensity level and **L*** values for all samples after washing and exposure to light treatments are listed. **F** value indicated that, for both washing and exposure to lighting treatments, there were differences among

TABLE 3. The Results of Color Fastness to Light.

Sample	Color fastness	ΔL*	Δint
MJS	1-2	2.29	5.92
Core-spun	2-3	3.35	6.33
Open-end	1-2	2.80	4.64
Carded	2	1.99	5.17
Combed	2-3	1.17	3.60

TABLE 4. The Results of Image Analysis Method and Colorimetry of Washed Samples.

Sample	MJS	Core-Spun	Open-end	Carded	Combed	F Value
Intens ity	123.32	125.66	124.56	120.62	122.23	12.28> 3.06
CV% Of Inten.	11.66	12.92	11.49	12.62	12.22	
L*	60.22	61.35	58.73	58.46	58.86	

TABLE 5. The Results of Image Analysis Method and Colorimetry of Lighted Samples.

Sample	MJS	Core-Spun	Open-end	Carded	Combed	F Value
Intensity	129.11	133.23	130.34	129.69	129.38	10.6> 3.06
CV% Of Inten.	11.93	13.94	12.4	11.69	12.23	
L*	60.50	62.95	61.04	60.11	60.05	

the fabrics. By using this method, the differences between at least two samples could be distinguished.

The difference between the **L*** values before and after treatments (Δ**L***) and intensity valeus (Δint) are presented in Tables 2 and 3. The correlation coefficients between the Δ**L*** and Δint were calculated to be 0.76 and 0.91 for the lighted and washed samples respectively. These correlations indicate that the Δint can be used instead of Δ**L*** as an indicator of fabric lightness changes due to washing or exposure to light treatments.

Correlation between L* and Intensity

By using correlation alanalysis, a possible relationship between the **L*** parameter and the corresponding fabric surface intensity could be reflected by the values of correlation coefficients. As shown in Table 6, there was sufficient correlation between **L*** (0.72) of the dyed fabric, **L*** (0.71) of the wahsed fabric, **L*** (0.96) of the lighted fabric, and intensity of fabric surface obtained by the image processing method.

Measurements of a wide range of fabrics (more than 50 samples) varying in both color and construction showed that there is a correlation coefficient of 96% between the intensity obtained by image processing techniques and **L*** value as measured by spectrophotometer. This is illustrated in Figure 2. These results indicated that it is possible to use the intensity level instead of **L*** as an indicator for

TABLE 6. Correlation Coefficient between L* and Intensity Measurement.

	Dyed	Washed	Lighted	Overall
Lightness VS. Intensity	0.72	0.71	0.96	0.96

measurement of fabric appearance lightness.

Protruding Yarns Under Washing

The angular power spectrum (APS) waveforms were applied to show fabric surface directionality as well as to differentiate surface protrusion changes as a function of washing treatment. The magnitude of the APS peaks were normalised by the corresponding mean values of the power spectrum. In this study, the importance of washing was revealed through its influence on the protruding yarn density. Figure 3 shows the normalized spectrum energy by the corresponding mean values of power spedctrum of carded sample.

The first prominent peak at 90° corresponded to the warp protruding yarns, which give lines in the warp direction on the fabric surface. The other prominent peak at 180° corresponded to the weft protruding yarns. Table 7 presents the total energy of prominent peaks obtained from APS analysis, including protruding yarns density and its reduction after dyeing and washing treatments. In general, protruding yarn density decreased after washing and its reduction was greater for warp yarns than for weft yarns. After washing, the warp protruding yarns disappeared, while the weft protruding yarns diminshed and the fabric appeared as a regular surface.

CONCLUSIONS

Current methods of lightness change assessment are based on subjective appraisal. The procedures developed in this study demonstrated the improtance of the image processing and ANOVA analysis as a new approach to distinguishing the differences of the lightness between different samples. The study showed that it was possible to use the changes in the intensity levels of the images of the fabrics to measure the lightness changes of fabric appearance due to washing and exposure to light treatments.

It was confirmed that for both washing and

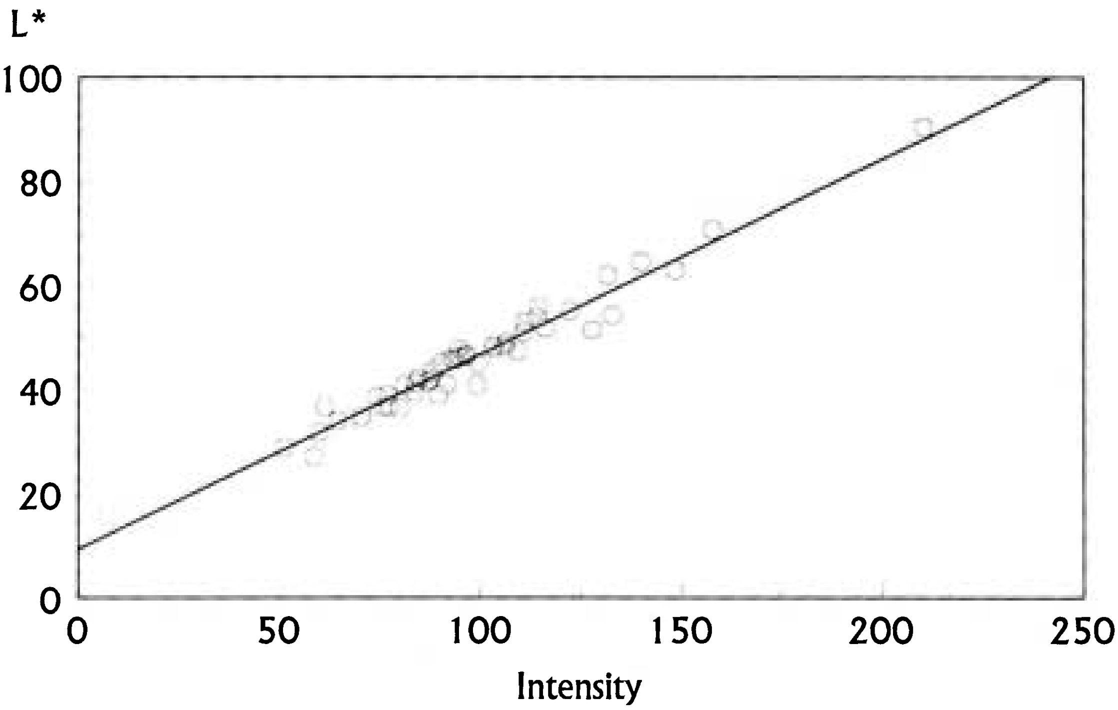
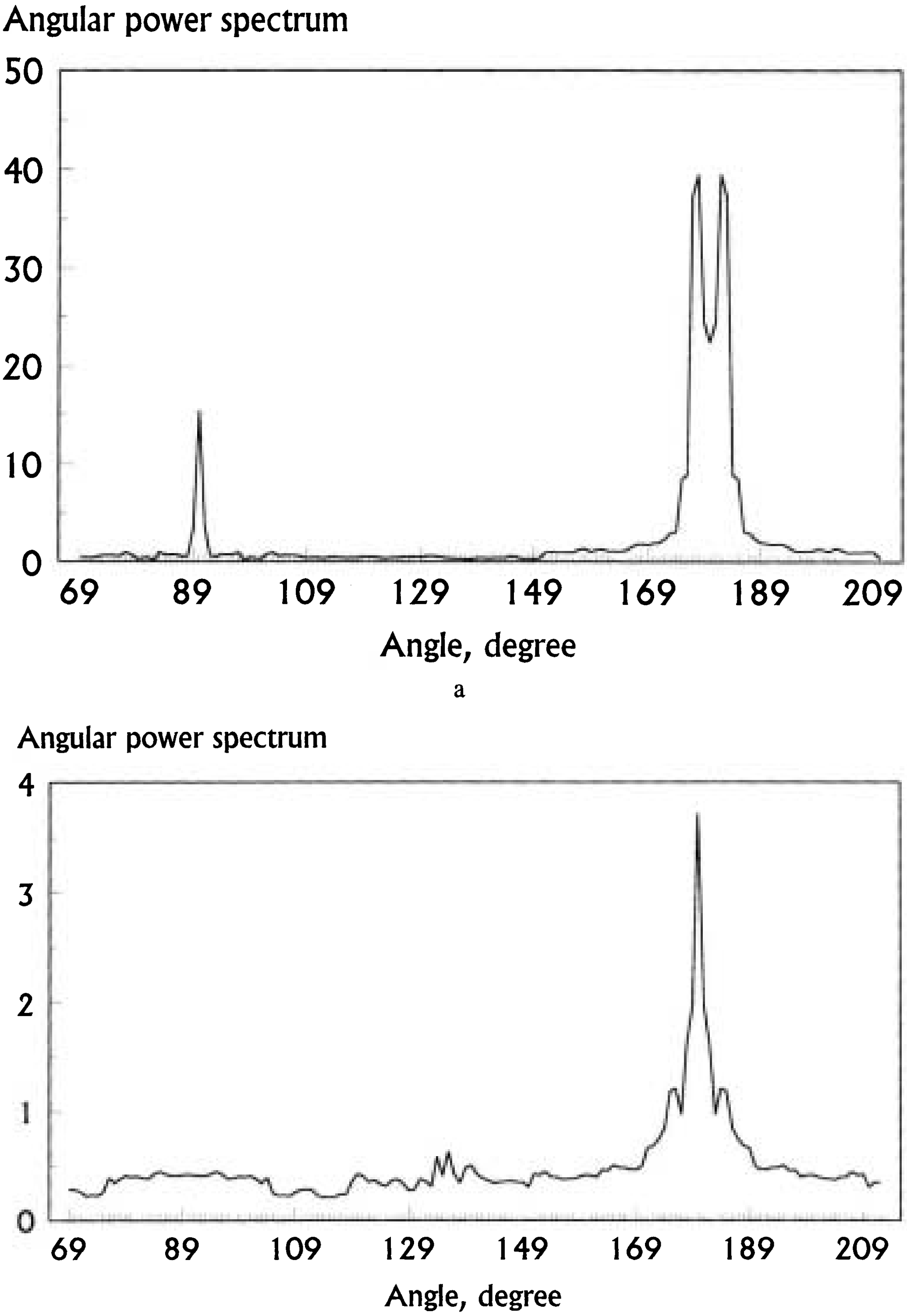


Figure 2. Relationship between intensity and lightness of fabric surface.



a

Angular power spectrum
4
3
2
1
0
69
89
109
129
149
169
189
209
Angle, degree

b

Figure 3. a) Angular power spectrum of fresh carded fabric, **b)** Angular power specturm of washed carded fabric.

TABLE 7. Protruding Yarn Density under Washing (se/mps)[A].

	Untreated Samples Direction		Dyed Samples Direction		Washed Samples Direction	
	Warp	Weft	Warp	Weft	Warp	Weft
MJS	13.6	267.7	-[B]	147.0	-	96.4
Core-spun	11.6	222.0	3.9	162.5	5.8	103.3
Open-end	21.8	223.8	-	39.0	-	27.0
Carded	17.0	352.6	-	160.0	-	20.0
Combed	16.6	252.4	-	123.0	-	80.0

A: Spectral energy/mean of power spectrum
B: The value is less than one.

exposure to light treatments, there were differences among the color fastness of the fabrics made from yarns produced by the various spinning systems.

The reduction of protruding yarns after washing was evident. For weft protruding yarns, carded and open-ended types had the highest reduction while MJS and core-spun types had the lowest reduction.

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