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A Simple Method for Measuring Fabric Drape Using Digital Image Processing

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Abstract

Drape is an important property, which affects the aesthetic appearance of fabrics used in garments in this study, a simple, easy and precise method for measuring fabric drape using the image processing technique was demonstrated. The study was conducted using a range of knitted and woven fabric samples. The fabrics were conventionally evaluated using the German drape meter instrument. The average drape coefficient of each fabric sample obtained through the conventional drape meter technique was compared statistically with that obtained through the new proposed digital technique. The results agreed with those obtained from the image processing technique with a high correlation coefficient (r=0.9970). Drapeability assessment has been done on the basis of changes in drape coefficient (DC), drape parameters, node parameters and structural parameters. Also, a method of expressing drape, node and structural parameters relating to the drape coefficient of fabrics has been developed. This method involves the area of polygon area. Two regression models were proposed for both conventional and digital image techniques and for all fabrics using the multiple linear regressions. The regression results were analyzed in terms of correlation coefficients. These regression models are shown to predict the drape coefficient accurately.

Keywords: Image processing; Drape coefficient; Drape parameters; Node parameters; Matlab program; Multiple regression; Polygon area

Introduction

Fabric drape is defined as the ability of a fabric (a circular specimen of known size) to deform when suspended under its own weight in specified conditions [1]. Drape is a unique property that allows a fabric to be bent in more than one direction describing a sense of graceful appearance. The role of drape in a garment is an important aspect of aesthetics. It is also one of many factors that influence the aesthetic appearance of a fabric and has an outstanding effect on the formal beauty of the cloth [2-4].

The drape characteristic of a fabric is a 3-D phenomenon. Conventionally, drape is measured using a drape meter and characterized by drape coefficient (DC). The drape coefficient is the widely used parameter to describe fabric drape but it needs other parameter to explain the fabric behaviour [5]. Along with drape coefficient, there have been other node parameter such as; number of nodes, nodes dimensions (node width, node height and node length), nodal distance and other drape parameters such as drape distance ratio, drape profile area, fold depth index and amplitude are required [6-11].

Chu et al. [12] concluded that the drape diagram provides three parameters; the area of the sample, the number of nodes, and the shape of the nodes. They further concluded that the node number is directly related to the drape coefficient. Moreover, there is no method available which can combine all aesthetic attributes to express the fabric quality from appearance point of view. Efficiency and effectiveness of industrial work mostly depend on labour work, manufacturing time, fixed cost and variable cost. The main aim of this paper is to decrease labour work time, as well as cost. So high efficiency can be obtained. In this work a computer vision system is proposed to measure and integrate most important aesthetic attributes of an apparel fabric.

The objective of this paper is to develop a simple, easy and accurate method, based on image processing techniques, to measure and recognize fabric drape of different coloured and printed dresses fabrics.

Experimental Work

Fabrics used

For this study, twelve cotton fabric samples were used with a wide range of areal densities and thickness. Detailed specifications of each sample are listed in Table 1.

Methods of measuring fabric drape

Conventional drape technique: The apparatus used for measuring drape coefficient was the German Drape meter Instrument as shown in Figure 1**.** Figure 1 shows the front view of the German drape tester. The German drape tester is widely used to measure drape of the fabrics in the textile and apparel industries especially in Egypt.

German drape meter instrument illustrated in Figures 1and 2 was used to measure fabric drape coefficient. This apparatus consists of base (1) fixed on it a regulator slider (2), short ruler (3) and pointer (4) can be used for measuring the radius of the outline edges of the draped fabric by the help of a movable sensitive pin (5). Two support discs (7) of 15 cm in diameter are mounted on the top of vertical shaft (8) and fabric sample of 25 cm in diameter is placed between them provided that the center of both discs and fabric sample is the same. The movable graduated disc (6) is fixed in the vertical shaft at a height of 1 cm from base. The perimeter of graduated disc (6) is equally divided into 16 divisions. The two support discs (7), vertical shaft (8), and graduated

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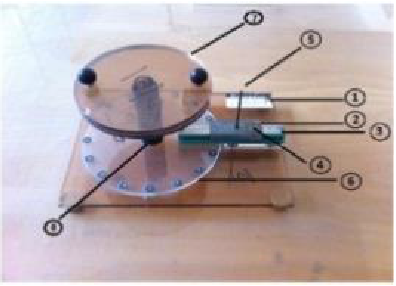
Sample No.	Fabric structure	Fabric weight (g/m²)	Fabric thickness (mm)	No. of yarns (cm⁻¹)		Yarn linear density (tex)	
				warp/wale	weft/course	warp	weft
1	S. jersey	146.7	0.6	21	16	-	46.1
2	S. jersey	96.8	0.45	27	20	-	29.5
3	S. jersey	208.8	0.75	20	14	-	66
4	Plain weave	95.7	0.12	36	34	14	16.2
5	Plain weave	152.8	0.15	30	30	43	55.2
6	Plain weave	113.1	0.37	30	30	20.2	20.2
7	Plain weave	123.3	0.4	36	30	20.9	20.9
8	Plain weave	84.5	0.2	30	27	14	16.2
9	Plain weave	125.3	0.35	31	26	20.9	20.9
10	Plain weave	146.7	0.1	32	29	45.1	57.3
11	Plain weave	171.1	0.67	15	9	43.7	58.5
12	Plain weave	250.6	0.8	16	12	38.6	36.5

Table 1: Specifications of fabric samples.



1- Base, 2-Regulator Slider, 3-Short ruler, 4-Pointer, 5-Sensitive pin, 6-Graduated Disc, 7-Two support discs, 8-Vertical Shaft

Figure 1: German drape tester.

Figure 2: Top view of draped fabric sample No. (5).

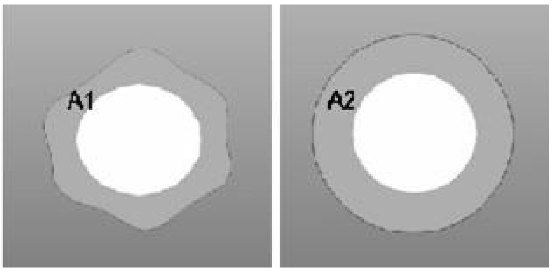


Figure 3: Areas of A_1 and A_2.

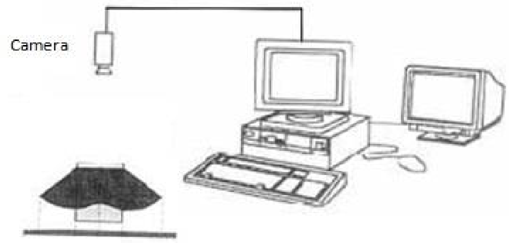


Figure 4: The schematic diagram of the digital drape meter.

disc (6) go round together as one unit. The vertical shaft and its fixed group is mounted and allowed to rotate over the base of the tester.

Measurement: In this conventional method, a circular fabric sample 25 cm in diameter (d_2) is allowed to drape horizontally over a support disc (7) of 15 cm in diameter (d_1). Typically, the fabric deforms as a series of folds around the disc. By rotating the graduated disc (6) horizontally, the polar radius of the outline of draped sample across the sixteen divisions was measured using the sensitive pin (5). The average of the sixteen radii can be calculated (r) and consequently, the average diameter of the annular ring (d_s) can be calculated (ds=2r). By using the values of d_1, d_2 and d_s drape coefficient (DC) is conventionally calculated as follows [13]:

$$DC = \frac{\textit{Area under the draped sample} - \textit{Area of support disc}}{\textit{Area of the specimen} - \textit{Area of support disc}} \quad (1)$$

$$Dc = \frac{d_2^2 - d_1^2}{d_2^2 - d_1^2} = \frac{d_2^2 - 225}{400} \quad (2)$$

I.e., The drape coefficient (DC) is expressed as the ratio of (A_1) and (A_2) in percentage as shown in Figure 3 and eqn. (3).

$$\text{Drape Coefficient(DC)} = \frac{A_1}{A_2} \times 100 \quad (3)$$

Two specimens, 25 cm in diameter, were cut from each of the fabric samples. The test was carried out six times for each fabric sample, three times with the face of the fabric and three times with the back of the fabric.

Digital image drape technique: In the suggested digital image process, the instrument setup shown in Figure 4 consists of: a digital camera to capture the draped image of the mounted fabric sample (25 cm in diameter) placed on a rigid support disc (15 cm in diameter) which is fixed over a vertical shaft with its pedestal (13 cm in height). The smaller rigid support disc (15 cm in diameter), the vertical shaft and its pedestal are placed on a frosted glass table (lighting box) with a homogenous white light from the bottom; and a personal computer (PC) to analyze the captured image and translate it into appropriate output. Figure 5 shows a typical schematic drape profile captured by this technique. The digital camera was mounted above the draped fabric. The camera was mounted at a height 62.5 cm from the frosted glass table sufficient to focus the area of shaded part of the draped configuration. The size of the captured images is 640 × 480 pixels which represents a fabric sample with dimensions of 28.572 × 21.429 mm.

In this investigation, a 25 cm diameter fabric sample was used to provide a uniform platform for testing the fabric samples in both conventional and digital methods. In the suggested image process, sample mounting, that is lowering the sample to form the drape configuration of the fabric, was executed identically to the conventional method. After allowing the sample to fall, the image of the draped configuration was captured using a commercial digital camera. Next, the captured image was transmitted to a computer and processed using a Matlab program.

This image was then saved in the computer and processed by the program to give the various drape parameters such as drape coefficient (DC), drape distance ratio (DDR), drape profile area circularity (DPA), fold depth index (FDI), amplitude (A), and number of nodes (NON). These additional five parameters describe the folds generated during wearing. The drape distance ratio shows the inner distance of the folds whereas the fold depth index is the index for the generated folds. Amplitude gives the idea of the depth of the folds, while the value of (DPA) ranges from 0 to 1, the value of 1 for the perfect circle and value towards zero for complex profiles whereas number of nodes is the total number of folds generated in the profile.

***Definition of geometrical drape parameters*:**

$$\text{Drape Coefficient }(\text{DC}) = \frac{A_s - A_1}{A_2 - A_1} \quad (4)$$

$$\text{Drape Distance Ratio }(\text{DDR}) = \frac{r_2 - r_s}{r_2 - r_1} \times 100\% \quad (5)$$

$$\text{Drape Profile Area Circularity}(\text{Roundness}),\ (\text{DPA}) = 4p\frac{As}{p^2} \quad (6)$$

$$\text{Fold Depth Index}(\text{FDI}) = \frac{r_{max} - r_{min}}{r_2 - r_1} \times 100(\%) \quad (7)$$

$$\text{Amplitude}(A) = \frac{r_{max} - r_{min}}{2} \quad (8)$$

Where A_s is the area of the draped fabric image

A_1 is the area of the fabric supporting

A_2 is the area of the undraped fabric sample

r_1 is the radius of the fabric supporting disc

r_2 is the radius of the undraped fabric sample

r_s is the average distance to edge of draped fabric (ri) and

P is the perimeter length of the profile outline of the draped fabric.

***Definition of node parameters*:** The number of nodes (NON) was counted and measurements node width (NW), node height (NH), node length (NL) from the center of the sample and node distance (ND), respectively, were taken for each node as shown in Figures 6 and 7, [14-16].

In earlier papers [5,11,17,18] both drape and node parameters were measured and calculated as depicted in Figure 5, [12,16].

***Application of proposed image processing technique to calculate drape coefficient*:** A more economical way to calculate drape coefficient (DC) was developed in this study. This new method was based on counting the number of pixels of inner and outer area of the draped image. Therefore, this principle can be applied to calculate the drape coefficient. Procedure of this method is described below:

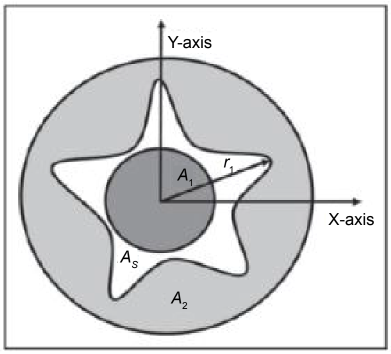


Figure 5: The outline of a drape profile.

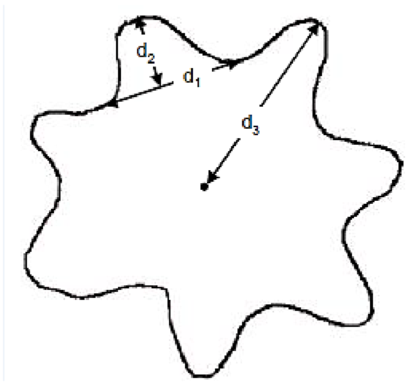


Figure 6: Measurement of nodes and node dimensions.

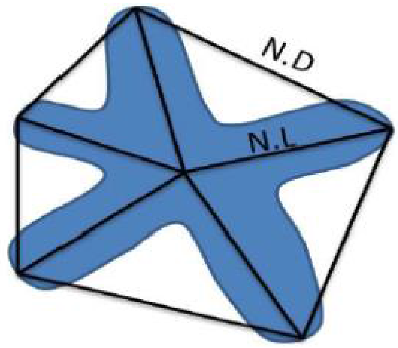


Figure 7: Diagram depicting manual method of calculating node parameters.

Image acquisition**: 1)** A Sony digital camera 20X optical zoom model (DCR-TRV460E) was used to capture the images of each draped sample with a resolution of 568.946 pixels per inch. **2)** The fabric samples (25 cm in diameter) were mounted on a rigid support disc (15 cm in diameter) which is fixed over a shaft with its pedestal (13 cm in height).

The support disc and the shaft with its pedestal are placed on a frosted glass table (light box) with a homogeneous white light from the bottom. **3)** The camera is fixed over the center of the support disc at a height of 62.5 cm from the frosted glass table using a frame grabber.

Four images for each draped sample were captured to calculate the average area of each one. The draped configuration of the captured image was then selected using the best resolution.

Image transmission to a matlab program: The captured images were transmitted to a computer using Matlab program.

Image reading on a matlab program**:** Then, the images were read on the Matlab program as RGB images to make a processing on them afterwards.

Image conversion from RGB to gray: In order to make processing on images, the RGB images were converted into gray ones to simplify dealing with them. An example of this conversion is presented in Figure 8a and 8b.

Image enhancement**:** The RGB image were converted into gray ones to remove the noise and makes the images more clear.

Image conversion from gray to binary**:** After removing the noise from the images, they will be ready to be converted into black and white image, to be suitable for the next step. An example of applying this step is presented in Figure 9a and 9b.

Figure 8a: Image of a draped.

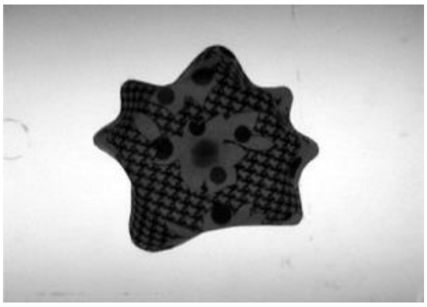


Figure 8b: Image of a draped.

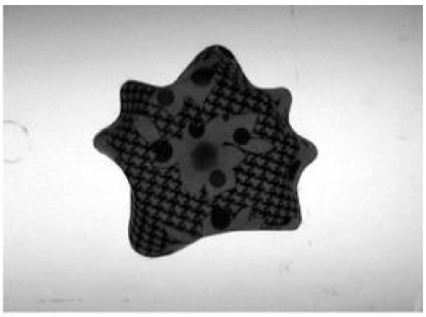


Figure 9a: Image of the draped fabric before converting it RGB to binary

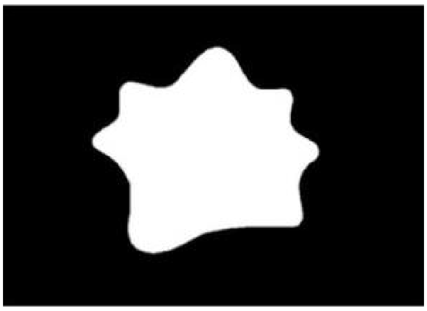


Figure 9b: Image of draped fabric after converting it from gray to binary.

Object recognition**:** A Matlab program was created to recognize the objects in every image. It is obvious to the eye that each image has one object only of the shaded part of the draped sample, which is confirmed also by the Matlab program.

Calculating the area of shaded part**:** Then, the Matlab program is used to calculate the area of the shaded part in pixels to be used consequently in drape coefficient (DC) calculations.

Calculating the drape coefficient (DC): According to the calculated area of the shaded part in pixels in the previous step, the following equation was used to calculate drape coefficient (DC) [19].

$$DC = \frac{(\text{Total selected pixels} \div \text{pixels per cm}^2) - \text{Area of support disc } \left(\text{cm}^2\right)}{\text{Areaof the specimen}\left(\text{cm}^2\right) \; - \; \text{Areaof support disc}\left(\text{cm}^2\right)} \quad (9)$$

Comparison between image processing technique and conventional drape meter technique**:** A comparison between the results of the image technique and conventional drapemter technique showed that the results of both techniques are very close. Thus, the suggested digital image technique is very simple, easy and accurate and can be used in a wide range to avoid the human errors during testing the drapeability in the laboratory.

Evaluation of drape parameters**:** The drape coefficient is the widely used parameter to describe fabric drape but it is not sufficient to completely explain the fabric behavior. Thus, five drape parameters e.g., drape coefficient (DC) drape distance ratio (DDR) drape profile area circularity (DPA), fold depth index (FDI), and amplitude (A) and five node parameters e.g. number of nodes (NON), node dimensions (node width d1, node height d2, node length d3) and node distance (ND) of these fabrics were measured using a special developed vision system [20] based on the image processing technique.

Polygon area method: This method involves the use of polar diagram, which offers a pictorial representation of the drape of the fabric. It was felt that such a polar diagram might form the basis of a simple method for expressing drape completely in a numerical form.

The inclusive assessment of fabric drape could be estimated by using the relative characteristics method of the quality [21]. The relative characteristics of fabric drape could be calculated from the following equations:

$$Kj = \frac{Xi}{Xmax}, \text{(for positive characteristics)} \quad (10)$$

$$Kj = \frac{Xmin}{Xi}, \text{(for negative characteristics)} \quad (11)$$

Where,

Kj=relative characteristics of drape

Xi=individual readings of each property

Xmax=max. value of the same property

Xmin=min. value of the same property

This method can be represented from a knowledge of number of properties (n) in the inclusive assessment, which starts from the same point at the center and make an angle (2π/n) between them. And the coordinates can be joined and a polygon can be obtained (Table 1).

For the inclusive assessment of fabric drape the area of this polygon could be calculated from the following equation:

$$A = \frac{1}{2}\mathrm{Sin}(2p/n)\left(K_1K_2 + K_2K_3 + K_3K_4 + K_4K_5 + K_5K_6 + K_6K_1\right) \quad (12)$$

Where A=polygon area of each fabric;

n=6-number of the measured properties.

Also, an inclusive coefficient of fabric drape (I) can be calculated as follows:

$$I = (A/Amax) \times 100, \quad (\%) \qquad (13)$$

Where

Amax= maximum polygon area when $K_1=K_2=K_3=K_4=K_5=K_6=1$ and equal to 2.598

Results and Discussion

The face, back and overall average (DC) values using both conventional and digital image techniques are listed in Table 2. Each face and back value is the average of four readings from two test specimens. A total of sixteen trials were carried out to estimate the variation caused by repeated draping of the same fabric sample.

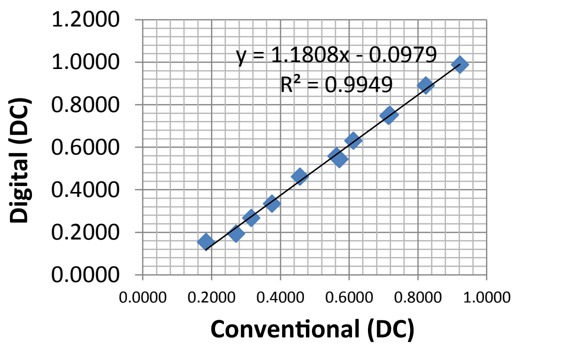


Figure 10: Relationship between conventional and digital drape coefficient.

The difference percent in drape coefficient (DC) obtained with the suggested simple digital process and the conventional process for each sample is given in Table 1. It should be noted that the value of each drape coefficient measurement ranges from 0.1836 to 0.9219 for the conventional process and from 0.1550 to 0.9885 for the suggested simple digital image process. The mean difference percent for the tested fabric sample was in the range of +3.95 % for drape coefficient (DC).

The overall average drape coefficient (DC) for each of the twelve fabrics tested with conventional and digital image methods is shown in Figure 10. A correlation coefficient (R) of 0.9973 demonstrates that the suggested simple digital method of obtaining drape coefficient results compared to those obtained using the conventional German drape tester is valid and accurate.

The two methods of measuring drape coefficient (DC) were stated: The results from a paired t-test (tcal.=0.0104099 is less than t tabular=2.228), suggest that there is no significant difference between the drape coefficients obtained using the conventional.

German drape meter and the digital image process: This shows that measurement of drape using the image processing method is a viable alternative to using the German drape meter. In order to evaluate the appearance of fabric drape, the meaning of accurate representation of a specific fabric must be defined.

The range of variation exhibited by each fabric in the drape parameters: (drape coefficient (DC), drape distance ratio (DDR), drape profile area circularity (DPA), fold depth index (FDI) and amplitude (A)) and node parameters: (number of nodes (NON), node width (NW), node height (NH), node length (NL) and node distance (ND) and structural parameters: (fabric weight (W), fabric thickness (T) and fabric bulk (B) are listed in Table 3.

Comparison between conventional and digital image techniques

Statistical analyses were made by calculating the correlation coefficients to compare the various means of assessing fabric drape. Correlations were examined between fabric properties and measured drape coefficient (CD). The results are shown in Table 4. Significant and strong correlations were noted between drape coefficient (DC) and fabric properties as listed in Table 5. The results of this study led to a modification of the properties considered to be important components

Sample No.	Fabric structure	No. of Nodes	Drape Coefficient (DC)						Difference %
			Conventional method			Digital image method			
			Face	Back	(Average)	Face	Back	(Average)	
1	jersey	13	0.1928	0.1744	0.1836	0.155	0.1548	0.155	15.63
2	jersey	10	0.2778	0.2636	0.2707	0.1945	0.1941	0.1943	28.22
3	jersey	8	0.3129	0.3167	0.3148	0.269	0.268	0.2685	14.71
4	Plain	8	0.3826	0.3681	0.3754	0.335	0.3354	0.3352	10.71
5	Plain	7	0.4601	0.4526	0.4563	0.461	0.4622	0.4616	-1.16
6	Plain	5	0.5387	0.5871	0.5629	0.558	0.5586	0.5583	0.817
7	Plain	6	0.5532	0.5898	0.5715	0.544	0.5446	0.5443	4.76
8	Plain	6	0.6229	0.6005	0.6117	0.6305	0.6315	0.631	-3.16
9	Plain	8	0.735	0.6933	0.7141	0.748	0.7478	0.7479	-4.73
10	Plain	5	0.7017	0.7343	0.718	0.759	0.7594	0.7592	-5.738
11	Plain	6	0.8145	0.8314	0.8229	0.89	0.8914	0.8907	-8.24
12	Plain	4	0.929	0.9149	0.9219	0.988	0.989	0.9885	-7.22

Table 2: Conventional and image drape coefficient values of fabric samples.

Sample No.	Drape parameters					Node parameters	
	Y	X_1	X_2	X_3	X_4	X_5	X_6
	DC (-)	DDR (+)	DPA (-)	FDI (+)	A (+)	NON (+)	NW (-)
1	0.155	77.25	0.5124	38	0.95	13	31.31
2	0.1943	67.44	0.6394	57.5	1.4375	10	44.7
3	0.2685	62.67	0.6405	67.25	1.68125	8	58.25
4	0.3352	56.31	0.5771	56	1.4	8	63.75
5	0.4616	48	0.6832	81.5	2.0375	7	94.57
6	0.5586	37.84	0.84	57.5	1.4375	5	131.4
7	0.5442	37.03	0.8088	86	2.15	6	102.83
8	0.631	33.28	0.8773	68	1.7	6	126.83
9	0.7479	24.03	0.9434	49.5	1.2375	8	105.13
10	0.7529	23.69	0.8953	46	1.15	5	127
11	0.8907	14.59	0.9569	40	1	6	137.33
12	0.9889	6.33	0.9959	34.8	0.87	4	191.5

Table 3: Values of drape and node parameters of fabric samples.

Sample No.	Node parameters			Structural parameters		
	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
	NH (-)	NL (-)	ND (-)	W (-)	T (-)	B (+)
1	14.54	131.62	63.209	146.7	0.6	4.08998
2	24.7	143.3	88.042	96.8	0.45	4.64876
3	33.88	153.75	113.881	208.8	0.75	3.59195
4	39.88	163.13	122.473	95.7	0.12	1.25392
5	47.86	173.29	149.074	152.8	0.15	0.981675
6	56	177	203.708	113.1	0.37	3.27144
7	43.83	176	164.858	123.3	0.4	3.24412
8	47.33	183.6	136.749	84.5	0.2	2.366864
9	32.25	180.38	137.655	125.3	0.35	2.793296
10	52.4	187.2	191.432	146.7	0.1	0.68166
11	39	189.5	152.186	171.1	0.67	3.915839
12	48.75	194.75	191.503	250.6	0.8	3.192338

Table 4: Values of drape and node parameters of fabric samples (continued).

No.	Fabric properties	Drape coefficient (DC)	
		Conventional method	Digital image method
		(M_1)	(M_2)
Drape parameters			
1	Drape distance ratio (DDR)	- 0.99859 *	- 0.99502 *
2	Drape profile area (DPA)	0.96112 *	0.95604 *
3	Fold depth index (FDI)	-0.2266	-0.3259
4	Amplitude (A)	0.62988	-0.22663
Node parameters			
1	Number of node (NON)	- 0.81544 *	- 0.79363 *
2	Node width (NW)	0.94381 *	0.94073 *
3	Node height (NH)	0.62037 *	0.60419*
4	Node length (NL)	-0.04533	-0.03022
5	Node distance (ND)	0.77827 *	0.76095 *
Structural parameters			
1	Fabric weight, g/m² (W)	0.36486	0.37659
2	Fabric thickness, mm (T)	0.08815	0.09225
3	Fabric bulk, cm³/ g (B)	-0.41313	0.21191

*The highest correlation coefficient and more than 0.50.

Table 5: Correlation coefficients for drape coefficient measurement versus fabric properties.

of drape and to be included in any polar diagram according to the correlation coefficient (>0.5) between drape coefficient and each property. Therefore, drape distance ratio (DDR), drape profile area circularity (DPA), number of nodes (NON), node height (NH) and node distance (ND) were retained while the other properties were eliminated.

Moreover, determination of the fabric drape coefficient by using digital image has several advantages, such as simplicity in its evaluation, accurate and easy to use in the textile testing laboratory as well as the difficult coloured and printed fabrics [1,4,8,12].

The relative values of properties considered to be the most important were plotted to produce the polygon diagrams for sample [1,4,8,12] as shown in Figure 11 . Hence, the polygon area of each sample was determined as listed in Table 5. The lager polygon area the lower drape coefficient (the better fabric). The fabric drape was measured by the above mentioned method in order to compare the reliability of the results obtained by the suggested methods. The results are given in Table 6. Correlation between the different values of the drape coefficient which are determined by the different methods are given in Table 7. All the values of fabric drape coefficient were significantly correlated at 0.05 level to the drape coefficient measured by the suggested digital image method (M_2).

Relating aesthetic properties using multiple regression analysis

To investigate the interaction of selected fabric parameters, an equation relating the drape coefficient to the various parameters of drape distance ratio, drape profile area, number of nodes, node width

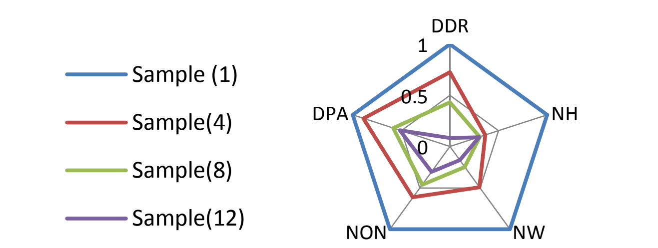


Figure 11: Polygon diagrams for tested samples.

Sample No.	Drape coefficient (DC)		Polygon area (M3)	
	Conventional method	Digital image method		
	(M_1)	(M_2)	A	I, %
1	0.1836	0.155	2.59808	100
2	0.2707	0.1943	1.43611	55.277
3	0.3148	0.2685	1.03381	39.7925
4	0.3754	0.3352	1.16057	44.6716
5	0.4563	0.4616	0.66727	25.6839
6	0.5629	0.5586	0.42641	16.4128
7	0.5715	0.5442	0.49736	19.144
8	0.6117	0.631	0.45557	17.5352
9	0.7141	0.7479	0.50689	19.5105
10	0.718	0.7529	0.32552	12.5295
11	0.8229	0.8907	0.3342	12.8637
12	0.9219	0.9889	0.184044	7.08406

Table 6: Values of fabric drape coefficient measured by the different method.

Method No.	Conventional method	Digital image method	Polygon area method	
	(M_1)	(M_2)	A	I, %
M1	-	0.99734	-0.84915	100
M2	-	-	-0.82656	55.277
M3	-	-	-	39.7925

Table 7: Correlation coefficient between the fabric drape coefficient for the different methods.

and node height was fitted to the experimental results using multiple linear regression analysis [22] in the following form.

$$y = Co + \sum_{i=1}^{6} CiXi \quad (14)$$

where Y=drape coefficient, Xi=measurable drape and node parameters and co, and ci the constant and coefficient terms.

a) **For conventional method (M1)**

DC=1.045-0.01 DDR-0.082 DPA-0.002 NON+0.001 NW -0.002 NH

(R^2=0.999) (15)

b) **And for digital image method (M2):**

DC=0.942 -0.013 DDR -0.170 DPA+0.022 NON+0.001 NW+0.001 NH

(R^2=0.994) (16)

It is clear from the above that the number of nodes, node width and node height can be considered as strong parameters when compared to the other drape parameters. The total appearance of the fabric is the complex interaction between various aesthetic properties and they have both independently and together been related to drape distance ratio (DDR) and drape profile area circularity (DPA) of fabric. Since, Equations (15,16) show relationships between drape coefficient (DC), drape distance ratio (DDR) and drape profile ratio (DPA). The fitted regression equations were used to predict the drape coefficient for each fabric. Table 8 and Figure 12 show the verification between the measured and predicted drape coefficient. As can be seen, the points fall on a straight line normally distributed with no bias, indicating that empirical Equations (15,16) give a good fit to the experimental data.

Sample No.	Drape coefficient (DC)			
	Conventional method (M_1)		Digital image method (M_2)	
	measured	predicted	measured	predicted
1	0.1836	0.2067	0.155	0.1825
2	0.2707	0.2935	0.1943	0.245982
3	0.3148	0.3403	0.2685	0.286535
4	0.3754	0.4026	0.3352	0.391493
5	0.4563	0.4938	0.4616	0.498286
6	0.5629	0.6071	0.5586	0.60468
7	0.5715	0.6115	0.5442	0.601774
8	0.6117	0.6604	0.631	0.666379
9	0.7141	0.752	0.7479	0.782612
10	0.718	0.7469	0.7529	0.771229
11	0.8229	0.865	0.8907	0.897987
12	0.9219	0.986	0.9889	1.018657

Table 8: Comparison between measured and predicted values of drape coefficient for conventional and digital image method.

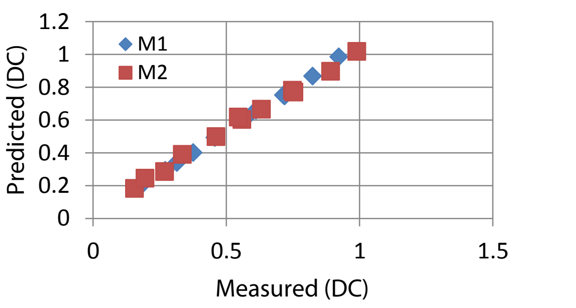


Figure 12: Verification of the measured with predicted drape coefficient.

The multiple correlation and coefficients between the fitted equations and the experimental results as indicated in equations (15,16) are 0.999 and 0.994 respectively. Thus, the empirical equations discussed above predict the drape coefficient for twelve random sample well.

Conclusion

In this paper, a simple, rapid and precise technique of image processing is being developed for measuring fabric drape. This technique is advantageous for industrial economization for different dresses fabrics in addition to coloured and printed fabrics.

Also, the new suggested explained digital method was found to have advantages of reducing manual error and storing an archived image of the draped samples for future reference to help apparel industry to be developed.

Drape coefficient (DC) obtained through the new digital method has been shown to be highly correlated (R=0.9973) with the drape coefficient obtained through the conventional German drape meter technique.

A method of expressing drape and node parameters relating to the fabric drape has been developed. This method involves the area of polygon diagram which offers a representation of the drape of a fabric.

This study included the following three different methods by which the fabric drape could be assessed: drape coefficient measured (by German conventional method), (by digital image processing), and polygon area method.

We concluded that there was a fairly good agreement between the different methods used in this study.

The multiple regression analysis has enabled successful computation of drape coefficient and DDR, DPA, NON, NW and NH. Thus, it will be possible to predict drape coefficient from the above equations for the known variables.

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