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New Approach to Directly Acquiringe the Drape Contours of Various Fabrics

Abstract
A drape instrument for fabric was designed that employed a backlight to directly acquire drape images of a fabric. The image segmentation method including a gradient operator and Kittler & Illingworth's threshold method were used to find the fabric contour moving inward from the outer edge of the image. The contour was then used to calculate the drape coefficient of the fabric. Experiments have shown that this method can directly acquire a fabric contour which is not readily obtainable by means of projective capture or no-backlight acquisition.

Key words: *drape instrument for fabric, image segmentation, fabric-drape contour, fabric-drape coefficient, gradient operator method.*

Introduction

In 1950 Chu et al designed an F.R.L. Drapemeter to measure the drape of a fabric [1]. By projecting a parallel light vertically onto fabric drape, this instrument calculated the projected area using the Planimeter method. In 1968 a diverging light was installed on Cusick's Drapemeter to replace the costly parallel light [2]. At the same time the paper-weighting method was employed to replace the Planimeter method. In 1993 Vangheiuwe and Kiekens employed Computerised Image Analysis to measure the drape coefficients of a fabric according to the pixels showing on the projected area [3]. That way the subjectivity caused by the paper-weighting method could be avoided. In 1997, a stepping motor was employed by Cheng to control the rotational speed of a Drapemeter [4]. As a result, the dynamic drape of a fabric can be measured by calculating the projected area with the help of computer software specialised in analysing computerised image. In 2005, Kenkare and May-Plumlee captured a digital image of draped fabric using Cusick's Drapemeter, which was then processed using Adobe Photoshop software to measure the drape coefficient [5 - 6]. In 2007, Shyr and Cheng successfully developed an automatic measuring system for dynamic drape to evaluate the static and dynamic drape coefficients of natural-fibre fabrics [7 - 9].

Here the drape image of a fabric is typically obtained via the methods of projective capture [1 - 7] and direct acquisition [8 - 12]. Several researches have developed computer techniques, such as the finite-element and finite-difference methods, the particle-based method for the simulation of fabric behaviours [13 - 16]. When finding the fabric contour via the projective capture method, the fabric image appears as a single gray scale image. This eliminates the difficulty of finding the contour of fabric that has a pattern. However, the projected light is not truly parallel, and consequently the scattering of the projection causes the edges of the fabric to be blurry; therefore the edge cannot be found with certainty. Furthermore, it is difficult to find the real contour when the fabric is relatively transparent with a distinct pattern in a deep colour. In addition, when the projective capture method is used on a relatively thin fabric, the high transparency leads to an obvious difference in the gray scale between the overlapping and non-overlapping portions of the drape folds. This also makes it hard to find the real edge points of the contour. Variations in colour depth in relatively transparent fabric may also cause significant local transparency variations in the fabric image.

The direct acquisition method is mainly used with plain fabric [8 - 12]. When the foregoing acquisition methods are used to analyse fabric with colours and patterns, the colours and patterns will lead to a large gray scale contrast during gray scale processing. In addition, when the direct acquisition method is used to analyse highly reflective fabric, the fabric image tends to contain areas with significant gray scale differences. This method usually makes mistakes in locating the fabric contour. How to distinguish the true drape contour remains a problem in edge identification technology. In order to resolve this problem, a fabric drape instrument was designed in this study using a backlight to directly acquire images. The use of a backlight can increase the contrast between the fabric and background, enhance the clarity of the profile, and highlight the contour of the fabric. In addition, the use of a backlight ensures that the gray scales of the background are very uniform. The image segmentation method, including a gradient operator, and Kittler & Illingworth's threshold method were used to find the contour edge of a fabric. A program was written for tracing the profile contour. This program can locate all types of gray scale and transparency contour by working inward from the outer edge of the image, as well as calculate the drape coefficient.

Procedure for locating the drape contour

The method used in this study for locating the drape contour of fabric is shown in ***Figure 1***. The steps include the use of a backlight to directly acquire a drape image, conversion to a gray scale image, calculation of the gradients of the image, calculation of the threshold value of the gradients using Kittler & Illingworth's threshold method, and finding the edge points of the fabric contour from the outer margin. The connection of these points forms a contour, which is then used to calculate the area of the fabric drape, and the drape coefficient.

Drape instrument for fabric using backlight to directly acquire images

the drape instrument for fabric developed in this study uses an even backlight behind and underneath the fabric to obtain a clear image of the drape contour. Since the light shines up from below, an acrylic plate is placed above the illumination source to diverge the light. This ensures a more even background brightness, enhances the contrast between the background and fabric image, and facilitates tracing of the fabric contour. We refer to a fabric image obtained directly using a backlight as the "backlight image," and a fabric image acquired using natural light without a backlight as the "no-backlight image." A CCD camera is located above the fabric and directly acquires a fabric image using backlight, as shown in ***Figure 2***. Backlight consists of a light source, such as a cold cathode fluorescent (CCFL) and a rectangular light guide, which is also referred to as a light pipe. In this study two 24W cold cathode fluorescent (CCFL) tubes were used as a light source.

Image segmentation of the drape contour

Image segmentation seeks to determine the edge between objects and the background. Because there is a sudden change in the gray scale at the edge between the object and background, we can use the gray scale gradients to find the edge. First the gray scale gradients in the image are calculated, and then they are used to calculate the threshold value (T). When the gradient of a pixel in the image is greater than the threshold (T), the pixel is defined as an edge point [17 - 19]. The calculation method is shown below, where $f(x,y)$ gives the image's gray scale, and the gradient is defined as:

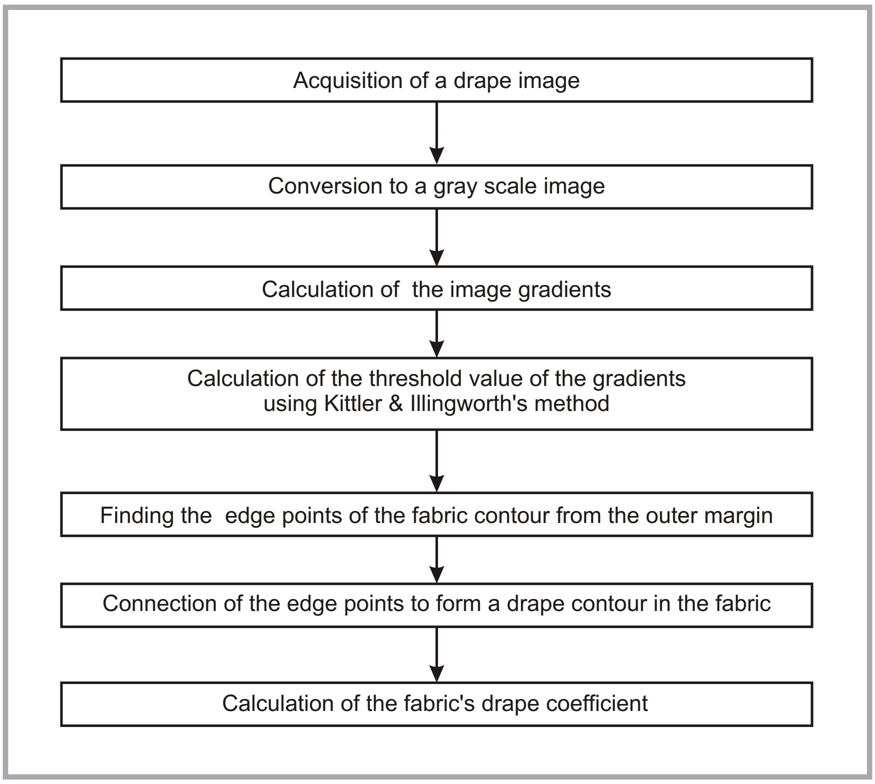

Figure 1. *Diagram of procedures for locating a drape fabric's contour.*

$$\nabla f = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad (1)$$

Using a finite difference, we can obtain

$$\frac{\partial f}{\partial x} \approx f(x+1, y) - f(x, y) \quad (2)$$

$$\frac{\partial f}{\partial y} \approx f(x, y+1) - f(x, y) \quad (3)$$

The magnitude of the gradient can be expressed as:

$$|\nabla f| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \quad (4)$$

Each pixel gradient obtained using the foregoing gradient operator is defined as $G(x,y)$. Kittler & Illingworth's threshold method is then used to obtain the threshold (T) [20]:

$$T = \frac{\sum (G(x,y) \times S(x,y))}{\sum S(x,y)} \quad (5)$$

Here,

$$S(x,y) = \max(|-G(x-1,y) + G(x+1,y)|, |-G(x,y-1) + G(x,y+1)|) \quad (6)$$

The threshold method requires little computation time and can, therefore, speed up the process of finding the fabric drape's contour.

Constructing a fabric profile contour

As mentioned above, all edge points in the image of the fabric can be detected using a gradient operator and the threshold method. However, to avoid mistaking an internal pattern for an edge point of the fabric contour, the edge points of

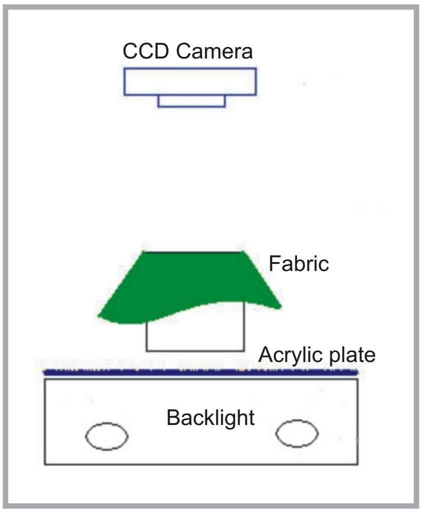

Figure 2. *Schematic diagram of direct acquisition of a fabric image using backlight.*

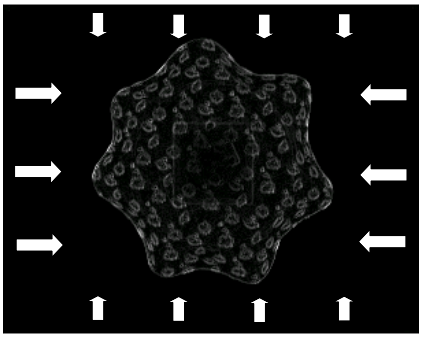

Figure 3. Schematic diagram of the location of the contour edge points of a fabric by searching inward from the outer margin of the fabric image.

the contour are located on the outside. A schematic diagram of the location of the edge points of the contour is shown in ***Figure 3***. A selected fabric with different depths of colour, different patterns, high transparency, and local variations in transparency was used in a detailed account of the procedure of locating the drape contour. The method we used finds the contour edge points of a fabric by looking at individual points, starting from the outer margin and working inward, as shown by the arrow. The program will stop searching after finding the first edge point of the contour. If the program fails to find an edge point, it saves searching time by concluding its search in an area of one-half of the search dimension. Some fabrics have a small number of contour edge points missing because of high transparency or the gray scales of the edge points and background are rather similar as a result of low contrast. In such a case, the program connects each edge point with the nearest one, thus creating a complete drape contour.

Calculation of the drape coefficient

After the drape contour has been found using the foregoing method, the total number of pixels within the contour is calculated and used to find the real area of the fabric image, which allows the actual drape area (A) to be derived. This result is substituted into the drape coefficient formula below and yields the drape coefficient of the fabric. The drape coefficient is calculated as follows.

$$\text{Drape coefficient in \%} = \frac{\acute{A} - \acute{A}_1}{\acute{A}_2 - \acute{A}_1} \times 100 \qquad (7)$$

where A, A_1, and A_2 are the actual projected area of the specimen in cm^2, the area of the supporting disk in cm^2, and the area of the specimen in cm^2, respectively.

Experiment

The present study obtained empirical results for 12 selected woven fabric samples. For each of the samples, it is difficult to find the real contour using the methods of projective capture and no-backlight acquisition. Analyses were performed on samples in static states with different thicknesses, different depths of colour, different patterns, different transparencies, local transparency variations, and different degrees of reflection. Fabric for the experiment was bought from the open market. The composition of the warp and weft raw material was the same. The linear density of each fabric was calculated and listed in ***Table 1***. The specifications of the experimental woven fabrics are given in ***Table 1***.

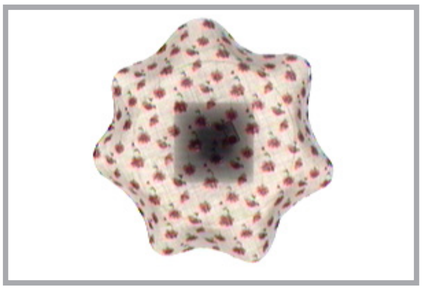

Figure 4. Digital image of a fabric.

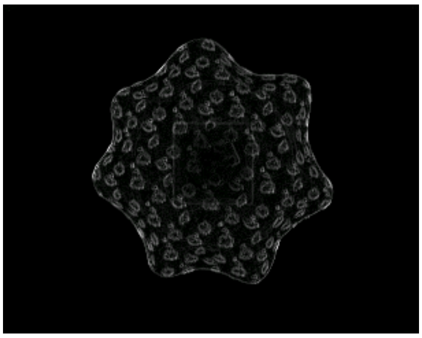

Figure 5. Image of a gray scale gradient.

We will first define some of the image types mentioned in this paper in order to facilitate the explanation and discussion of the experimental results. These include a directly acquired digital image with a 304×240 image resolution (see ***Figure 4***), a gray scale gradient image (see ***Figure 5***), an image of the edge points of a fabric contour detected using the gradient operator from Equation 4 and Kittler & Illingworth's threshold method from Equation 5 (see ***Figure 6***), an image of the fabric contour (see ***Figure 7***), and

Table 1 *Basic properties of the selected woven fabrics.*

Sample no.	Colors group	Fabric type	Warp density, ends/cm	Weft density, picks/ cm	Linear density*		Thickness, mm	Weight, mg/cm^2
					count	dtex		
1	different patterns	Cotton	38	28	32	–	0.42	11.77
2	local transparency variations	Cotton	31	30	36	–	0.58	10.01
3	different patterns	Cotton	28	25	20	–	0.65	16.43
4	different patterns	Cotton	32	38	40	–	0.47	10.56
5	local transparency variations	Linen	25	25	64	–	0.47	12.97
6	local transparency variations	Linen	28	22	48	–	0.56	17.33
7	various colours	Silk	47	60	-	15	0.18	5.51
8	various colours	Silk	50	40	-	25	0.32	7.43
9	relatively high transparency	Silk	71	54	-	15	0.20	4.99
10	relatively high transparency	Silk	50	40	-	27	0.28	8.09
11	relatively high transparency	Silk	63	39	-	15	0.21	5.33
12	various colours	Wool	28	25	32	-	0.47	15.85

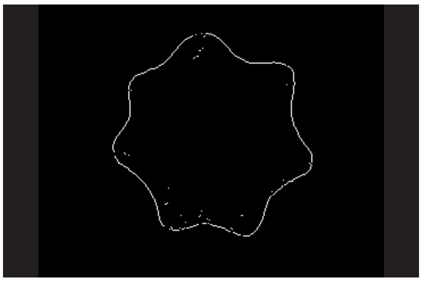

Figure 6. Image of the edge point of a fabric contour.

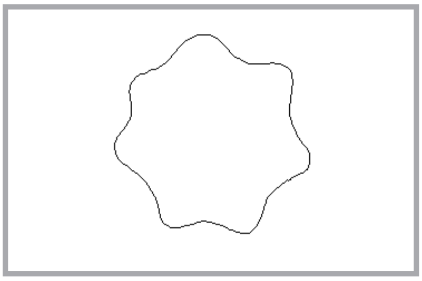

Figure 7. Image of a fabric contour.

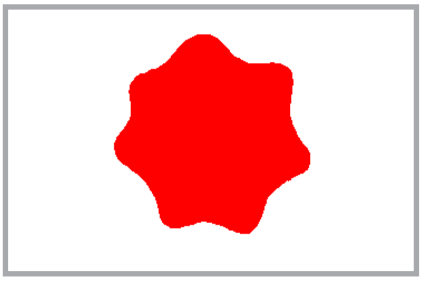

Figure 8. Image of a soli fabric contour.

an image of a solid fabric contour (see ***Figure 8***).

Figure 4 shows a directly acquired digital image taken in a darkroom using a backlight. ***Figure 5*** shows the resulting gray scale gradient image when the gray scales of the digital image are substituted into a gradient operator (Equation 4) to calculate the gradients, which are compressed within a range of 0-255. ***Figure 6*** shows the results of using Kittler & Illingworth's method (Equation 5) to calculate the threshold condition. The threshold is used to find the edge points of the fabric contour, which are indicated as white dots. Each fabric drape contour was captured once in this study. ***Figure 6*** also reveals that some contour edge points were not found due to the fact the the search proceeded inward from the outer margin, and continued to find the contour edge points of the fabric's internal pattern. The contour's edge points found are not true for the fabric contour due to the fabric's high transparency or the reflective luster of the fabric's surface. ***Figure 7*** shows the image of the fabric contour that results from connecting the edge points of the fabric contour located. ***Figure 8*** shows the image of a solid fabric contour resulting from adding a red colour to the image of the fabric contour. The number of red pixels in this image is used to calculate the fabric drape area. The drape coefficient of the fabric can then be calculated.

Results and discussion

Comparison of the Backlight and No-backlight Images

In order to compare the effect of backlight on a fabric drape image, ***Figure 9*** shows images of two fabric samples with patterns. The left upper row contains digital images of two pieces of patterned fabric acquired with a backlight in a darkroom. The lower left row contains images of located edge points of the fabric contour. The upper right row contains digital images of the fabric taken under natural illumination without backlighting. The lower right row contains images of the fabric contour edge points obtained using natural illumination. These images reveal that the fabric contour is clearly visible when the image is acquired directly under a backlight, which helps improve the gray scale contrast between the fabric and background. The contrast between the edge points of the fabric contour and the background is not distinct when there is no backlight, which makes it difficult to find a clear profile contour of the fabric. The edge points of the fabric contour appear intermittently, many of which being erroneous. It is obvious that the direct acquisition of a fabric drape image using a backlight yields clear and complete contour edge points.

Finding the fabric drape's contours

Images were acquired from samples of cotton, linen, silk, and woven wool fabrics, which included different thicknesses, different depths of colour, different patterns, different transparencies, local transparency variations, and different degrees of reflection. In order to achieve significant contrast between the fabric image and background in the gray scale images, images were obtained in a darkroom. Since all illumination, apart from the backlight, was eliminated, even the fabrics with a high reflectivity did not have surface reflections. Some representative drape fabric images and contour location results are shown in ***Figures 10, 11, 12,*** and ***13*** (see pages 58 and 59). ***Figure 10*** shows images of fabrics with different colours; from left to right the colours are deep gray, light violet and dark red. The first row shows digital images of three fabric samples. The second row contains fabric contour images, and in the third row there are drape coefficients of the fabrics. ***Figure 11*** shows images of fabrics with different colour combinations and patterns; from left to right the patterns consist of spots, stripes and checks. ***Figure 12*** shows images of three pieces of fabric with high degrees of transparency. ***Figure 13*** shows images of fabrics with different depths of colour, different patterns, high transparency, and local variations in transparency.

Finding the fabric contour in the foregoing samples revealed that when gray scale processing is performed on fabrics with varied colours and patterns, such as the samples shown in ***Figure 10***, the patterned portion of the fabric with deep colours will yield greater gray scale contrasts than other portions of the fabric. In the method of locating the edge points of the fabric contour by working inward from the margin, we can avoid the mistake of taking the edge points of patterns

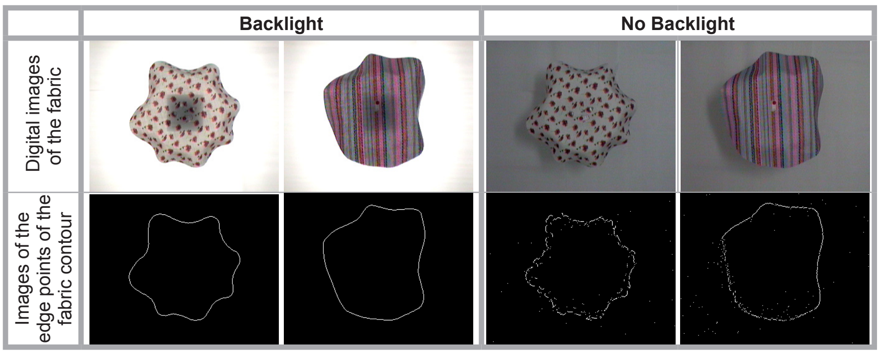

Figure 9. Comparisons of directly acquired fabric drape images with and without a backlight.

for the real edge points of the fabric contour. In the case of relatively thin, highly transparent fabrics, such as the samples in ***Figure 12***, the high transparency of the fabric tends to cause a greater gray scale contrast in places where the fabric drape is clearly visible and where the fabric image overlaps at the drape folds. While it is relatively easy to identify and locate the edge points of a fabric contour in these places, the small gray scale contrast between the fabric contour and background in other places makes it harder to find the real contour edge points. However, for all the samples analysed, a small number of edge points can not be detected in each image. In such cases each contour edge point is connected with the nearest one using a straight line, creating a complete fabric contour. In the case of highly transparent fabrics with different depths of colour, such as the samples in ***Figure 13***, fabric images tend to have a local internal variation in transparency. In such a case the direct image acquisition method, the use of a backlight to increase the gray scale contrast between the fabric and background, and the location of the edge points of the fabric by searching inward from the margin can yield clear fabric image contours. This facilitates the location of the edge points of a fabric contour, which enables the construction of a fabric contour image and the calculation of the fabric's drape coefficient.

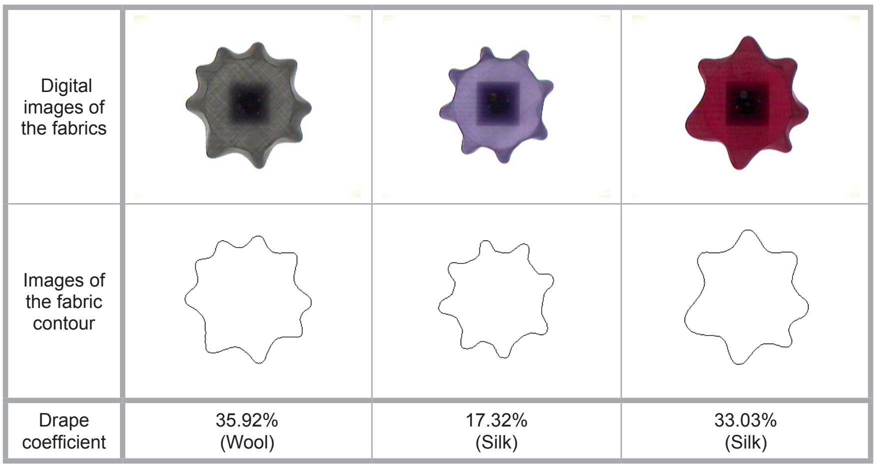

Figure 10. *Images of fabrics with varied colors.*

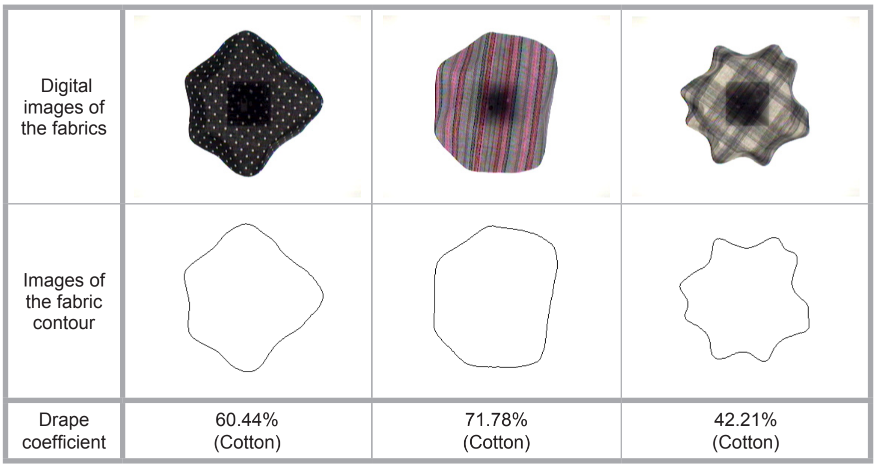

Figure 11. *Images of fabrics with different patterns.*

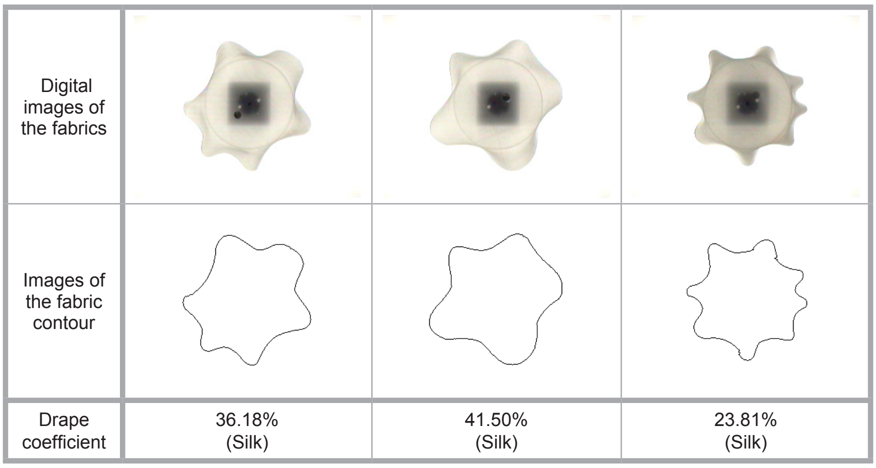

Figure 12. *Images of fabrics with relatively high transparency.*

Conclusions

The foregoing experimental results clearly prove that the fabric drape instrument developed in this study can effectively enhance the gray scale contrast between the fabric and background when directly acquiring fabric drape images using a backlight in a darkroom. The resulting significant difference in the gray scale facilitates the use of the image segmentation method including a gradient operator and Kittler & Illingworth's threshold method to determine the real edge points of the fabric contour , construct a fabric contour image, and calculate the fabric's drape coefficient. In locating the edge points of the fabric contour by working inward from the outer margin, we can avoid problems such as too close grey level between the edge points of the fabric contour and the background, as well as the mistake of identifying the edge points of the fabric's internal pattern as edge points of the fabric contour . If the edge points of the fabric contour are discontinuous, the program will subsequently connect the nearest points to form a continuous fabric contour. The experiments showed that this method can directly acquire fabric drape images using a backlight in a darkroom and can calculate the drape coefficient of fabrics made of different fibres, possessing different thicknesses, different depths of colours, different patterns and designs, high transparency, local transparency variations, and high reflection.

Acknowledgment

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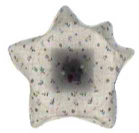
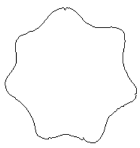
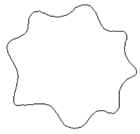
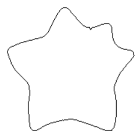
Digital images of the fabrics			
Images of the fabric contour			
Drape coefficient	49.76% (Linen)	37.67% (Linen)	29.47% (Cotton)

Figure 13. *Images of fabrics with local transparency variations.*

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