# A New Analysis Method for the Drape Shape of Fabric

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**Abstract:** A new method of the analysis of drape-ability of fabrics using Fourier descriptor is proposed. Drape-ability is conventionally evaluated by measuring the drape coefficient related to mechanical property of fabrics. However, it was pointed out that the visual appearance of drapes was not always related to the drape coefficient. Recently, a method of the direct characterization of the visual appearance of drapes using Fourier power spectrum was proposed. In this paper, it is proposed that the G-type Fourier descriptor, which is an expansion of a closed curve to a Fourier series, is employed for drape analysis. The proposed method achieves not only the characterization of drapes but also the circular abbreviation of drape shapes and selective reconstruction of vibrations based on their frequencies.

**Keywords:** drape analysis, image processing, Fourier descriptor,

## 1. INTRODUCTION

Drape-ability of a fabric is a characteristic yielding an unevenness on the surface of the fabric when it is hung down by its own weight. It is an important characteristic that is highly affective to visual kansei on the silhouette of dresses. A number of investigation has discovered that drape-ability is closely related to bending stiffness, shear properties, weight, and thickness of fabrics (Kawabata and Niwa, 1989; Dhingra et al., 1989). There is a discussion whether drape-ability should be evaluated in static status or its dynamic properties should be evaluated (Matsudaira et al., 1993).

The drape coefficient is a three-dimensional static evaluation which is widely used as a quantitative evaluation of drape-ability. When a sample of a curicular fabric is hung down from a cylinder top, the drape coefficient is defined as $(S_2 - S_0) / (S_1 - S_0)$, where $S_0$ is the area of the sample table, $S_1$ is the area of the sample, and $S_2$ is the area of the vertical projection of the sample, i. e. the area of the drape shape. It is a standard method in the textile science to use the drape coefficient of fabric in order to evaluate the drape-ability of the fabric. The conventional studies for drape coefficient have often focused on its accurate calculation methods or on its relationship with the mechanical properties (Sanad et al., 2012; Sanad et al., 2013).

However, Mizutani et al. pointed out that fluctuations in the traced contour line of fabric drape are different even when they showed the same value in the drape coefficients (Mizutani et al., 2005). It indicates that the drape coefficient does not always agree with the visual impression. Dhyr et al. proposed a new evaluation method that did not use the ratio of areas such as the drape coefficient but employed statistical abbreviations of the number and sizes of vibrations appearing on an actual fabric and showed relationships to the mechanical properties (Shyr et al., 2009).

Recently, a method of directly analyzing the visual appearance of drapes using Fourier transformation was proposed (Sanad et al., 2012; Sanad et al., 2013; Kokas-Palicska et al., 2008). This is an attracting method utilizing the progress of digital image processing. However, the method only uses the Fourier power spectrum as a general characteristic of a drape.

In this paper, we propose a novel method employing the G-type Fourier descriptor, which decomposes a closed curve into a series corresponding to the frequencies and amplitudes of waves composing the curve, for the analysis of the curves obtained by the measurements of drape-ability. The method generates the average circle of the curve, and generates simplified curves by selecting the frequency of vibrations for observing the characteristics of the vibrations precisely. We apply the method to several kinds of fabrics, and show the relationship between their visual appearance of drapes and their characteristics yielded by the proposed method.

## 2. G-TYPE FOURIER DESCRIPTOR

Fourier descriptor is a method of expressing characteristics of curves by transforming a curve into a function in some way and decomposing this function into a combination of waves by Fourier analysis. Fourier descriptor has been widely used as a method for feature extraction in pattern recognition problems such as hand-written character recognition. Fourier descriptor is categorized into several types based on the transformation method of a curve into a function. We employ the G-type Fourier descriptor (Granlund, 1972) in this study.

The G-type Fourier descriptor assumes that the target closed curve is on the complex plane. A starting point on the curve is fixed, and we define a function that assigns a complex number $x + yi$ to the length along the curve between the starting point and the point $(x, y)$ . This function is periodic, since it is composed by tracing the closed curve from a point. A periodic function is expressed as a Fourier series, i. e. a series of exponential functions corresponding to sinusoidal waves whose wavelengths are $1 / n$ $(n = 1, 2, \ldots)$ of the period of the original periodic function, and the complex amplitude of the wave of each wavelength is expressed as a Fourier coefficient. A partial sum of the terms where the corresponding wavelengths are longer than a certain value, i. e. the frequencies are lower, yields a simplified curve where vibrations of higher frequencies are removed.

Since the contour of the edge of a fabric is a closed curve in the measurement of drape-ability, the G-type Fourier descriptor can be applied to the analysis. We can obtain a circle that is the


**Figure 1:** Experimental setup.

**Table 1:** Profiles of the samples.

| Sample No. | a (W1) | b (C3) | c (C1) |
|---|---|---|---|
| Material | Wool 100% | Cotton 100% | Cotton 100% |
| Structure | Plain Wave | Plain Wave | Plain Wave |
| Thickness (mm) | 0.473 | 0.670 | 0.325 |
| Weight (mg/cm$^2$) | 17.03 | 16.08 | 7.58 |
| Bulk Density (g/cm$^3$) | 0.360 | 0.240 | 0.236 |
| Density | | | |
| Warp | 21.3 | 21.3 | 40.0 |
| Weft | 19.0 | 18.0 | 36.0 |
| Yarn Count | | | |
| Warp T | 40.6/2 | 41.5 | 8.5 |
| Warp S | 26.4/2 | 14.3 | 69.7 |
| Warp T | 39.2/2 | 34.0 | 11.9 |
| Warp S | 25.5/2 | 17.4 | 49.7 |

average shape of the drape, and we can extract the vibrations of the drape in the order from lower frequencies to higher ones.

Since the pixels are discretely arranged in actual digital images, the Fourier series is obtained by the discrete Fourier transformation of a sequence of complex numbers generated by tracing pixels on the curve and finding the corresponding complex numbers. The inverse Fourier transformation of a part of Fourier coefficients yields the partial sum of the Fourier series, i. e. a simplified curve.

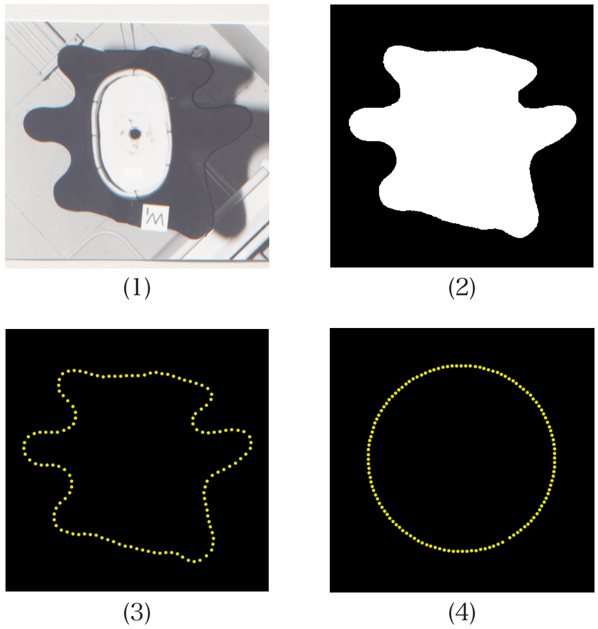



**Figure 2:** Drape and Fourier descriptor.

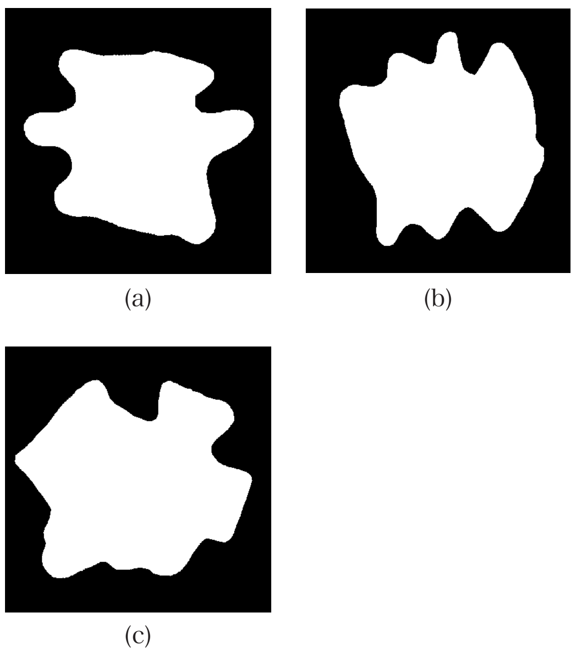



**Figure 3:** Examples of drapes.

## 3. EXPERIMENTS AND RESULTS

Figure 1 shows the employed hanging method for the analysis and evaluation of fabric drape in this paper. Table 1 shows the profiles of sample fabrics used for the experiment. The samples (a) and (b) show almost the same fabric weight (mg/cm2), while the former is a wool fabric and the latter is a cotton fabric. The sample (c) is another cotton fabric which show different fabric weight.

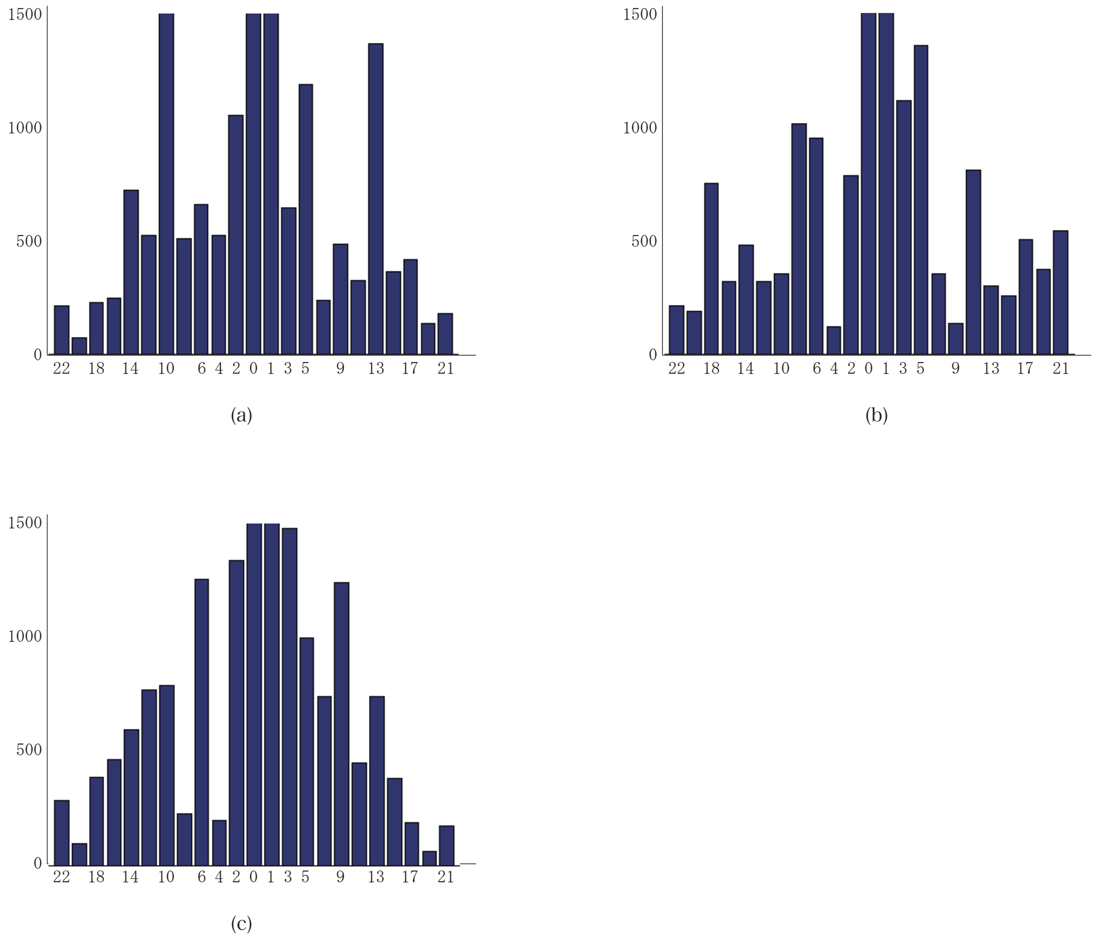
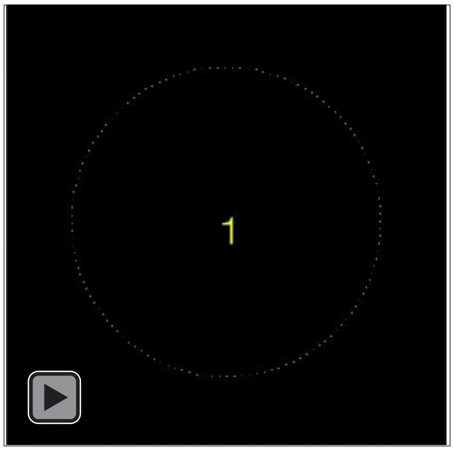



**Figure 4:** Fourier spectra. The horizontal axis indicates the order of the components, and the vertical axis indicates the absolute values of the intensities.

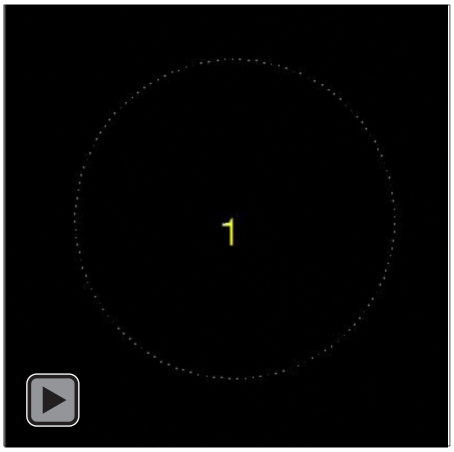
The sample fabrics shaped in gathered skirts were worn on a torso of standard woman's size instead of hanging down from the cylinder-shaped sample stage like a drape tester. This method allows us to evaluate the fabric drape properties of practical skirt directly. The images of cross sectional drape shapes were captured from the lower part of the torso with a hung down skirt, shown also in Fig. 1, and were analyzed for the drape properties of fabrics.

Figure 2 (1) shows an example of a drape of a fabric obtained by the method using this method. Figure 2 (2) shows the binarized image obtained by extracting the contour and its inside manually. The G-type Fourier descriptor was obtained by automatically tracing the contour and assigning 128 points. Figure 2 (3) shows the result of the inverse Fourier transformation using all the 128 Fourier coefficients. The images obtained by all the Fourier coefficients restores the original curve by a sequence of points. Note that the points on the restored images are enlarged and emphasized in color, in order to be visible even when the image sizes are reduced. Figure 2 (4) shows the restored curve by the 0th coefficient, which is a constant term, and the 1st coefficient only. It is the averaged circle of the original curve, and the vibration can be measured by overlapping this circle and the original curve in a manual measurement.

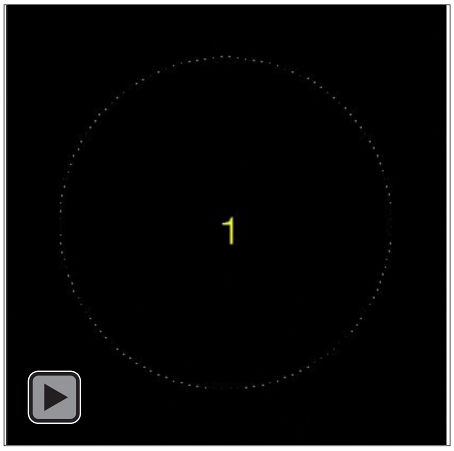
Figures 3 (a)-(c) show the contours extracted from the drapes yielded by the experimental




(a)




(b)




(c)

**Figure 5:** Reconstrution processes.

setups in Figs. 1 (a)-(c), respectively. Figures 4 (a)-(c) show the absolute values of the Fourier coefficients, which correspond to the square roots of the Fourier power spectra, of the contours in Figs. 3 (a)-(c), respectively. The vertical axis is truncated, since the 0th and 1st coefficients, which compose the averaged circle, are extremely larger than the other components. Each component corresponds to a periodic wave along the circle; the larger the order is, the higher the frequency of the wave is. The 0th component is centered, and the odd-ordered components are on the right side, and the even-ordered ones are on the left. Note that the components are not symmetrical since they are the Fourier transformations of complex functions.

Figures 5 (a)-(c) show animations of the reconstruction process of Figs. 3 (a)-(c), respectively, by appying the inverse Fourier transformation to all the coefficients of lower orders than each specific number. The number is indicated at the center. The animations are Flash movies and can be shown by Adobe Acrobat 9.0 or later and a Flash player. It is recommended to magnify the document to obtain sufficient visibility.

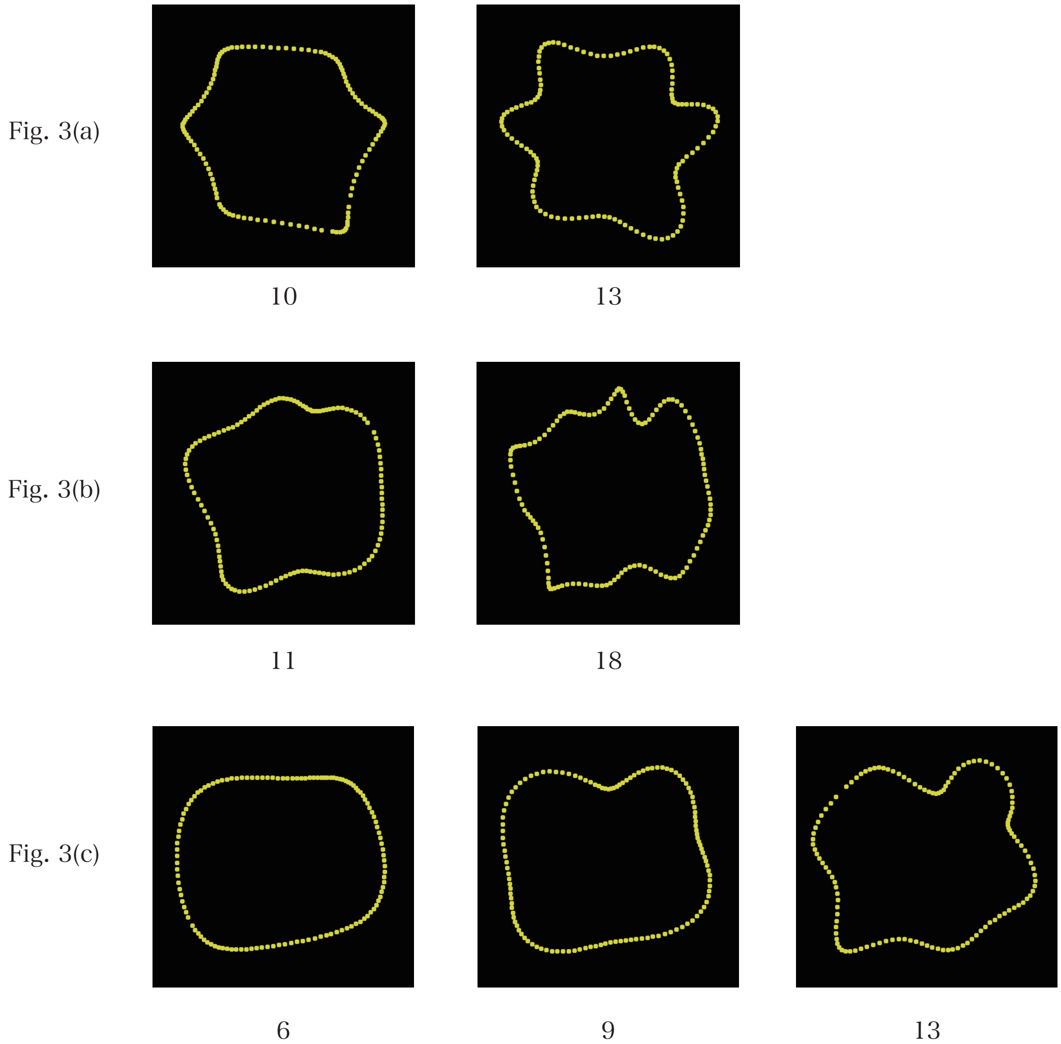



**Figure 6:** Characteristic shapes reconstructed by the inverse Fourier transformations.

Figure 6 shows partial reconstructions by the inverse Fourier transformations applied to a prominent component and all the components of the lower orders. Each row of Fig. 6 corresponds to each of the images shown in Fig. 3. The number shown under each image indicates the maximum order of the components. The images in Fig. 6 indicate that a prominent coefficient corresponds to a reconstruction of characteristic shape of the images.

## 4. DISCUSSION

The Fourier power spectra shown in figure 4 indicate that the strong feature of the sample (a) of wool fabric shows relatively long periodic waves, as the components of lower orders such as 5, 10 and 13 show highly prominent intensities.

While the relatively long periodic wave of the sample (b) of cotton fabric, whose weight is similar to the sample (a), shows moderate intensities in the components of lower orders but less than wool fabric, while prominent peaks appear in higher orders such as 18 and 21. It indicates short periodic waves are another remarkable characteristics of this fabric. In the case of the sample (c) of the cotton fabric in the lighter weight, the prominent component does not clearly appear in higher orders. It indicates that significant wave does not clearly appear on this fabric.

The sample (b), which has more remarkable characteristics in higher orders indicating waves of higher frequency, showed higher softness in visual impression than the sample (c), according to the visual evaluation of cotton fabrics in another experiment. The above results show the usability of the suggested analysis method in this paper for characterizing the drape properties of fabric relating with visual evaluations directly.

## 5. CONCLUSIONS

This paper has proposed a method of the measurement of drape-ability by regarding the contour composed by edge of a fabric as a closed curve and describing vibrations of the closed curve using the G-type Fourier descriptor. The method enables quantitative expression of visual characteristics of drapes. It yields the average circle of the contour and the restorations of simplified curve by selecting the frequencies of vibrations in the contour. We are now planning to analyze drapes of various fabrics using this method.

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## BIOGRAPHY


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