A New Evaluation Method for Fabric Wrinkles using the Morphological Technique

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Abstract: A new evaluation method of fabric wrinkles based on mathematical morphology is proposed. The method employs morphological size distribution to the shape of wrinkle caused by folding a fabric. The size distribution of a shape is measured by size density function, which shows proportion of areas of a part corresponding to each size in an image object. It is shown experimentally that the shape of wrinkle is characterized by the skewness of the size density function.

Keywords: wrinkle evaluation, mathematical morphology, size distribution

1. INTRODUCTION

Easiness of forming wrinkles on fabrics by bending process is often evaluated by the rheological viscoelasticity of the bending properties of the fabrics. However, it is not entirely in agreement with the evaluation of visual impressions on the appearance of the fabric wrinkles, because the edge angles formed by the wrinkles are often influenced by the thickness or area size of the fabric used in the final process.

In this paper, we propose a method that can quantitatively evaluate the strength of the edge and angle of the wrinkle appearance when a fabric has made wrinkles by bending. The shapes of the wrinkles are evaluated by using size distribution analysis based on mathematical morphology, which is a mathematical formulation of image processing and digital geometry (Soille, 2003). The method fits disks of various sizes to an object in an image, extracts the part of the object corresponding to each size from the object, and measures the area of the part corresponding to each size. The size distribution analysis offers the size density function, which expresses the relationship between a size and the relative area of the part corresponding to the size in an object.

We apply the size distribution analysis to the images of fabric wrinkles. The sharpness of a wrinkle is evaluated by the distribution of the area extracted from the part corresponding to each disk size. That is, the sharper the wrinkle edge is, the larger the ratios of the smaller sizes are in the size density function. This method was applied to the several fabrics made from different kinds of fibers. The result shows that the proposed method for evaluating fabric wrinkles has a strong relationship to the assessment of visual impressions.

We describe in Section 2 the standard method of wrinkle evaluation. In Section 3, we briefly explain the basics of mathematical morphology and size distribution analysis. We show experimental results of wrinkle evaluation using the proposed method in Secion 4, and we conclude our work in Section 5.

2. WRINKLE EVALUATION

In the 1960's, evaluation of the degree of sharpness of the wrinkle, crease and pleat has attracted by the garment product and consumers. It is a crucial time to establish the standards for the measurement of wrinkle/crease property (Industrial standards shown in the reference list) worldwide and since then various apparatuses were designed and developed. For those instruments, measuring principle is same and simple. It is called the wrinkle/crease angle test as follows:

> Fabric a rectangle shape of 10cmx20cm specimen (fabric) prepared, A fold fabric in half was placed(weighted) between two plates like tiles of 10cmx10cm so as to make coincide the folding line. After releasing, an angle of two wings of specimen, centralizing the pleat line.

The above method is observing a fold / crease of one fabric under a fixed weight load for a fixed time. The method has been widely used since it is directly related to mechanical properties of fabrics. On the other hand, methods of evaluating winkle roughness on the surface of the whole fabric using image processing and/or two-dimensional signal processing techniques were proposed, since wrinkles on the whole fabric have an influence to visual impressions on cloths (Su et al., 1999; Matsudaira et al., 2002).

It is well known that the impression on the wrinkle roughness on the whole cloth is related to its rheological property and has a temporal variation, since the fabric is composed of fiber materials (Cooke et al., 1954; Xu et al., 1995). The temporal variation of the wrinkle roughness is closely related to the temporal variation of the edge sharpness of each fold. Thus a further investigation of the evaluation method of a fold to develop a simple and effective method of evaluation is important in practical fabrication processes.

This paper aims to develop a method of analyzing the sharpness at central line area which is folded and to solve the instability of the observation using an image processing technique based on mathematical morphology.

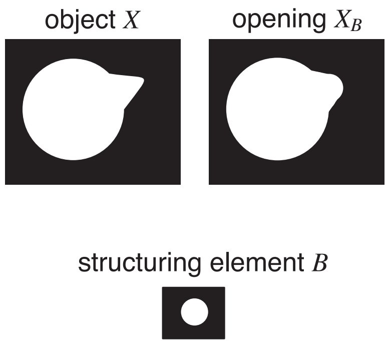


Figure 1: Opening.

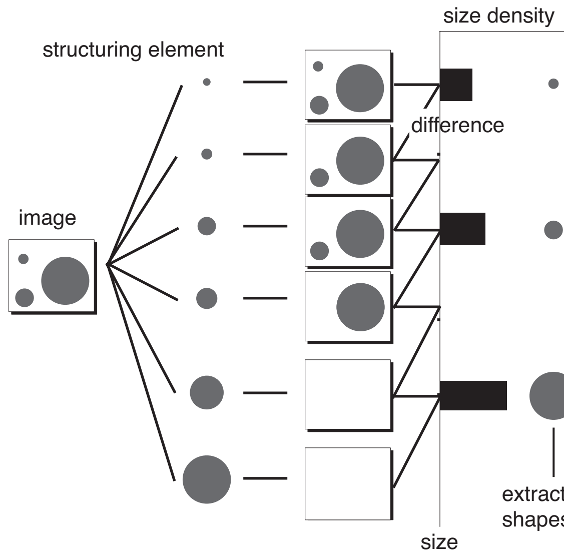


Figure 2: Size distribution analysis.

3. MATHEMATICAL MORPHOLOGY AND SIZE DISTRIBUTION

3.1. Basics of mathematical morphology and morphological opening

Mathematical morphology is a fundamental framework of image manipulation, and the morphological operations manipulate quantitatively the effect of shape and proportion of pattern or figure in an image with a small object called structuring element by set operations (Asano et al., 2006).

The fundamental operation of mathematical morphology is opening, which discriminates and extracts object shapes with respect to the size of objects. Opening of an image object X with respect to a structuring element B indicates the locus of B itself sweeping all the interior of X, and removes smaller white regions than the structuring element, as illustrated in Fig. 1. Since opening eliminates smaller structures than the structuring element, it has a quantitative smoothing ability.

3.2. Size distribution analysis

Size distribution analysis evaluates the size of each part in an image object utilizing the property of opening, that is, opening removes smaller parts than structuring element from the object and preserves larger parts.

We assume openings of a target image with respect to a structuring element and its homothetic magnifications, and a size is assigned to each magnifications of the structuring element, as shown in Fig. 2. The objects in the difference between the results of opening with the structuring element of size n and size $n + 1$ are those which are not removed by the structuring element of size n but removed by that of size $n + 1$. The objects are regarded to belong to size n, and the function of n to the area of objects belonging to size n is defined as the size density function.

Since the size density function has the same property as the probability density function of a random variable, the average and moments of size are derived from the size density function,

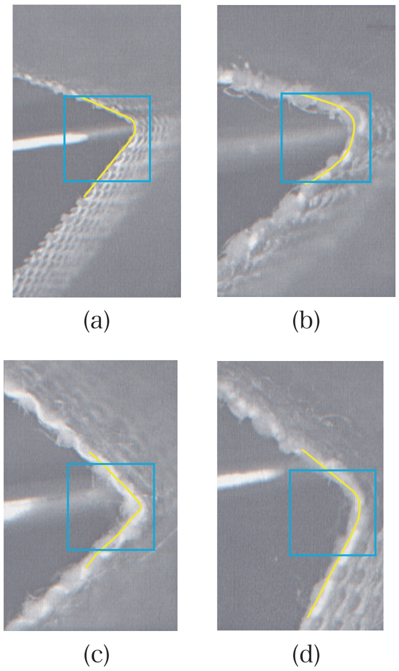


Figure 3: Examples of wrinkles.

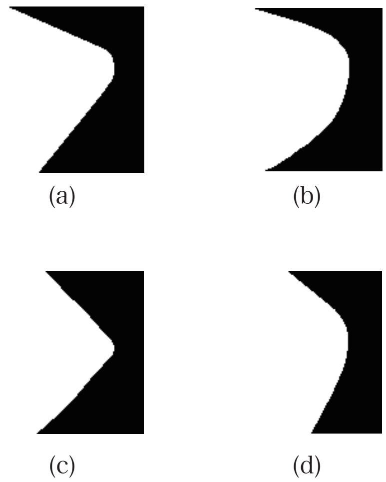


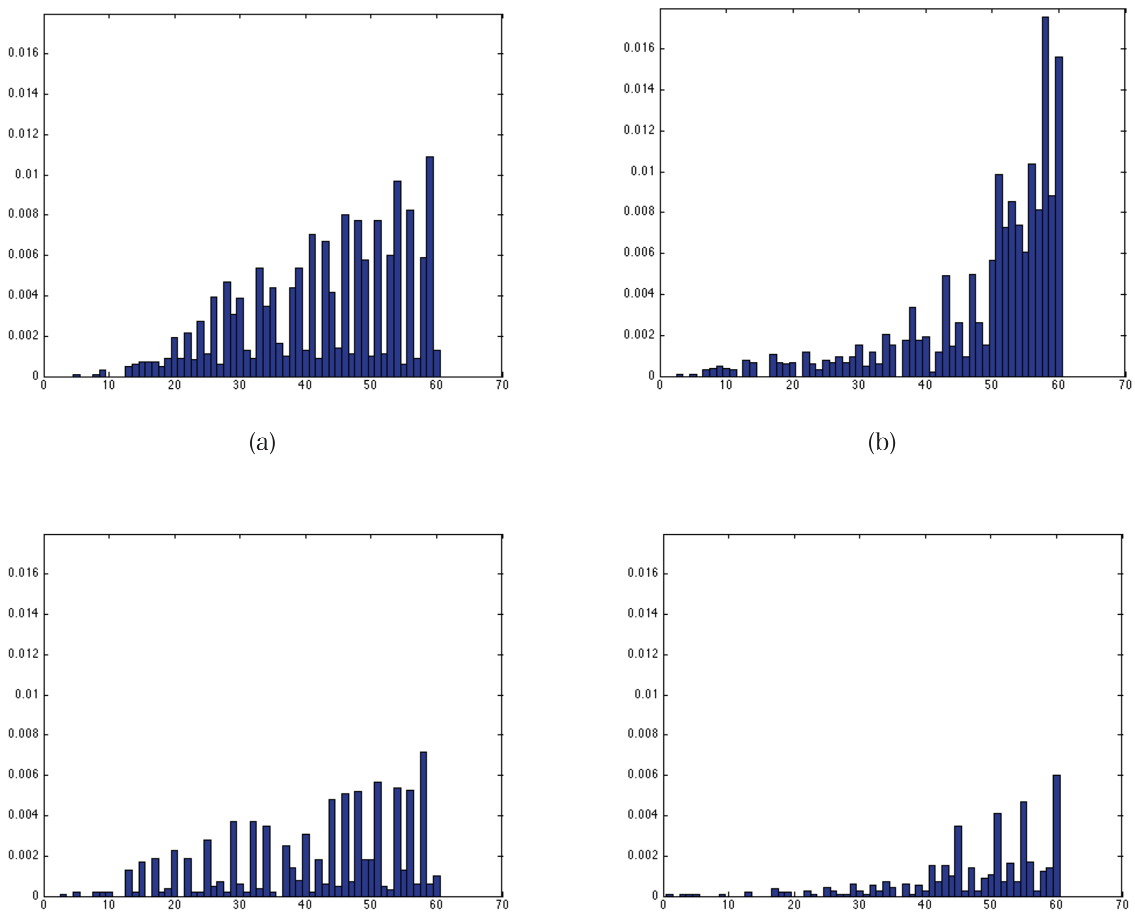
Figure 4: Transformed binary images.

similarly to the average and moments of the random variable. The average size indicates the size of the target object in one value. The skewness is the third order moment indicating the distortion of the shape of a density function from the symmetrical shape. If the skewness is positive (or negative), the shape of the size density function is biased to the smaller (or larger) sizes, and the absolute value of the skewness indicates the degree of bias.

4. EXPERIMENTAL RESULTS

Figure 3 shows examples of wrinkles yielded by the standard method of wrinkle evaluation explained in Sec. 2. A square region including the wrinkle, indicated in blue, is extracted from each of the images, and the shape of wrinkle is manually traced by yellow line in each square. Although the sizes of the images are slightly different, the scaling and the resolution, and the size of extracted square, are the same for all the images. The regions extracted from Fig. 3 (a)-(d) were transformed to binary images as shown in Fig. 4 (a)-(d), respectively. The size of the binary images is 128x128 pixels. The traced line is regarded as a boundary, and the left side is white and the right side is black in each of the binary images. Figures 5 (a)-(d) illustrate the side density functions of Fig. 4 (a)-(d), respectively, where the size is indicated on the horizontal axis and the size density is on the vertical axis. The structuring element is disk-shaped, and the size is defined as the radius of the disk. The maximum size is set to 60 pixels, since the height of the binary images is 128 pixels and the structuring element should not be larger than the image itself.

Table 1 shows the average size and the skewness for the size distributions where the maximum size is limited to 60 pixels. The average sizes are not so different for all the images, however,



(a) (b)

(c) (d)

Figure 5: Size density functions of Fig. 4 (a)-(d).

the skewnesses are significantly different. It is obviously indicated that the absolute values of the skewnesses are small for sharp wrinkles, and large for rounded wrinkles. Figure 5 indicates that the local maxima of the size densities are nearly linearly increasing for the small absolute values of the skewnesses, and those are increasing in some curve for the large absolute values of the skewnesses.

Figure 6 is a binary image of a corner, which was artificially generated, for reference. Its size density function is illustrated in Fig. 7. The average size is 40.26 pixels and the skewness is -1.92. The function is almost exactly linearly increasing, and the skewness in this case is similar to the real images of the sharp wrinkles. It supports our conclusions in the relationship between the shape of the wrinkle and the skewness.

Table 1: Average sizes and skewnesses of the size density functions in Fig. 5 (a)-(d).

	(a)	(b)	(c)	(d)
Average size	42.74	49.41	41.54	48.06
Skewness	– 1.23	– 4.15	– 2.10	– 6.87

Figure 6: An artificial corner image.

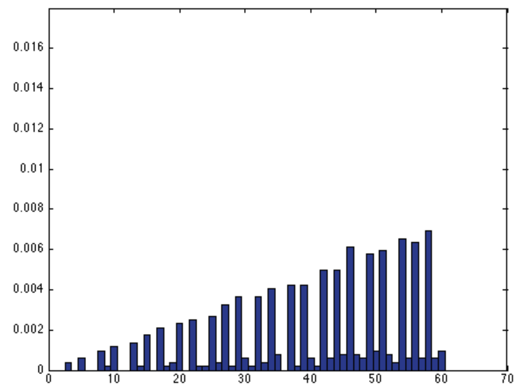


Figure 7: Size density function of the artificial corner image.

5. CONCLUSIONS

This paper has proposed a method of evaluating the sharpness of fabric wrinkles. Our method measures the morphological size density function of the image of a wrinkle. We have found that the sharpness of the wrinkle is evaluated by the skewness of the size density function.

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BIOGRAPHY

Chie Muraki Asano is an Associate Professor of the Department of Lifestyle Design, Yasuda Women's University, Japan. From 1997 to 2002, she was an Assistant Professor of the Department of Biosphere-Geosphere System Science, Okayama University of Science, Japan. Her current research interests are in the area of kansei science related with textile and apparel science. She is a member of Japan Society of Kansei Engineering, Japan Society of Home Economics, the Information Processing Society of Japan, the Japan Statistical Society, and Japan Society of Applied Statistics.

Akira Asano has been a Professor of the Faculty of Informatics, Kansai University, Japan, since 2011. He became a Research Associate of Kyushu Institute of Technology, Japan, in 1992. He moved to Hiroshima University, Japan, in 1998, and was promoted to a Professor in 2005. He was a guest scientist in the Institute for Information Transmission Problems, the USSR Academy of Sciences, in 1990, and a guest researcher in the VTT (National Technical Research Centre) Information Technology, Finland, in 1994-95. He received his Ph.D. degree in applied physics from Osaka University in 1992. His current research interests are in the area of mathematical morphology, medical image analysis, visual kansei science, and applied statistics. He is a member of Japan Society of Kansei Engineering, the Institute of Electronics, Information, and Communication Engineers, Japan, Japan Society of Applied Statistics, Japan Soceity for Oral and Maxillofacial Radiology, the Institute of Electrical and Electronics Engineers, and the Optical Society of America.

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Takako Fujimoto belonged to 1)Niigata University (1977-1981), and then has belonged to 2) Hokkaido University of Education (1992- at present) and has been professor since 1992. She has been i) Head, Japan Section of The Textile Institute of UK (2005-), ii) a member of council of TI, iii) a council member of Japan Research Association for Textile End-uses, iv) a visiting professor, University of University of New South Wales, Australia (1996.9-1997.3). Her major research areas in scientific achievement are a) theory of heat transfer of fibrous materials, b) mechanical properties and handle estimation of clothing fabrics, c) objective evaluation of clothing materials, d) durability of clothing materials. The number of her published original books is 5, of her published original papers and articles is around 130. She received three prizes and awards related to the above scientific achievements.