ORIGINAL ARTICLES

COGNITION OF VISUAL FEATURES OF WEAVING YARN AND METHOD OF REPRESENTING VISUAL FEATURES OF TEXTILES BY USING FRACTAL

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Abstract: This paper presents a method to visualize features of textiles using the fractal geometry, and provides a practical and effective application. Recently, visual impression of a textile by a customer is regarded as an important element in the textile market. Thus, the development of textiles which meet diverse personal needs is demanded. A person who has susceptible skin to an irritation by ramie may require a textile which has visual presentation similar to ramie. Therefore, this research focuses on a visual feature of yarn used for the textiles and attempts to separate the visual feature from textile's physical property. Generally, it has been difficult to represent the visual features of textile by using traditional techniques, but our research had been succeeded to represent visual feature by using the method of fractal. In this paper, the unevenness on the surface of yarn is analyzed by using the theorem of fractal geometry, and its fractal dimension is extracted as its characteristic value. Visual features on some typical kinds of the textile materials are measured in numerical values. This method also made it possible to grant one visual feature to other material yarn by controlling the yarn's shape. It was confirmed that a cotton textile characterized by the fractal dimension of ramie has a similar visual impression to the ramie textile, additionally, didn't irritate the skin on account of the cotton's physical property.

Keywords: *Fractal Geometry, Textile, Weaving Yarn, Image Processing*

1. INTRODUCTION

Dress designers incorporate new styles and sensational colors into the clothing every year, and customers look for and purchase new clothing meeting their own senses or needs. It is necessary that the clothing attracts the attention of the public through its design and practicality. Both designers and customers look for not only design and color but also new material that meets their needs. For example, a person who is allergic to ramie due to the physical characteristics of ramie may seek for "ramie-like" material instead of actual ramie made clothes. If the visual features of textiles are handled in a numerical definition, it will be possible to develop innovative textiles by separating or blending the features. Because most of the textile design information is stored in computers to visualize textile surface images now, it is required that the features recognized by human eyes are represented in numerical values. Where producers or consumers require the textile information according to their sense, visual differences between various textiles (e.g. between cotton and ramie textile) need to be represented in numerical values. The largest information of textile sensed by general customers is visual feature. In order to study the relationship between textile surface feature and human sense, it is

necessary to translate textile surface into numerical values. In this paper, a method to translate the textile feature to numbers and modify the feature of the weaving yarn by using Mandelbrot's fractal geometry[1] will be presented.

Fractal geometry was initialed by Mandelbrot in the 1970's along with its characteristic concept of "self-similarity" [1]. The simple definition of shapes with infinite detail and the definition of the shape as independent of a single resolution would be made possible by introducing self-similarity. The properties of fractal are seen frequently in the natural world and fractal geometry is appropriate to evaluate natural materials [1-3]. Many computer graphic artists create beautiful works by using fractal geometry. In addition, the properties of fractal were found in well-known works of art including classical music [4]. Therefore, fractal geometry is a useful theory to evaluate various object, and it owns broad application.

In this research, we focused on the shape of weaving yarn using natural material. This paper shows the fractal nature of shapes of weaving yarn. Moreover, it is possible to reproduce the practical visual features by controlling yarn's diameter using fractal. In section 2, the method for tracing shapes of weaving yarn and the

measuring method of fractal information in weaving yarn are explained. In addition, a method for composing fractal shape (in non-integral dimension) is introduced. The experimental way and result are shown in section 3. Section 4 shows conclusion. References are listed at the end of this paper.

2. EXPERIMENTS

2.1. Edge tracing method for weaving yarn image

In this section, the edge tracing method for the digital image of the weaving yarn is proposed to obtain the yarn's domain on a computer. Figure 1 shows a sample of a part of L^* value image in $L^*a^*b^*$ color coordinate system [5] as input image used in this research. The light domain shows yarn and dark domain shows background (black paper). As shown in figure 1, the part close to the yarn is crowded with its small fibers. However, those small fibers have no impact on human beings, perception of the textile/yarn features. In order to extract the visual features, in this study, we focused on the trunk of the weaving yarn and erase the small fibers around the trunk. General methods for domain detection [5] make use of the threshold of brightness value when dividing an image into several domains. However, in the case of this research, the two domains (yarn and small fiber) are connected, it is difficult to divide mixed domain into two separate domains. Moreover, where the two domains have the common brightness value, the pixels with threshold (exist in both domains) will belong to one of two domains. This defect gives an undesirable result. The detecting method to distinguish the weaving yarn from the small fibers is required.

The detecting method of the weaving yarn for this study is following. First, gradient images are obtained from images of weaving yarn by applying the following equation (1) in vertical direction.

$$G(x, y) = F(x, y + 1) - F(x, y - 1) \quad (1)$$

The x and y coordinates correspond to the horizontal and vertical position in the images, respectively. $F(x, y)$ and $G(x, y)$ are the L^* value on position (x, y) and the gradient at the same position, respectively. The absolute value image of gradient is shown in figure 2. Next, the gradient image is traced with the L^* value image in order to find out the trunk of weaving yarn. Scanning the images along

vertical lines, maximum L^* values on all vertical lines are obtained. Obtained maximum L^* values are inevitably on the trunk of the weaving yarn by the property of the yarn images such as figure 1. Finally, the first upper and lower discovered edges from the maximum L^* positions provide the effective edges of the weaving yarn. In order to remove inappropriate edges, original L^* values are referenced pixel by pixel. Figure 3 shows the outline of the yarn in figure 1 by this method. Diameter values of the weaving yarn are calculated from pixels of trunk of the yarn.

Figure 1: A part of the sample yarn image.

Figure 2: Vertical gradient image of figure 1.

Figure 3: Obtained outline of the weaving yarn shown in figure 1 by using our method.

2.2 Definition and composition of fractal shapes

In this section, we introduce the definition of the shape using the nature of fractal, and explain the composition of fractal shapes. Fractal shapes are generally defined by fractional Brownian motion (fBm) proposed by B.B.Mandelbrot and Van Ness [1-4]. The fBm is based on Brownian motion that has taken important part in mathematics and physics, and extends the core concept of Brownian motion. The fBm is one of the most effective mathematical models to represent the random fractals found in the natural world e.g.

mountains or crowds. Where the time-based fBm is defined as $V(t)$, the general statistical relation between $\Delta V = V(t_2) - V(t_1)$ and $\Delta t = t_2 - t_1$ is defined by the following formula [4].

$$\Delta V \propto \Delta t^H \quad (2)$$

The H in this formula is the parameter that provides the degree of self-similarity. When the H approaches 0, $V(t)$ has many jagged edges bounding its shape. As H approaches 1, $V(t)$ has a smooth outline shape. Therefore, if the shapes of the weaving yarn have the nature of fractal, it will be possible to control and change the visual features of weaving yarn by modifying the fBm. With regard to process of weaving yarns, the parameters of the controlled visual features are provided to the machine to control the diameters of the weaving yarn. In this way, the shape of the weaving yarn is characterized by its fractal dimension. Some sample fBm are shown in figure 4.

Figure 4: Three samples of fractional Brownian motion (fBm). (a) $D = 1.2$, (b) $D = 1.5$, (c) $D = 1.8$. Each D shows the fractal dimension.

3. RESULT AND EVALUATION

In this section, experimental results of our methods are shown and are evaluated. Images of the weaving yarn are entered by color image scanner with a suitable resolution (up to thousand pixels per inch) since this research needs to detect the visual features recognized by human eyes. Diameter values of four sample weaving yarn (ramie, Basho, hand-spun cotton, and industrial cotton yarn) are measured by digital image processing of our method. Obtained diameter information of each weaving yarns are transformed into frequency

components by applying the fast Fourier transform (FFT), and fractal dimension of unevenness of each weaving yarn is measured from the relationship between frequency components [1,4]. The power spectrum figure of one of the hand-spun cotton yarn is indicated in figure 5. The horizontal and vertical axes in figure 5 show the logarithm of the frequency and the logarithm of the power, respectively. As shown in figure 5, if most of the dots on the power spectrum graph approximately lie on a straight line, the nature of fractal exists in original shape. The fractal dimension is obtained from the inclination of the straight-line approximating those dots. The fractal dimensions of the other three weaving yarns are measured in the same way. In addition, in order to filter the extraneous errors, we compiled statistics of the fractal dimensions by using a great number of images for each weaving yarn. Obtained fractal dimensions are shown in table 1.

Figure 5: Power spectrum figure of frequency components on hand-spun cotton yarn. Horizontal and vertical axes show the frequency and power of frequency components.

Table 1: Fractal dimension of weaving yarn.

Kind of weaving yarn	Fractal dimension
Industrial cotton yarn	1.63
Ramie yarn	1.61
Hand-spun cotton yarn	1.58
Basho yarn	1.53

Next, we created the frequency components of the

weaving yarn using the same dimensions as obtained dimension of actual weaving yarn by using the Fourier filtering method [4]. In the Fourier filtering method, the power of each frequency component is determined by its period. In order to obtain the fBm, inverse fast Fourier transform (IFFT) is applied to those components. The obtained fBm is transformed a relevant diameter by a linear transform. Numerous such diameter values are stored in the computer, and are subsequently provided to a specific spinning machine that contains the associated diameter control mechanism. Figure 6 shows two types of textiles. Figure 6(a) shows the original ramie textile and figure 6(b) shows cotton textile characterized by the visual feature of ramie yarn. As shown in figure 6, by characterizing the shape of the weaving yarn with fractal dimension, the constituted visual features correspond to the original visual features. Some professionals who evaluated our textiles agreed that they closely reproduced the original textiles.

4. CONCLUSION

The goal of this study was to represent the visual features of the textiles and to modify visual feature of one textile to another textile features. We confirmed that the characteristic values of visual features were conspicuously seen in the fractal dimension. Consequently, the shapes of weaving yarn were recreated by a simple procedure. In our method, since the Gaussian random numbers were used to decide the power of frequency components [4], a number of diameter values for specific spinning machine were prepared on demand. This is an advantage of fractal geometry over some general representing method. Therefore, our method is practical method on the textile industry. It was found that where the fractal dimension of cotton weaving yarn was close to the ramie's fractal dimension, those two material weaving yarns had a common visual feature.

Our future work is the research of the relationship between human sense and fractal dimension of weaving yarn.

(a) Ramie textile.

(b) Cotton textile featuring with the fractal dimension of ramie yarn.

Figure 6: Comparison of original textile and characterized textile by fractal dimension.

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