Computer Image Recognition in Detecting Wool and Cashmere Fibers

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***Abstract*—According to the characteristics of Spatial Periodicity of fibers, wool and cashmere can be identified automatically by digital image processing technology. Fiber images were collected by Image acquisition devices and saved in computer. Then, fiber information like diameter, surface scale height and scale thickness was extracted by Image processing algorithms to analyze and detect the fibers. Results show false rate of detection decreases much when probability multiplication applied.**

Keywords- wool; cashmere; image recognition; fiber diameter; scale height; scale thickness; probability multiplication

I. INTRODUCTION

China is the world's largest producer and one of the main exporters of cashmere. Price of wool and cashmere varies greatly, but their physical and chemical properties are quite similar. It's always happening that wool and cashmere are mixed together. Thus, consumer's interests and China's reputation were seriously damaged. Therefore, identification of wool and cashmere is a very important topic.

Image analyzing technology was generated in the 1960s, and developed fast and was widely used in the 1970s. It was soon introduced to observe configurations of textile fibers, and sped up the development of traditional microscopic detection equipment towards digitalization, informationization and intelligent. Currently, it has become one of the major technologies to study the configurations of different textile fibers.

When coming to differentiate textile materials, great differences can be found between appearance characteristics and market value of wool and cashmere. Recognition rate and classification efficiency of natural fibers are much improved due to using of image recognition technology. And with computer's further application in a variety of areas, fiber recognition can be easily realized. The research done below was an exploration to detect wool and cashmere by computer.

II. FEATURE PARAMETERS OF WOOL AND CASHMERE

Diameter (d): That is fineness of wool and cashmere. The quality of sample wool's fineness can be divided into 14 grades, as Table I [1] shown below. And Table II [2] is comparison of diameter and scale structure parameters of wool and cashmere.

Table I. FINENESS RANGE OF WOOL'S DIFFERENT QUALITY COUNTS [1]

Quality counts (tex)	Fineness range (μm)	Quality counts (tex)	Fineness range (μm)
7.4	14.5~18.0	11.8	29.1~31.0
8.4	18.1~20.0	12.3	31.1~34.0
8.9	20.1~21.5	12.8	34.1~37.0
9.2	21.6~23.0	13.4	37.1~40.0
9.8	23.1~25.0	14.8	40.1~43.0
10.2	25.1~27.0	16.4	43.1~55.0
10.5	27.1~29.0	18.5	55.1~67.0

Scale height (l): That is the distance between the edges of two adjacent scales along the fiber axis.

Scale thickness (h): That is the height of certain scale edge, measuring the width of the projection of scales on the fiber surface.

Average diameter-height ratio: Average of ratios of fiber diameter and scale height measured on same fiber breed.

Average scale thickness: Average of scale thickness measured on same fiber breed.

Scale frequency: Scale numbers on fiber surface per unit length along the fiber axis.

Table II. COMPARISON OF DIAMETER AND SCALE STRACTURE PARAMETERS OF SHEEP WOOL AND CASHMERE [2]

Items	Cashmere			Sheep wool					
				Chinese local breed sheep wool			Merino wool		
	average	max.	min.	average	max.	min.	average	max.	min.
Diameter /μm	15.16	25.0	5.5	16.5	39.5	5.5	16.5	37.5	5.5
Scale thickness /μm	0.35	0.73	0.21	0.53	0.78	0.36	0.48	0.63	0.32
Scale frequency /(1000μm)	60	90	40	70	90	50	91	125	65
Scale structure	Mostly in annularity, few in variational annularity			Mostly in variational annularity, few in annularity			Number of scale shape in annularity is more than Chinese local breed wool		

Note: Diameter was tested by OFDA;
Scale thickness and frequency by SEM.

III. METHOD TO OBTAIN DIGITAL IMAGES

Digital images were collected by Zeiss KYKY-2800 scanning electron microscope. The scanned images getting from scanning electron microscope are using secondary electron imaging information by adjusting brightness. The images acquired are with high resolution, large depth of field, strong three-dimensional characteristics, and magnification from thousands to hundred thousands of times. The scanning electron microscope is able to clearly observe and reproduce fiber microstructure. As a powerful tool to visualize on the display the surface scale morphology of the wool, cashmere and other animal fibers, characteristics of the fiber’s scale value can be accurately measured. Animal fibers which was dyed or after certain chemical treatment on scale can also be distinguished according to the structure. And the collected fiber images should be saved into computer's memory for post-processing.

IV. PRINCIPLE OF DIGITAL IMAGE PROCESSING AND EXPERIMENTAL METHODS

The digital image processing system is an information system which processes image information by a computer or certain digital equipment. The image processing system includes image processing hardware and image processing software, as shown in Fig. 1 [3].

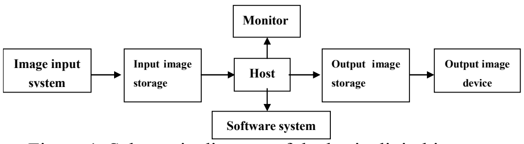

Figure 1. Schematic diagram of the basic digital image processing system [3]

The system is based on platform of Windows XP operating system, and uses Matlab, VC + + 6.0 and Photoshop for image processing.

A. Image enhancement

Image enhancement refers to emphasizing or sharpening some features of the image, such as the edge, contour and contrast, etc., for display, observation or further analysis and processing. The aim is to:

1) Using a range of technology to improve visual effects of the image and its clarity.

2) The image is turned into a form which is more suitable for human and machine analysis and processing.

Image enhancement techniques usually have two types of methods that are spatial domain method and frequency domain method. Spatial domain method mainly directly computes the image pixel gray value in spatial domain. It can be described as g (x, y) = f (x, y) • h (x, y). Among which, f (x, y) is the image before processing; g (x, y) is the image after processing; h (x, y) is a function of space operations. Frequency domain method is certain processing operations of the image transformation values in various transform domains (usually in the frequency domain) of the image, and then transform back to the spatial domain. The processes can be described as follows in Fig.2:

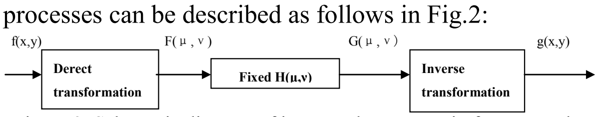

Figure 2. Schematic diagram of image enhancement in frequency domain

Among which, F (μ, ν) is the result of positive transformation of the original image f (x, y) in frequency domain, H (μ, ν) is the correction function in frequency domain, G(μ, ν) is the result of amendments, g (x , y) is the result of inverse transform of G (μ, ν), that is the enhanced image [4].

B. Image sharpening

In addition to reduce the noise and contrast expansion in image enhancement, sometimes it also needs to strengthen the image edges and contours. And edges and contours are often located where the image gray mutation, which can intuitively make one think of the difference of gray level edge and contour extraction. Common used methods are gradient and Laplacian sharpening operator.

Roberts gradient is used to sharpen the image [5]:	Laplacian for image sharpening [3]
I=imread(`rice.tif`); Imshow(I); BWI=edge(I,`Roberts`,0.1); Figure, imshow(BWI);	I=imread(`rice.tif`); Imshow(I); h=[0 -10;-14-1;0-10]; I2=imfilter(I,h) Figure, imshow(I2);

Comparison of images before and after processing is as Fig. 3 and Fig.4 .

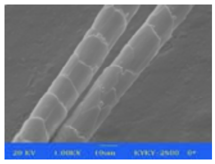

Figure 3. Original image

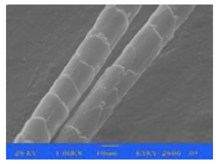

Figure 4. Image after sharpening

These two methods are commonly used in image processing. Laplacian for image sharpening was used in the research work here, and the result is shown in Fig. 4.

C. Grayscale conversion

Grayscale image correction should use different correction method according to different degraded image situations. And for uneven image, point by point different levels of gray-level correction are used. Image histogram is a very important and practical tool in image processing. It summarizes the contents of gray scales in a picture. Mathematically speaking, the image histogram is a function of statistical characteristics of the gray values and image gray value. It counts in an image the number or occurrences of each gray level or probability. In fact, the gray image histogram is a discrete function:

$$pf(f_k)=nk/n \quad (k=0，1，\cdots，L). \qquad (1)$$

Among (1), f_k is the k-level grayscale of image f (x, y), nk is the number of pixels which has a gray value of f_k in image f (x, y), n is the total number of image pixels, L is the image gray degrees. Because pf (f_k) provides statistics of probabilities of f_k, so the image histogram gives information of distribution of gray values in an image. In order to realize gray level transformation of microscopic cashmere images, a dialog class named “ZFT” was defined to display the image histogram. Specific effect is shown below in Fig. 5, 6.

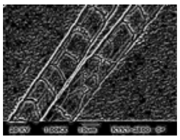

Figure 5. Original image of cashmere

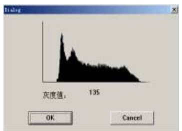

Figure 6. Image histogram

Fig. 5 is an original image of cashmere. 135 in Fig. 6 shows that under the current mouse position the gray level is 135 in the histogram. It can be seen from the histogram the gray in cashmere images mainly distributes in the middle and high gray level, and almost zero pixels in the low gray level.

D. Collection and comparison of data

Experimental samples are the 8.9 tex sheep wool and top grade cashmere, refer to the International standard (GB/T 14593-1993 [6] and GB/T 16988-1997 [7]). Raw fibers were extracted with petroleum ether in laboratory to remove grease, vegetable matter and washed with distilled water, and made into experimental samples. After being balanced in an external environment, like at room temperature of 20^0C and relative humidity of 65%, the pictures of wool and cashmere can be taken by scanning electron microscope (Diameter and surface scales height with magnification of 1000 times, and surface scale thickness with magnification of 10,000 times). There are differences in diameter, the surface scale height, surface scale thickness, scale angle, and scale edge morphology and some other aspects between sheep wool and cashmere. Finally, diameter, surface scale height and thickness were chosen as parameters. Two kinds of fibers were measured one by one, and after converting, the raw data were obtained. To improve accuracy of measurement, when magnified by scanning electron microscopy, fibers were pasted in the flat on the stage with a conductive adhesive. When adjusting the level of fiber axis, the fiber axis in horizontal plane can be rotated, tilted left and right are not allowed to guarantee the uniformity of image magnification in three-dimensional space.

After obtaining all fiber images, to make the selected data more accurately, image enhancement, sharpening and conversion should be made on the experimental images. Table III shows the testing data.

Table III. TESTING DATA OF 8.9TEX SHEEP WOOL AND TOP GRADE CASHMERE

Samples	Diameter, d (μm)			
	d	σd	CV	Decision bound
8.9 tex sheep wool	20.5	5.09	0.25	> 19.38
Cashmere	16.6	3.14	0.19	< 19.38
Samples	Surface scale height, h (μm)			
	h	σh	CV	Decision bound
8.9 tex sheep wool	8.3	1.09	0.23	< 8.57
Cashmere	10.6	0.22	0.21	> 8.57
Samples	Surface scale thickness, t (μm)			
	t	σt	CV	Decision bound
8.9 tex sheep wool	0.82	0.21	0.26	> 0.62
Cashmere	0.41	0.14	0.33	< 0.65

V. RESULTS AND ANALYSIS

Diameter, surface scale height and thickness 3 parameters were chosen in this experiment. And there is certain difference between sheep wool and cashmere from the measured and calculated data. But meanwhile, there also exist great crosses in different parameters between wool and cashmere. The crosses can be seen from the frequency distributions of two fibers' diameter, surface scale height and thickness. As shown in Fig. 7-9.

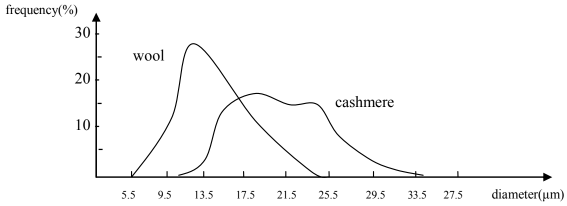

Figure 7. Frequency distribution of diameter of wool and cashmere

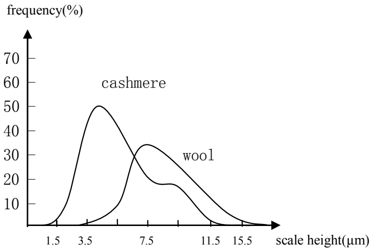

Figure 8. Frequency distribution of surface scale height of wool and cashmere

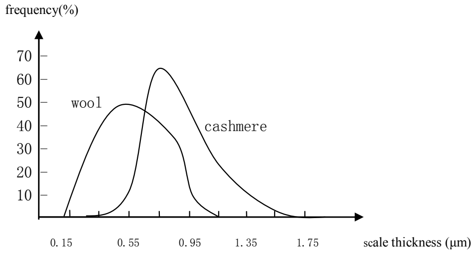

Figure 9. Frequency distribution of surface scale thickness of wool and cashmere

According to frequency distributions of wool and cashmere, false rate can be calculated respectively, as shown in Table IV. It can be seen under any one of the three separate parameters, the false rate of wool and cashmere are very high. The result is unreliable. So principle of "probability multiplication" in probability theory was used to further processing the data. The so-called probability multiplication is the probability that one fiber is determined as certain types of fiber when it meets three kinds of boundary conditions at the same time. The mathematical concept is that under the condition of all conditions are linearly independent from each other; the total probability is equal to the product of each index. That is: $P=P_1P_2P_3P_4P_5P_6\ldots\ldots P_n$. Here P_1, P_2 ... ... P_n is linearly independent [8].

Therefore, the linear correlation can be made for diameter d_1, d_2, surface scale height h_1, h_2, and surface scale thickness t_1, t_2 of wool and cashmere. Results are as follows:

$h_1=7.854+0.026d_1$ $r_1=0.0579$;
$t_1=0.550+0.016d_1$ $r_2=0.0759$;
$t_1=0.815+6.3 \cdot 10^{-5} h_1$ $r_3=0.0014$;
$h_2=9.170+0.081d_2$ $r_4=0.1134$;
$t_2=0.364+0.042d_2$ $r_5=0.0789$;
$t_2=0.412+0.0013 h_2$ $r_6=0.0199$.

Table IV. MISJUDGEMENT PROBABILITIES OF WOOL AND CASHMERE

Items	The probability of sheep wool misjudged for Cashmere			The probability of Cashmere misjudged for sheep wool		
	P_d	P_h	P_t	P_d	P_h	P_t
Theoretical value	0.397	0.386	0.163	0.259	0.178	0.094
Actual value	0.471	0.335	0.129	0.188	0.216	0.074
Total misjudgment probabilities (theoretical value)	0.02496			0.004336		
Total misjudgment probabilities (Actual value)	0.02548			0.004082		

According to the correlation coefficient, it can be determined that these three parameters are basically very weak correlations. So the total misjudgment probability $P=P_d \cdot P_h \cdot P_t$. From the data shown in Table IV, the misjudgment probabilities of sheep wool and cashmere are greatly reduced. And the actual error rates are consistent with the theoretical error rates. Thus, probability multiplication proves the correctness of reducing misjudgment.

VI. CONCLUSION

1) By using MATLAB, VC 6.0 and Photoshop, it's realizable for application of microscopic image enhancement processing algorithm on 8.9tex wool and cashmere. And the visual effects of the images can be much improved by enhancing the image details and reducing the magnitude of the noise.

2) According to effective calculation and analysis, these three parameters of wool and cashmere, that is, the diameter at 19.38μm, the surface scales height at 8.57μm, the surface scale thickness at 0.65μm, the decision boundary can be determined here. Thus it makes sense for this work. Meanwhile, the actual values are highly consistent with the theoretical values. It indicates the correctness of this experiment and conclusion. The selection of these three parameters makes a significant reduction in error identification probability, and that shows the selection of appropriate parameters.

3) The combination of image recognition technology and fiber detection methods much improves the efficiency of fiber testing. Meanwhile, the error identification probability is much reduced; the measurement error can reach the required level; the working intensity of manual measurement is also greatly eased; and the work is easier to practice.

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