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Measuring the Blend Ratio of Wool/Cashmere Yarns Based on Image Processing Technology

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Abstract

In this study, an image processing technique was developed for testing the blend ratio of wool/cashmere yarns. Cashmere and wool were sliced and images clearly attributed to the obvious colour divergence after staining. In the image processing procedure, a support vector machine (SVM) was used to remove the background and separate wool and cashmere fibers. Some other parameters of the SVM were selected to identify wool and cashmere fibers beyond the colour character. When the wool and cashmere fibers were completely separated, the blend ratio was calculated by means of the picture-handling and data-handling functions of MATLAB software. This research work presents an accurate and fast method of analyzing the blend ratio, and the results obtained were a confirmation of this.

Key words: image processing technology, support vector machine (SVM), wool/cashmere, blend ratio.

difficult due to the similar shape feature of keratin cells, hence little progress has been made. Thus, how to test the cashmere ratio accurately and quickly has now become a hot research topic and challenge.

There are various techniques available to identify cashmere and wool [1 - 3]. Traditionally, fiber identification was made by expert microscopists with high power optical or electron microscopes [4]. Fiber characteristics such as diameter, internal morphology, cuticle scale height have been measured for hundreds of individual fibers from each sample analysed. This procedure is complicated, and even skilled personnel have great difficulty in the positive identification of fiber blends [5]. Therefore, infrared spectroscopy technology [6], DNA technology [7], and image processing technology [8] have been developed for the identification of wool and cashmere fibers. However, infrared spectroscopy technology and DNA technology need some delicate instruments, which make these methods inefficient. Due to its simplicity of operation, high processing speed and higher accuracy, modern image processing technology has been widely used in fiber identification [9, 10]. By using image processing technology, Tao C. distinguished cashmere and wool fibers successfully based on the dimension coefficient extracted [11]. She F.H. classified merino and mohair fibers by using artificial neural networks and image processing [12]. Furthermore, some other researchers have also used image processing technology to identify wool, cashmere and other animal fibers [13, 14]. But the infinitesimal

discrepancy between the structural character of wool and cashmere would confuse identification. Therefore, the identification of wool and cashmere fibers must require some other parameters showing an obvious difference between wool and cashmere fibers.

Although the structure and appearance of wool and cashmere are very similar, there are still some differences between cashmere and wool in terms of physical and chemical properties, the dyeing characteristic being the most distinct one. Therefore, the clear colour divergence of cashmere and wool after staining was used in this study to identify fibers, and some structure parameters were selected to facilitate the identification of wool and cashmere fibers beyond the colour characteristic. The image processing technique was used for extracting the colour and structural parameters, in which a support vector machine (SVM) [15 - 16] was utilised to identify wool and cashmere fibers as well as test the blend ratio of the yarns.

Materials and experiments

The different internal structure of wool and cashmere fiber affects the discrepancy of the dyeing effect [17], therefore the discrepancy was used as a paramount element to distinguish wool and cashmere fiber. To ensure the most distinct discrepancy of the dyeing effect between wool and cashmere fibers, an orthogonal test was designed and carried out. The optimal condition (temperature: 60 °C, dyeing time: 15 min) and best dye (HI-1 Pula Blue) were obtained.

Introduction

It is well-known that the cashmere obtained from goats is often treated as speciality or luxury fiber because of its high economic value, softness, luster and scarcity. The differentiation of cashmere has attracted great attention in recent years in order to curb the adulteration of cheap wool fibers in cashmere and calculate the blend ratio of wool/cashmere yarns. The development of the differentiation of cashmere and wool is

Preparation of materials

The materials included wool/cashmere blend yarns and HI-1 Pula Blue dye liquor. The blend yarns were spun in a spinning machine using raw material at different blend ratios. The dye liquor was produced as follows:

The dye liquor consisted of one gram of HI-1 dye, 10 ml of n-propanol and 90 ml of distilled water, which was strongly stirred at 60 °C. When staining the blend yarns, a ratio of yarn weight in

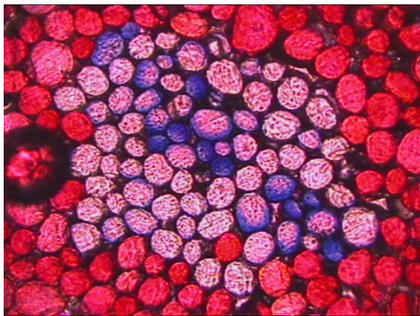


Figure 1. Original image.

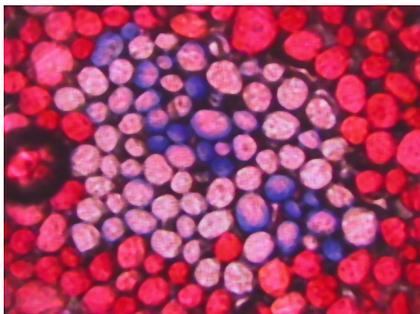


Figure 2. Image after pretreatment.

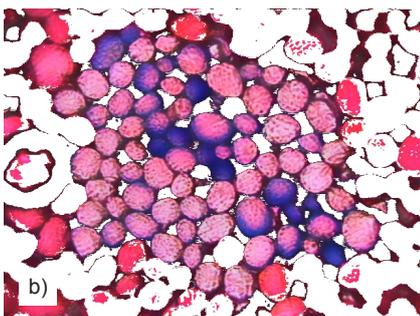
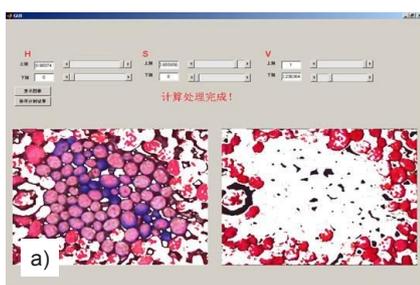


Figure 3. Background removal (a), image after background removal (b).

to solution volume in ml of 1:30 was selected. After dyeing for 15 min, the dyed samples were washed with distilled water and dried at 60 °C for 24 h.

A cross-section of the specimen was made by a Y172 slice maker, and sample images were obtained by a ZX3 video microscope. It was known that the colour of cashmere would become purple and that of wool - peach pink after the staining progress. The original image of the sample is shown in **Figure 1**. It is clear that there are three kinds of fibers in the same image: the red parts represent foreign fibers, the pink parts - wool fibers, and the purple parts are cashmere fibers.

Image processing procedure

Pretreatment

As shown in **Figure 1**, there were some bright spots on the images, which may be unexpected results of the process of making the blend yarn slice, taking the pictures or transmitting the image. Thus it is essential to remove these bright spots with the aim of achieving high accuracy. Furthermore, the RGB image obtained directly from the experiment must be converted into an HSV [18] image in this process, considering that the HSV colour model could provide extract parameters for the next fiber identification process. **Figure 2** shows an image of a sample after the pretreatment, in which, as expected, there are no bright spots.

Background removal

When the image was changed into HSV format after the pretreatment, the hue (H), saturation (S) and brightness (V) could be set to remove the background cursorily. The process can be seen in **Figure 3.a**, and the result after the first segmentation - in **Figure 3.b**. Compared to the original image, most of the foreign fibers and black background have been removed from the image, as shown in **Figure 3.b**. However, there is still some background and foreign fibers remaining, and the image must continue to be treated to remove them. Therefore the support vector machine (SVM) was essential for extraction of the target region.

SVM object extraction

The support vector machine is based on the statistical learning theory as proposed by Vapnik and Chervonenkis [19]. With structural risk minimisation, an SVM can effectively undertake small sample, non-linear and high-dimensional pattern

recognition etc, and it has achieved good application effects in pattern recognition, function approximation and probability density estimation [20, 21]. In the object extraction process, image segmentation is the key step, in which the optimal threshold value is the most complex problem. Combining the SVM classification method and image segmentation, image features can be obtained more quickly and accurately, avoiding the difficult questions of seeking the threshold. In this research work, colour features and some structural parameters, such as the roundness [22], deformation degree [23], and abnormality Degree [24] were selected for the SVM classification process.

The value of colour features such as the hue (H), saturation (S) and brightness (V) was applied in the background removal process, and some structural parameters were shown as follows:

- Roundness:

$$R = \frac{4\pi A}{P^2} \quad (1)$$

where A is the area of the target region, and P - the perimeter of the target region.

- Deformation degree:

$$d_r = \frac{d_{\min}}{d_{\max}} \quad (2)$$

where d_{\min} is the minimum diameter of the target region, and d_{\max} - the maximum diameter of the target region.

- Abnormality degree:

$$A_d = \frac{P}{P_e} \quad (3)$$

where P is the perimeter of the target region, and P_e - the perimeter of the external ellipse of the target region.

After the first segmentation, the features (Roundness, Deformation degree, and

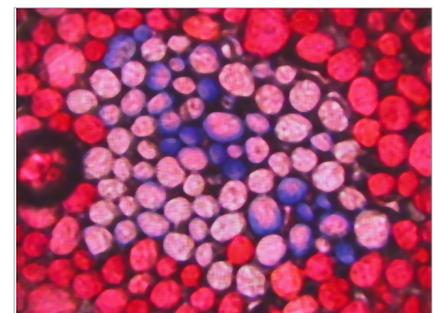


Figure 4. Extracted image.

Abnormity degree) were extracted from each target region and inputted to the SVM. The SVM then separated the target region into two classes: the target and background. The target region identified by the SVM is shown in *Figure 4*. The background and foreign fibers were completely removed after this process, and only wool and cashmere fibers were left in the image.

Wool and cashmere segmentation

It is obvious that the main difference between wool and cashmere is the colour diversity in the image. Thus the HSV colour model is the primary parameter to distinguish wool and cashmere fibers. During identification of fibers, if the colors of the sample are not clear, it is quite possible for the computer to mistake a fiber for another kind. Therefore, another parameter – the diameter - was required in the process.

According to the diameter range of cashmere and wool, the diameter can be regarded as another characteristic parameter [25, 26]. The maximal diameter of wool and cashmere fibers regulated by each standard is different, and corresponding standards should be chosen according to the origin of samples. The Chinese National Standard GB18267—2000 [27] was adopted in this study, and the following was used for pattern recognition: fiber with a diameter greater than 25 μm was classified as wool, and that with a diameter less than 10 μm - as cashmere. In this step, the image in *Figure 4* was separated into two parts; the wool fiber part is shown in *Figure 5.a* and the cashmere part - in *Figure 5.b*.

Image treatment

With no change in the basic characteristics of images, the goal of image treatment is to convert the original images into binary ones, which have only two colours: white and black, for the calculation stage. The white portion is fiber, and the black portion represents the background. This process includes [28, 29] image inversion, noise removal, image enhancement, brightness adjustment, and binarisation.

- Image inversion: In this process, the HSV image was converted into a gray-level image.
- Noise removal: There were some bright spots existing in the gray level image. Mask processing was used to remove the noise factor. After this process the characteristic of the

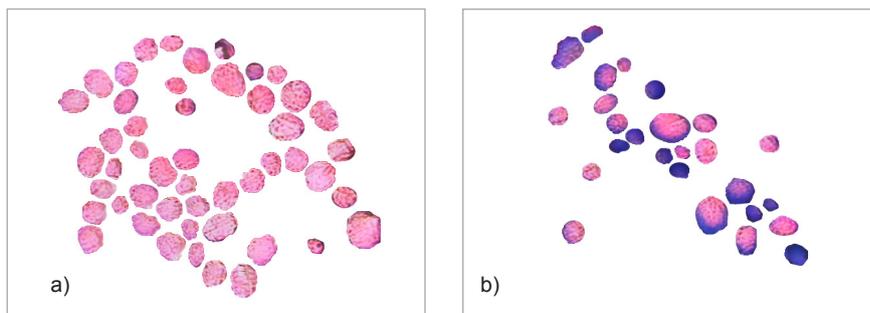


Figure 5. Image segmentation; a) Wool, b) Cashmere.

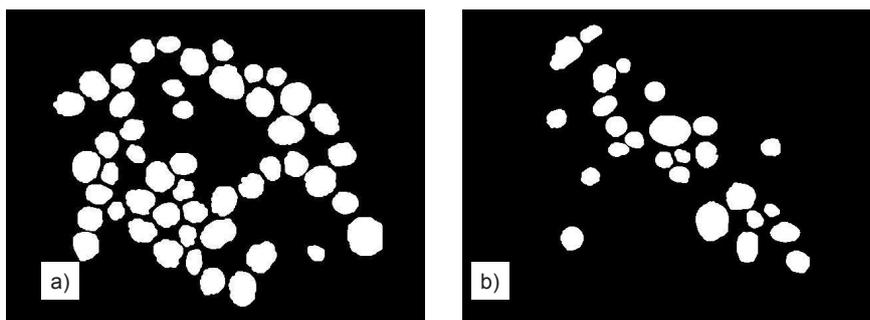


Figure 6. Binarisation image; a) Wool, b) Cashmere.

specimen's image remained the same as the original one because the noise removal process did not cause the boundary to fuzz.

- Image enhancement: By using this method, the histogram of the gray-level image expanded the range of the gray-level value, thereby enhancing the overall contrast gradient of the image.
- Brightness adjustment: Since the brightness of the image may be non-uniform in the photography process, it is essential to adjust the non-uniform brightness.
- Binarisation: Since it was not easy to identify and calculate from gray-level images, the gray-level image was converted into a binary one.

The threshold was obtained using the Graythresh function of MATLAB [30, 32]. An image of the sample after 11 procedures is shown in *Figure 6*. *Figure 6.a* is the binary image of wool, in which the white part is wool, and the black part - the background. *Figure 6.b* is the binary image of cashmere, the white part - cashmere and the black part is the background.

Calculation of the blend ratio

Calculation method

The blend ratio of cashmere and wool was calculated by the following [33]:

The ratio of wool:

$$X_w = \frac{1}{1 + \left(\frac{d_c}{d_w}\right)^2 \left(\frac{r_c}{r_w}\right) \left(\frac{N_c}{N_w}\right)} \quad (4)$$

Hence the ratio of cashmere:

$$X_c = 1 - X_w$$

where d is the equivalent diameter, r the density, and N is the amount. The subscripts w and c represent the wool and cashmere fiber, respectively.

Although the yarn cross section is not a true circle, and the diameter (d) of fibers can not be measured or reckoned exactly, the area (A) of the fiber cross section with irregular sections can be calculated accurately by MATLAB software [34]. Therefore, formula (4) should be changed as follows.

$$X_w = \frac{1}{1 + \left(\frac{A_c}{A_w}\right) \left(\frac{r_c}{r_w}\right) \left(\frac{N_c}{N_w}\right)} \quad (5)$$

where A is the area of the fiber cross section, r the density, and N is the amount. Subscripts w and c represent the wool and cashmere fiber, respectively.

Parameters A and N should be obtained from *Figure 6* using MATLAB software. If the density of the wool and cashmere is certain ($r_w = 1.31 \text{ g/cm}^3$, $r_c = 1.30 \text{ g/cm}^3$),

Table 1. Test results.

Sample	Test results (wool/cashmere), %					Mean, %	Abs. error, %	Strd dev., %
A	90.7/9.3	90.6/9.4	89.9/10.1	90.7/9.3	92.1/7.9	90.84/8.99	0.84	0.905
	89.4/10.6	90.5/9.5	89.1/10.9	91.3/8.7	91.9/8.1			
	91.5/8.5	91.0/9.0	89.6/10.4	91.2/8.8	91.3/8.7			
	92.3/7.7	91.4/8.6	89.8/10.2	90.9/9.1	91.6/8.4			
B	81.7/18.3	82.6/17.4	80.2/19.8	81.8/18.2	79.0/21.0	80.98/19.02	0.98	1.277
	82.4/17.6	82.8/17.2	81.4/18.6	81.2/18.8	79.3/20.7			
	80.6/19.4	81.6/18.4	82.1/17.9	78.6/21.4	79.6/20.4			
	82.3/17.7	81.2/18.8	80.4/19.6	81.5/18.5	79.4/20.6			
C	70.1/29.9	70.5/29.5	71.7/28.3	71.7/28.3	68.6/31.4	70.37/29.63	0.37	1.207
	69.5/30.5	69.4/30.6	71.6/28.4	70.8/29.2	68.6/31.4			
	72.2/27.8	72.5/27.5	70.5/29.5	70.3/29.7	69.0/31.0			
	69.6/30.4	71.5/28.5	69.4/30.6	70.8/29.2	69.1/30.9			

then the ratio of wool and cashmere can be calculated by formula (5).

Results and discussion

In the introduction above, the methods and process of fiber identification and blend ratio calculation are clearly described, and three kinds of wool/cashmere blend yarns with different blend ratios were adopted to test the accuracy of the method. Samples were (A) wool/cashmere blend yarn (90/10), (B) wool/cashmere blend yarn (80/20), and (C) wool/cashmere blend yarn (70/30). Each blend yarn was cut into segments of about 20 cm every two meters to obtain 20 samples - 60 in total. By staining, image processing and calculation, the blend ratios of each wool and cashmere sample were obtained, as listed in *Table 1*.

It can be seen from *Table 1* that the standard deviation of the result, calculated using the identification algorithm based on the support vector machine, is less than 1.3. The experimental result matches the factual situation very well, although there were still some errors and factors in the experimental process: First, some fibers may be not stained well in the process of dyeing because of the yarn itself, its twist or dyeing conditions. Thus, it is quite difficult for the computer to identify fuzzy colours, and as a result it would yield errors.

Secondly, because of the process of spinning, the wool and cashmere content is uneven in each cross section. The blend ratio calculated according to the cross section is also not constant. There should be a series of data concerning the blend ratio. Therefore, error in the test is unavoidable.

Although unavoidable error exists in the test, the total absolute error is less than 5%, which is in an allowable range. The method of calculating the blend ratio of wool/cashmere yarns based on image processing technology is applicable and reliable.

Conclusions

In this study, image processing technology and a support vector machine were employed to calculate the blend ratio of cashmere/wool. It included staining a blend yarn of cashmere and wool first, then identifying the fibers and testing the ratio. Although, there are some factors in the preparation of the cross-section slice, as well as in the imaging process, the result showed that the experimental results match the factual situation very well, which suggests that testing the ratio of cashmere/wool blend yarn by image processing technology is feasible with high accuracy.

References

1. Wortmann F. J., Wortmann G., Arn W.; *Textile Research Journal*, 1989, 59(2) pp. 73-80.
2. Fujishige S., Koshiba Y.; *Res. J.* 67 (1997) pp. 619-620.
3. Qin S. Z. *Science*, 6 (2006) pp. 57-59.
4. Langley K. D., Kennedy T. A.; *Text. Res. J.* 51 (1981) pp. 703-709.
5. Appleyard H. M.; *Guide to the identification of animal fibres*. WIRA, Leeds, 1978.
6. Zhao G. L., Xu J.; *Wool Textile Journal*, 1 (2006) pp. 42-44.
7. Nelson G., Hamlyn P. F., Holden L.; *Textile Research Journal*, 62(10) (1992) pp. 590-595.
8. Zheng Z. M. *Wool Textile Journal*, 2005(10): pp. 44-46.
9. Tang J. Z., Wang R. W.; *Wool Textile Journal*, 2002(5): pp. 12-15.

10. Ni G. J., Zhang Y.; *Advanced Textile Technology*, 2004, 12(4): pp. 40-42.
11. Xu B., Ting Y. L.; *J. Test. Inst.*, 1996, 87(3): pp. 284-295.
12. Robson D.; *Textile Research Journal*, 2000, 70(2): pp. 116-120.
13. TAO C. *Wool Textile Journal*, 2009, 37(2): pp. 47-50.
14. She F. H., Kong L. X., Nagavanandi S., Kouzani A. Z.; *Textile Res. J.*, 2002, 72, (7): pp. 594-600.
15. Yang W. Z., LiD. L., Zhu L., etc.; *Computers and Electronics in Agriculture*, 2009 (68): pp. 68-77.
16. Liu Y. B., Cao S. G., Liu Y. C.; *Journal of Chongqing University*, 2008, 31(7): pp. 720-724.
17. Yu W. D., Chu C. Y.; *Textile Physics*. Shanghai, Donghua University Publishing Company, 2002
18. Wu D. H.; *J. China Textile Inst.* 1993, (3): pp. 34-38.
19. Vapnik V. N.; *The Nature of Statistical Learning Theory*, Springer-Verlag, NewYork, 1995.
20. Tian Y. W., Li T. L., Li C. H., etc.; *Transactions of the Chinese Society of Agricultural Engineering*, 2007, 23 (6) pp. 175-180.
21. Wu L. L., Liu J. Y., Wen Y. X., Deng X. Y.; *Transactions of the Chinese Society for Agricultural Machinery*, 40(1) 2009: pp. 162-166.
22. Cha Z. H., Yu X. Y.; *China Textile University Transaction*, 1998, 24: pp. 82-85.
23. Tang G. H., Yang J. H., Zhang Z., etc.; *Coal Conversion*, 2004, 27(1): pp. 71-75.
24. Wu Z. P., Yu X. F.; *Journal of Shanghai University of Engineering Science*, 1995, 9(3): pp. 6-10.
25. Robson D.; *Textile Research Journal*, 2000, 70(2): pp. 116-120.
26. Xu B., Ting Y. L.; *J. Test. Inst.*, 1996, 87(3): pp. 284-295.
27. Bauters M.; *Study of the proteins extracted by formic acid from wool and mohair*. *Proceedings of the 7th International Wool Textile Research Conference*, Tokyo, vol. 1: pp. 162-165.
28. Chiu S. H., Chen J. Y., Lee J. H. *Techniques Textile Re.J.*, 1999(6): pp. 417-422.
29. Jan V. B., Joris V. A., Marc S.; *International Biodeterioration & Biodegradation*. 2005 (56): pp. 178-187.
30. Zhou J. P.; *Graph and Picture Processing and Application Example of MATLAB6.5*. Scientific Publishing Company, Beijing, 2003.
31. Hu X. F., Zhao H. *Visual C++/MATLAB Image Processing and Identification Applied Case Handpick*. People post Publishing Company, Beijing, 2004.
32. Gerald R. W.; *Numerical methods with MATLAB implementation and application*. China Machine Press, Beijing, 2004
33. Yao M. *Standard and test of cashmere/wool fiber*. Beijing, China Textile Press, 1997.
34. Hua Z. P., Gan Y.; *Research and Technology*, 2004, 3: pp. 16-18.

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