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A novel digital analysis method for measuring and identifying of wool and cashmere fibers

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ABSTRACT

The identification of wool and cashmere is always considered as a challenge in the field of textile and clothing industry. A novel digital analysis method based on fractal algorithm, parallel-line algorithm, and K-mean clustering algorithm was proposed in the paper to improve the accuracy of fiber measurement and identification. First, the original images of 600 cashmere fibers and 600 wool fibers were captured by optical microscope attached with a digital camera, the self-developed image preprocessing was carried out to obtain the binary image and contour image of cashmere and wool fibers. Then, the fractal algorithm was used to calculate the box-counting and information dimension of fiber binary images, and the parallel-line algorithm was used to measure the fiber fineness of the contour image. These features can be used as the representation of fiber surface morphological features. Finally, the cluster analysis of the extracted feature set was carried out by k-means algorithm, the specimens used for the identification include three sets of wool and cashmere fibers blended with different proportions. The experimental results showed that the accuracy of the fractal-based and diameter-based identification of three sets with different fiber blending proportions was higher than that of traditional methods, the average identification accuracy rate was 97.47%. Through this investigation, the novel digital analysis method proposed in the paper was proved to be feasible to measure and identify the wool and cashmere fibers, it had the protentional application of digital and automatic fiber classification in the future, in terms of both equipment, method and standard.

1. Introduction

Wool and cashmere are two very important protein natural fibers in the field of textile and clothing industry. Although these two kinds of fibers possess very similar morphology and texture, the price and performance of them are quite different. In this case, wool fibers may be used to replace cashmere fibers while with the claim of 100% cashmere in current market, which leads to the damage and loss of market reputation and the legitimate rights of consumers.

Until now, there are several methods used for the identification of wool and cashmere [1,2], including electrophoresis, extensional quantitative analysis and other physical methods, DNA analysis, amino acid analysis and other biological methods, as well as optical projection microscopy, scanning electron microscopy and other microscopic methods. The physical and biological methods require professional judges, the operation is quite complex and time consuming, meanwhile, it has low fault tolerance rate. The microscopic method usually requires high quality images with good clarity, it also depends on the human experience and knowledge of the quality evaluation.

What's more, it is necessary to investigate the fiber identification based on texture and appearance parameters of the natural protein fibers systematically, therefore, with the quick development of computer science and technology, the image-based methods are gradually used as the mainstream way for the identification of wool and cashmere fibers.

In 1989, Robson D et al. proposed an image analysis method for the measurement of cuticular scale of animal fibers [3]. Then, in 1997, he continued to investigate the animal fiber identification method based on imaging technique, which was proved to be an effective way to identify animal fibers [4].

In 2002, Yang et al. proposed an image analysis method-based on the surface appearance of scale of cashmere and wool fibers. One set of image processing algorithms was adopted and some related indexes such as inner and outer square factor were brought forward by which the cashmere fiber was identified automatically [5].

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In 2007, Shen et al. proposed an HSV based color analysis method for the identification of cashmere and wool, the shape and size of the fibers were determined to improve. The recognition rate of this method, which was reported to reach as high as 90.83% [6].

In 2010, Jiang et al. proposed a method based on the feature of the spectral line for the identification of cashmere and wool. The fiber surface information was mainly obtained through image processing, the corresponding spectral lines were determined by the projection method, meanwhile, the features of the segmented spectral lines were extracted. It was reported that the recognition rate of this method reached 95.2% [7,8].

In 2016, Wang et al. proposed one method for the identification of wool and cashmere based on near-infrared spectroscopy technology, it could be used to collect the near-infrared spectrum of wool and cashmere. Then the spectral modeling of normalized spectrum was developed to classify the fibers by the support vector machine with the recognition rate of 95% [9].

In 2017, Lu Kai et al. proposed a visual word bag model-based method to identify cashmere and wool fibers, which mainly was used to extract local features from the fiber morphology and generate visual words. It was reported that the recognition rate of this method reached 86% [10,11].

In 2018, Tao et al. proposed a gray level co-occurrence matrix method to extract texture features and used the central axis to extract morphological features for the identification of wool and cashmere, it was reported that the recognition rate of this method reached 93.1% [12].

Although quite a lot of researches have been done to provide some effective methods to classify the wool and cashmere fibers, image analysis algorithms are still under investigation to optimize the robustness and improve the reliability of these methods. Our research is targeted for the fiber measurement and identification based on computer vision and artificial intelligence, a novel digital analysis method based on fractal algorithm, parallel-line algorithm and K-means clustering algorithm is presented to improve the recognition rate of wool and cashmere fibers.

2. Methodology

2.1. Image preprocessing

The original images of wool or cashmere fibers could be digitalized using the microscope attached with a high-resolution digital camera. It is possible to generate some bubbles and other impurities during the sample preparation of these animal fibers, which may lead to the fuzzy edge and noisy textures. Therefore, it is necessary to remove noise objects and enhance image features through image preprocessing for improving the efficiency of further analysis. The detailed preprocessing algorithm flow chart is shown in the Fig. 1, from which the fiber binary image and the fiber contour image for the feature extraction could be obtained individually.

Contrast stretching algorithm is used here for the image enhancement, which uses the simple piecewise linear function to improve the dynamic range of grayscale during image processing [13]. The adaptive threshold algorithm is used for the image binarization, which is an effective method to convert gray level images into binary images [14–16]. The histogram of input gray level images is analyzed and divided into two sections, one threshold is set to achieve the largest difference between these two sections. The dividing or separation is operated based on the determined threshold for the image segmentation.

Those bubbles and other impurities of the sample preparation can be regarded as the isolated noise points, and they can be removed by noise elimination algorithm. What's more, the morphological processing is used to fill holes between fiber profiles [17,18] and the Canny algorithm, which was firstly proposed by John Canny in 1986 [19], is used to detect and extract the edge of fiber images.

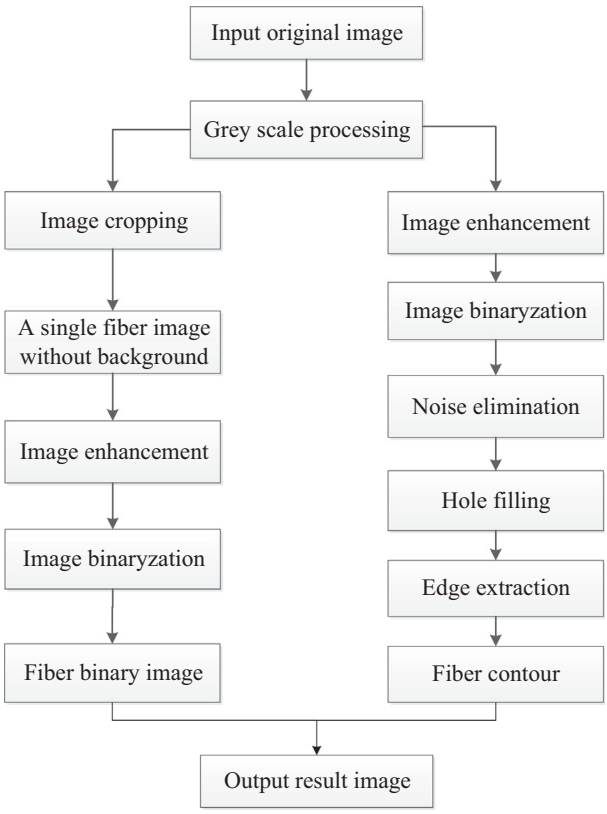

Fig. 1. Flow chart of image preprocessing algorithm.

2.2. Fractal analysis

The concept of fractal was firstly proposed by American French mathematician B. B. Mandelbrot in 1975 [20,21]. It can be described as "a shape similar to a whole in some form", which introduces the inherent laws of complex nonlinear systems by a convenient and quantitative method. The introduction of the fractal analysis algorithm provides a new solution to solve the problems of image segmentation, texture analysis, edge detection and so on, it has been widely applied in many fields.

2.2.1. Concept of fractal

Fractal is an important feature of the image analysis. It can combine the spatial information and grayscale information of the image to describe the texture characteristics of an object. At present, many kinds of dimensions, which consist of topological dimension, self-consistent dimension, Hausdorff dimension, box-counting dimension, capacity dimension, information dimension, correlation dimension and Lyapunov dimension, have been proposed based on the concept of the fractal [22].

Because the box-counting dimension of the fiber image can be calculated easily, supposing the black texture of the binary image is marked as '1', the white background is marked as '0' [23]. Meanwhile, the proportion of the labeled texture pixels "1" can be calculated, which is the number of information dimension. The texture features of the binary images of wool and cashmere fibers could be described by the box-counting dimension and information dimension in this paper.