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Objective Measurement of Wool Fibre Diameter Based on Staple Textural Features

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ABSTRACT

There is a huge demand for objective on-farm techniques, which would enable identification of the ‘outliers’ of sheep for the purpose of breeding selection, reducing the fineness (or micron) of woolgrowers’ flocks with greater confidence, and maintaining the uniform quality throughout the wool clips. In this study, we employ the concept of texture analysis based on Gabor filtering and extract textural features from the images of wool staples with different fineness. It is justified by our experiments that those textural features are rotation invariant and also sensitive to the fineness of wool staples and efficient in discrimination of wool staples with different finenesses. Since it requires minimum manual operations, this approach has a great potential to be applied on farm or in shearing shed.

Keywords: wool staple, fineness, Gabor filter, texture analysis, textural feature, feature extraction, on farm technique

1. Introduction

A wool fleece is made up of a large number of clusters or groups of wool fibres which are known as staples. Because of their growing nature, wool staples differ in many characteristics including fineness and visual properties. These characteristics have great influence on its grade and spinning capabilities. Especially, the fineness of fibres is the most important attribute of wool fibres.

On a wool farm, the outliers of sheep in the mob, which produce coarse wool fibres and have distinct visual characteristics from others, need to be identified and slaughtered for the purpose of breeding selection, reducing the fineness (or micron) of the woolgrower’s flocks and maintaining a uniform quality throughout wool clip. In a wool shearing shed, it is usually necessary to class out wool fleeces that are broader, as distinct from the bulk quality of the sheep mob. Producing as even lines as possible from the same property will help maximise woolgrower’s return and provide fibres to processors who can use with confidence. Usually, well-trained woolclassers are employed to

perform those tasks. Generally, woolclassers need to achieve up to 2 micron difference in the fineness between the main fleece line and the broad line.

These visual characteristics, which are used in current practice, are defined as crimp, curvature or style. Over the years in the past, many research groups have examined these properties of individual fibres and tried to find relationship between those properties and fibres’ fineness [1-7]. For instance, it was found that a wool fibre with a finer diameter will have a smaller crimp and will have more of them per unit fibre length; when the sheep is well breed, the wool fibres produced have very-defined and evenly spaced crimps, which are also called good style. However, it was also found that crimp is not reliable and wool-fibre curvature is relatively unstable. Some research has suggested that breeders should be careful when using fibre curvature measurements in the implementation of their breeding plans [2]. The style of wool staples is not well defined as well. Thus, those features are neither reliable nor robust enough to describe visual traits of wool staples on their own and their relationships with fibre’s fineness are complicated.

In fact, wool staples can be considered as so-called textural objects, which are often described as fine or coarse, grained, smooth or rough, etc. In the past, many extensive studies have been done to understand the principles of human texture perception and design textural features for artificial visual system. Among them, a theory, supported by many psychophysical and neurophysiological data, holds that the human visual system is performing some form of local spatial-frequency analysis on the retina image and that this analysis is done by a bank of tuned bandpass filters [8]. The concept of local spatial frequency, or local frequency, had been put forth in the context of communication systems many years earlier by Gabor [9]. Classically, images are viewed as either a collection of pixels (spatial domain) or a sum of sinusoids of infinite extent (spatial-frequency domain). Gabor, however, observed that the spatial representation and the spatial-frequency representation are just opposite extremes of a continuum of possible joint space/spatial-frequency representation. Therefore, Gabor filters have been successfully used for analysing textural images.

In this study, we will employ the concept of texture analysis based on Gabor filtering, which is popularly used in many other applications but not yet to wool staples. In more details, firstly, images of wool staples with different fineness and visual properties will be taken and pre-processed; secondly, texture analysis based on Gabor filtering will be applied on each pre-processed image and Gauss filters used to smooth the random noises. Thirdly, a set of textural features are extracted to describe overall fineness of wool staples and a feature library is established. Finally, it will be justified whether those textural features are efficient to characterise wool staple fineness. The schematic diagram is shown in Figure 1.

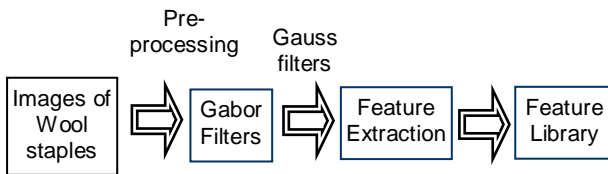


Figure 1: Schematic diagram of textural feature extraction from wool staples

2. Materials and Image Pre-processing

In this work, three bags of wool staples, which are collected from Adelaide Wool company, consist of superfine wool (with a mean diameter of 16.5 microns, which is read from OFDA), fine wool (with a mean diameter of 19 microns, read from OFDA) and medium wool (with a mean diameter of 21-22 microns, read from OFDA), respectively. It can be noticed that the superfine wool staples have smaller crimps while medium wool fibres have larger crimps.

Images of wool staples are taken and stored by a digital CCD camera. The regions with too many impurities, such as vegetable matters in wool staples are avoided. The images are transferred to a computer. In Figure 2, three images including a superfine wool staple, a fine wool staple and a medium wool staple are shown.

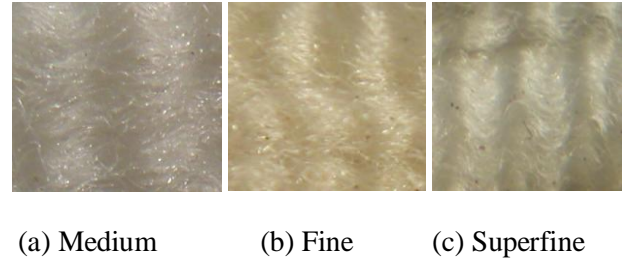


Figure 2: Wool staples: (a) medium, (b) fine, (c) superfine

In real time, the images of wool staples may be captured in different illumination conditions and illumination is also not uniform in one image. To make feature extraction more efficient, those images obtained are automatically pre-processed. In this step, our algorithm, which is written in Visual C++ language, will automatically extract a portion of an image (i.e., a cropped image) with the size of 256×256 pixels from the center of each raw image of wool samples. Then the cropped image is divided into 32×32 blocks. In each block (with 8×8 pixels), the gray intensity of every pixel is set to the average gray level of all elements in that block. Actually, the image obtained from the operations above shows a coarse estimation of the background illumination. This image is subtracted from the original cropped image to correct the non-uniform illumination in the cropped image.

Next, to prevent the effect of the first order statistics of gray intensities in the images, the

image resulted from above is normalized to the same mean intensity and variance using histogram equalization techniques. In this way, 50 images of wool staples, including 24 images for superfine, 11 for fine and 15 for medium wool fibres, are prepared for feature extraction in the next step.

3. Textural Features of Wool Staples and Their Extraction

In this step, each pre-processed image is filtered by Gabor filters at different centre frequencies and then smoothed by Gauss filter to eliminate the random noises. Finally, the magnitudes of the outputs of the Gabor filters are used as textural features to characterize wool staples. For each fineness group of wool staples, the mean value and variance of the features are calculated to establish feature library of wool staples.

To get rotation-invariant textural features, we used circular Gabor filters, which are defined as follows:

$$G(x, y) = g(x, y) \sin(2\pi F \sqrt{x^2 + y^2})$$

where F is the central frequency of a circular Gabor filter and

$$g(x, y) = \frac{1}{2\pi\delta^2} \exp[-\frac{1}{2\delta^2}(x^2 + y^2)]$$

where δ characterizes the spatial extent and bandwidth of the Gabor filter.

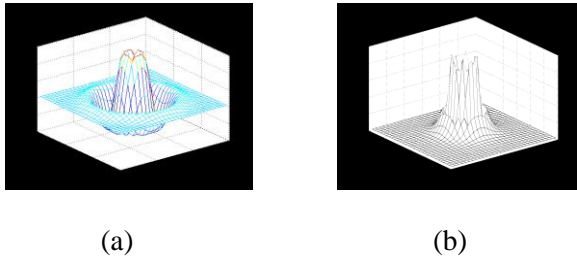
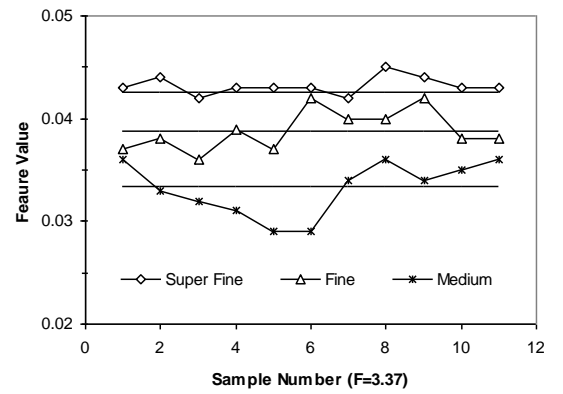


Figure 3: Circular Gabor function: (a) in the spatial domain; (b) in the spectrum domain

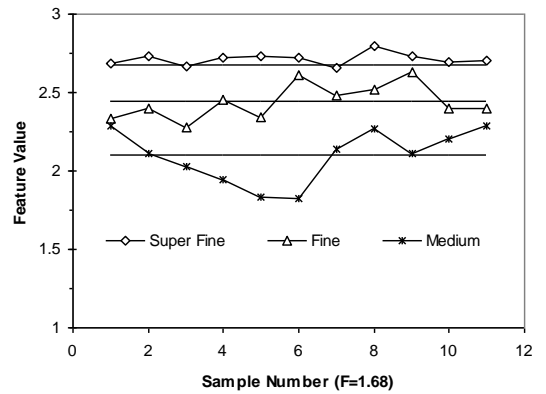
Since most of the spectral energy of natural image often centres at low frequency, the frequency F is selected as 3.37hz、1.68hz、0.84hz、0.42hz、0.21hz respectively for all images of wool staples. From the outputs of the Gabor channels, textural information at those five different spatial frequencies is obtained.

To improve the performance of Gabor filters for texture analysis, Gaussian smoothing is utilized for post-filtering the channel amplitudes. The Gaussian filters have the same shape as the corresponding channel filters but greater spatial extents than Gabor filters.

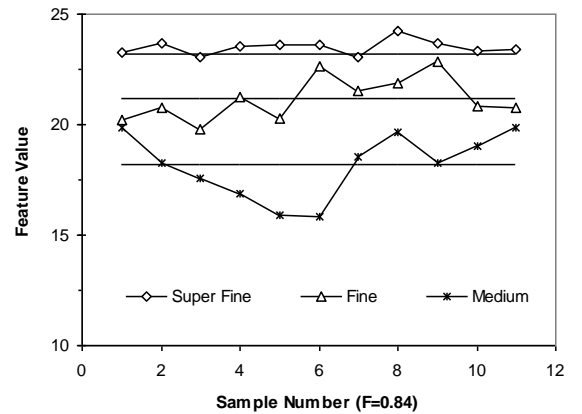
Then, the mean magnitude of the outputs is calculated as the feature to characterize each wool staple. Corresponding to five different central frequencies, five sets of features are obtained for each image of wool staples as shown in Figure 4. In the Table 1, the statistical information of those features is summarised.



(a) Central Frequency = 3.37



(b) Central Frequency = 1.68



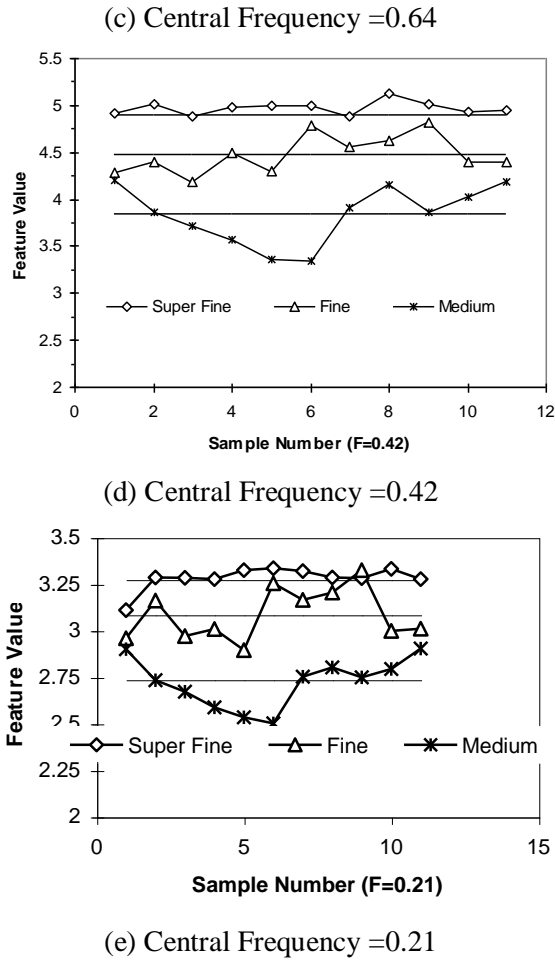


Figure 4: Textural features of wool staples with different fineness (superfine, fine and medium) by Gabor filters with different central frequencies

Table 1: Statistic information of textural features for superfine, fine and medium wool staples: \bar{X} and σ denoting mean and variance respectively

Frequency		3.37	1.68	0.84	0.42	0.21
Super fine	\bar{X}	0.043	2.68	23.2	4.91	3.28
	σ	0.00	0.005	0.40	0.02	0.003
Fine wool	\bar{X}	0.039	2.44	21.2	4.48	3.09
	σ	0.00	0.01	0.95	0.04	0.02
Medium fine	\bar{X}	0.034	2.10	18.2	3.86	2.74
	σ	0.00	0.03	2.30	0.10	0.024

4. Results and Discussion

From Figure 4, it can be noticed that the feature values of three types of wool staples have similar trend although the Gabor filter has different central frequencies and finer wool staples have higher feature values while coarse wool staples have lower feature values for all central frequencies. The features for three types of wool

staples are also separable or discriminable at different value scale when the Gabor filter has different central frequencies. That means that the features extracted in this study are insensitive to the central frequency of the Gabor filter.

However, the responses from the Gabor filter with central frequency of 0.84hz are the highest for three types of wool staples. The absolute differences in these responses between those three types of wool staples are also the largest. This indicates that the spatial-frequency components of dominant texture characterizations of those wool staples are caught by the Gabor filter with the central frequency of 0.84hz while all other Gabor filters have much smaller responses, which can be ignored as characteristic of this particular texture.

As shown in Table 1, the mean feature value of superfine wool staples is the highest while that of medium wool staples is the lowest for five different central frequencies; the variance of feature values of superfine wool staples is the lowest while that of medium wool staples is the highest when all different central frequencies except 3.37hz are utilized. These results indicate that finer wool staples not only have greater gray variations in spatial domain but also are evenner according to the features extracted in this study. The conclusion is consistent with human observation as indicated above.

Furthermore, those features extracted in this study are rotation invariant since we utilize the circular Gabor filters. Thus this makes sample preparation and image capturing much easier and more convenient than traditional methods.

5. Conclusions

On wool farms and in shearing sheds, woolgrowers and woolclassers need to assess and classify wool staples based on their visual characteristics and fineness. This kind of subjective assessment method is time-consuming, tedious and incurs human errors. Currently, there is no objective way of assessing the visual properties of wool staples and how these properties are related to wool fibres' fineness. However, there is a huge demand for on-farm fibre measurement (OFFM) techniques, which would enable identification of the 'outliers' of sheep for the purpose of breeding selection, maintaining the uniform quality throughout the wool clips, and reducing the micron of

woolgrowers' flocks faster and with greater accuracy, confidence and commercial benefit [10].

In this study, images of wool staples with different fineness were taken by a digital CCD camera and an algorithm in Visual C++ language were developed to automatically reduce undesirable noises in the images, which may be caused by the non-uniform illumination and/or impurities (i.e., vegetable matters) attached on wool samples and extract textural features using Gabor filters to characterise wool staples. From the results shown in this study, it is found that finer wool staples not only have greater gray variations in spatial domain but also are evenner according to the textural features extracted in this study. These results are consistent with human observations.

The textural features obtained in this study are separable or distinguishable for wool staples with different fineness, i.e., superfine, fine and medium wool fibres. This result approves that those textural features are closely relevant to the fineness of wool staples. Since the sample preparation required is minimized and much more fibres can be measured at one time in this approach, this approach has great potentials to be used for sheep breeding selection or ranking animals on farm or for classification of wool staples in a shearing shed once a discrimination classifier is implemented into the system in the near future.

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