DENOISING AND SEGMENTATION OF MCT SLICE IMAGES OF LEATHER FIBERS

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Abstract. A series of image denoising algorithms, segmentation algorithms and reconstruction algorithms are designed for processing in-situ leather fiber MCT images and resin-embedded MCT slice images. Three-dimensional reconstruction images of fiber bundles were obtained.

1 Introduction

The braiding structure of leather fibers has not been understood clearly and it is very useful and interesting to study it, whether in theory or in application.

Microscopic X-ray tomography (MCT) technology can produce cross-sectional images of the leather fibers without destroying their structure. The three-dimensional structure of leather fibers can be reconstructed by using MCT slice images, so as to show the braiding structure and regularity of leather fibers. The denoising and segmentation of MCT slice images of leather fibers is the basic procedure for three-dimensional reconstruction. In order to study the braiding structure of leather fibers, the resin-embedded leather fiber MCT slice images and the in-situ leather fiber MCT slice images were analyzed and processed. It is showed that the resin-embedded leather fiber MCT images were quite different from the in-situ leather fiber MCT images. The in-situ leather fiber MCT images could be denoised relatively easily. But denoising of resin-embedded leather fiber MCT images is a challenge because of its strong noises. In addition, some fiber bundles that adhere to each other in the slice image are difficult to be segmented. Lots of image denoising and segmentation methods and algorithms have been proposed up to now. But each image processing method and algorithm may be effective only in some cases. There is no general method to deal with all types of images. In this paper, a series of computer-aided denoising and segmentation algorithms are designed for in-situ MCT slice images and resin-embedded MCT slice images of leather fibers. Each fiber bundle is reconstructed in three dimensional. The structure is fine that has never been seen before.

In this paper, there are two main image denoising methods introduced: one is threshold-denoising method based on grayscale value for the image with lower grayscale level, and the other is threshold-denoising method based on areas for the image with higher grayscale level. The MCT slice image of embedded leather sample has strong noises, which is much more difficult to denoise than the in-situ MCT slice image. According to the distribution of the grayscale value of the fiber region, background region and the distribution of the block area, the Grayscale-threshold method based on pixel values or region areas are selected for image denoising.

The fiber bundles in wide field MCT images are distributed densely and adherent to each other. Many fiber bundles are separated in one of the images but tightly bound in the adjacent image. This leads to great difficulties for image segmentation. In the process, three main segmentation methods are used: The Grayscale-threshold segmentation method, the Region-growing segmentation method and the Three-dimensional Segmentation method.

2 Image acquisition

Oxygen resin embedding method was used to acquire MCT images. The concentration of epoxy resin is set to be 25% and the curing temperature is set to be 80°C.

2357 embedding section images and 2357 in-situ section images were acquired by MCT method, respectively.

The size of the raw MCT image is 4032×4032 pixels, and the size of each pixel is 0.31um×0.31um. After image acquisition, the images were resized by removing the redundant parts, producing smaller images, in order to perform denoising, segmentation and reconstruction algorithms on the computer automatically and effectively.

Fig.1(a) shows a small part of a raw in-situ leather fiber MCT image, with the size of 1250×1250 pixels; Fig.1(c) shows a small part of a raw resin-embedded leather fiber MCT image, with the size of 1250×1250 pixels.

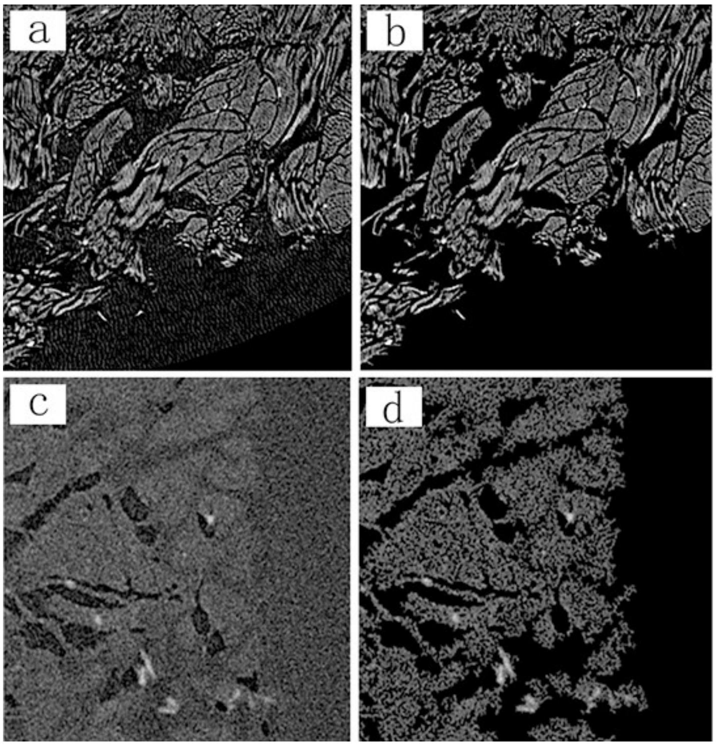

Fig. 1.. a. A part of the raw in-situ leather fiber MCT image; b. A part of the denoised in-situ leather fiber MCT image; c. A part of the raw resin-embedded leather fiber MCT image; d. A part of the denoised resin-embedded leather fiber MCT image.

3 Denoising Algorithms

It is relatively easy to denoise in-situ MCT images with the help of two threshold algorithms. Firstly, remove pixels of lower grayscale value, and then remove isolated islands with small areas. In the process of denoising, the low-gray-value pixels inside the fiber bundle may be removed at the same time. The Region-filling Algorithm, the Region Expansion and the Region Contraction Algorithm can be used to compensate the 'erroneously deleted' pixels. Fig.1(b) shows a small part of the denoised in-situ MCT image.

For embedding images, a series of image processing algorithms were used to perform denoising procedure, including the Threshold Algorithm based on the grayscale value and based on the area of region, respectively, the Region-filling Algorithm, the Expansion Algorithm and the Corrosion Algorithm. Fig.1(d) shows a small part of the denoised embedding MCT image.

All the works mentioned above were performed with the help of the software Matlab automatically.

As shown in Fig.1.(c), the resin-embedded leather fiber MCT images have much more strong noises than the in-situ leather fiber MCT images.

4 Segmentation and Reconstruction Algorithms

The fiber bundles in wide field MCT images are distributed densely and adherent to each other. Many fiber bundles are separated in one image and tightly bound in another. This leads to great difficulties to image segmentation. In the process of segmenting fiber bundles, the following segmentation methods are used:

a. the Grayscale-threshold Segmentation method: Since the boundary of some adjacent fiber bundles has relatively lower grayscale values, so it can be removed by a grayscale threshold value. This makes different fiber bundles separated.

b. The Region-growing Segmentation method: A set of pixels from the fiber bundle was chosen and expanded by connecting their neighborhood to obtain the maximum connected region.

c. Three-dimensional Segmentation method: Because of the complexity of fiber structure, it was not effective to segment the fiber bundles slice by slice. The cross-sectional shape of the same fiber bundle may be quite different in two adjacent slices. It is difficult to determine whether it belongs to the same fiber bundle. The reconstruction procedure works well with the segmentation algorithm for segmenting some of this kind of bundles but not all.

On the basis of denoising and preliminary image segmentation as mentioned above, Three-dimensional Reconstruction algorithms is carried out. In this process, Forward-tracking method and Backward-tracking method are used. The Forward-tracking method is to select the cross-sectional area of a fiber bundle from the first slice image and connects the cross-sectional area of the bundle on the adjacent image in turn until reaching the last one. This algorithm may lead the loss of some of the backward branches of the fiber bundles. In order to remedy this defect, on the basis of the three-dimensional reconstruction of the fiber bundle obtained by the Forward-tracking method, the cross-section area of the fiber bundle in the front adjacent image is connected in turn from the last picture of the fiber bundle to the first one. This algorithm is called the Backward-tracking method.

The Three-dimensional Reconstruction Algorithm combined with the Forward-tracking method and the Backward-tracking method produces a three-dimensional reconstruction image, as shown in Fig.2.

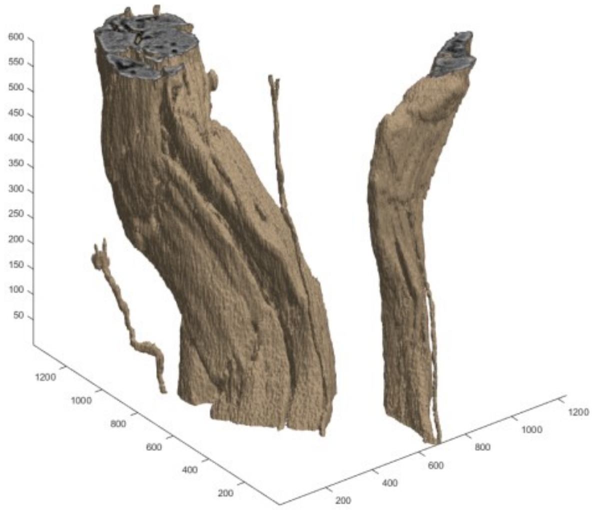

Fig. 2. 3-D reconstruction of the in-situ leather fiber MCT image in part. The scale unit is the pixel.

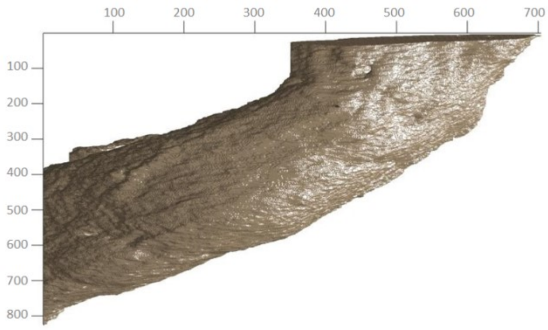

Fig. 3. 3-D reconstruction of the in-situ leather fiber MCT image in small part. The scale unit is the pixel.

Since the size of three-dimensional reconstruction image is usually too large to display with the software Matlab, it is necessary to reduce the size of the image to display panorama, or display some parts of the image in order to show details, as shown in Fig.3.

5 Conclusions

A series of image denoising algorithms, segmentation algorithms and reconstruction algorithms are designed for processing in-situ leather fiber MCT images and resin-embedded MCT slice images. These algorithms are automatically implemented by computer with software Matlab. For the in-situ leather fiber MCT images, two main algorithms were developed to do image denoising and segmentation. One is the Threshold-denoising Algorithm based on grayscale value for the image with lower grayscale level, another is the threshold-denoising method based on area for the image with higher grayscale level. For the embedded MCT images, the Grayscale Threshold Algorithm based on pixel values and the Grayscale Threshold Algorithm based on region areas were used to do image denoising according to the distribution of the grayscale value of the fiber region and background region and the distribution of the block area. At last three-dimensional reconstruction images of fiber bundles were obtained.

The image denoising, the image segmentation and the image reconstruction algorithms proposed in this paper have remarkable effect in processing the in-situ leather fiber MCT images. A series of three-dimensional images based on this work demonstrate the fine spatial braiding structure of leather fibers, which would help us to understand the braiding structure of leather fibers better. Due to the complexity of the fiber structure, interlaced bundles of fibers are not yet well segmented. Further study is needed.

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References

1. *D. Birk, E.I. Zycband, D.A. Winkelmann, R.L. Trelstad, Collagen Fibrillogenesis in Situ: Fibril Segments are Intermediates in Matrix Assembly, PNAS,USA, 1989, 86, 4549–4553.*
2. *I. Johanes, E. Mihelc, M. Sivasankar, A. Ivanisevic, Morphological Properties of Collagen Fibers in Porcine Lamina Propria, J. Voice, 2011, 25(2), 254–257.*
3. *J.A.M. Ramshaw, Probing Collagen Structure and Function, Heidemann Lecture, 2017.*
4. *S. Osher, J.A. Sethian, Fronts Propagating with Curvature Dependent Speed ：Algorithms Based on Hamilton-Jacobi Formulations, J. Comput. Phys., 1988, 79,12–49.*
5. *W. Denk, H. Horstmann, Serial Block-face Scanning Electron Microscopy to Reconstruct Three-Dimensional Tissue Nanostructure, Plos. Biol., 2004, 2, 1900–1910.*
6. *H.Y. Zhang, Y.M. Xia, J.Y. Cheng, L. Shi, T.D. Li, A Novel Technique for Getting Leather Section Image Based on Metallographic Sample Preparation, JALCA, 2013, 108 (5), 166–170.*
7. *H.Y. Zhang, Y.M. Xia, L. Shi, T.D. Li, Characterization of Leather Structure via Metallographic Sample Preparation, JALCA, 2014, 109 (1), 1–7.*
8. *H.Y. Zhang, H.W. Lu, Y.L. Zan, Y.M. Xia, T.D. Li, Characterization of Goat Leather Structure Using A Metallographic Technique, JALCA, 2015, 99(1), 23–29.*

1. *9.Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing,Third Edition, New Jersey :Pearson Education, Inc.*
2. *10.Matlab-The Language of technical Computing,The Math Works,Inc.*
3. *11.Rafael C.Gonzalez, Riechard E.Woods, Digital Image Processing,Third Edition.Pearson Education.Inc.,2010.*