City Research Online

City, University of London Institutional Repository

This is the accepted version of the paper.

This version of the publication may differ from the final published version.

Permanent repository link: https://openaccess.city.ac.uk/id/eprint/33932/

Link to published version:

A comparative study of fibre tracing in biomedical images.

Youssef Arafat [iD][1], Esther Castellano[2]

Cristina Cuesta-Apausa[2], Constantino Carlos Reyes-Aldasoro [iD][1,3]

[1]Department of Computer Science, City, University of London, UK

[2]Tumour-Stroma Signalling Lab, Universidad de Salamanca, Salamanca, Spain

[3]The Institute of Cancer Research, UK

September 5, 2024

Abstract

Identifying traces and features of elongated structures is a crucial task in many computer vision workflows. In biomedical applications, analysing traces of vasculature, nerves, or extracellular matrix fibres can provide insights into processes like angiogenesis or the impact of specific treatments. This paper demonstrates an objective comparison of six established methods (Edge detection [1], CT Fire [2, 3], Scale Space [4, 5], Twombli [6], U-Net [7] and Graph-Based [8, 9]) alongside a new approach named Trace Ridges to trace biomedical images exhibiting fibre-like structures. Trace Ridges is a fully automated and fast algorithm that integrates a series of image-processing techniques including filtering, watershed transform [10, 11], and edge detection, to achieve precise delineation of fibre-like structures rapidly. For the comparison, four biomedical datasets with diverse characteristics were chosen. The ground truth was established through manual delineation of the fibre-like structures. Three pre-processing filtering techniques were employed initially: no filtering, Gaussian low-pass and DnCnn [12], a deep-learning based filter. Three distance error metrics (total, average and maximum distance from traces to ground truth) and processing time were calculated. The results indicated that no single algorithm outperformed the others across all metrics. For the total distance error, which was deemed the most significant, Trace Ridges ranked first, followed by Graph Based, U-Net, Twombli, Scale Space, CT Fire and Edge detection. In terms of processing speed, Trace Ridges was the second fastest, only slightly slower than Edge Detection. Trace Ridges was employed to detect and analyse morphological differences in collagen structures as collagen concentration increased from 1.7 mg/ml to 6.6 mg/ml, using Second Harmonic Generation and Confocal Reflectance Microscopy images.

Keywords— Fibre tracing, ECM, Tracing algorithms

References

[1] John Canny, "A Computational Approach to Edge Detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. PAMI-8, no. 6, pp. 679–698, Nov. 1986, Conference Name: IEEE Transactions on Pattern Analysis and Machine Intelligence.

[2] Jeremy S. Bredfeldt, Yuming Liu, Carolyn A. Pehlke, Matthew W. Conklin, Joseph M. Szulczewski, David R. Inman, Patricia J. Keely, Robert D. Nowak, Thomas R. Mackie, and Kevin W. Eliceiri, "Computational segmentation of collagen fibers from second-harmonic generation images of breast cancer," *Journal of Biomedical Optics*, vol. 19, no. 1, pp. 016007, Jan. 2014.

[3] Y Liu and et al., "Fibrillar Collagen Quantification With Curvelet Transform Based Computational Methods," *Frontiers in Bioengineering and Biotechnology*, vol. 8, 2020.

[4] T. Lindeberg, "Edge detection and ridge detection with automatic scale selection," *Int J Comp Vision*, vol. 30, no. 2, pp. 117–154, Nov. 1998.

[5] Tony Lindeberg, "Feature detection with automatic scale selection," *International Journal of Computer Vision*, vol. 30, no. 2, pp. 79–116, 1998.

[6] Esther Wershof, Danielle Park, David J. Barry, Robert P. Jenkins, Antonio Rullan, Anna Wilkins, Karin Schlegelmilch, Ioannis Roxanis, Kurt I. Anderson, Paul A. Bates, and Erik Sahai, "A FIJI macro for quantifying pattern in extracellular matrix," *Life Science Alliance*, vol. 4, no. 3, Mar. 2021, Publisher: Life Science Alliance Section: Methods.

[7] Olaf Ronneberger, Philipp Fischer, and Thomas Brox, "U-Net: Convolutional Networks for Biomedical Image Segmentation," in *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015*, Nassir Navab, Joachim Hornegger, William M. Wells, and Alejandro F. Frangi, Eds., Cham, 2015, pp. 234–241, Springer International Publishing.

[8] Anca-Ioana Grapa, *Characterization of fibronectin networks using graph-based representations of the fibers from 2D confocal images*, Phd thesis, Universite Cote d'Azur, Nice, France, Dec 2020, Available at `https://theses.hal.science/tel-03052167`.

[9] Anca-Ioana Grapa, Georgios Efthymiou, Ellen Van Obberghen-Schilling, Laure Blanc-Féraud, and Xavier Descombes, "A spatial statistical framework for the parametric study of fiber networks: Application to fibronectin deposition by normal and activated fibroblasts," *Biological Imaging*, vol. 3, pp. e25, Jan. 2023.

[10] S. Beucher Meyer, F., "The Morphological Approach to Segmentation: The Watershed Transformation," in *Mathematical Morphology in Image Processing*, pp. 433–481. CRC Press, 1992, Num Pages: 49.

[11] Fernand Meyer, "Topographic distance and watershed lines," *Signal Processing*, vol. 38, no. 1, pp. 113–125, July 1994.

[12] Kai Zhang, Wangmeng Zuo, Yunjin Chen, Deyu Meng, and Lei Zhang, "Beyond a Gaussian Denoiser: Residual Learning of Deep CNN for Image Denoising," *IEEE Transactions on Image Processing*, vol. 26, no. 7, pp. 3142–3155, July 2017.