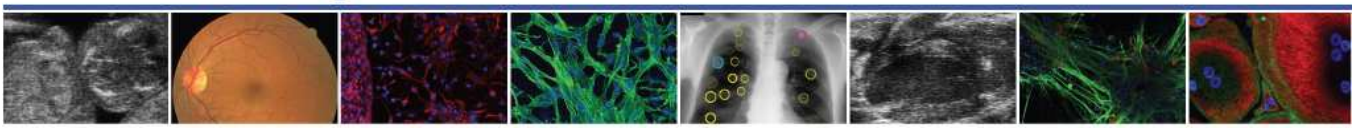
BIOIMAGING 2013
INTERNATIONAL SYMPOSIUM IN APPLIED BIOIMAGING
FROM MOLECULE TO MAN
BIBLIOTECA ALMEIDA GARRETT, PORTO, OCTOBER 3-4, 2013



Submitting Abstract: ***Oral presentation***

Symmetric junctions in biological micrographs

Zsuzsanna Püspöki, Cédric Vonesch, Michael Unser
(e-mail: zsuzsanna.puspoki@epfl.ch, cedric.vonesch@epfl.ch, michael.unser@epfl.ch)
Biomedical Imaging Group, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Abstract

We propose a framework for the detection of symmetric junctions in biological micrographs. The specificity of our work is that we design steerable wavelets that have optimal angular selectivity, so as to provide both multi-scale detections and a good estimation of the orientation of the junction. The approach we have developed is general and can be used for the detection of any kind of symmetries.

Introduction

Bilateral and 3-fold symmetric objects are common in nature. 2-fold symmetries are present in filaments, fibers and membranes, hexagonal patterns are realized in endothelial cells (e.g. eyes), in the parenchyma (e.g. maize), on the surface of many diatoms and in the stem cross-section of plants (e.g. Convallaria). The detection of these symmetries and junctions is an important image-processing task for the analysis of microscopic images. Operations such as counting of cells, or making image statistics require a precise identification of junctions and symmetry centers. As a particular example, certain experiments in stem cell research need the accurate detection of cell structures (like tight junctions), which exhibit polygonal shapes [10].

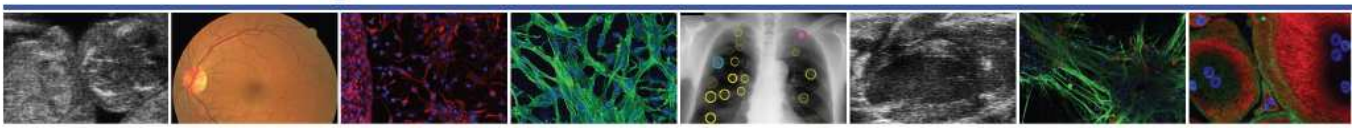
Materials and Methods

There are several existing methods for junction detection. Broadly, one can separate them into three categories: methods based on the detection and analysis of edges and gradients [1, 8], those relying on feature analysis with structure tensors and their derivatives [5, 2], and approaches based on template matching [7, 3], including some that use steerable filters [4, 9, 6]. Methods belonging to the first two categories are typically adapted to differentiate between junctions and edges or other keypoints. The last category includes detectors with parametric templates corresponding to specific types of junctions (T, Y, X, etc.). With the exception of steerable filters, these approaches generally involve discretizing rotation angles, which entails a compromise between angular precision and computational cost of detection. Finally, all of the existing approaches are focused solely on detection, and, they do not provide a framework for the decomposition and analysis/synthesis of images based on junctions and symmetry.

The algorithm we propose is able to detect the desired features in a scale and rotation invariant way. To that end, we design 2-D steerable wavelet frames that are polar separable in the Fourier domain, such that the pyramid characterized by a radial wavelet function and the directional components can be formed using circular harmonics. The result is a symmetric tight wavelet frame that facilitates the detection and analysis of features at different scales, can deal with arbitrary rotations in an efficient and systematic manner, and permits energy-based analysis and image reconstruction thanks to its tightness.

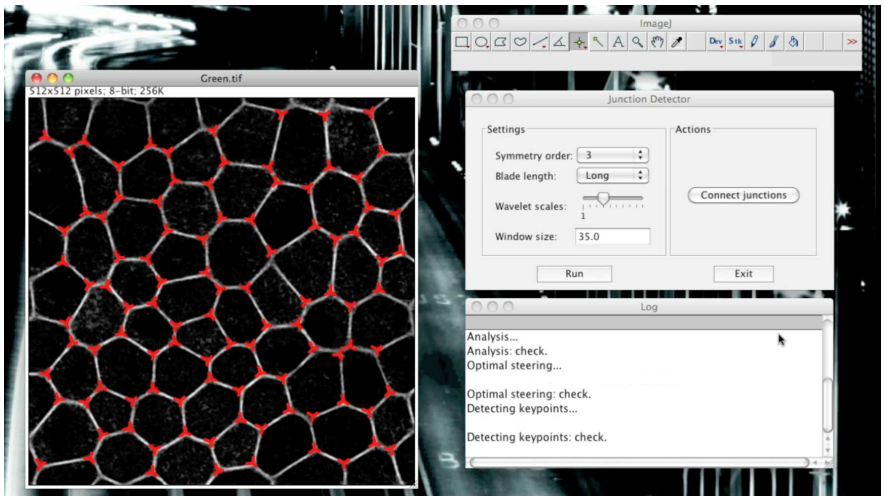
The detection algorithm comprises the following steps:

1. Wavelet design for M-fold symmetric wavelets
2. Wavelet analysis with optimally steered wavelets
3. Maximum intensity projection across scales
4. Thresholding and local maxima detection.



Results and Discussion

Our symmetry detection algorithm has been implemented as an ImageJ plugin. The following image shows the plugin and the results obtained for a cornea image.



Conclusions

The main advantages of the algorithm are

1. the steering property of the detector wavelet - thus the detections can be obtained in a fast and computation effective way regardless of the orientation of the pattern,
2. the multi-scale approach - thus we get a precise estimate of junctions at different scales,
3. and the tight frame property – thus we are able to do energy-based analysis and reconstruction from features.

The output of the algorithm is a detection map, where the orientations of the features are also indicated.

References

[1] D.J. Beymer. Finding junctions using the image gradient. *A.I. Memos, M.I.T. Atrificial Intelligence Laboratory*, AIM-1266: 1-46, Dec.1991.

[2] J. Bigun, T. Bigun, and K. Nilsson. Recognition by symmetry derivatives and the generalized structure tensor. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 26(12) :1590–1605, Dec. 2004.

[3] F. Escolano, P. Suau, and B. Bonev. *Information Theory in Computer Vision and Pattern Recognition*. Springer, 2009.

[4] W. T. Freeman. *Steerable Filters and Local Analysis of Image Structure*. PhD thesis, Massachusetts Institute of Technology, 1992.

[5] Ullrich Köthe. Edge and junction detection with an improved structure tensor. In Bernd Michaelis and Gerald Krell, editors, *Pattern Recognition*, volume 2781 of *Lecture Notes in Computer Science*, pages 25–32. Springer Berlin / Heidelberg, 2003.

[6] M. Muehlich, D. Friedrich, and T. Aach. Design and implementation of multisteerable matched filters. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 34(2) :279–291, Feb. 2012.

[7] L. Parida, D. Geiger, and R. Hummel. Junctions : detection, classification, and reconstruction. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 20(7) :687–698, July 1998.

[8] The-Anh Pham,M. Delalandre, S. Barrat, and J. Ramel. A robust approach for local interest point detection in line-drawing images. *Document Analysis Systems (DAS), 2012 10th IAPR International Workshop on*, pages 79–84,Mar. 2012.

[9] E.P. Simoncelli andH. Farid. Steerablewedge filters for local orientation analysis. *Image Processing, IEEE Transactions on*, 5(9) :1377–1382, Sep. 1996.

[10] O. Fumitaka et al., "Toward the generation of rod and cone photoreceptors from mouse, monkey and human embryonic stem cells," *Nature Biotechnology*, no. 2, p. 215-224, 2008