NEURON RECONSTRUCTION ALGORITHMS

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Background

One of the hot topics in science is brain research. Several recently initiated worldwide projects on neurobiology focus on exploring brain structure, organization, and function at the molecular, cellular, and organ level. Imaging is used increasingly as a tool for capturing the information on brain cell structure.

The structure of the brain carries important information about its functionality. Understanding the role of neuronal cell network features can be inferred from the structure of the neuronal tree.

The aim of the project is to develop advanced algorithms for digital reconstruction of neuronal morphology at the cellular level. The algorithms will consist of new image feature detection methods and probabilistic model-based tracing methods.

References

[1] E. Meijering. Neuron tracing in perspective. *Cytometry A., 77:693-704, 2010.*

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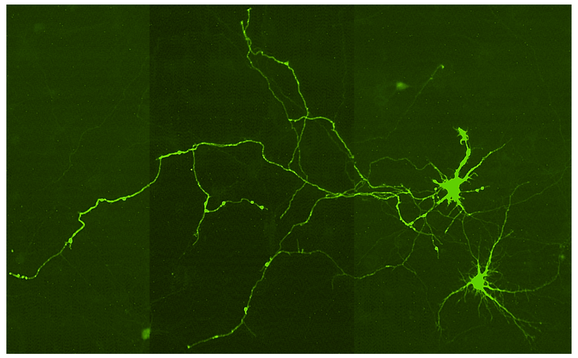
[3] T.A. Gillette, K.M. Brown, K. Svoboda, Y. Liu and G.A. Ascoli. DIADEMchallenge.Org: A Compendium of Resources Fostering the Continuous Development of Automated Neuronal Reconstruction. *Neuroinform, 9:303-304, 2011.*

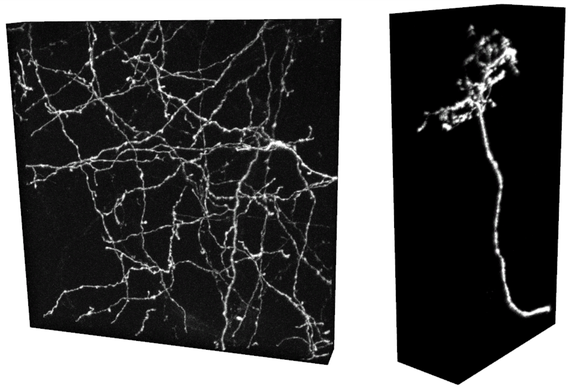
[4] P. Steiner, J-CF. Sarria, B. Huni, R. Marsault, S. Catsicas and H. Hirling. Overexpression of neuronal Sec1 enhances axonal branching in hippocampal neurons. *J Neurosci., 113(4):893-905, 2002.*

[5] H. Peng, Z. Ruan, F. Long, J.H. Simpson and E.W. Myers. V3D enables real-time 3D visualization and quantitative analysis of large-scale biological image data sets. *Nature Biotechnology, 28(4):348-353, 2010.*

Challenge

Appearance - the key characteristic of neurons is their tree-like structure with variety of branching styles and complexities in shape.
Imaging - varying noise and contrast, foreground intensity discontinuities.
Methodology - the state of the art of neuron tracing algorithms provides limited solutions, none of which is accurate or robust enough to replace often used manual or semi-automatic tracing.



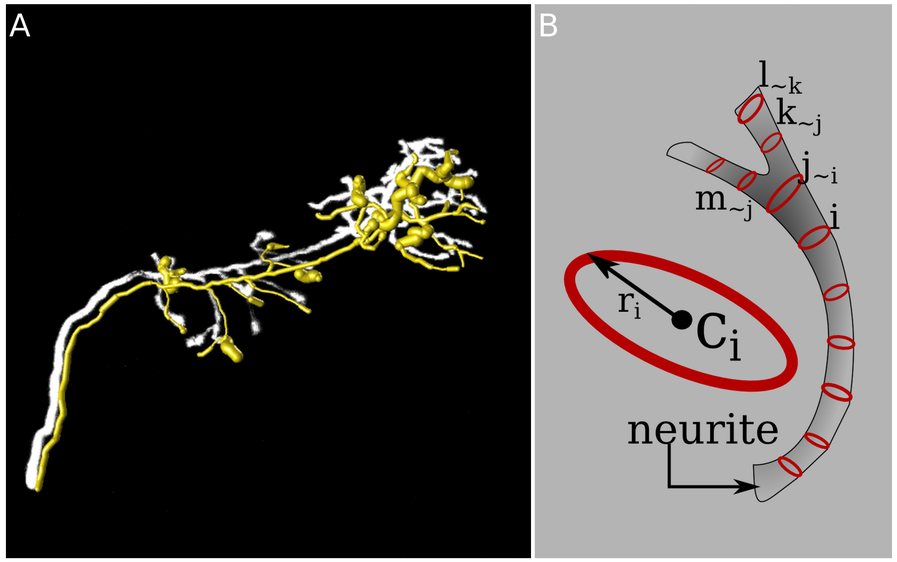


Neuron cells 2D/3D fluorescence images of the cells acquired by optical imaging techniques [4, 2].

Skilled researcher can spend weeks reconstructing the details and resolving ambiguities.

Digital reconstructions

The reconstruction algorithm uses a Bayesian probabilistic method for the tracing of single branches based on a model of the neuron branch body. Branches are recursively traced by comparing the underlying image content, using different hypotheses predicted with a predefined mathematical model to obtain the likelihood for each hypothesis. Knowing the prior, the method is able to recursively estimate the posterior probabilities for each hypothesis.

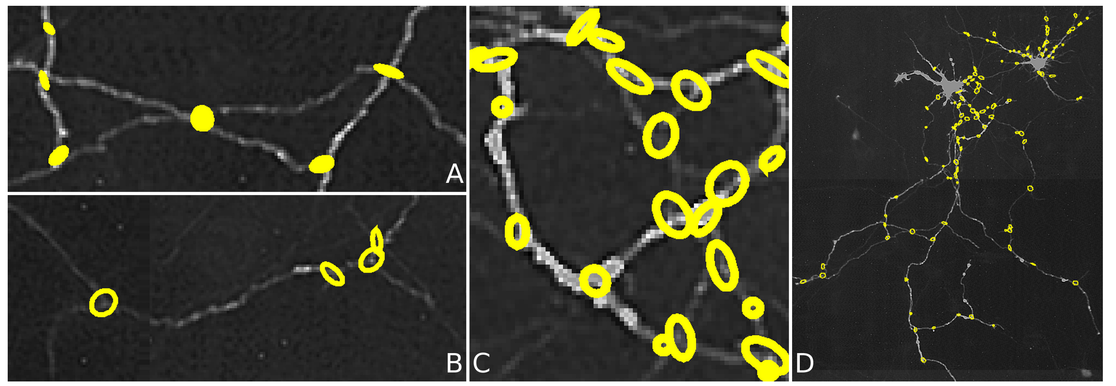


A: Neuron branch reconstruction using the developed tracing algorithm (yellow, rendered using Vaa3D visualization tool [5]).
B: Reconstruction scheme: consists of rings (C_i, r_i) locally modelling neuron body, associated in a structure with recursive sequence (i, j, k, l, m).

(*image*: Drosophila Olfactory projection Fibers, DIADEM challenge dataset [2])

Bifurcation detection

Accurate detection of branches remains a difficulty in neuron reconstruction methodology. The detection scheme is based on locating and comparing peak values in surrounding directional intensity responses.



Bifurcation detection A, **B** and **C** - magnified regions of the neuron image with detections, **D** - complete neuron image