

Probabilistic segmentation and analysis of horizontal cells

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www.liv.ac.uk, Geoff Lewis, Mark Verardo

Horizontal cells: Hard to segment

Rat's nest of neurites, many of which do not even belong to any of the cells in the image

Laser-scanning confocal (calretinin, neurofilament, calbindin)

[Geoff Lewis]

Horizontal cells

- Patterns
 - Number of neurites
 - Neurite thickness
 - Do they taper?
 - Branching
 - Connection
- Response to injury
 - Grow more?
 - Branch more?
 - Different distribution of neurofilaments?
 - Connections

[webvision.med.utah.edu]

Top-down approach: Visual vocabulary [ICDM 2005]

Step 1: Tile image

Step 2: Extract tile features {CS, CL, HT} MPEG-7

Step 3: ViVo generation ICA, PCA

Visual vocabulary

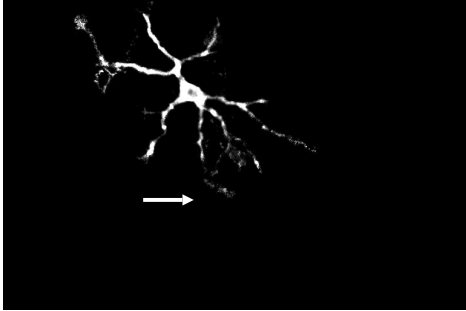
Dim₂

Dim₁

Binary segmentation leads to large segmentation errors

Watershed algorithm

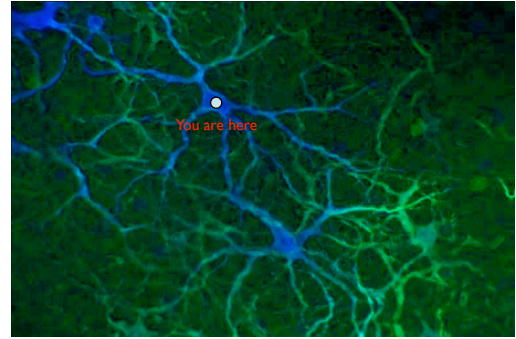
Can we find a probabilistic segmentation?



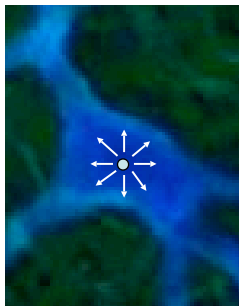
For each pixel, a probability that the pixel belongs to the cell

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Segmentation by repeated random walk

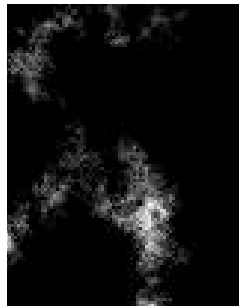


8



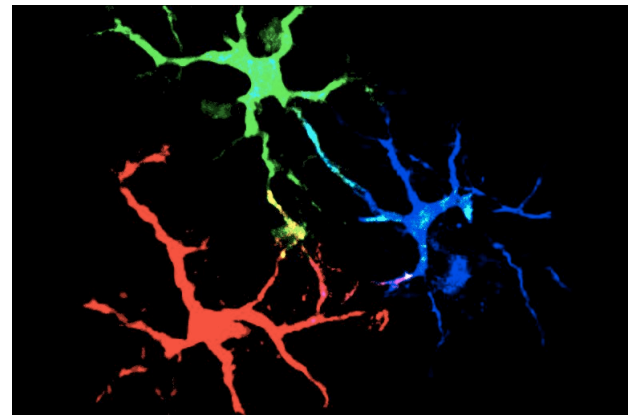
Random step in one of eight directions, biased by the intensity.

Return to start with probability $c = 0.0001$



Result after 1000 steps.
Repeat until convergence.

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Result at convergence (3 cells)

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Eigenvector problem

$$\mathbf{x} := (1 - c)\mathbf{P}\mathbf{x} + c\mathbf{s}$$

Probabilistic mask

Transition matrix (very sparse)

Restart probability

Initial location

Define new transition matrix \mathbf{Q} :
[Camoglu et al., Bioinformatics, 2006]

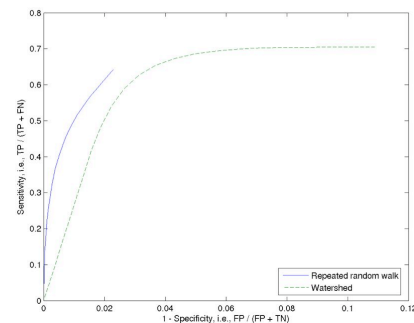
$$Q_{ij} = \begin{cases} (1 - c)P_{ij} & \text{if } s_i \neq 1 \\ (1 - c)P_{ij} + c & \text{if } s_i = 1. \end{cases}$$

At convergence, $\mathbf{x} = \mathbf{Q}\mathbf{x}$.
Largest eigenvalue is 1.

Corresponding eigenvector is the probabilistic mask (stationary probability of the Markov chain).

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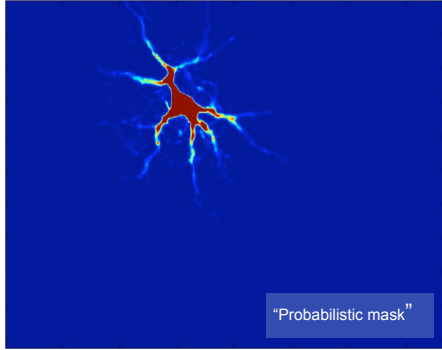
Better sensitivity and specificity than watershed



... but that is not the main point

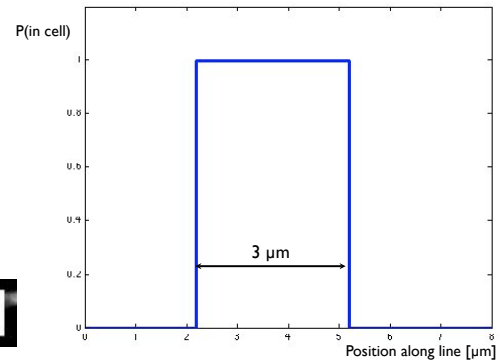
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Cell segmentation as a probabilistic value



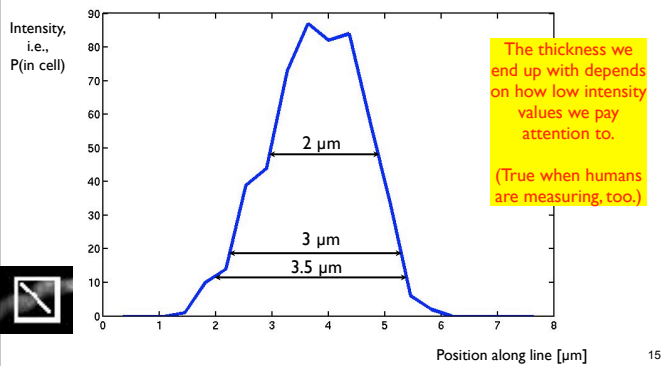
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How does this affect analysis and mining? A simple example: How to measure neurite thickness?



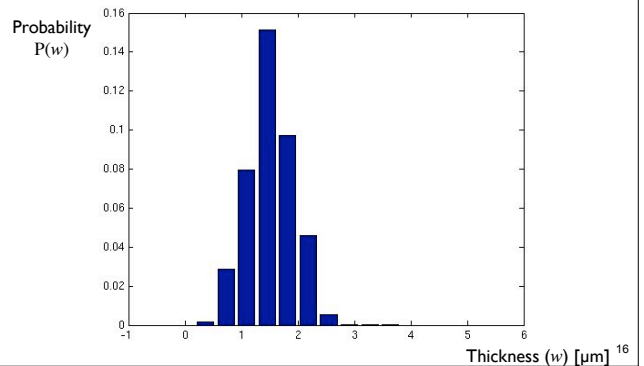
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How to measure neurite thickness?



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Probabilistic thickness measurement



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Summary

- Cannot always have perfect data
 - The curse of research biology
 - Must make use of images we cannot segment perfectly
- Probabilistic segmentation
 - Better segmentation result, more information
 - Must revamp analysis, mining, and database techniques
- How does this affect higher-level analysis and mining?
- One step closer to bringing data-driven research to microscopy-based fields

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