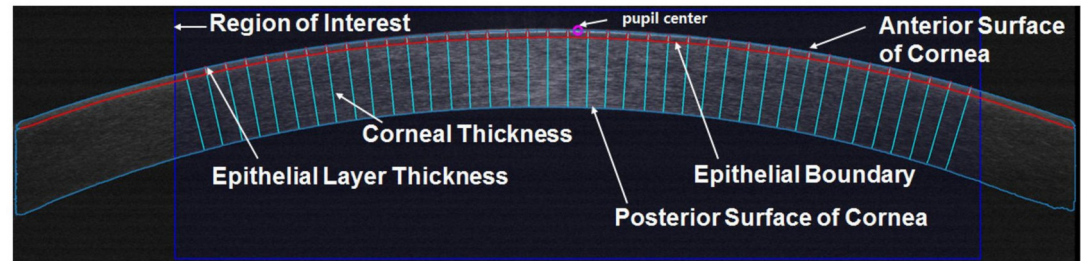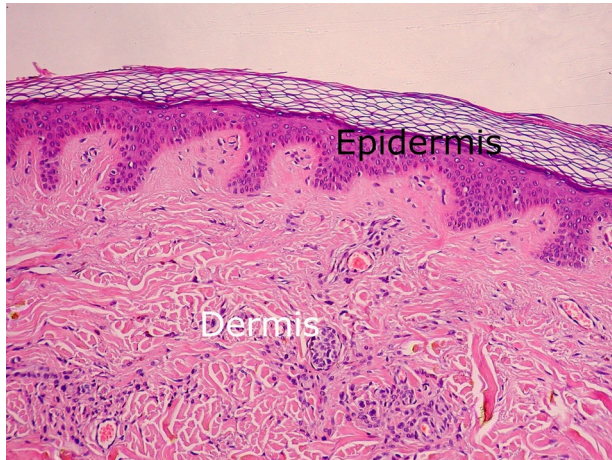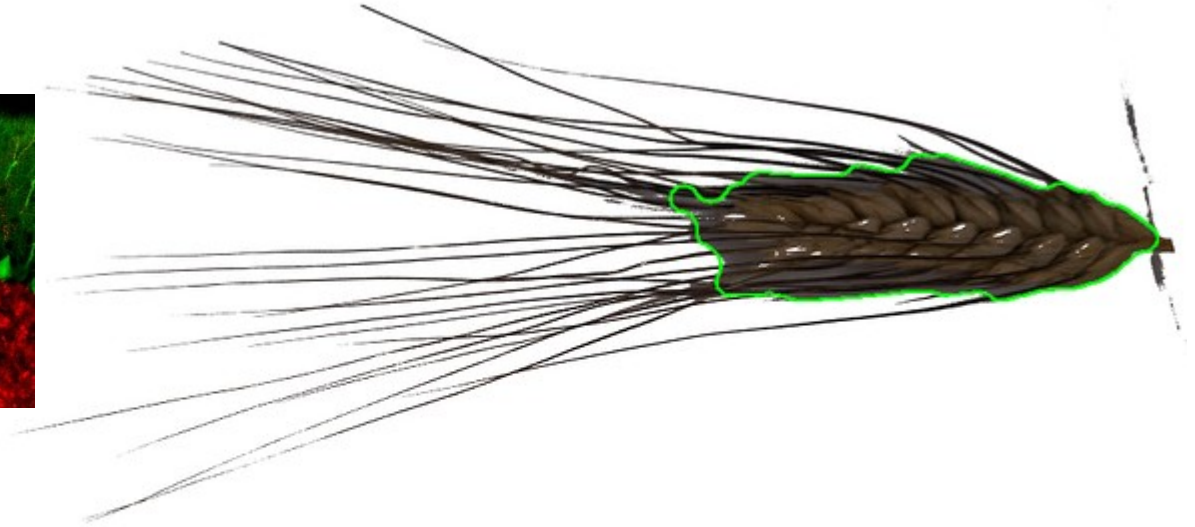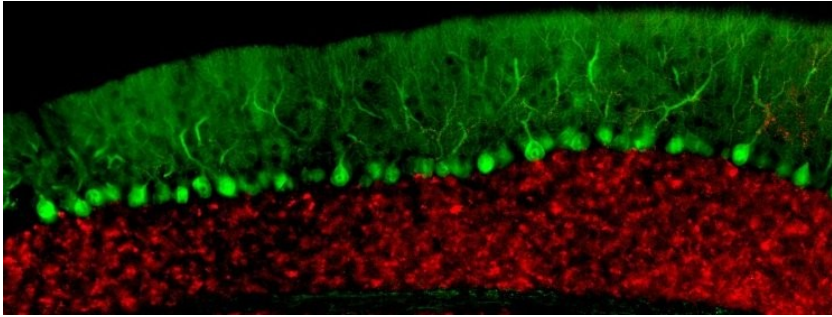# Width Profile Tools

I2K 2024
Workshop

Volker Baecker

Biocampus Montpellier
Montpellier Ressources Imagerie
MRI-Center for Image Analysis (MRI-CIA)
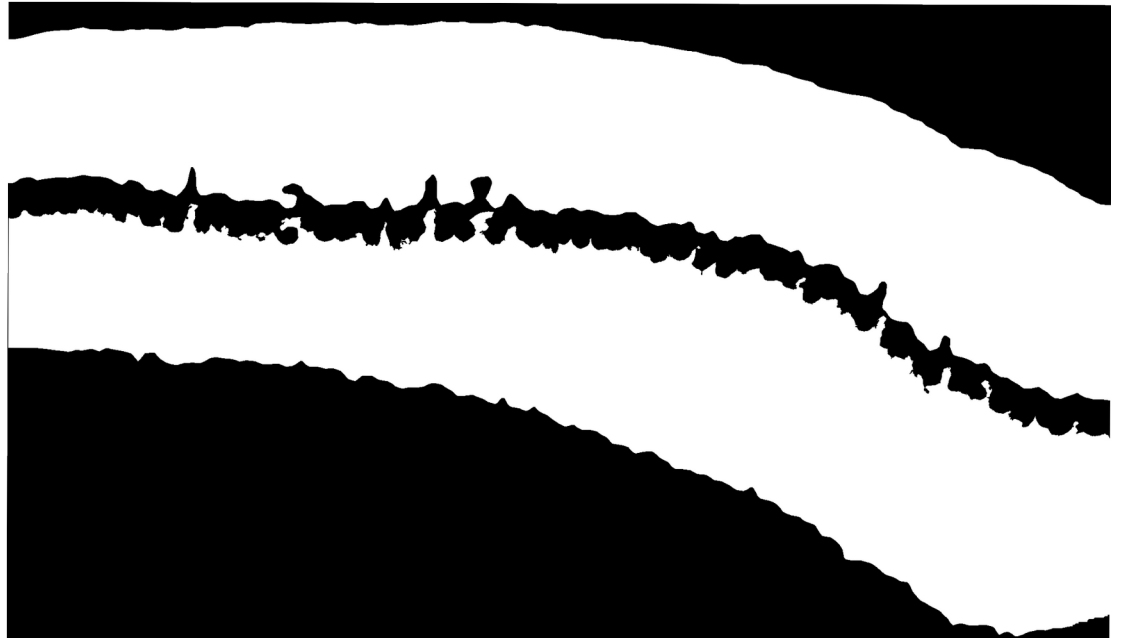
How far is it across the river?
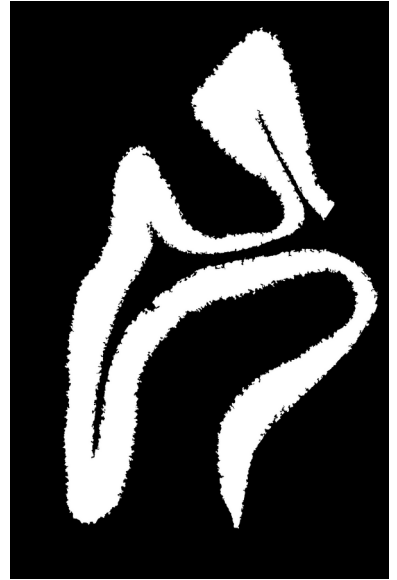

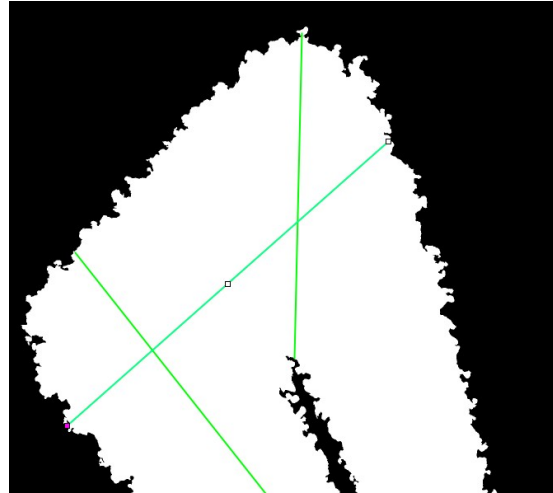earthobservatory.nasa.gov

Applications

Segmentation
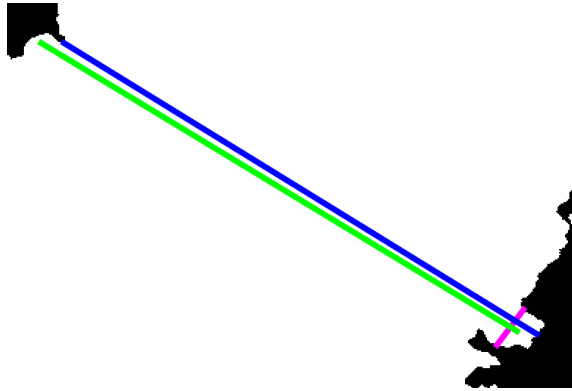
- Once the segmentation done

- Measuring the width should be easy

Width- But what width?

- min, max, average, median?
  - Profile, Distribution
- What does "across" mean?
- Should small irregularities be taken into account?
- What, if there are islands in the river?
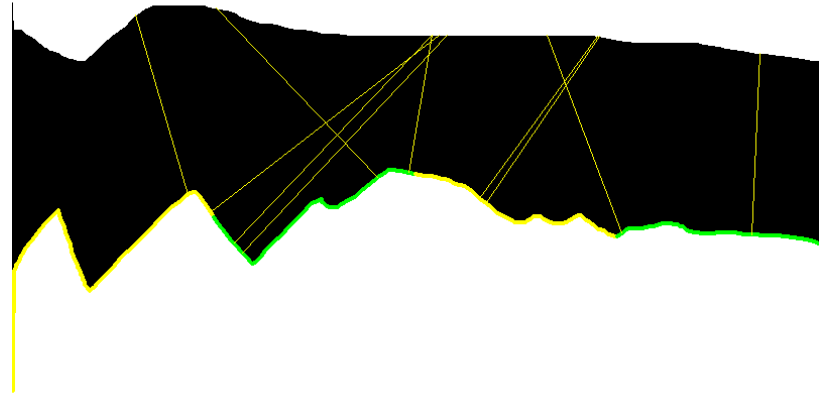- Width at elbows?
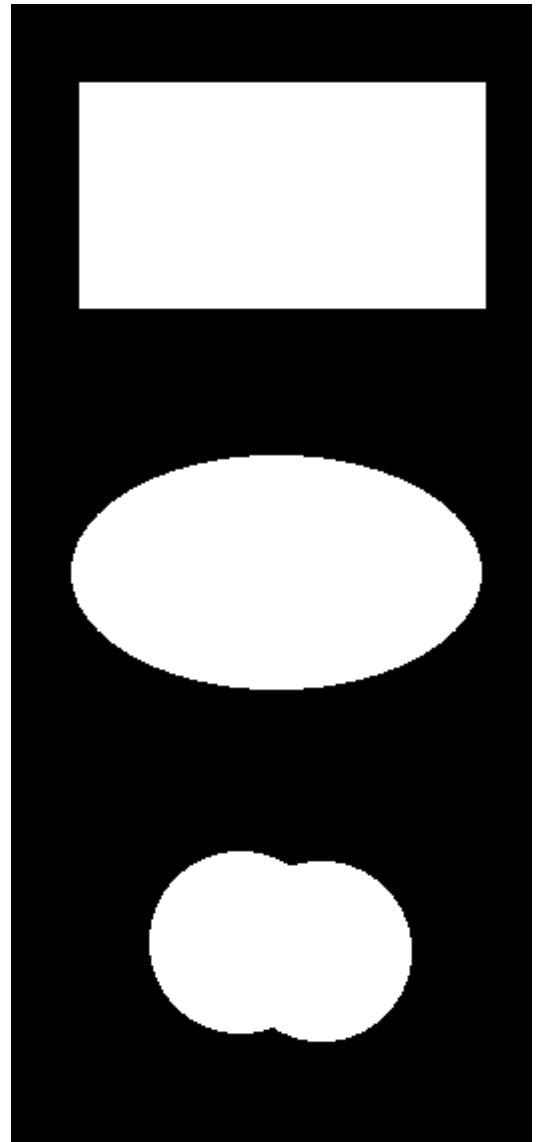
How (usually) not to do it!

- Vertical lines across the structure
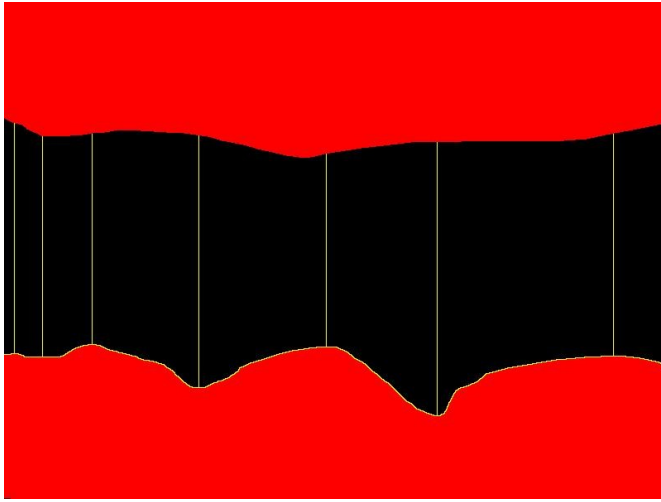
- Perpendicular to the border

Properties

- Give the expected results for simple forms
  - Rectangle
  - Ellipse
- Correspond to a distance from border to border

Ideas

- Measure distance to borders perpendicular to a "centerline"

- Use distance maps

Definitions

[Blum67]

- Medial axis

  – The medial axis of an object is the set of all points having more than one closest point on the object's boundary.

- Medial axis transform (MAT)

  – The medial axis together with the associated radius function of the maximally inscribed discs
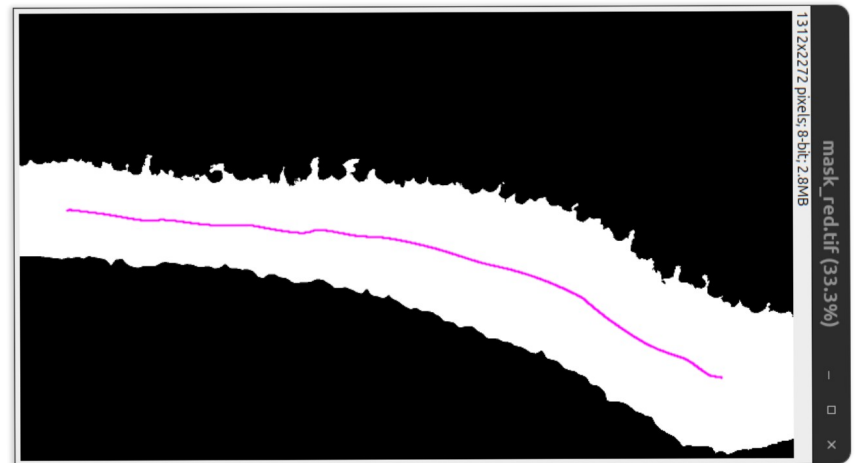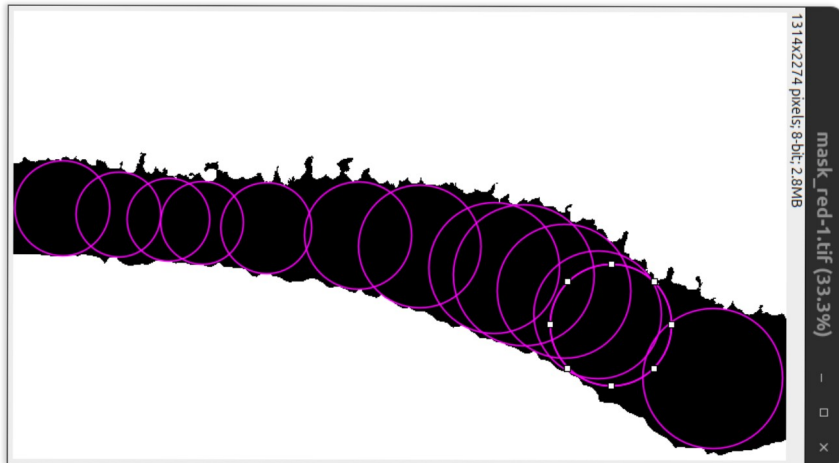
Medial axis

- ## Medial axis transform

  - Allows to reconstruct the original mask
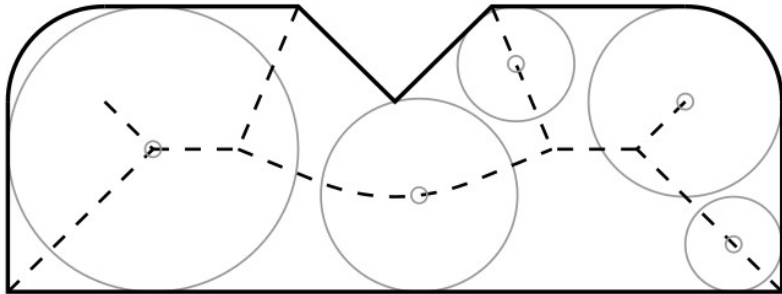
- Grassfire Transform

  - Fire is simultaneously lit at all boundary points
  - The fire propagates inside the object at a uniform velocity.
  - The skeleton is formed as the union of all quench points, where two independent fire-fronts meet

[Blum67]

Approach in MorpholibJ

- MorpholibJ thickness measurement   [Legland16]

  - Create distance map

  - Create skeleton

  - Use the double of the values of the distance map that lie on the skeleton

- Problems:

  - Spurious branches

  - The skeleton does not exactly lie on the

- Solutions:

  - Smooth borders

  - Prune skeleton

DUP_mask_red-3.tif (50%)

ening-Closing-fillHoles-Erosion (50%)
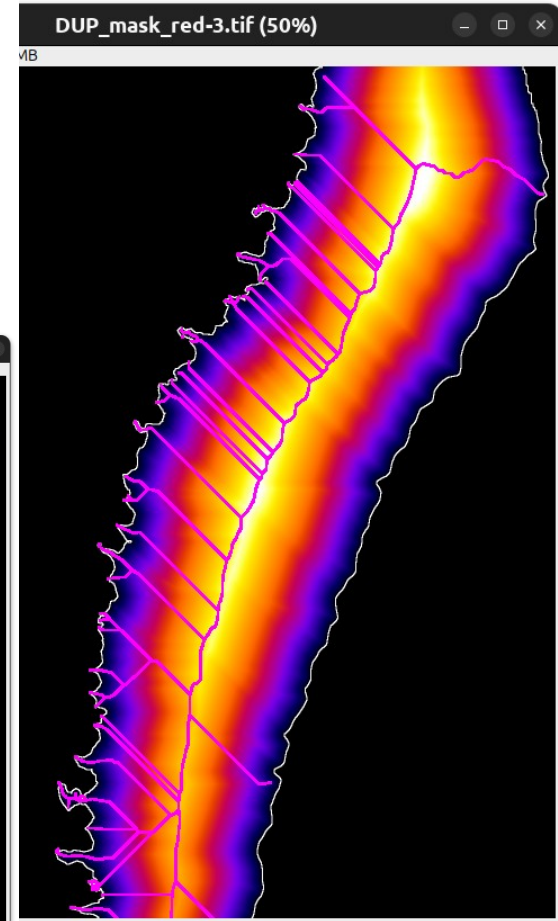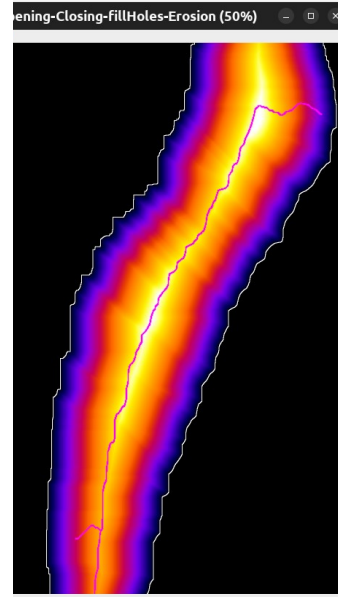
Approach Local Thickness

- For each point inside the object its local thickness is
  - The diameter of the largest sphere (circle), that fits inside the object and contains the point
- Volume (area) thickness, not surface (border) thickness

[Hildebrand1997]
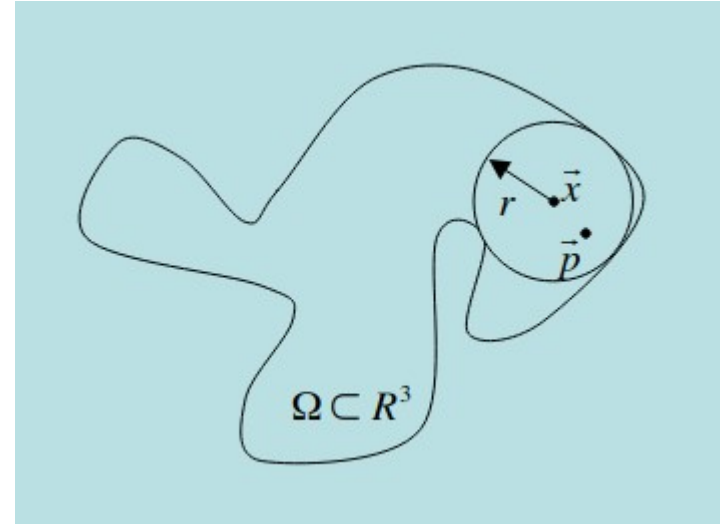
Computing Local Thickness of 3D Structures with ImageJ, 2007
Robert P. Dougherty
OptiNav, Inc. Bellevue, WA, USA

Approach Local Thickness

map   ridge   local thickness   cleaned
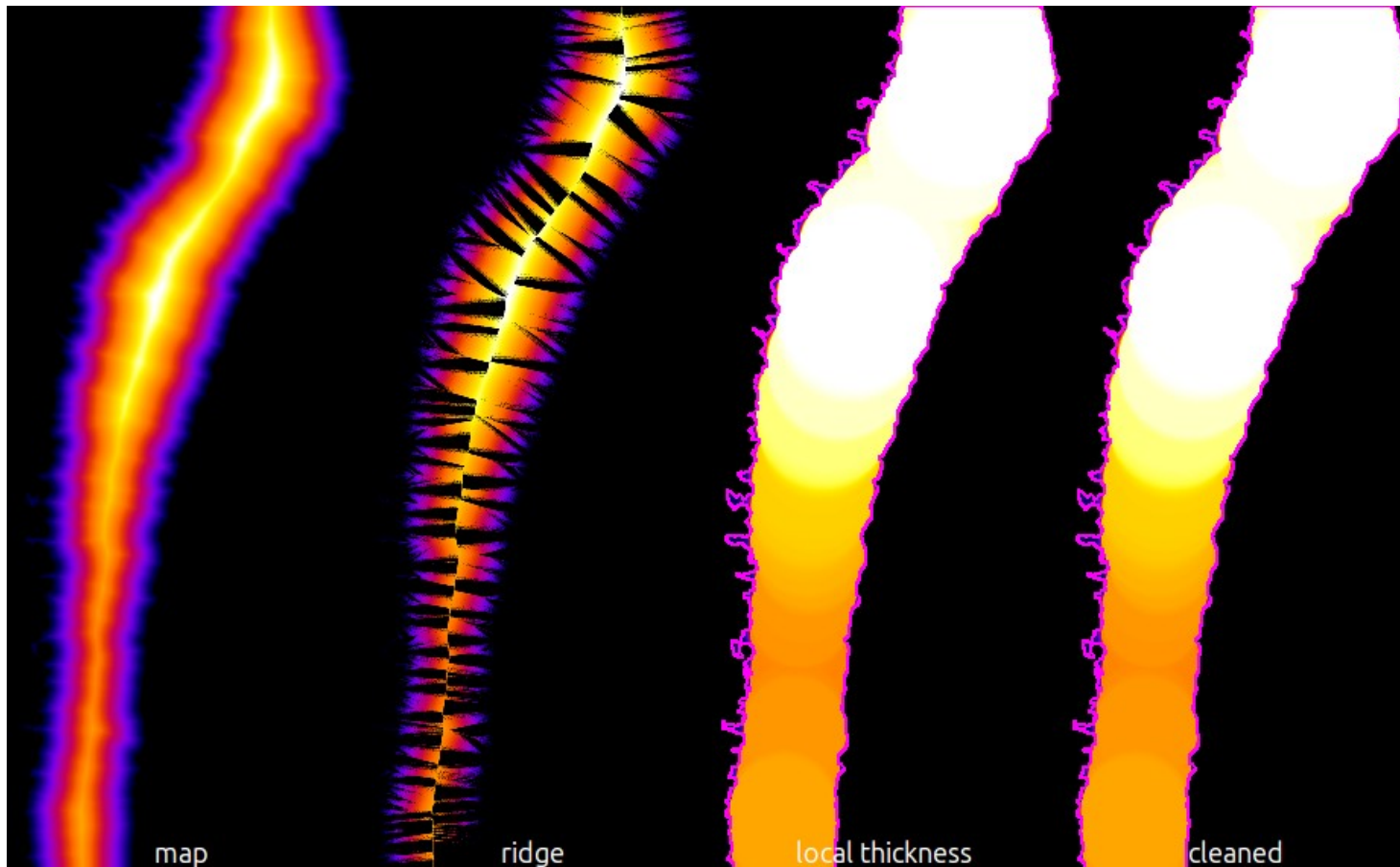
Local thickness

- Advantages
  - Works in 2D and 3D
  - Always gives a result
  - No parameters

- Problems
  - Overestimates the distance
  - Smoothing the border makes the average thickness bigger
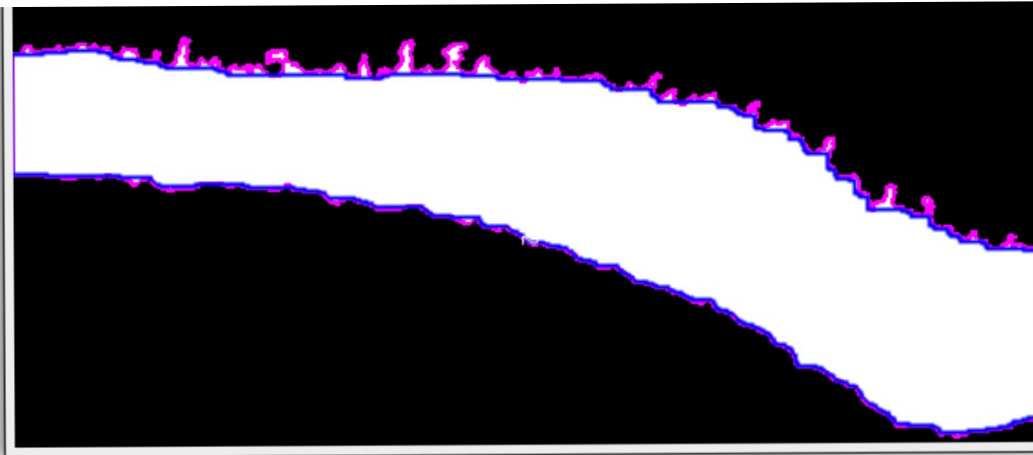
Approach Voronoi

- Divide the plane, so that all points in a cell have the same closest object

- The points on the edges of the cells have the same distance to multiple objects
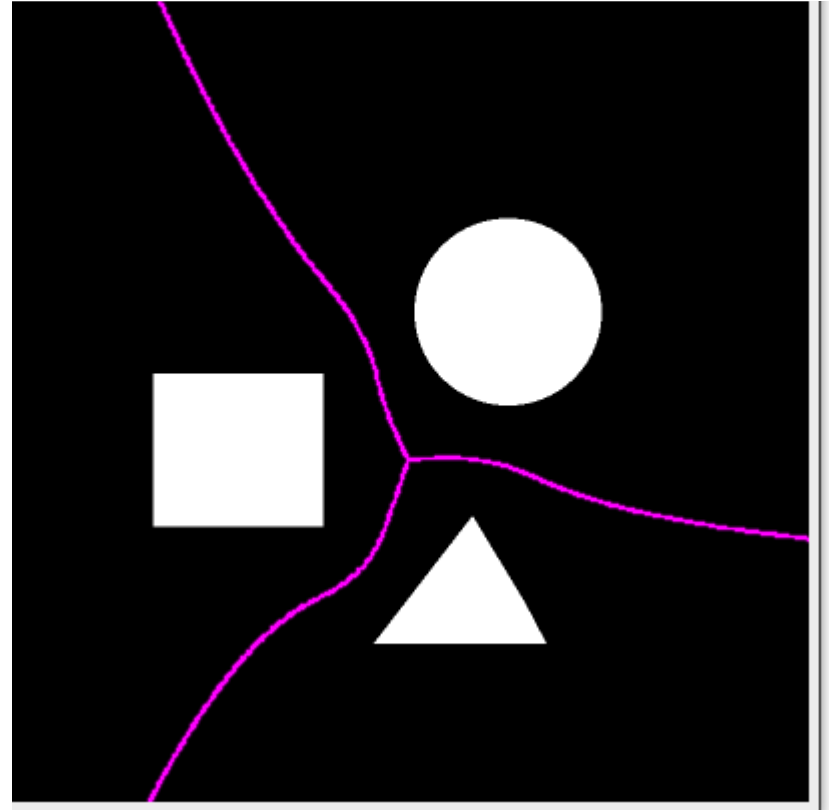
Voronoi

- The Voronoi edges correspond to the ridge of the distance transform of the background

- The Voronoi edges are a superset of the Medial Axis Transform
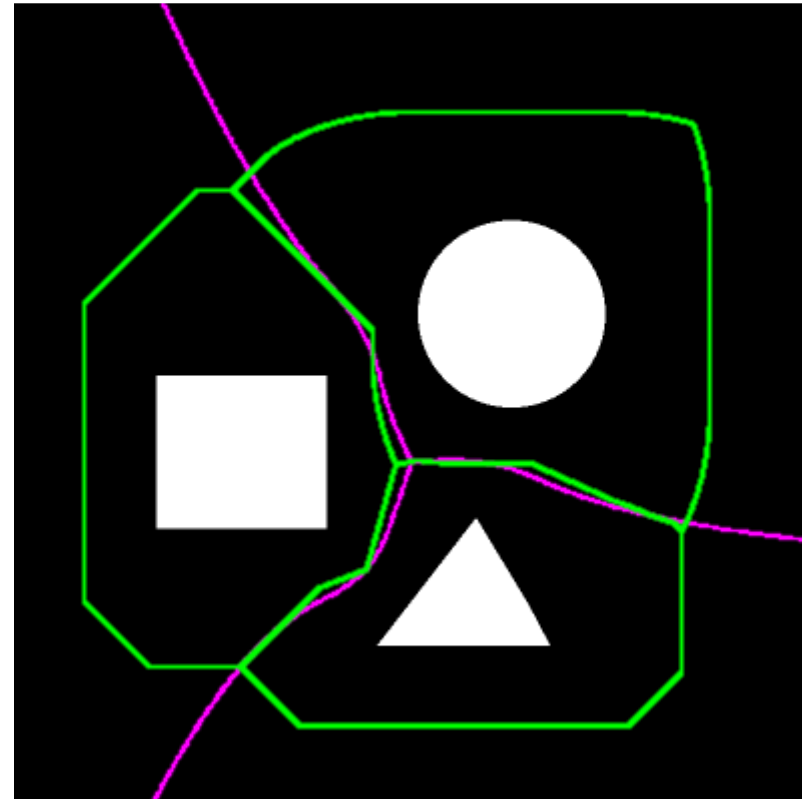
Green – Skeleton
Magenta - Voronoi

Approach Voronoi

- Treat the two "opposite" borders as objects and calculate the Voronoi cell edges between them

- The outline of the object, must be separated into two objects
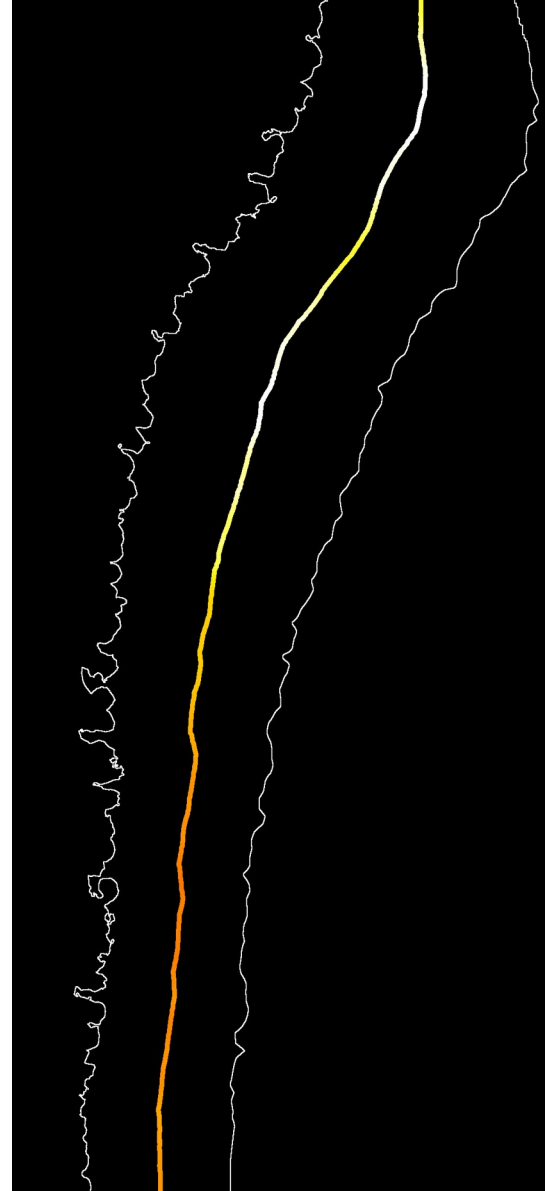
Approach
Perpendicular to inertia axis

- Sample the distance across the object

  – Using equidistant lines

  – Perpendicular to the inertia axis

- The object must be "reasonably straight"

- Stop at a distance from the borders of the image

- Rotate the object

  – To make the inertia axis parallel to the x-axis

  – Use vertical lines
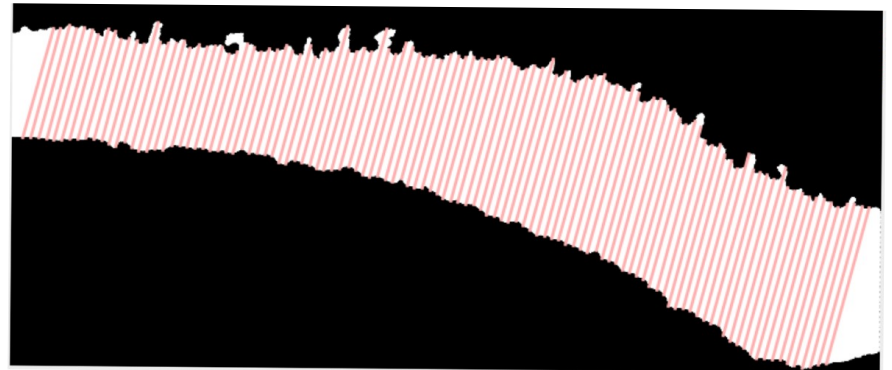
Approach
Perpendicular to "centerline"

- Calculate a "centerline"

- Sample the distance across the object
  - Using equidistant lines perpendicular to the centerline
  - Calculate the local direction of the centerline at a point using n neighbors

- Problem at "elbows"

- Result depends on the "centerline"
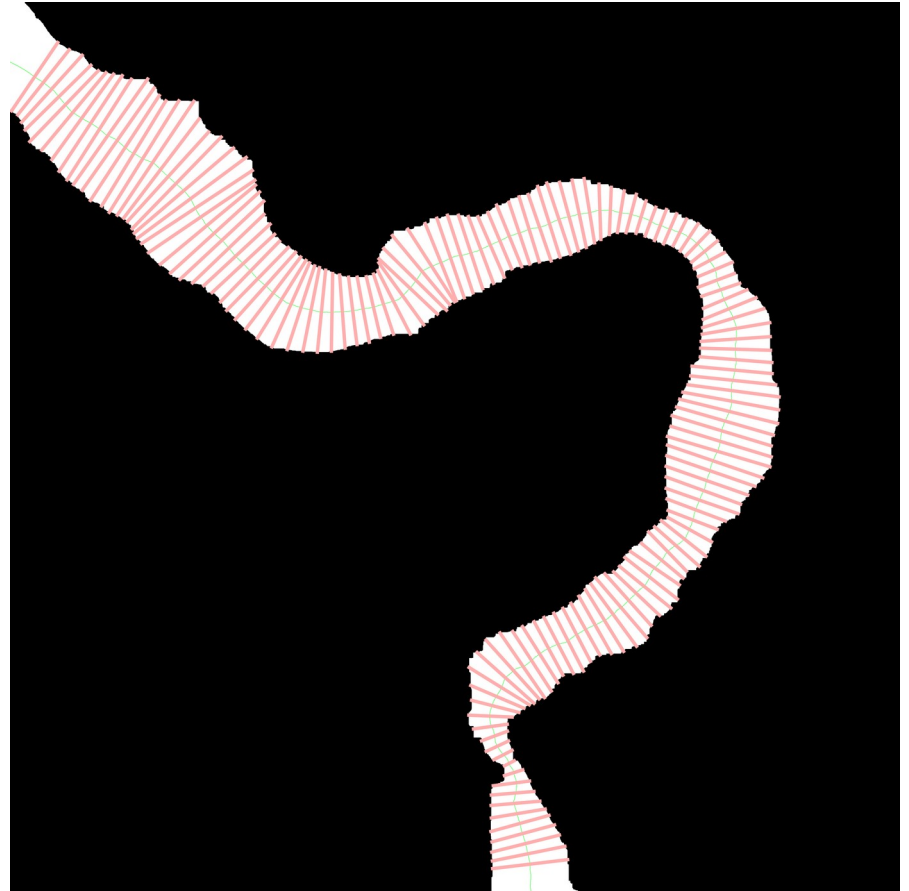
Width Profile Tools
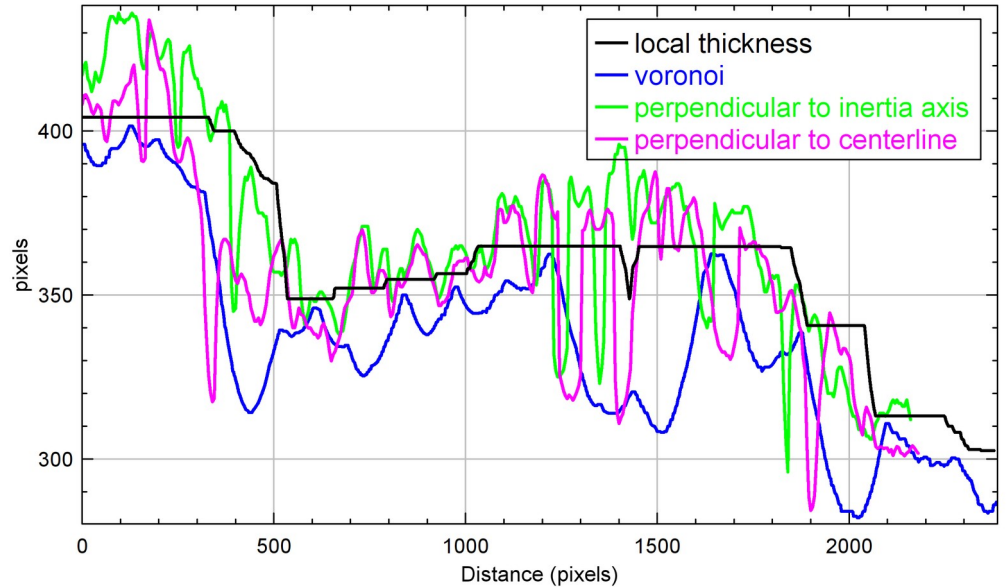

- t – local thickness

- v – voronoi

- i – perpendicular to inertia axis

- C – perpendicular to centerline

- Right click – options

- First button (image) – help page

- Tools
  - Select centerline
  - Smooth mask

- Install tool

- Download/Open sample images
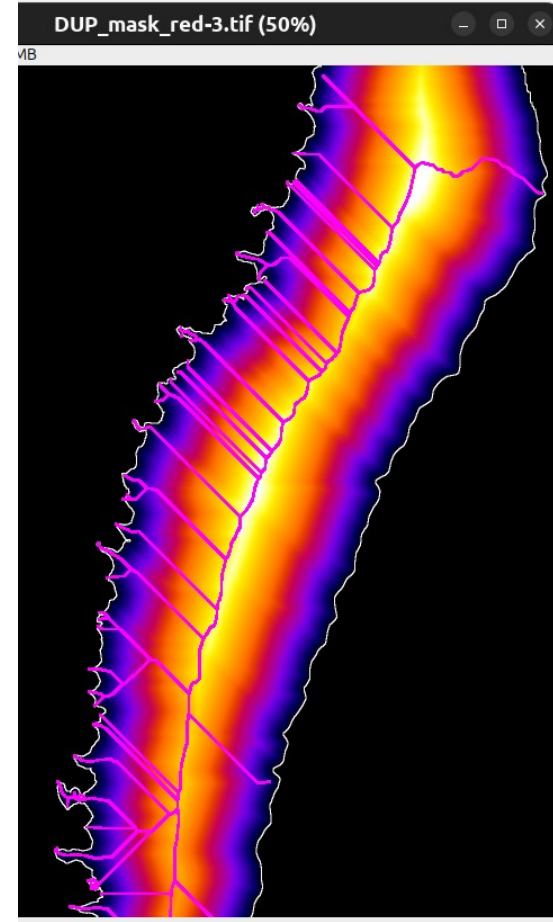
Exercise

- Select an image
  - A binary mask
- Calculate the width profile using the four methods
- Compare the results

Supplementary Exercise

1) Calculate the average thickness with MorpholibJ

2) Do the steps manually:

   1) Calculate the skeleton and the distance map

   2) Measure the average of the distance values that lie on the skeleton

DUP_mask_red-3.tif (50%)

Literature

Blum 1967
Blum, Harry (1967). "A transformation for extracting new descriptors of shape". In Wathen-Dunn, Weiant (ed.). Models for the Perception of Speech and Visual Form (PDF). Cambridge, Massachusetts: MIT Press. pp. 362–380.

Legland 2016
David Legland, Ignacio Arganda-Carreras, Philippe Andrey; MorphoLibJ: integrated library and plugins for mathematical morphology with ImageJ. Bioinformatics 2016; 32 (22): 3532-3534. doi: 10.1093/bioinformatics/btw413

Hildebrand 1997
Hildebrand, T., and Rüegsegger, P. (1997). A new method for the model-independent assessment of thickness in three-dimensional images. Journal of Microscopy 185, 67–75. 10.1046/j.1365-2818.1997.1340694.x.