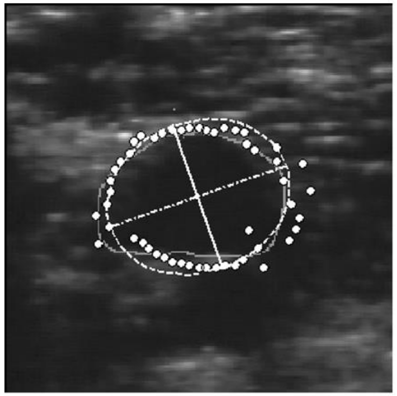
Basic Medical Image Segmentation

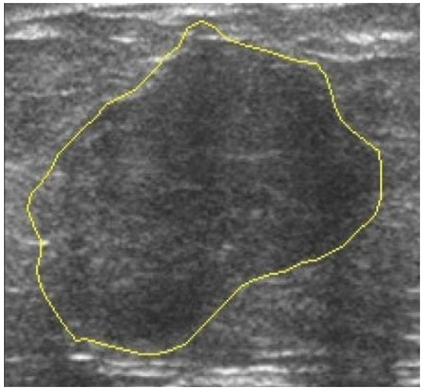
Credit: an earlier version of this presentation on was created by Ehsan Dehghan, PhD, Perk Lab, School of Computing, Queen's University

What is Segmentation?

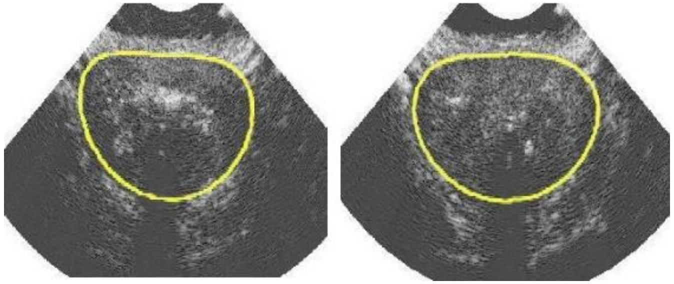
- Delineation of a Region of Interest in an image.



Vessels



Breast tumor



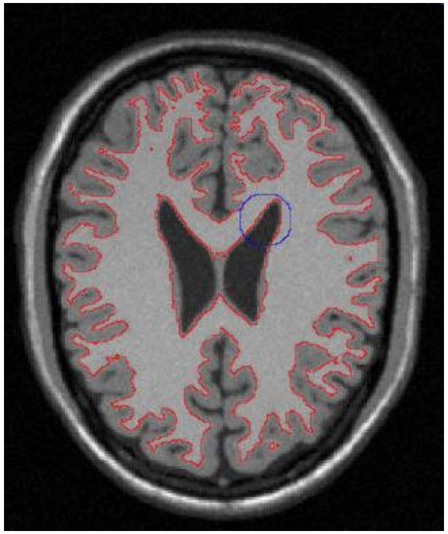
Prostate

Segmentation Methods

- Segmentation is a complicated problem.
- There is no single method that works for all the problems (problem-specific).
- Usually requires manual interaction.

Manual segmentation = hard labor

- Manual segmentation can be very cumbersome.
- Automatic segmentation methods are required fast and accurate segmentations.



Assume segmenting white matter manually for 180 slices!

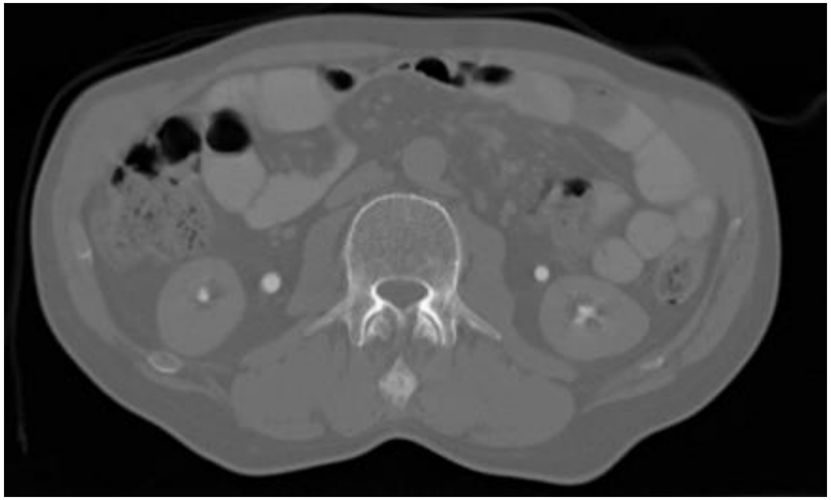
Brain image courtesy of Jakub Krátký and Jan Kybic Department of Cybernetics, Czech Technical University in Prague, Prague, Czech Republic

Segmentation Methods

- Thresholding
- Region Growing
- Edge tracing
- Radial edge search
- (More Sophisticated ones:
  - Active Contours (Snakes)
  - Live wire
  - Watershed Transform
  - Shape Models
  - Level set Segmentation
  - …)

Thresholding

- A binary classification of the image into “interesting” and “not interesting” regions based on the gray level value.
- Every pixel with a value greater than the threshold *T* belongs to the object and every pixel with gray value less that *T* does not.



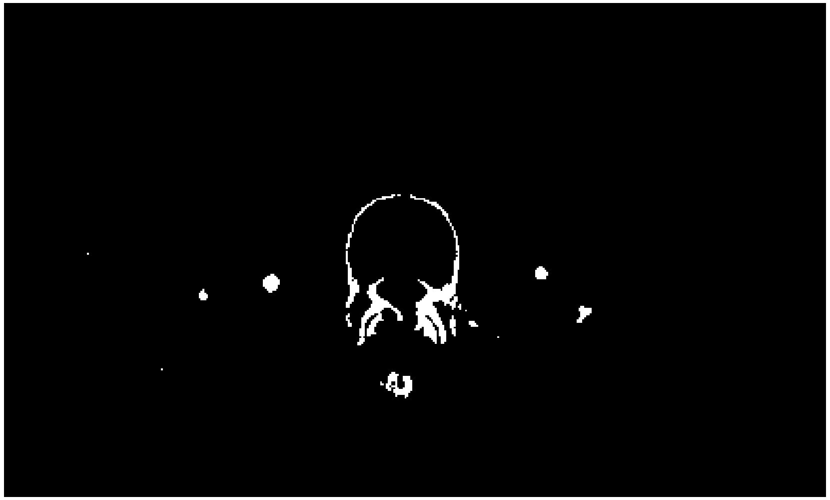
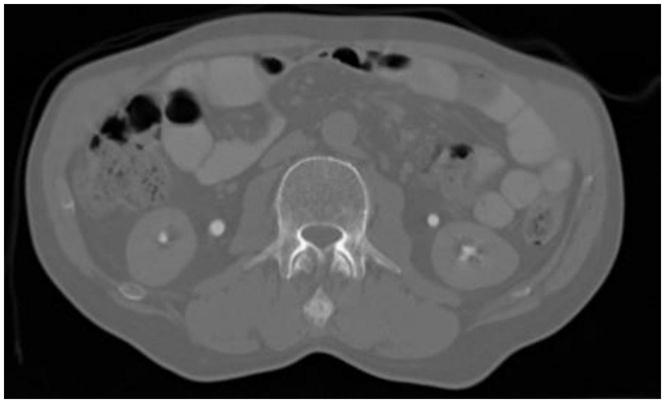
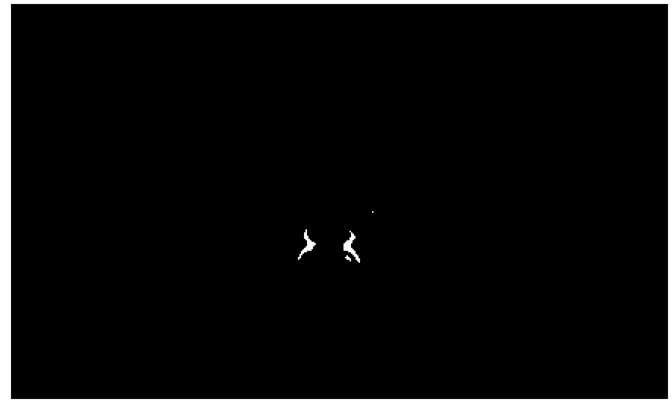


Image data courtesy of the Dept. of Diagnostic Radiology, Medical University Vienna

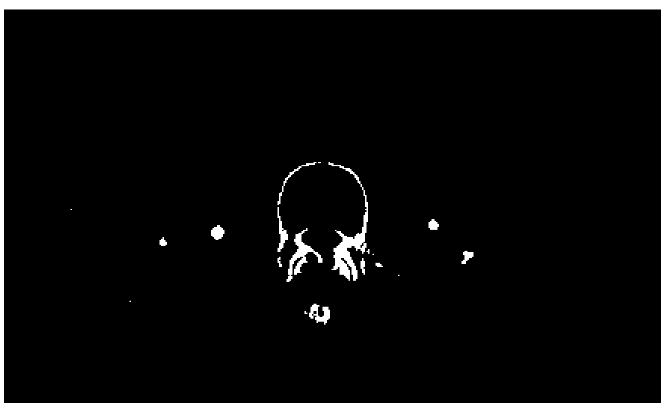
Thresholding



T=200



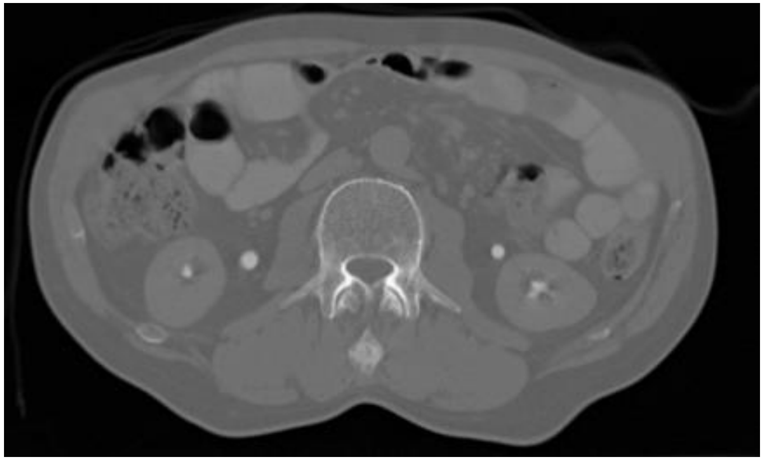
T=150



T=100

How to Find *T* ?

- The value of the threshold (*T*) can be assigned globally or locally using the image histogram.



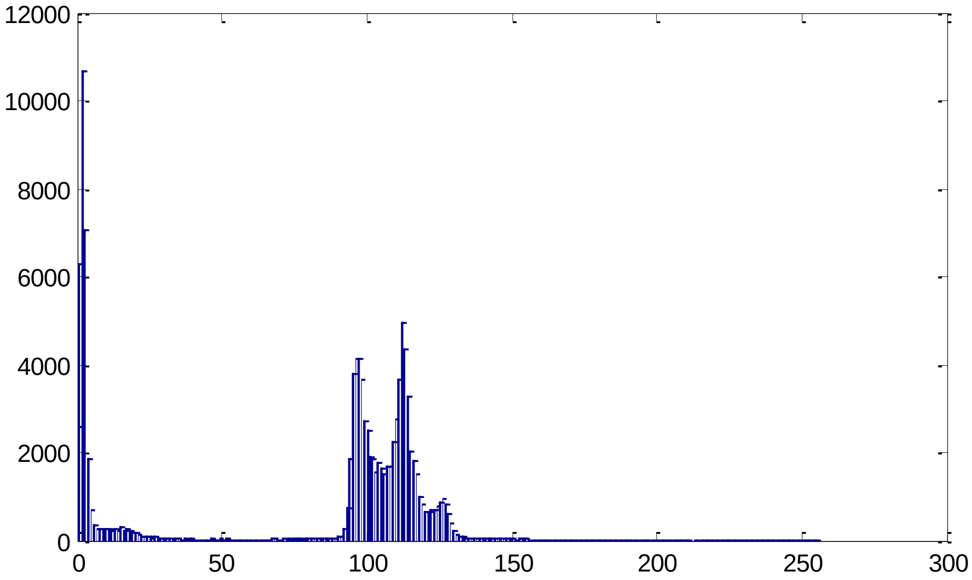
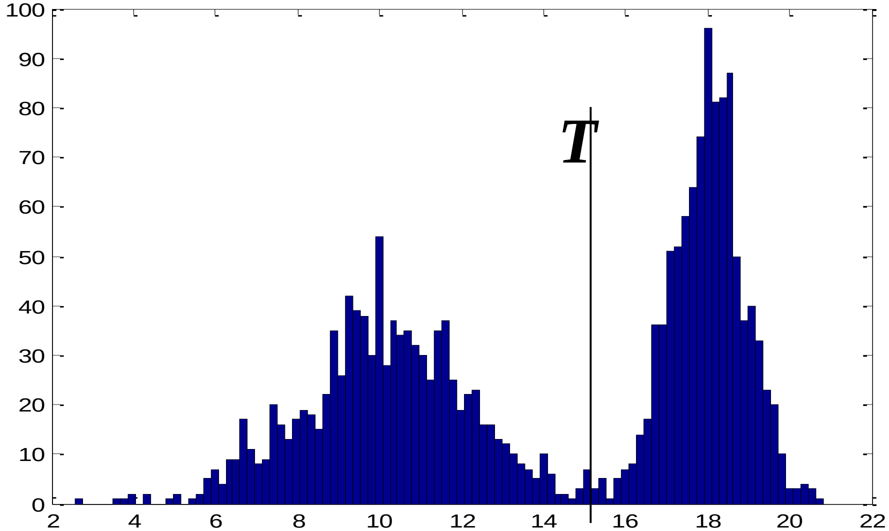


Image data courtesy of the Dept. of Diagnostic Radiology, Medical University Vienna

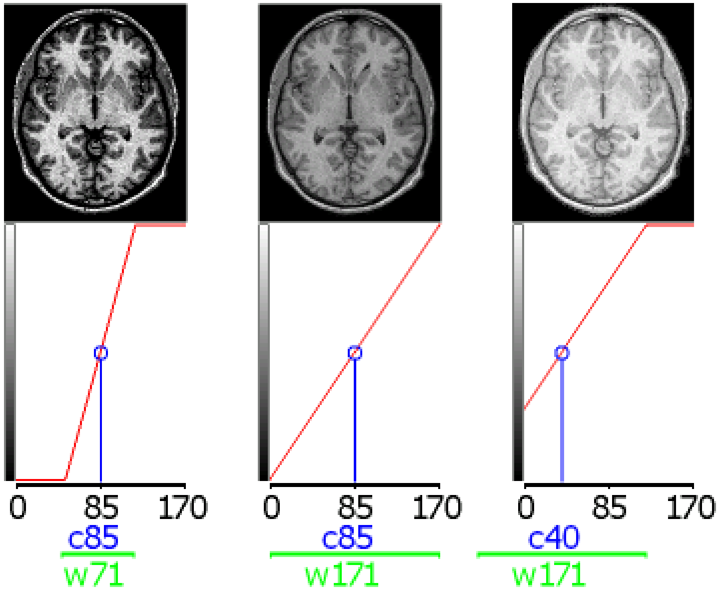
How to Find *T* based on Histogram?

- Histogram shows the density of data in non-overlapping bins.
- If the histogram shows two separate regions, an optimal *T* can be calculated to maximize the probability of correct segmentation.



- Unfortunately, this is usually not the case.

Window Level Thresholding



- Top row: views of the same image with different C/W settings.
- Bottom: colour mapping for each image (with the vertical axis of the graph showing rendered brightness and the horizontal axis showing the image intensity).
- Consider this image with intensities ranging from 0 to 170.
- Good starting estimate for this image might be a center of 85 (mean intensity) and width of 171 (full range of values) – middle image
- Reducing the width to 71 would increase the contrast (left)
- Keeping a width of 171 but reducing the center to 40 would make the whole image appear brighter.

Window Thresholding

- Instead of defining a global threshold, define a threshold for every window inside the image.
  1. Define a typical area (i.e. a rectangle) .The average gray value is *R*.
  2. Define the threshold value *T* for this window.
  3. Do the decision making based on this threshold.
  4. Go to the next window.
- You do not need to have one Threshold value. You can assume that the ROI has a gray value between *T1* and *T2*.
- Window thresholding is successful incases whit changing illumination (scarce in medical imaging with exception of video imaging with endoscope).

Thresholding Problems

- Generally difficult to automatically define the threshold value.
- Usually not convincing.

- However, thresholding is an important first step for many other segmentation methods.

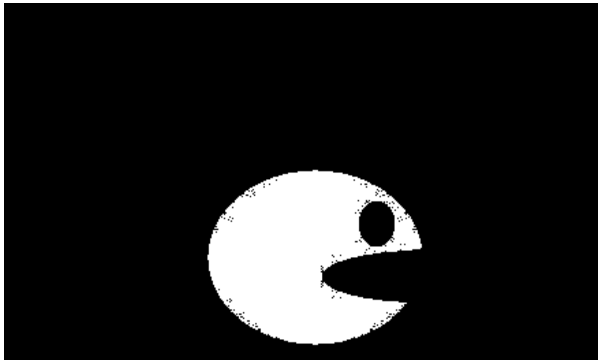
Image data courtesy of the Dept. of Diagnostic Radiology, Medical University Vienna

Region Growing

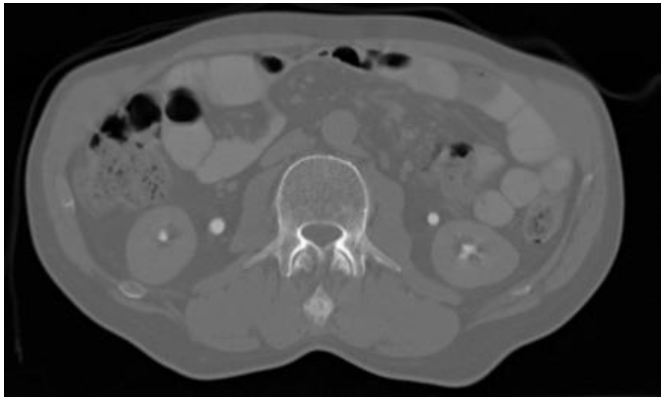
- Select an image element that belongs to the structure that should be segmented (seed).

1. If another image element has a gray value close the gray value of the seeds, and
2. Is connected to the seed (4-connected or 8-connected),

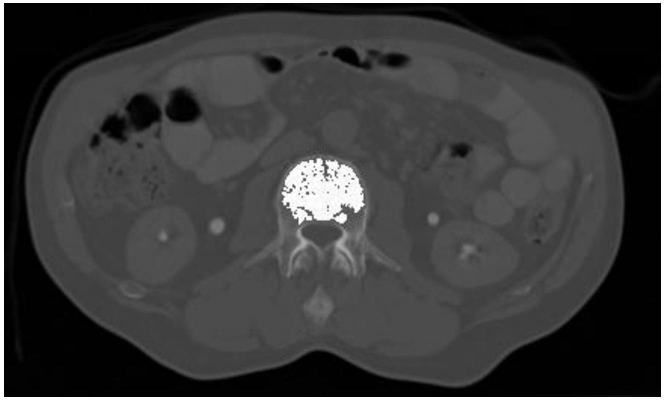
is part of the segmented region and is a seed itself.



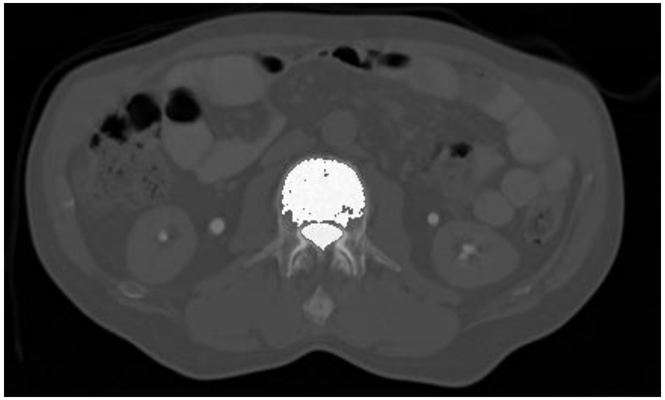
Region Growing



T=+-10



T=+-15



T=+-21

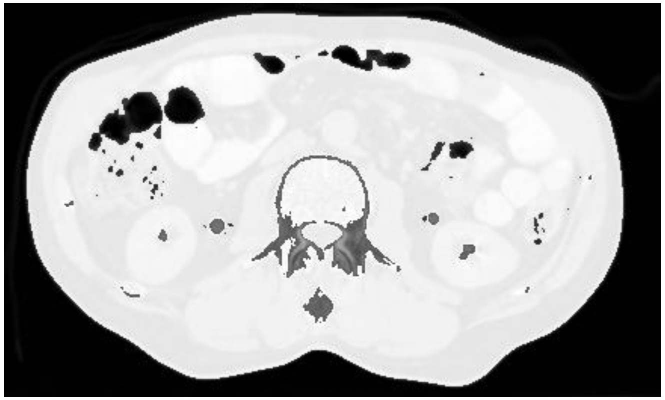


Image data courtesy of the Dept. of Diagnostic Radiology, Medical University Vienna

Region Growing

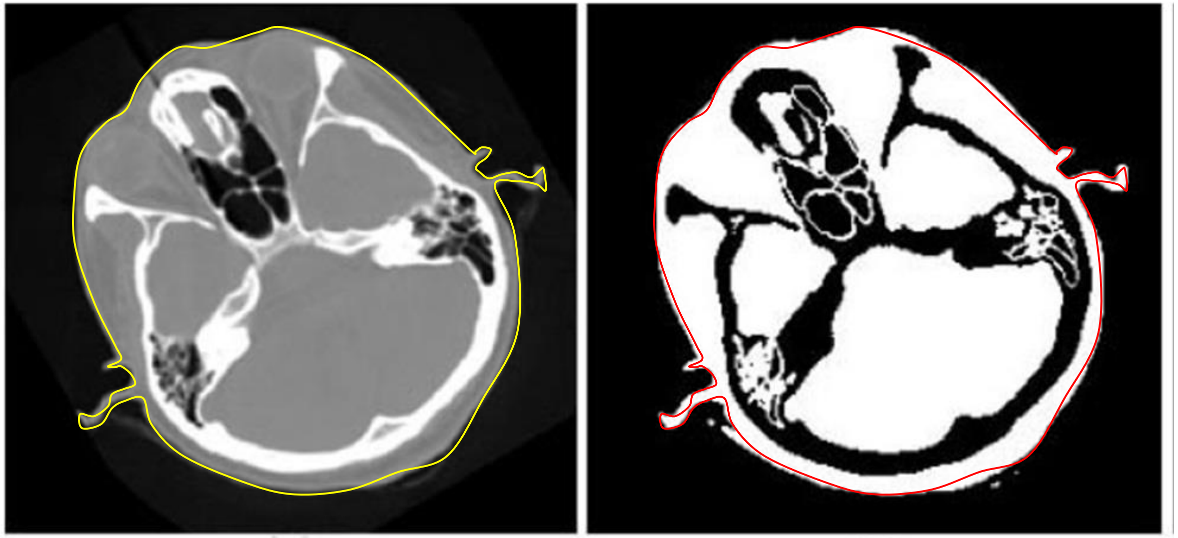
- More successful than thresholding.
- Works based on local gray value information.
- The "closeness" of the gray value of a point to a seed needs upper and lower thresholds.
- Choosing these thresholds is tricky.
  - Small threshold leads to a very small segmented area.
  - Large threshold leads to overflow.
- Bridging may occur.

Region Growing

Image data courtesy of the Dept. of Diagnostic Radiology, Medical University Vienna

Contouring

Draw a polygon around the region of interest to be segmented



(a) (b)

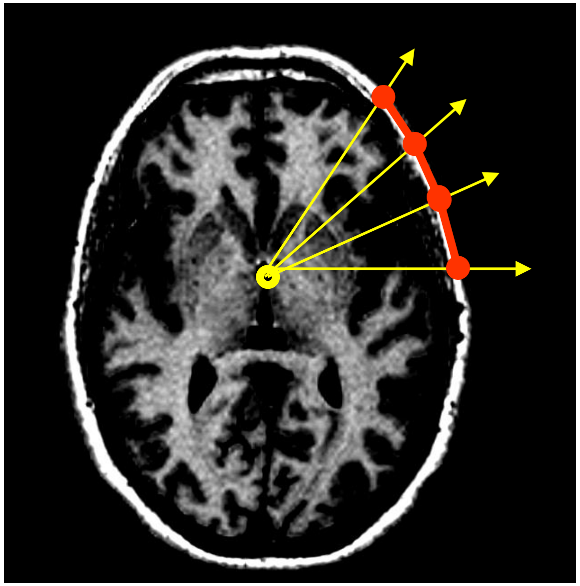
Edge tracing

- Threshold first, then trace bright edge
- Set winding direction
- Find one edge point
- Walk around the edge
- Yields a very dense contour
- May need to be resampled

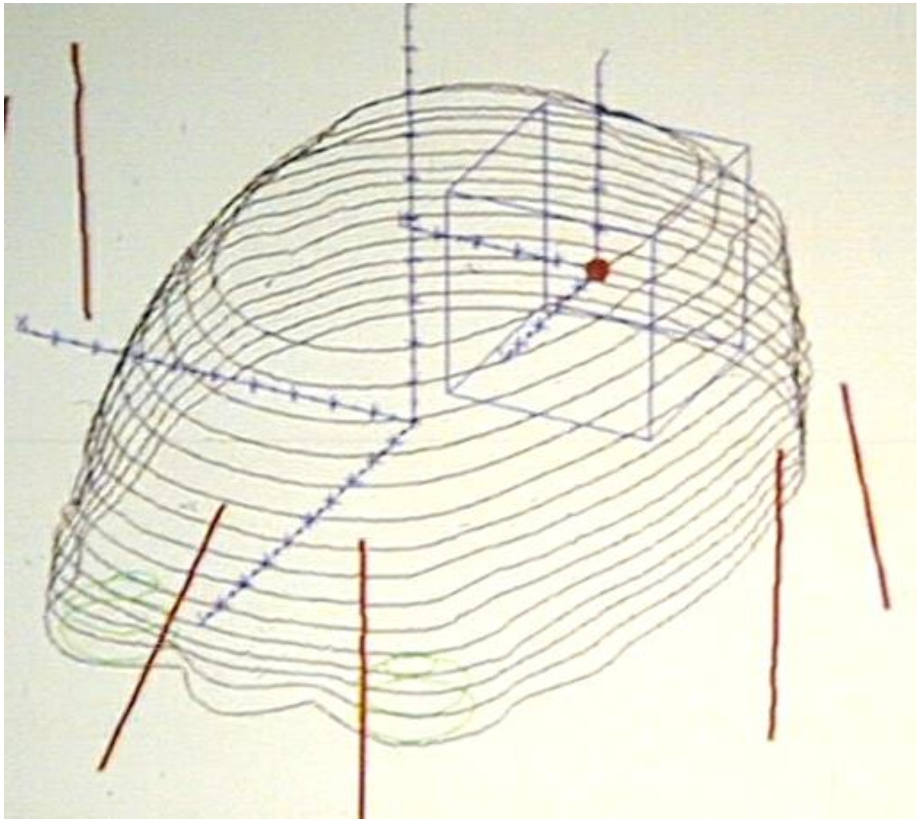
(b)

Radial search

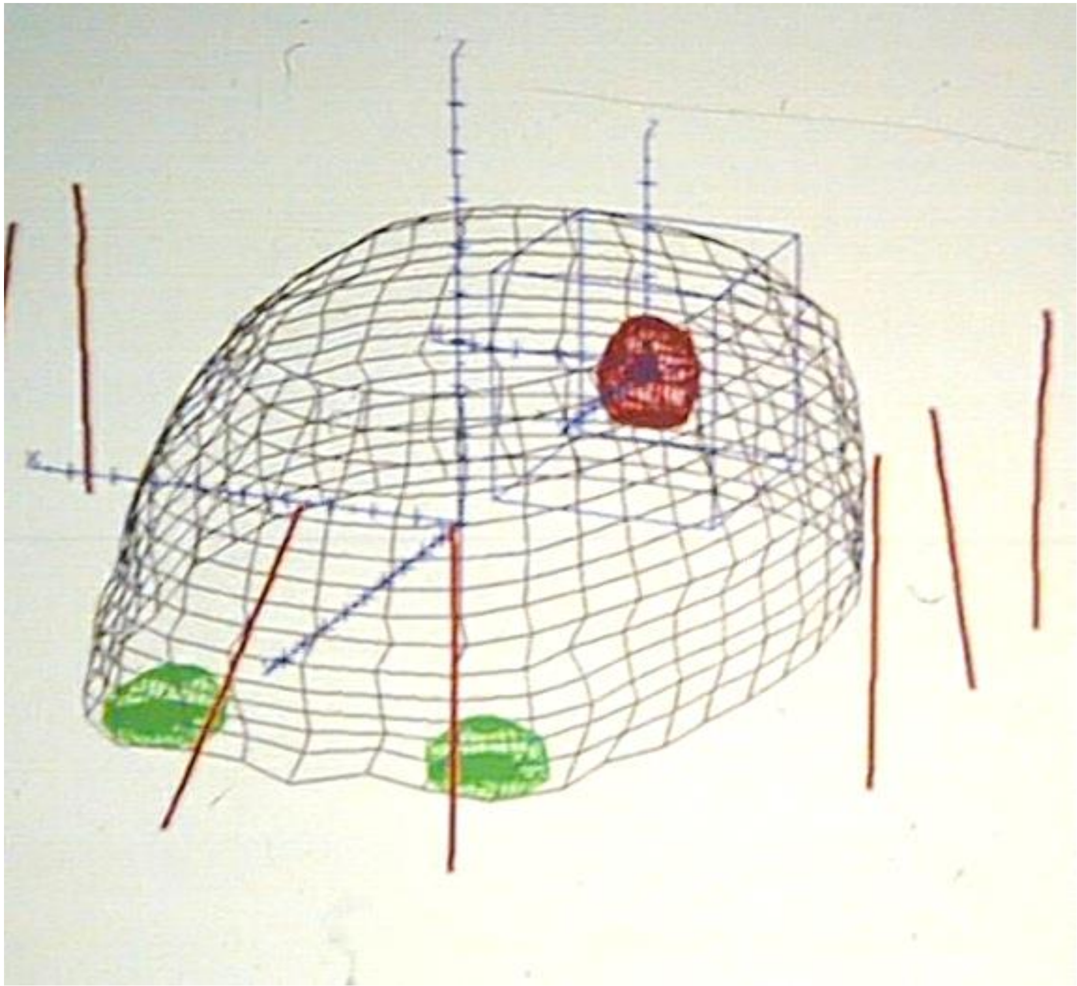
- May threshold first
- Set winding direction
- Find convex center point
- Shoot rays out in every direction
- Find outermost edge point
- Connect the edge points into polygon
- Contour density is controlled
- Allows for easy 3D meshing



Stacked contours in 3D



3D meshing after radial search



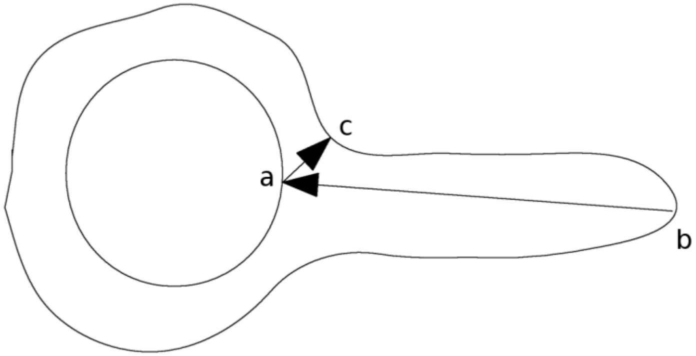
How to Evaluate Segmentation Results?

- Segmentation results should be compared against a ground truth.
- The ground truth is often segmentation results manually done by physicians.
- *Hausdorff-distance* of two contours is a useful measure for contours.

$d(S_1,S_2)$ is the maximum of the closest distance between each point on S_1 to all the point on S_2.

$$d(S_1,S_2) \neq d(S_1,S_2)$$

Hausdorff Distance



$$H(S_1, S_2) = \max\{\sup\inf\ d(S_1, S_2),\ \sup\inf\ d(S_2, S_1)\}$$

Dice Coefficient

- Dice-coefficient is a good measure to compare two regions. It is proportional two the number of shared pixels over the total number of pixels in two regions.

$$D = \frac{2\left|A_1 \cap A_2\right|}{\left|A_1\right| + \left|A_2\right|}$$