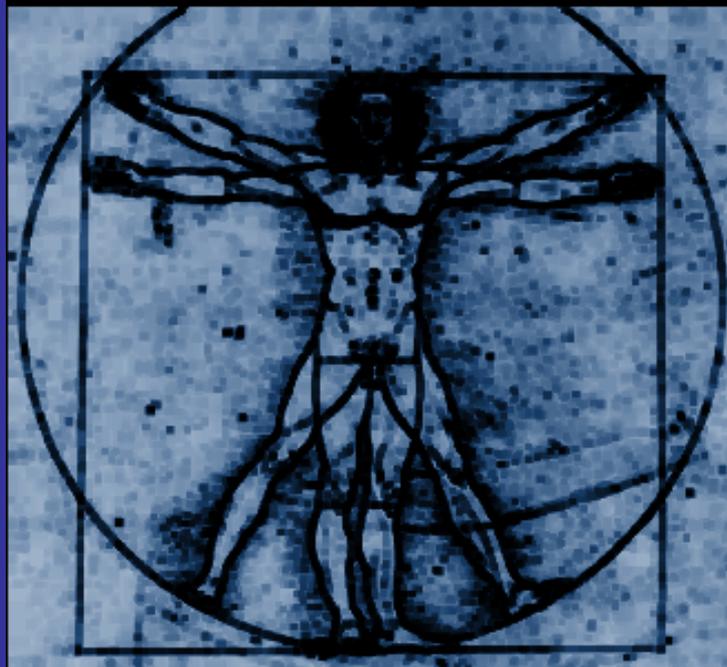


# MIPAV



MEDICAL IMAGE PROCESSING AND VISUALIZATION

<http://mipav.cit.nih.gov>



# Segmentation and Annotation of Medical Images with MIPAV

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dcb.cit.nih.gov/~senseneyj

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Center for Information Technology

mipav.cit.nih.gov



# MIPAV Team

## Employees

Ruida Cheng

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Evan McCreedy

Justin Senseney

## Fellows

Sara Shen

## Contractors

Alexandra Bokinsky, Geometric Tools Inc. (Visualization)

Olga Vovk, SRA International Inc. (Technical Writing)

## Alumni

Paul Hemler, Agatha Munzon, Nishith Pandya,

Beth Tyrie, Hailong Wang



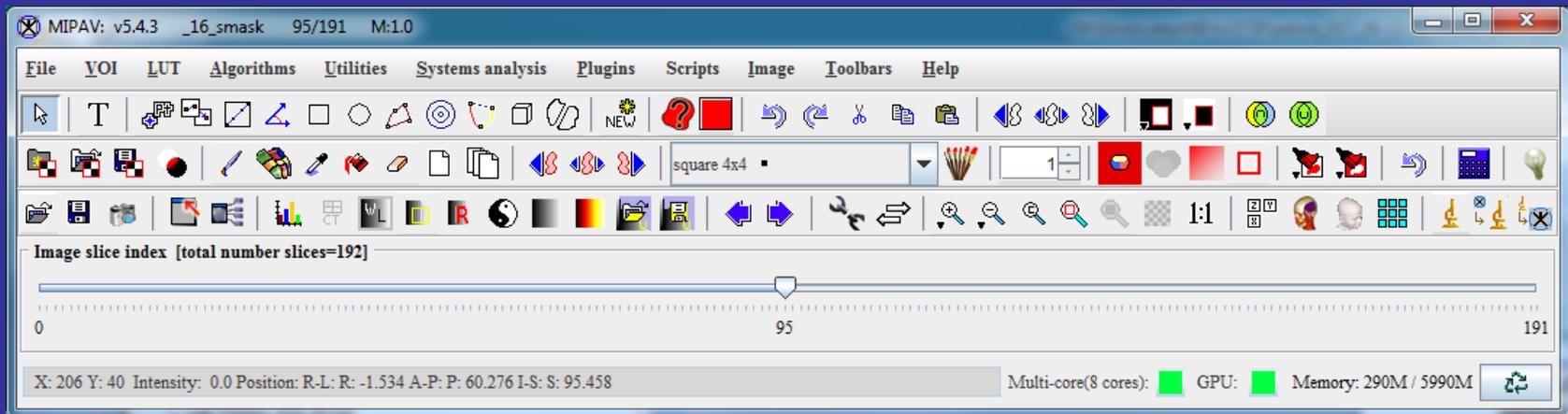
# Agenda

- Review
- VOI
  - Creation
  - Manipulation
- Masks
  - Creation
  - Conversion
  - Morphological operators (2D and 3D)
- Paint
  - Creation
  - Fill
  - Segmentation
    - Fuzzy C-means
    - Level set
    - Thresholding
    - Watershed
- Histogram
  - Equalization and matching



# Review

- MIPAV as collaboration tool
  - Opens all image formats
  - Scriptable
  - Quantitative and qualitative



# VOI

Volume of interest



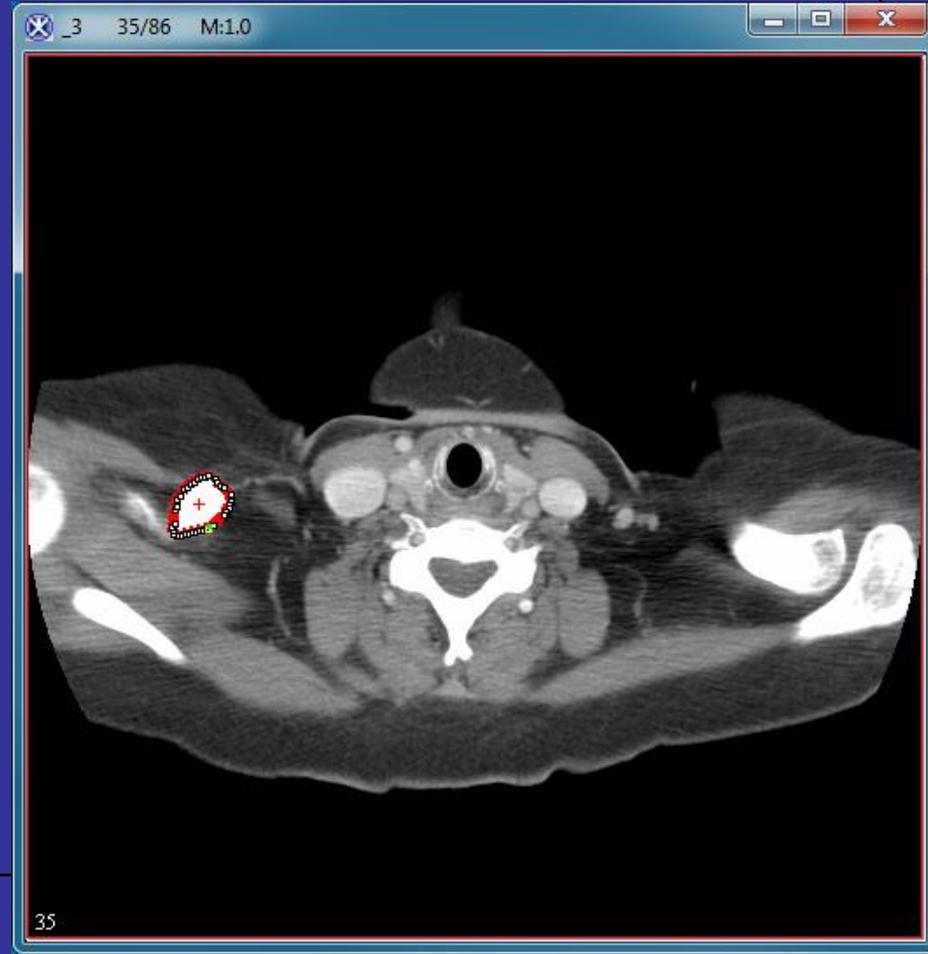
# Agenda

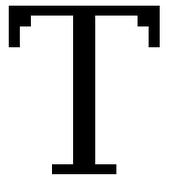
- VOI (Volume of interest)
  - Definition
  - Creation
    - Annotations
    - Points
    - Lines
    - Curves
    - Cube
  - Manipulation
    - Split
    - Undo/Redo
    - Cut/Copy/Paste
    - Propagation



# VOI

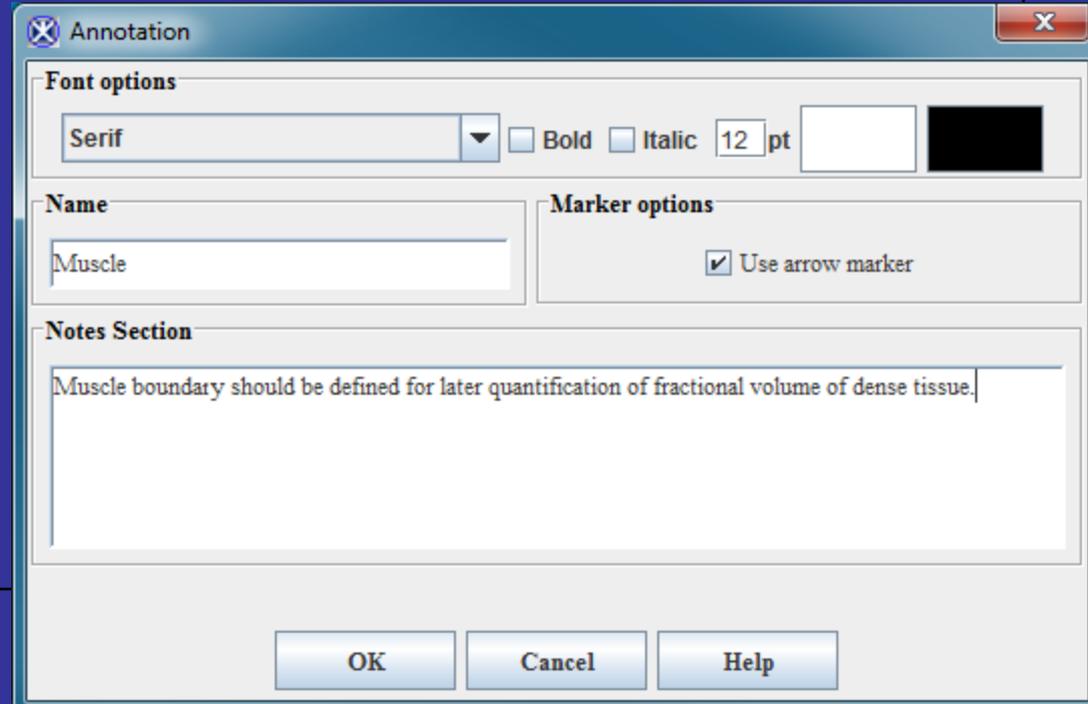
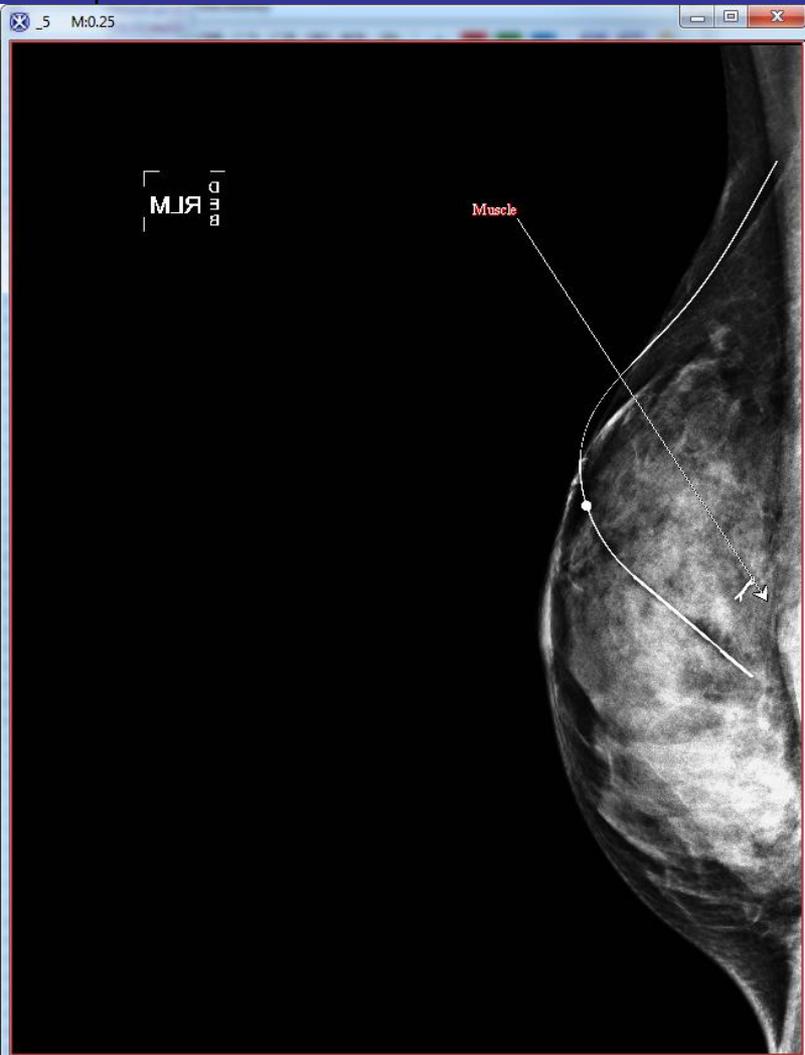
- Volume of interest – one or more contours on an image

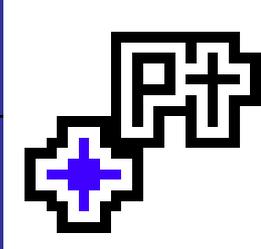




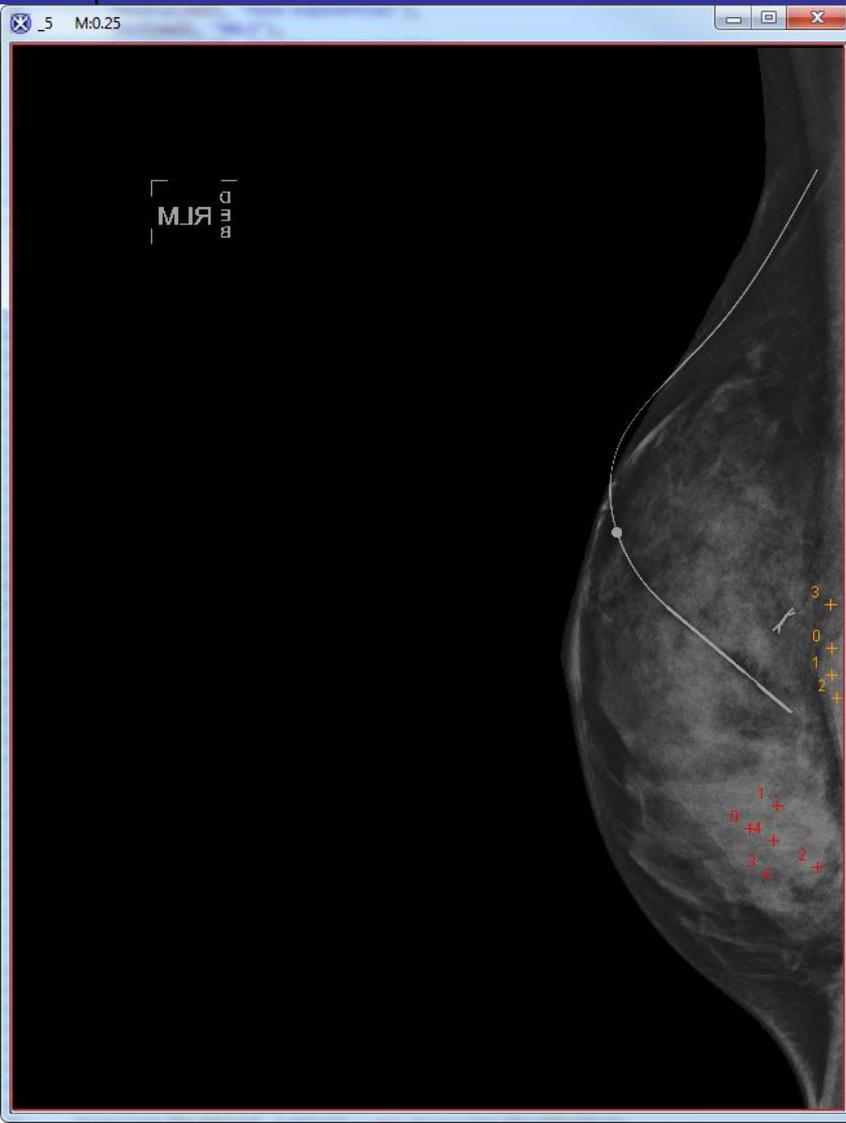
# Annotation

- Save names and notes
- Place in text location, move arrow

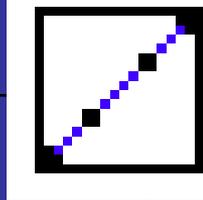




# Point

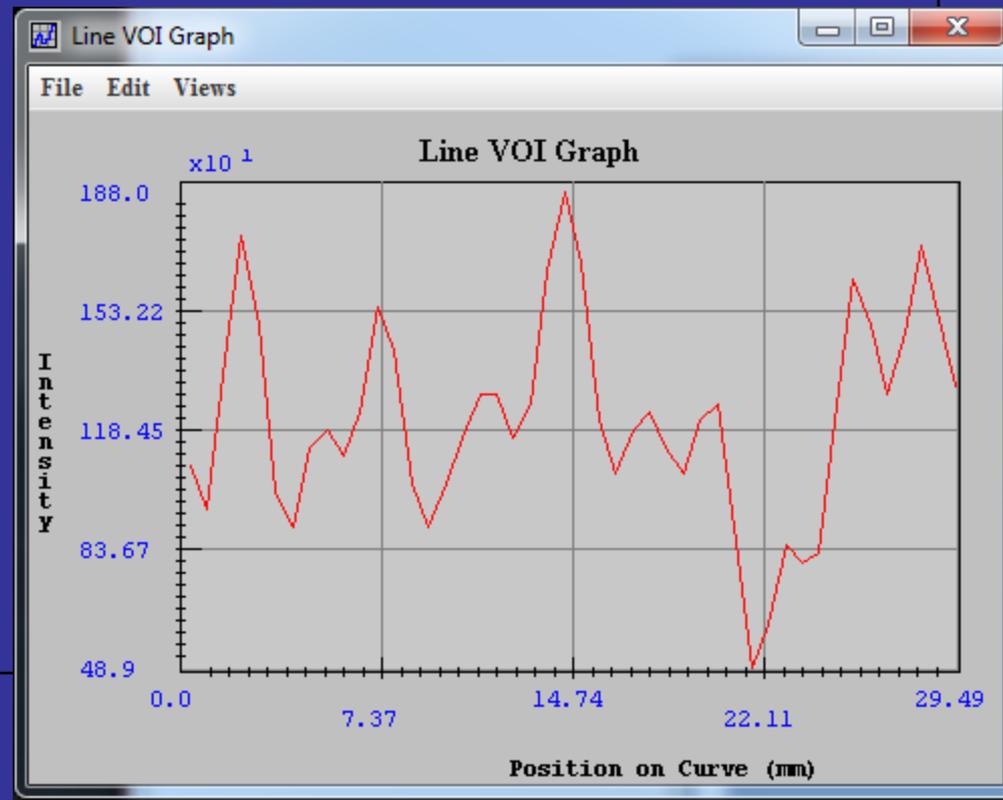
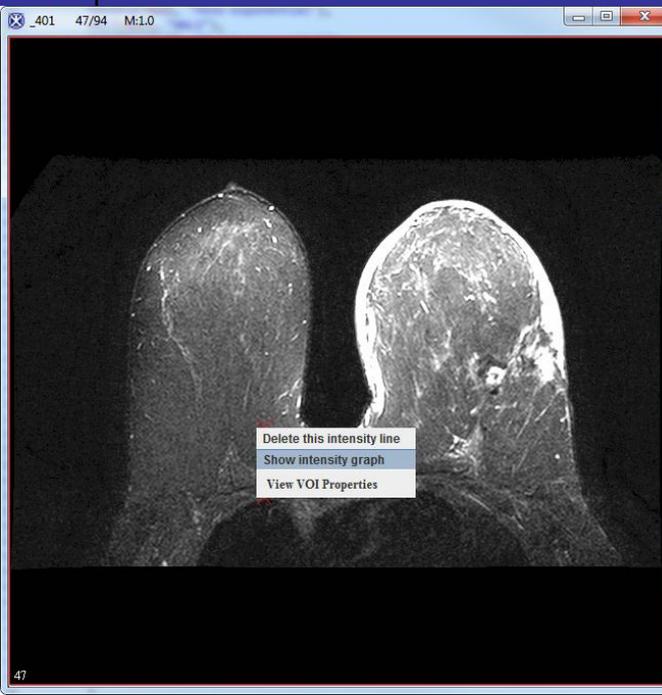


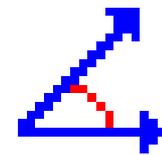
- Shift for multiple points
- Delete removes, renumbers to keep consecutive
- Can move



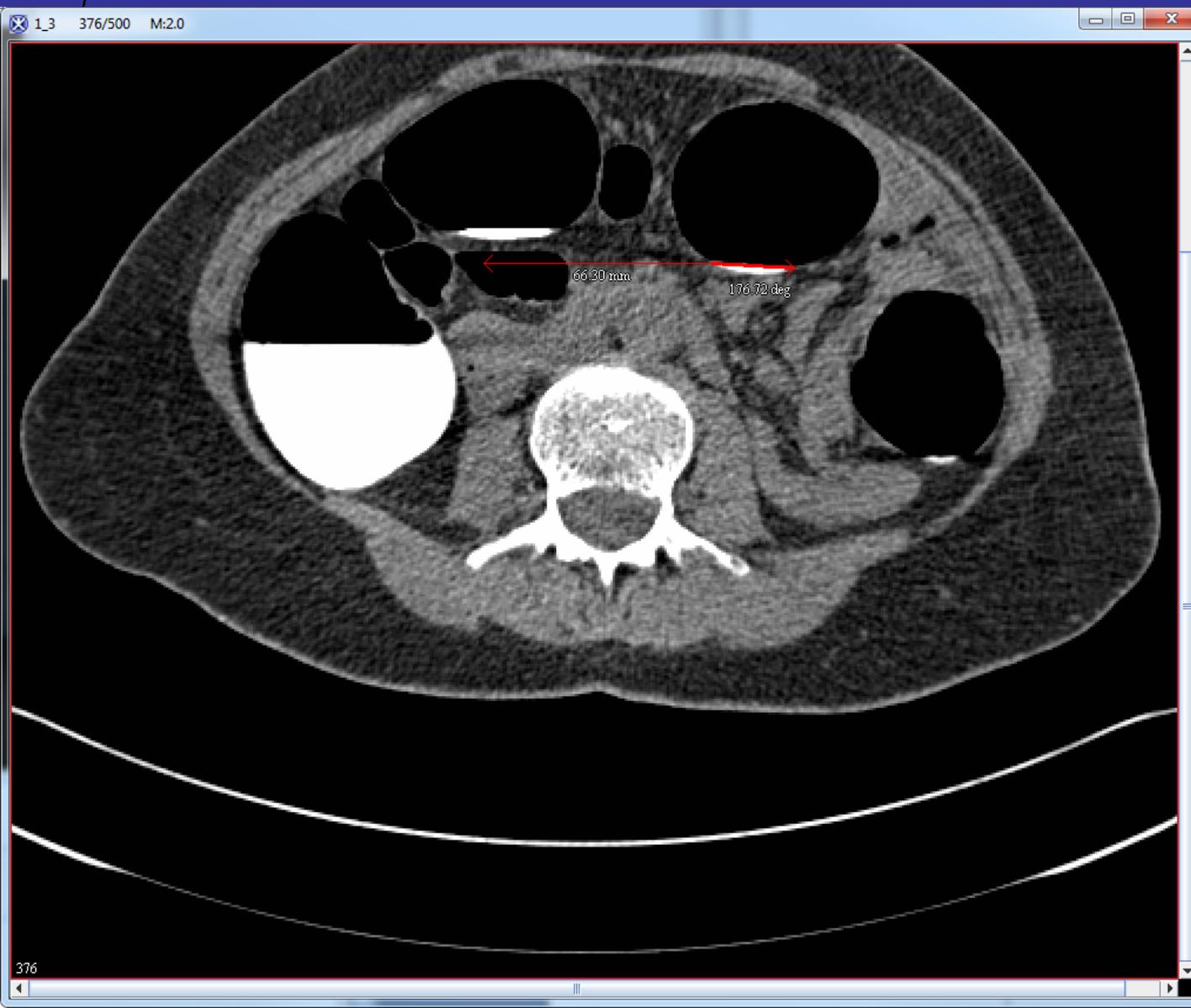
# Line

- Right click to show options
- Intensity plot from green point





# Protractor

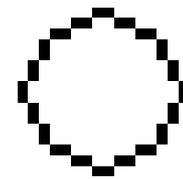


- Initial point is intersection of two lines
- Draw outwards
- Re-click to orient angle

# Square

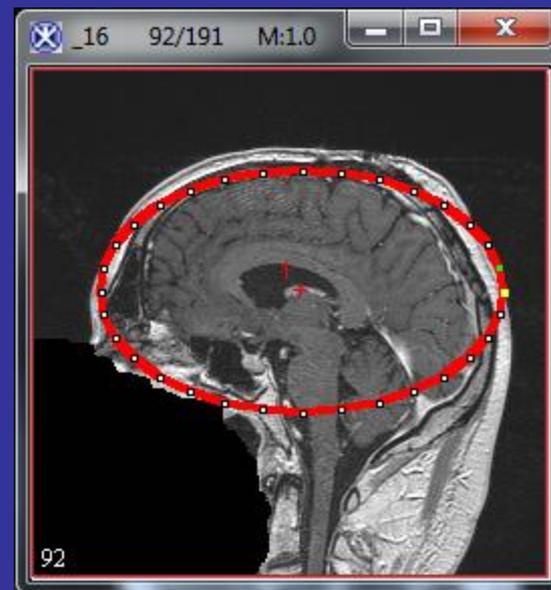
- Start with any corner, drag in any direction
- To modify, click a point, becomes “active” VOI.



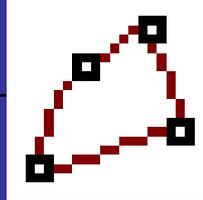


# Circle

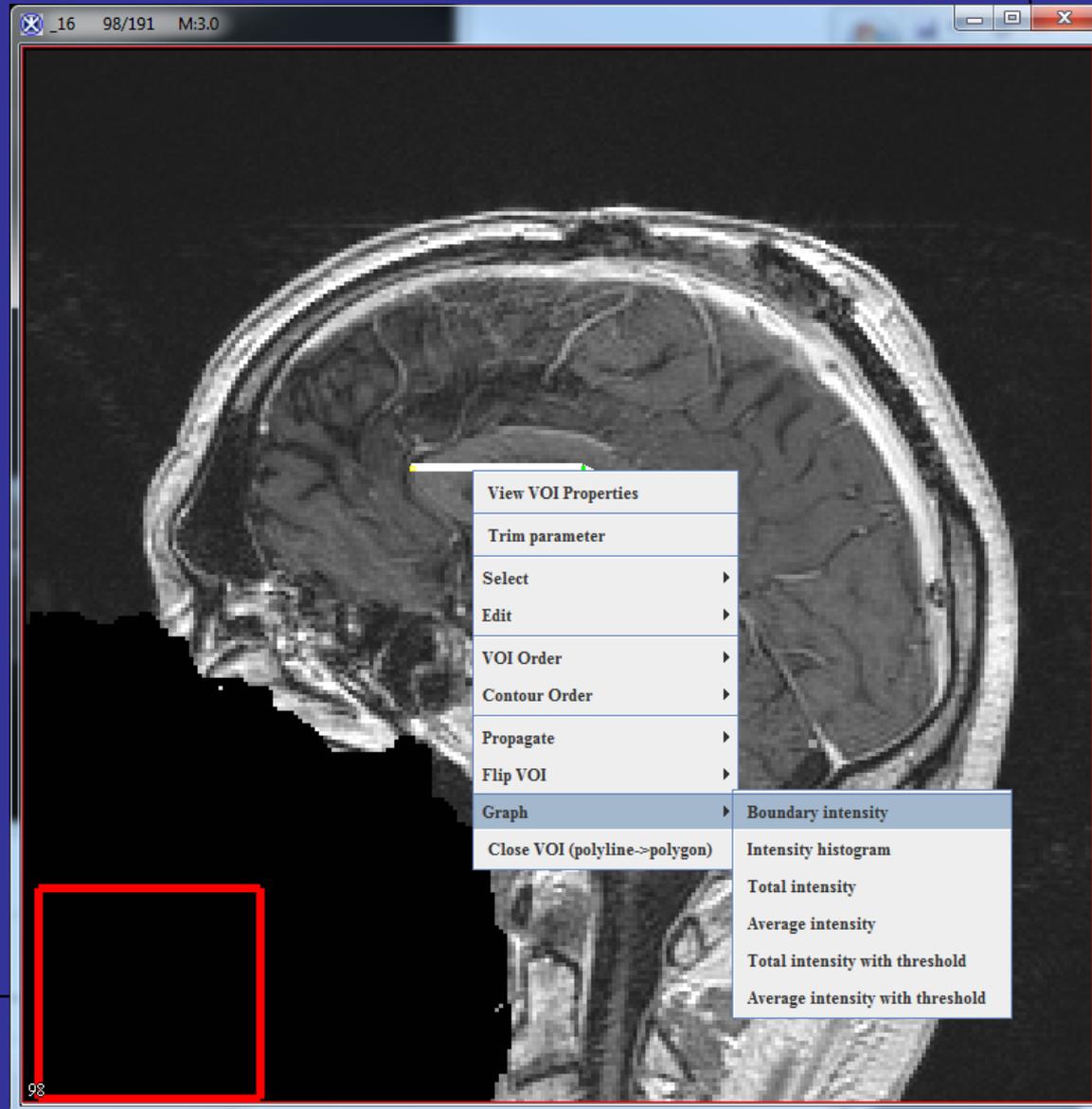
- Start at circle center
- Drag entire shape

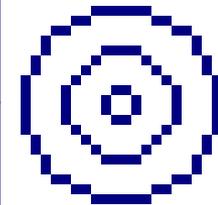


# Polyline/polygon



- Shape can be open

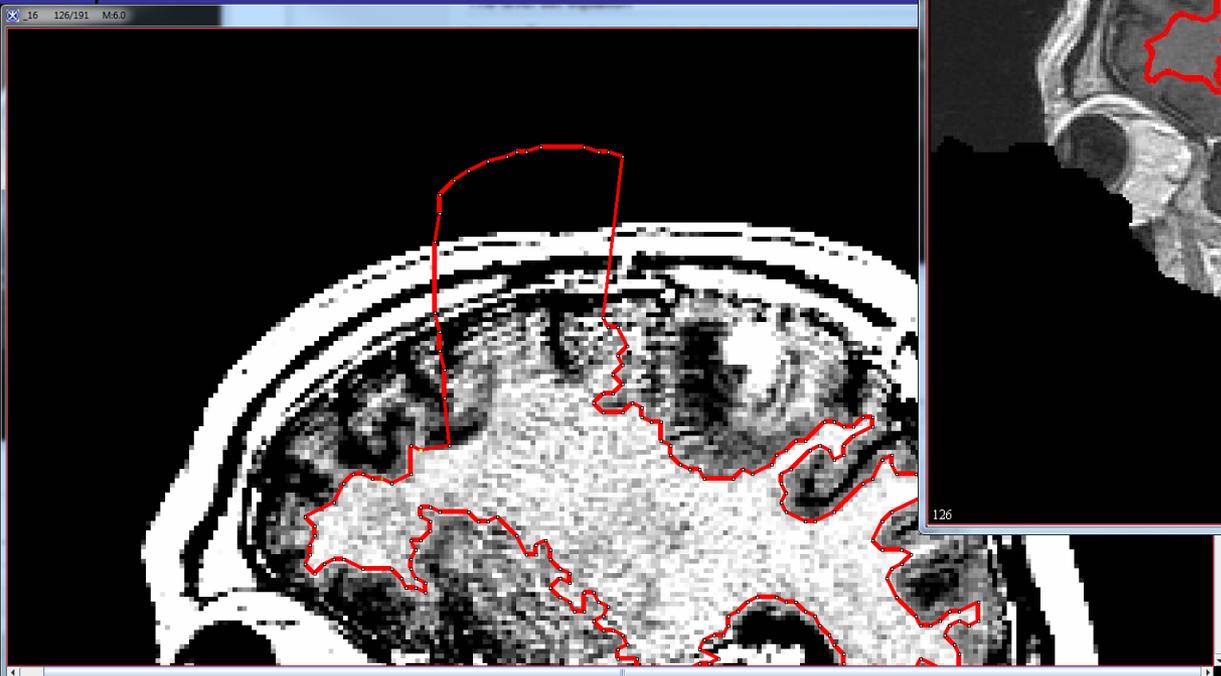




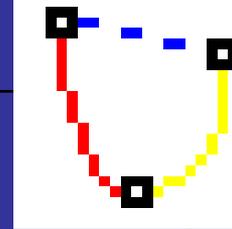
# Levelset

- Looks for closest intensity value
- Topographic map
- Once active, alt+hold down mouse to modify boundary.

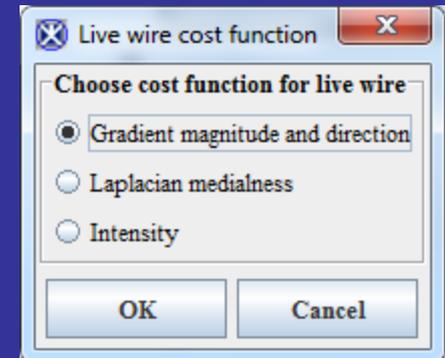
X: 104 Y: 78 Intensity: 273.0 Position: R-L: R: -32.534 A-P: A: -41.724 I-S: S: 57.458



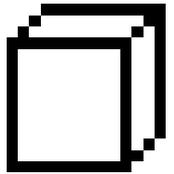
# Livewire



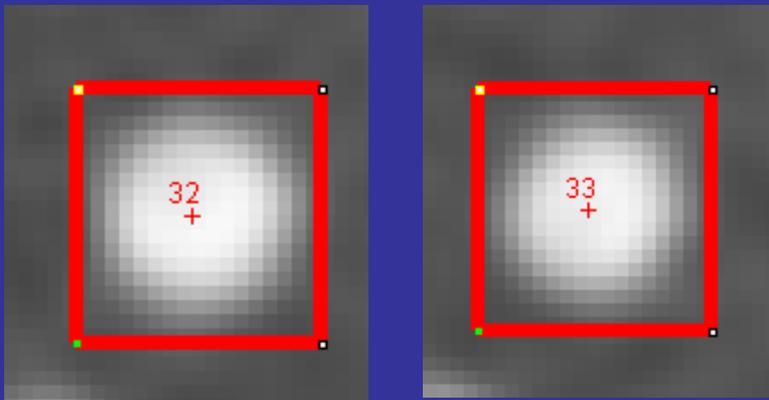
- Larger changes in magnitude with smaller distance.
- Minimum cost



# Cube



- “0” is always the initial curve
- Numbering does not indicate slice



**VOI Properties/Statistics - 1664073**

**VOI properties**

VOI name:

VOI UID:

VOI thickness:

VOI color: ■

Show contour bounding box

Include for processing

Show VOI name

Display VOI shading

**Opacity**

**VOI Browser**

- [-] Slice 27
- [-] Slice 28
- [-] Slice 29
- [-] Slice 30
  - [-] 31
- [-] Slice 31
  - [-] 0
- [-] Slice 32
  - [-] 32
- [-] Slice 33
  - [-] 33
- [-] Slice 34
- [-] Slice 35

**Statistics to calculate:**

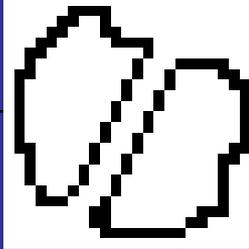
- # of Voxels
- Volume
- Area
- Perimeter
- Min Intensity
- Max Intensity
- Avg Voxel Intensity
- Std Dev of Intensity
- Sum Intensities
- Geometric center
- Center of Mass
- Principal Axis
- Eccentricity
- Major axis length
- Minor axis length
- Coefficient of skewness
- Coefficient of kurtosis
- Largest slice distance
- Largest distance
- Median Intensity
- Mode Intensity
- Mode Count

**Pixel Exclusion**

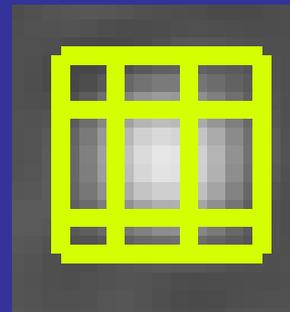
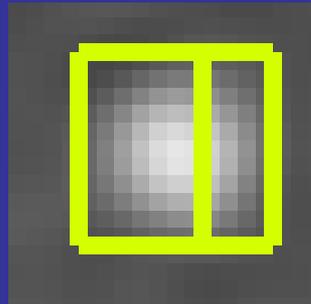
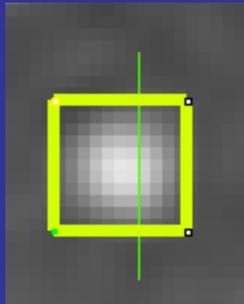
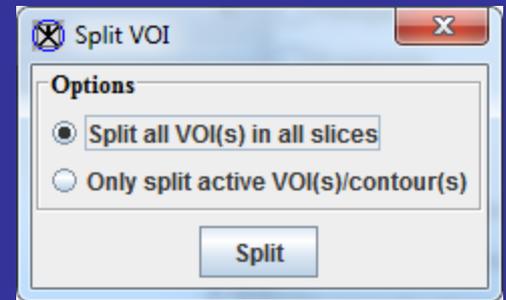
**Tree options**



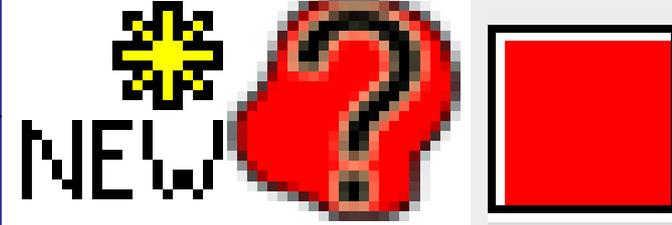
# Split



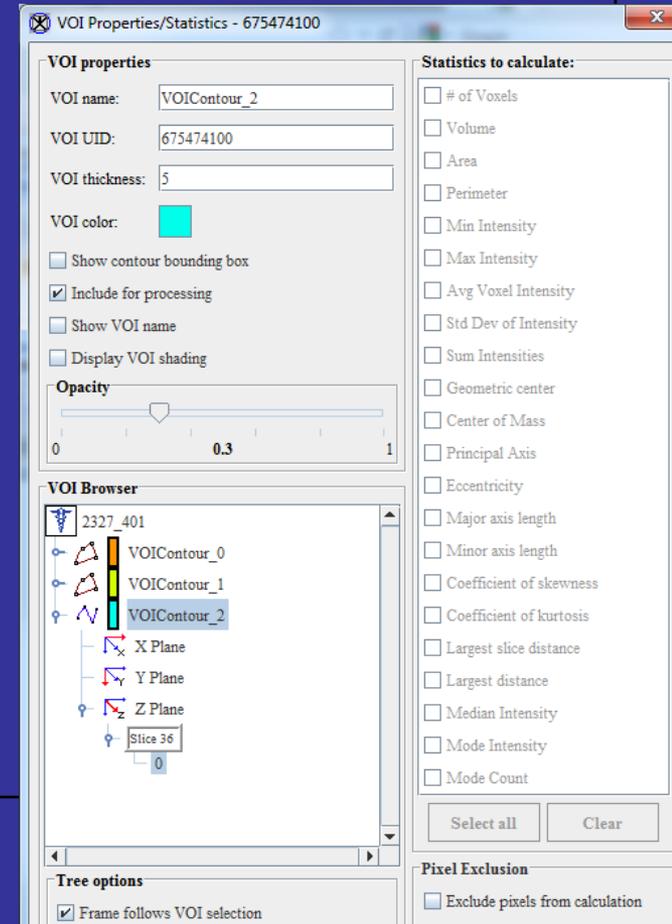
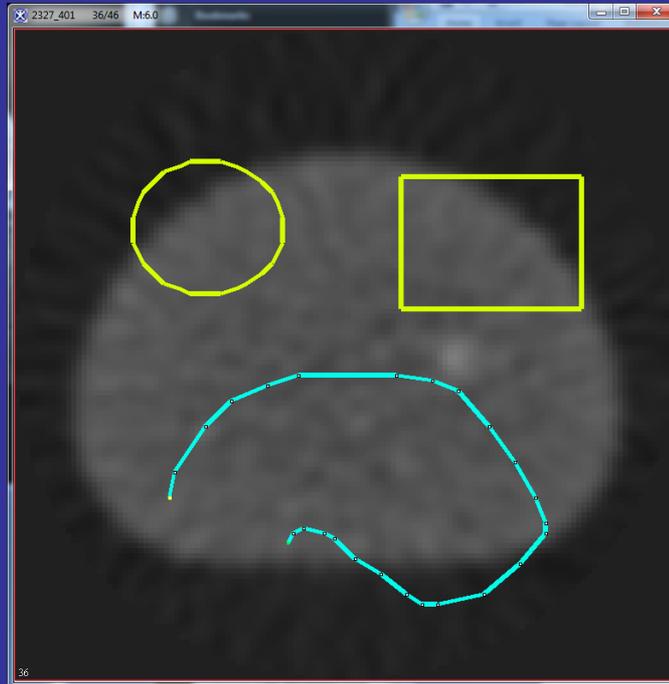
- Splits into same VOI, different contour
- Each contour is closed
- Multiple VOIs split
- Multiple contours split



# New VOI



- Open/closed VOIs cannot be combined
- Statistics



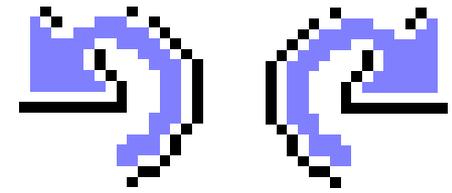
# Quiz

- Manual VOI change using ALT+hold down mouse. Which direction is required?
- A. clockwise
- B. counter-clockwise

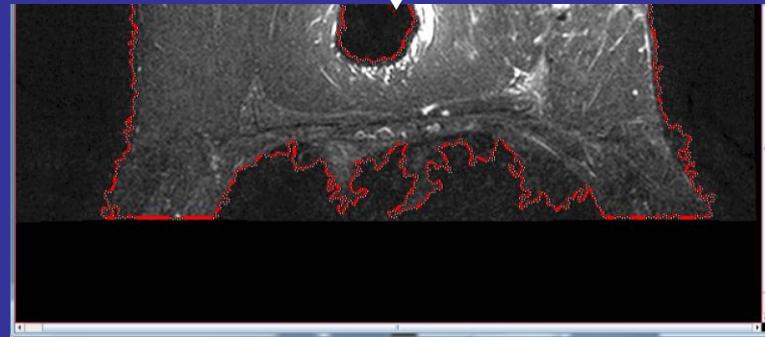
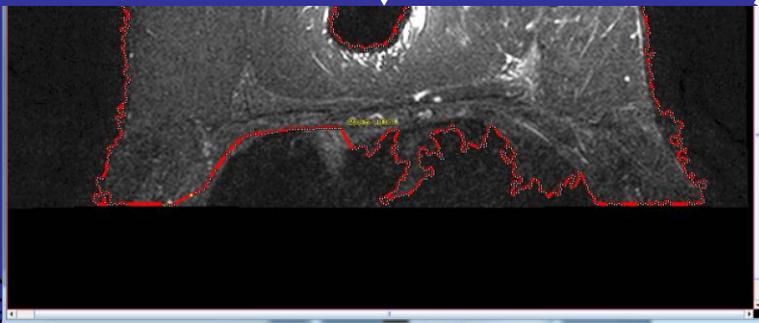
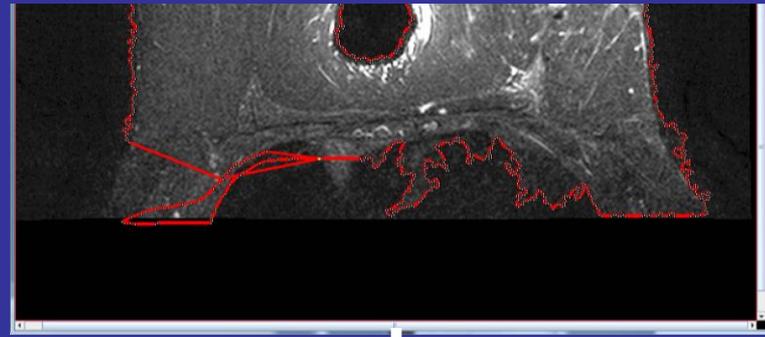
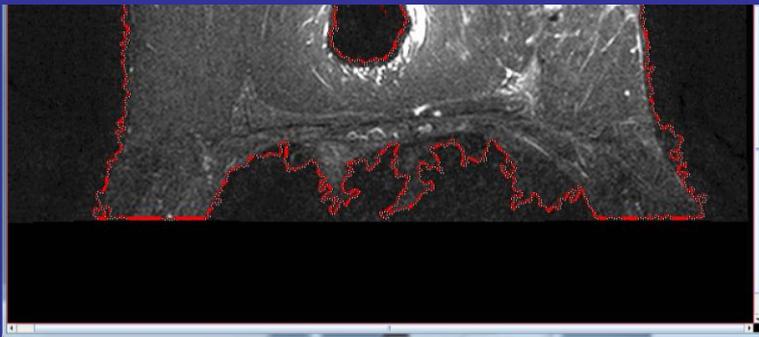
Answer: Both, but choose one each time



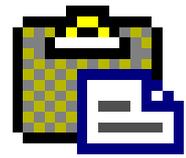
# Undo/Redo



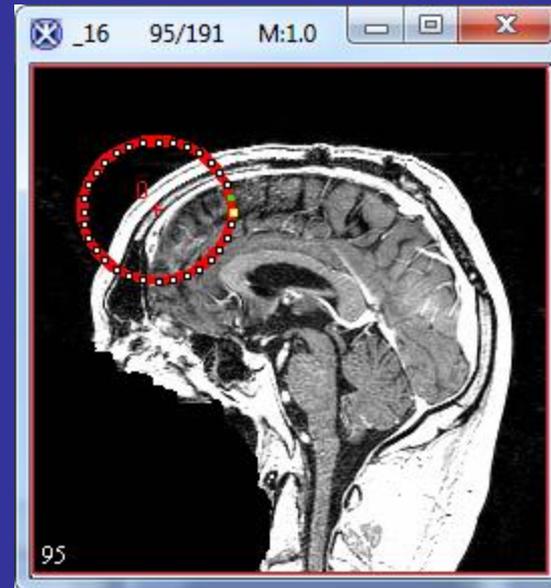
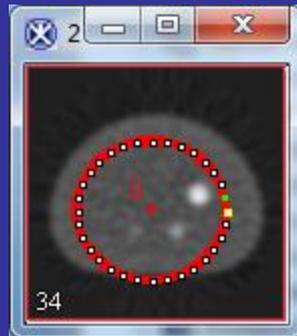
- Applies to VOI operations only
- Keyboard shortcut: Ctrl+Z (Undo), Ctrl+Y (Redo)



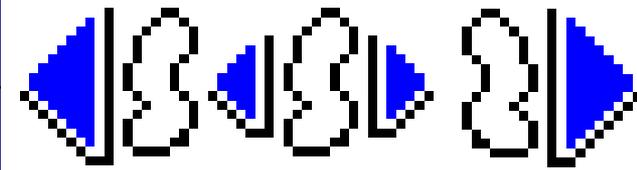
# Cut/Copy/Paste



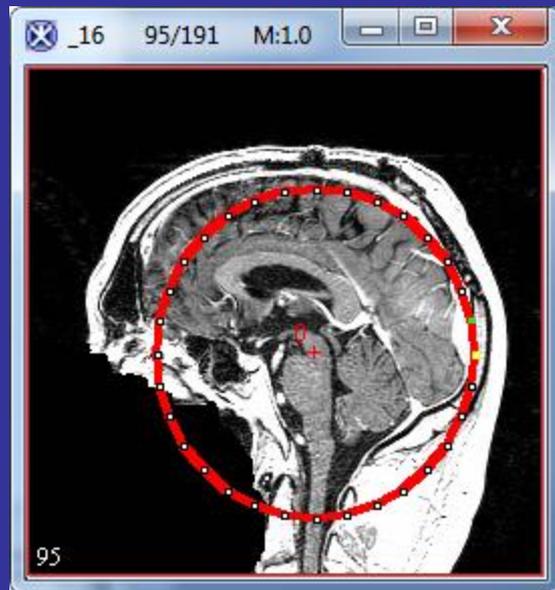
- Cut – delete, store to paste
- Copy – store to paste
- Paste – Place active VOI in current slice of active image



# Propagate



- Down one slice
- Up one slice
- To all slices



**VOI Properties/Statistics - 1604282459**

**VOI properties**

VOI name: VOIContour\_0

VOI UID: 1604282459

VOI thickness: 5

VOI color: ■

Show contour bounding box

Include for processing

Show VOI name

Display VOI shading

**Opacity**

0 0.3 1

**Statistics to calculate:**

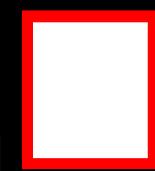
- # of Voxels
- Volume
- Area
- Perimeter
- Min Intensity
- Max Intensity
- Avg Voxel Intensity
- Std Dev of Intensity
- Sum Intensities
- Geometric center
- Center of Mass
- Principal Axis
- Eccentricity
- Major axis length
- Minor axis length
- Coefficient of skewness
- Coefficient of kurtosis
- Largest slice distance
- Largest distance
- Median Intensity
- Mean Intensity

**VOI Browser**

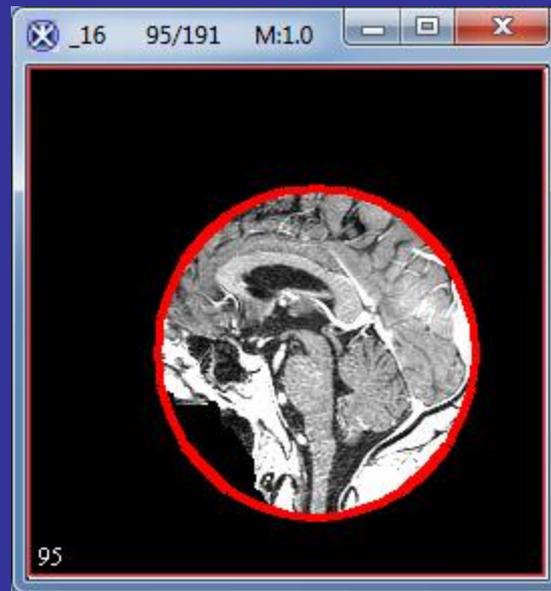
- \_16
  - VOIContour\_0
    - X Plane
    - Y Plane
    - Z Plane
    - Slice 0
    - 1
    - Slice 1



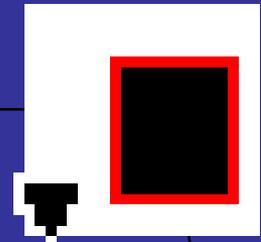
# And



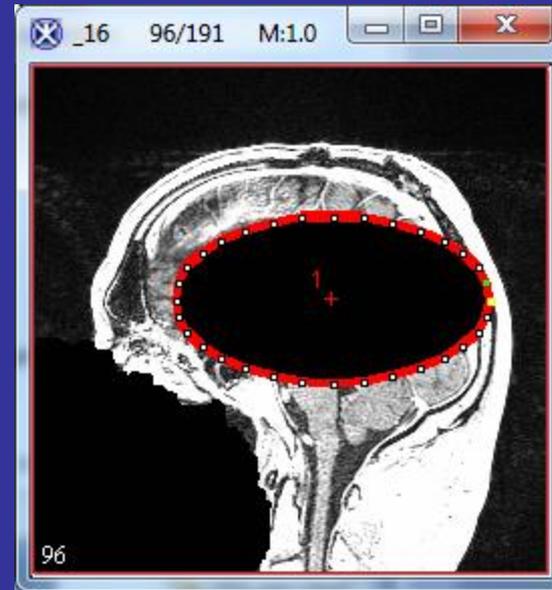
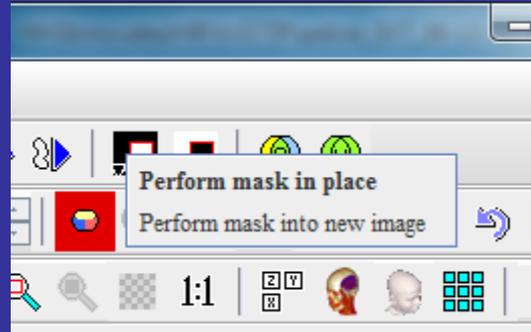
- Default is in place



# Fill



- Fills with zeros



# Evolve Boundary

- Active contour
- Combine with propagation to adjacent slices
- Small Gaussian sensitive to noise

**Evolve Boundary**

**Scale of the Gaussian**

X Dimension (0.5 - 5.0)	2.0
Y Dimension (0.5 - 5.0)	2.0
Z Dimension (0.0 - 5.0)	2.0

**Resolution options**

Use image resolutions to normalize Z scale.

Corrected scale = 2.0

**Evolve Boundary**

Single slice

Propagate to adjacent slices

Replace Original Contour

**Algorithm parameters**

Move boundary	Any direction
Boundary iterations	50
Smoothness (0.5 - 2.4)	2.0

OK Cancel Help



# Interpolate

- Define contours on non-contiguous slices
- Contours part of same VOI
- Must be selected

Slice 86



Slice 89



Slice 95



# Break

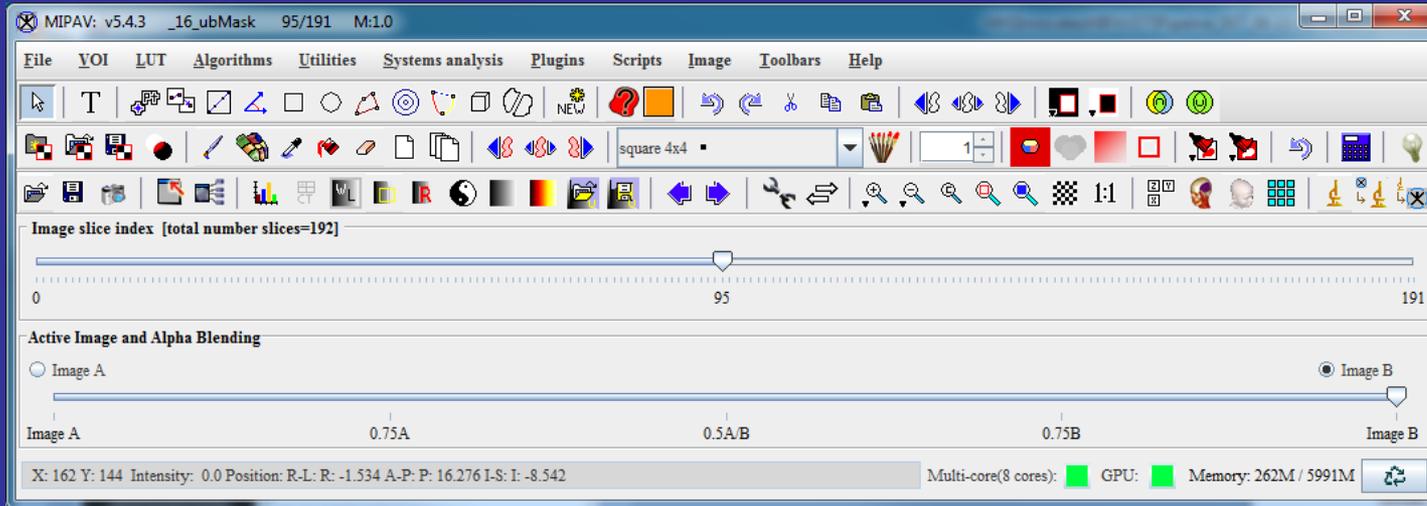
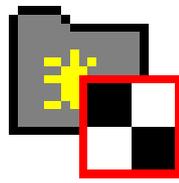


# Mask

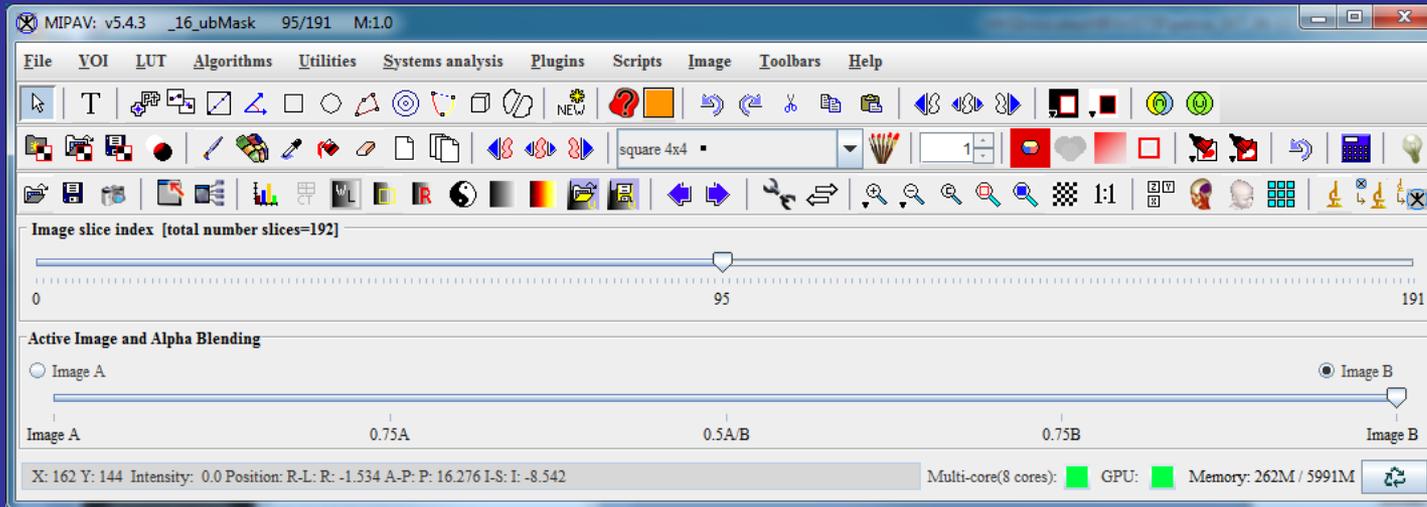
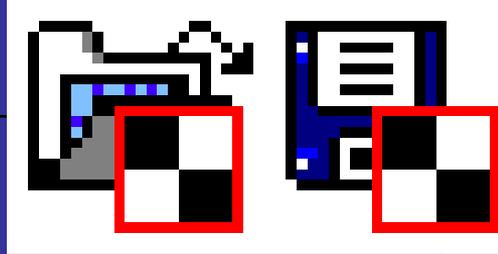
Defined on pixels



# Create new mask

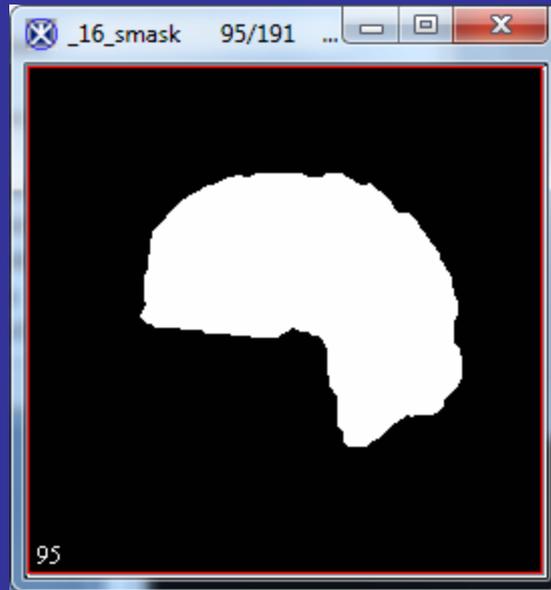
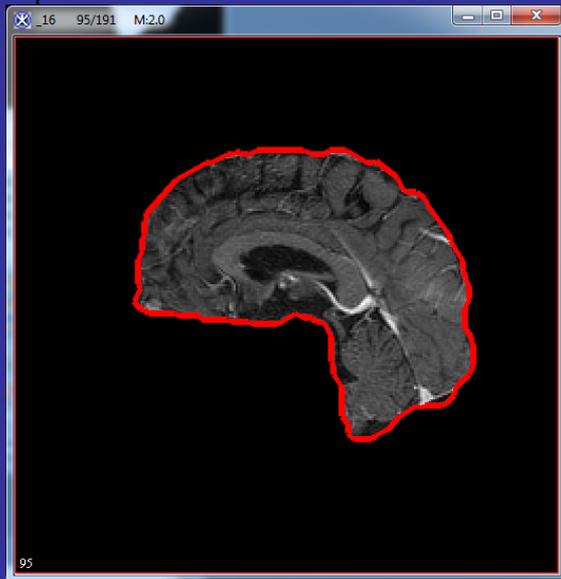
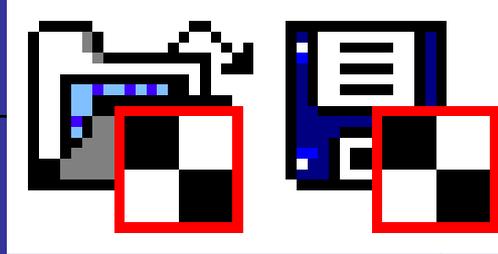


# Open/Save mask

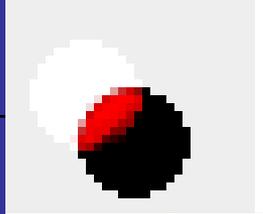


# Conversion

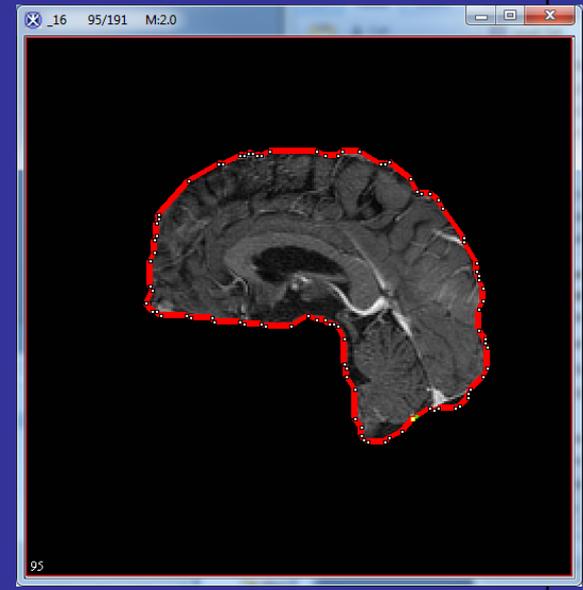
VOI menu options



# AND Mask operation



Performs actual conversion



# Morphology



# Mathematical Morphology

- Erosion
- Dilation
- Opening
- Closing
- Distance maps

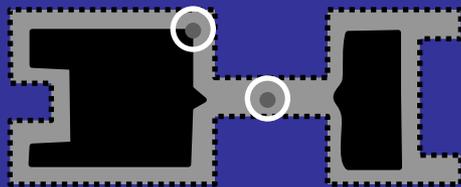


# Mathematical Morphology

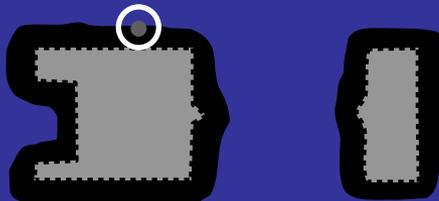
## Opening



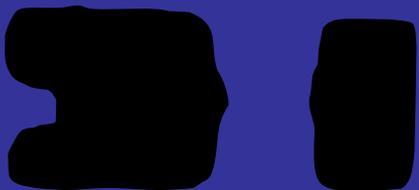
Source object



Erosion



Dilation



Result: Erosion + Dilation = Opening

○ Structuring Element

0	1	0
1	1	1
0	1	0

2D 3x3 structuring element

0	0	0	0	1	0	0	0	0
0	1	0	1	1	1	0	1	0
0	0	0	0	1	0	0	0	0

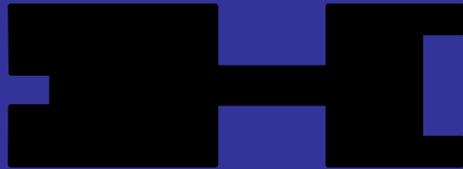
3D 3x3x3 structuring element



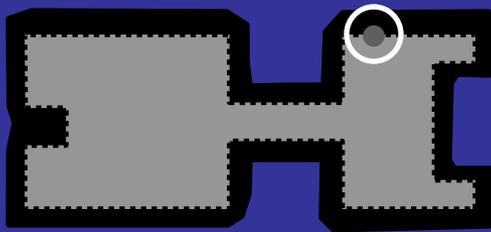
# Mathematical Morphology

## Closing

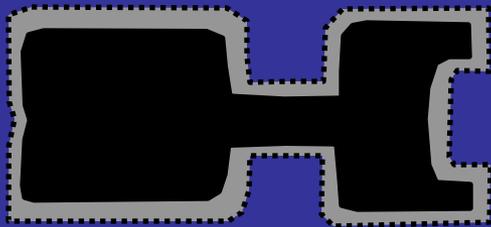
○ Structuring Element



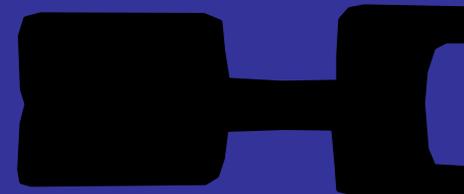
Source object



Dilation



Erosion

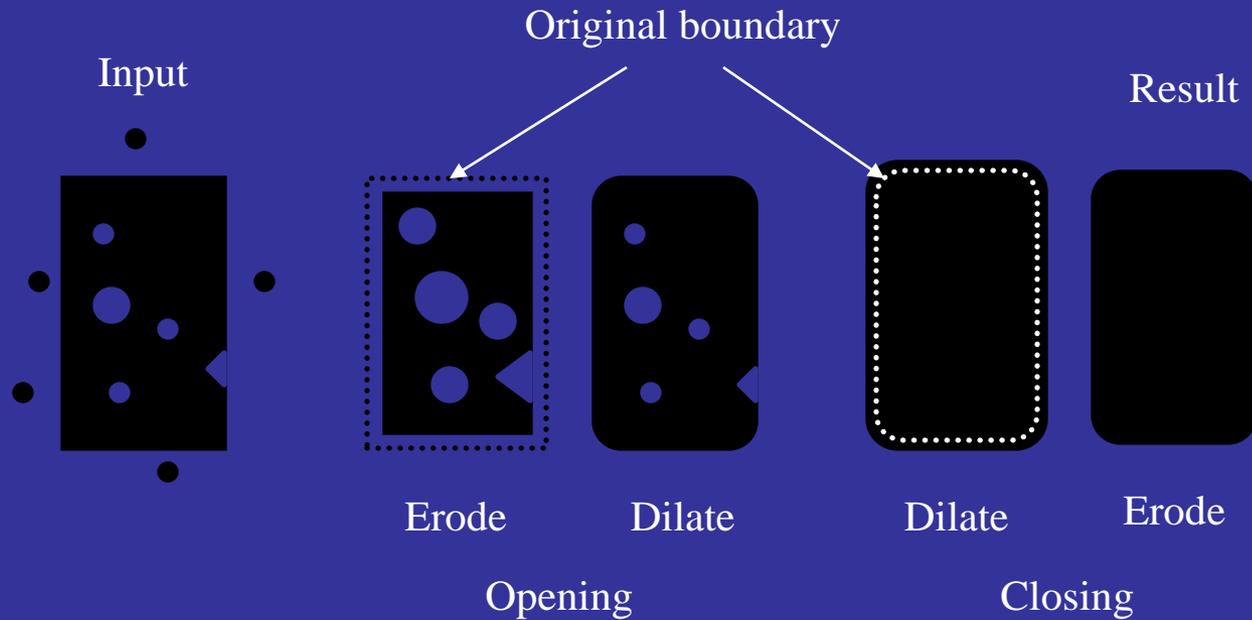


Result: Dilation + Erosion = Closing

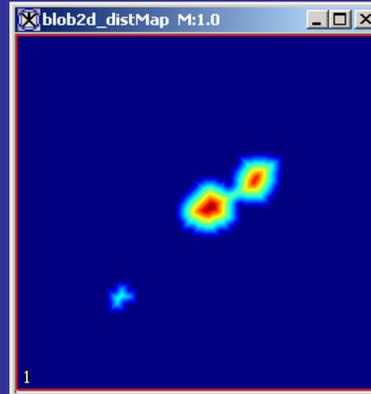
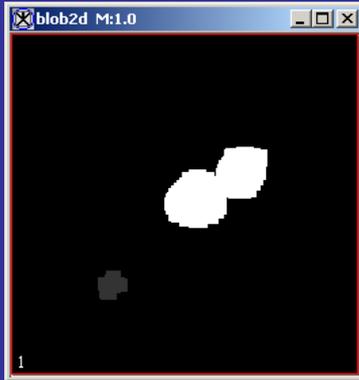


# Mathematical Morphology

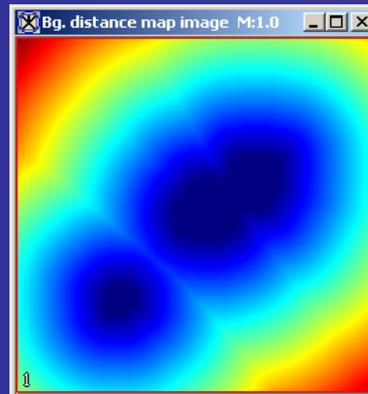
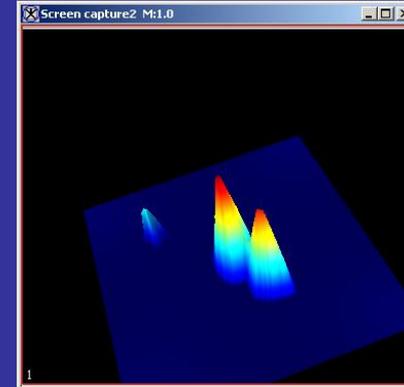
## Noise Removal



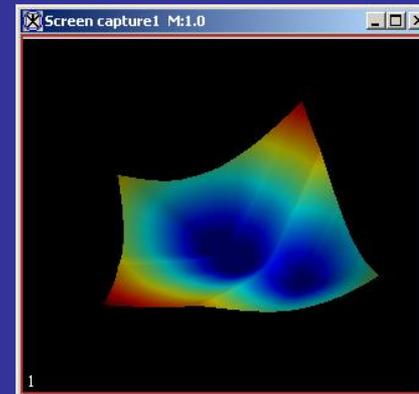
# Distance transform



Object distance - minimum Euclidian distance from any edge to a point interior to the object



Background distance - minimum Euclidian distance from any edge to a point exterior to the object (i.e. background)

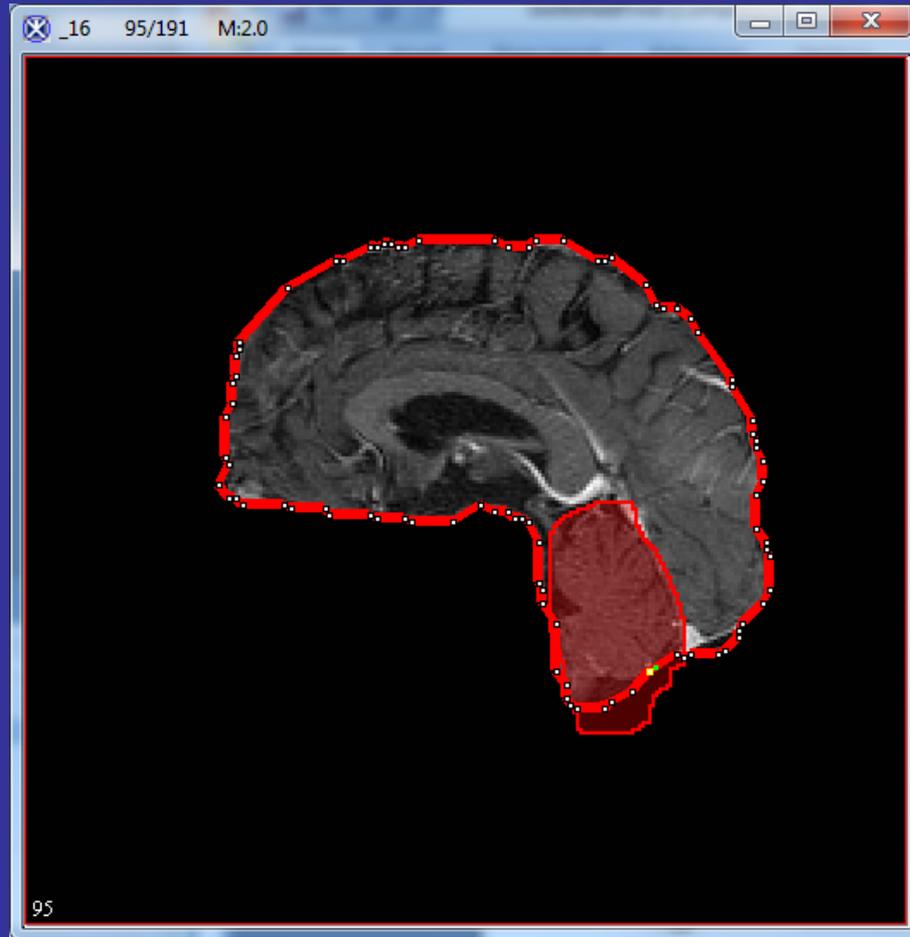


# Paint

Defined on masks

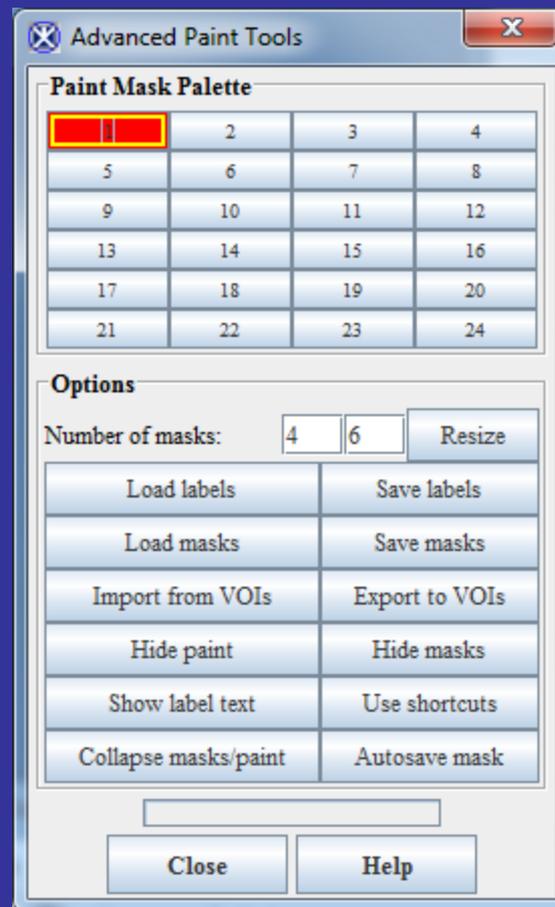
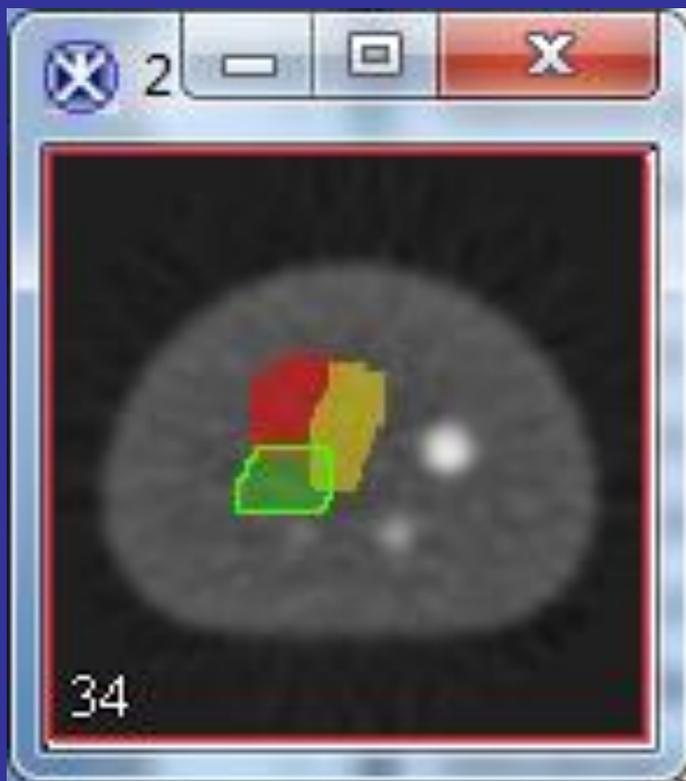


# Brush



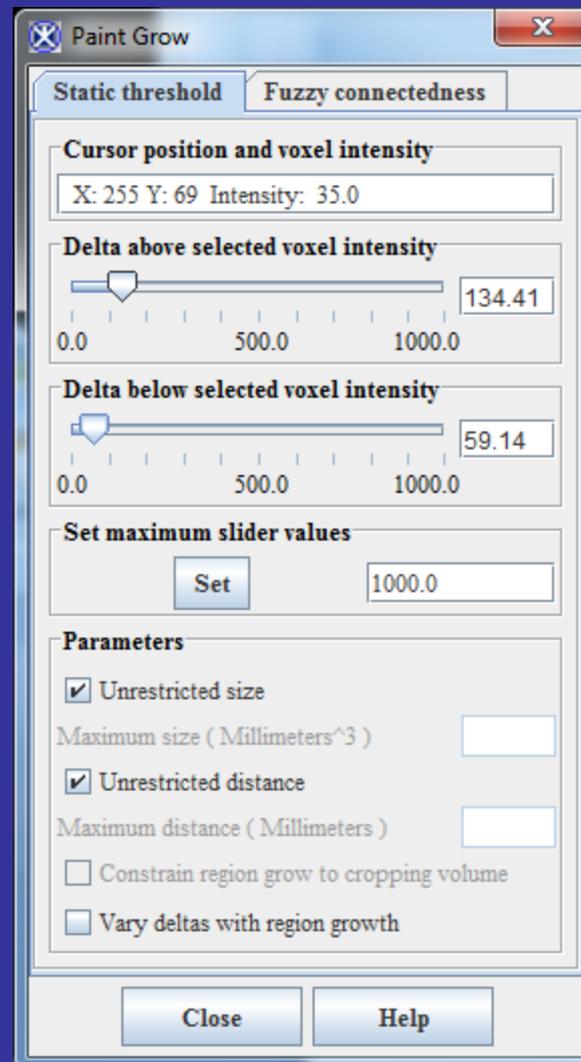
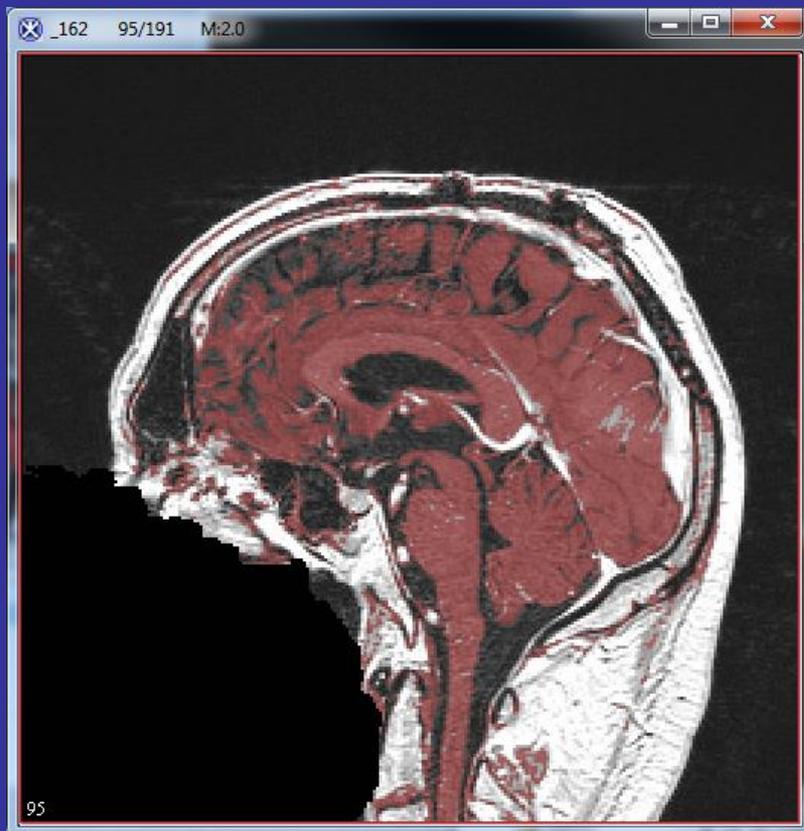


# Advanced Paint

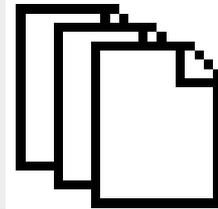
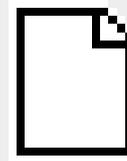




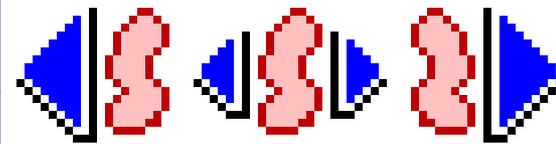
# Region Grow



# Eraser



# Propagation



- Same as VOI options
- No active contour solution





square 4x4 ■

1	+
	-

# Paint brush options

- Brush size

square 4x4 ■	▼
square 2x2 ·	▲
square 4x4 ■	
square 8x8 ■	
square 16x16 ■	

- Brush pattern

Create paint brush

Grid options


Left-mouse to draw, right-mouse to erase

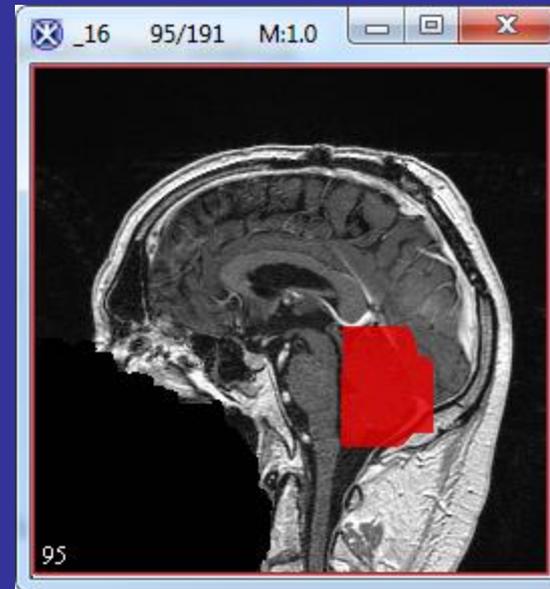
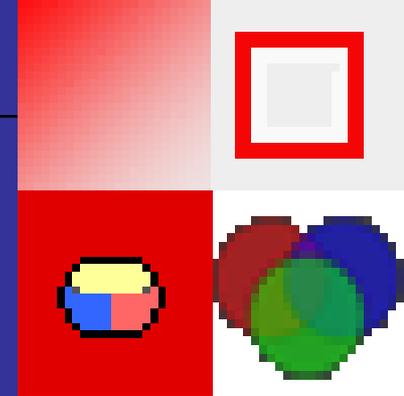
- Brush intensity

1	+
	-

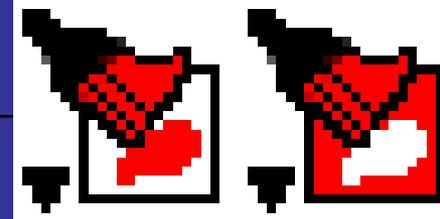


# Paint display options

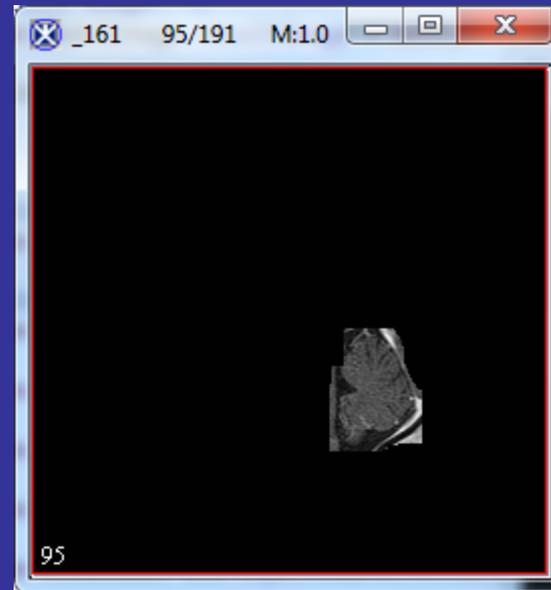
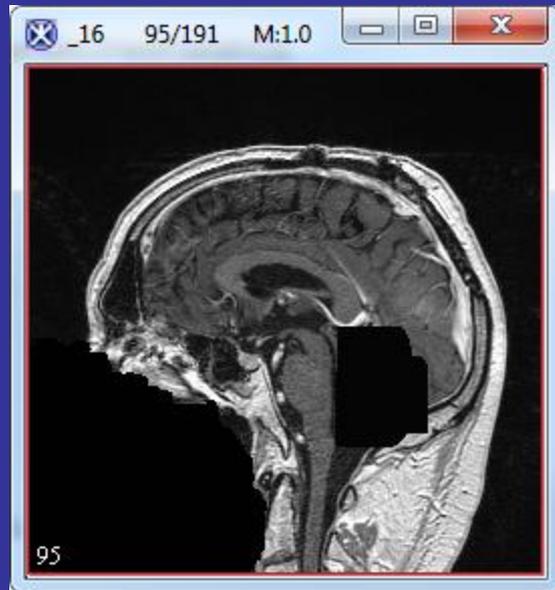
- Select color
- Change opacity
- Show border



# Mask options



- Just like VOI mask options, another conversion tool



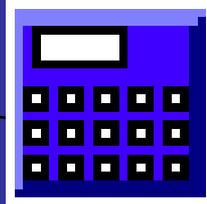


# Undo paint

- Only applies to paint
- Does not change masks



# Calculate volume



- Units of image
- Resolution of image

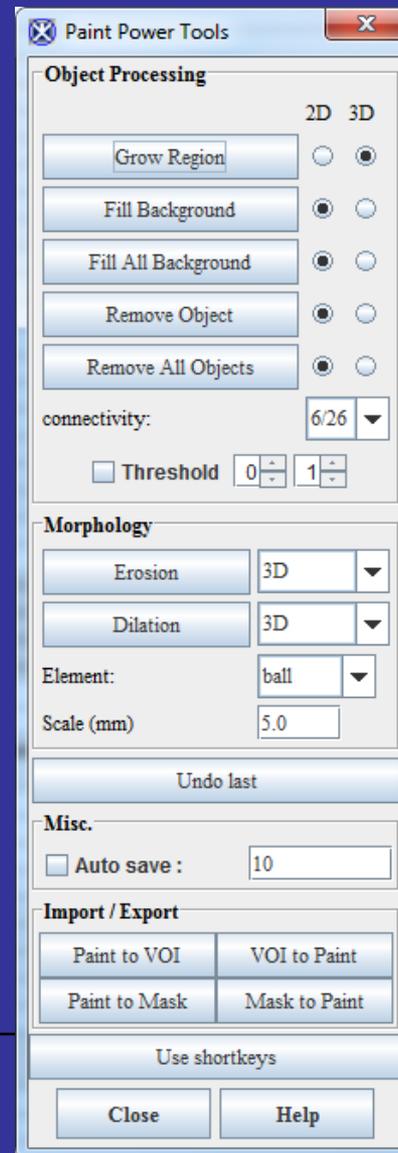
Info: \_16\_smask: 100

Essential Image Information	
Name	Value
Description	
Linked-image	
Image-offset	0
Dimension 0	256
Dimension 1	256
Dimension 2	192
Type	Short
Min	0.0
Max	1.0
Orientation	Sagittal
Axis X Orientation	Anterior to Posterior
Axis Y Orientation	Superior to Inferior
Axis Z Orientation	Left to Right
Pixel resolution 0	1.0 Millimeters
Pixel resolution 1	1.0 Millimeters
Pixel resolution 2	1.0 Millimeters
Slice thickness	0.0 Millimeters
Origin 0	-145.72397
Origin 1	135.45763
Origin 2	-6.5338984
Endianness	Little Endian
Matrix	0.0000 0.0000 -1.0000 0.0000 1.0000 0.0000 0.0000 0.0000 0.0000 -1.0000 0.0000 0.0000 0.0000 0.0000 0.0000 1.0000
Modality	Other
History	
Subject Information	
Name	Value
Subject Name	
Subject ID	
Race	
Diagnosis	
Date of Birth	0000-01-01
Height	0
Weight	0
Sex	Unknown
Body Part	
Scan Attributes	
Name	Value
Equipment Model Name	
Scan ID	
Protocol	

Add Set Edit tag Expand Tags Remove Parameter Add Surface Remove Surface Close



# Power paint tools



# Segmentation

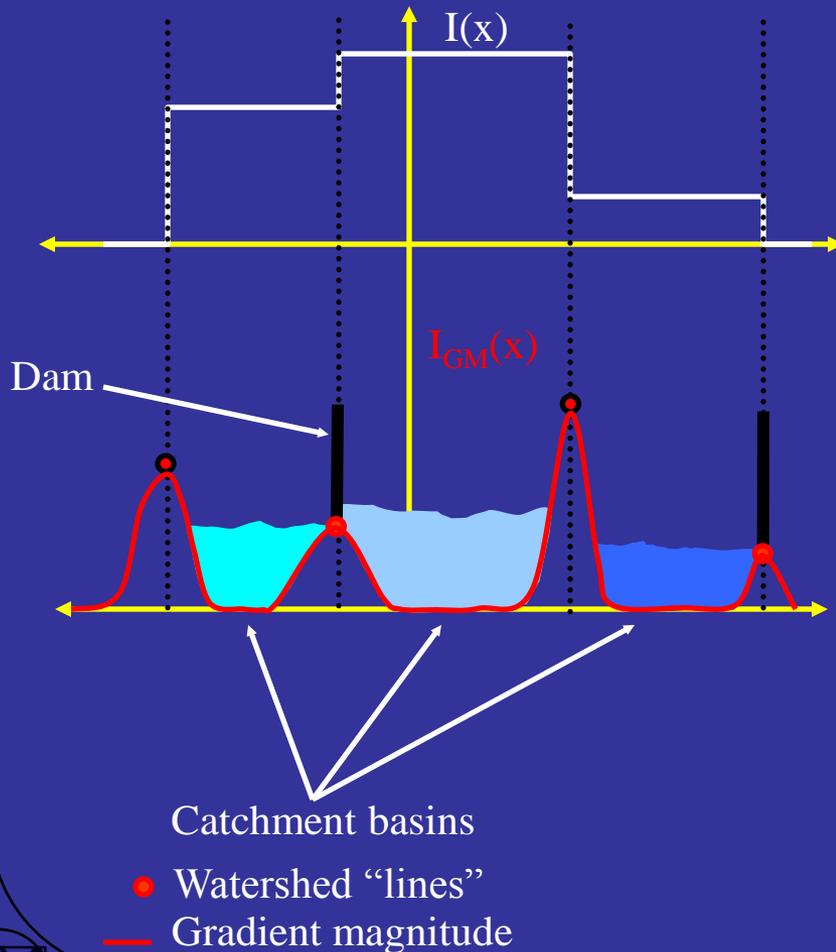


# Watershed Segmentation

- Watersheds are a classic field of topography.
- Example of a watershed: *Great Divide* of the U.S.
  - A drop of water falling one side flows down until it reaches the Atlantic ocean, whereas a drop falling on the other end flows until it reaches the Pacific ocean.
- The above two watersheds or catchment basins are separated by what is termed the watershed line.
  - Catchment basins: minima of the watershed
  - Watershed line: maxima of the watershed



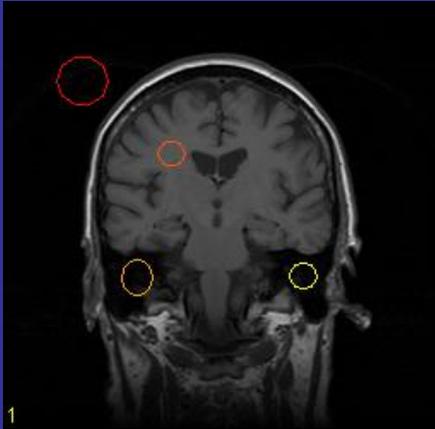
# Watershed Segmentation



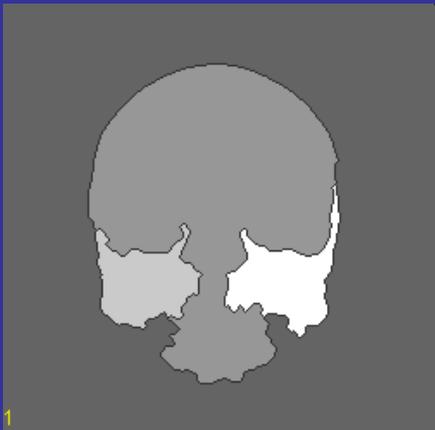
- Find the lowest point in each basin and begin "flooding".
- When two basins meet a watershed point (1D) is identified and a dam is formed.
- Continue flooding until all basins and watershed points are formed.
- Note: this method can produce over segmentations.



# Watershed Segmentation: Interactive



MRI image with ROIs



Segmented basins

- Find the lowest point in each basin identified by a Region of Interest (ROI) and force the gradient magnitude to zero at all ROIs. Begin “flooding” in those regions.
- When two basins meet a watershed line (2D) is identified and a dam is formed.
- Continue flooding until all ROI basins until all regions are flooded.

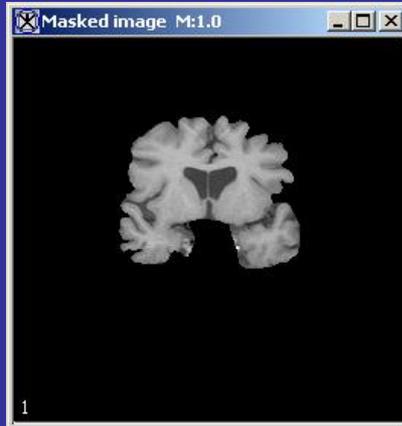


# Voxel Classification

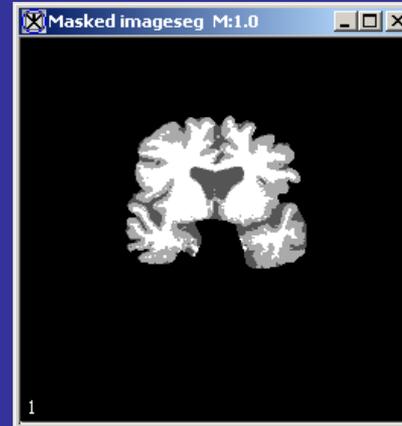
- Groups of voxels are not physically connected then the segmentation technique is termed voxel classification and voxels sets are referred to as **classes**
- Cluster methods do not inherently incorporate spatial information and therefore can be sensitive to factors like intensity inhomogeneities.



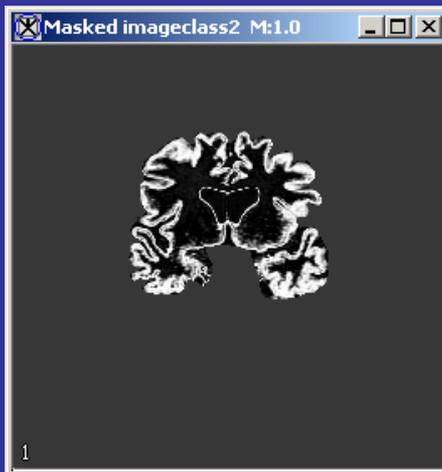
# Fuzzy C-means



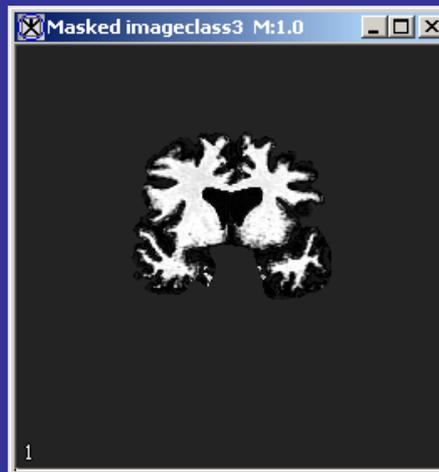
T1 – MRI



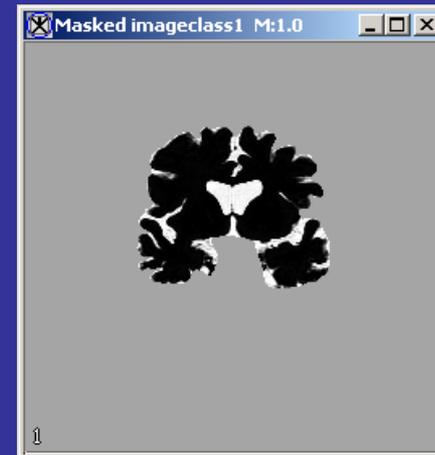
Hard segmentation – G,W,CSF



Fuzzy Gray



Fuzzy White

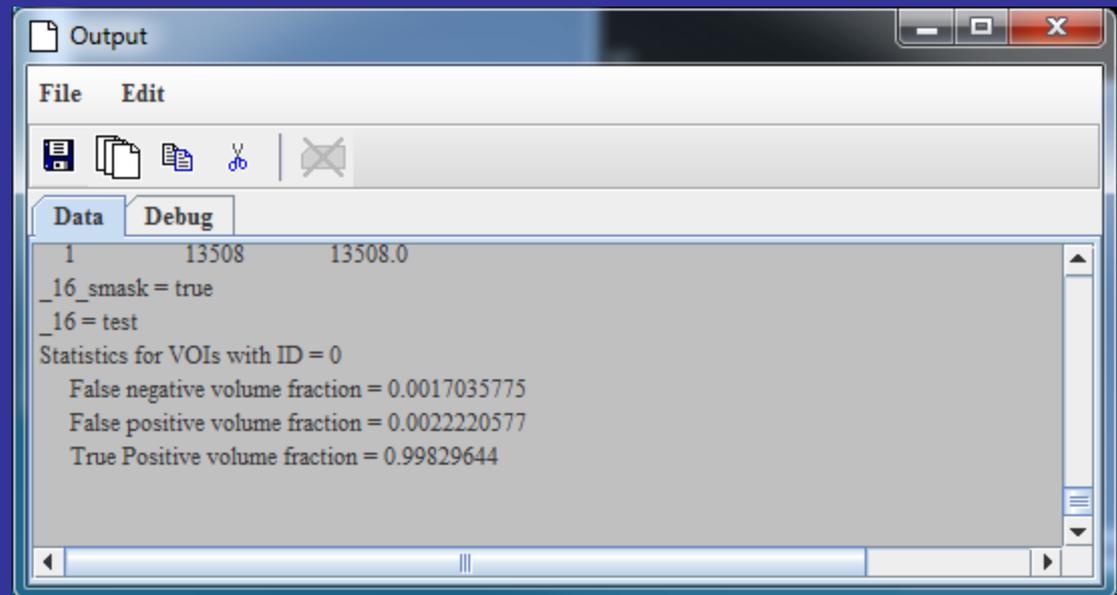


Fuzzy CSF



# Segmentation Evaluation

- Compared to ground truth VOI
- Requires converting masks to VOIs



The screenshot shows a window titled 'Output' with a menu bar containing 'File' and 'Edit'. Below the menu bar is a toolbar with icons for file operations. The window has two tabs: 'Data' and 'Debug'. The 'Data' tab is active and displays the following text:

```
1      13508      13508.0
_16_smask = true
_16 = test
Statistics for VOIs with ID = 0
  False negative volume fraction = 0.0017035775
  False positive volume fraction = 0.0022220577
  True Positive volume fraction = 0.99829644
```



# Acknowledgments

- Images from NCI's Cancer Imaging Archive:  
<http://cancerimagingarchive.net/>
- Examples from NIH collaborators.



Thank you!

