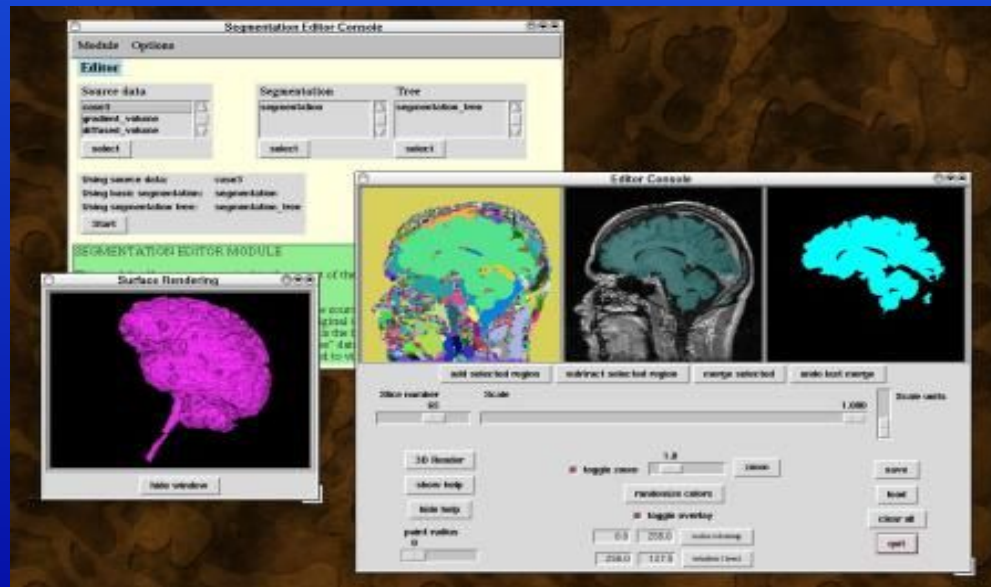


# Demo 1

## User-assisted Watershed Segmentation



# Demo 1: How the segmentation works

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A hierarchy of global image segmentations is generated using the watershed transform

The user picks and combines regions from the watershed hierarchy to produce a final segmentation

# Demo 1: User-assisted Watersheds

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How the application is constructed

- ITK image processing (watersheds)

- VTK visualization

- Tcl/Tk scripted user interface

# Watersheds GUI Design

InsightApplications/SegmentationEditor

User

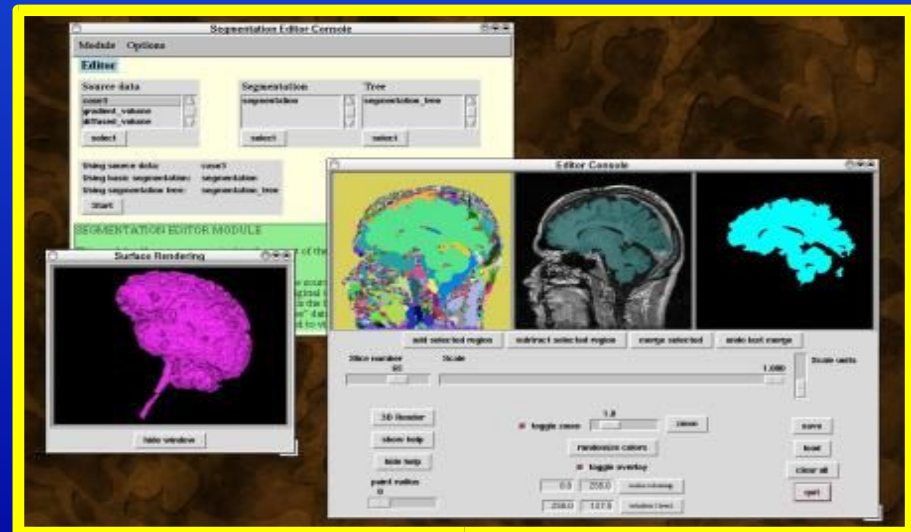
Tk Graphical User Interface

Tcl Wrapper

vtkITK IP Pipeline

VTK Vis. Pipeline

Input  
Data



# Watersheds Interface Overview

**Watershed transform**

**Data with overlay**

**Segmentation in progress**

**Sliders manipulate watershed depth and position in the hierarchy.**

**3D isosurface rendering**

**Watershed Depth Threshold**

The screenshot displays the Watersheds Interface with several key components: a top row of three image windows (watershed transform, data with overlay, and segmentation in progress), a central control panel with sliders and buttons, a bottom-left panel showing a watershed hierarchy tree, and a bottom-right panel for 3D isosurface rendering. Red arrows point from text labels to specific interface elements.

The interface includes a central control panel with the following elements:

- Buttons: "add selected region", "subtract selected region", "merge selected", "multi seed merge", "show help", "help help", "point radius", "change point value", "toggle zoom", "toggle overlay", "toggle autohiding", "toggle vtk autohiding", "add renderers", "hide window".
- Sliders: "Scale" (set to 0.25), "toggle zoom" (set to 7.5), "toggle overlay" (set to 0.0), "toggle autohiding" (set to 0.0), "toggle vtk autohiding" (set to 0.0).
- Buttons: "randomize colors", "set color map", "set color map", "set color map", "set color map".

The bottom-left panel shows a watershed hierarchy tree with a vertical axis labeled "Watershed Depth Threshold". The tree structure is as follows:

- Root node (green circle)
- Left child (orange circle)
- Right child (red circle)
- Left child of orange (green circle)
- Right child of orange (red circle)
- Left child of red (brown circle)
- Right child of red (black circle)
- Left child of green (orange circle)
- Right child of green (red circle)
- Left child of red (black circle)
- Right child of red (orange circle)

The bottom-right panel shows a 3D isosurface rendering of a yellow object, with a vertical axis labeled "Watershed Depth Threshold".

# Demo 1: User-assisted Watersheds

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This demo leads you through a segmentation of a brain tumor in a 3D MRI dataset using the Watershed Segmentation Editor.

How to run the demo program

Click once on the “Demo 1” icon

Follow the instructions in the green windows

# Watershed segmentation theory.

---

The remainder of this document outlines the theory behind the watershed segmentation algorithm and some validation work conducted at the University of Utah. This material is helpful for understanding the demo. It is not necessary for running the demo.

# Morphological Watersheds Theory

Large body of research over 20 years

Inspired by hydrology – treat image as landscape and look for its watershed regions

“Watershed Transform” – the algorithm that identifies the watershed regions

## Main Variations

- ✓ Top-down: classify pixels by shortest *topological* distance to local minima
- × Bottom-up: simulated immersion algorithms

- L. Vincent, P. Soille, Watersheds in digital spaces: An efficient algorithm based on immersion simulations, PAMI 13 (6) (1991) 583–598.



# ITK Watershed Transform

---

Image treated as a topological relief map –  
intensity represents height

Gradient descent defines ***segmented regions***

- Set of all pixels whose paths of steepest descent terminate in same local minimum
- Bounded by image features

Global – operates on entire image at once

No parameters except preprocessing

# The Watershed Transform Illustrated

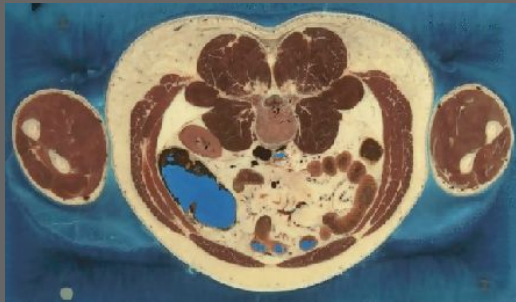
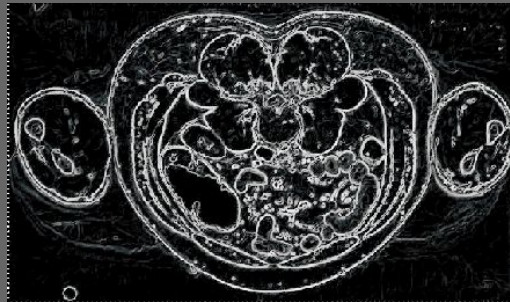


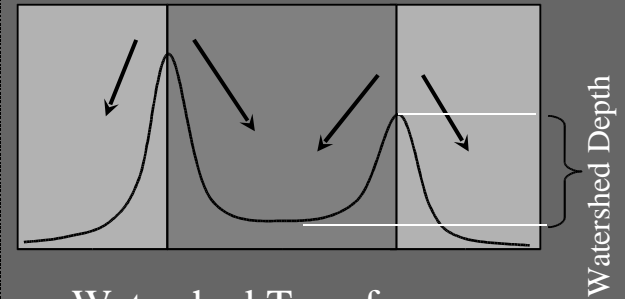
Image (filtered)



Feature Extraction  
“Edge Map”



Watershed Transform



# The Oversegmentation Problem

Watershed transform produces too many regions

- One per local minimum
- Especially in noisy or highly detailed data

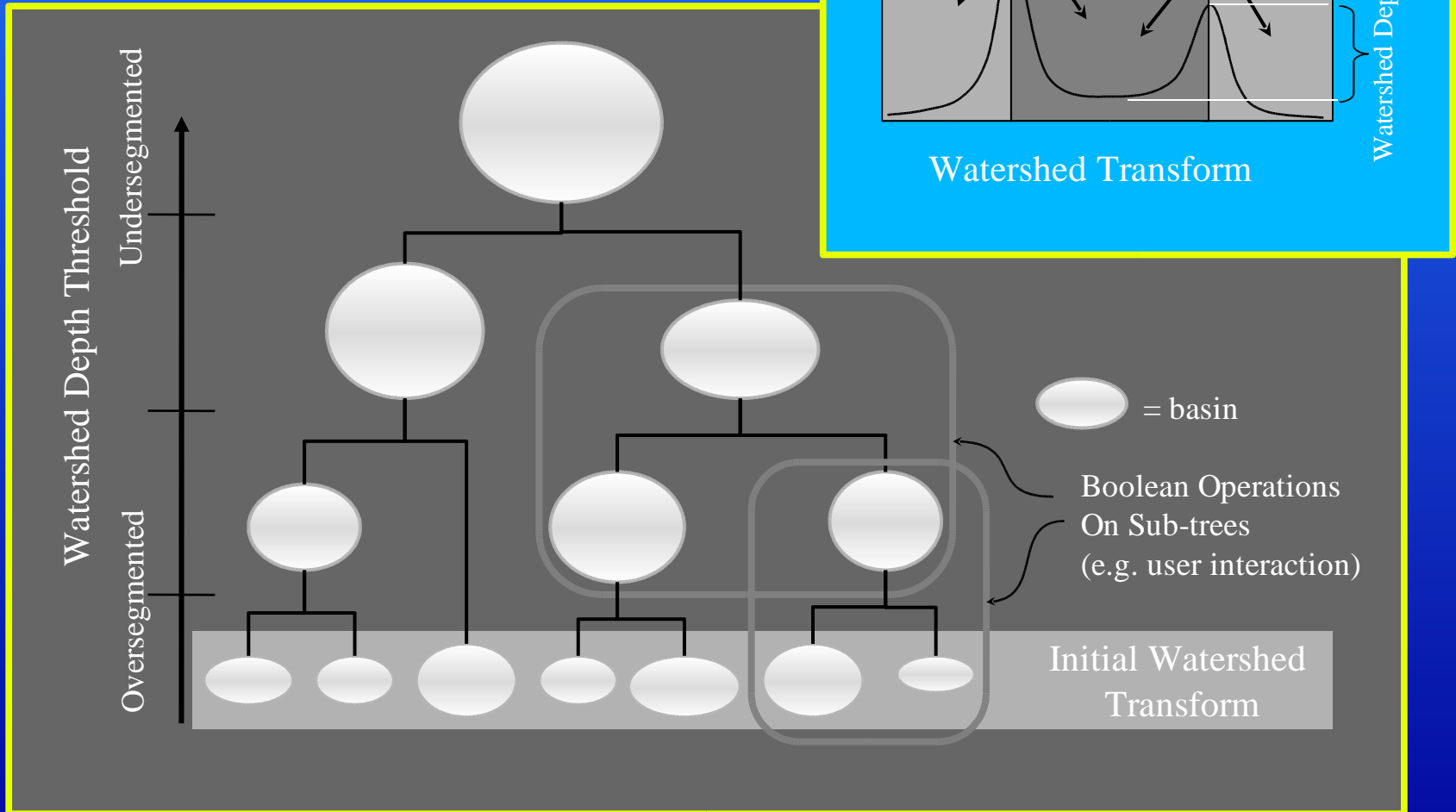
To alleviate oversegmentation

- ✓ Hierarchical approach – merge adjacent regions according to increasing *watershed depth*

- A. P. Mangan, R. T. Whitaker, Partitioning 3D surface meshes using watershed segmentation, IEEE Transactions on Visualization and Computer Graphics 5 (4) (1999) 308–321.

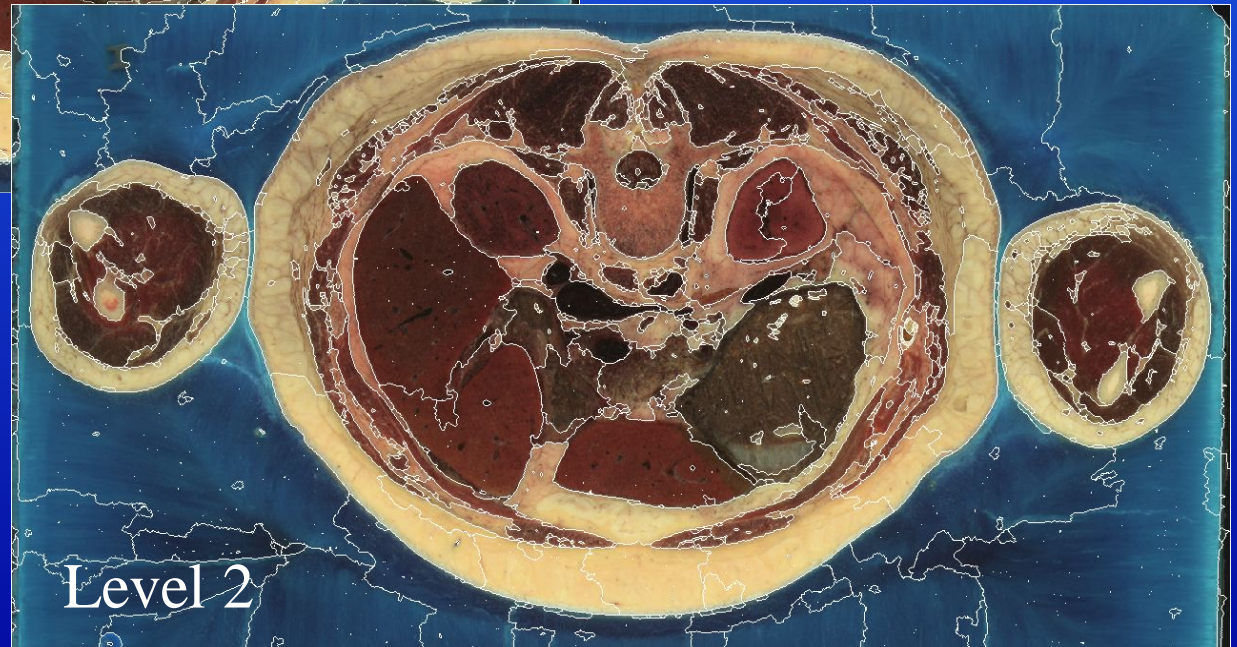
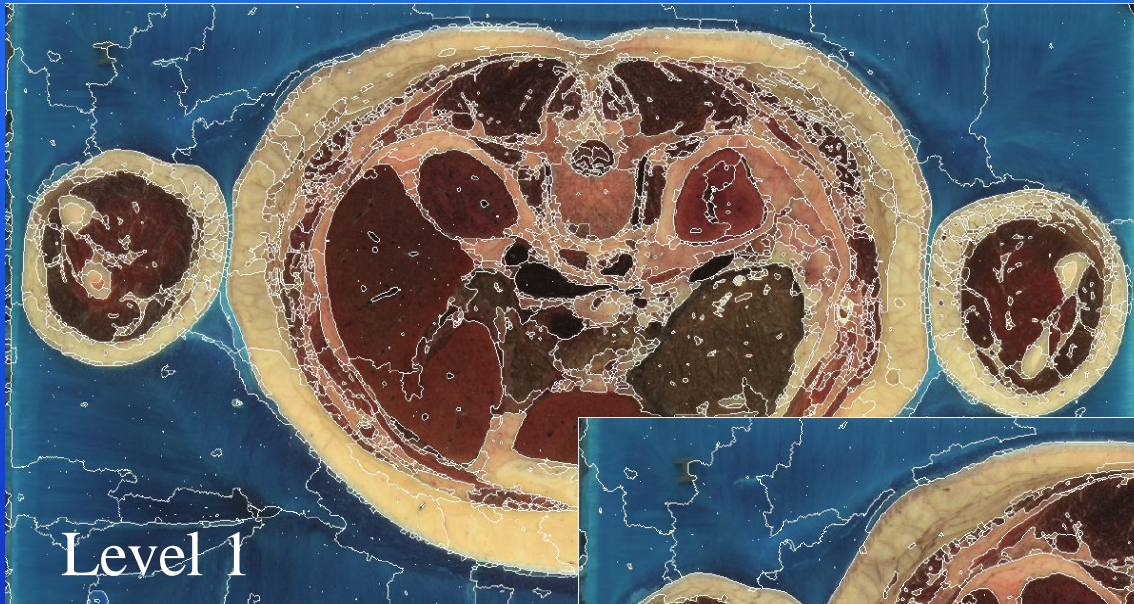
# Watersheds Hierarchy

Enforce minimum watershed depths at successively higher levels.





# Reducing Oversegmentation with Hierarchies

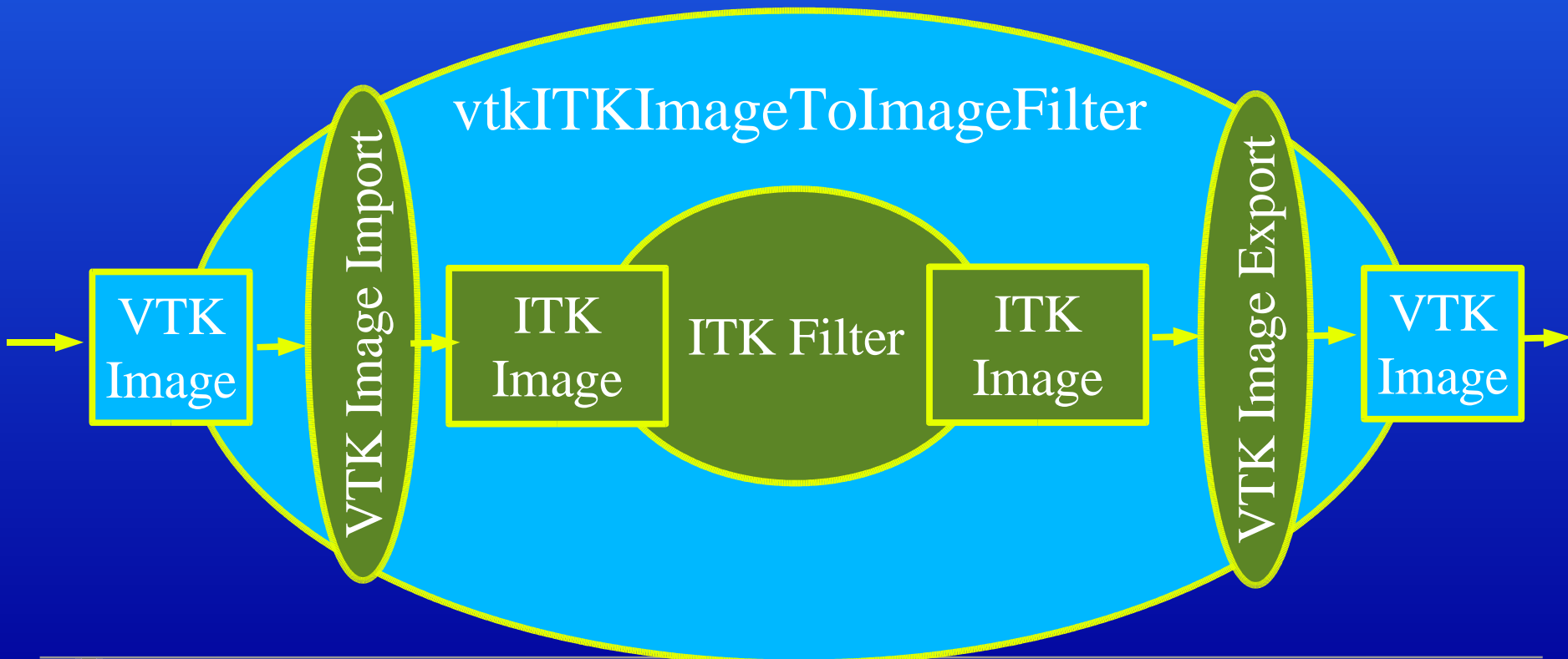


# How is ITK integrated with VTK? vtkITK

InsightApplications/vtkITK

Mechanism for converting ITK filters into VTK filters

VTK wrapped for Python, Tcl, Java



# Interactive Watersheds Validation: User Study

*Comparison of user-assisted hierarchical watersheds with hand-contouring*

## Hand contouring

- *De facto* standard
- General and reliable(?)

## Issues

- Can a general purpose segmentation algorithm compete?
- (Are our validation tools up to the task?)

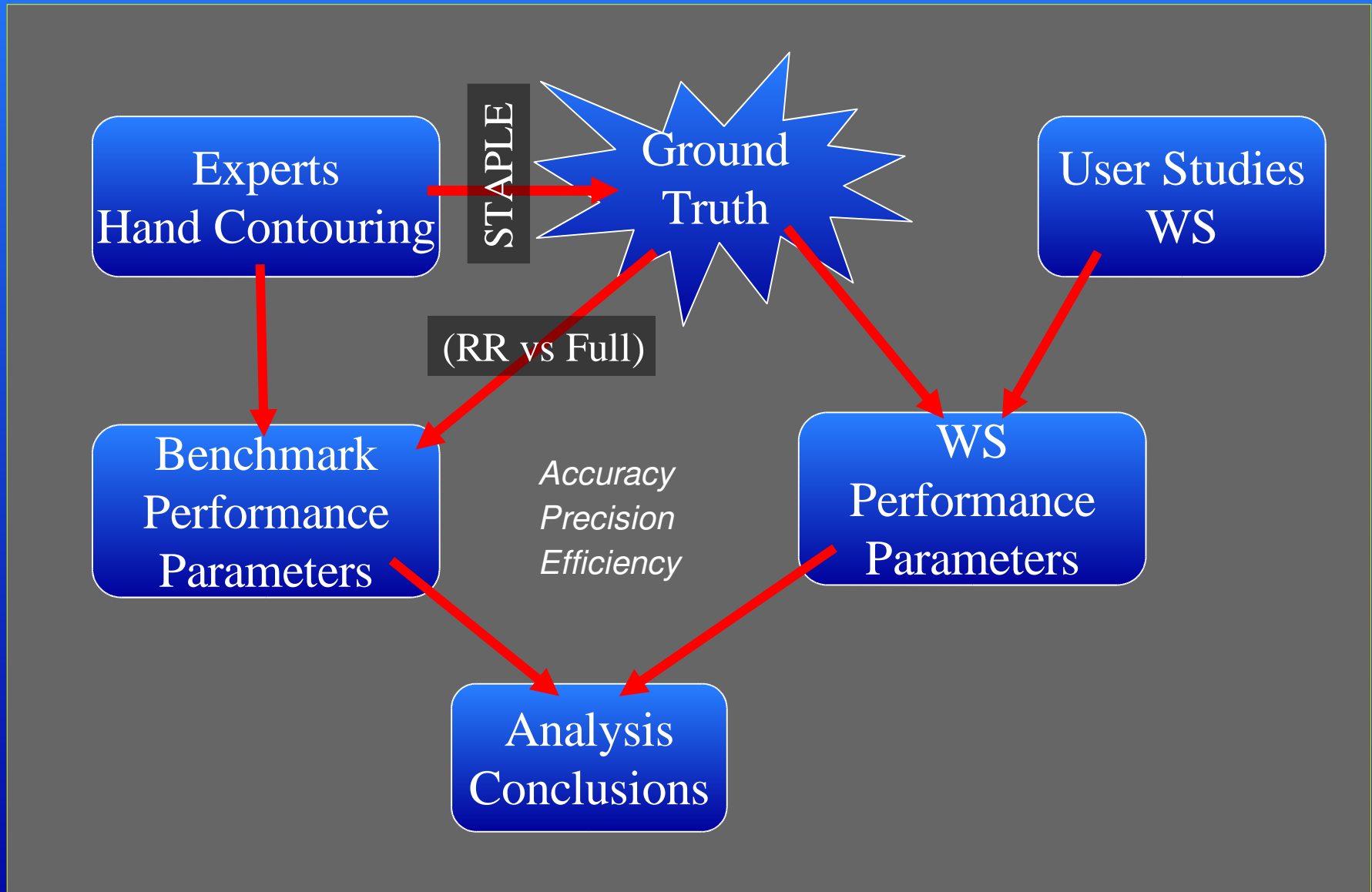
Cates, Whitaker, Jones, "Case Study: An Evaluation Of User-Assisted Hierarchical Watershed Segmentation", Medical Image Analysis, Under review.

# User Study Overview

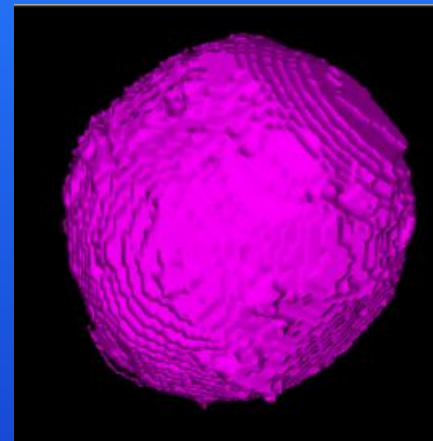
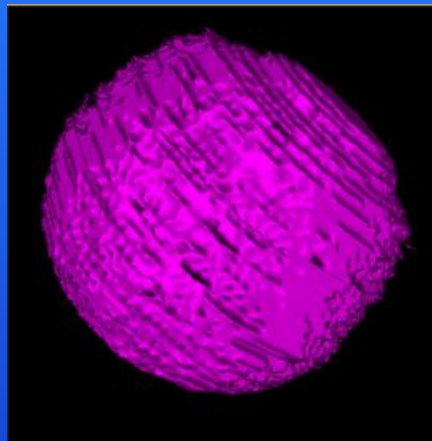
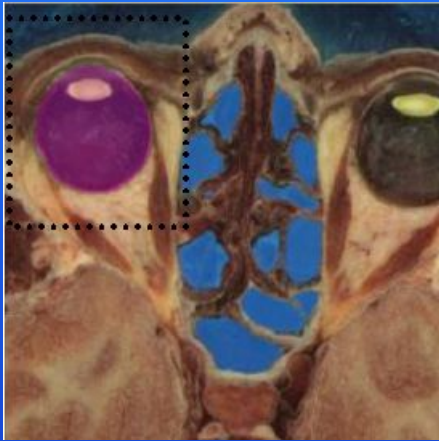
	Ground Truth Subjects (Slicer)	WS Segmentation Subjects
MRI Brain Tumor (4 cases)	Slice from HBW BT database (4 per case)	Radiologists (3) from Univ of Utah
VHP Cryosection (Eyeball, optic nerve, lateral rectus)	3rd-year med. students at HBW and Utah (EB-4, ON-3, LR-8)	3rd-year med. students at Utah (7)



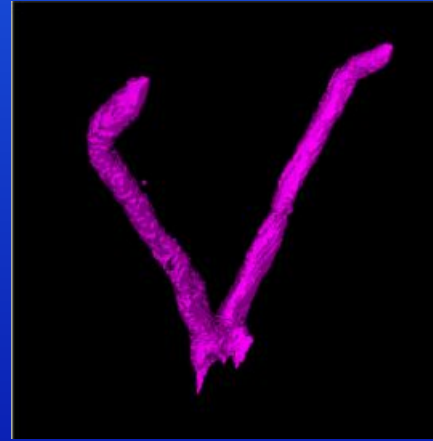
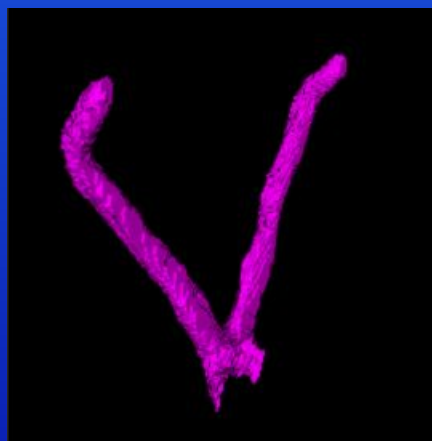
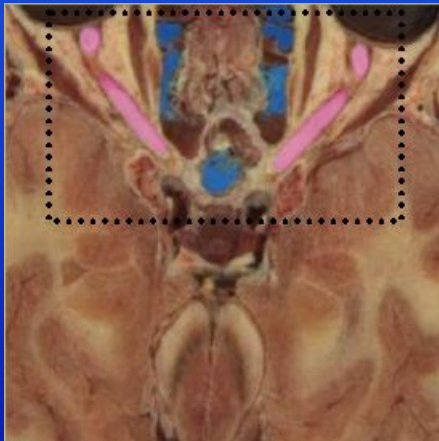
# Validation Strategy



# Validation Results



Eyeball



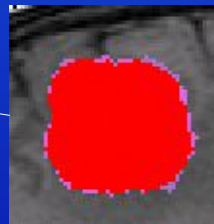
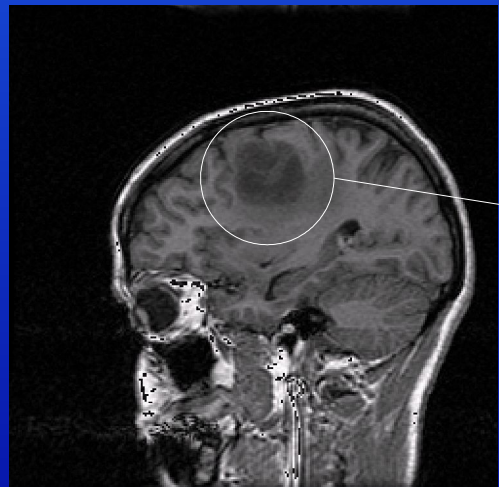
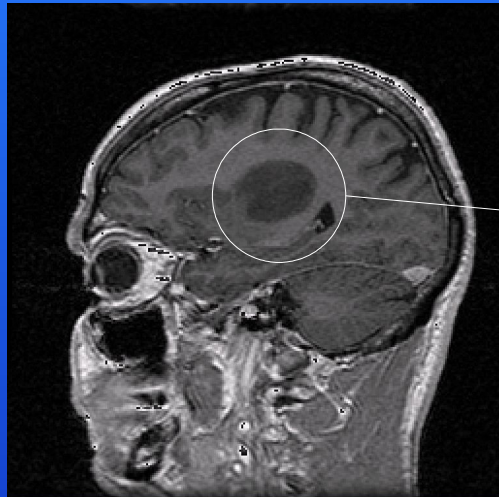
Optic nerves

Data

Hand contour

Watersheds

# Validation Results

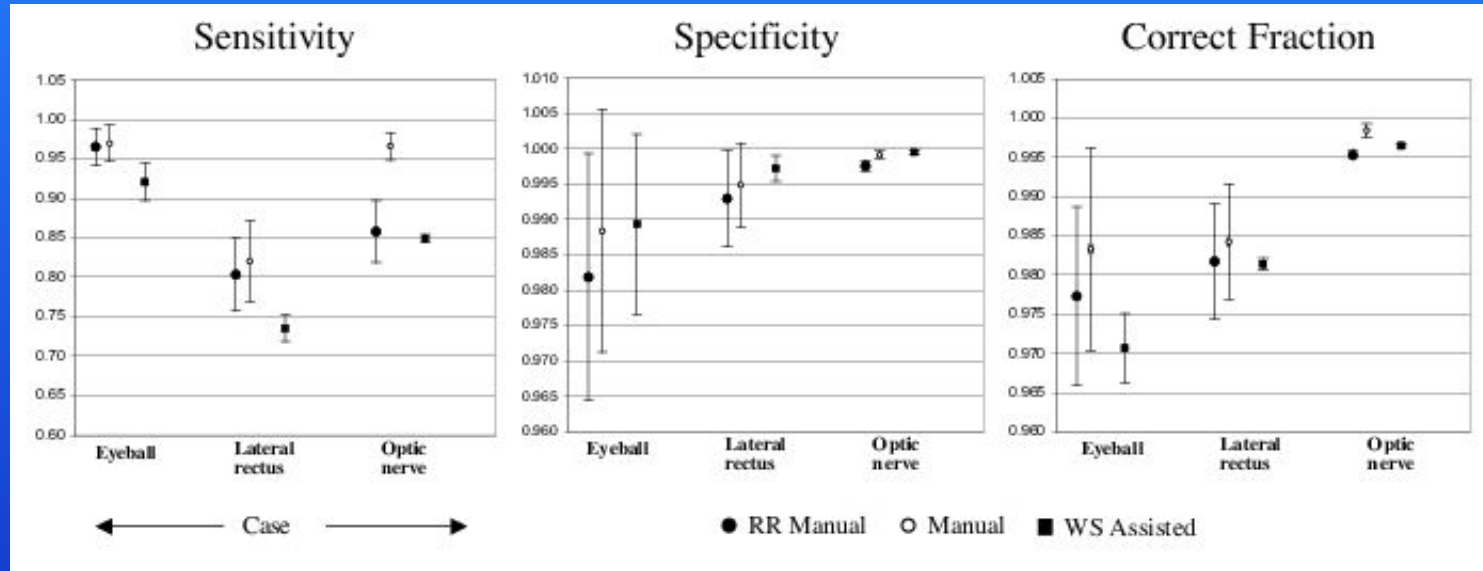


Hand contour

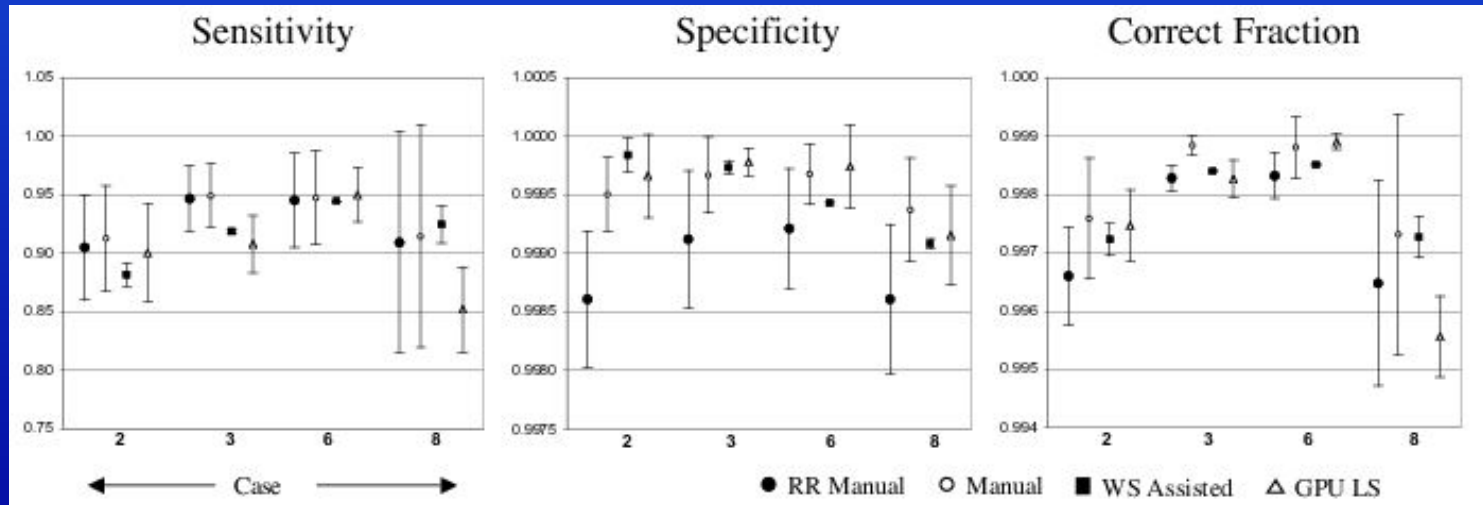
Watersheds

# Validation Results

Visible Human cryosections



Brain tumor MRI



# Summary of Validation Results

## Accuracy

- Sensitivity (TPF) is generally low
- Total correct fraction generally within variation of experts (better for tumor data)
- Generally better than *level-set* approach

## Precision

- Significantly better than both hand contouring and level-set

## Efficiency

- Versus hand contouring, no comparison (30 min vs. 2-3 hours)
- Versus level-set, more preprocessing and comparable user times

Time/expertise to tune hidden parameters issue

# Validation Conclusions

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## Watershed Segmentation

- WS probably makes more sense vs hand contouring in many applications
- True positive fraction is an issue – could tune for that metric

## Validation

- Rich set of systematic tools
- Pixel-based – shape metrics lacking
- Hand contouring for ground truth questionable