Interactive Segmentation

EVERYONE!

NA-MIC Interactive Segmentation

- Growcuts
- RSS
- Statistical/Geometric Active Contours
- Coupled Active Contours
- Preliminary Results

From the Proposal

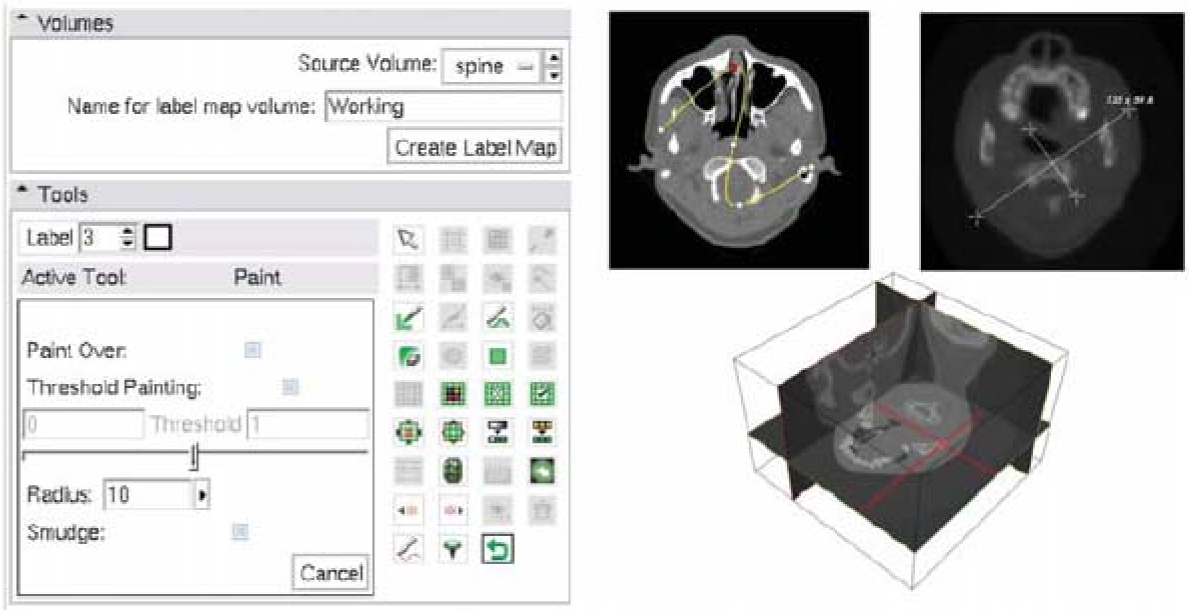
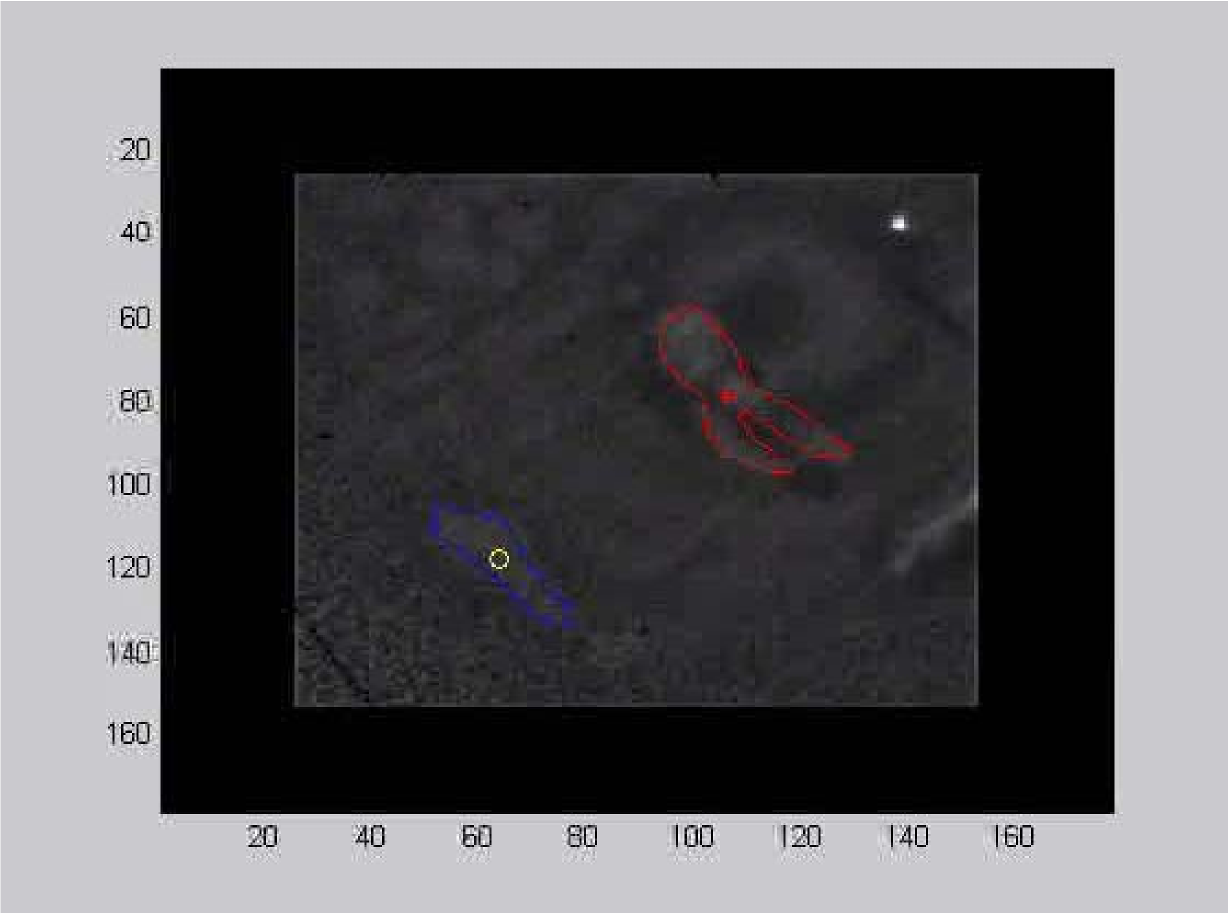


Fig. 3-6. Editor Tools. Interactive segmentation tools will build upon the 3D Slicer Editor module (left) and upon BTK Widgets (right).

Why Interactive

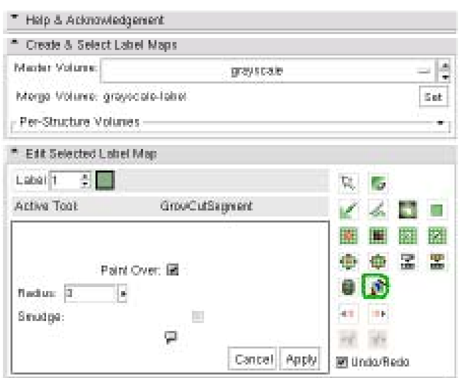


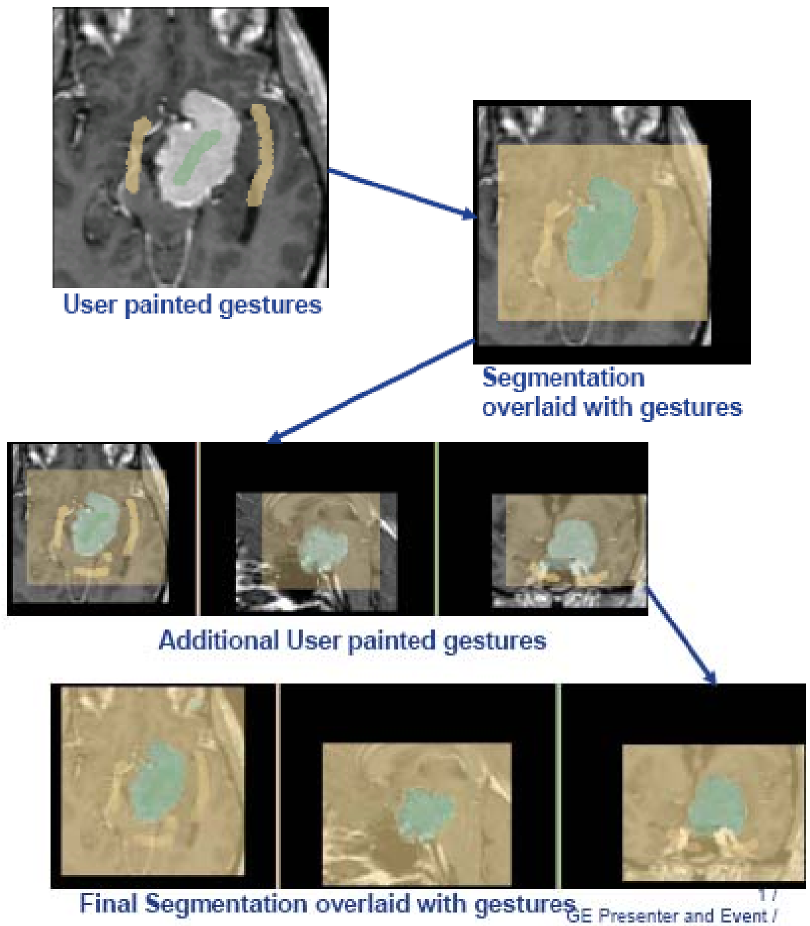
GrowCut: Jim Miller et al.

Given a small number of user-labeled pixels, the rest of the image is segmented automatically by a Cellular Automaton. The process is iterative, as the automaton labels the image, user can observe the segmentation evolution and guide the algorithm with human input where the segmentation is difficult to compute. In the areas, where the segmentation is reliably computed automatically no additional user effort is required.

Interactive Segmentation in Slicer3.6.2

- GrowCut image segmentation is in Slicer's Editor Effect
  - Incorporates paint tool interaction
  - Optionally interact using "draw", "paint" Editor effect
- Supports simultaneous viewing of user inputs and segmentation
- Supports editing segmentation with additional gestures
- Simple user interface (no exposed parameters)





imagination at work

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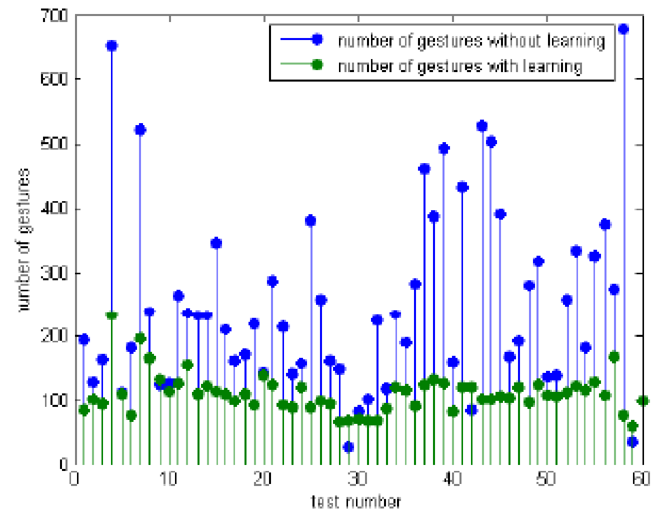
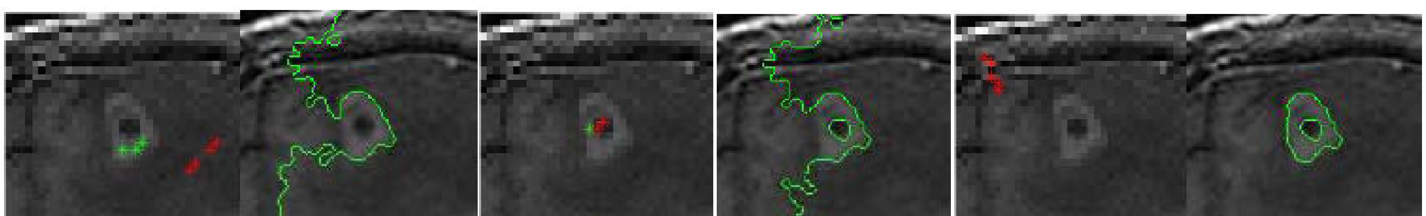
Active Learning For Guiding Gesture Placements

- **Gesture suggestions to user** combines GrowCut segmentation with active learning using SVM
  - Suggestions are selected using a two-step approach
  - **Step I** treats GrowCut segmentation and SVM classification as diverse ensembles to select query candidates
  - **Step II** employs SVM margin-based gesture selection on the query candidates
- Number of interactions required for novel image segmentation with learning is 50% less than without learning
- Algorithm guided interactions minimizes segmentation variability





1. User input gestures

2. GrowCut Segmentation

3. Gesture Suggestion Accepted & Labeled by User

4. GrowCut Segmentation

5. Gesture Suggestion Accepted & Labeled by User

6. GrowCut Segmentation

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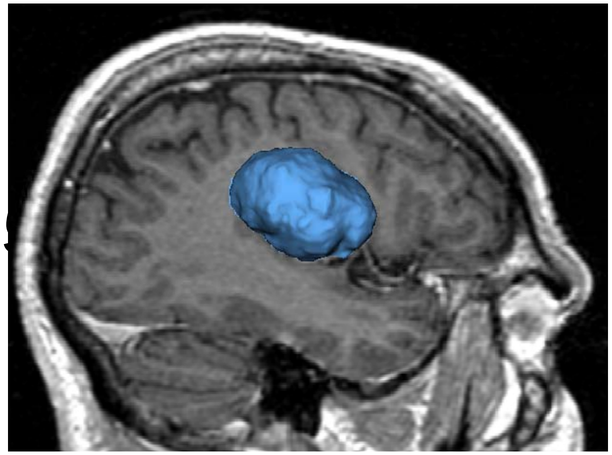
Robust Statistics Segmentation(RSS)

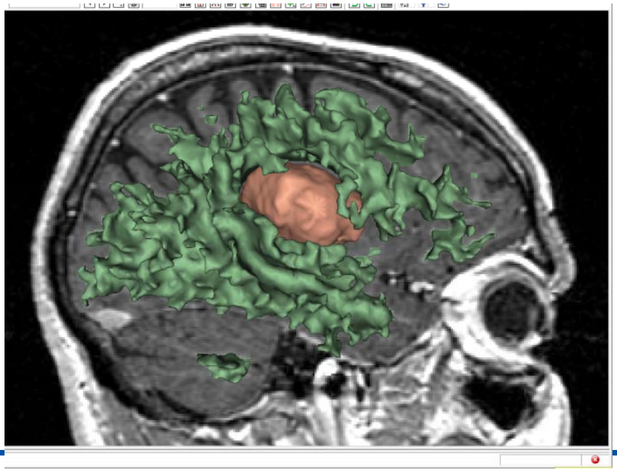
Yi Gao et al.

Single/multiple target(s)

- Single target RSS
  - *Segmentation module*

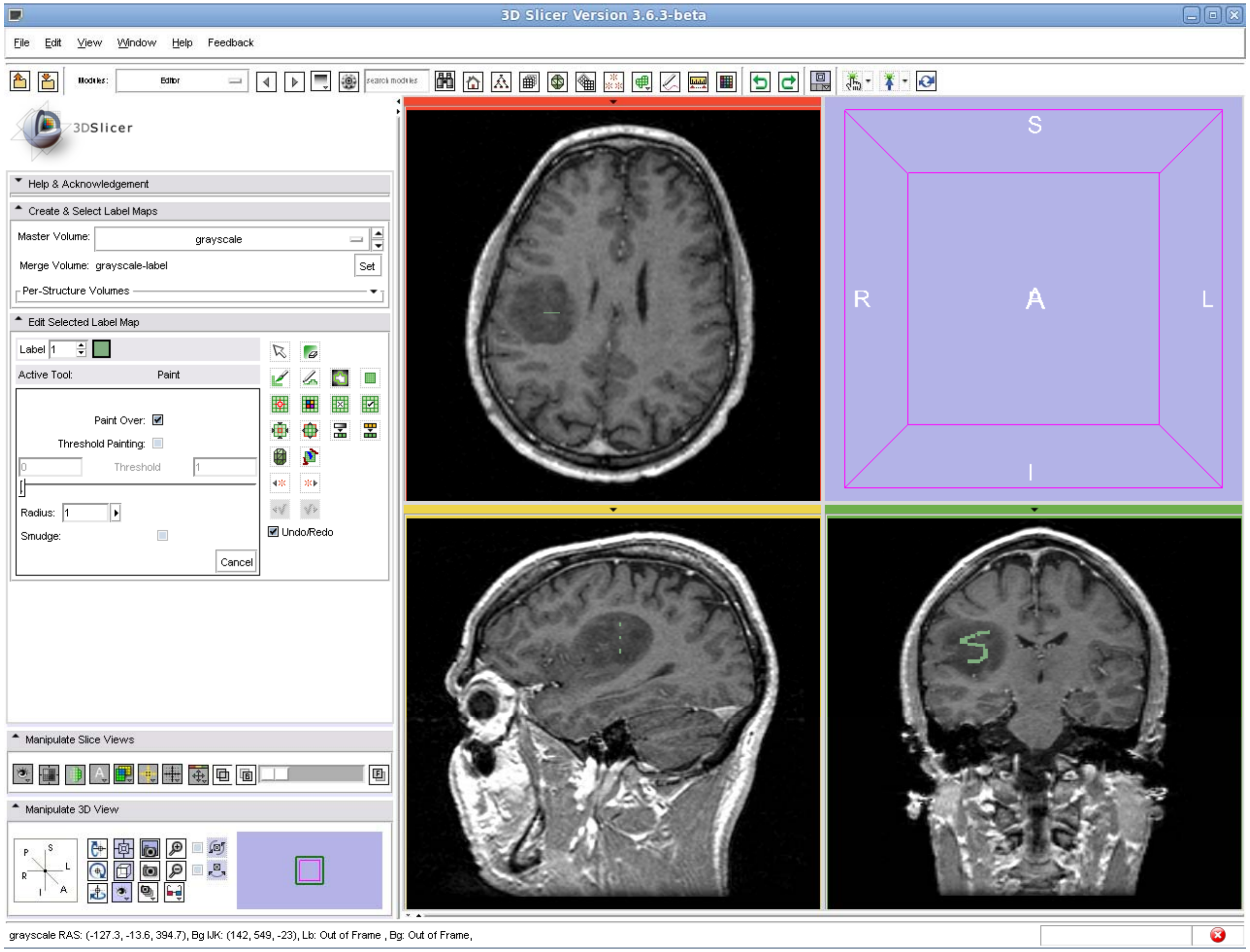


- Multiple target RSS
  - *Extension*



Single target RSS

1. Draw some <u>seeds</u>
2. “Apply”



Behind the Scenes

- Robust Statistics Feature Image

$$\boldsymbol{f}(\boldsymbol{x}) = (MED(\boldsymbol{x}), IQR(\boldsymbol{x}), MAD(\boldsymbol{x}))^T \in \mathbb{R}^3$$

median absolute deviation

inter-quartile range

median (around ***x***)

- For each pixel $I(\mathbf{x})$, compute $\boldsymbol{f}(\mathbf{x})$ in a 3x3x3 neighborhood.

Behind the Scenes, cont

- Robust Statistics Feature Image

$$\boldsymbol{f}(\boldsymbol{x}) = (MED(\boldsymbol{x}), IQR(\boldsymbol{x}), MAD(\boldsymbol{x}))^T \in \mathbb{R}^3$$

- Learn the features around Seeds

$$p_i(\boldsymbol{f}) = \frac{1}{|G_i|} \sum_{\boldsymbol{x} \in G_i} K_\eta(\boldsymbol{f} - \boldsymbol{f}(\boldsymbol{x}))$$

The i-th seed set

Gaussian kernel, stddev = η

Contour evolution

- Find optimal contour, minimizing:

$$\boxed{E_i(C_i) := \int_{\boldsymbol{x}\ in\ C_i} (p^c - p_i(\boldsymbol{f}(\boldsymbol{x})))d\boldsymbol{x} + \lambda \int_{C_i} ds}$$

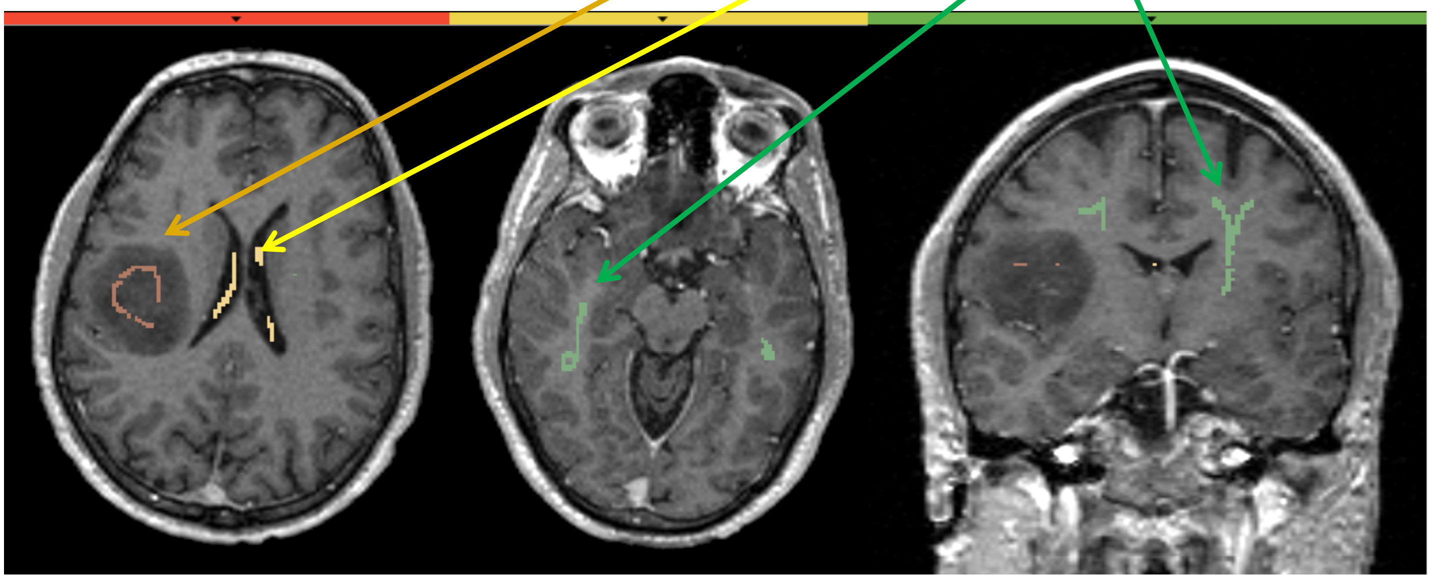
- Flow:

$$\boxed{\frac{\partial C_i(q,t)}{\partial t} = [p^c - p_i(\boldsymbol{f}(C_i(q,t))) + \lambda\kappa_i(q,t)]\,\boldsymbol{N}_i(q,t)}$$

Multiple target RSS

- Seeds:
  - Multiple seed groups
  - Different labels

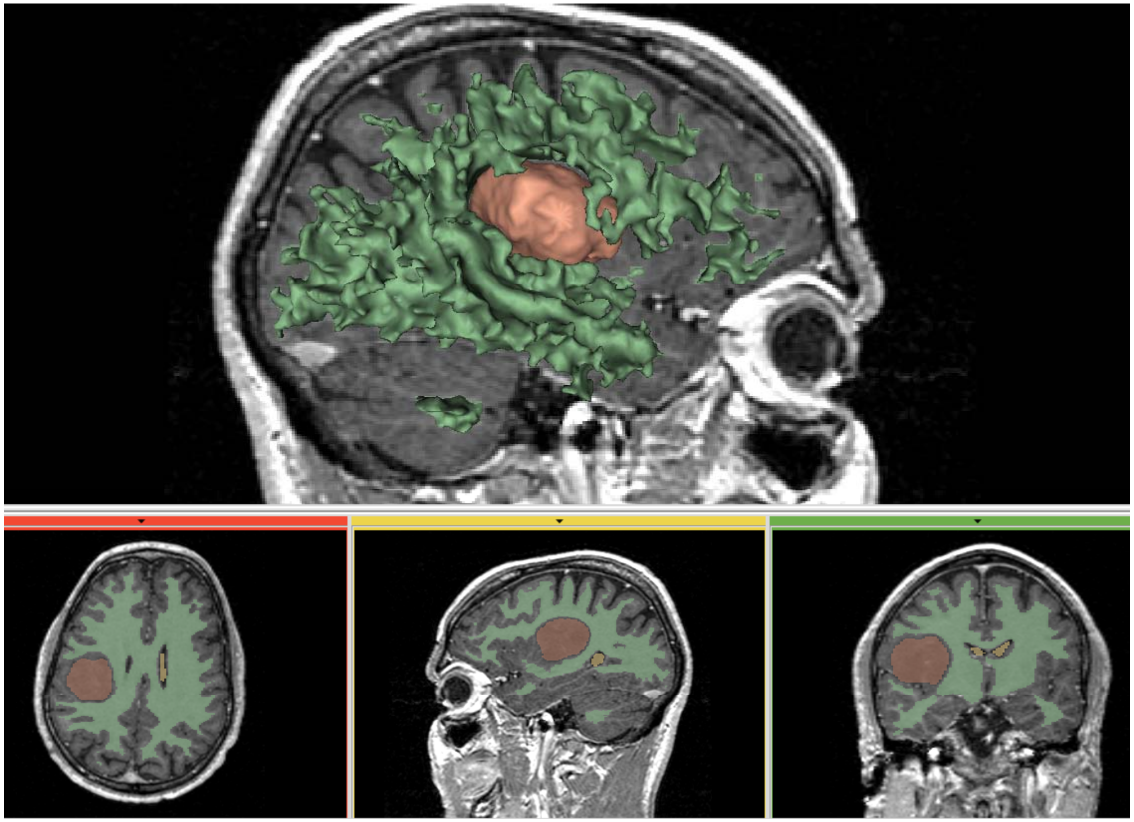
- Tumor
- Ventricle
- White matter



Multiple target RSS, cont.

Properties:

- 3D understanding of anatomy
- Non-overlapping



Behind the Scenes

- Contour interaction:
  - External force:

$$F_i^{ext}(\boldsymbol{p}) = -\sum_{j \neq i} \int_{C_j} e^{-|\boldsymbol{p}-C_j(w,t)|}(p_j(\boldsymbol{f}(\boldsymbol{p})) - p^c)\boldsymbol{N}_j(\boldsymbol{p})dw$$

  - Total force:

$$\boxed{\frac{\partial C_i(q,t)}{\partial t} = [p_i(\boldsymbol{f}(C_i(q,t))) - p^c - \lambda\kappa_i(q,t)]\,\boldsymbol{N}_i(q,t) + F_i^{ext}(C_i(q,t))}$$

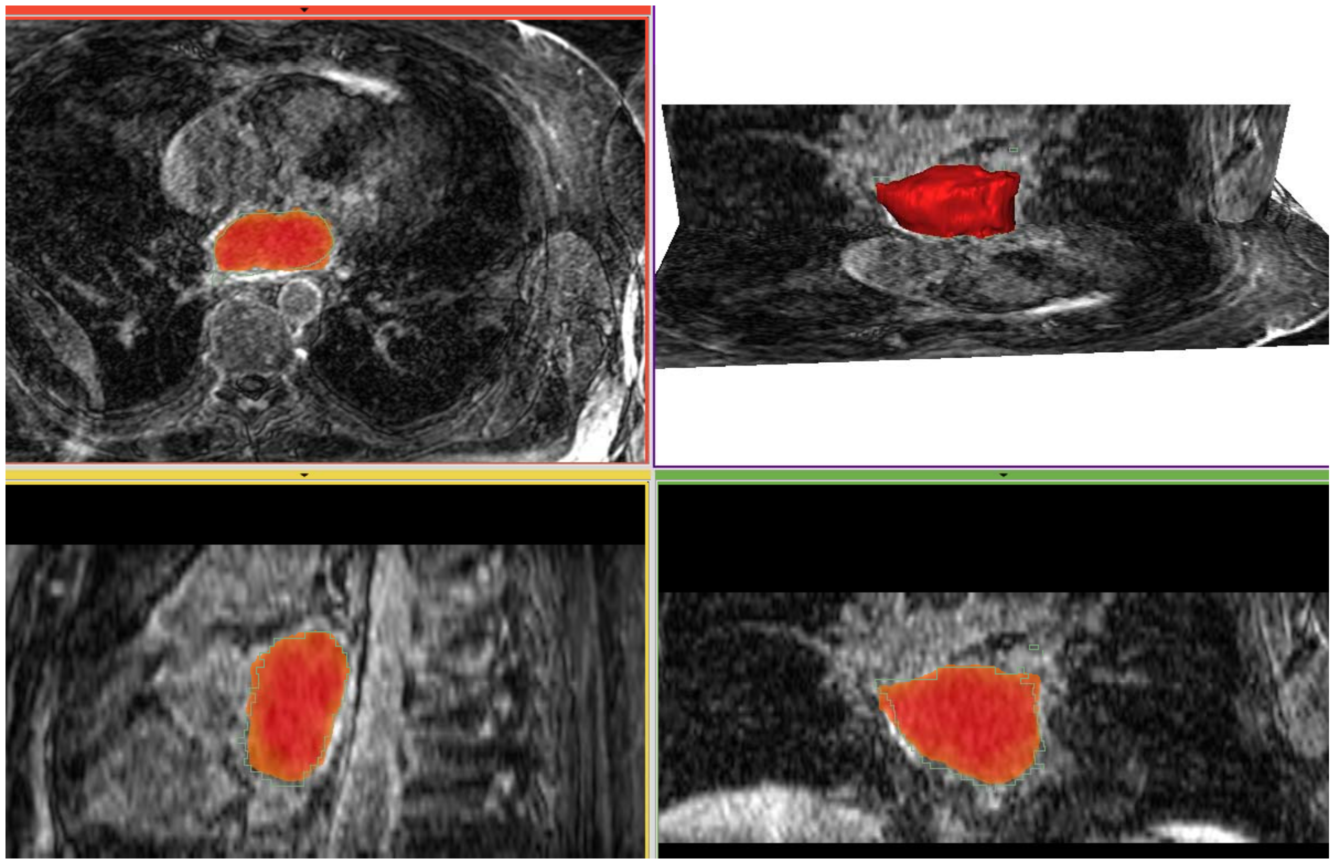
Segmentation for AFib

Yi Gao and Behnood Gholami et al.

Endocardium segmentation

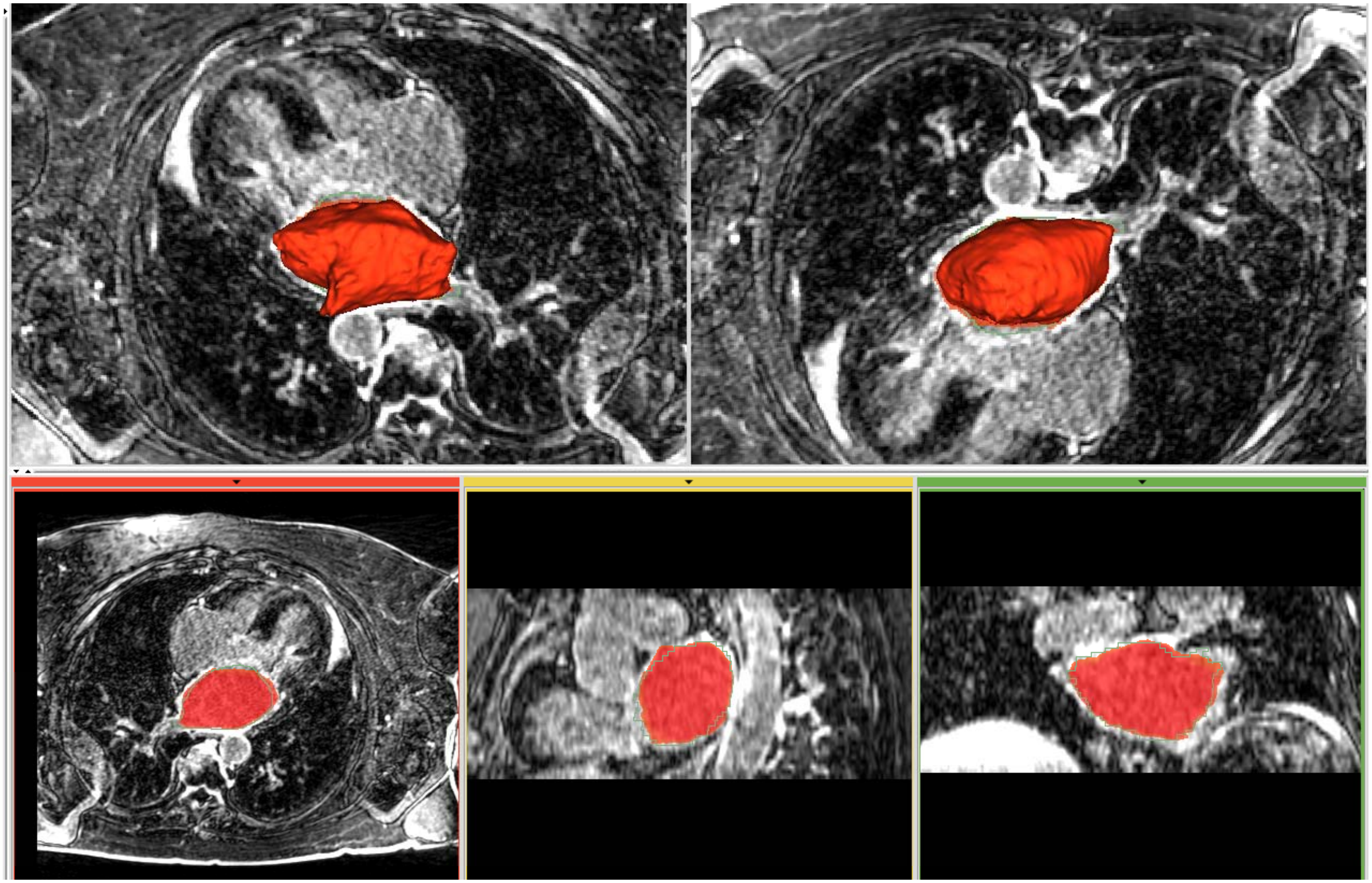
Blood pool segmentation: A combination of multi-atlas and active contour

Axial	3D
Sagittal	Coronal



Endocardium segmentation

Blood pool segmentation: A combination of multi-atlas and active contour

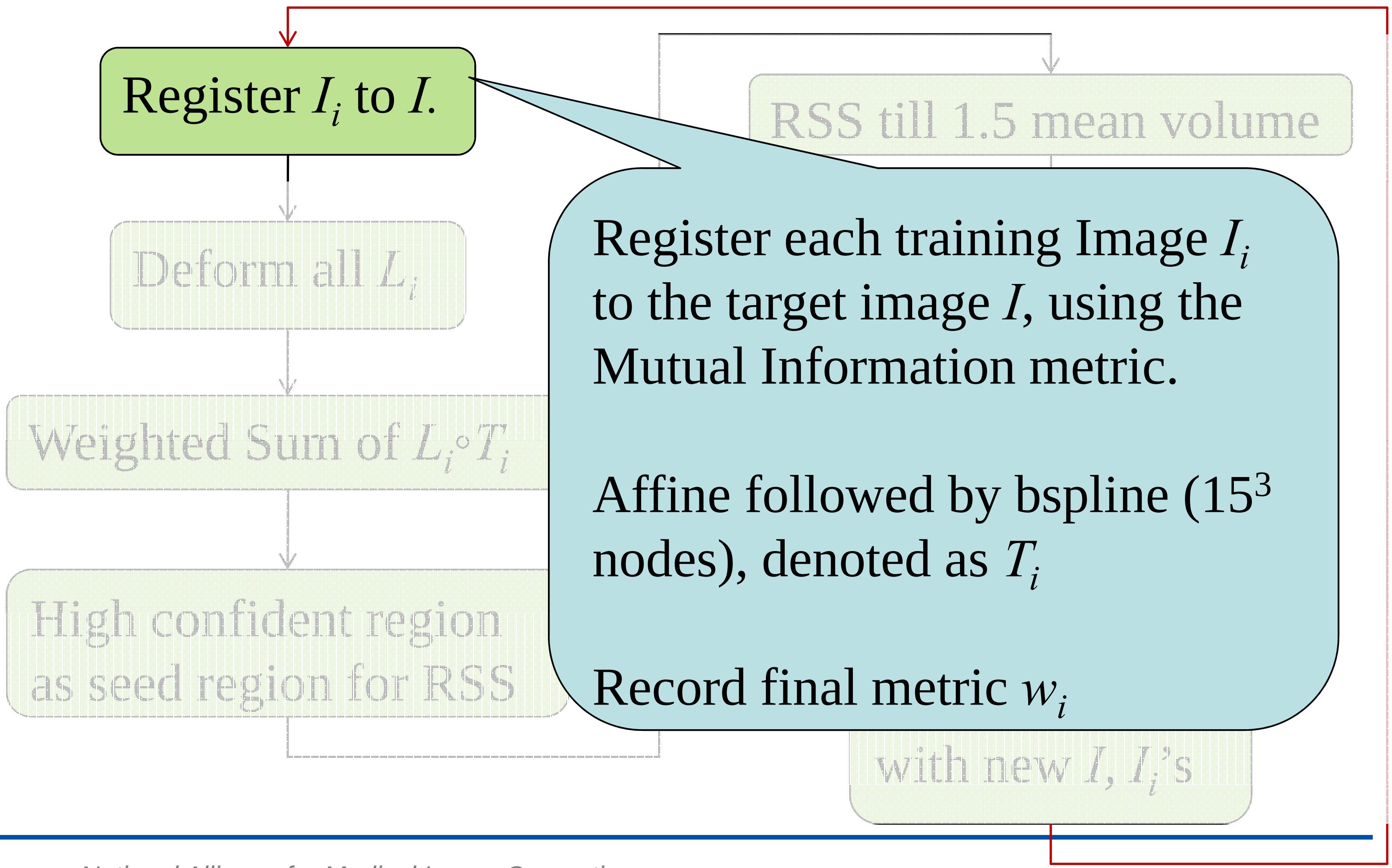


3D		3D
Axl	Sagi	Coro

Segmentation method

- Notations:
  - Target image to be segmented: I
  - Training set:
    - Training MR images: I_i, $i=1, \ldots, N$
    - Manual Endocardium mask: L_i

Segmentation method



Segmentation method

Register I_i to I

Deform all L_i

Deform each manual mask L_i by the optimal transformation T_i (affine followed by bspline) computed from the registration.

Weighted Sum of $L_i \circ T_i$

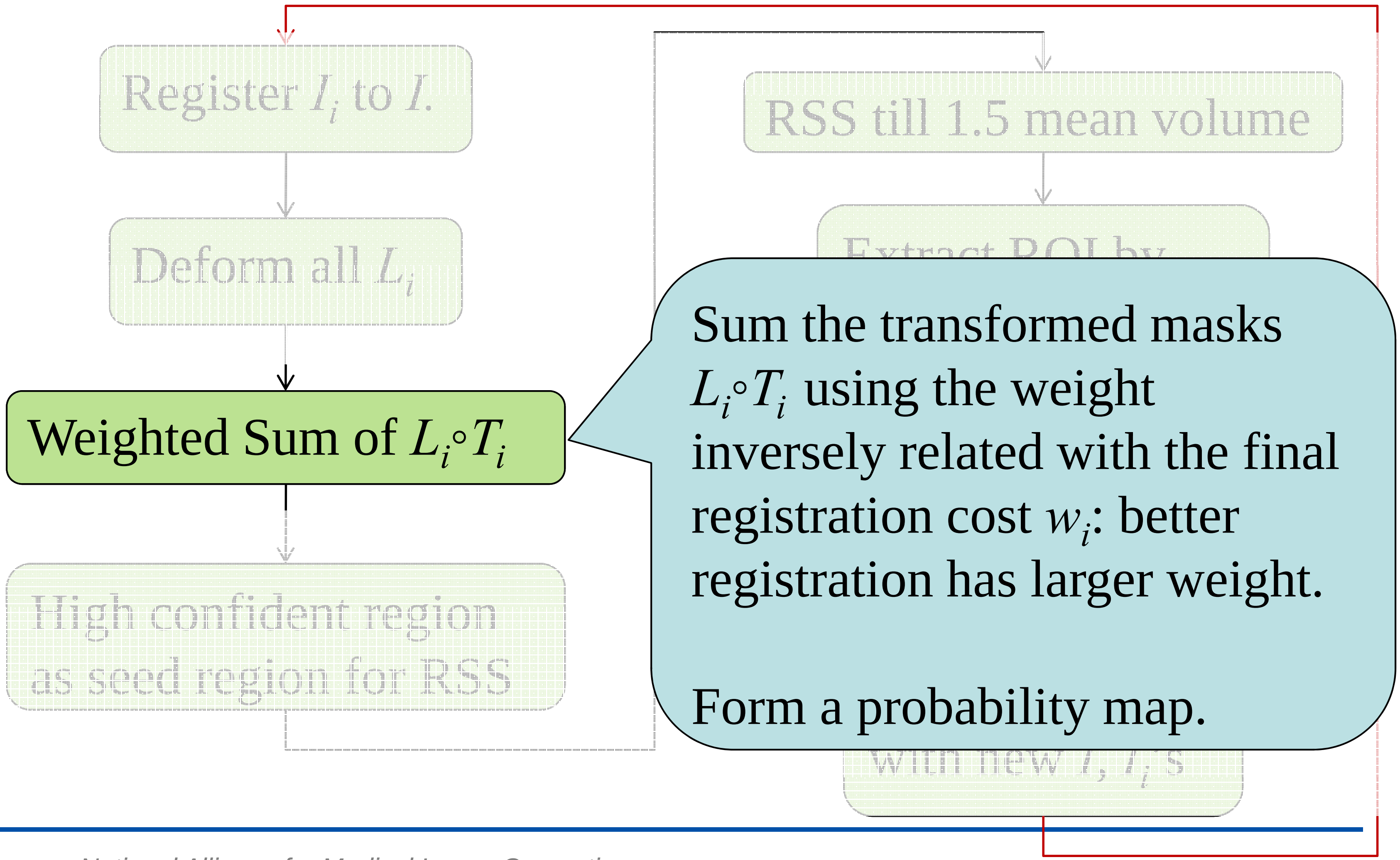
High confident region as seed region for RSS

RSS till 1.5 mean volume

by bounding box

Goto beginning with new I, I_i's

Segmentation method



Segmentation method

Register I_i to I.

Deform all L_i

Weighted Sum of $L_i \circ T_i$

High confident region as seed region for RSS

The probability map is NOT good enough. However, the high probability region are in the object.

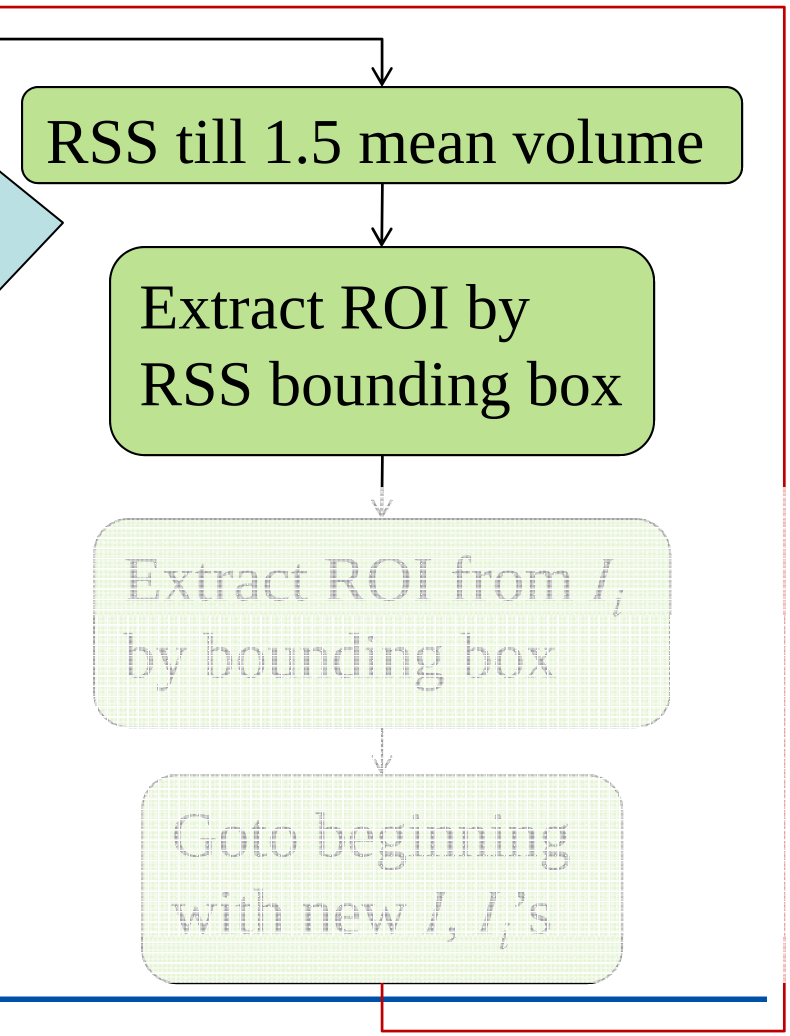
Use those regions as seed for the RSS segmentation algorithm --- Learn the target feature on-line.

Goto beginning with new I, I_i's

Segmentation method

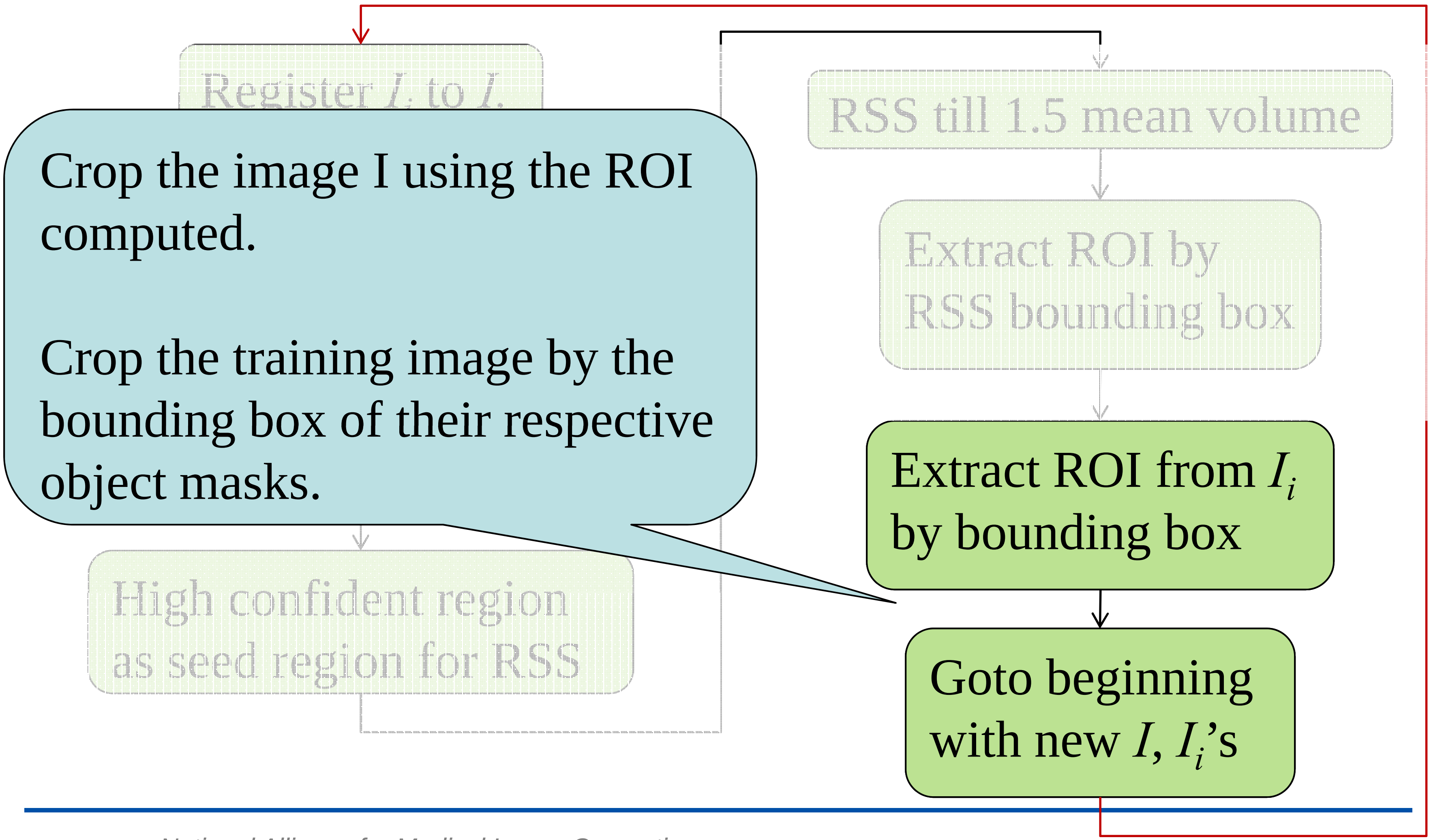
The RSS is only used to extract the Region-Of-Interest around the target object, therefore the RSS is run till a little larger than the mean training volume.

Extract the ROI as the bounding box of current contour.

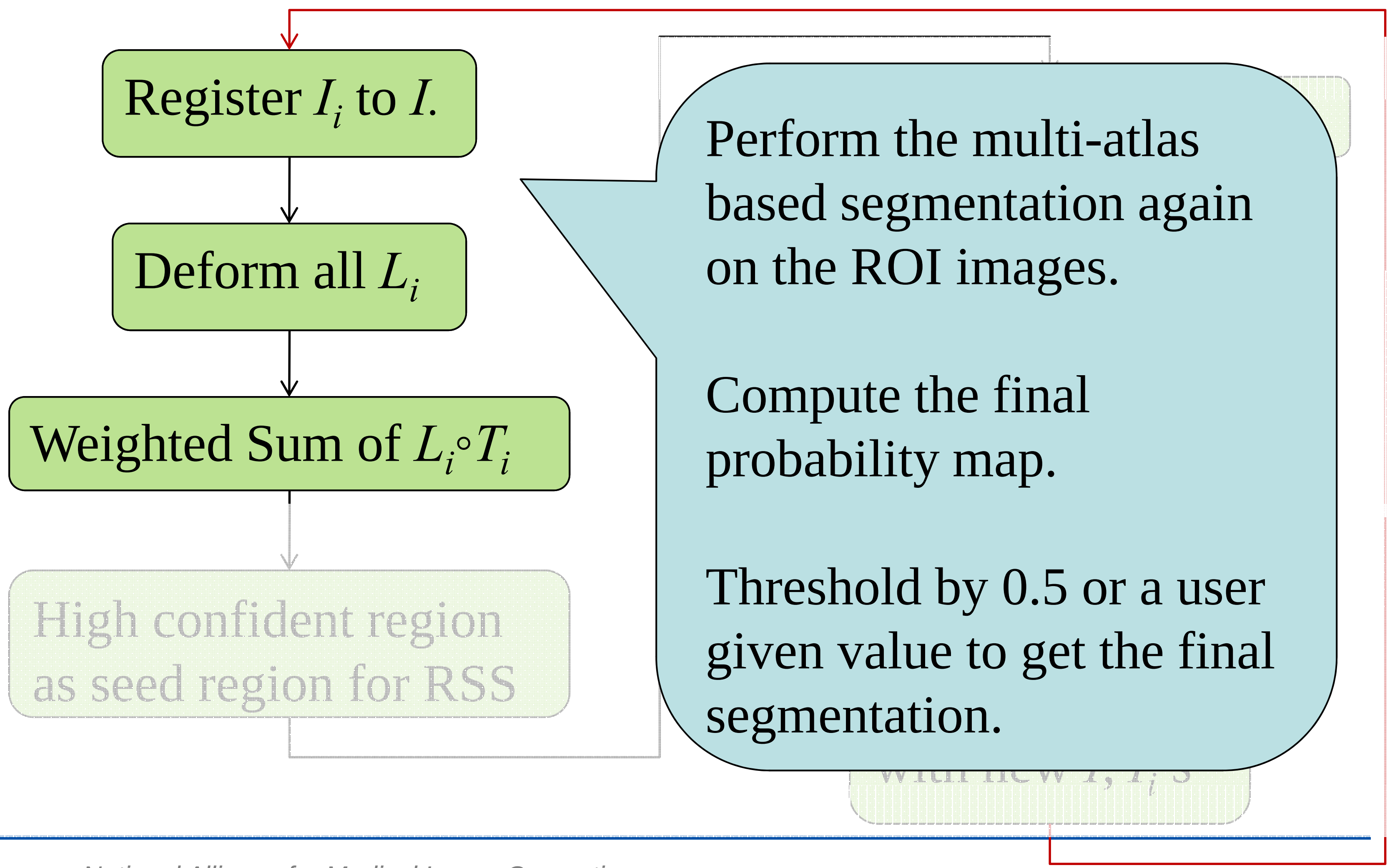


as seed region for RSS

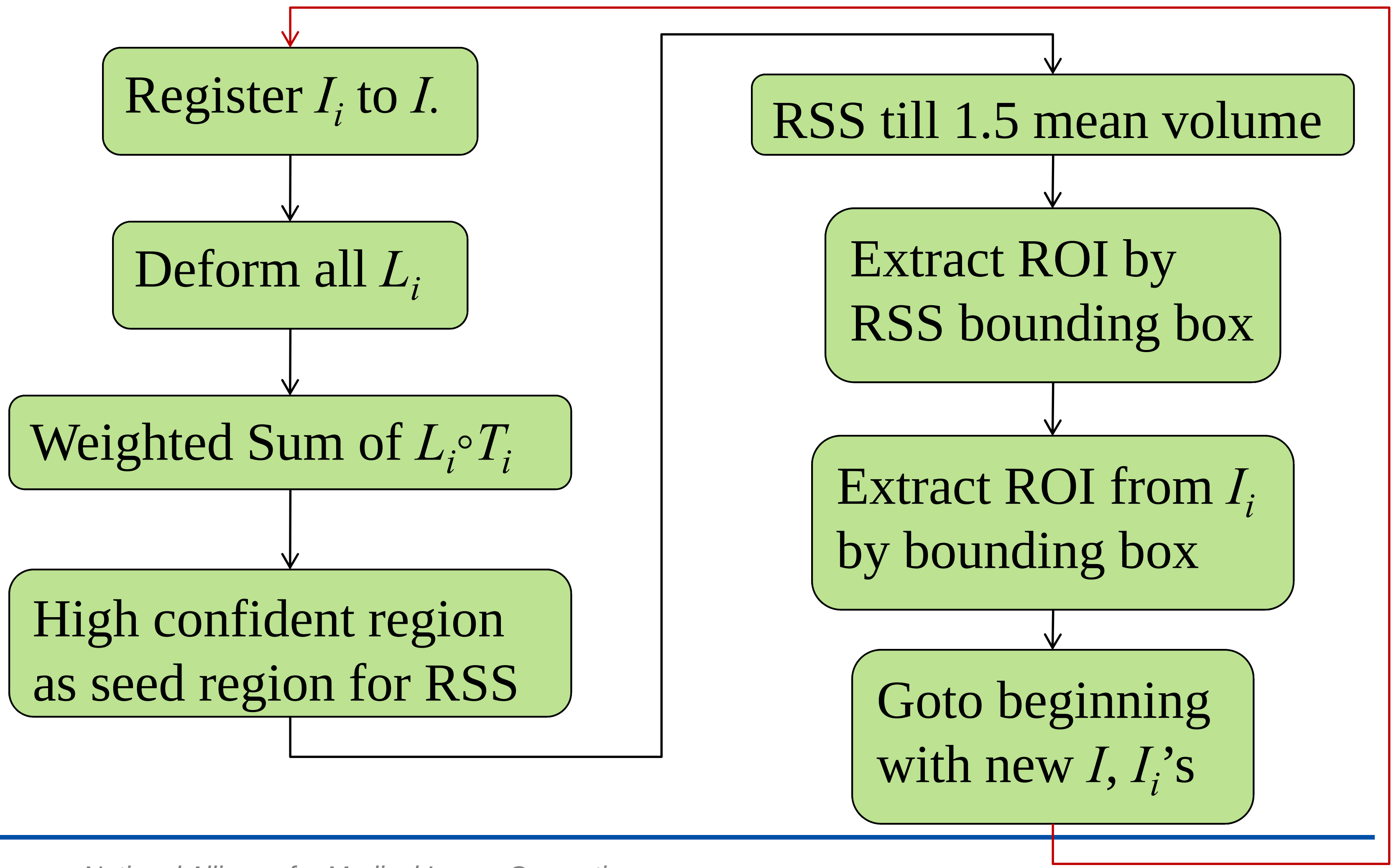
Segmentation method



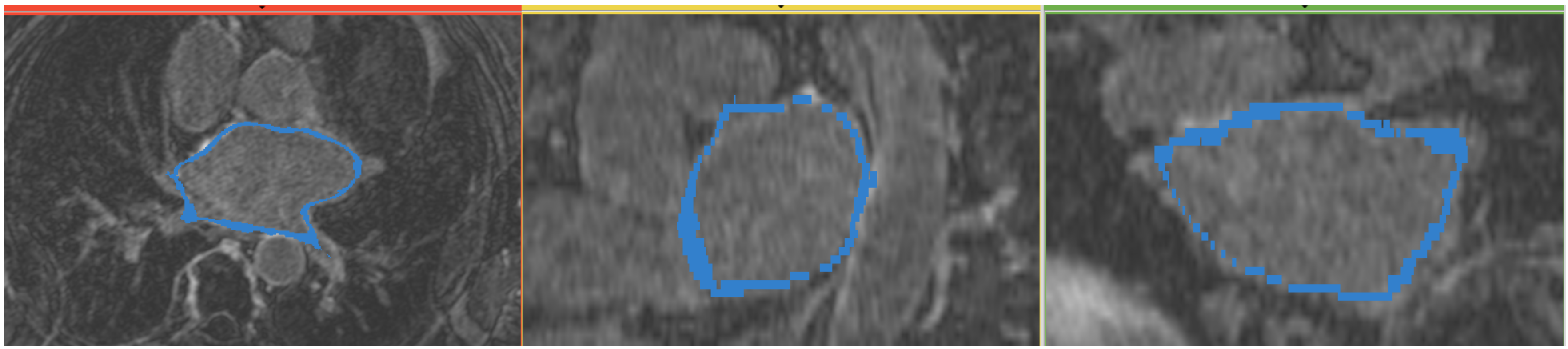
Segmentation method



Segmentation method



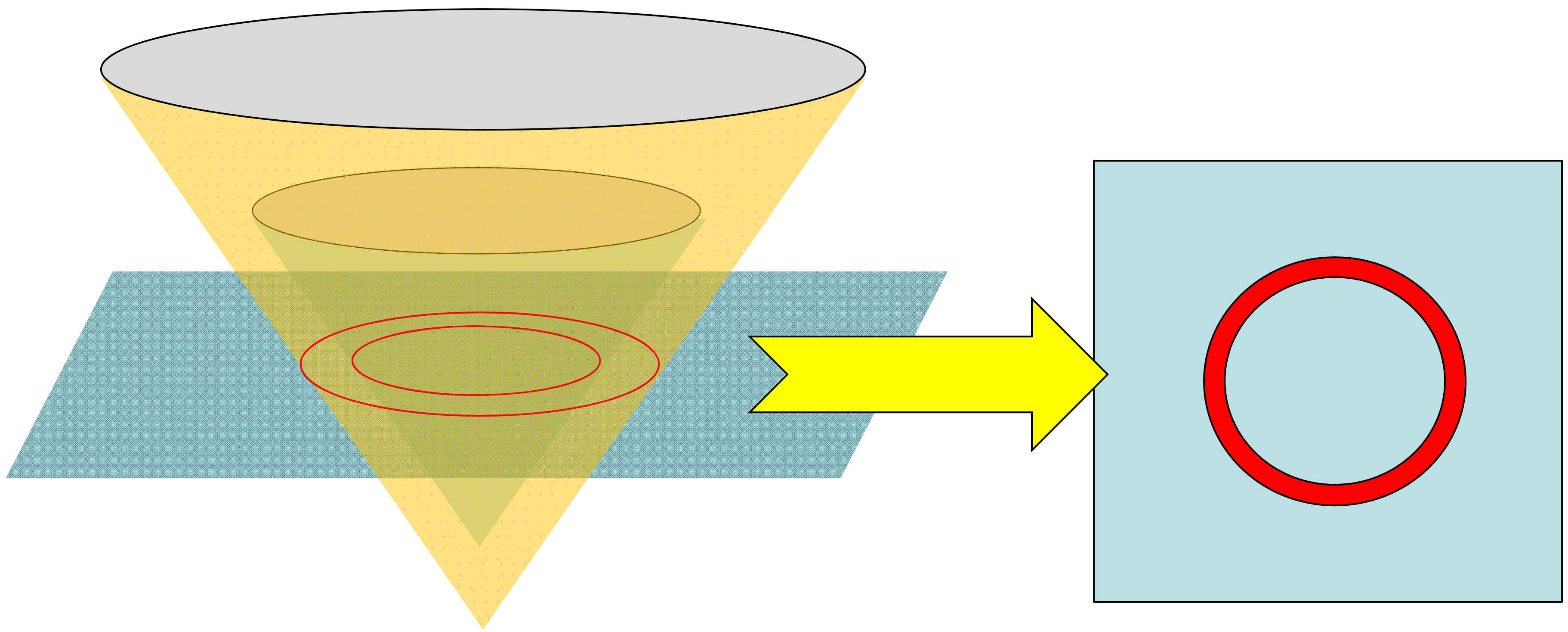
Wall segmentation



- Wall segmentation
  1. Coupled active contours
  2. Local Region Statistics between contours

Segmentation method

1. Coupled active contour



Coupled active contour

- ψ_1 and ψ_2 for inner/outer boundary of a ring/wall
- Wall region: $W = \{x \mid \psi_1(x) \geq 0, \psi_2(x) \leq 0\}$

Local Region Statistics between contours

- Evolve ψ_1 and ψ_2 so that the difference between $\mu(W)$ and $\mu(\overline{W})$ is maximized.
- Where:

  $\mu(W)$ mean intensity in the wall

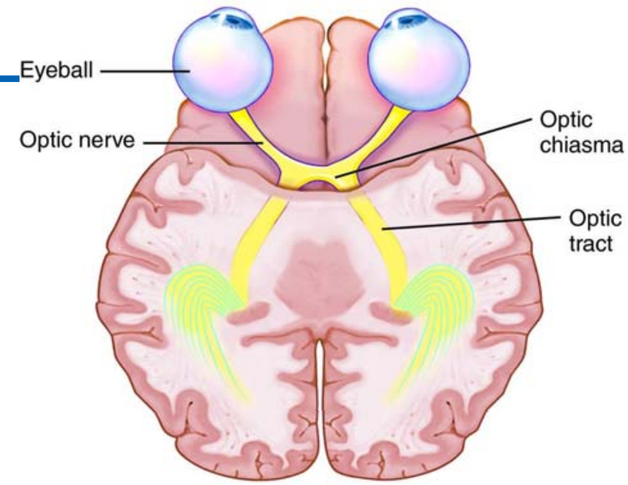
  $\mu(\overline{W})$ mean intensity outside the wall, with in a layer same thickness as the wall

Adaptive Radiotherapy

Ivan Kolesov, Yi Gao et al.

Semi-automatic Segmentation

- First priority: segment eye structures
  - Eyeball
  - Lens
  - Optic Nerve
  - *Optic Chiasm
  - Above structures are highly sensitive to radiation



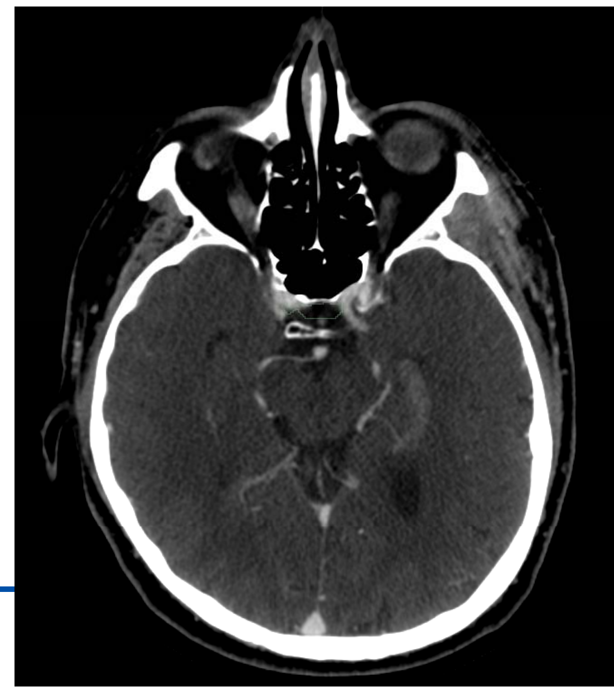
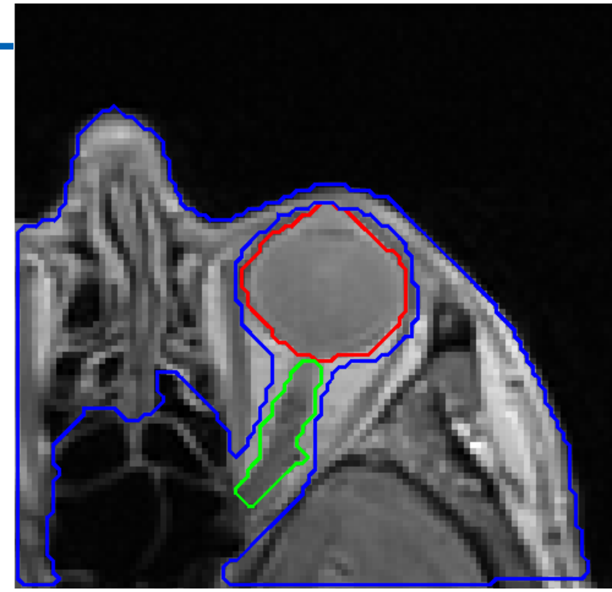
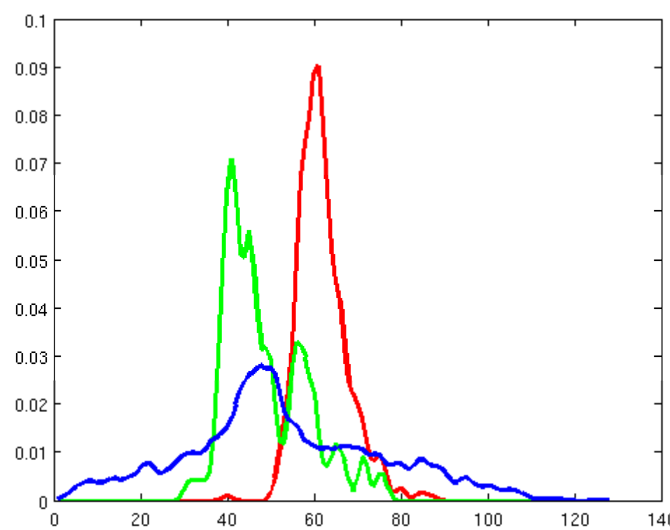


Image from http://medical-dictionary.thefreedictionary.com

Segmentation Approach



- Organs have heterogeneous intensity profiles
- Structures are in close proximity to each other
- Intensity information not sufficient
- Need user input and/or shape constraint



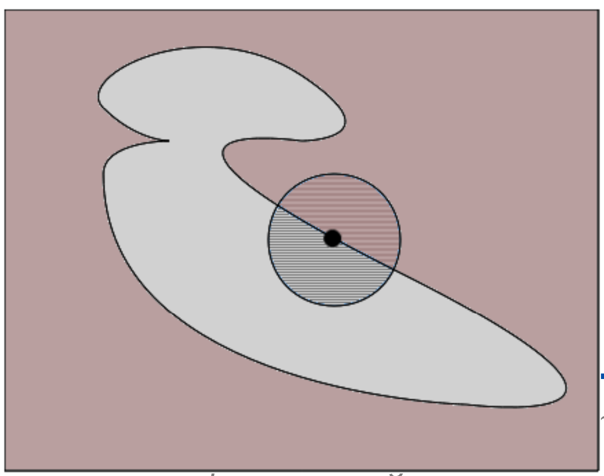
User Constrained Segmentation

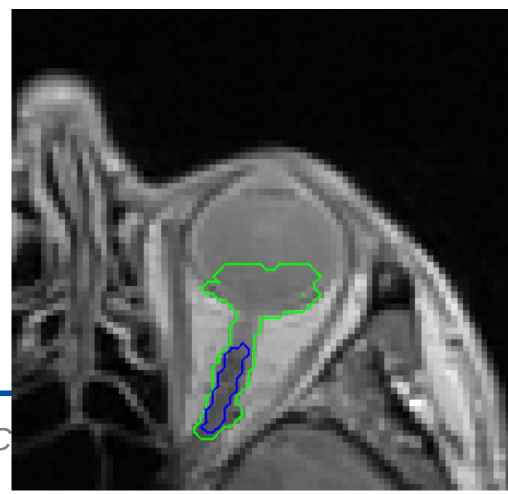
- Employ variational active contours
- Use local energies
- User seeds determine object of interest

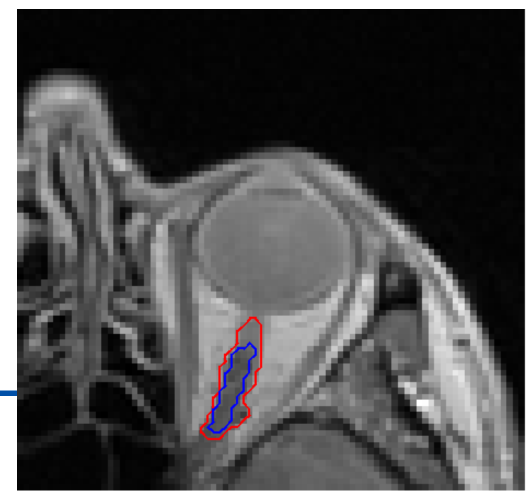
$$E_{cv}(\phi) = \int_{\Omega_x} \delta\phi(x) \int_{\Omega_y} \mathcal{B}(x,y)\cdot\left(\mathcal{H}(\phi(y))(I(y)-u_l)^2 + (1-\mathcal{H}(\phi(y)))(I(y)-v_l)^2\right) dy\, dx$$

$$E_{user}(\phi) = \int_{\Omega_x} \delta\phi(x) \int_{\Omega_y} \mathcal{B}(x,y)\cdot\left(\mathcal{H}(\phi(y))(I(y)-u_{seed})^2 dy\ dx\right.$$

$$E_T(\phi(x)) = E_{cv}(\phi(x)) + \lambda E_{user}(\phi(x))$$

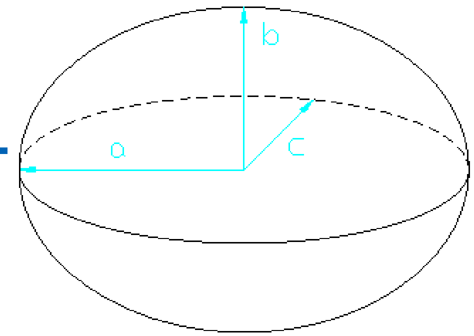


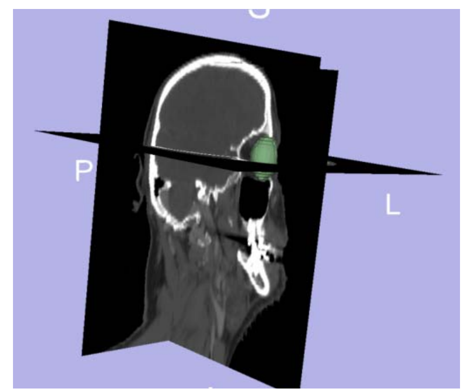




Eyeball Segmentation

- Roughly a sphere slightly elliptical
- Reduce dimensionality, impose shape constraint
- Heterogeneous intensity profile, look for edges





$$E(a,b,c,x_c,y_c,z_c) = \int_{\Omega} g(|\nabla I(C(q)|)dq + \alpha\left(\left(1-\frac{a}{b}\right)^2 + \left(1-\frac{c}{b}\right)^2\right) - \lambda\,(a+b+c)$$

$$g\left(\left|\nabla I\left(C\left(a,b,c,x_c,y_c,z_c,q\right)\right)\right|\right) = \frac{1}{1+\left|\nabla I\left(C\left(q\right)\right)\right|^2}$$

Conclusions

- Next year we hope to have substantial results with our DBP partners!