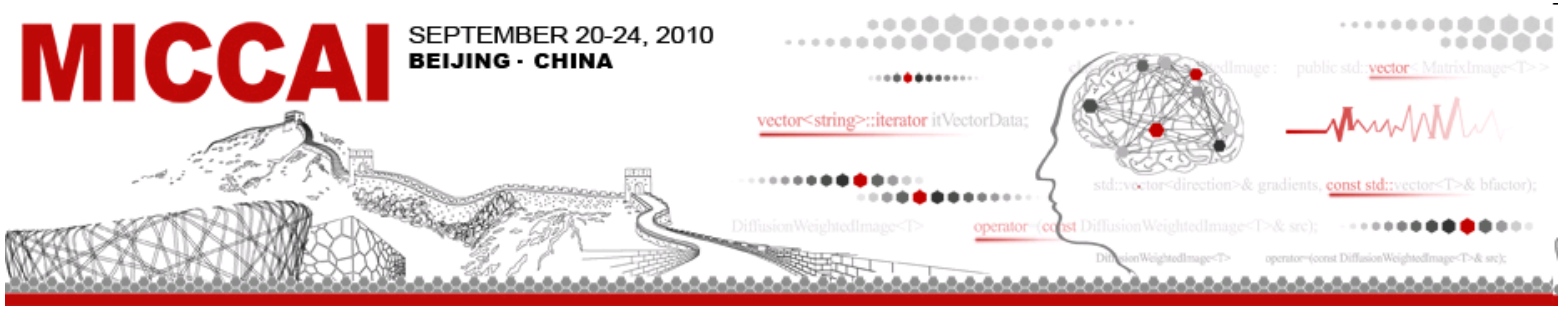
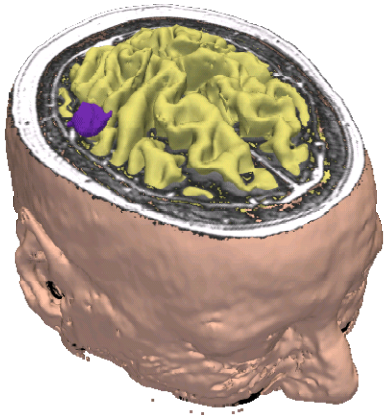
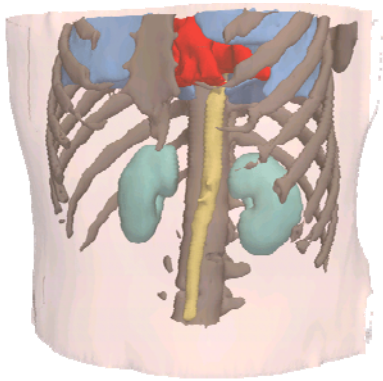


Image Segmentation: EM Segmenter

by

Kilian Maria Pohl





Kilian.Pohl@uphs.upenn.edu ♦ https://www.rad.upenn.edu/sbia/Kilian.Pohl/

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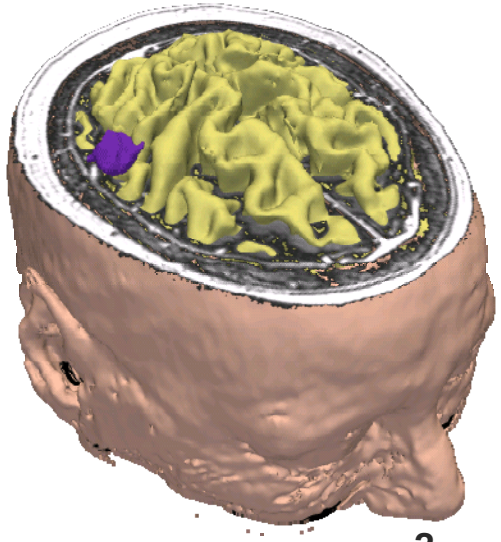
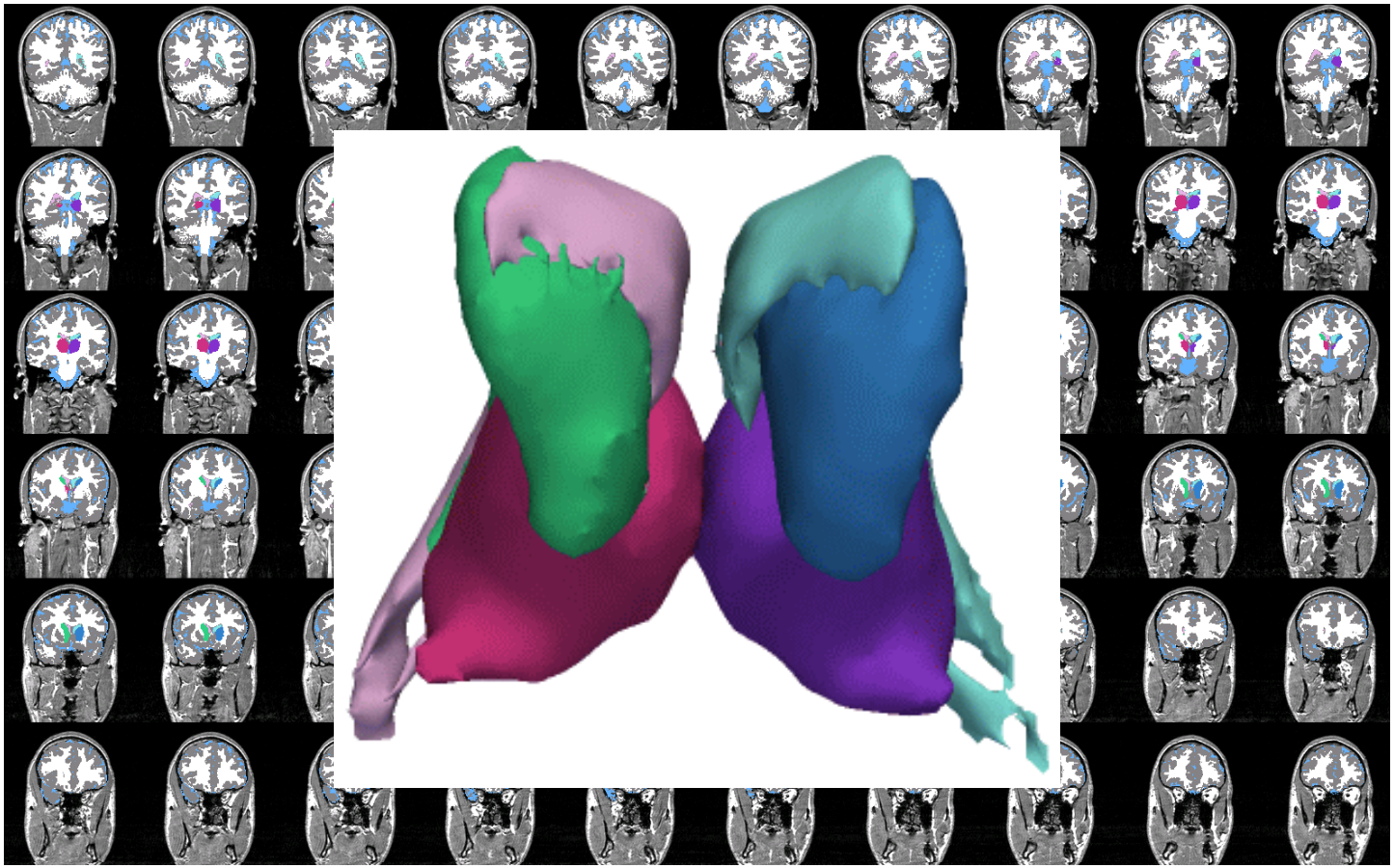


Neuroscience Studies

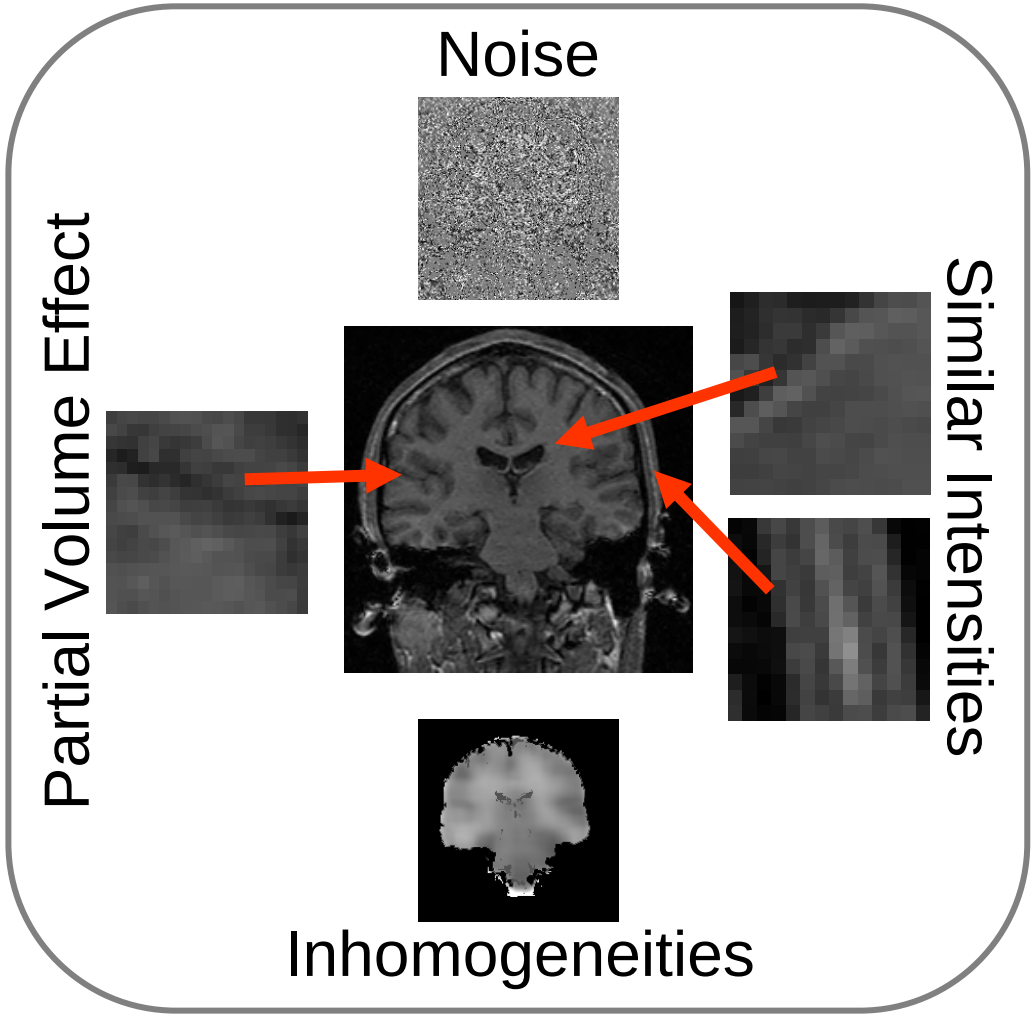


Manual vs. Automatic

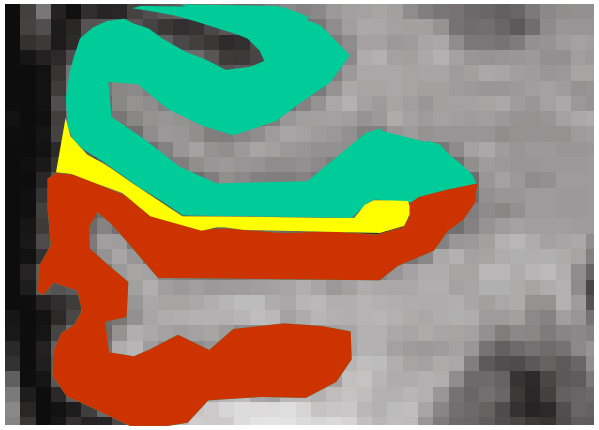
Manual Segmentation:
- Very expensive
- High risks related to observer reliability

Automatic segmentation:
- Relatively cheap
- Quality is often lower than manual segmentations

Image Artifacts



Different Evidence of Boundaries



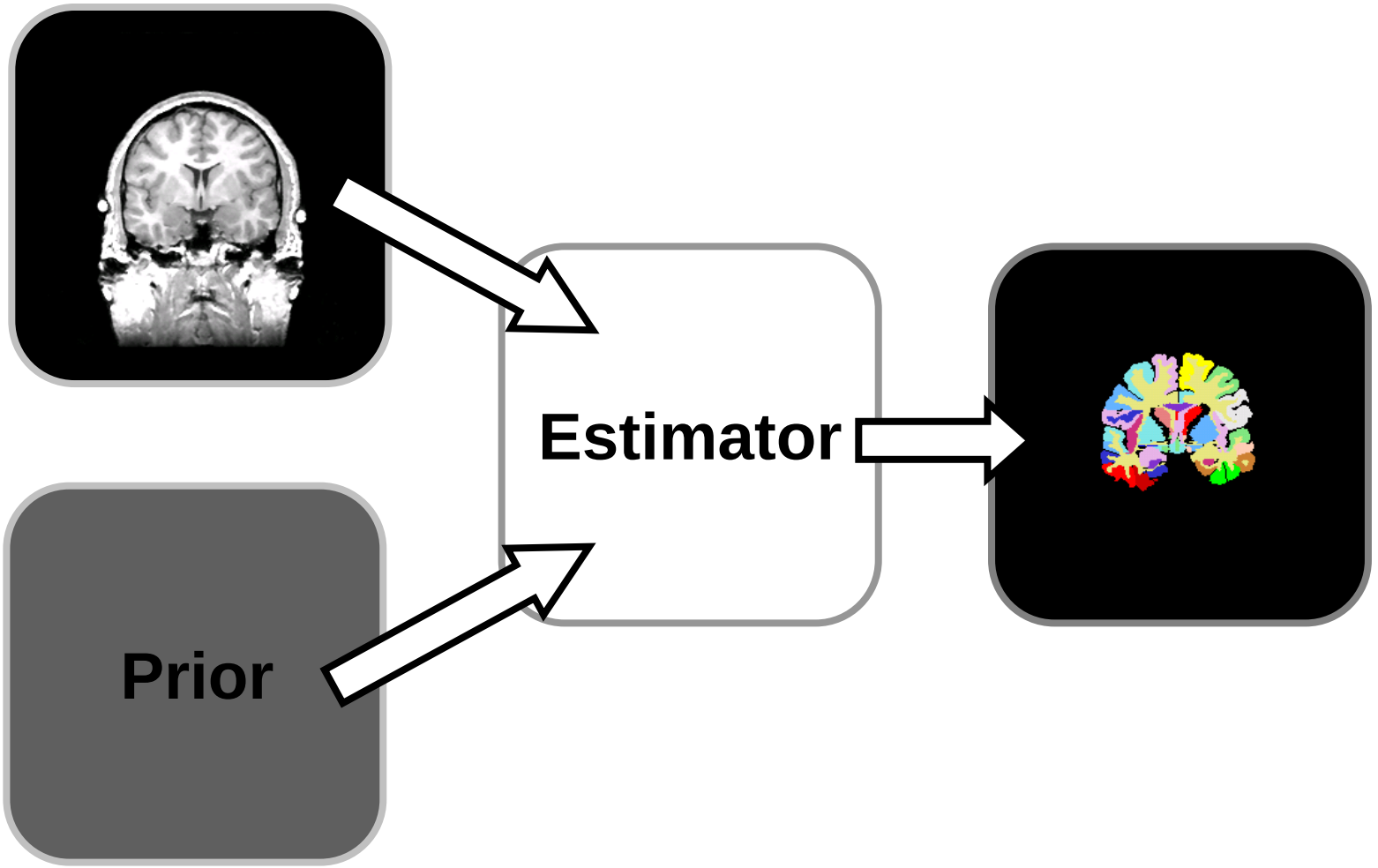
T_1-weighted

T_2-weighted

Some anatomical compartments

- are visible in multiple input channels
- are visible only in one input channel
- have boundaries not based on image contrast

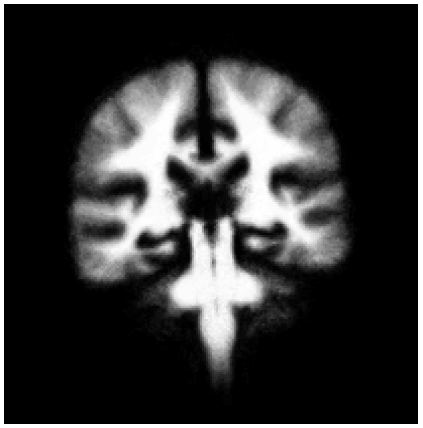
Mission

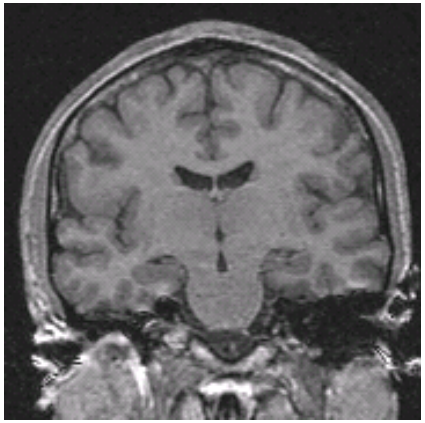


Goal

Develop a general purpose segmenter based on a modular framework:

- fast and flexible
- requiring minimal amount of training effort
- uses probabilistic atlas as prior





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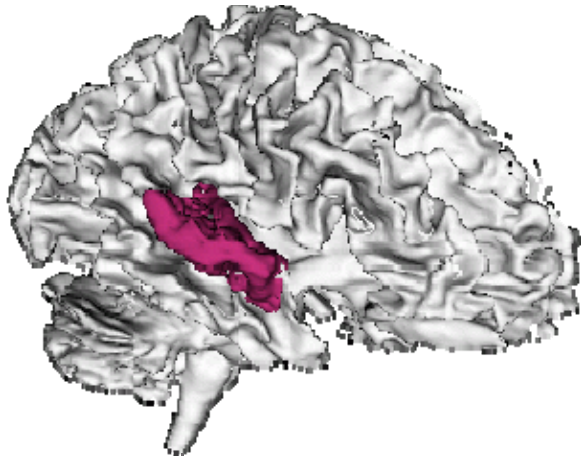
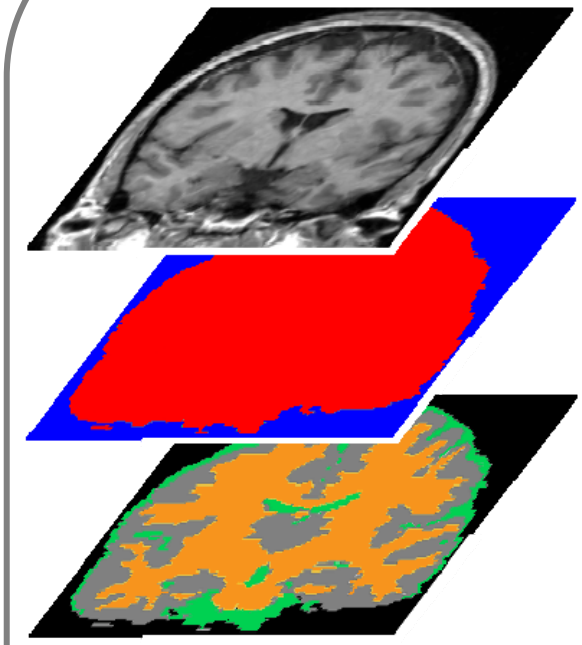
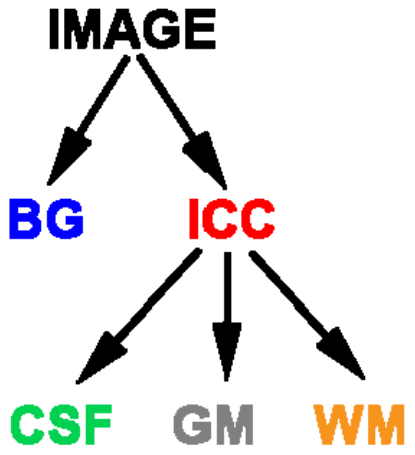


Hierarchical Tree

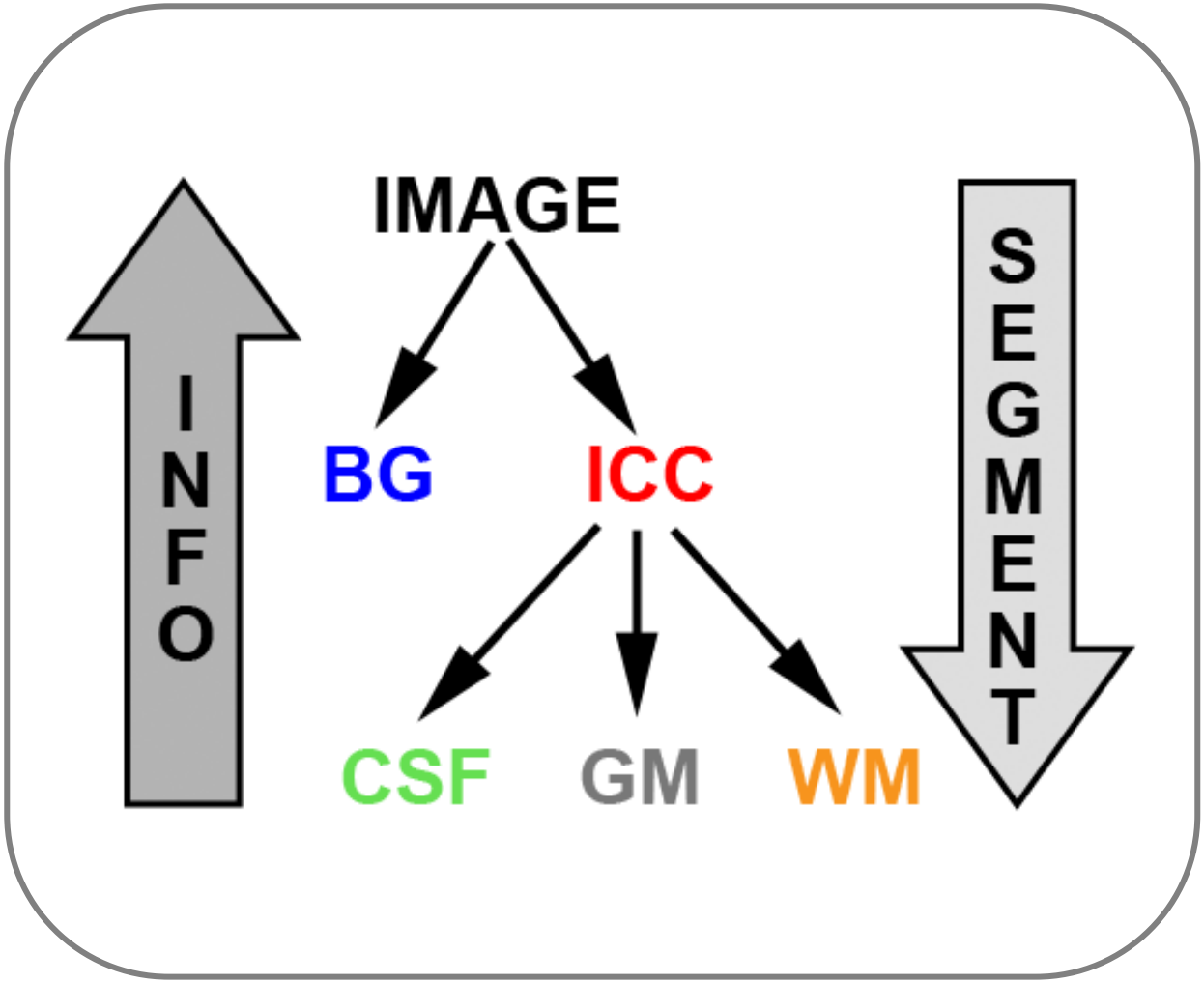


Find Cranial Cavity:

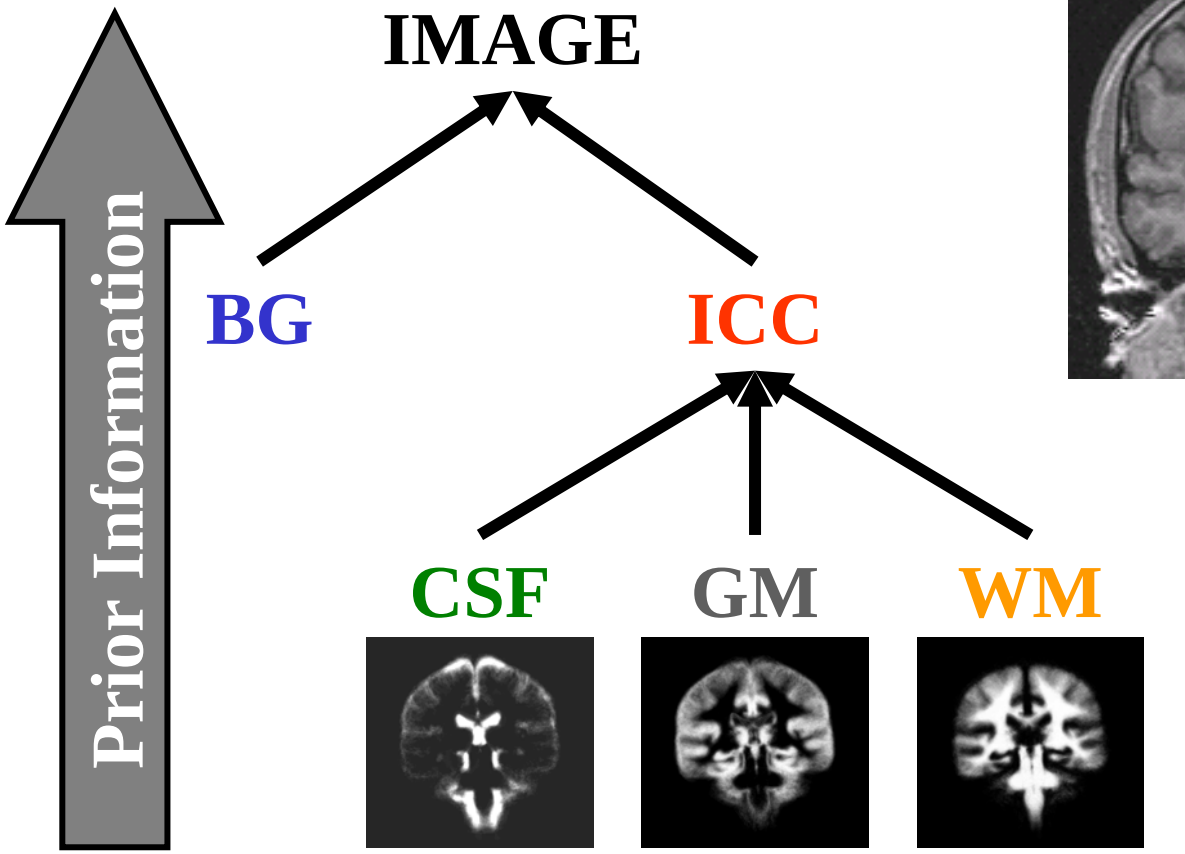
Find Tissue:

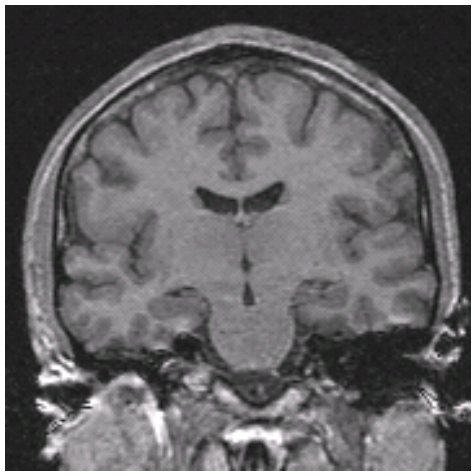


Design of Algorithm



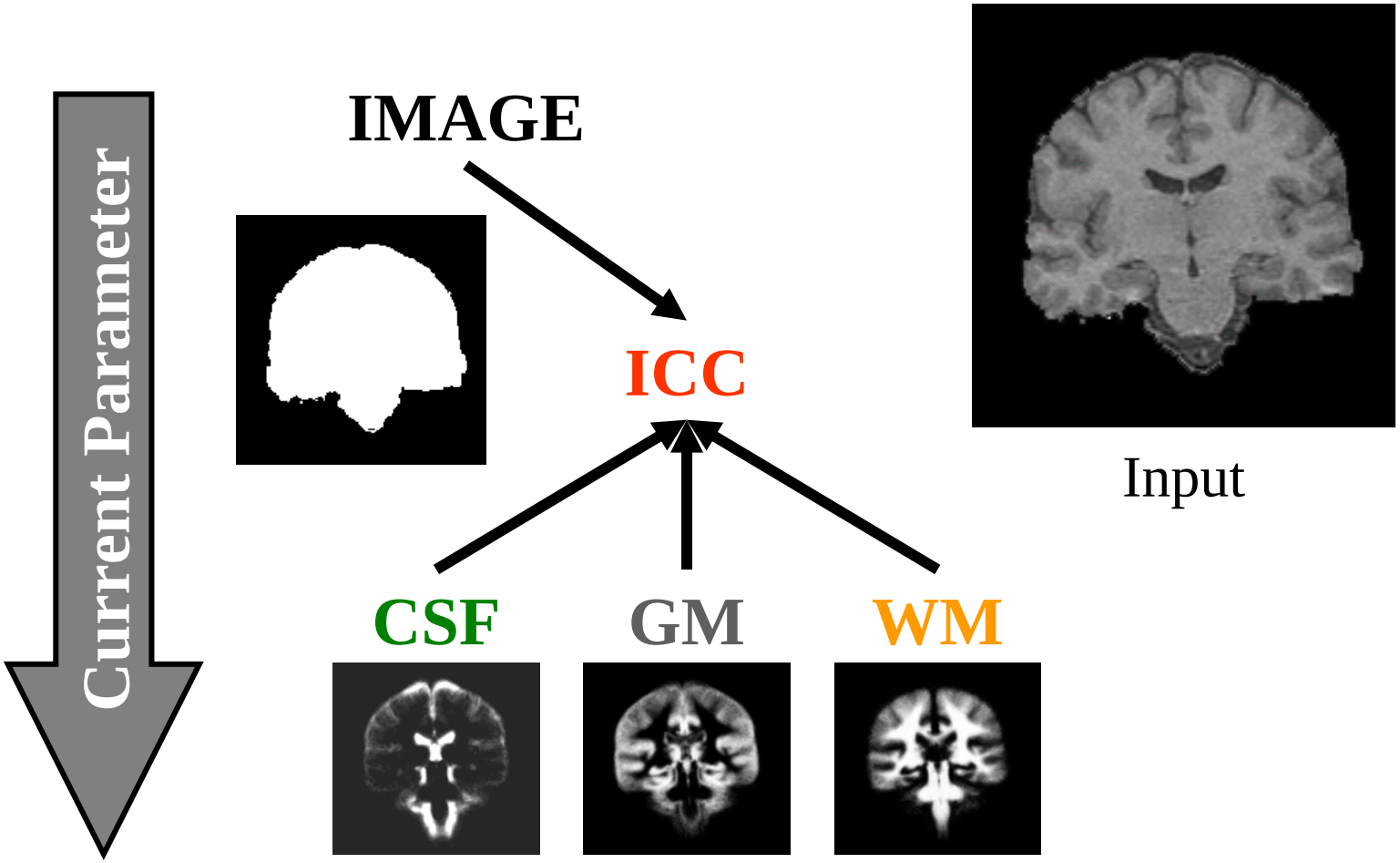
Level 1



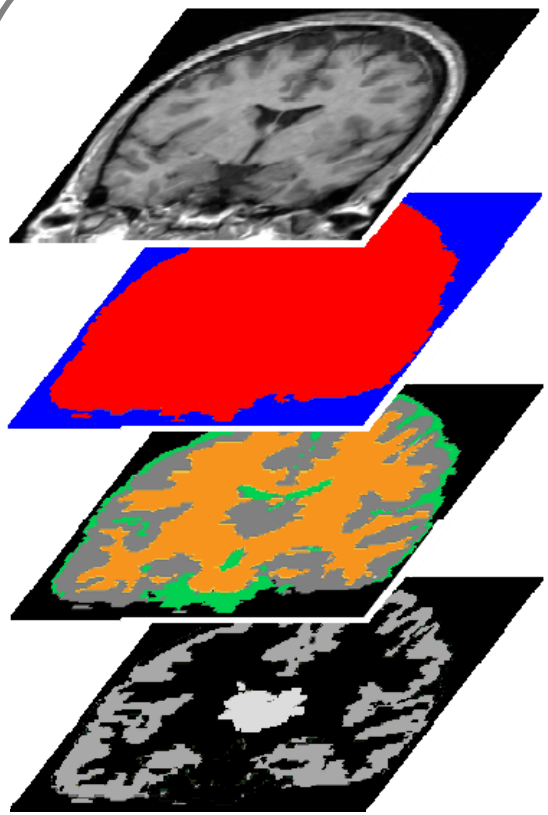


Input

Level 2



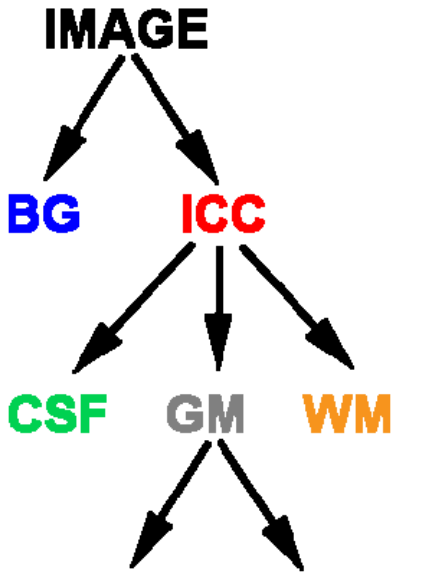
Modify the Tree



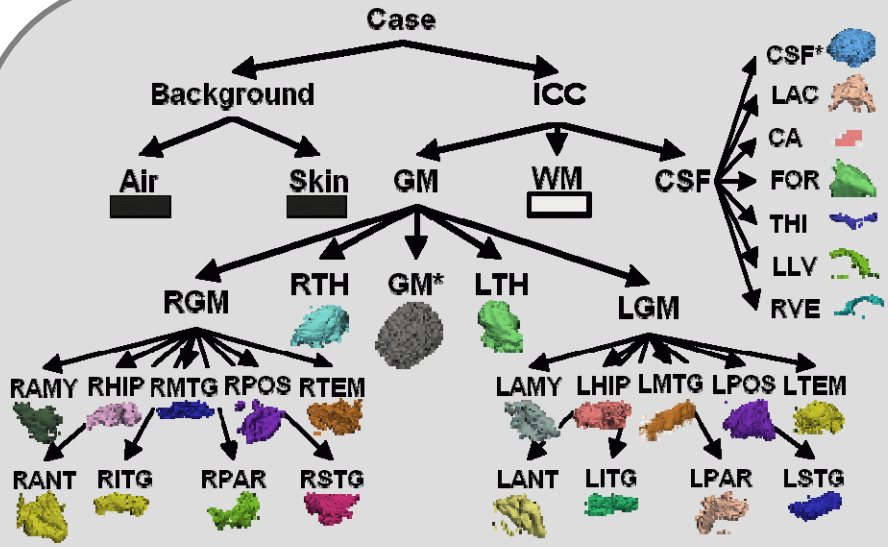
Find Cranial Cavity:

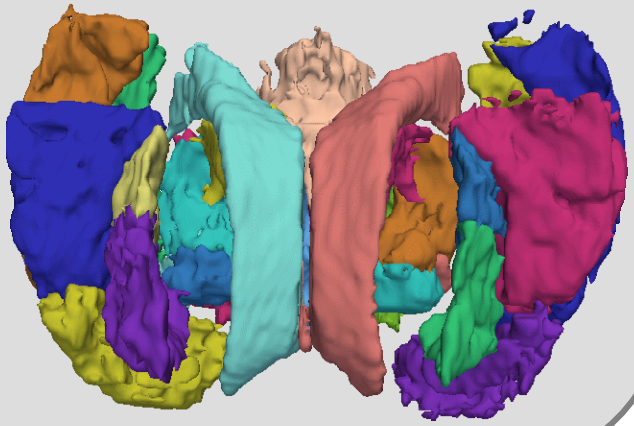
Find Tissue:

Find Substructures:



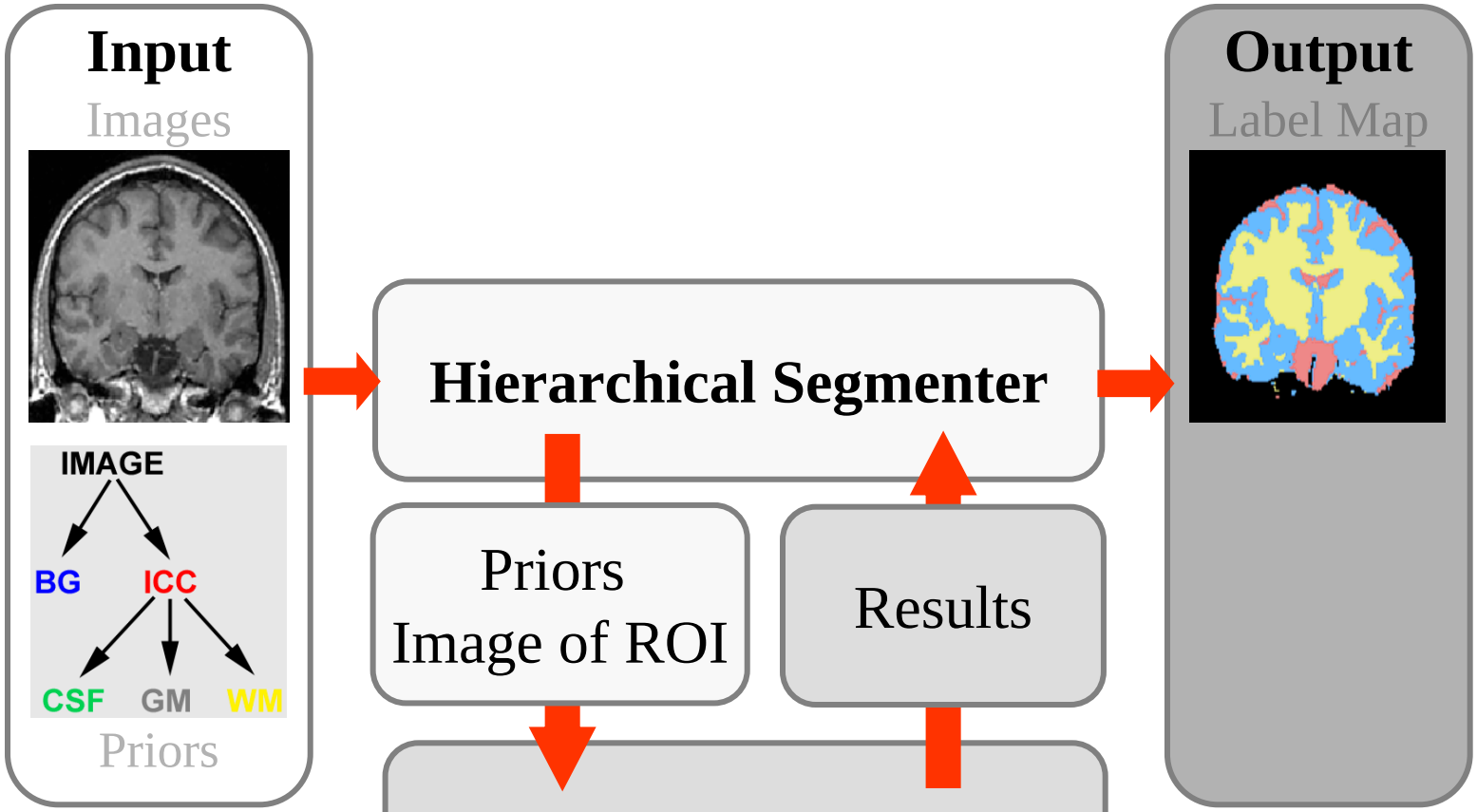
Segmentation of 31 Structures



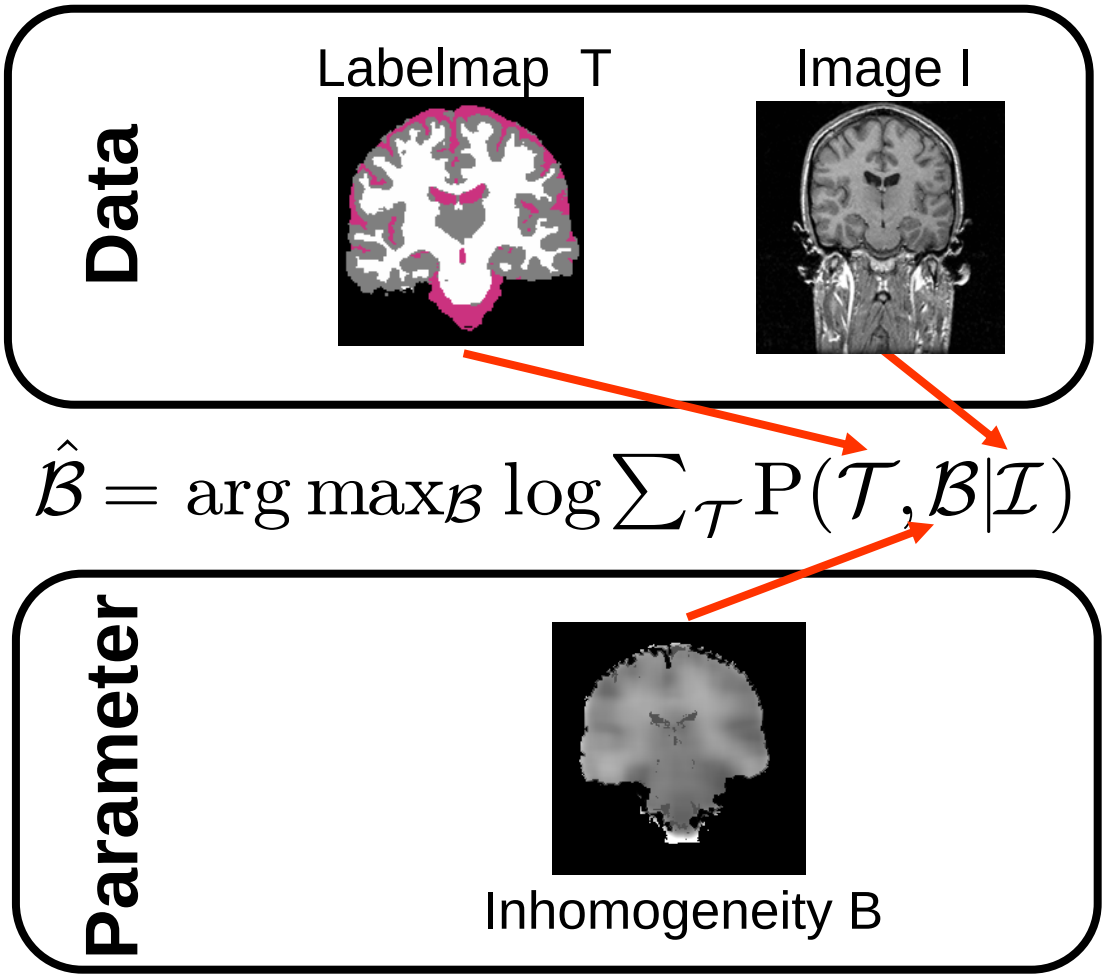


Pohl et al., ISBI 04

Hierarchical Implementation



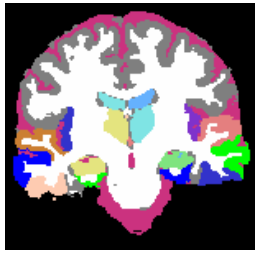
EM Segmenter (Wells et al. 96)



Extended Observed Data

Data

Labelmap T



Hierarchy H

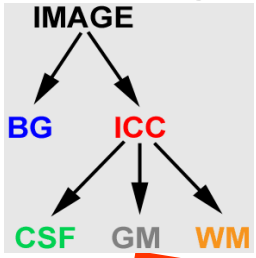
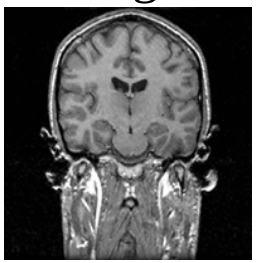
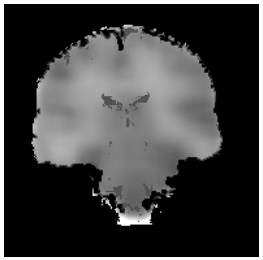


Image I



$$\hat{\mathcal{B}} = \arg\max_{\mathcal{B}} \log \sum_{\mathcal{T}} \mathrm{P}(\mathcal{T}, \mathcal{B} | \mathcal{I}, \mathcal{H})$$

Parameter



Inhomogeneity B

EM Implementation

Expectation Step: Calculate **Weights**

$$\mathcal{W} \equiv \frac{1}{Z} P(\mathcal{I}|\mathcal{T}, \mathcal{B}', \mathcal{H}) \cdot P(\mathcal{T}|\mathcal{H})$$

Maximization Step: Optimize the **estimates**

$$\mathcal{B}' \leftarrow \arg\max_{\mathcal{B}} \mathcal{W} \log \mathrm{P}(\mathcal{B}|\mathcal{I}, \mathcal{T}, \mathcal{H})$$

Definition of Weights

$$\mathcal{W} \equiv \frac{1}{Z} P(\mathcal{I}|\mathcal{T}, \mathcal{B}', \mathcal{H}) \cdot P(\mathcal{T}|\mathcal{H})$$

Intensity Model

Wells $\quad \mathrm{P}(\mathcal{I}|\mathcal{T} = \mathrm{j}, \mathcal{B}') \equiv \mathcal{N}(\mathcal{I}; \mathcal{B}' + \mu_{\mathrm{j}}, \Upsilon_{\mathrm{j}})$

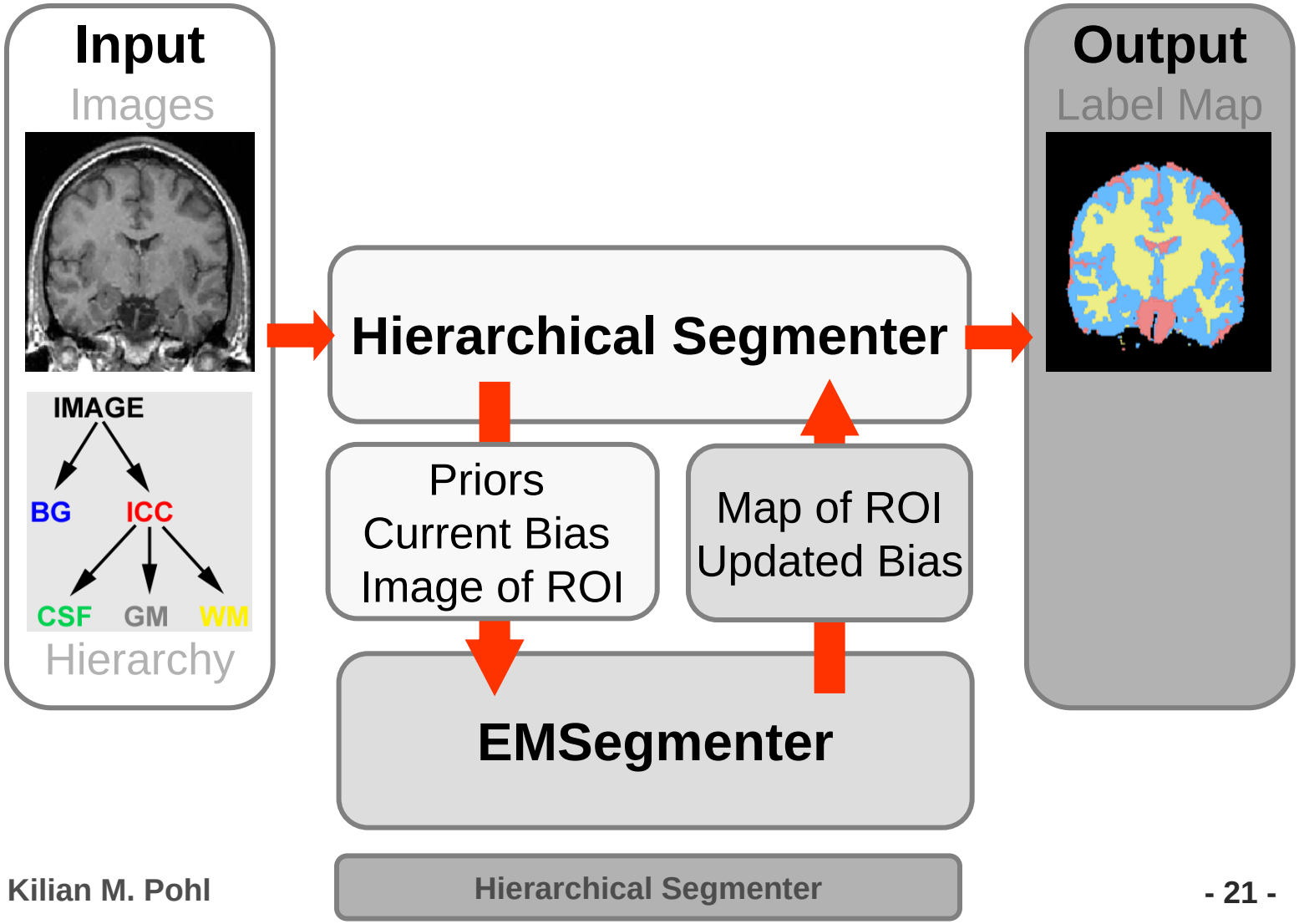
Modified $\quad \mathrm{P}(\mathcal{I}|\mathcal{T} = \mathrm{j}, \mathcal{B}', \mathcal{H}) \equiv \mathcal{N}(\mathcal{I}; \zeta_{\mathcal{H}}^{\mathrm{T}}(\mathcal{B}' + \mu_{\mathrm{j}}), \zeta_{\mathcal{H}}^{\mathrm{T}} \Upsilon_{\mathrm{j}} \zeta_{\mathcal{H}})$

Spatial Prior

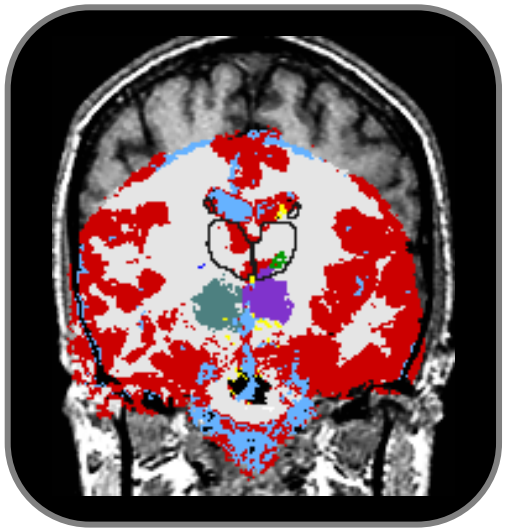
Wells* $\quad \mathrm{P}(\mathcal{T} = \mathrm{j}) \equiv \mathcal{F}_{\mathrm{j}}$

Modified $\quad \mathrm{P}(\mathcal{T} = \mathrm{j}|\mathcal{H}) \equiv (1 - \lambda_{\mathcal{H}}) \cdot \frac{1}{\mathrm{d}} + \lambda_{\mathcal{H}} \cdot \mathcal{F}_{\mathrm{j}}$

Hierarchical Implementation



Alternative Prior Model



Simultaneous Registration and Segmentation

Pohl et al. A Bayesian Model for Joint Segmentation and Registration. NeuroImage, 31(1), pp. 228-239, 2006

Shape Based Segmentation

Pohl et al., “Using the Logarithm of Odds to Define a Vector Space on Probabilistic Atlases", Medical Image Analysis, 2007 MedIA –MICCCAI Best Paper Prize 2006

Pohl et al. Active mean fields: Solving the mean field approximation in the level set framework.IPMI, vol. 4584 of LNCS, pp. 26-37, 2007.

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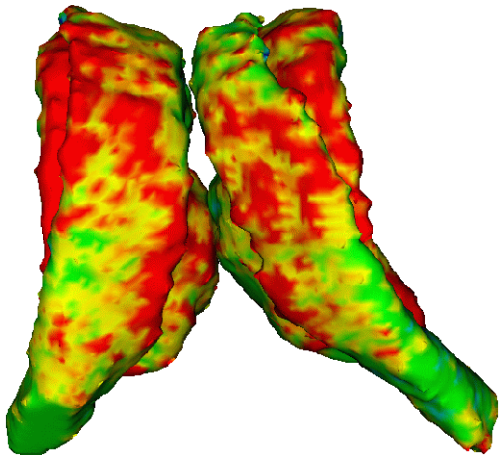
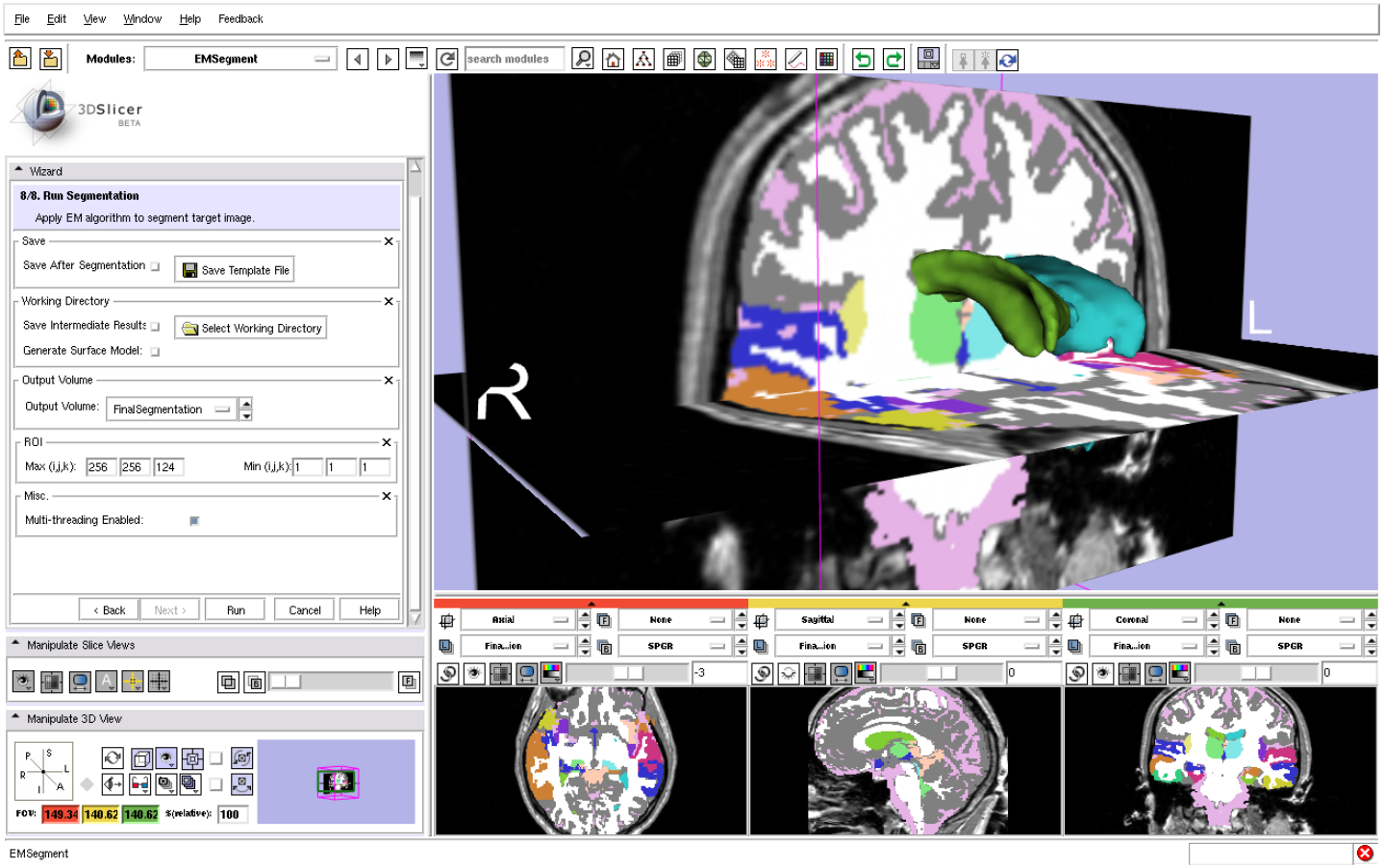
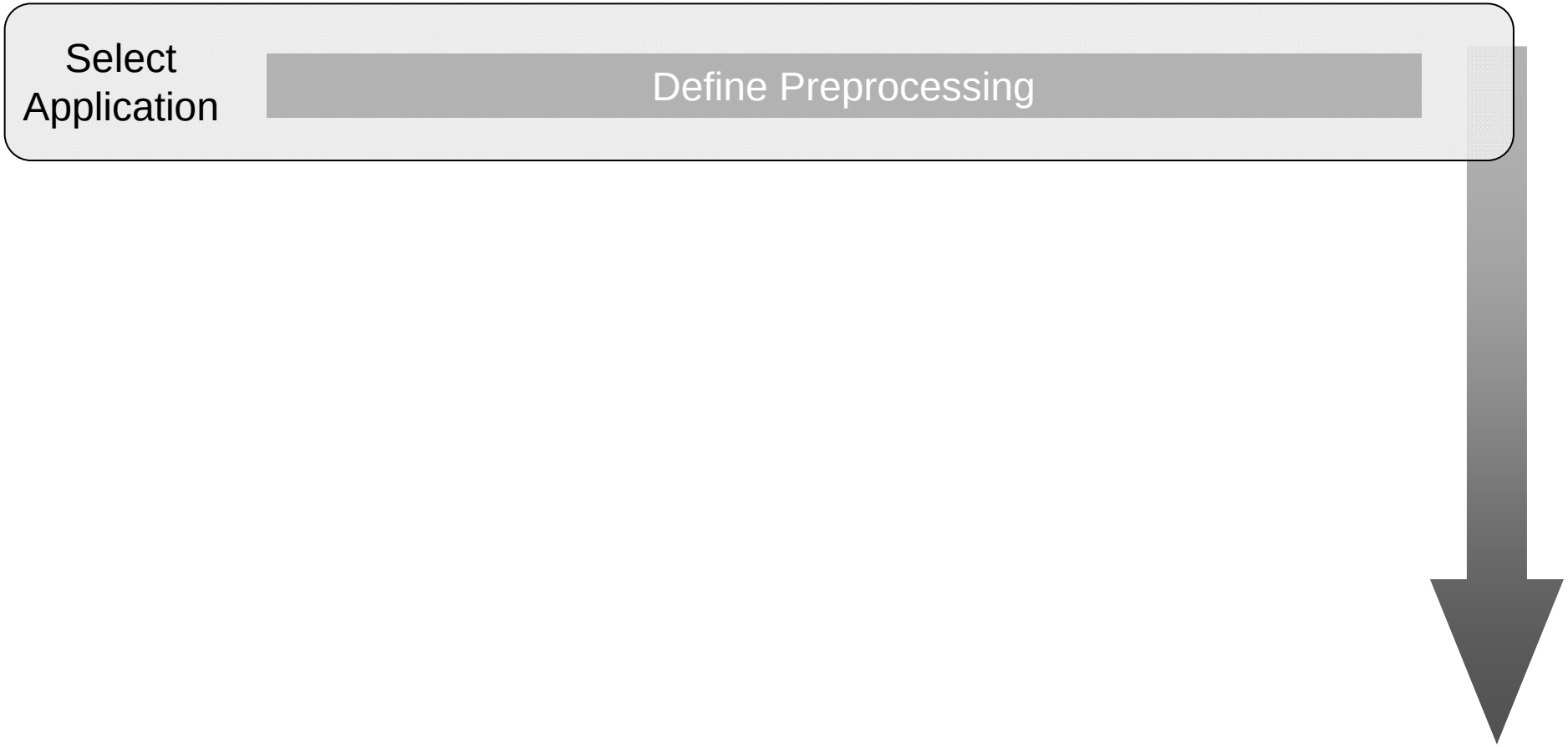


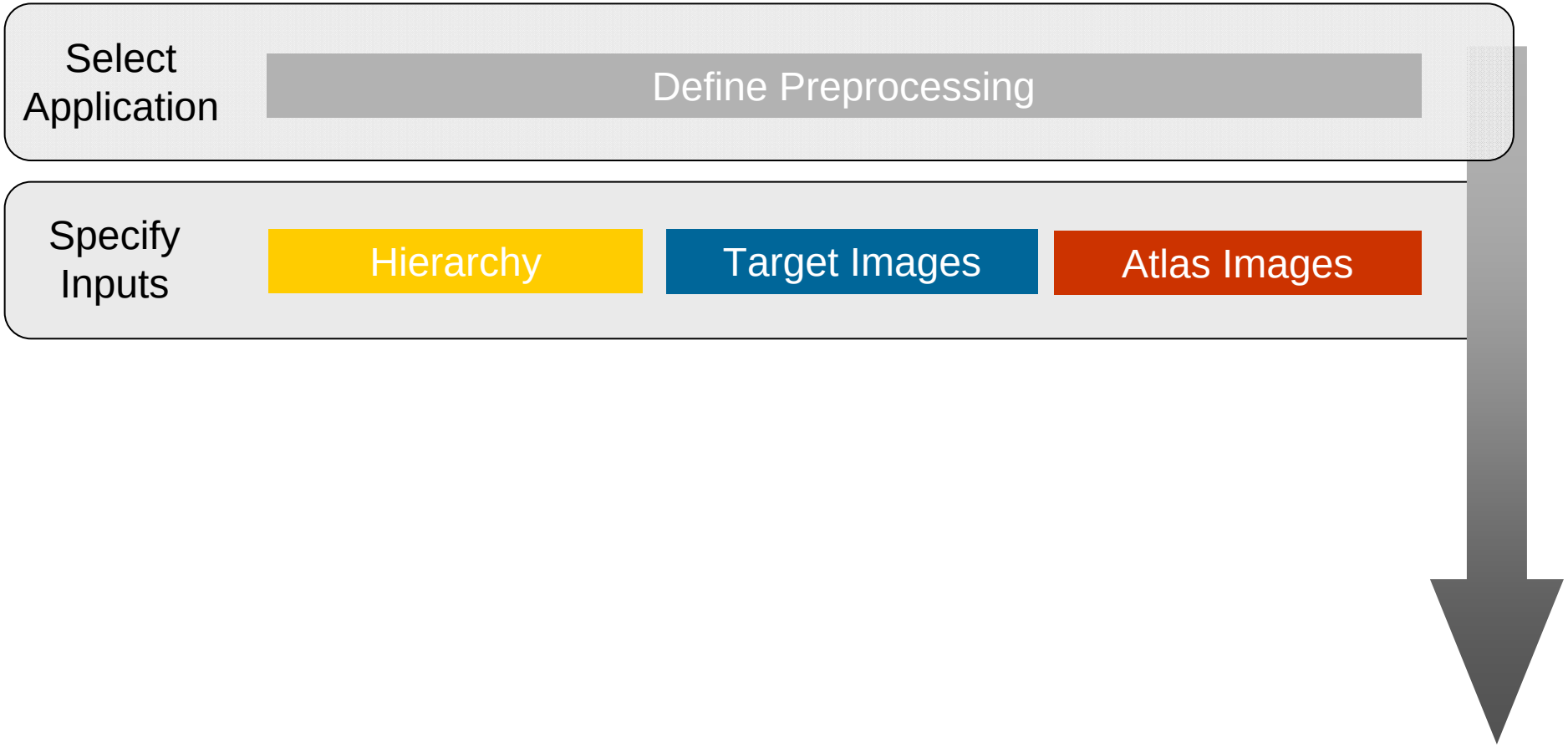
Implementation in 3D Slicer



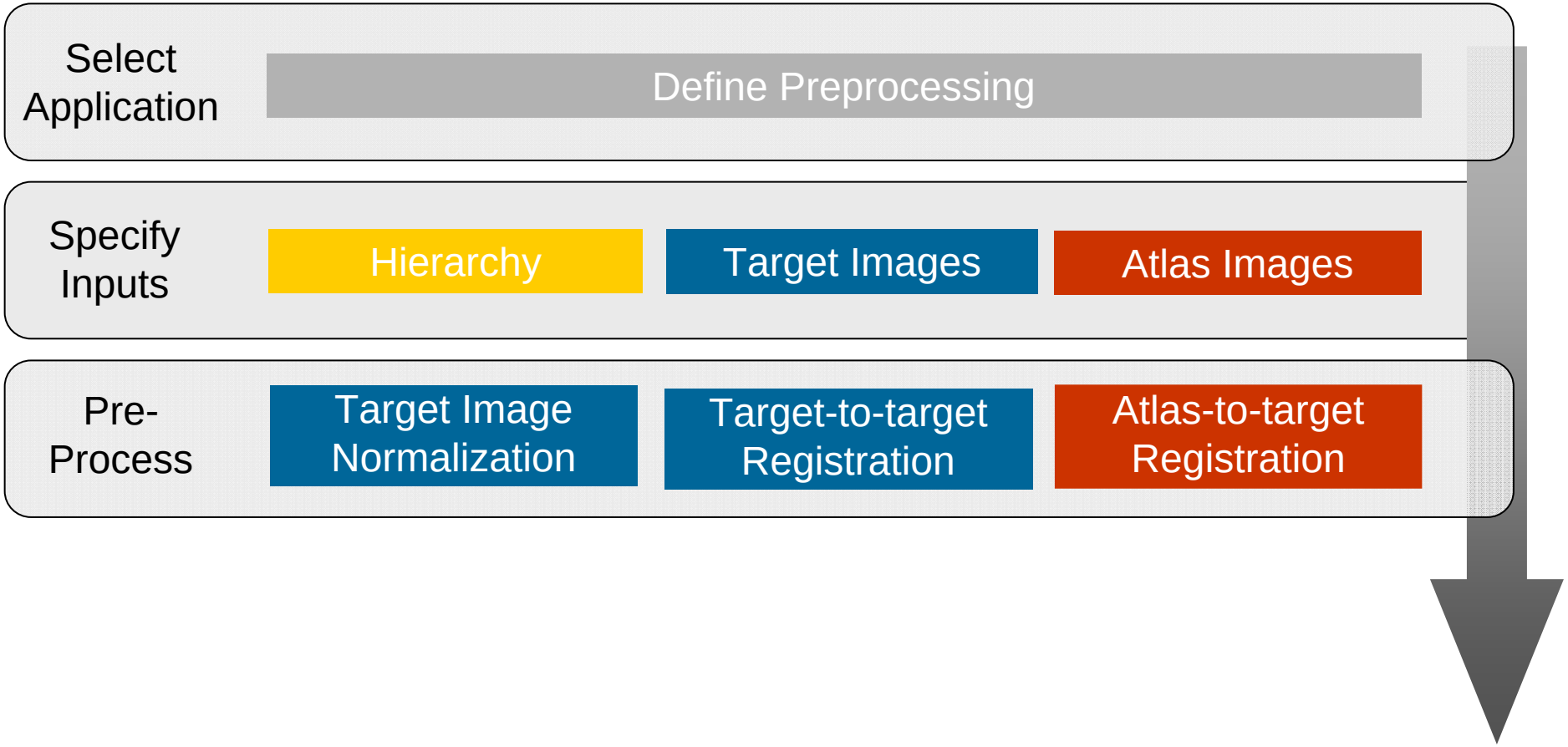
EM Segment Workflow



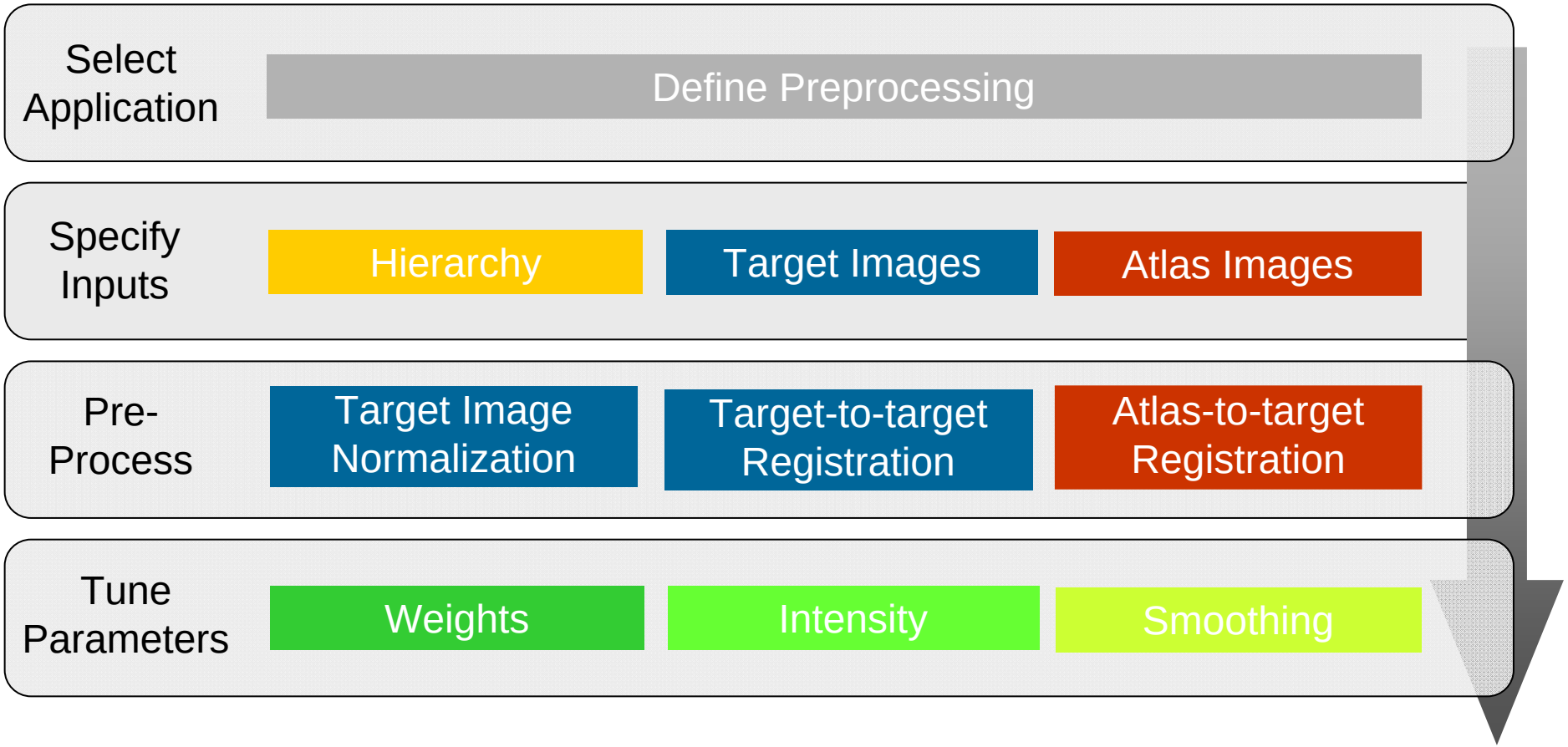
EM Segment Workflow



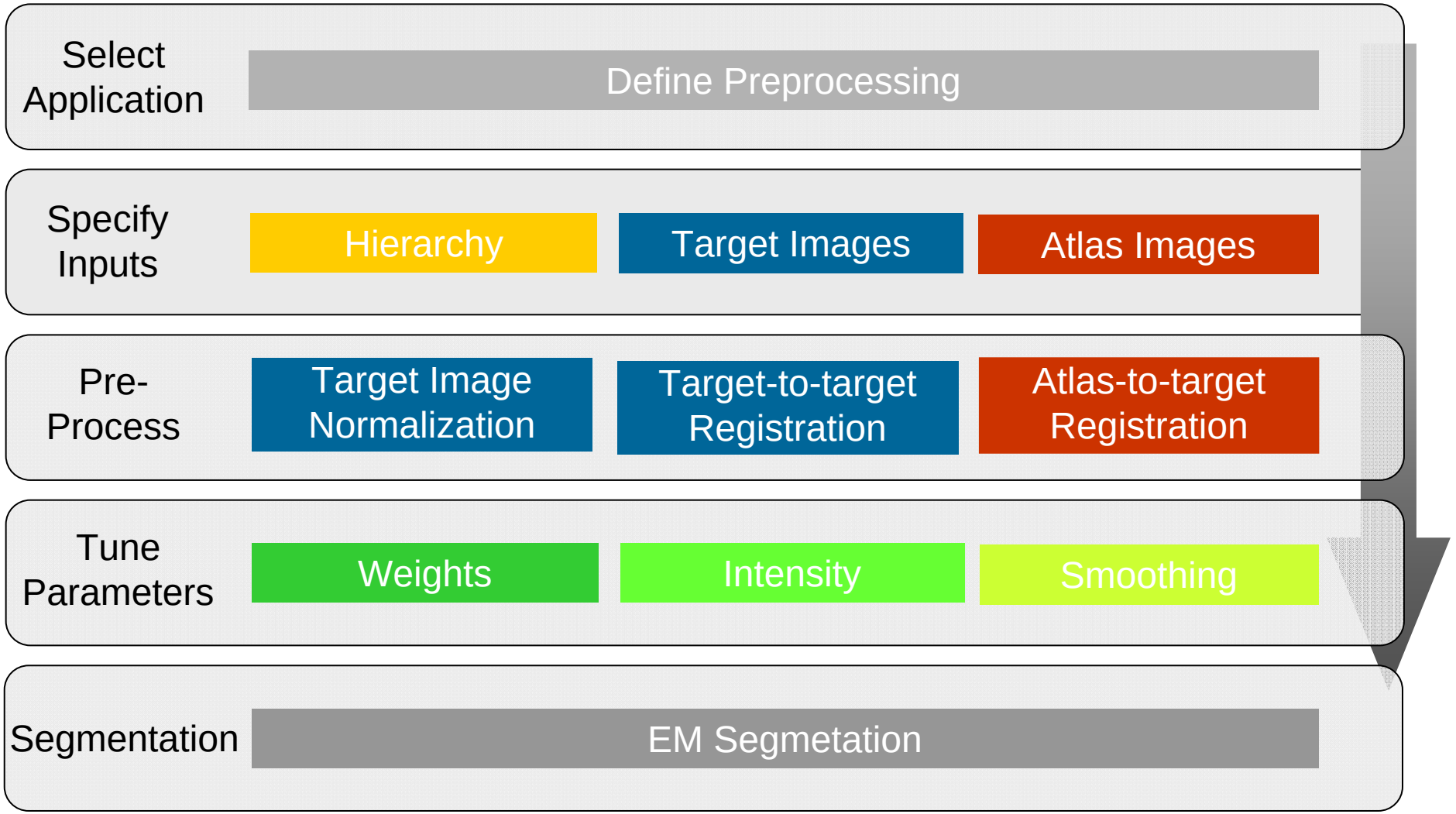
EM Segment Workflow



EM Segment Workflow

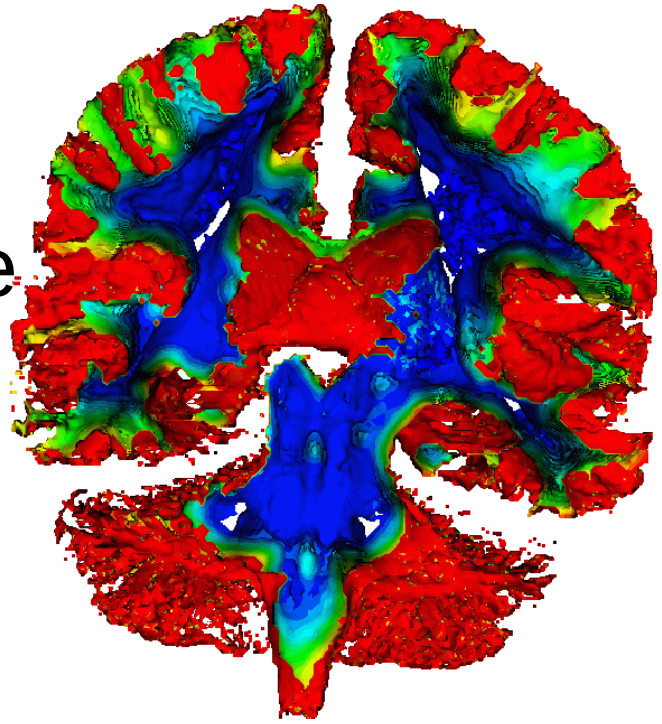


EM Segment Workflow



Interacting with EM Segmenter

- Application Builder
- Simple Mode
- Command Line Module



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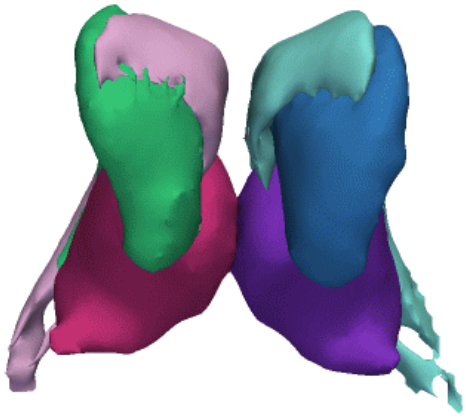
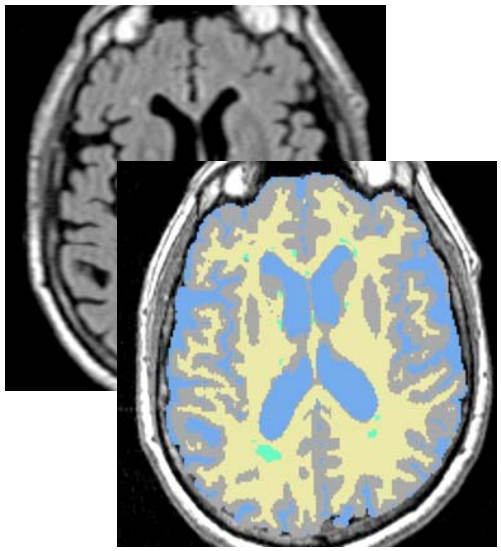
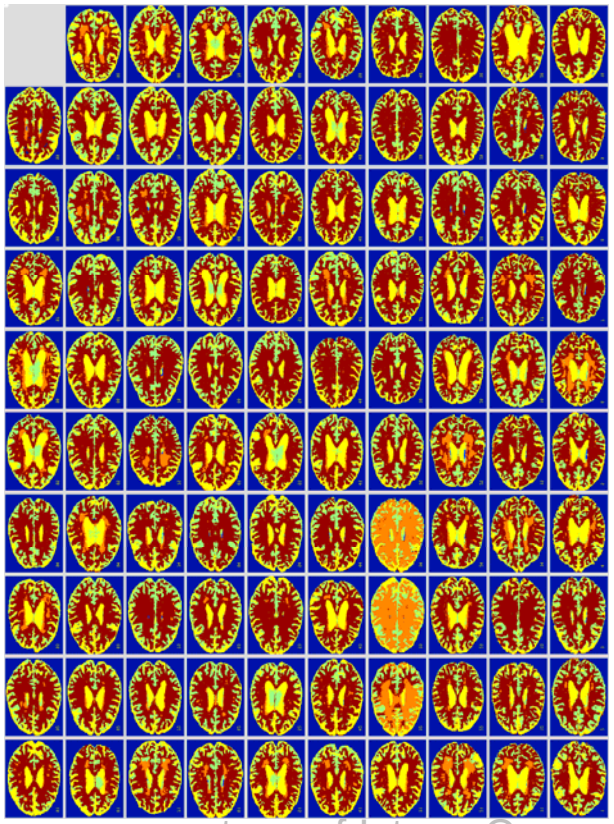


Human Brain

Psychiatry
Neuroimaging Lab
BWH

Lesion Detection



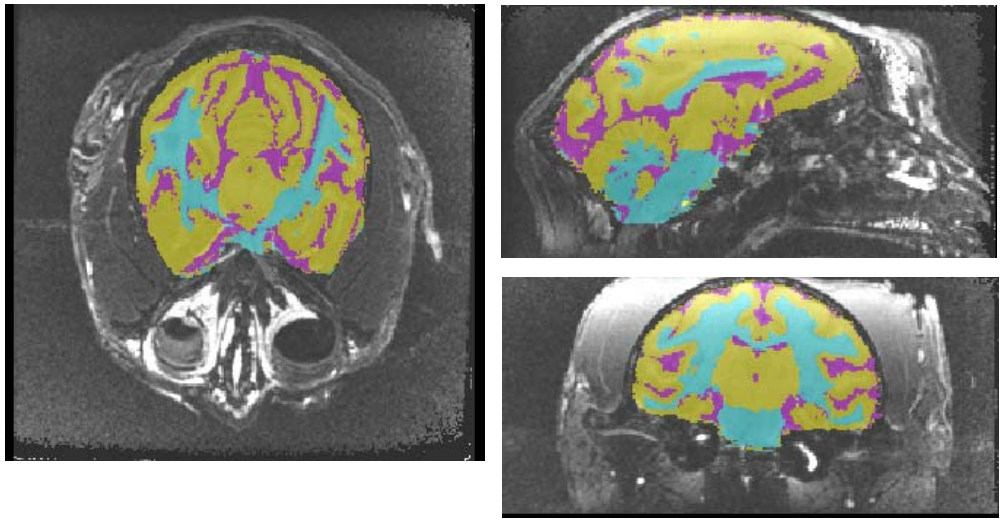


courtesy of Istvan Csapo

Progression of Multiple Sclerosis lesions

Non-Human Primates

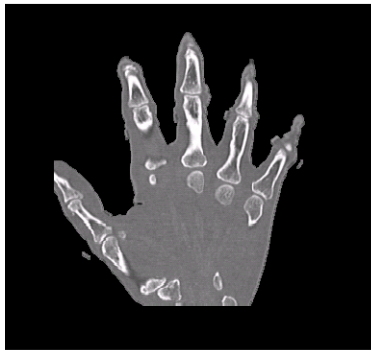
VIRGINIA TECH WAKE FOREST UNIVERSITY
School of Biomedical Engineering and Sciences



courtesy of Chris Wyatt

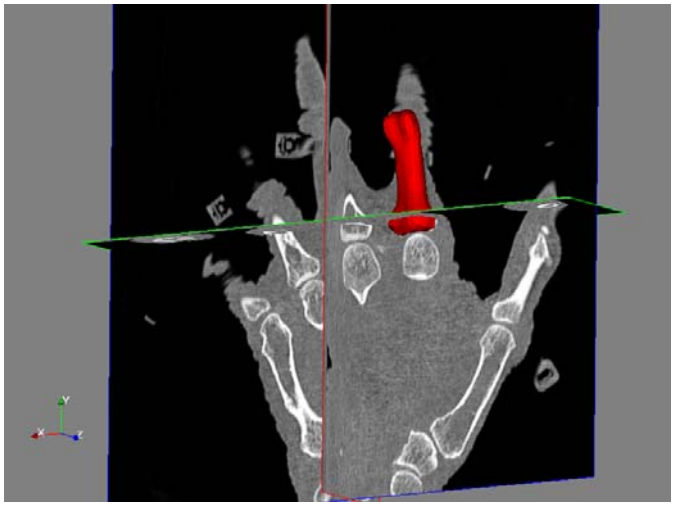
Measuring Alcohol and Stress Interactions with Structural and Perfusion MRI

CT Hand Bone Segmentation



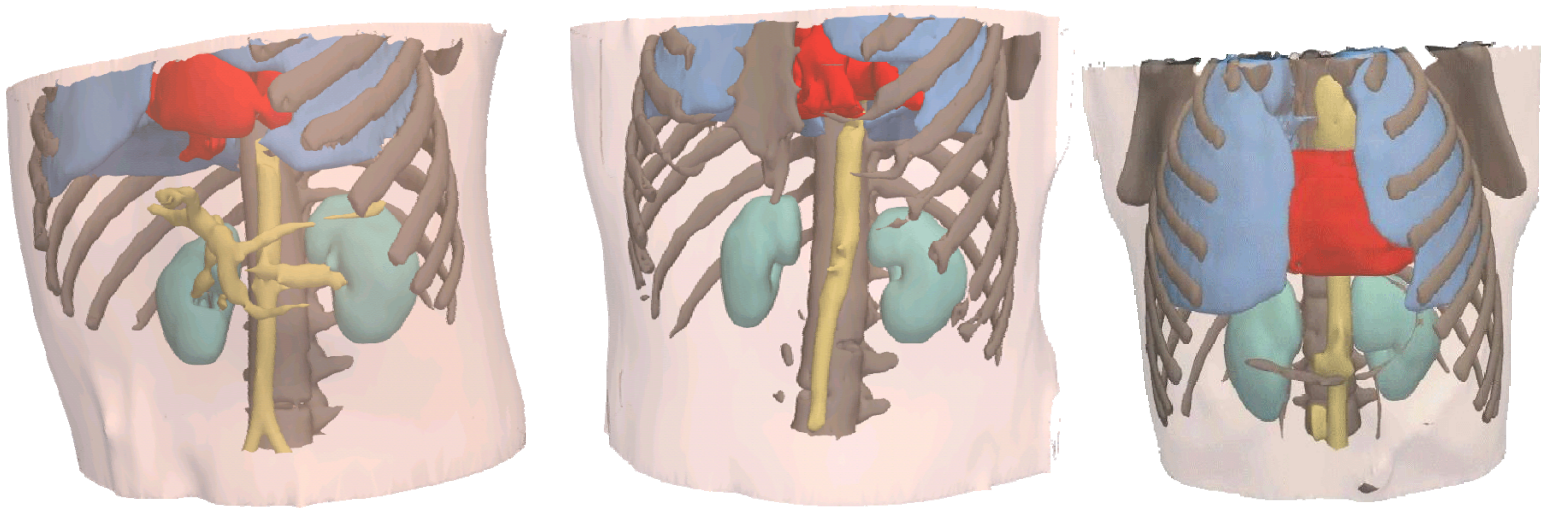
MIMX
THE UNIVERSITY OF IOWA

Developing patient-specific kinematic models



courtesy of Austin Ramme and Vince Magnotta

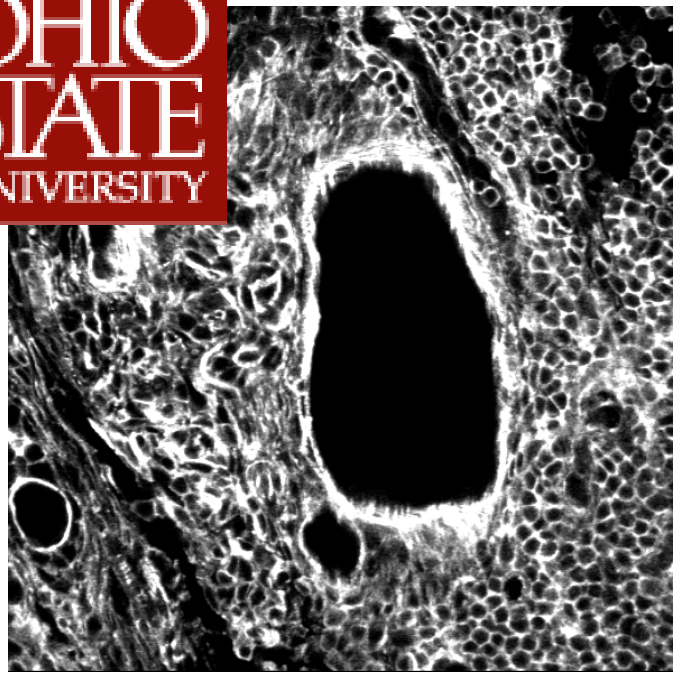
CT Torso Segmentation

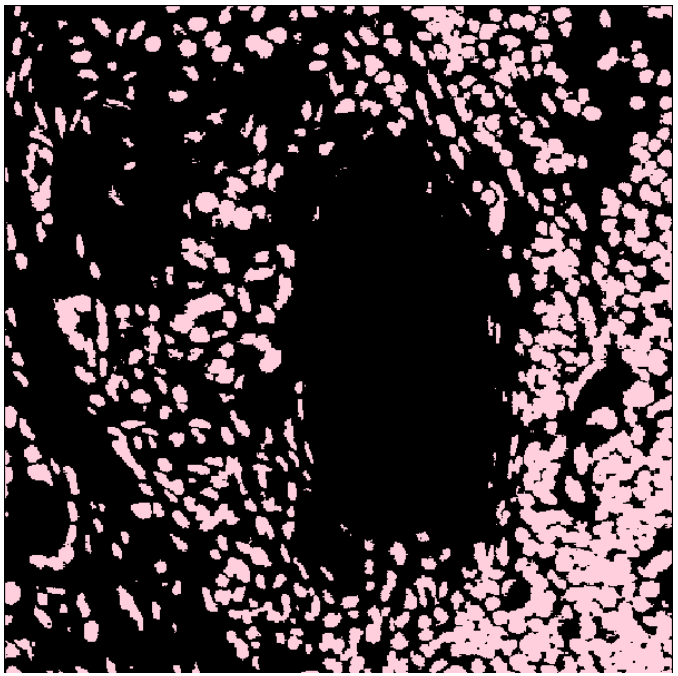


Detect internal hemorrhage in the field setting

CIMIT
Center for Integration of Medicine & Innovative Technology

Segmentation of Microscopy Images

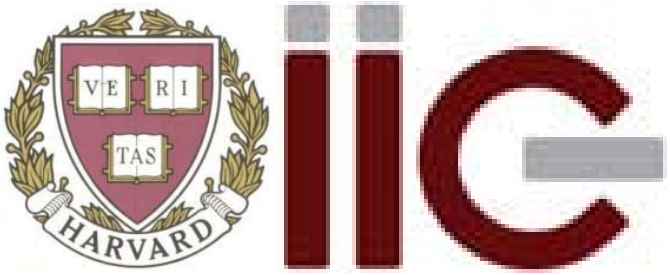




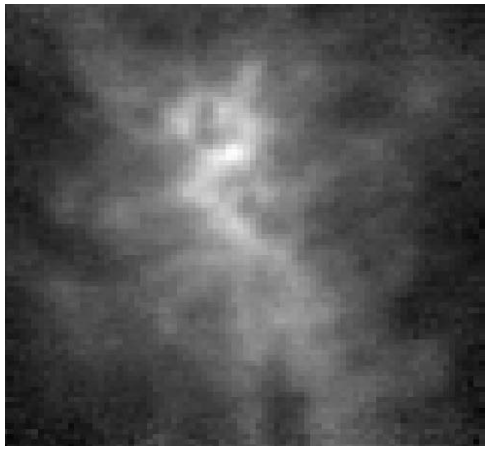
courtesy of Brad Davis

Detecting patterns in biology

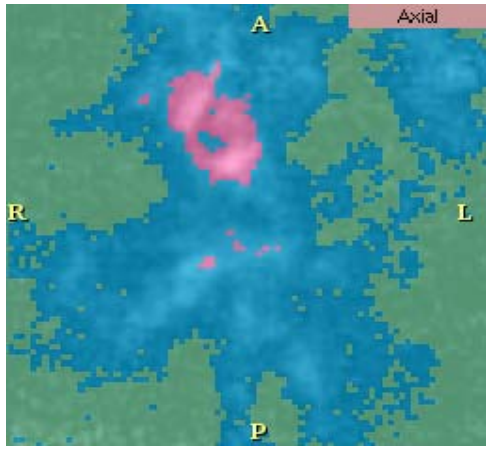
Astronomy Images



Initiative in Innovative Computing, Harvard



Detecting Star Forming Regions



courtesy of Michelle Borkin

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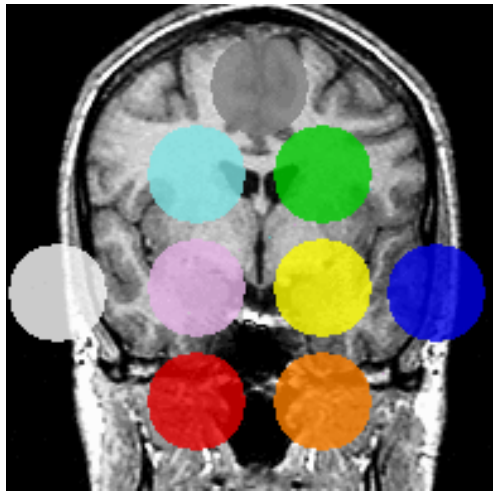

Publications

- Pohl et al. A hierarchical algorithm for MR brain image parcellation. IEEE Transactions on Medical Imaging, 26(9), pp 1201-1212, 2007.
- Nakamura et al. Neocortical gray matter volume in first episode schizophrenia and first episode affective psychosis: a cross-sectional and longitudinal MRI study. Biological Psychiatry, 2007. In Press.
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Papers are accessible through
https://www.rad.upenn.edu/sbia/Kilian.Pohl/publications

Slicer3 Documentation

- Documentation

  http://www.slicer.org/slicerWiki/index.php/
  Modules:EMSegmentTemplateBuilder3.6

- Developer Page

  http://wiki.na-mic.org/Wiki/index.php/
  Projects:ARRA:SlicerEM:Developer

- NIH Progress Report

  http://wiki.na-mic.org/Wiki/index.php/Projects:ARRA:SlicerEM

- Bug Report

  http://www.na-mic.org/Bug/

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