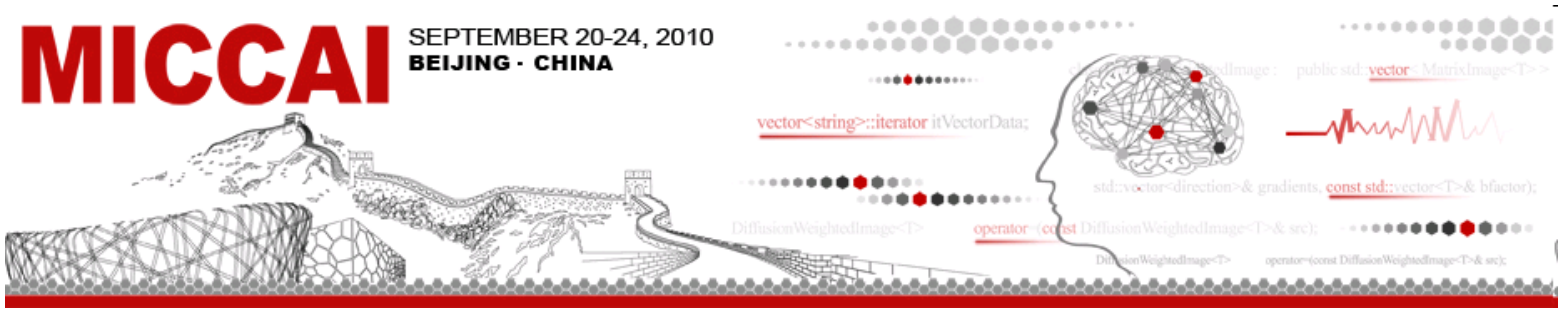
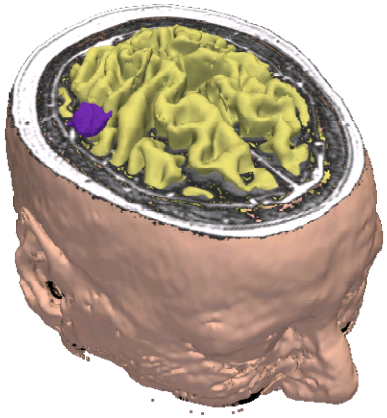
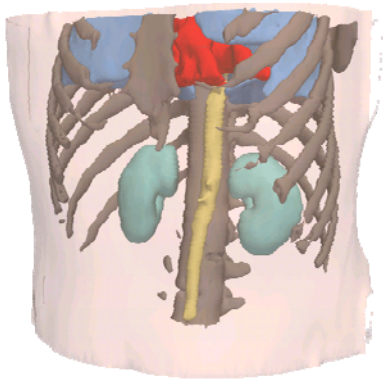


Image Segmentation: EM Segmenter

by

Kilian Maria Pohl



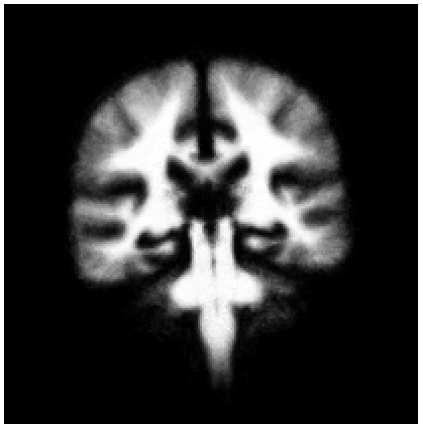


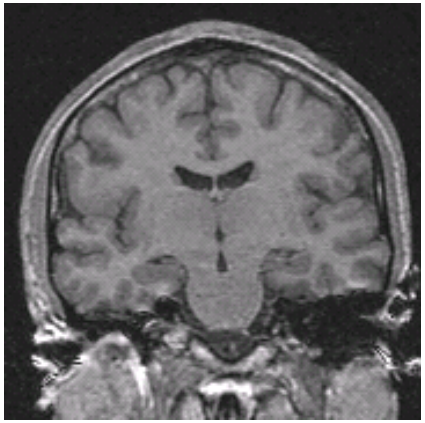
Kilian.Pohl@uphs.upenn.edu ♦ https://www.rad.upenn.edu/sbia/Kilian.Pohl/

Goal

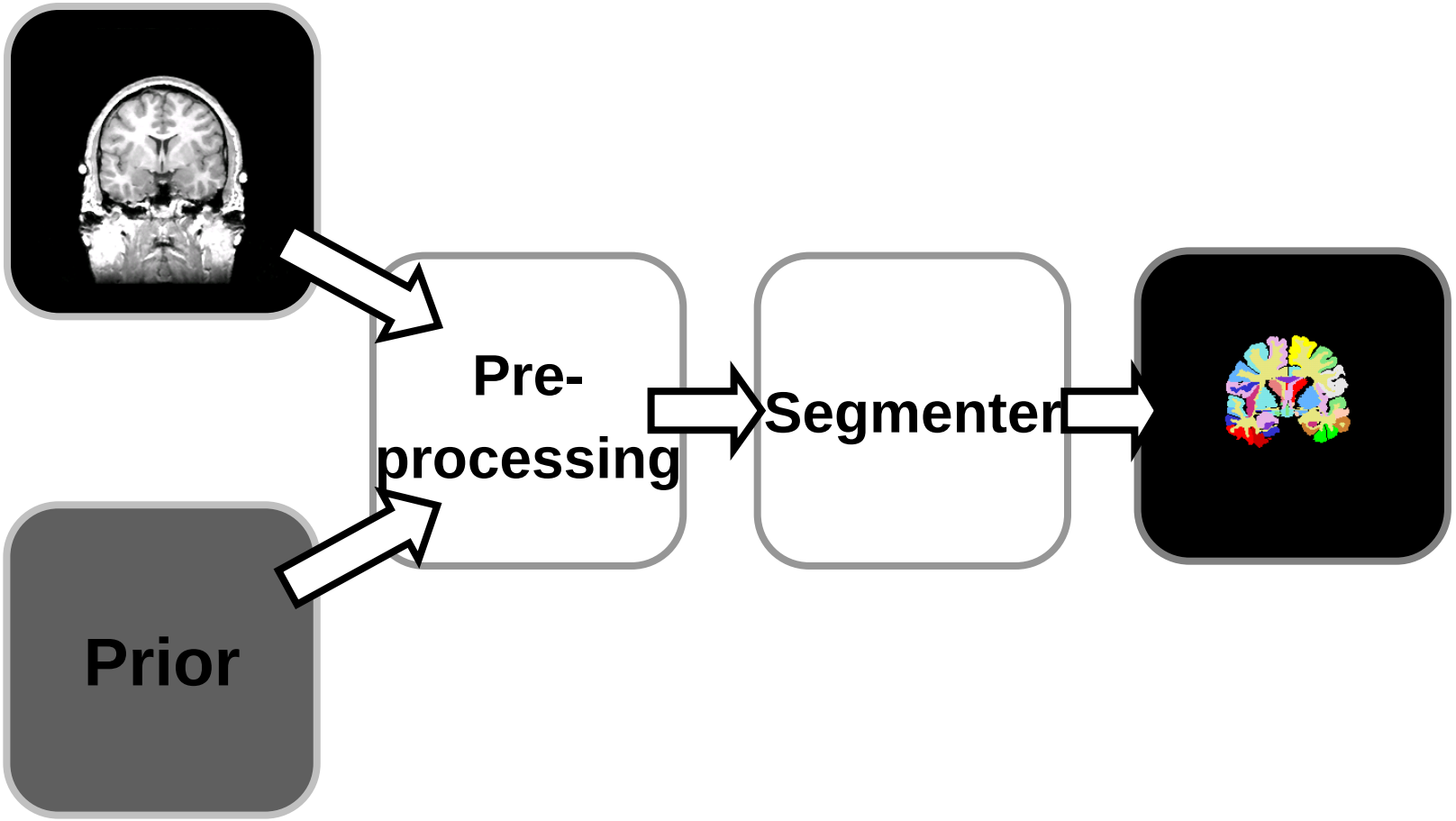
Develop a general purpose segmenter based on a modular framework:

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

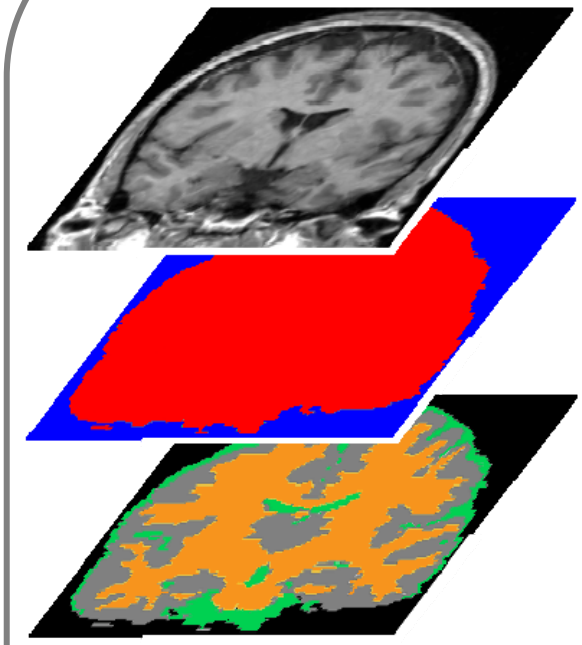




Design

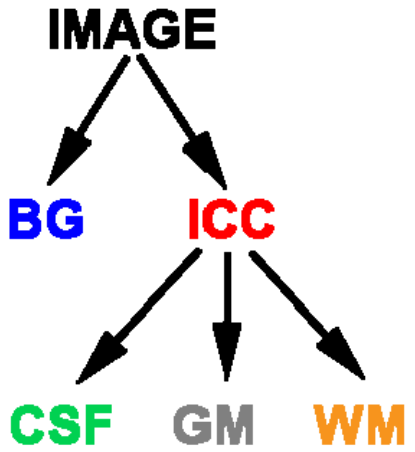


Hierarchical Tree

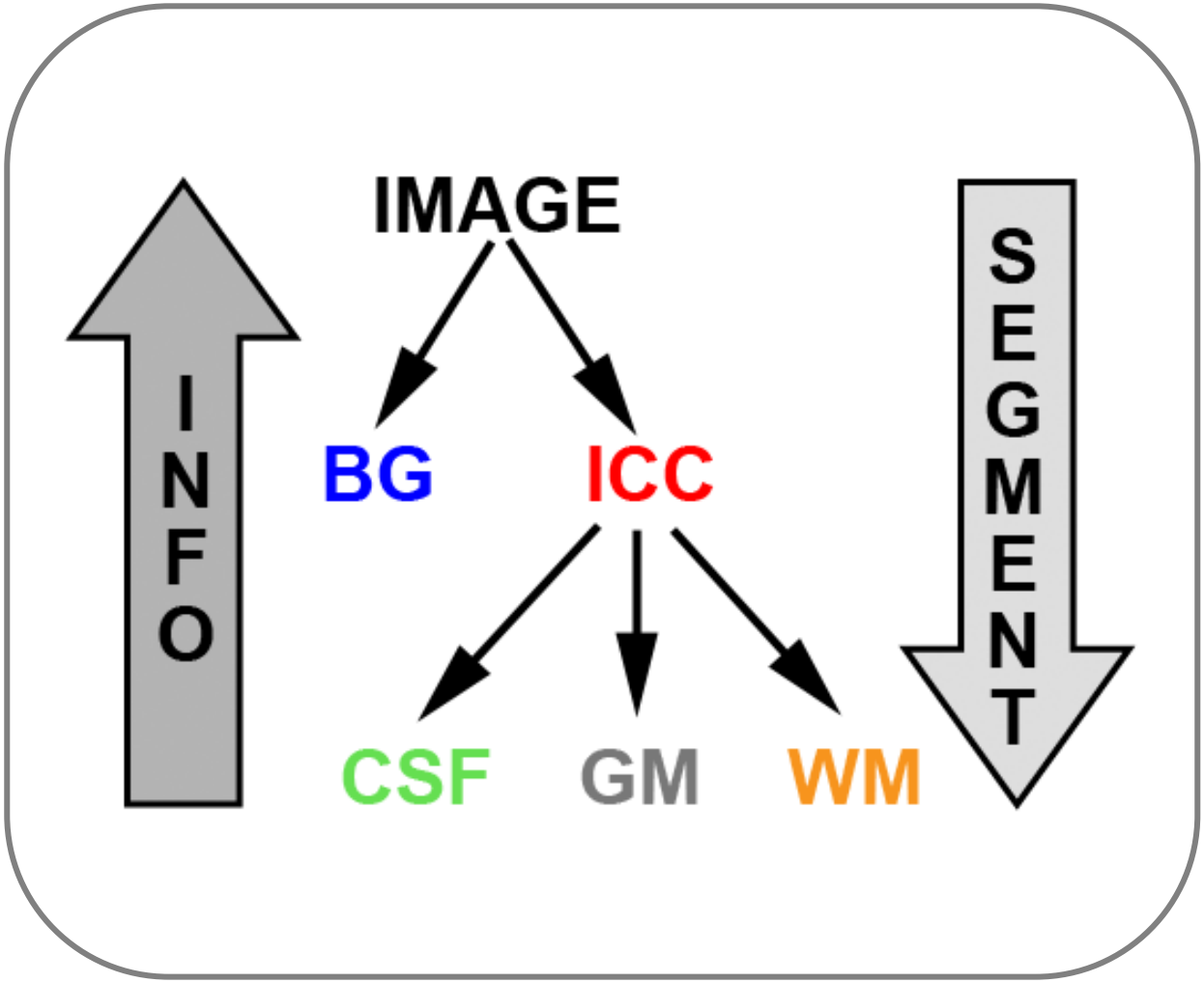


Find Cranial Cavity:

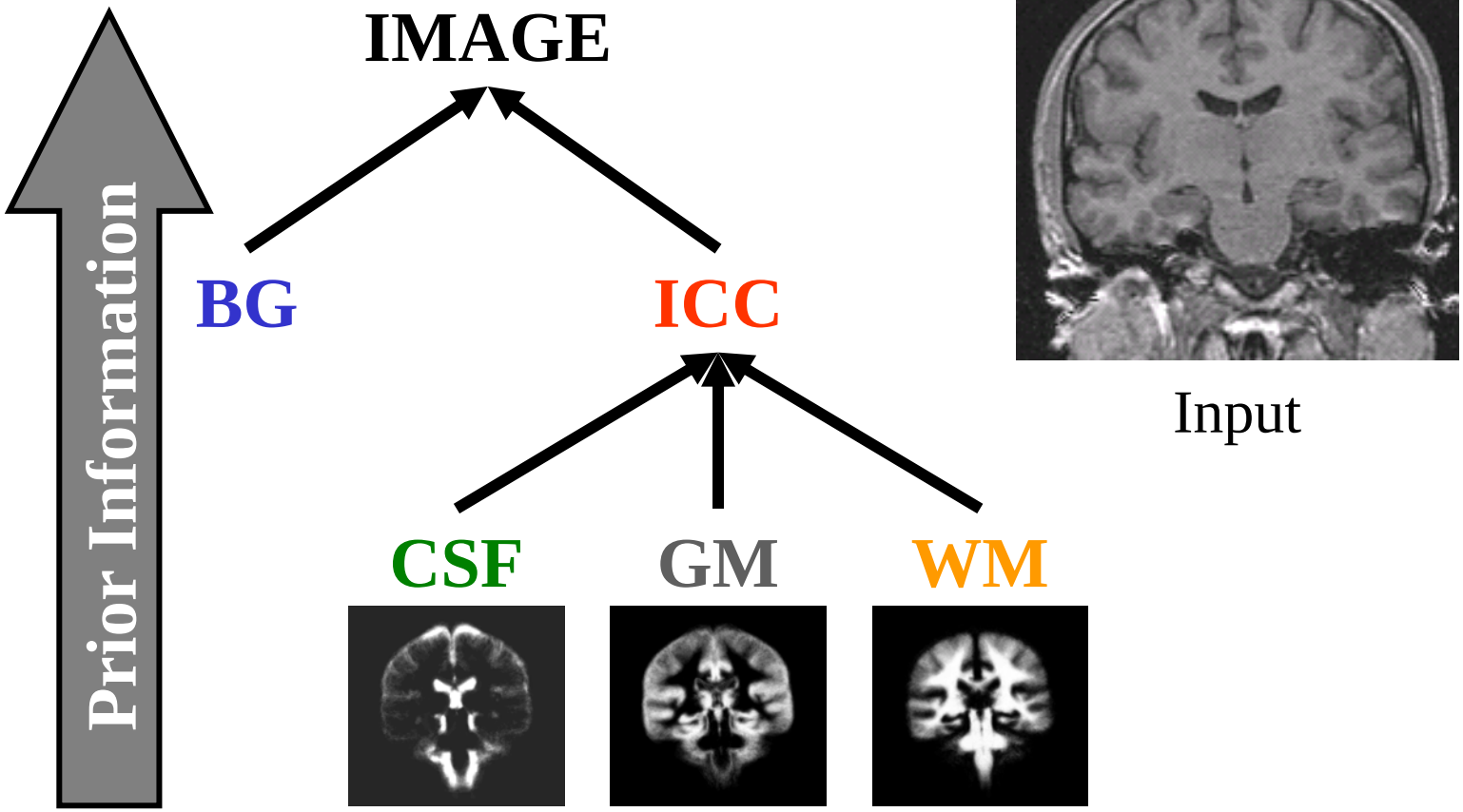
Find Tissue:



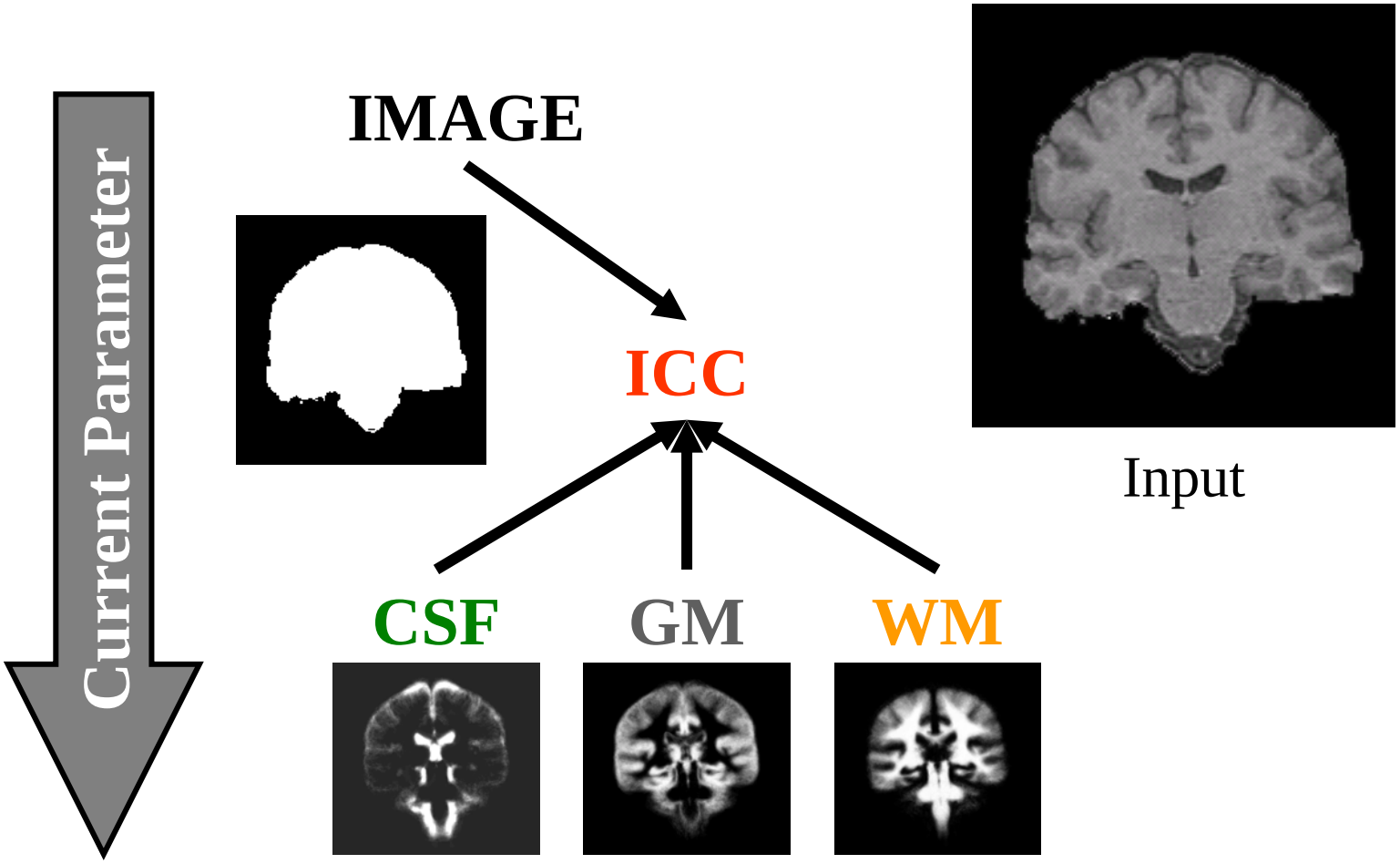
Design of Algorithm



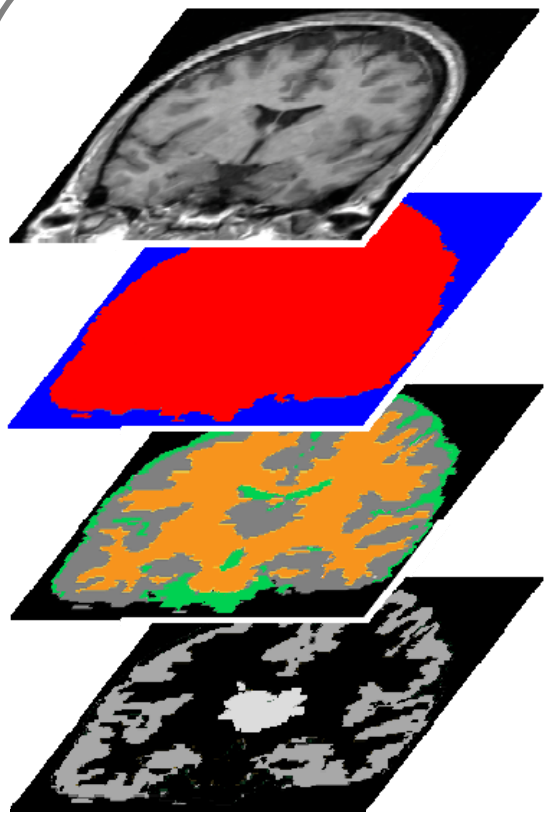
Level 1



Level 2



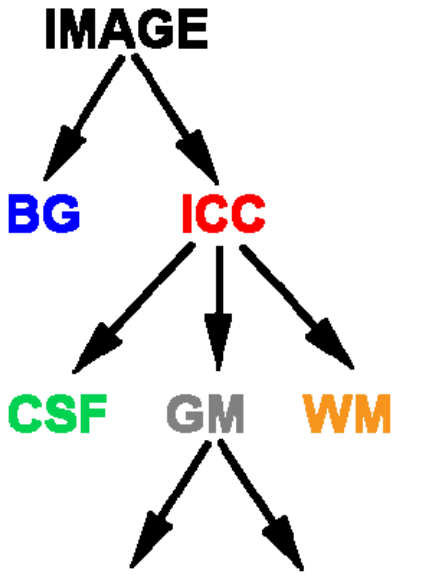
Modify the Tree



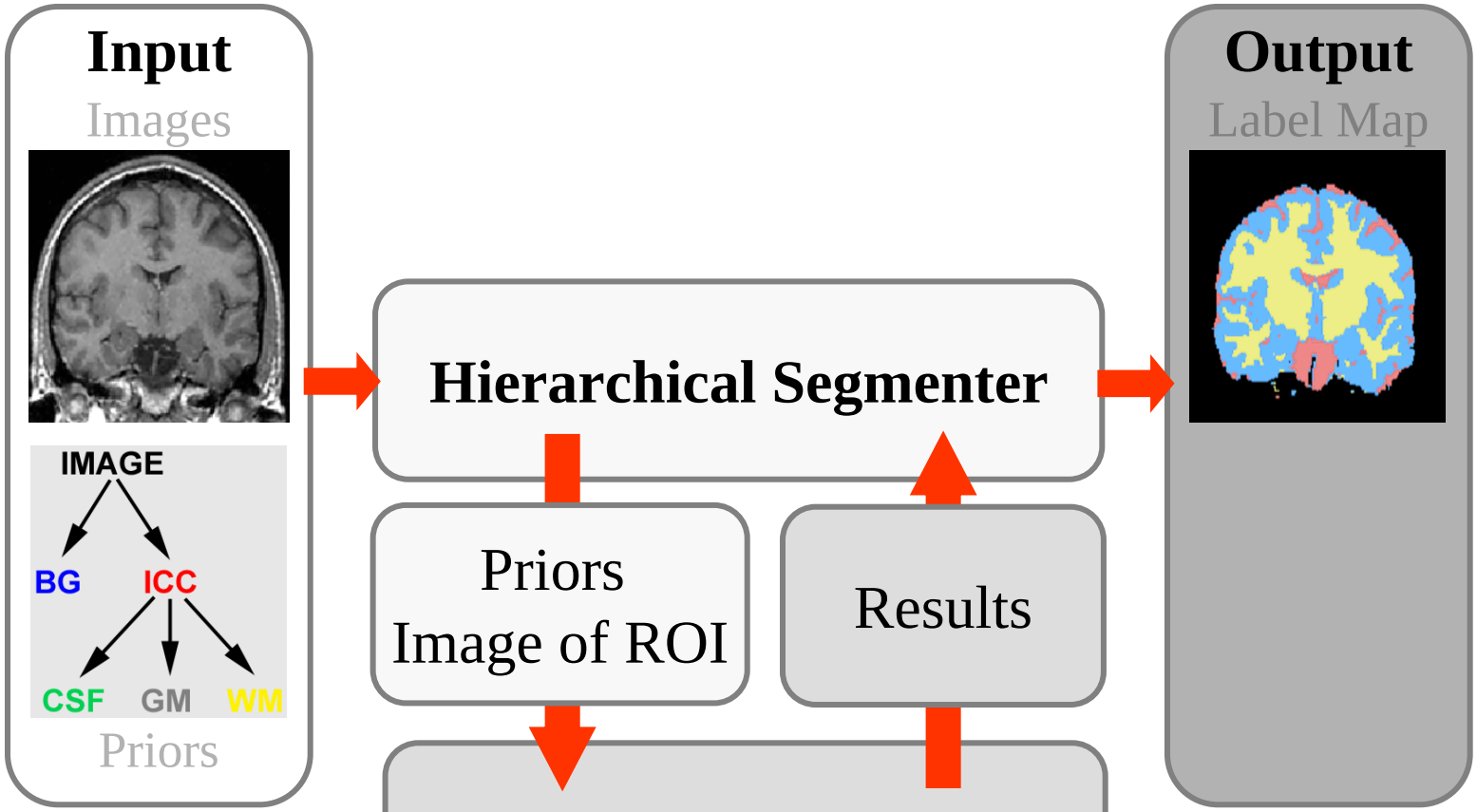
Find Cranial Cavity:

Find Tissue:

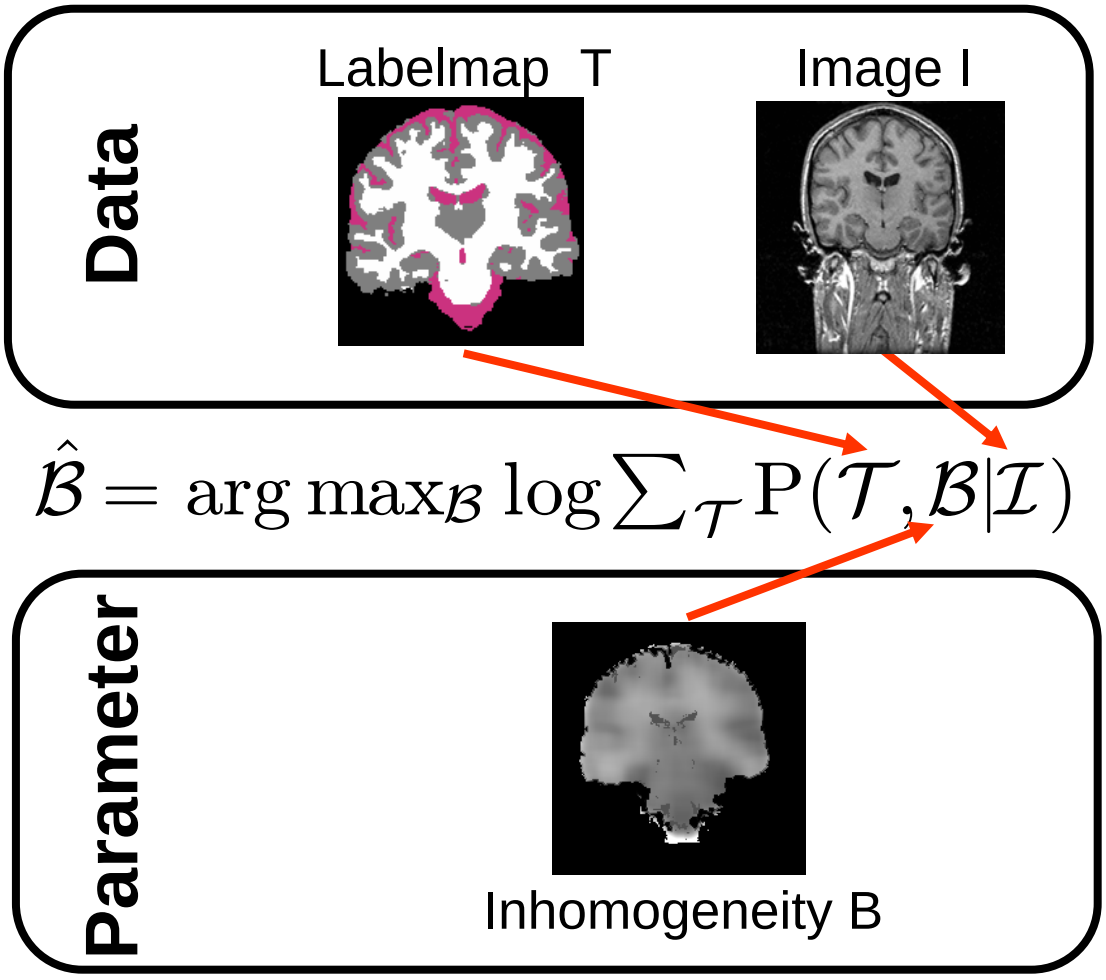
Find Substructures:



Hierarchical Implementation



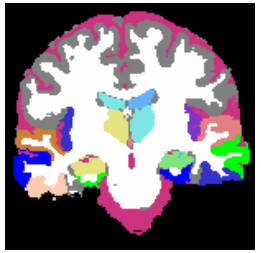
EM Segmenter (Wells et al. 96)



Extended Observed Data

Data

Labelmap T



Hierarchy H

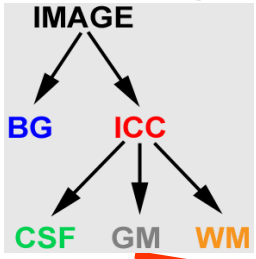
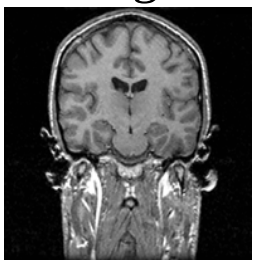
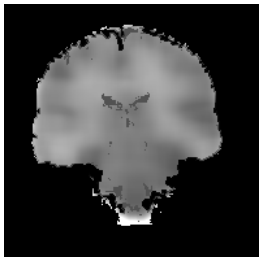


Image I



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

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

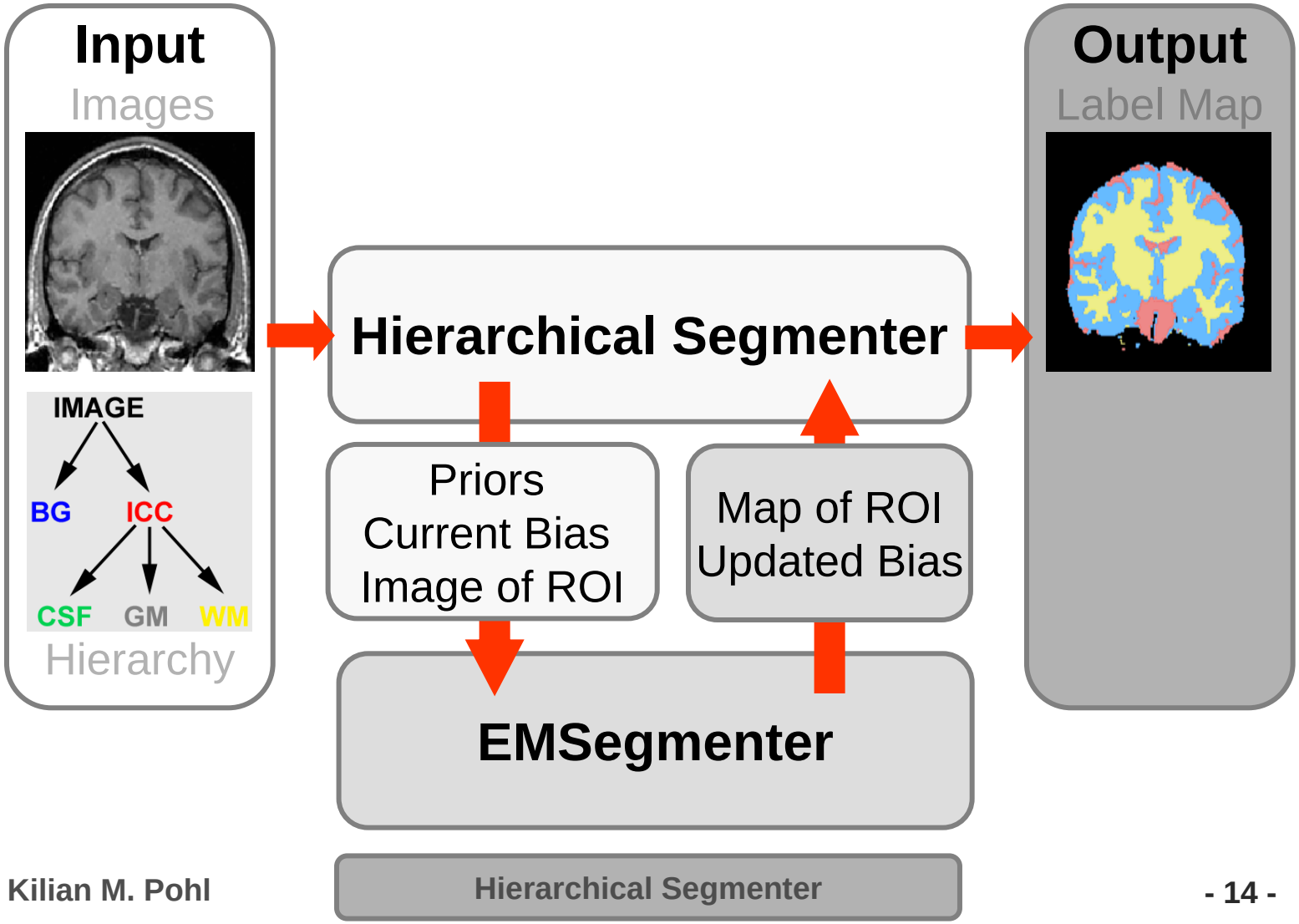
Modified $\quad \mathrm{P}(\mathcal{I}|\mathcal{T} = \mathrm{j}, \mathcal{B}', \mathcal{H}) \equiv \mathcal{N}(\mathcal{I}; \zeta_{\mathcal{H}}^{\mathrm{T}}(\mathcal{B}' + \mu_{\mathrm{j}}), \zeta_{\mathcal{H}}^{\mathrm{T}} \Upsilon_{\mathrm{j}} \zeta_{\mathcal{H}})$

Spatial Prior

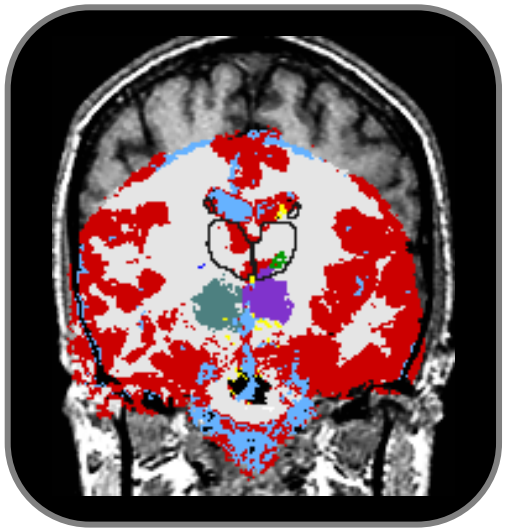
Wells* $\quad \mathrm{P}(\mathcal{T} = \mathrm{j}) \equiv \mathcal{F}_{\mathrm{j}}$

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

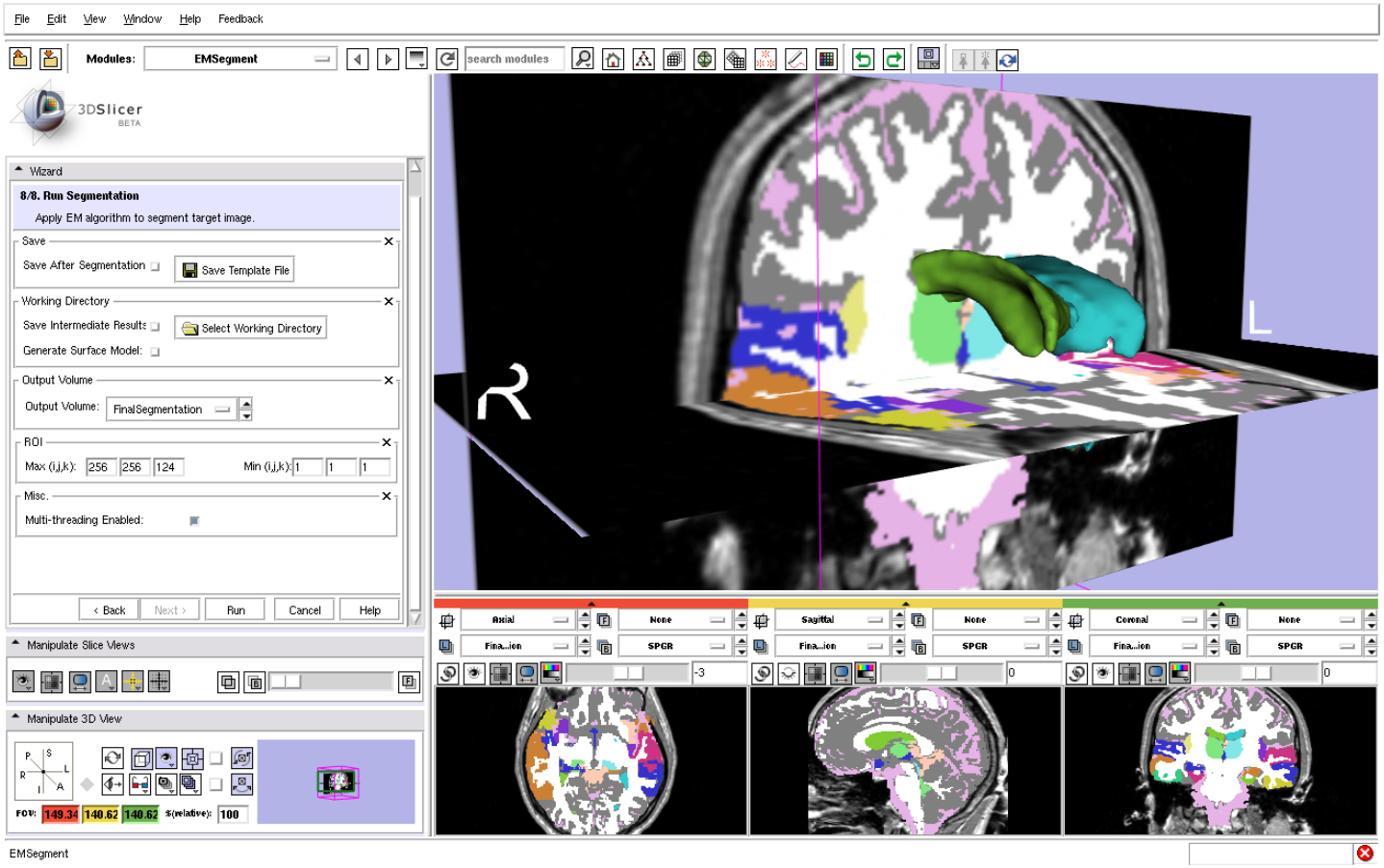
Pohl et al. A Bayesian Model for Joint Segmentation and Registration. NeuroImage, 31(1), pp. 228-239, 2006

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.

Implementation in 3D Slicer

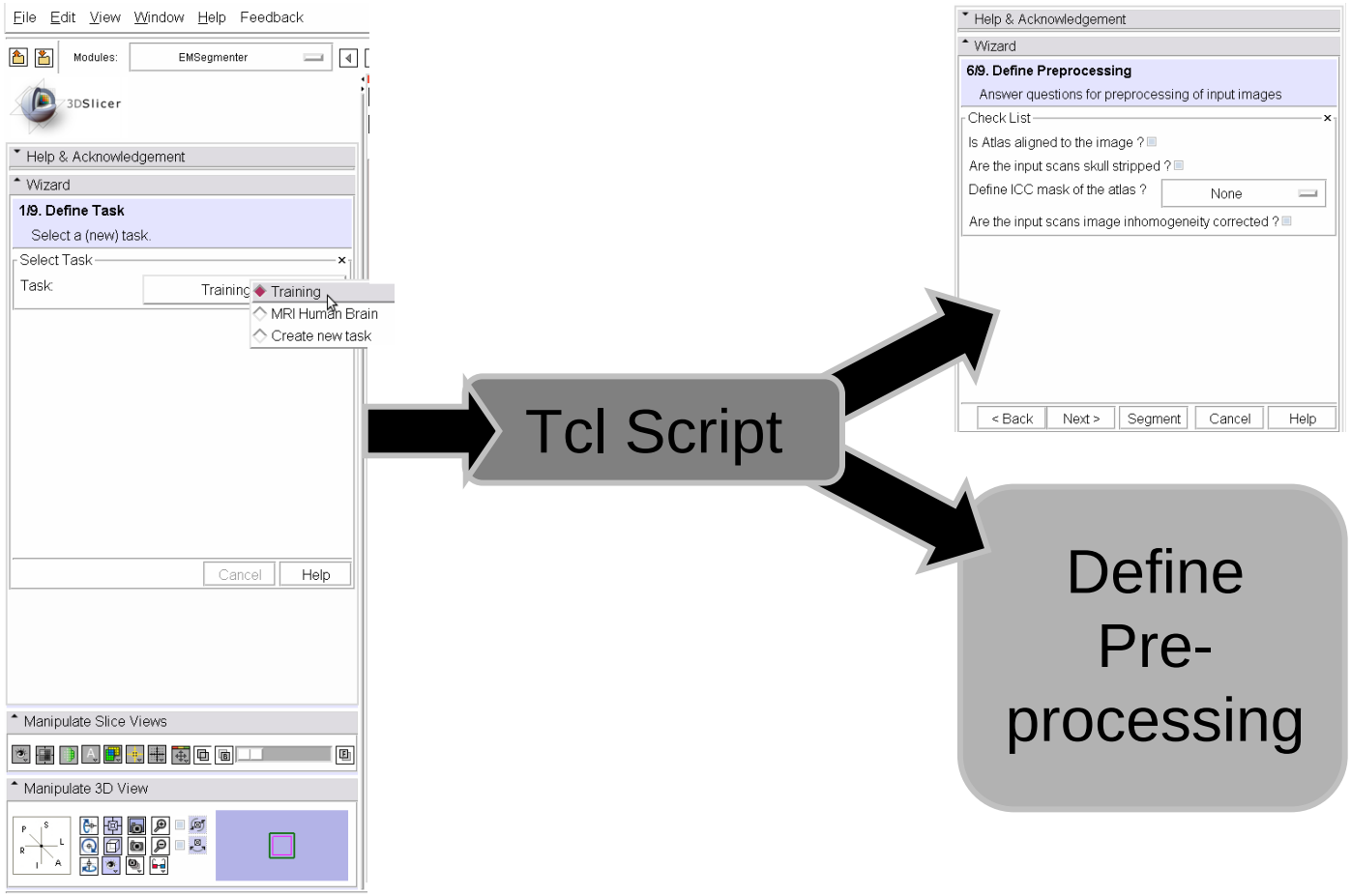


EM Segment Workflow

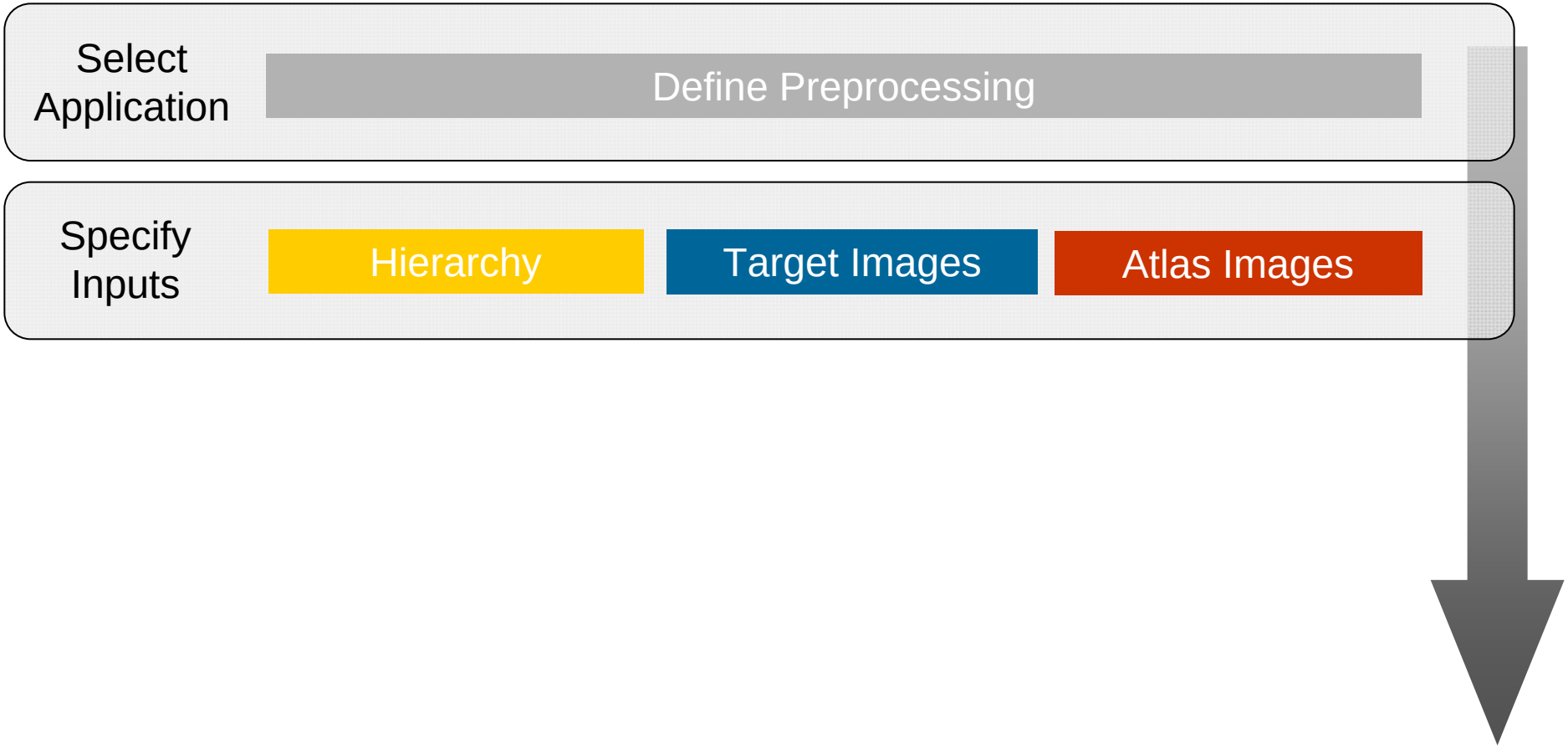
Select Application

Define Preprocessing

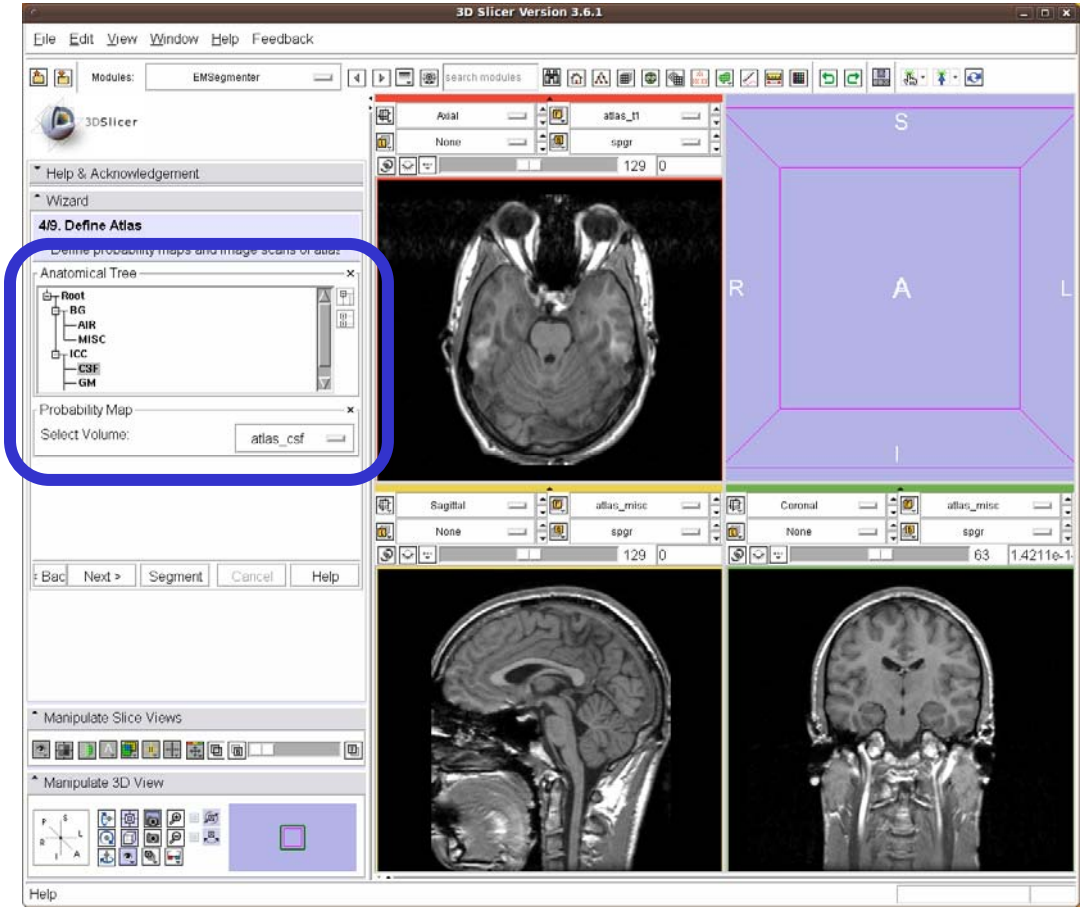
Define Task


File Edit View Window Help Feedback
Modules: EMSegmenter
3DSlicer
Help & Acknowledgement
Wizard
1/9. Define Task
Select a (new) task.
Select Task
Task:
Training
Training
MRI Human Brain
Create new task
Cancel
Help
Manipulate Slice Views
Manipulate 3D View
Tcl Script
Help & Acknowledgement
Wizard
6/9. Define Preprocessing
Answer questions for preprocessing of input images
Check List
Is Atlas aligned to the image ?
Are the input scans skull stripped ?
Define ICC mask of the atlas ?
None
Are the input scans image inhomogeneity corrected ?
< Back
Next >
Segment
Cancel
Help
Define Pre-processing

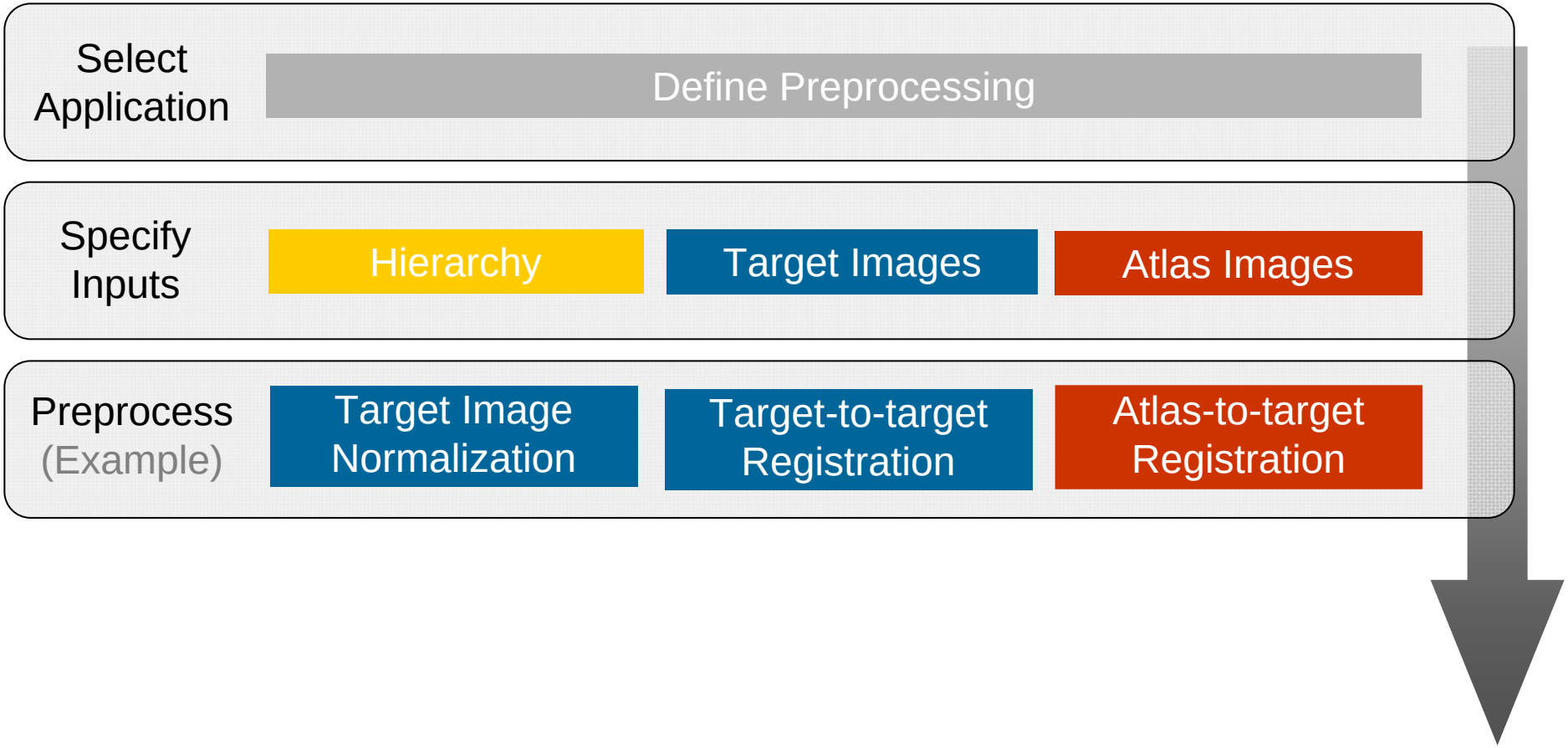
EM Segment Workflow



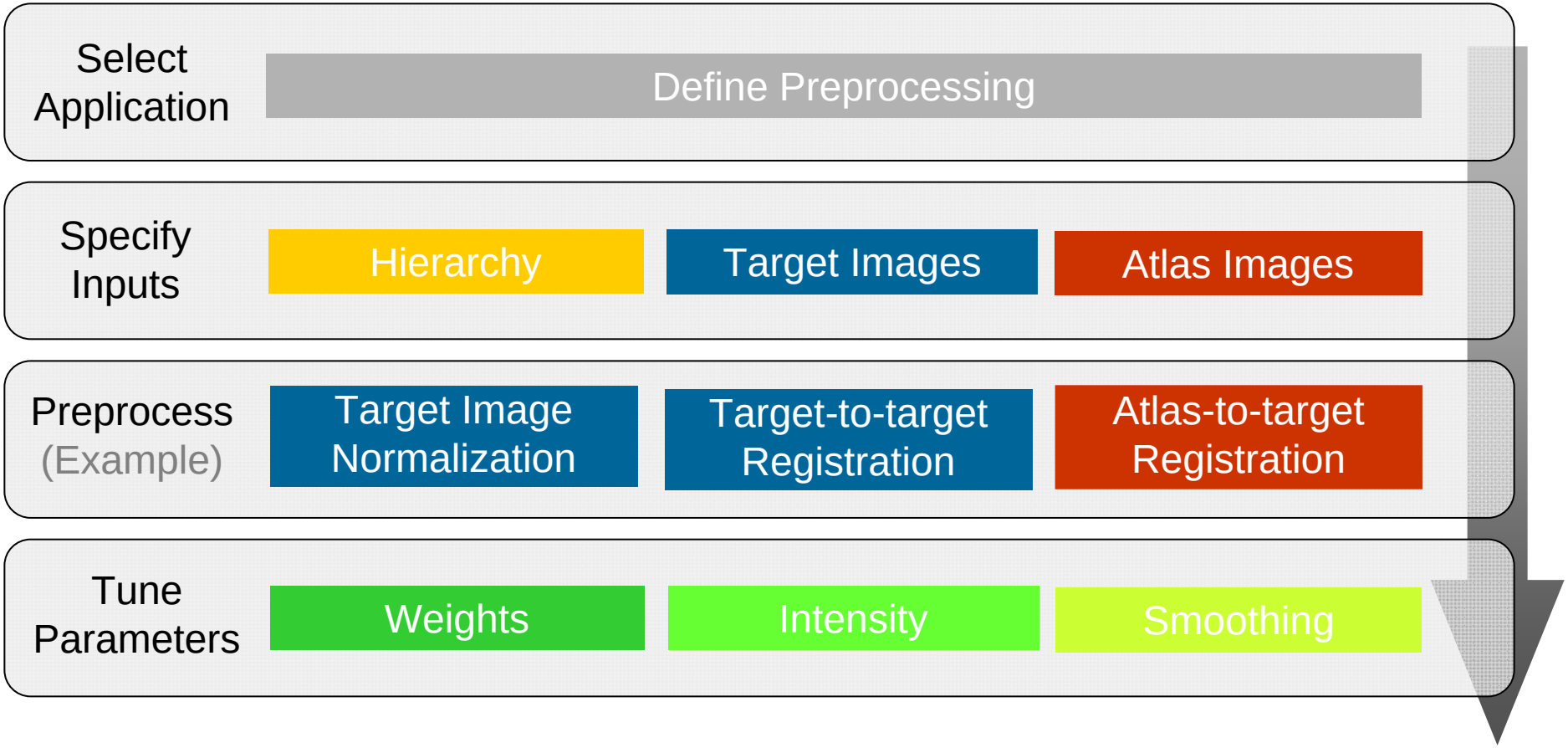
Define Hierarchy



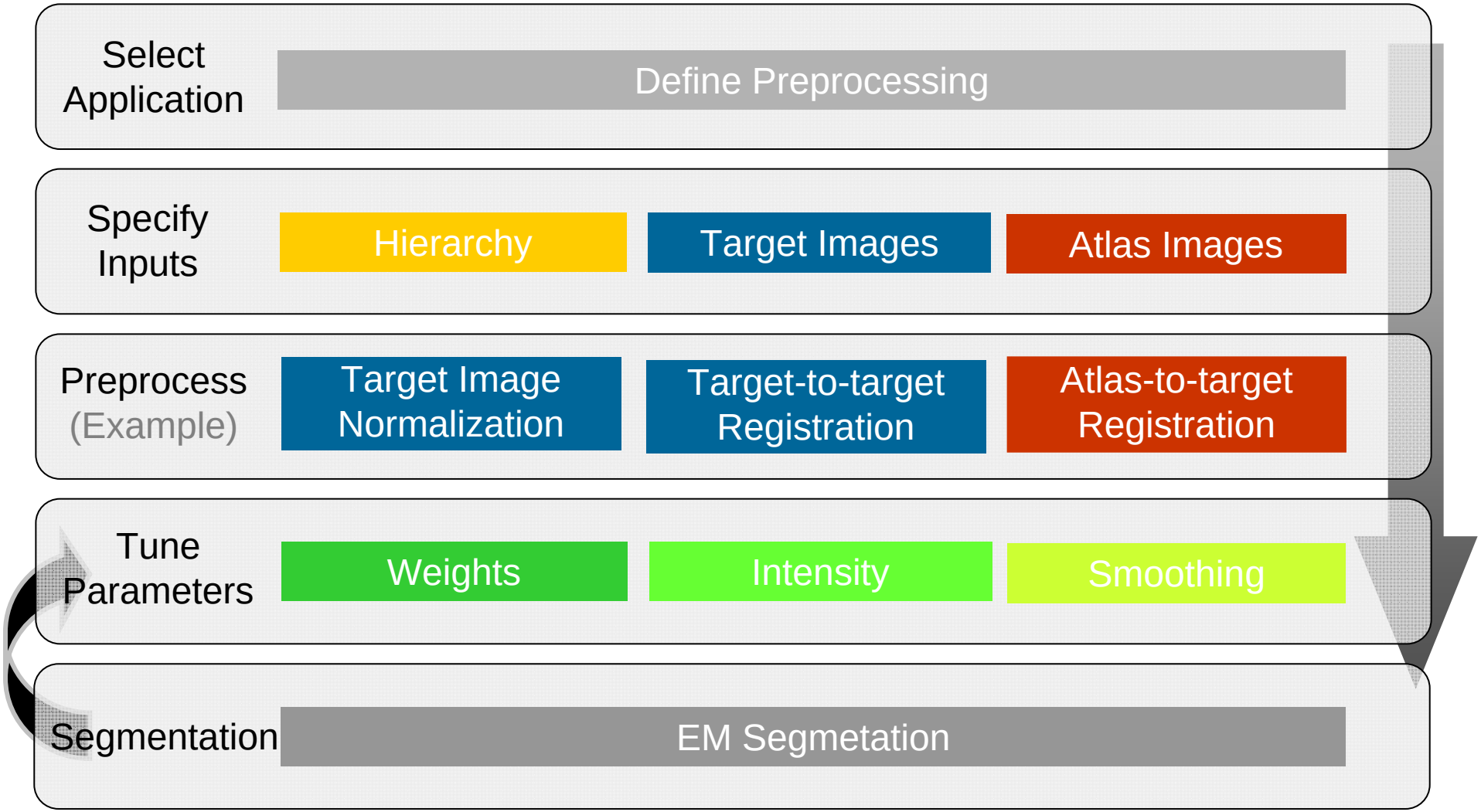
EM Segment Workflow



EM Segment Workflow

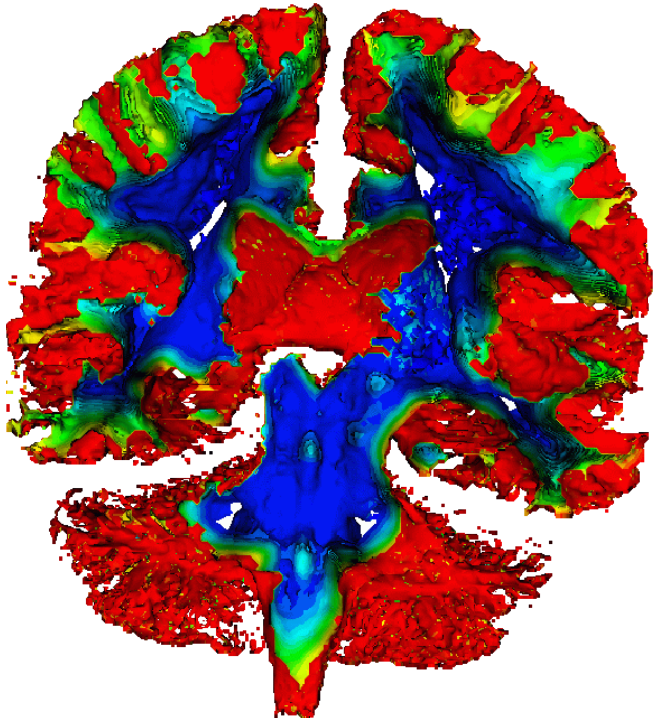


EM Segment Workflow



Interacting with EM Segmenter

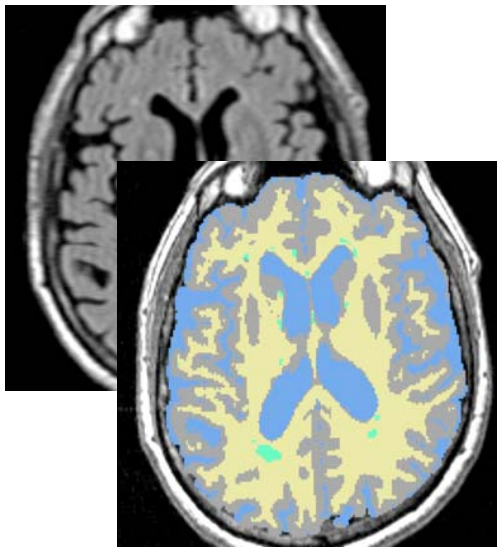
- Fine-tune Setting to Application
- Apply Setting to New Scan
- Command Line Module

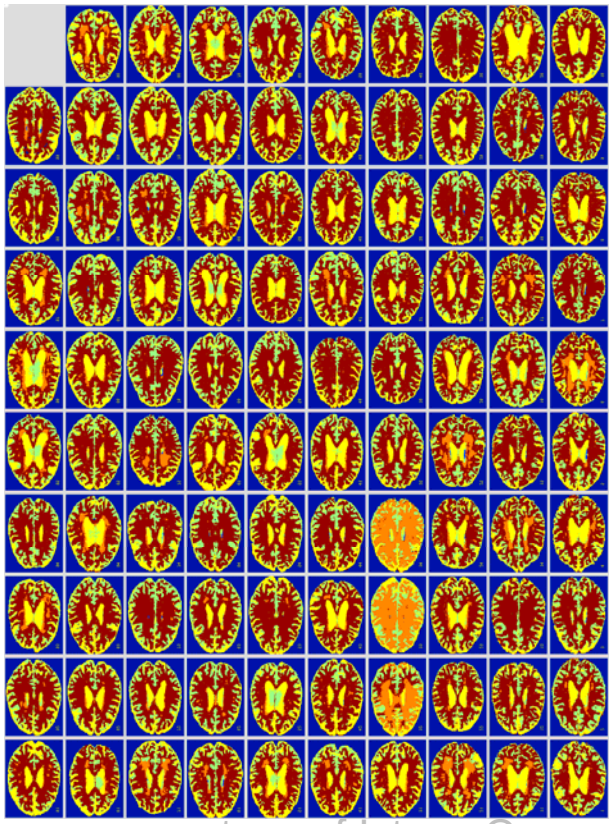


Human Brain

Psychiatry
Neuroimaging Lab
BWH

Lesion Detection



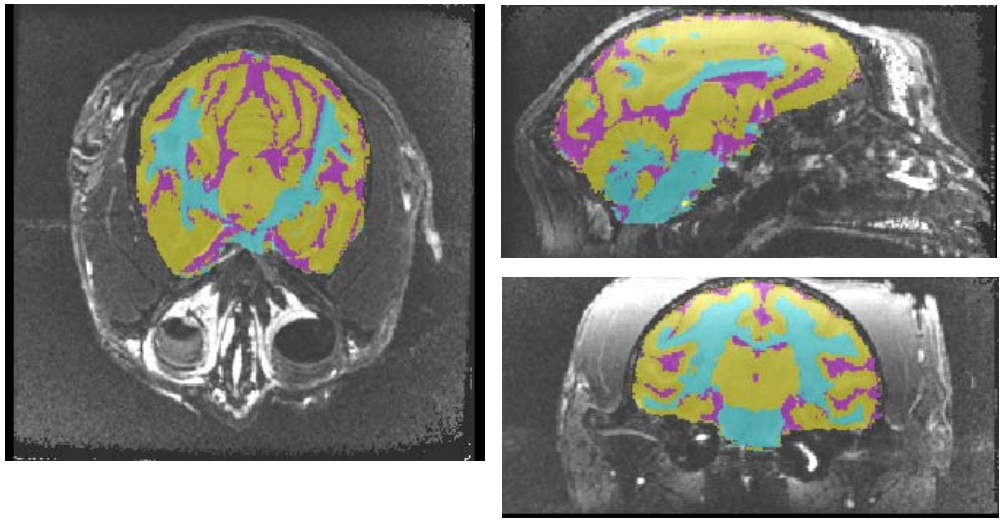


courtesy of Istvan Csapo

Progression of Multiple Sclerosis lesions

Non-Human Primates

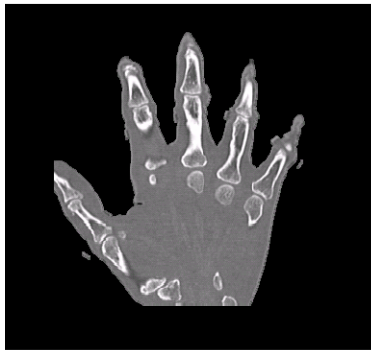
VIRGINIA TECH WAKE FOREST UNIVERSITY
School of Biomedical Engineering and Sciences



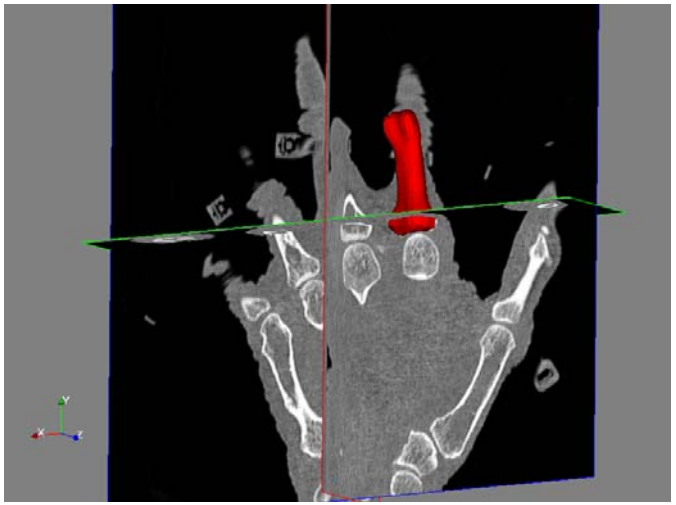
courtesy of Chris Wyatt

Measuring Alcohol and Stress Interactions with Structural and Perfusion MRI

CT Hand Bone Segmentation



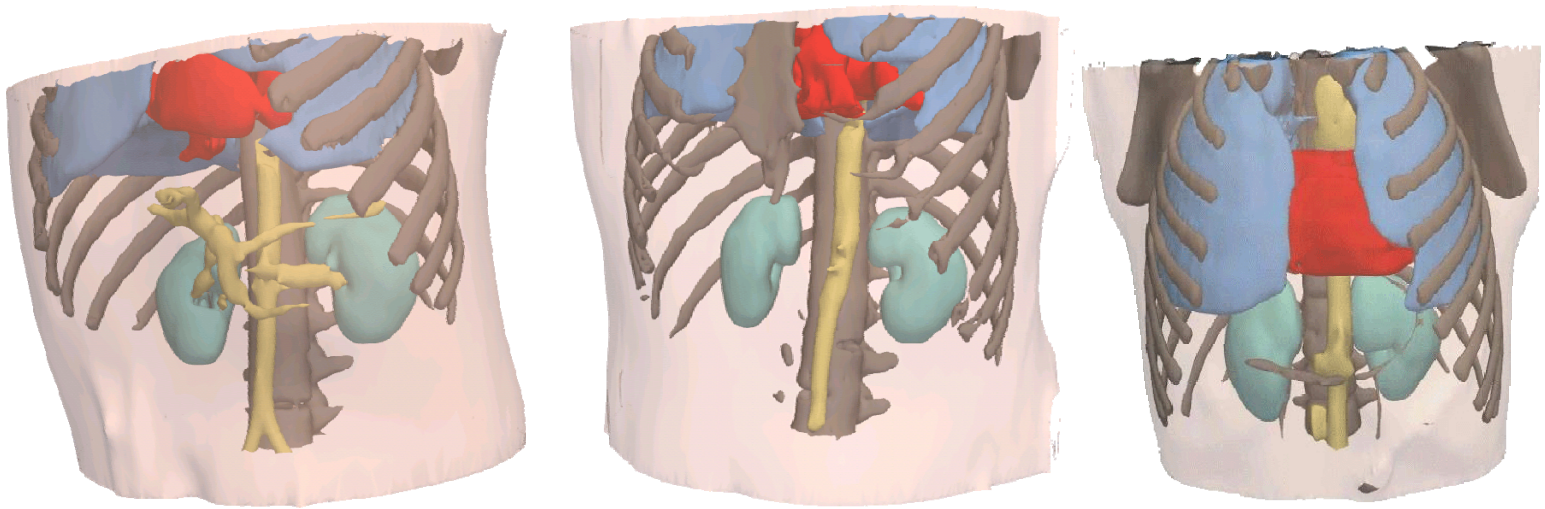
MIMX
THE UNIVERSITY OF IOWA



courtesy of Austin Ramme
and Vince Magnotta

Developing patient-specific kinematic models

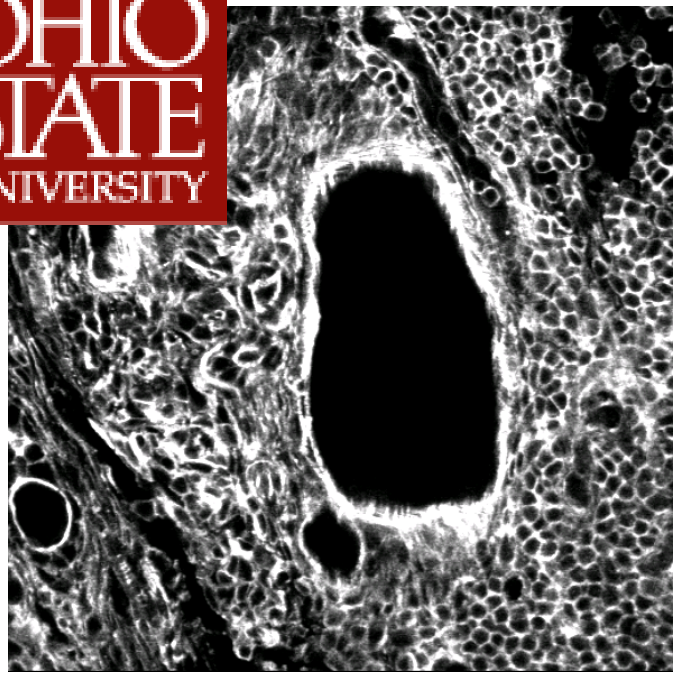
CT Torso Segmentation

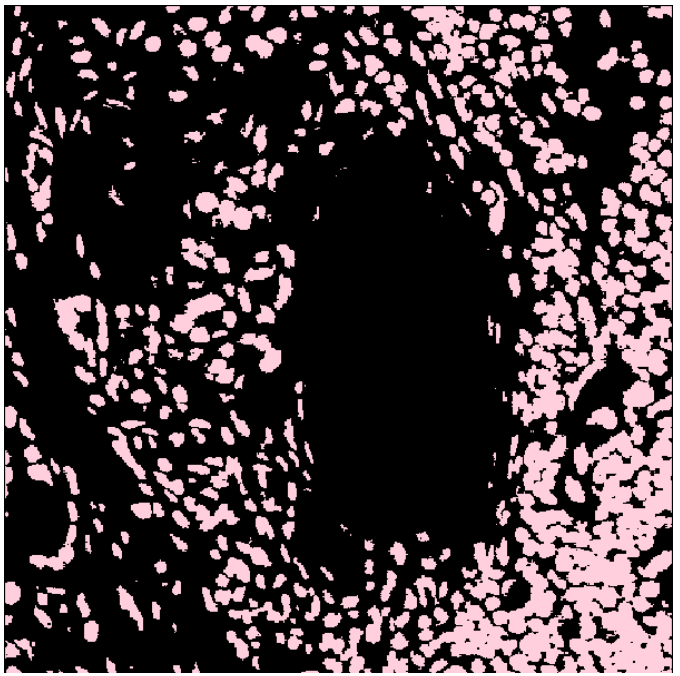


Detect internal hemorrhage
in the field setting

CIMIT
Center for Integration of Medicine
& Innovative Technology

Segmentation of Microscopy Images

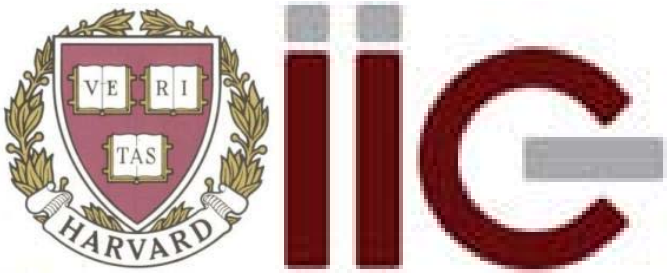




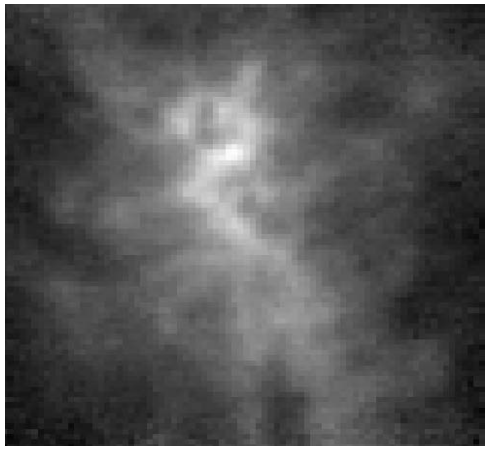
courtesy of Brad Davis

Detecting patterns in biology

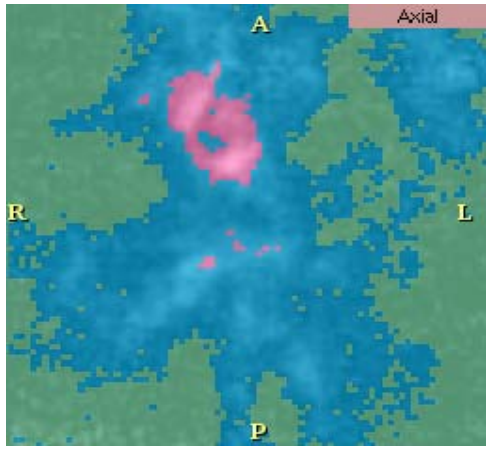
Astronomy Images



Initiative in Innovative Computing, Harvard



Detecting Star Forming Regions



courtesy of Michelle Borkin

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.
- Koo et al. Smaller neocortical gray matter and larger sulcal CSF volumes in neuroleptic-naive females with schizotypal personality disorder. Archives of General Psychiatry, 63, pp. 1090-1100, 2006.
- Zöllei et al. The Impact of Atlas Formation Methods on Atlas-Guided Brain Segmentation, MICCAI 2007
- Pohl et al. Anatomical Guided Segmentation with Non-Stationary Tissue Class Distributions in an Expectation-Maximization Framework, In Proc. ISBI'2004, pp. 81 – 84, 2004.

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/

Thank You

Daniel Haehn
Dominique Belhachemi