MICCAI SEPTEMBER 20-24, 2010 BEIJING · CHINA

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

HAMMER: Hierarchical Attribute Matching Mechanism for Elastic Registration

By Dinggang Shen

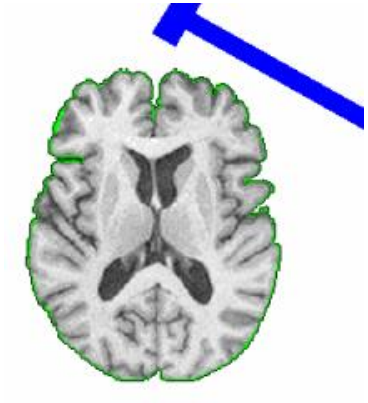


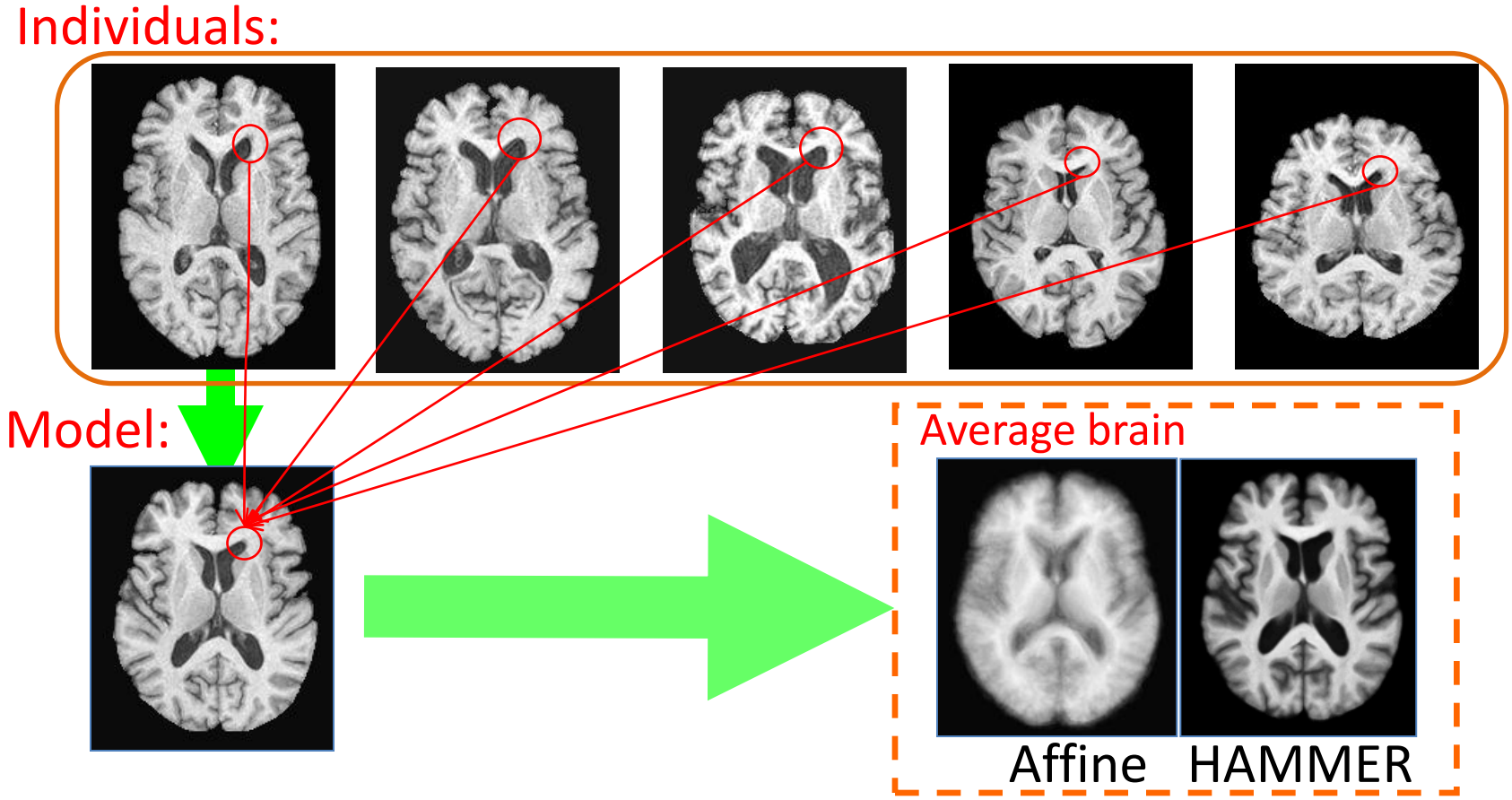
Image Display, Enhancement, and Analysis IDEA

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Email: dgshen@med.unc.edu homepage: http://www.med.unc.edu/~dgshen/

Motivations

Develop a fully automatic registration method by robust anatomical correspondence detection.



Innovations

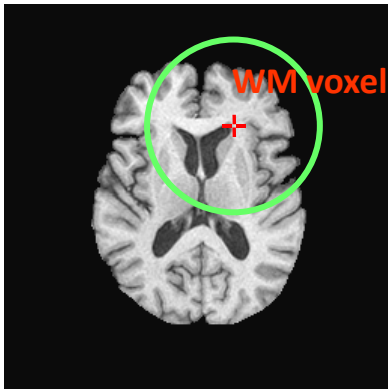
1. Use attribute vector to detect the correspondence
   (*image intensity, edge types, geometric moment invariants*)

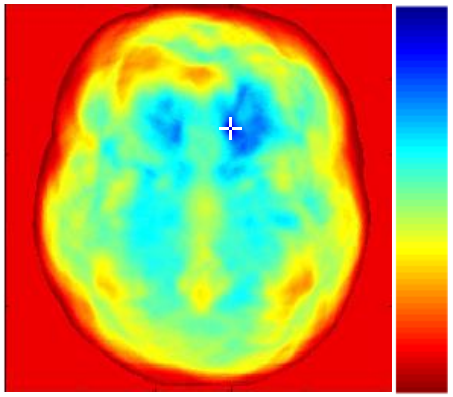
Distinctive attribute vectors

Reduce the ambiguity in feature matching

Select most distinctive voxels in the image

Driving voxels

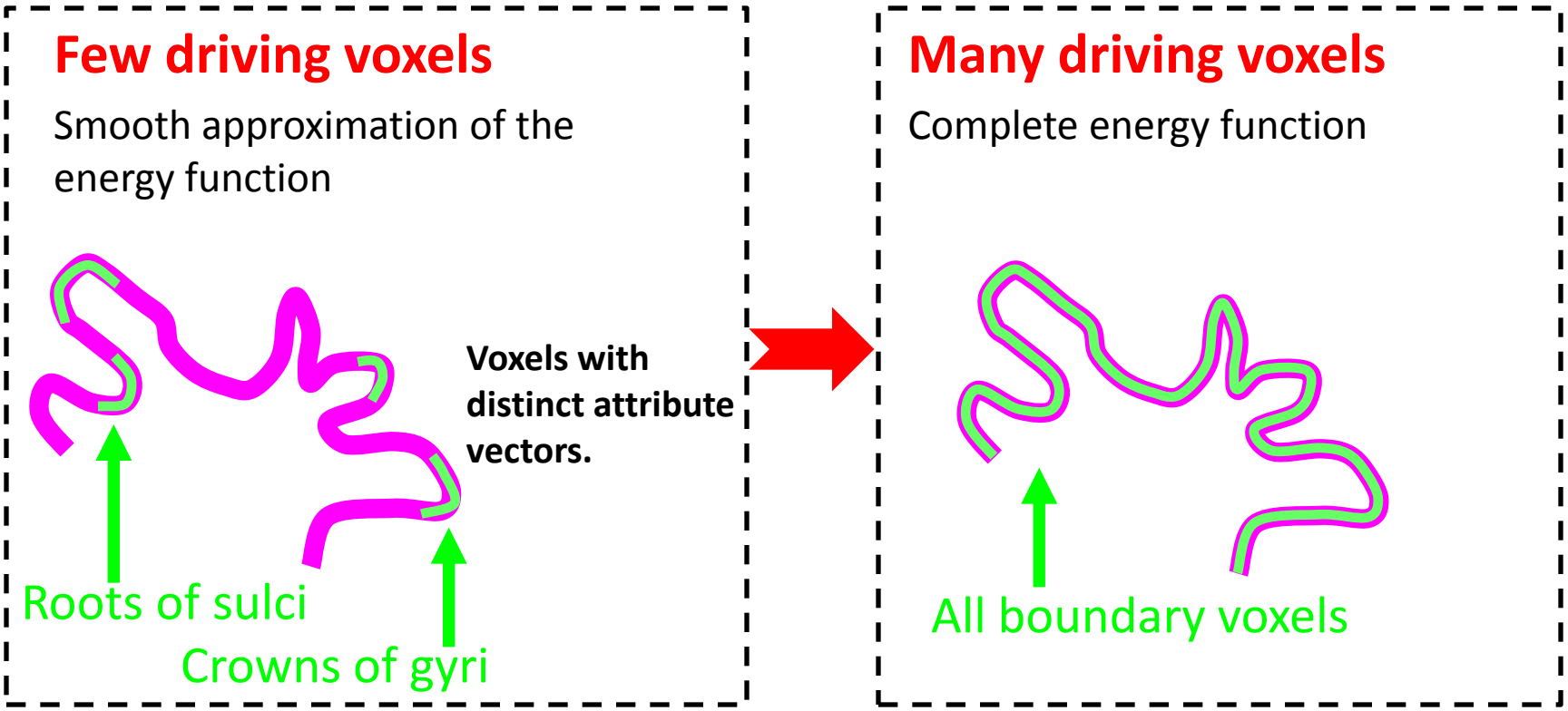




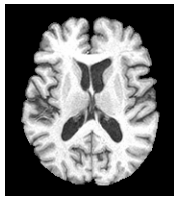
Similarity map

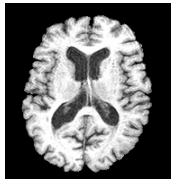
Innovations

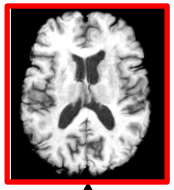
2. A hierarchical approximation of the energy function, initially by *lower* dimensional energy functions with significantly *fewer* local minima.



Methods







1. Remove the global different by linear registration

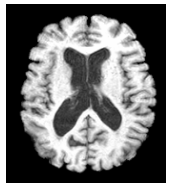
2. Hierarchically select driving voxels

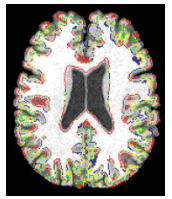
3. Establish the correspondence on driving voxels

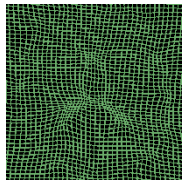
4. Interpolate the dense deformation field

5. Relax the criterion of driving voxel

Linear registration result



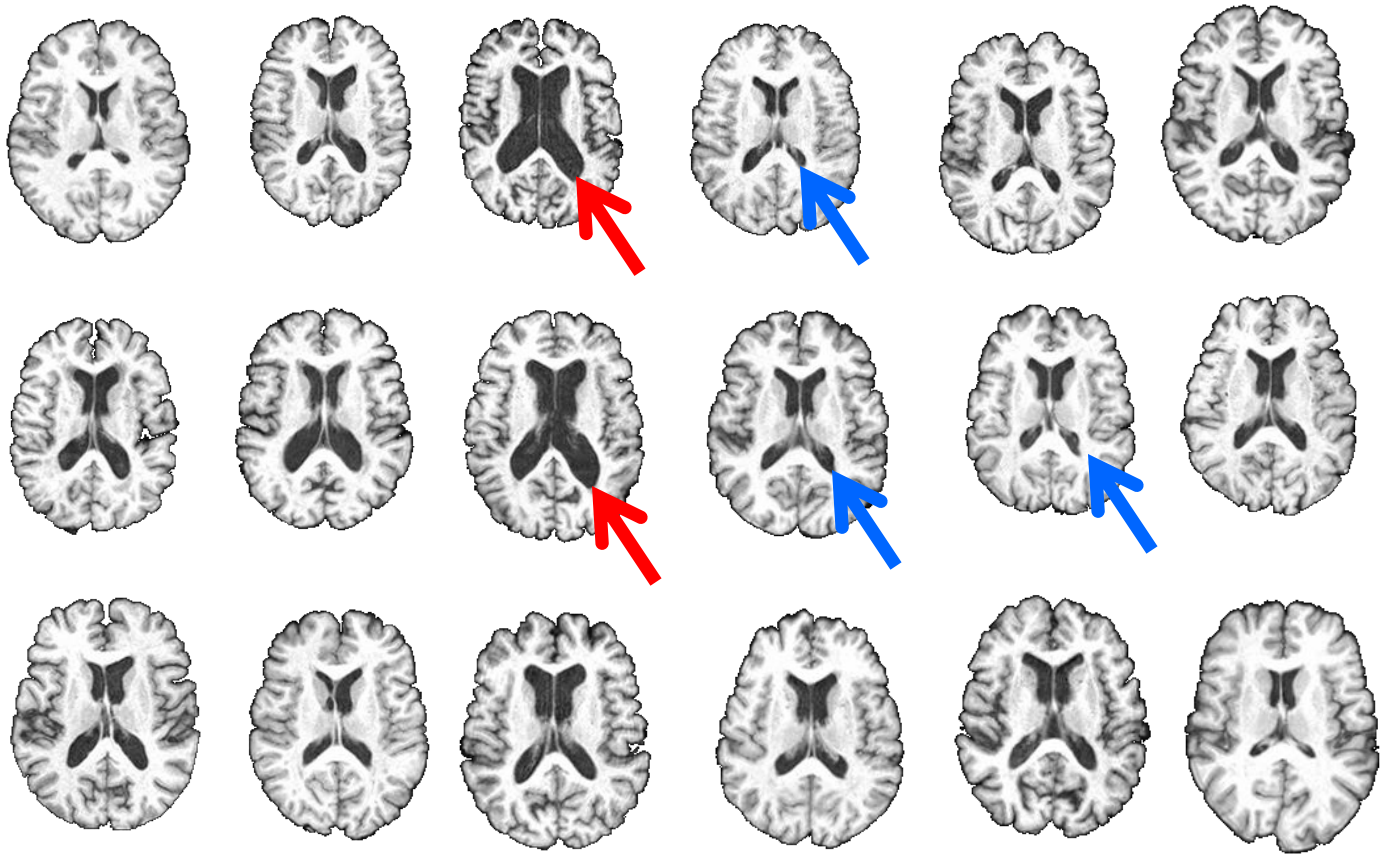




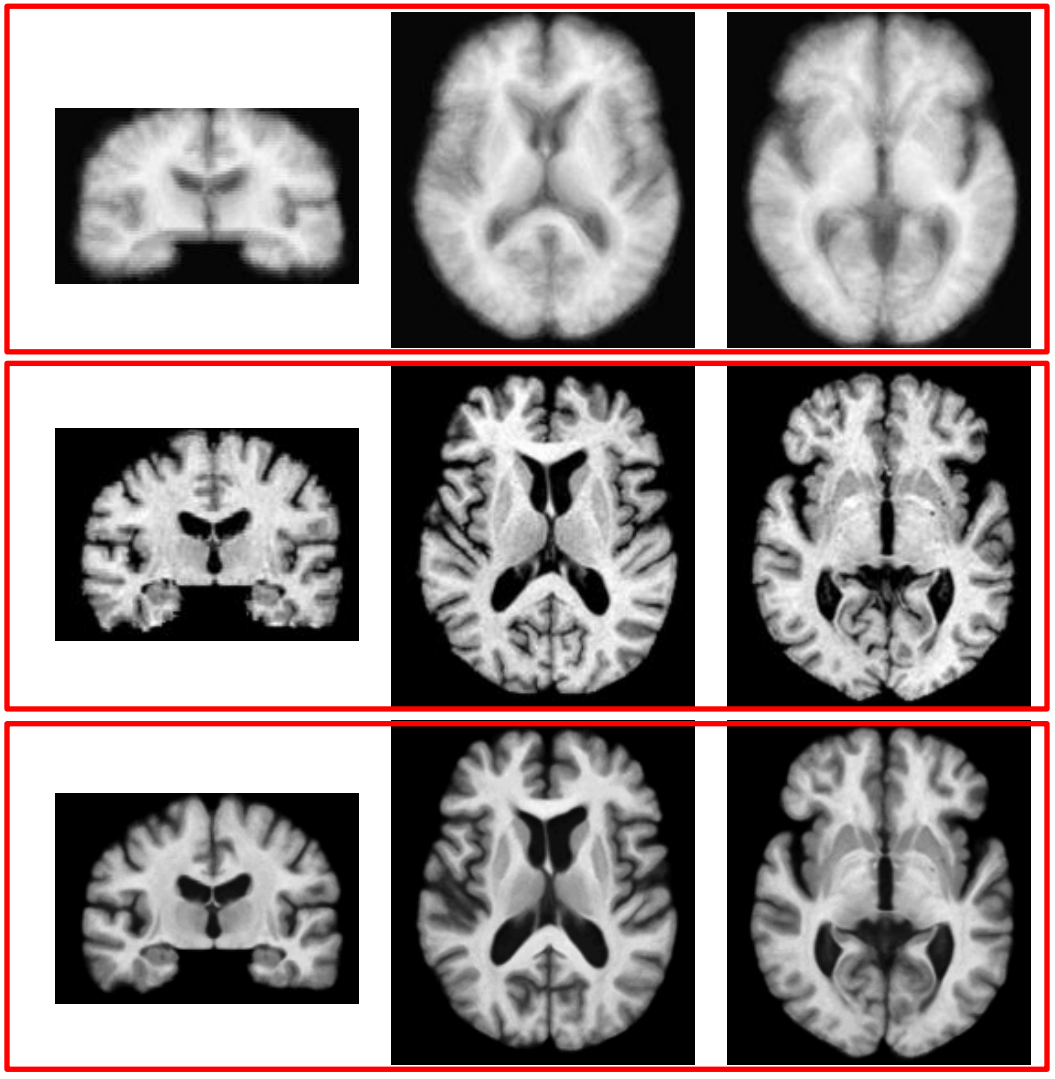
- Shen, *et al.*, "Very High Resolution Morphometry Using Mass-Preserving Deformations and **HAMMER** Elastic Registration", *NeuroImage*, 18(1):28-41, Jan 2003.
- Shen, *et al.*, "**HAMMER**: Hierarchical Attribute Matching Mechanism for Elastic Registration", *IEEE Trans. on Medical Imaging*, 21(11):1421-1439, Nov 2002. **(2006 Best Paper Award, IEEE Signal Processing Society)**

Results

18 elderly brain used to construct the average brain



Results

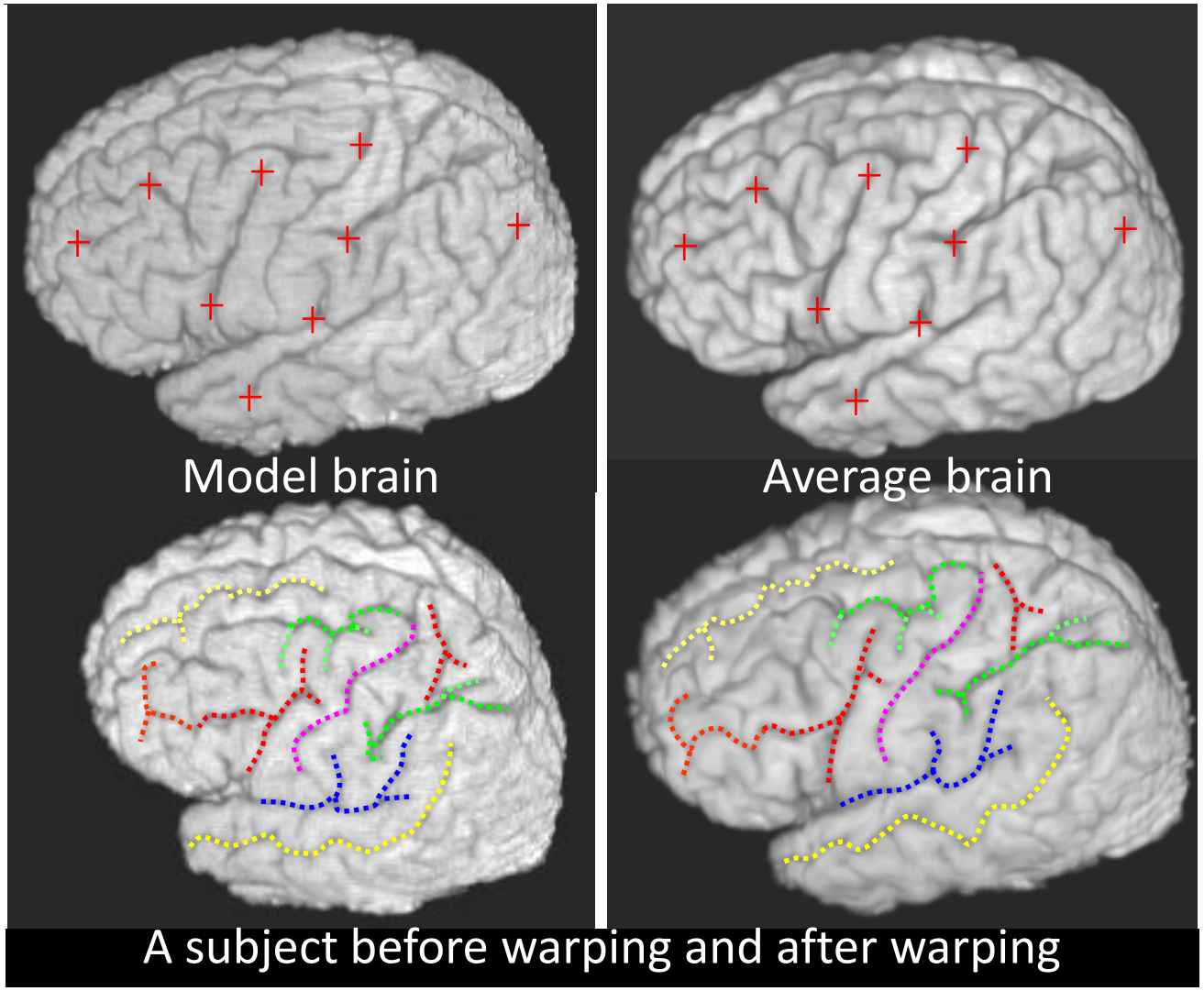


Linear registration

Model

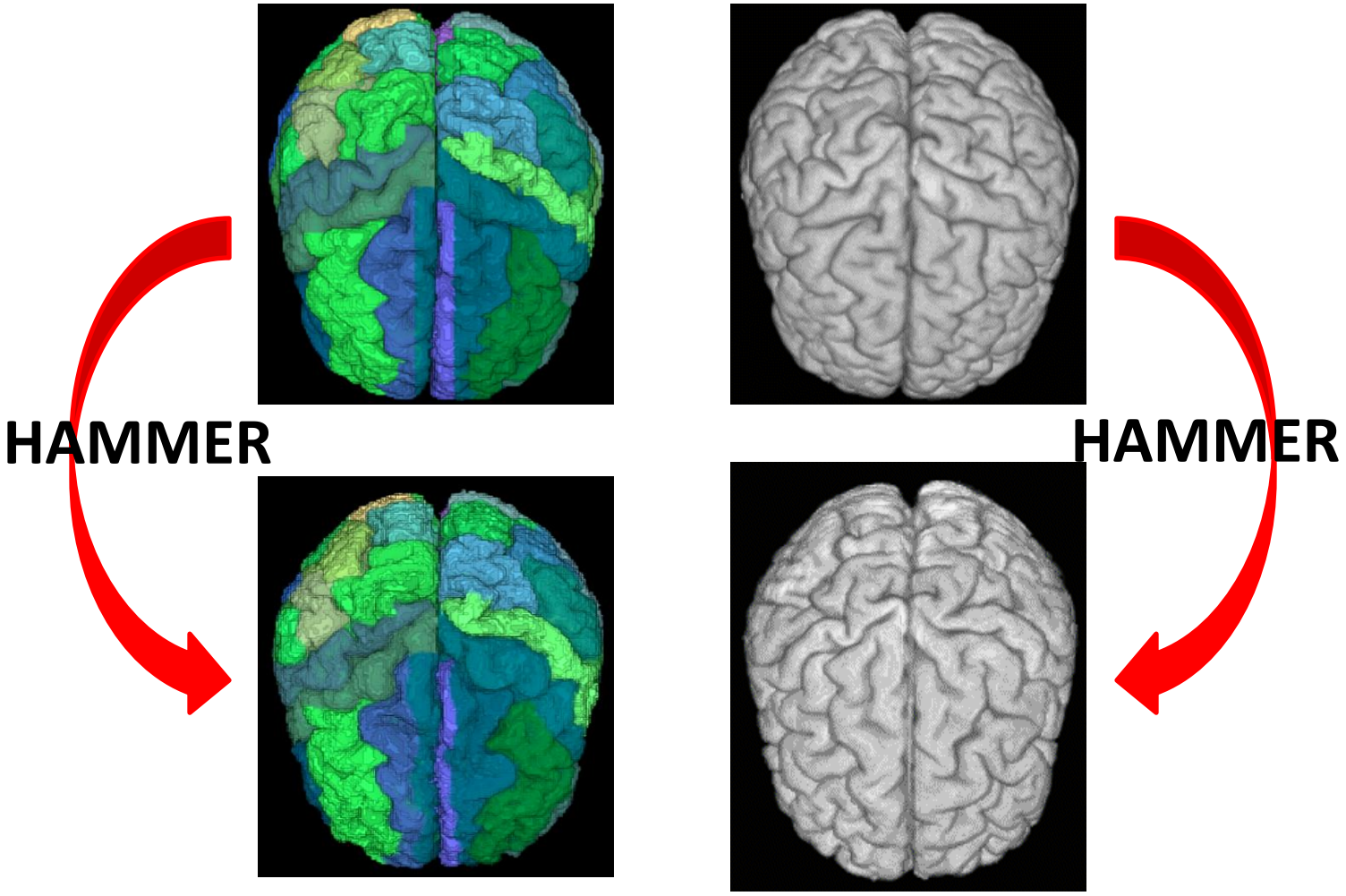
Average brain by HAMMER

Results


Model brain
Average brain
A subject before warping and after warping

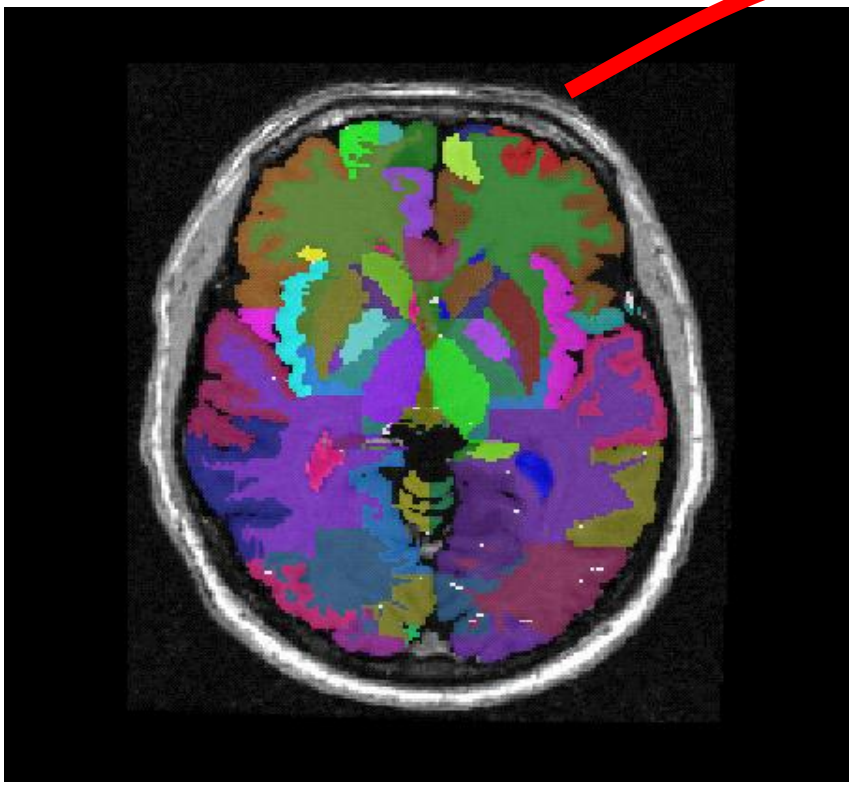
Results

HAMMER in labeling brain structures

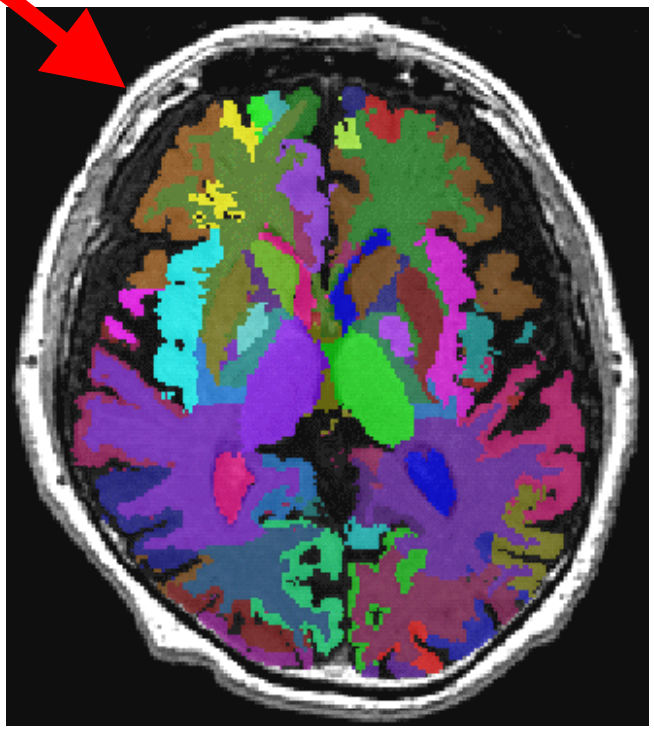


Results

Cross-sectional views



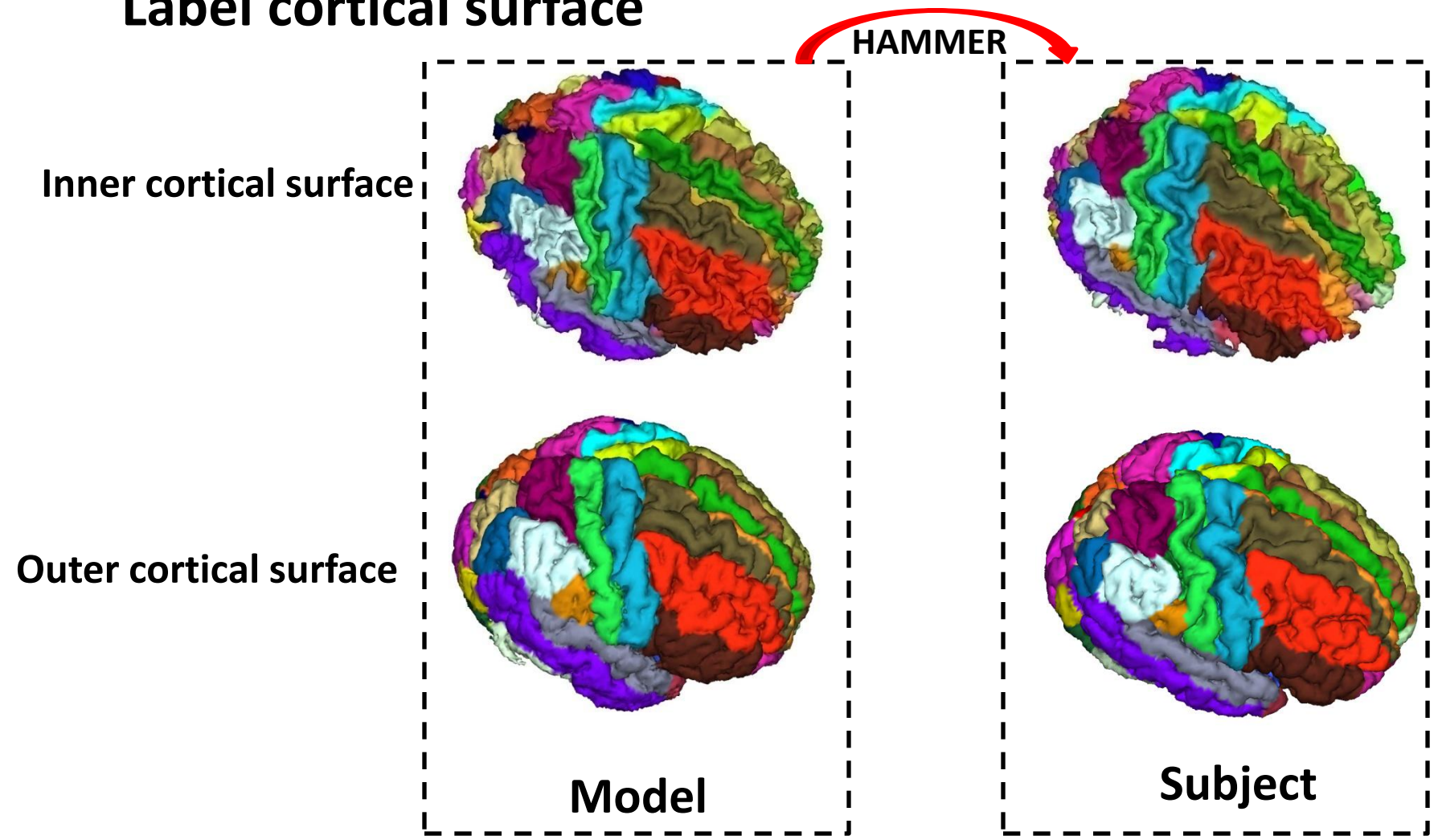
Model



Subject

Results

Label cortical surface



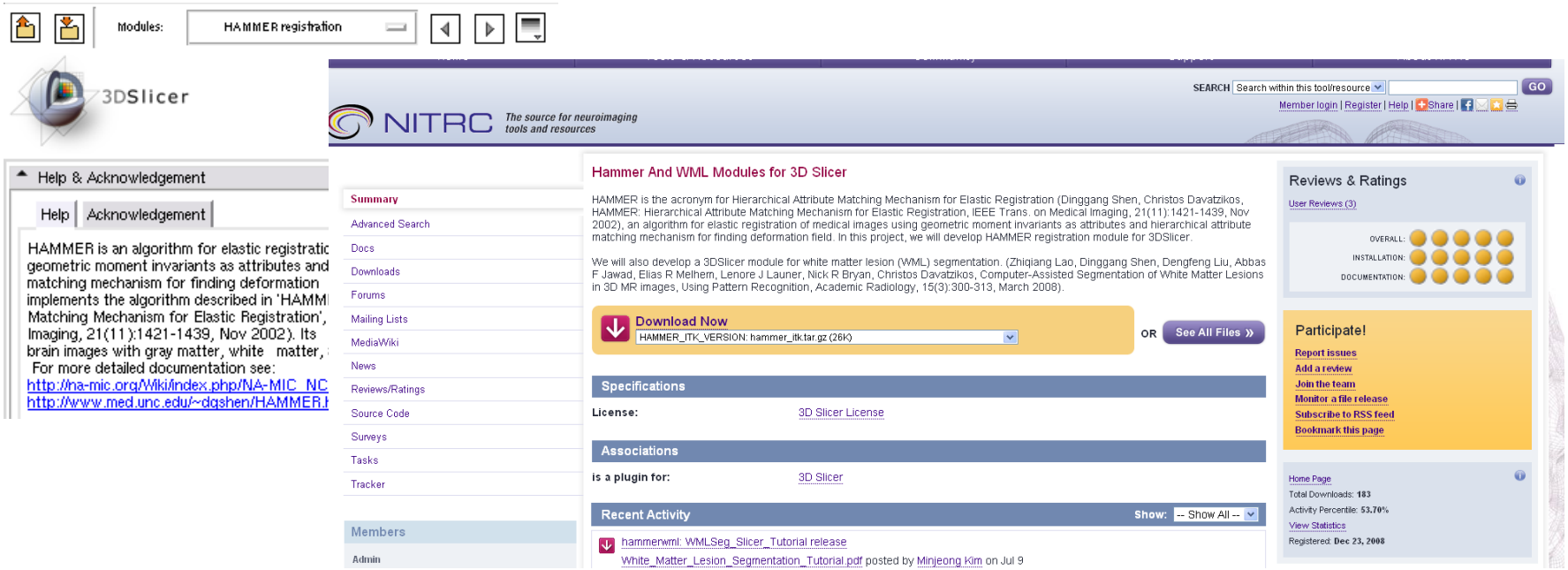
Successful Applications of HAMMER

10^{+} large clinical research studies and clinical trials involving >10,000 MR brain images:
(5000+ downloads for software)

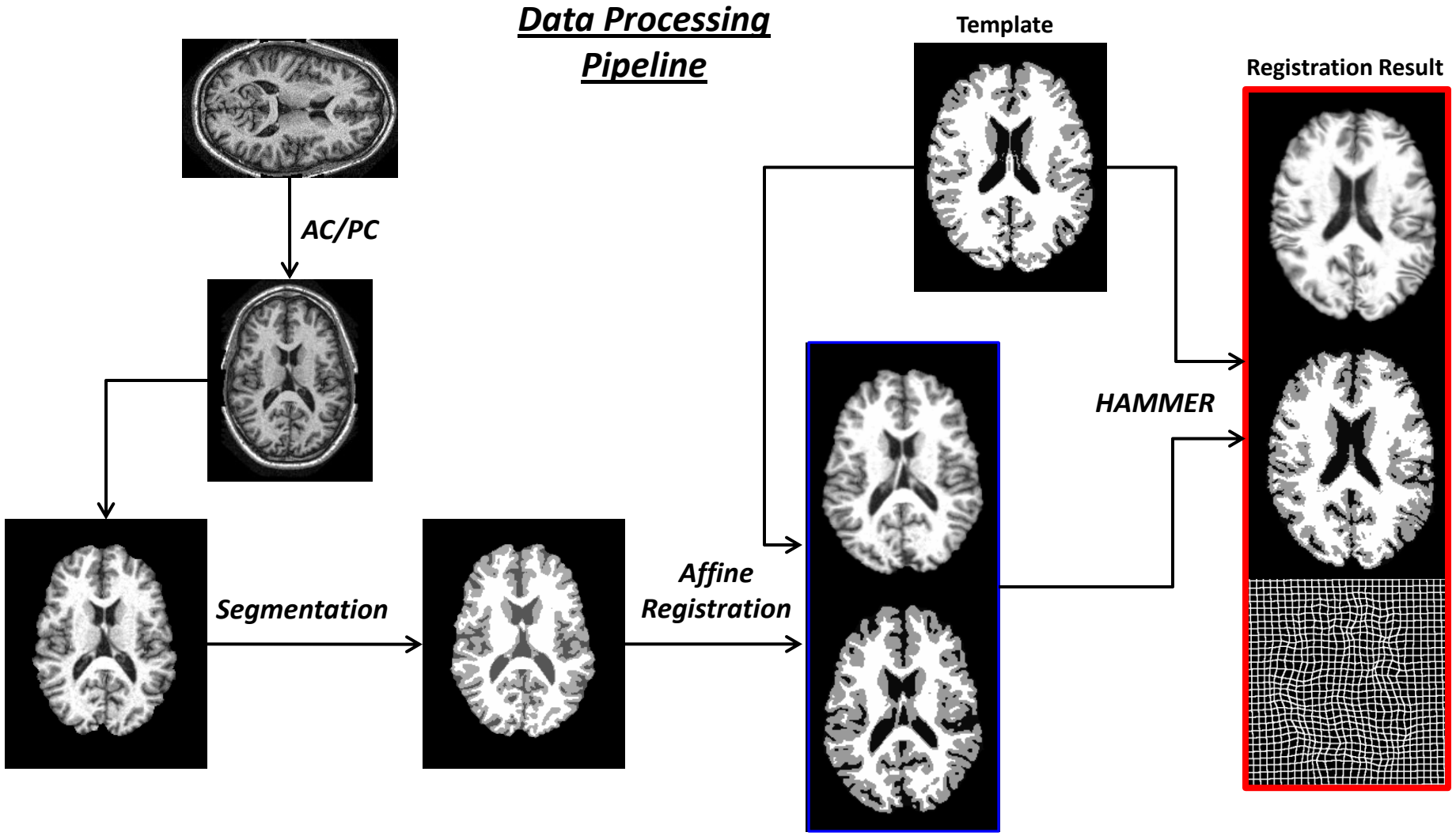
- **One of the largest longitudinal studies of aging in the world to date,**
  (an 18-year annual follow-up of 150 elderly individuals)
- **A relatively large schizophrenia imaging study (148 participants)**
- **A morphometric study of XXY children**
- **The largest imaging study of the effects of diabetes on the brain to date**
  (650 patients imaged twice in a 8-year period)
- **A large study of the effects of organolead-exposure on the brain**
- **A study of effect of sustained, heavy drinking on the brain**

HAMMER in Slicer

- ✓Successfully implemented HAMMER in ITK. (Over 2,000 lines of code)
- ✓Integrated HAMMER into Slicer3
- ✓Verified and tested its performance in Slicer3
- ✓Tutorial on using HAMMER in Slicer 3 can be found at *http://wiki.namic.org/Wiki/index.php/AHM_2010_Tutorial_Contest_-_Hammer_Registration*



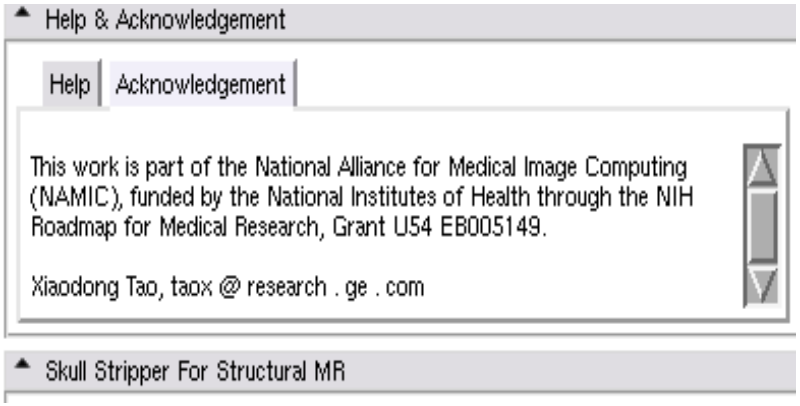
HAMMER in Slicer

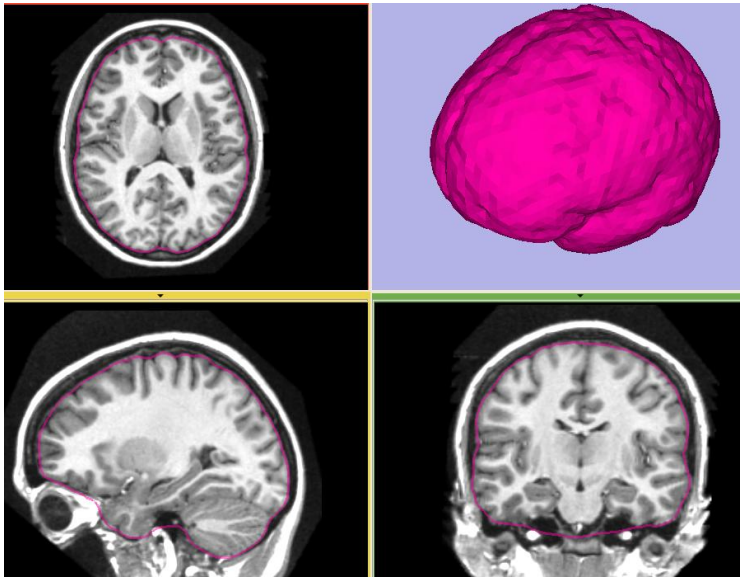


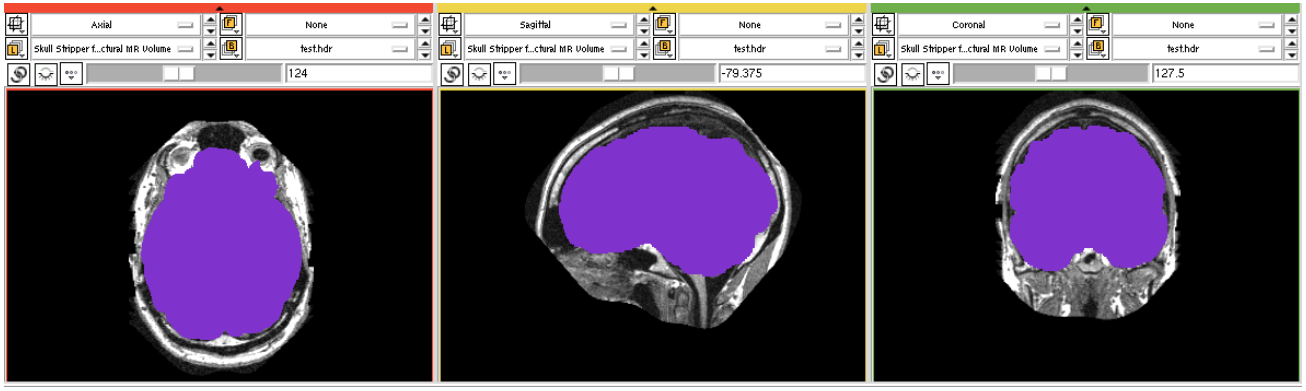
HAMMER in Slicer

Preprocessing step in Slicer

Skull strip module in Slicer, developed by Xiaodong Tao



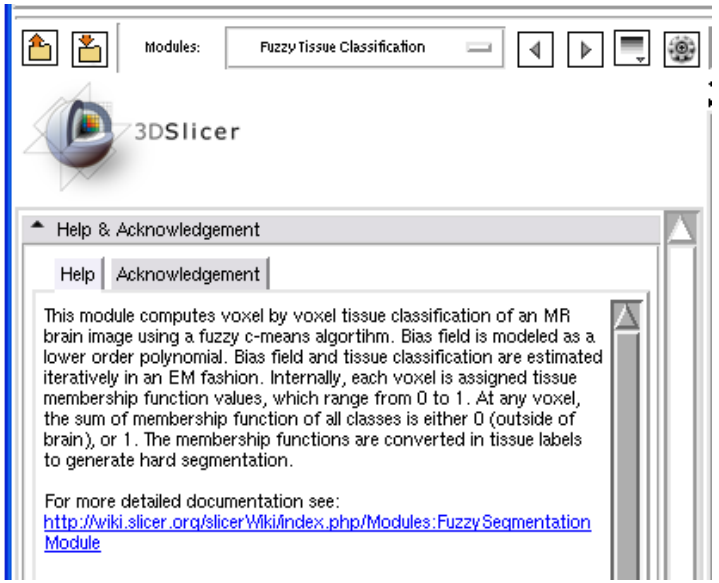


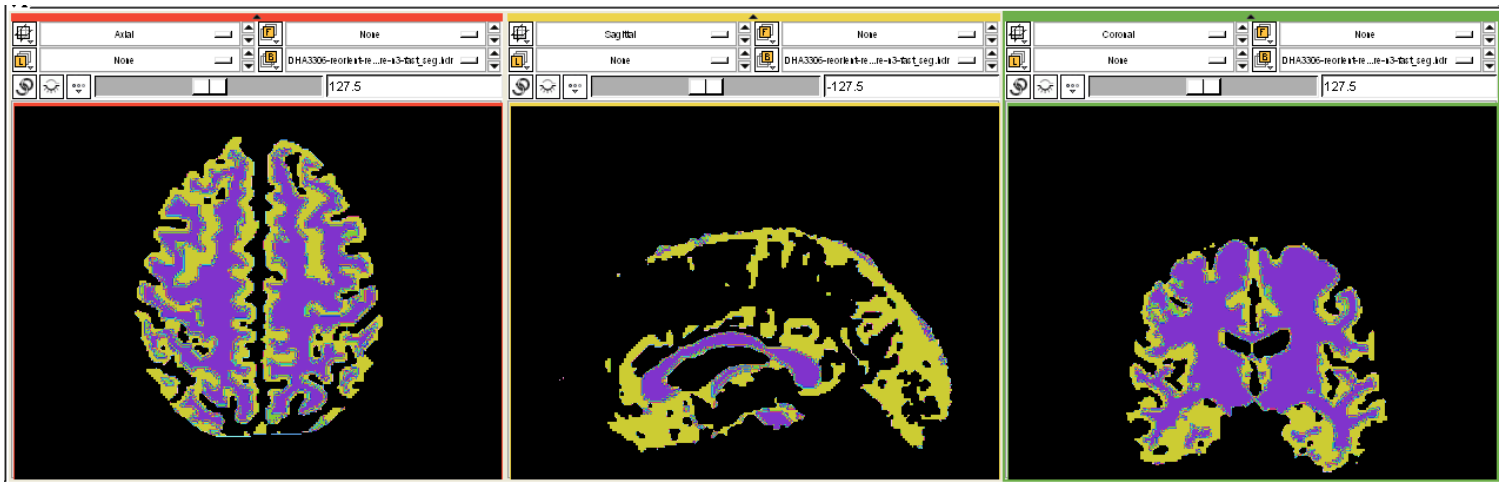


HAMMER in Slicer

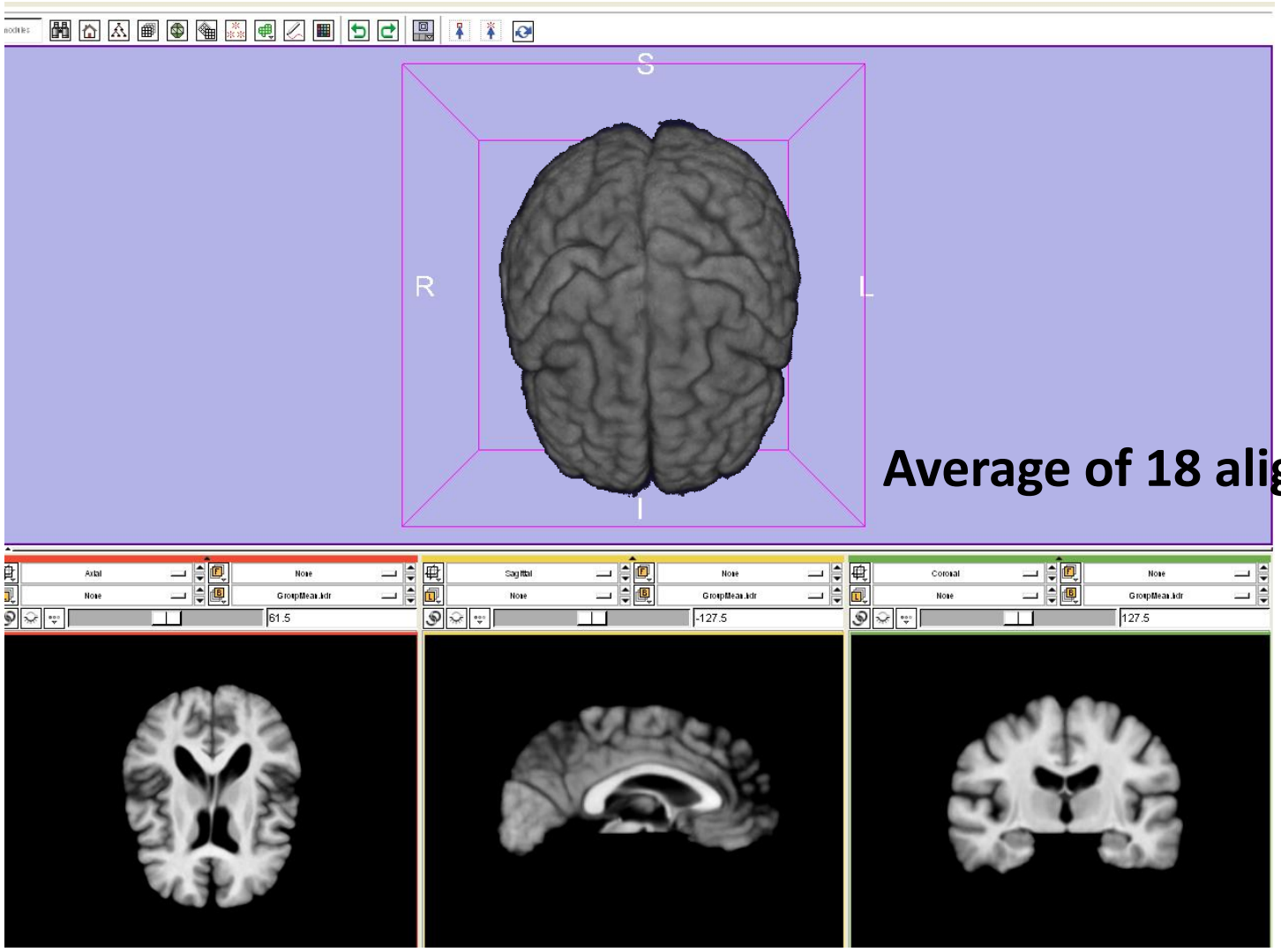
Preprocessing step in Slicer

Fuzzy tissue segmentation module in Slicer, developed by Xiaodong Tao





HAMMER in Slicer



Average of 18 aligned images

HAMMER in Slicer

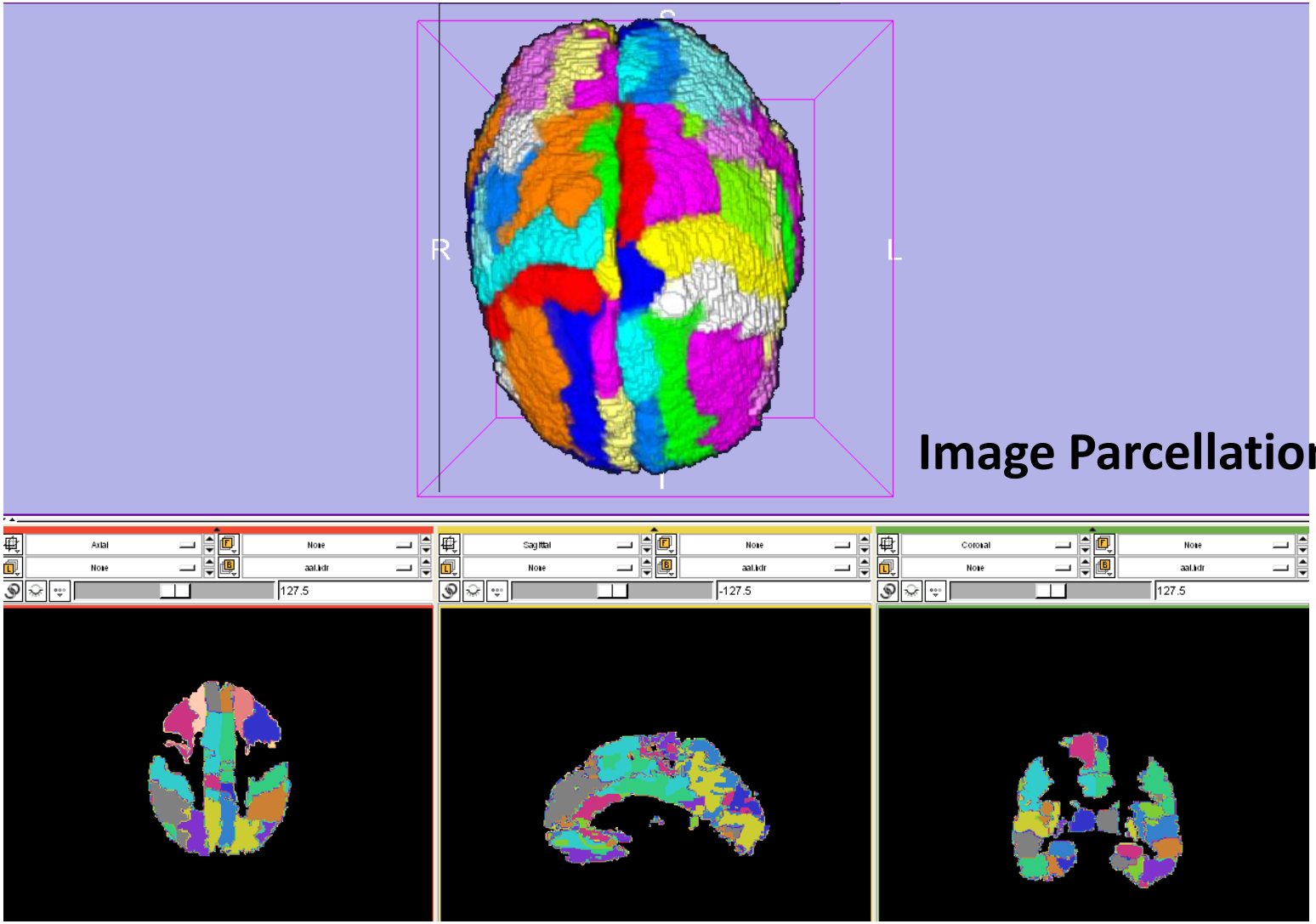
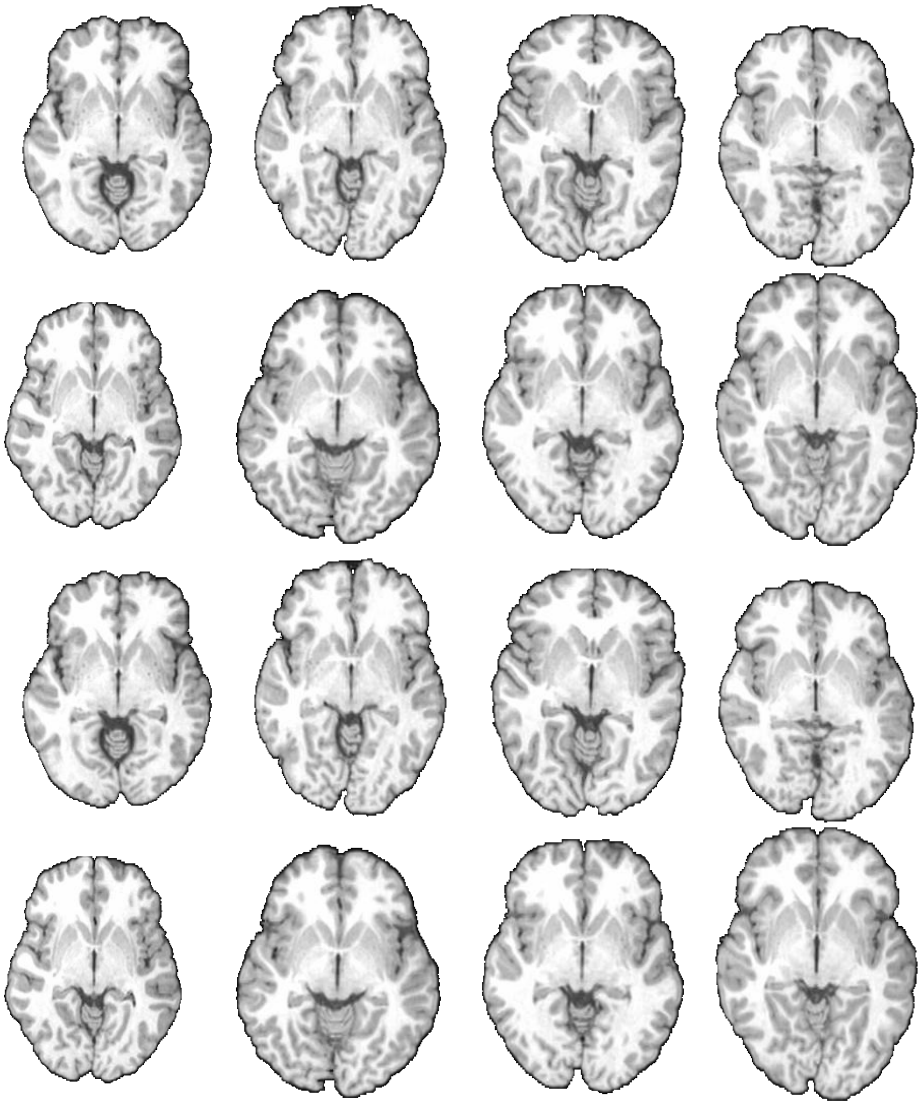


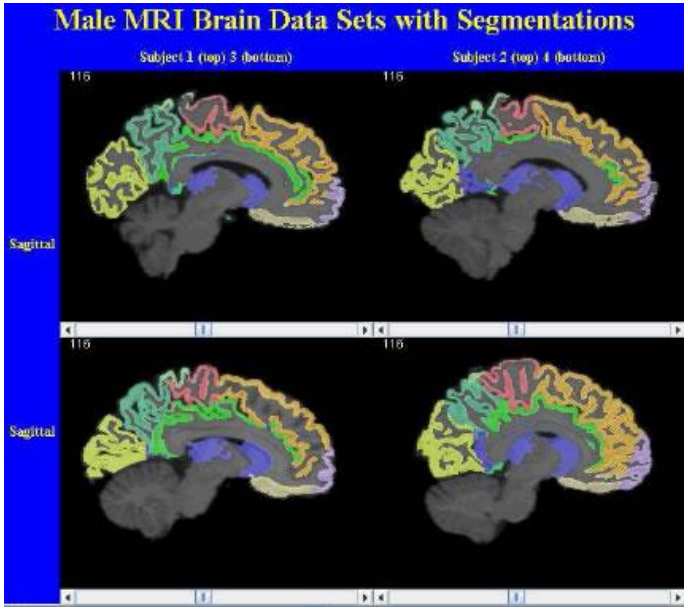
Image Parcellation Result

HAMMER in Slicer

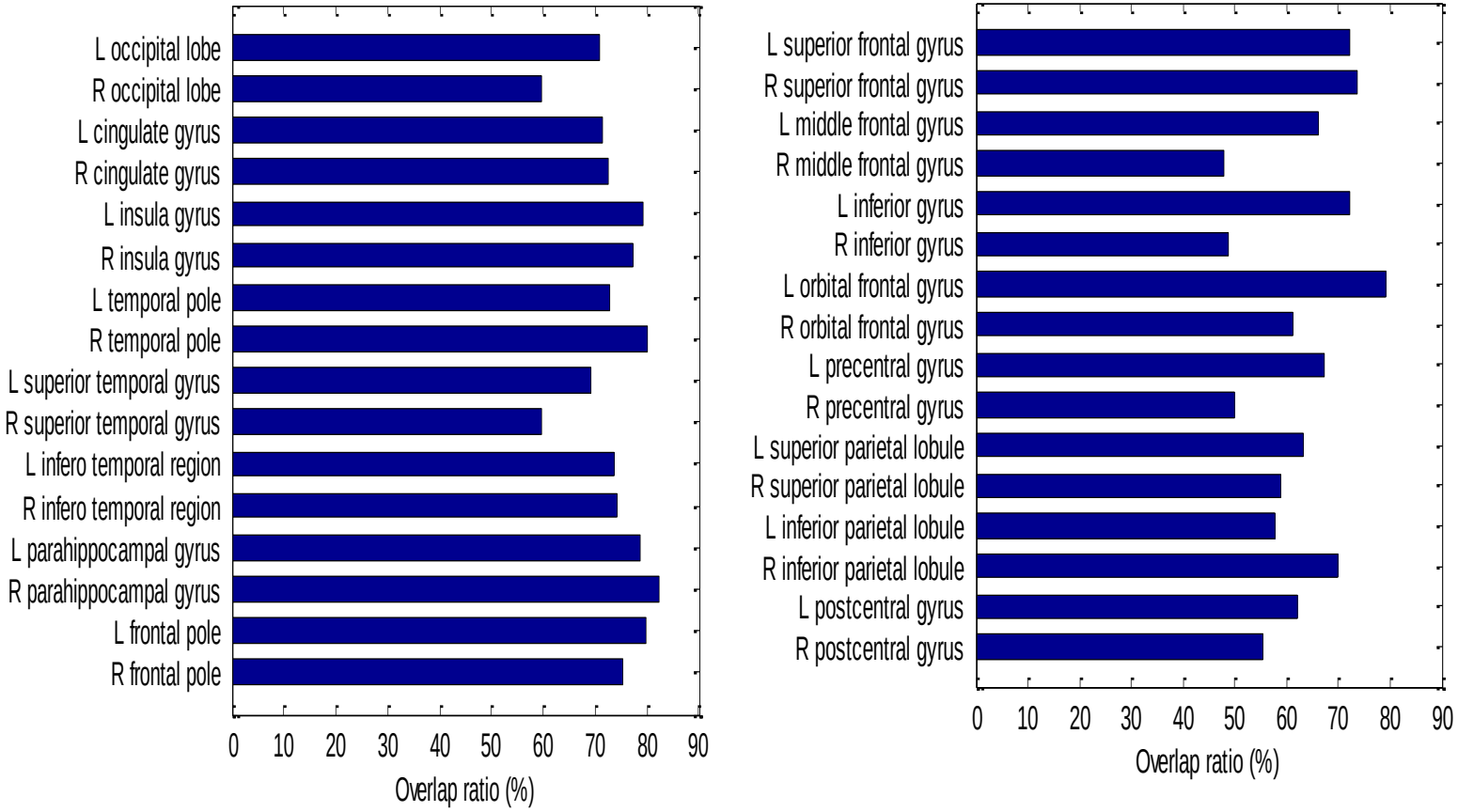


NIREP Dataset
16 subjects with manually labeled 32 ROIs

http://www.nirep.org



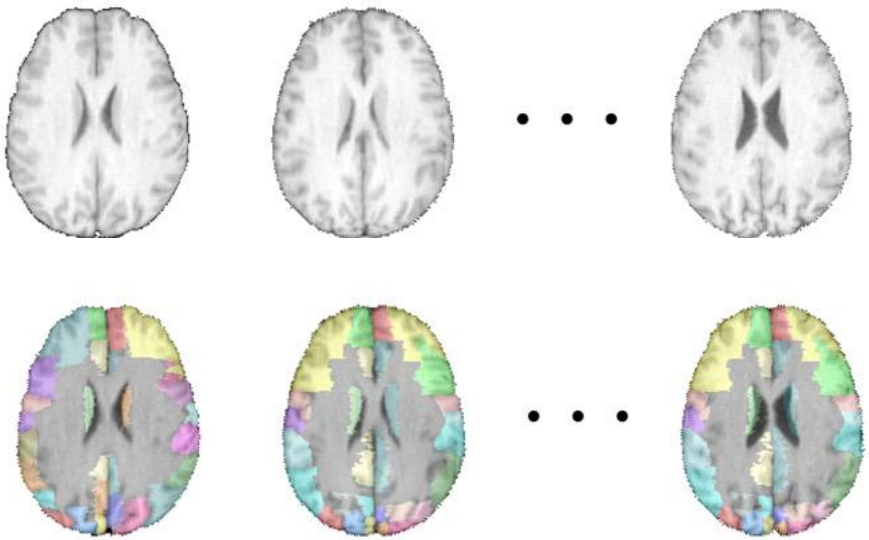
HAMMER in Slicer



Overall Dice ratios on 32 ROIs by HAMMER on 16 NIREP dataset

HAMMER in Slicer

LONI LPBA40 Dataset
40 subjects with 54 manually labeled ROIs



Frontal lobe
- L superior frontal gyrus
- R superior frontal gyrus
- L middle frontal gyrus
- R middle frontal gyrus
- L inferior frontal gyrus
- R inferior frontal gyrus
- L precentral gyrus
- R precentral gyrus
- L middle orbitofrontal gyrus
- R middle orbitofrontal gyrus
- L lateral orbitofrontal gyrus
- R lateral orbitofrontal gyrus
- L gyrus rectus
- R gyrus rectus

Parietal lobe
- L postcentral gyrus
- R postcentral gyrus
- L superior parietal gyrus
- R superior parietal gyrus
- L supramarginal gyrus
- R supramarginal gyrus
- L angular gyrus
- R angular gyrus
- L precuneus
- R precuneus

Limbic Lobe
- L cingulate gyrus
- R cingulate gyrus
- L hippocampus[b]
- R hippocampus[b]

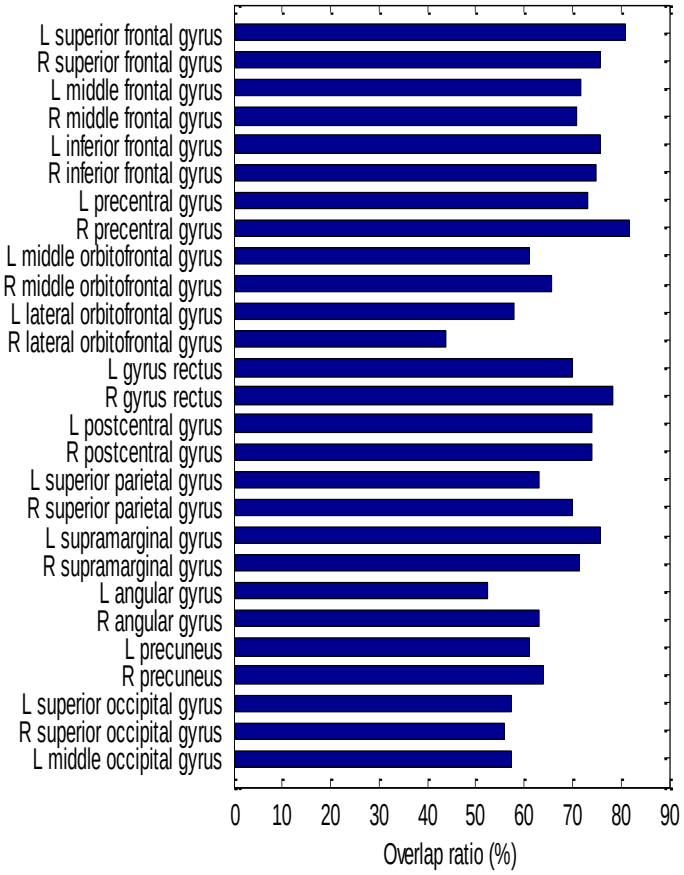
Occipital lobe
- L superior occipital gyrus
- R superior occipital gyrus
- L middle occipital gyrus
- R middle occipital gyrus
- L inferior occipital gyrus
- R inferior occipital gyrus
- L cuneus
- R cuneus

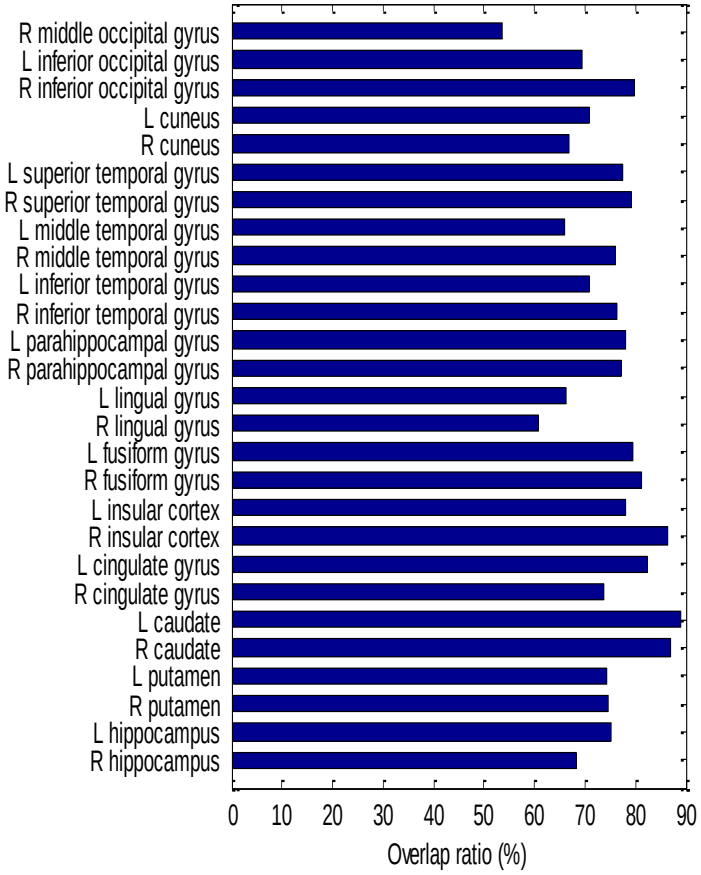
Temporal lobe
- L superior temporal gyrus
- R superior temporal gyrus
- L middle temporal gyrus
- R middle temporal gyrus
- L inferior temporal gyrus
- R inferior temporal gyrus
- L parahippocampal gyrus
- R parahippocampal gyrus
- L lingual gyrus[a]
- R lingual gyrus[a]
- L fusiform gyrus[a]
- R fusiform gyrus[a]

Other structures
- L insular cortex
- R insular cortex
- L caudate
- R caudate
- L putamen
- R putamen
- Cerebellum
- Brainstem

Shattuck DW, Mirza M, Adisetiyo V, Hojatkashani C, Salamon G, Narr KL, Poldrack RA, Bilder RM, Toga AW, Construction of a 3D Probabilistic Atlas of Human Cortical Structures, NeuroImage (2007).

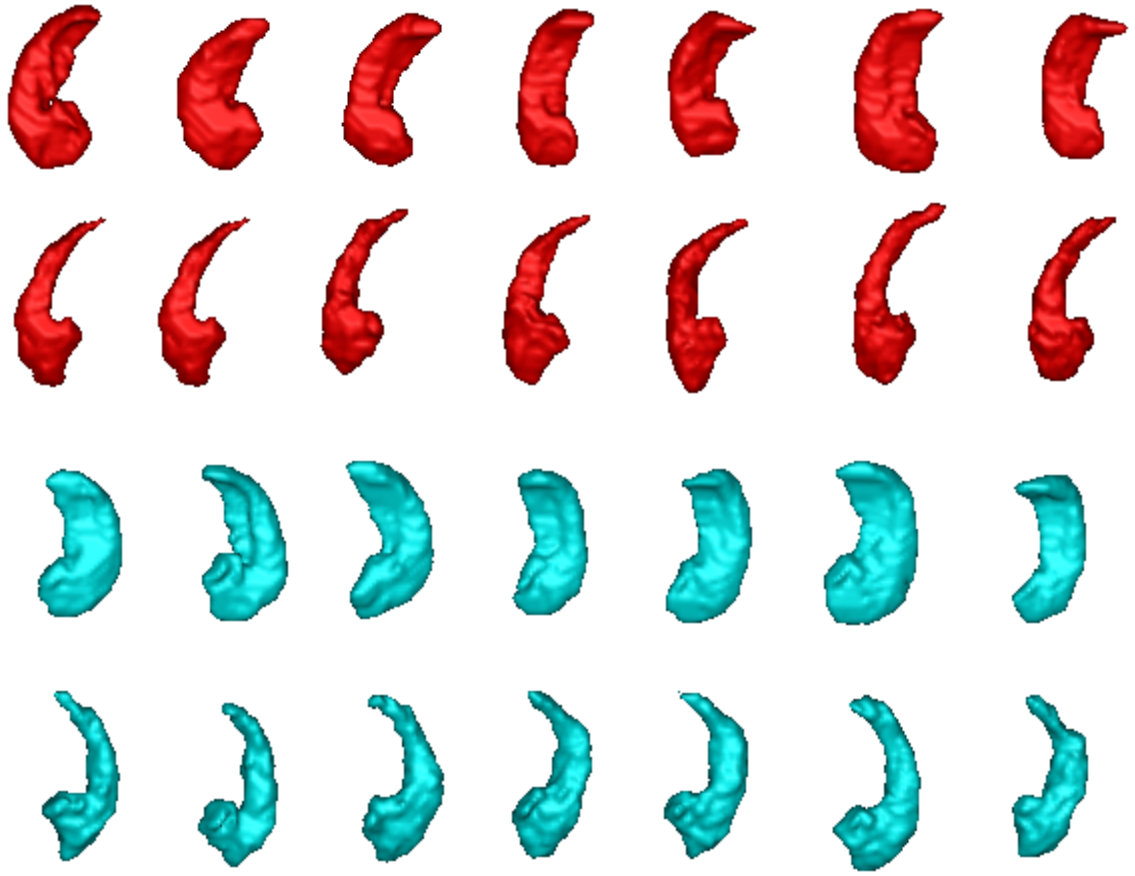
HAMMER in Slicer





Overall Dice ratios on 54 ROIs by HAMMER on 40 LONI dataset

HAMMER in Slicer



Left hippocampus

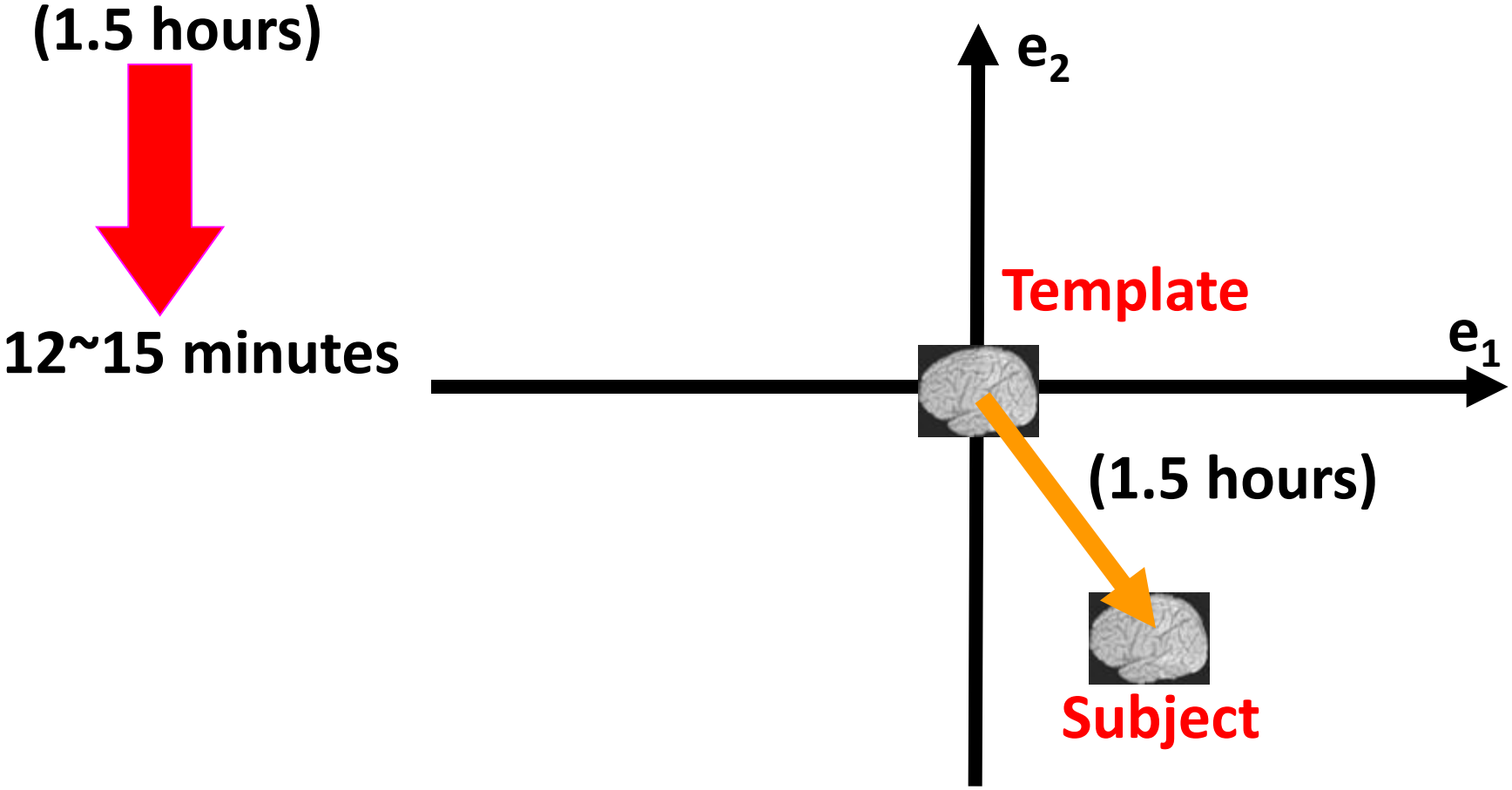
Warped result of left hippocampus

Right hippocampus

Warped result of right hippocampus

Further Improvements on HAMMER

RABBIT: To speed up our HAMMER registration algorithm



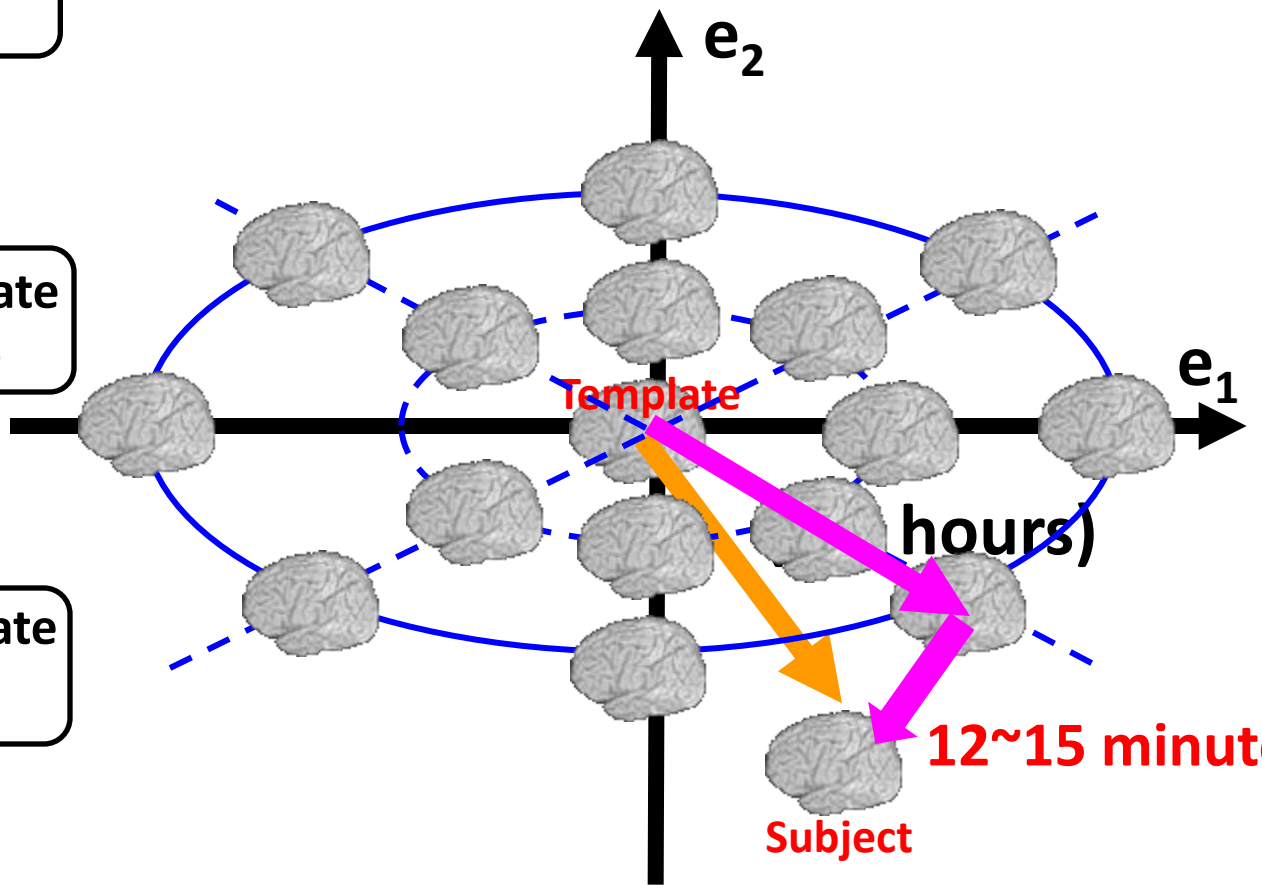
- Tang et. al., RABBIT: Rapid Alignment of Brains by Building Intermediate Templates. *Neuroimage*, 47(4):1277-87, Oct 1 2009.

Further Improvements on HAMMER

Construct a statistical deformation model

Estimate an intermediate deformation/template

Refine the intermediate deformation field

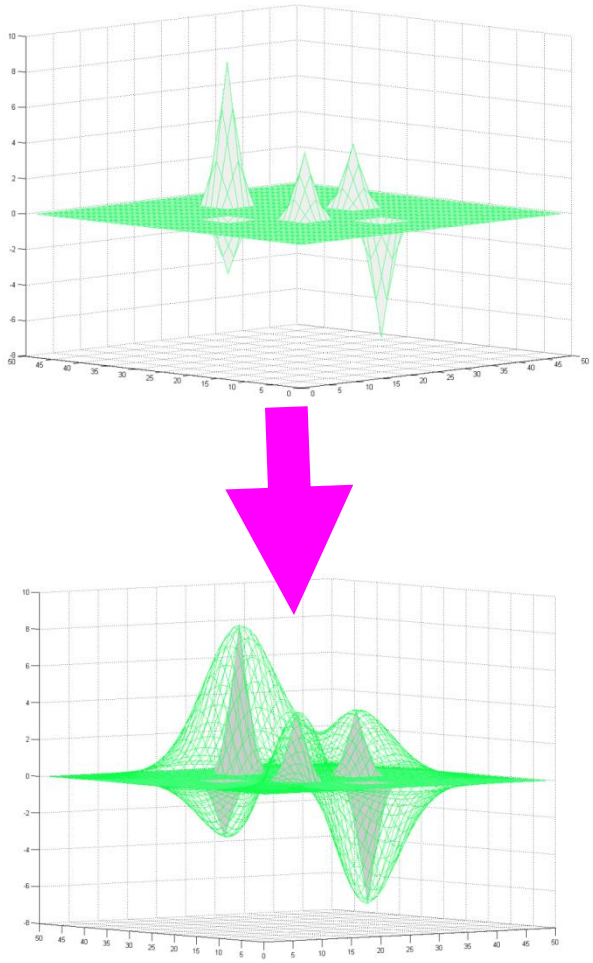


- Tang et. al., RABBIT: Rapid Alignment of Brains by Building Intermediate Templates. *Neuroimage*, 47(4):1277-87, Oct 1 2009.

Further Improvements on HAMMER

TPS-HAMMER:

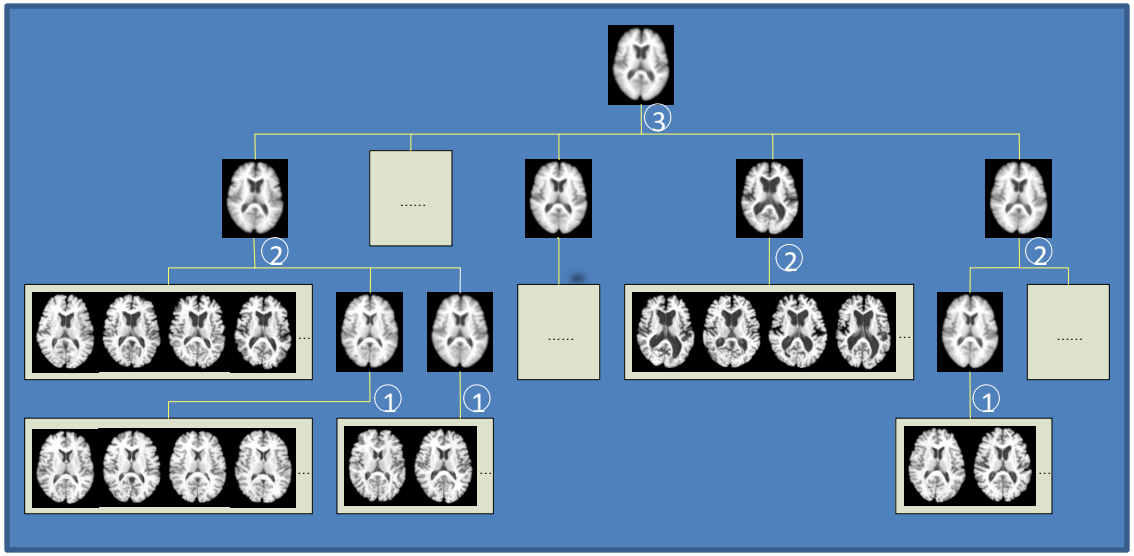
- **Use soft correspondence detection to robustly establish correspondences for the driving voxels**
- **Use Thin Plate Splines (TPS) to effectively interpolate deformation fields, based on those estimated at the driving voxels**

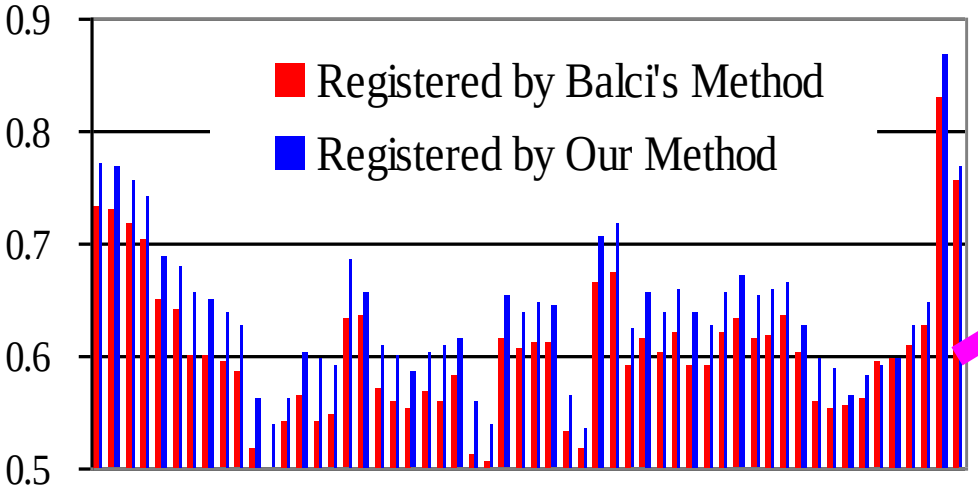


- Wu et. al., TPS-HAMMER: Improving HAMMER Registration Algorithm by Soft Correspondence Matching and Thin-Plate Splines Based Deformation Interpolation. *Neuroimage*, 49(3):2225-2233, Feb 2010.

Groupwise Registration

Hierarchical Groupwise registration:





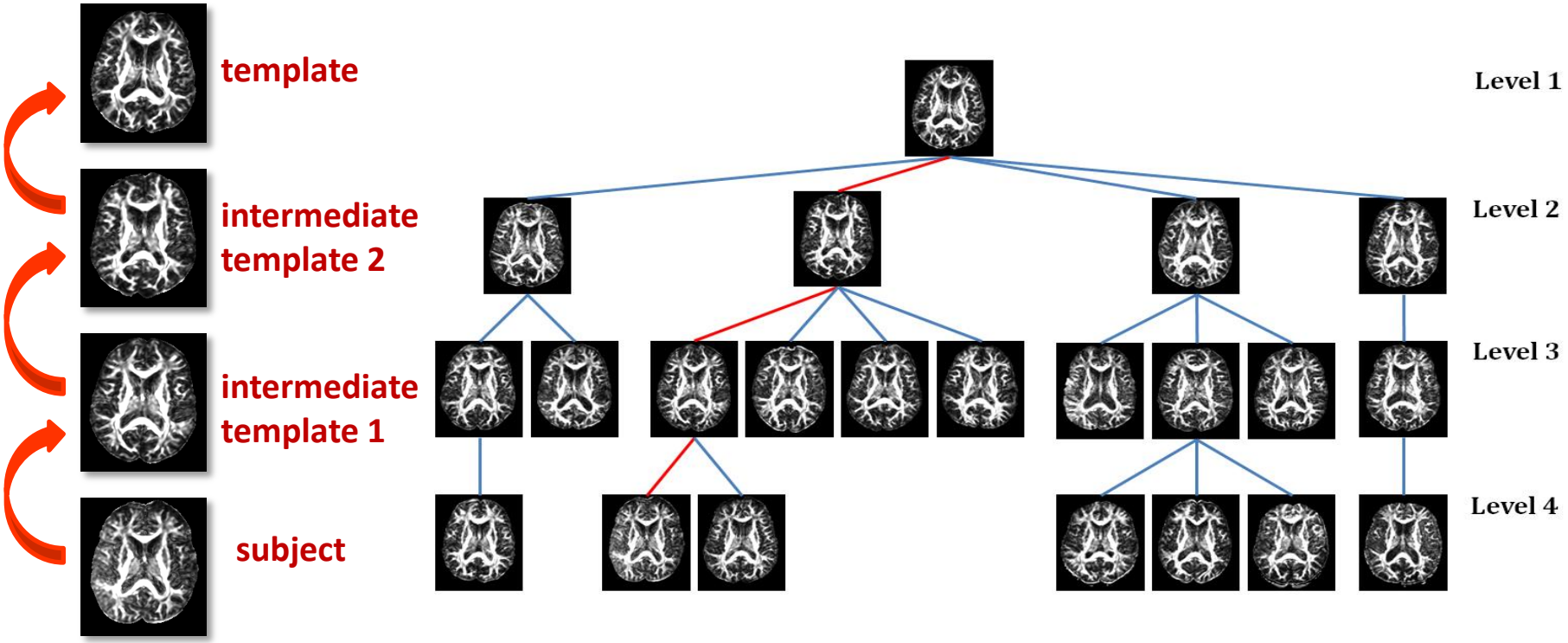
6.0% increase for Dice ratio

40 subjects with 54 manual ROIs

- Wang et al, "Groupwise Registration Based on Hierarchical Image Clustering and Atlas Synthesis", *Human Brain Mapping*, 31(8):1128-1140, Jan. 2010.

Groupwise Registration

Tree-based Groupwise registration:



- Jia et al, “Intermediate Templates Guided Groupwise Registration of Diffusion Tensor Images", Revised for *Neuroimage*, 2010.

Groupwise Registration

ABSORB:

Initial inputs

Global center (1st iteration)

Pair-wise deformation between subject and its qualified neighbors in 1st iteration

Moving direction in 1st iteration

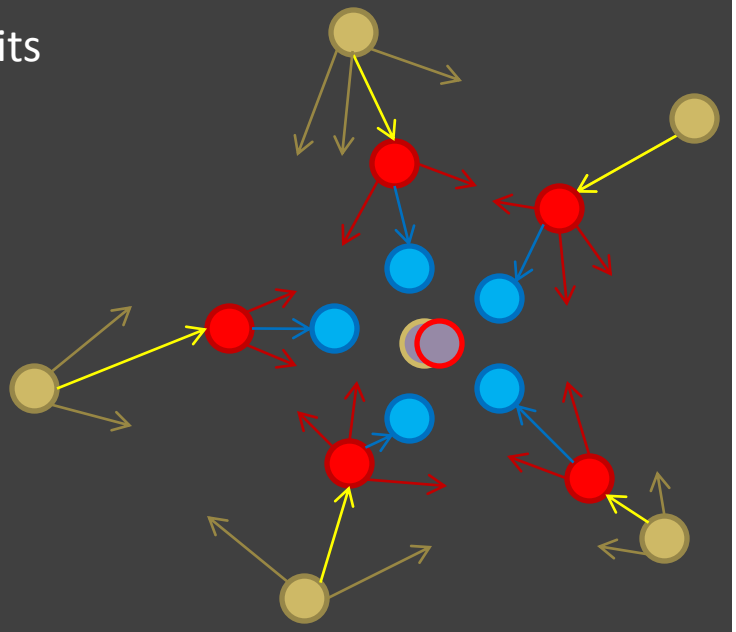
Outputs in 1st iteration

Global center (2nd iteration)

Pair-wise deformation between subject and its qualified neighbors in 2nd iteration

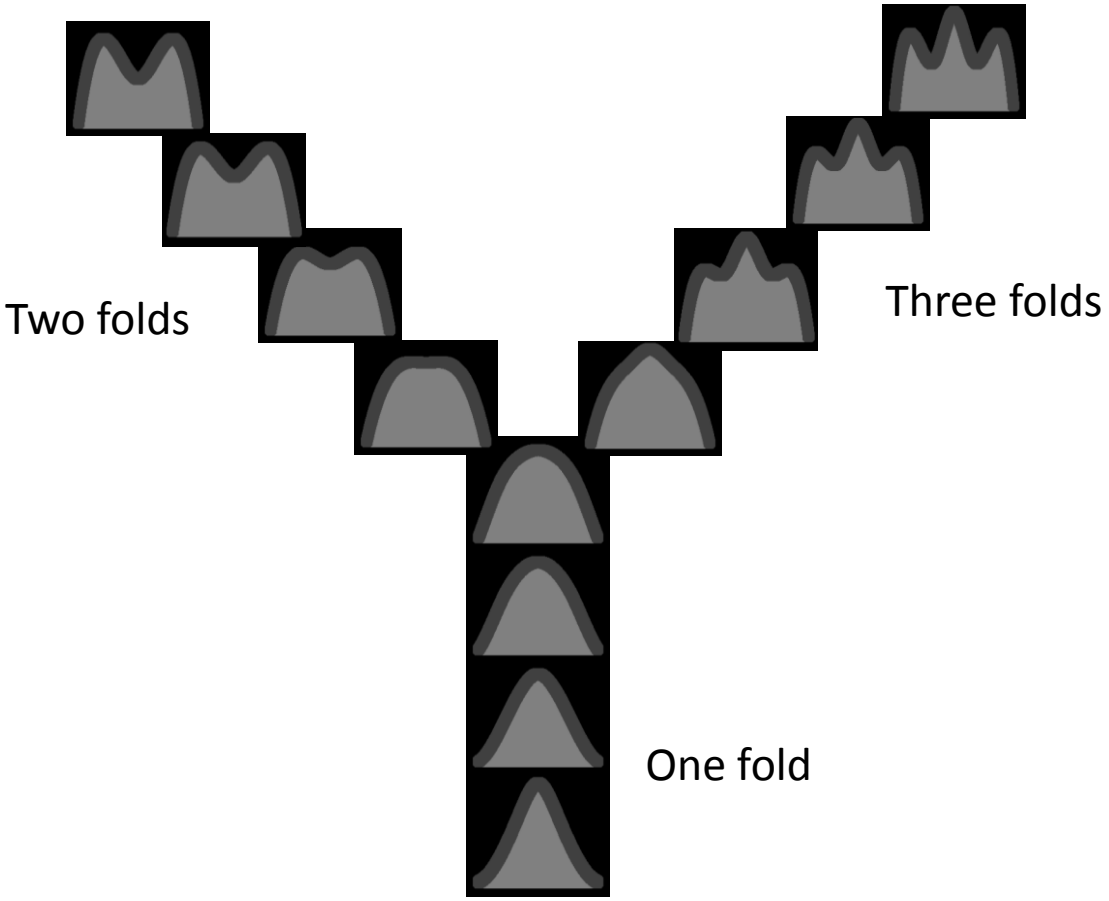
Moving direction in 2nd iteration

Outputs in 2nd iteration



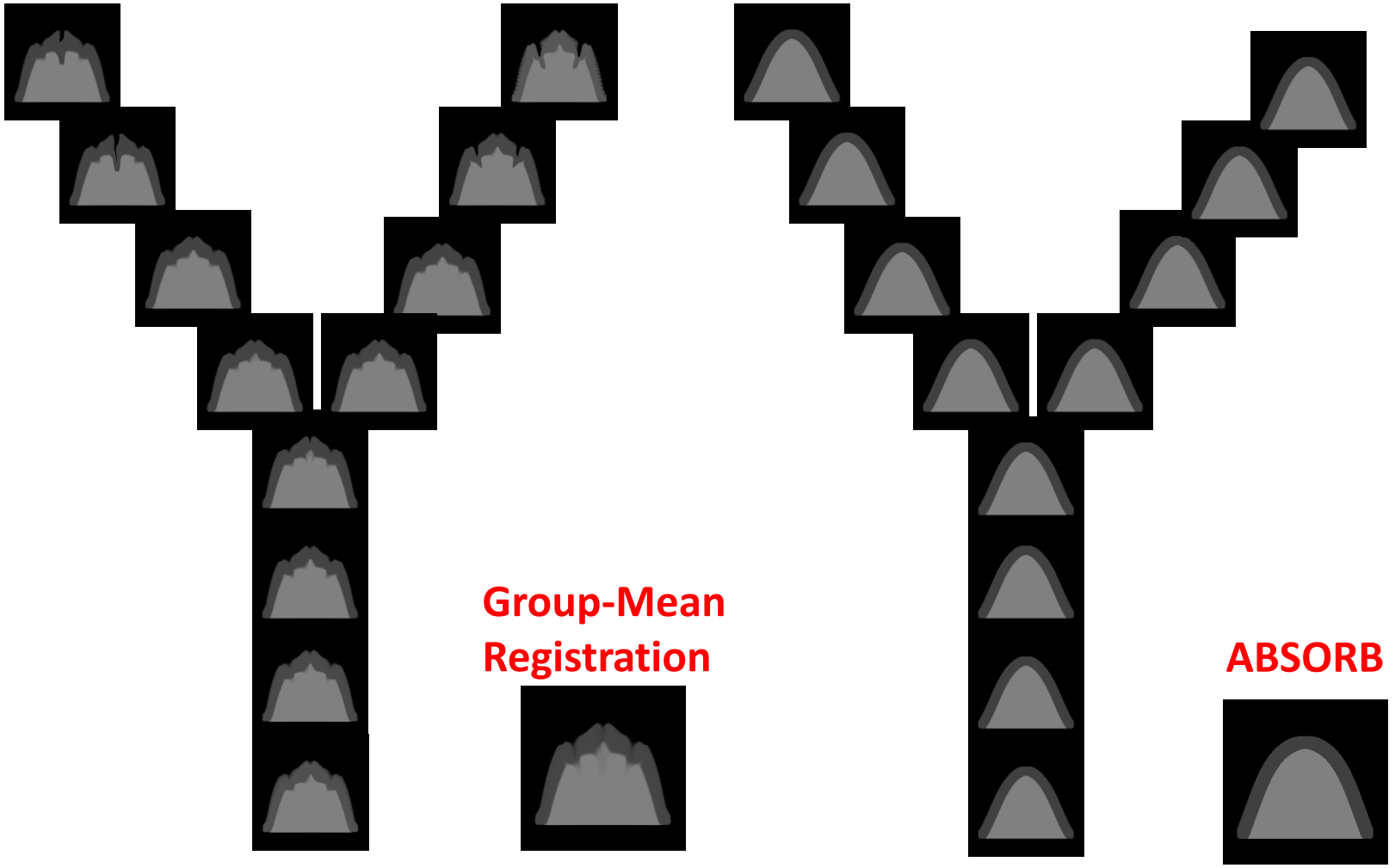
- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

Groupwise Registration



- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

Groupwise Registration



- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

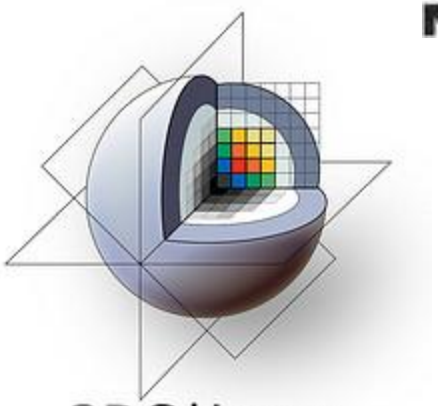
Groupwise Registration

Our new registration methods in this MICCAI:

- Pahal Dalal, Dinggang Shen, Feng Shi, Song Wang, "Multiple Cortical Surface Correspondence using Pairwise Shape Similarity", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010. **Oral**
- Guorong Wu, QianWang, Hongjun Jia, and Dinggang Shen,"Groupwise Registration by Hierarchical Anatomical CorrespondenceDetection", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010.
- Guorong Wu, Hongjun Jia, Qian Wang, and Dinggang Shen, "Groupwise Registration with Sharp Mean", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010.
- Guorong Wu, Qian Wang, Hongjun Jia, and Dinggang Shen,"Registration of Longitudinal Image Sequences with Implicit Template and Spatial-Temporal Heuristics", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010.
- Minjeong Kim, Guorong Wu, Pew-Thian Yap, Dinggang Shen, "A Generalized Learning Based Framework for Fast Brain Image Registration", *MICCAI 2010*, Beijing, China, Sep. 20-24, 2010.

Acknowledgement

MICCAI



3DSlicer

THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL