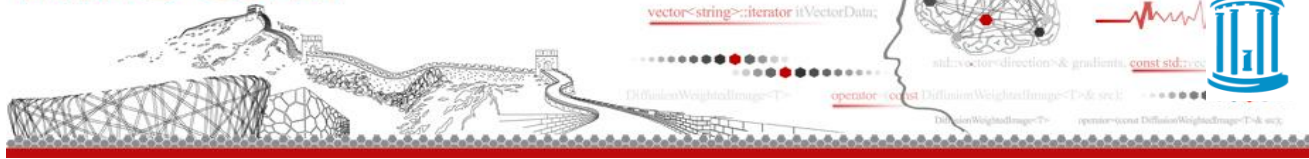




MICCAI SEPTEMBER 20-24, 2010
BEIJING - CHINA



THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

HAMMER: Hierarchical Atttribute Matching Mechanism for Elastic Registration

By Dinggang Shen

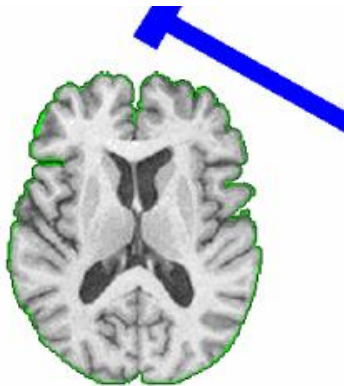


Image Display, Enhancement, and Analysis
IDEA

THE UNIVERSITY
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at CHAPEL HILL

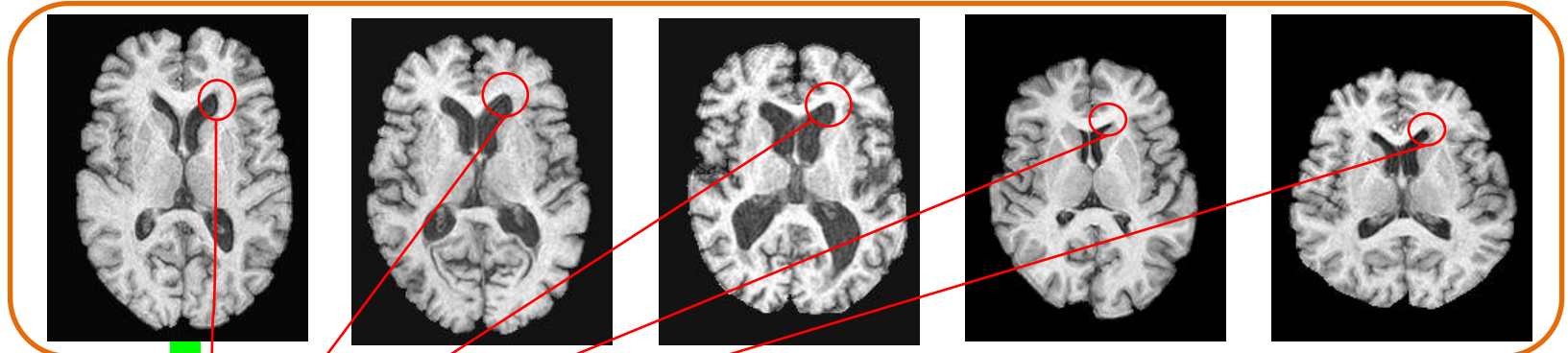
Email: dgshen@med.unc.edu

homepage: <http://www.med.unc.edu/~dgshen/>

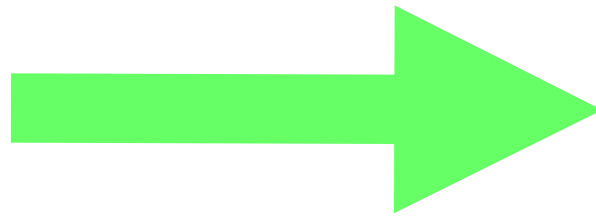
Motivations

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

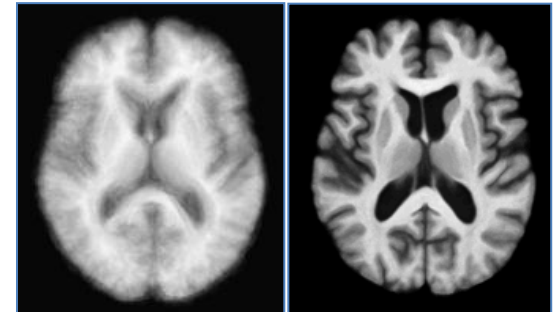
Individuals:



Model:



Average brain



Affine HAMMER

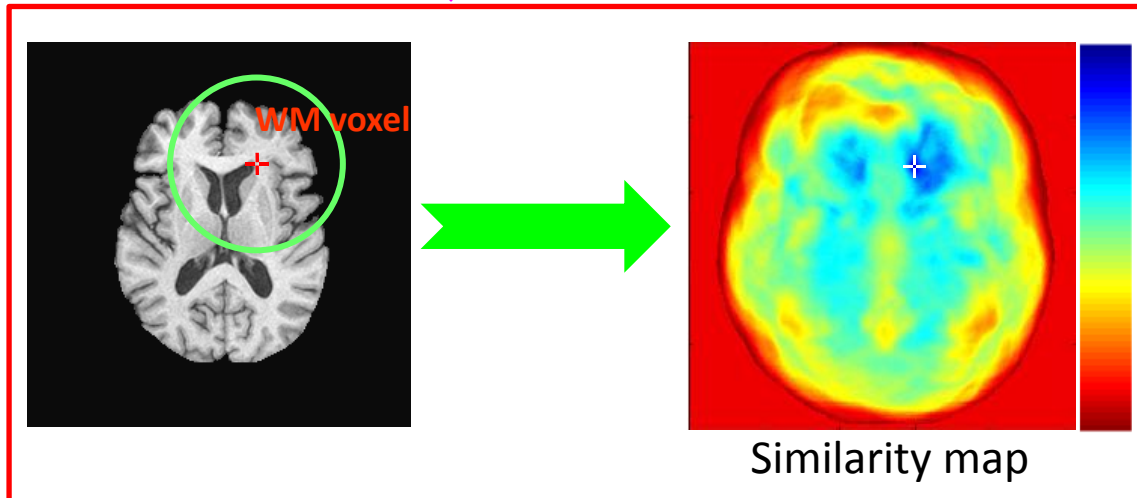
Innovations

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

Distinctive attribute vectors

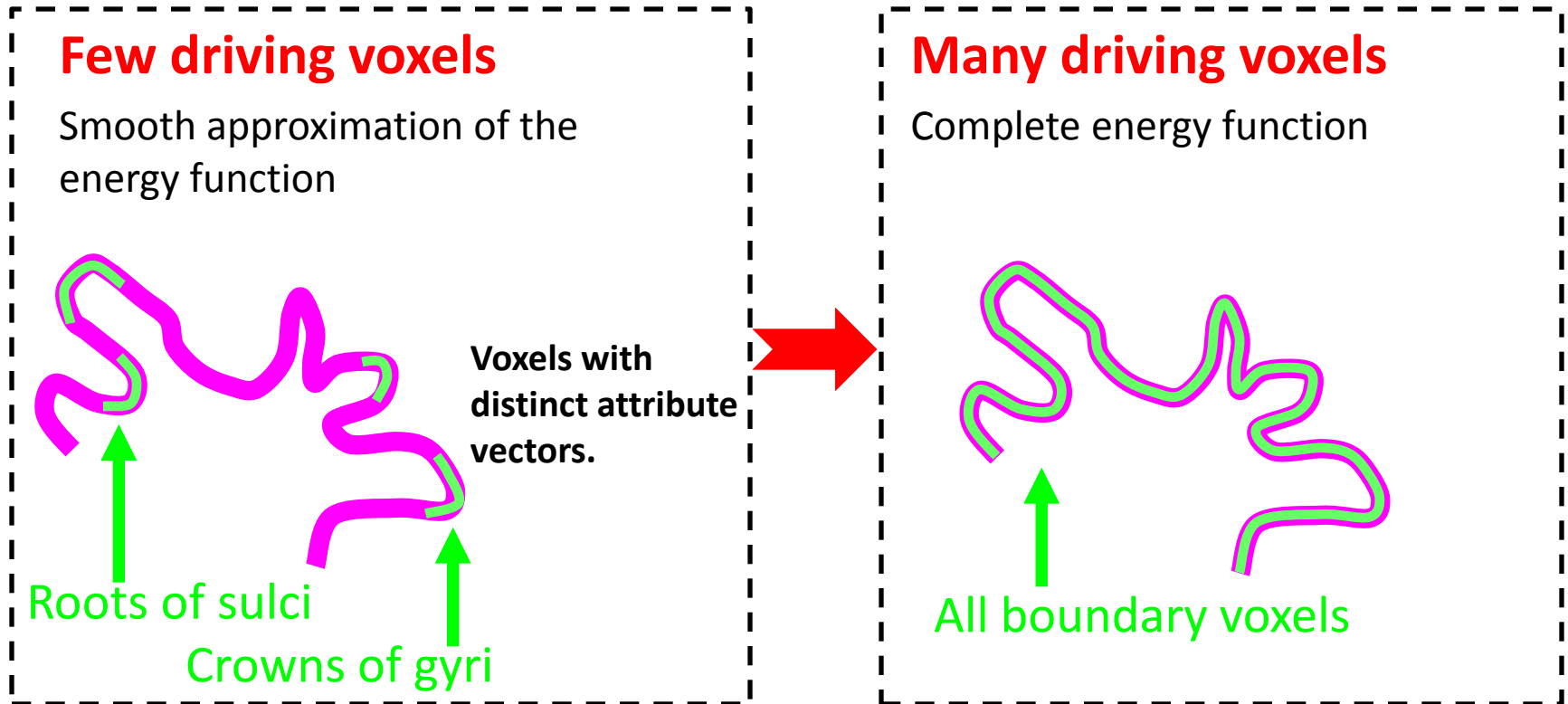
Reduce the ambiguity
in feature matching

Select most distinctive
voxels in the image

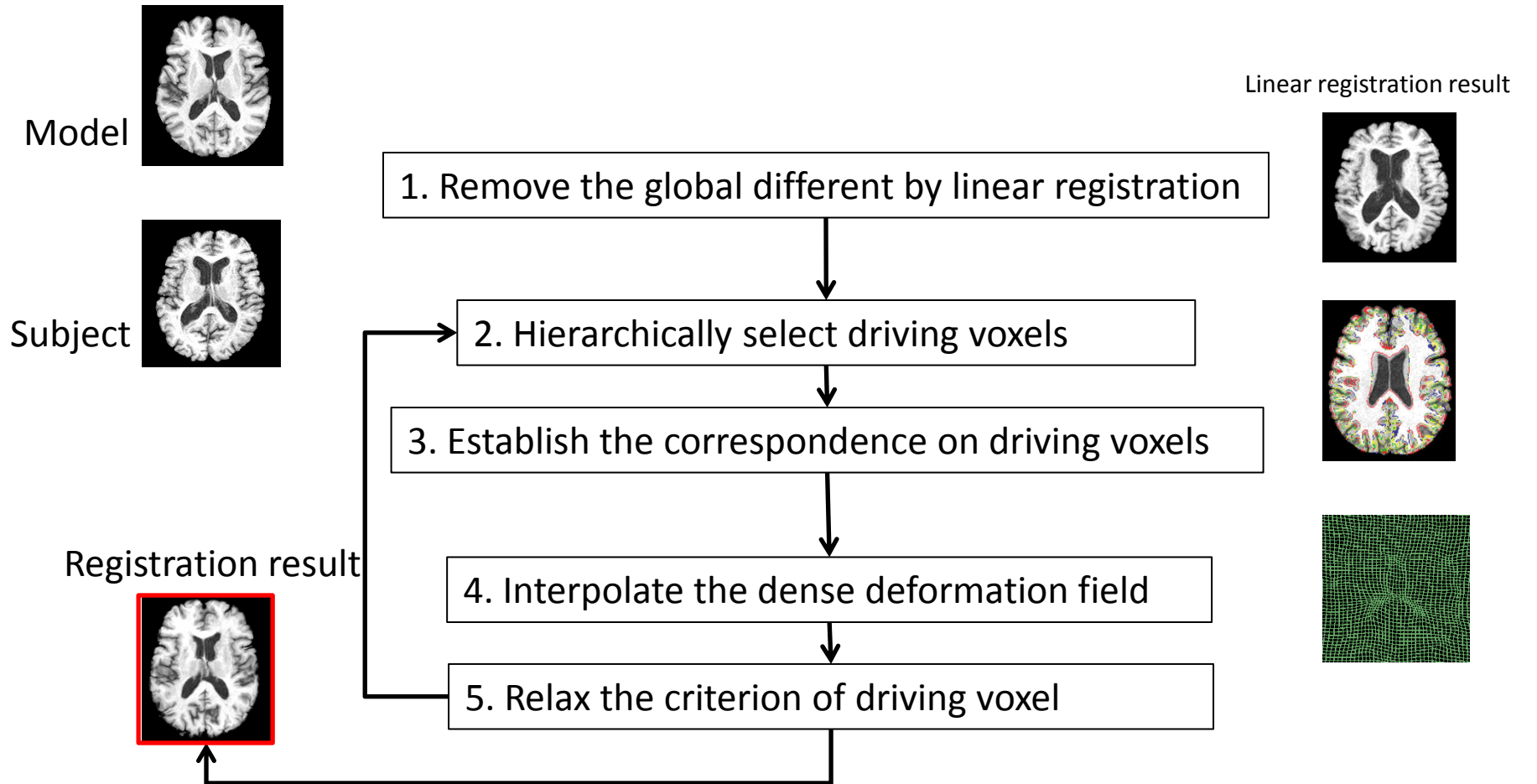


Innovations

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



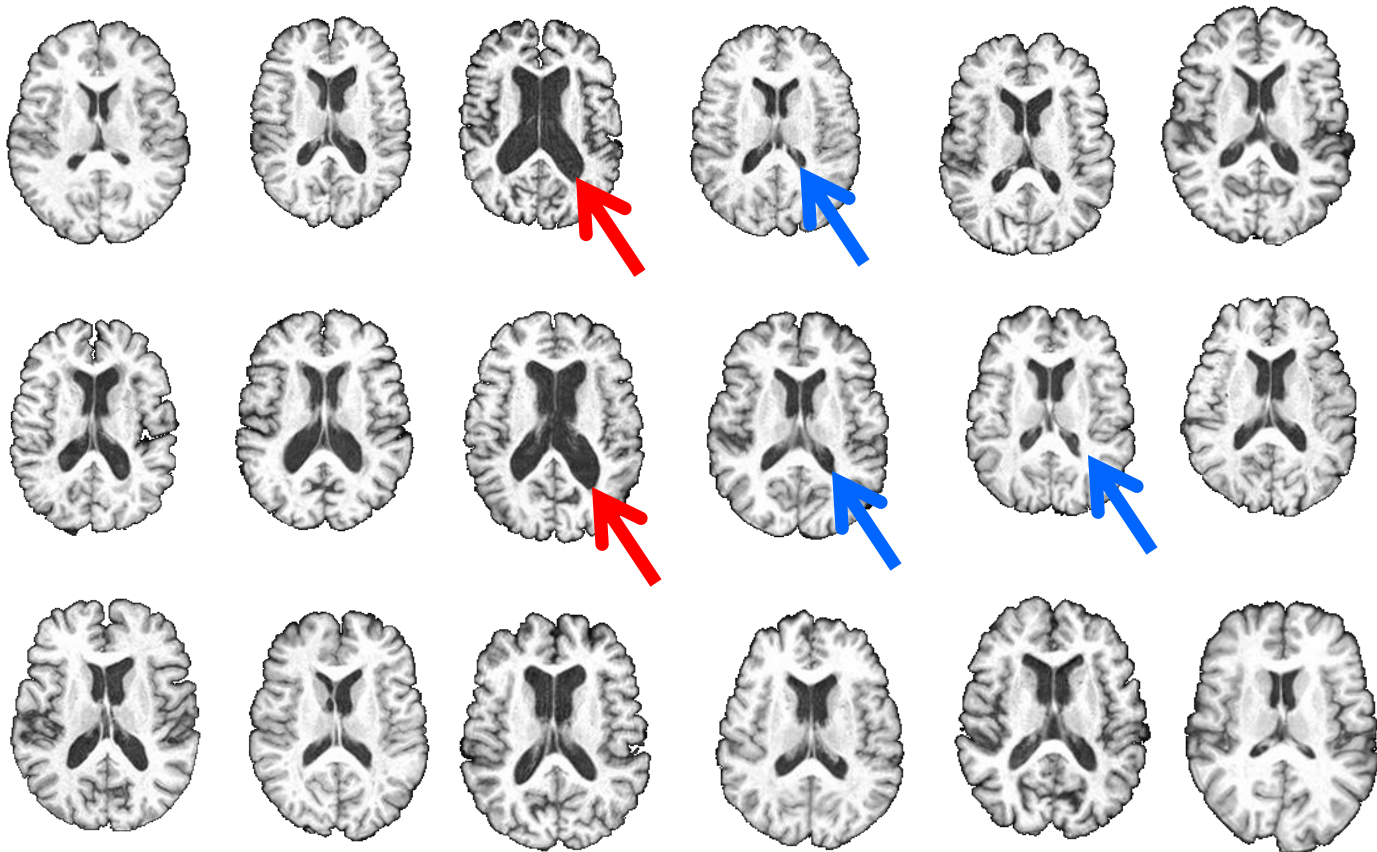
Methods



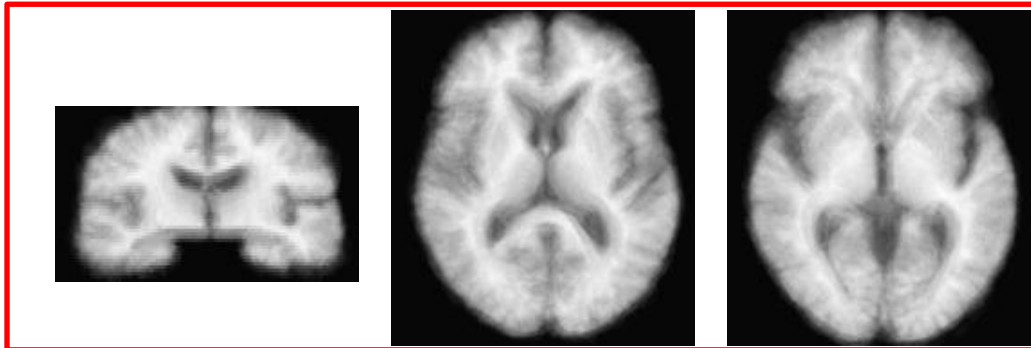
- Shen, et al., "Very High Resolution Morphometry Using Mass-Preserving Deformations and **HAMMER** Elastic Registration", *NeuroImage*, 18(1):28-41, Jan 2003.
- Shen, et al., "**HAMMER**: Hierarchical Attribute Matching Mechanism for Elastic Registration", *IEEE Trans. on Medical Imaging*, 21(11):1421-1439,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

Results

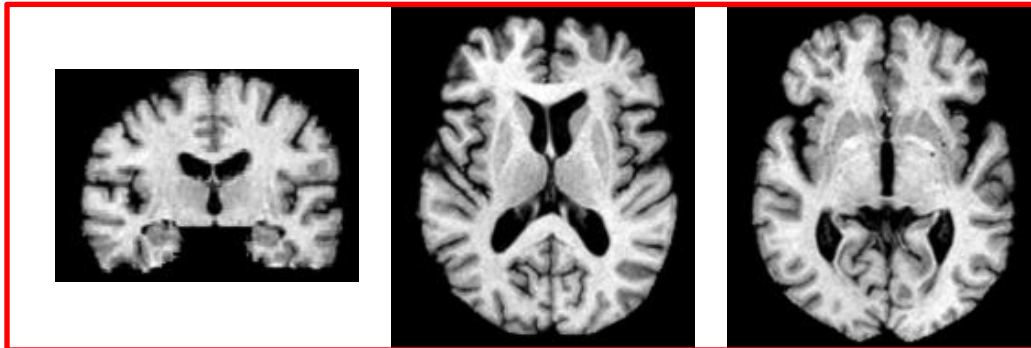
18 elderly brain used to construct the average brain



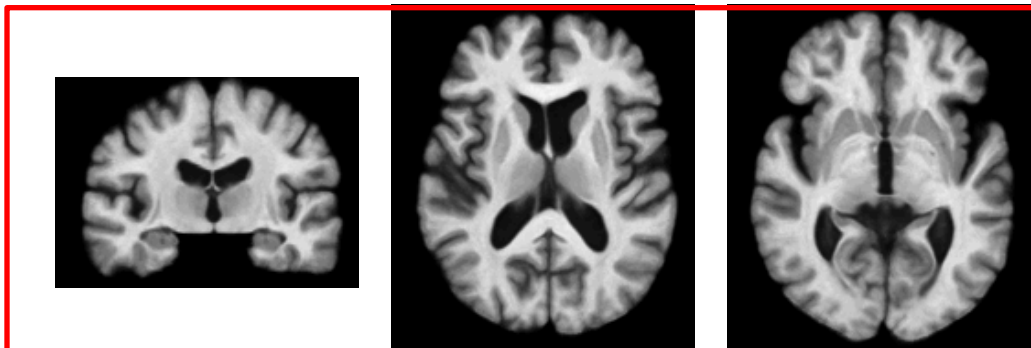
Results



Linear registration

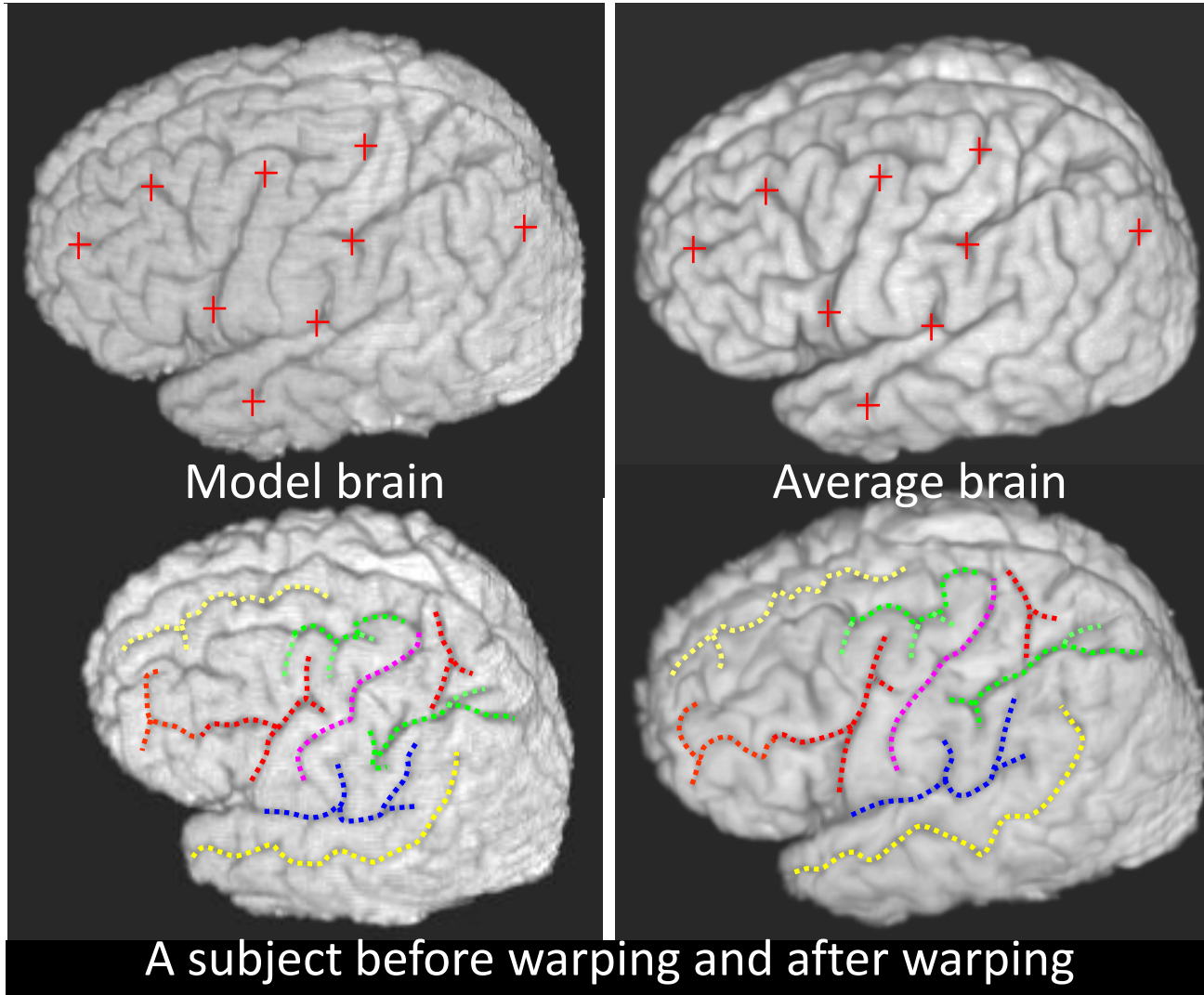


Model



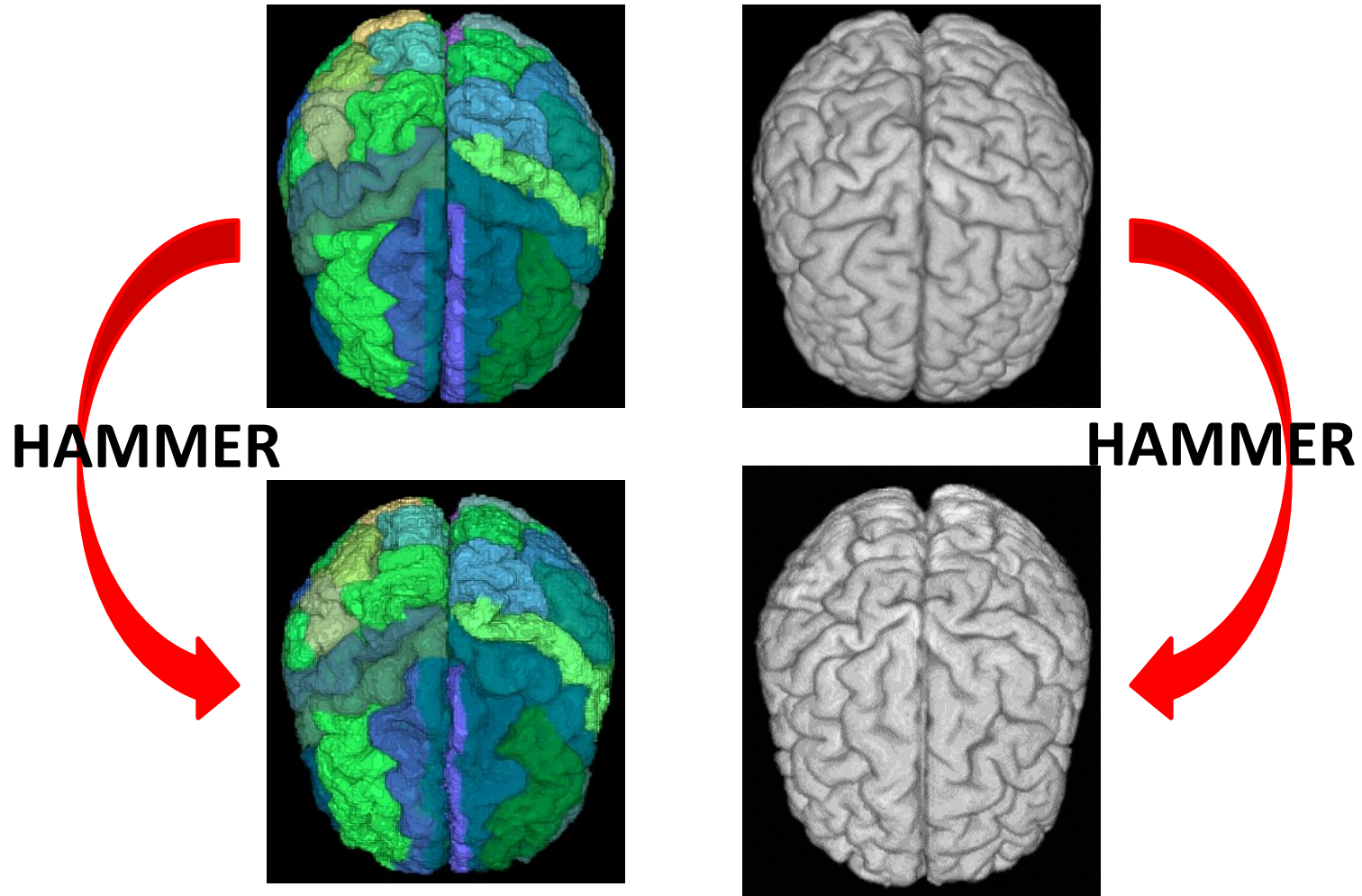
Average brain by HAMMER

Results



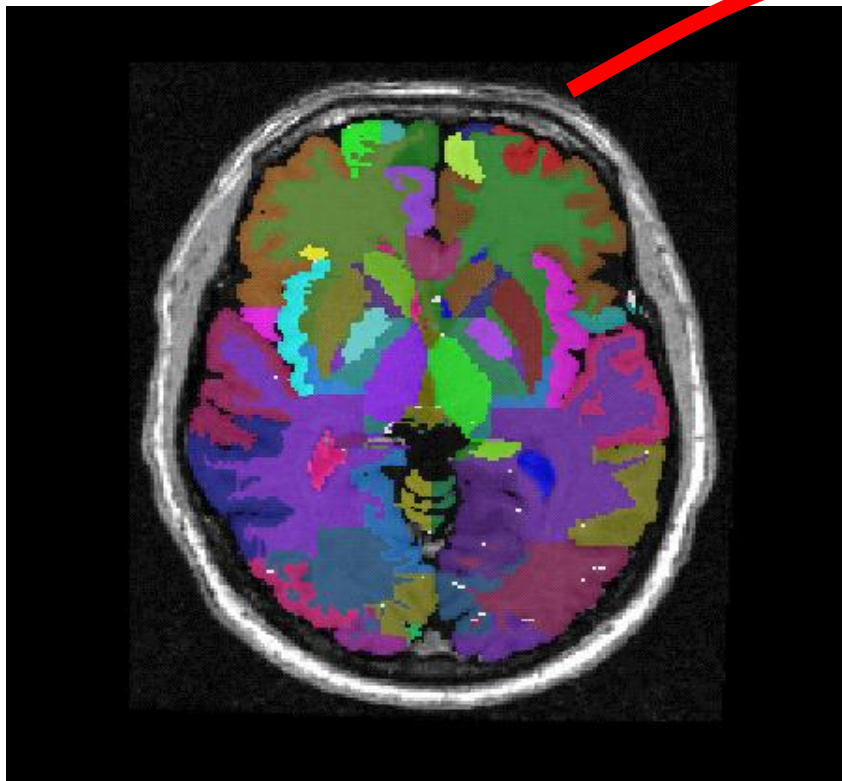
Results

HAMMER in labeling brain structures

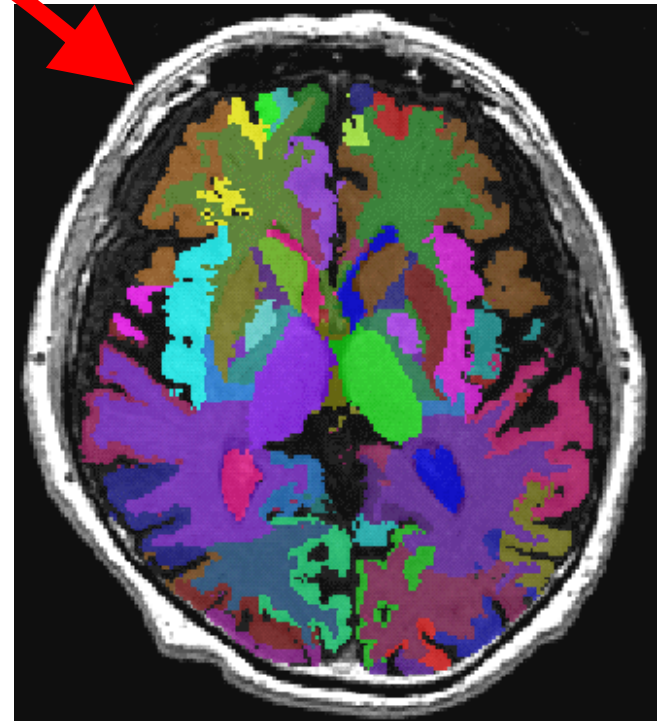


Results

Cross-sectional views



Model

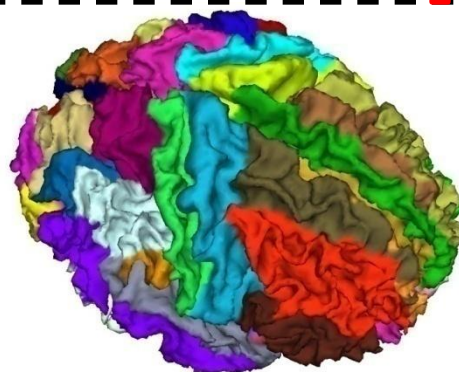


Subject

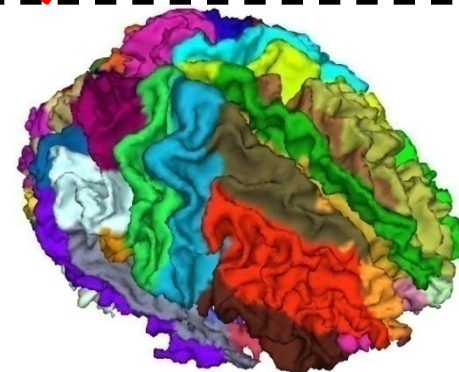
Results

Label cortical surface

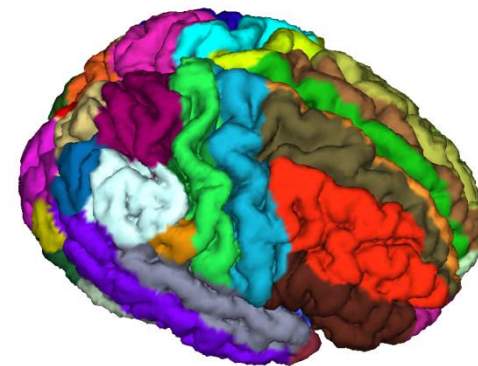
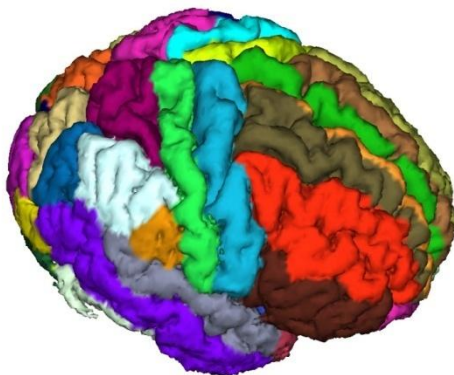
Inner cortical surface



HAMMER



Outer cortical surface



Model

Subject

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

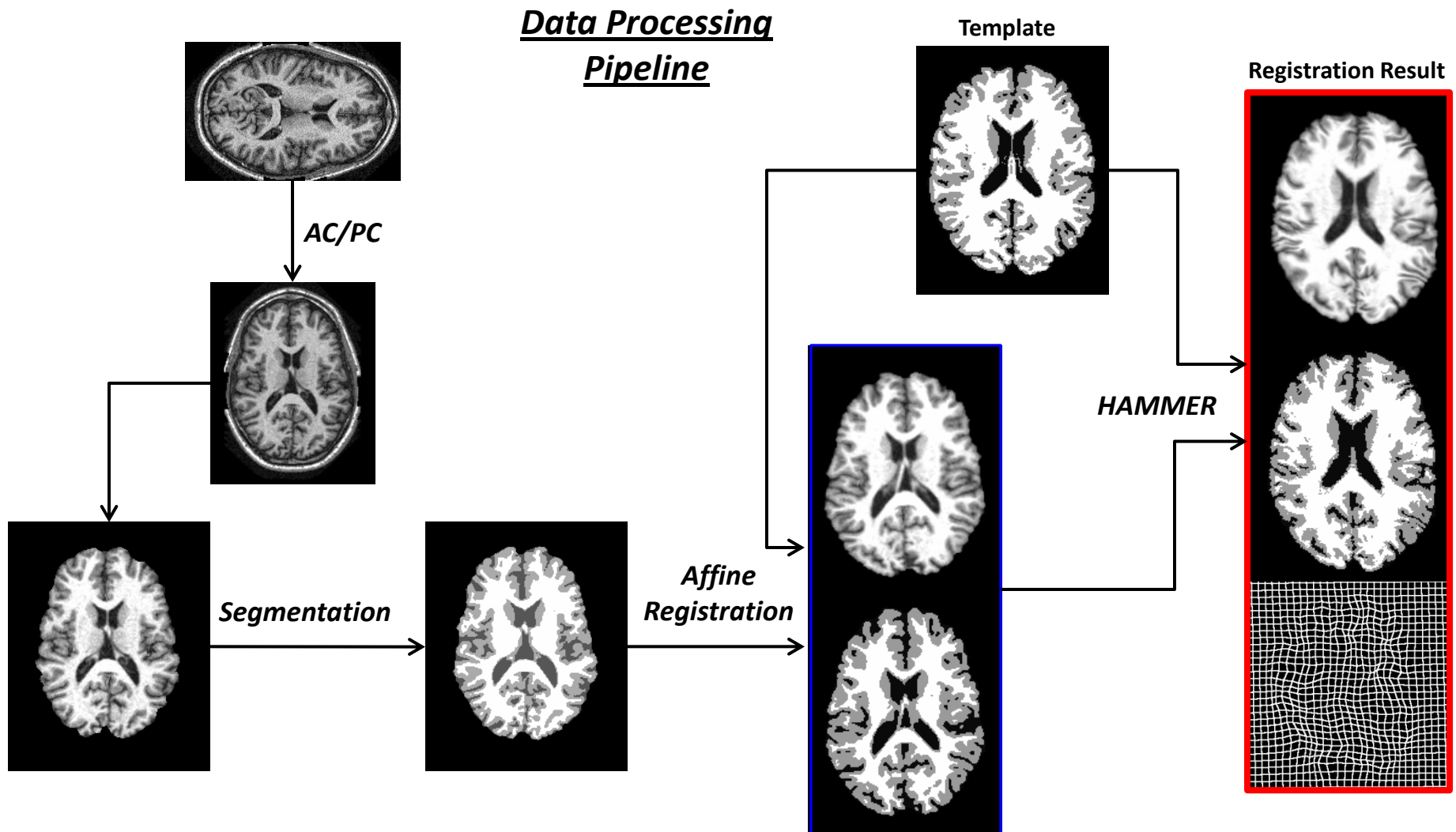
- ✓ Successfully implemented HAMMER in ITK. (Over 2,000 lines of code)
- ✓ Integrated HAMMER into Slicer3
- ✓ Verified and tested its performance in Slicer3
- ✓ Tutorial on using HAMMER in Slicer 3 can be found at [http://wiki.namic.org/Wiki/index.php/AHM_2010_Tutorial_Contest - Hammer Registration](http://wiki.namic.org/Wiki/index.php/AHM_2010_Tutorial_Contest_-_Hammer_Registration)

The screenshot displays the 3DSlicer website interface. At the top, there is a navigation bar with the 3DSlicer logo and the text "The source for neuroimaging tools and resources". A search bar is located on the right side of the header. Below the header, the main content area is titled "Hammer And WML Modules for 3D Slicer". The page is divided into several sections:

- Summary:** Contains a list of links for "Advanced Search", "Docs", "Downloads", "Forums", "Mailing Lists", "MediaWiki", "News", "Reviews/Ratings", "Source Code", "Surveys", "Tasks", and "Tracker".
- Download Now:** A yellow button with a download icon and a dropdown menu showing "HAMMER_ITK_VERSION: hammer_itk.tar.gz (26K)". To the right of the button is an "OR See All Files >>" link.
- Specifications:** A blue header section.
- License:** A blue section with the text "3D Slicer License".
- Associations:** A blue header section.
- is a plugin for:** A blue section with the text "3D Slicer".
- Recent Activity:** A blue header section with a "Show: -- Show All --" dropdown. Below it, a red download icon is followed by the text "hammerwml: WMLSeg_Slicer_Tutorial release" and "White_Matter_Lesion_Segmentation_Tutorial.pdf posted by Minjeong Kim on Jul 9".
- Reviews & Ratings:** A blue header section with a "User Reviews (3)" link. Below it, there are three rows of yellow circles representing ratings for "OVERALL:", "INSTALLATION:", and "DOCUMENTATION:". The "OVERALL:" row has 10 circles, "INSTALLATION:" has 10 circles, and "DOCUMENTATION:" has 10 circles.
- Participate!:** A yellow section with a "Participate!" header and several links: "Report issues", "Add a review", "Join the team", "Monitor a file release", "Subscribe to RSS feed", and "Bookmark this page".
- Home Page:** A blue header section with a "Home Page" link. Below it, there are statistics: "Total Downloads: 183", "Activity Percentile: 53.70%", "View Statistics", and "Registered: Dec 23, 2008".

On the left side of the page, there is a sidebar with a "Help & Acknowledgement" section. The "Acknowledgement" sub-section is active, showing the text: "HAMMER is an algorithm for elastic registratic geometric moment invariants as attributes and matching mechanism for finding deformation implements the algorithm described in 'HAMMM Matching Mechanism for Elastic Registration', Imaging, 21(11):1421-1439, Nov 2002). Its brain images with gray matter, white matter, For more detailed documentation see: http://na-mic.org/Wiki/index.php/NA-MIC_NC <http://www.med.unc.edu/~dqshen/HAMMER.I>

HAMMER in Slicer



HAMMER in Slicer

Preprocessing step in Slicer

Skull strip module in Slicer, developed by Xiaodong Tao

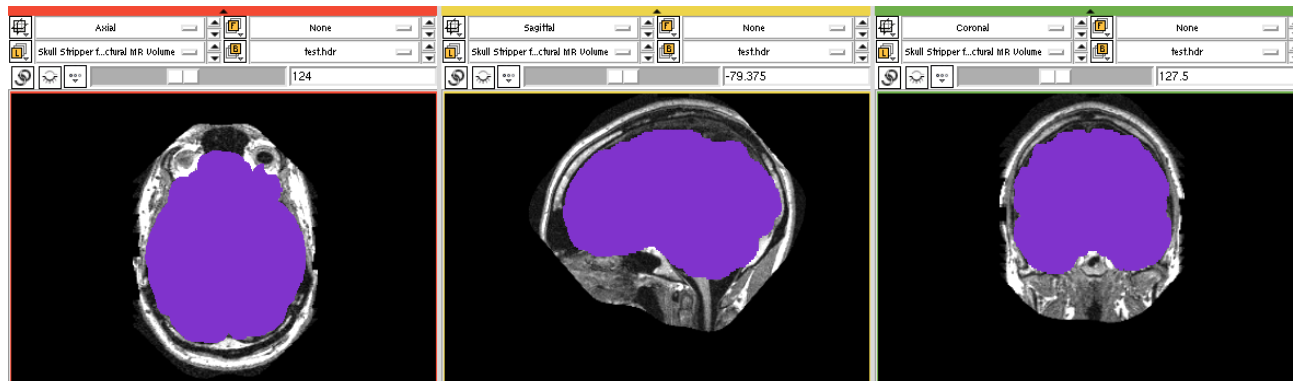
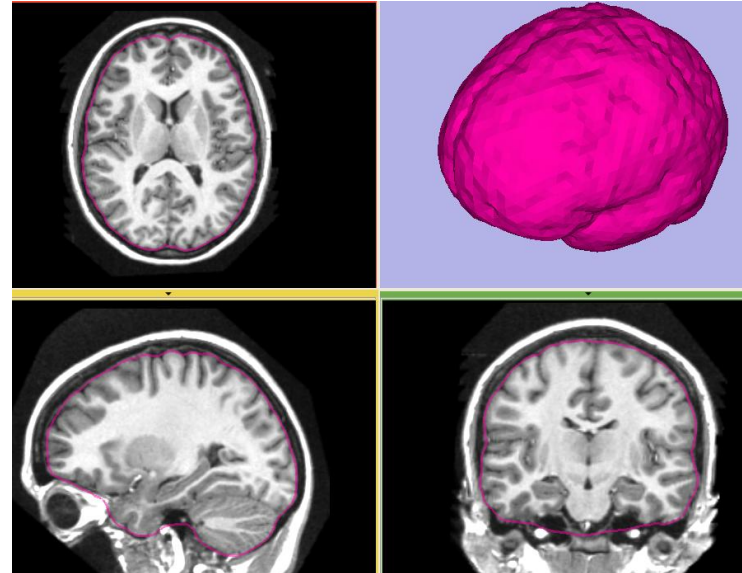
▲ Help & Acknowledgement

Help | Acknowledgement

This work is part of the National Alliance for Medical Image Computing (NAMIC), funded by the National Institutes of Health through the NIH Roadmap for Medical Research, Grant U54 EB005149.

Xiaodong Tao, taox@research.ge.com

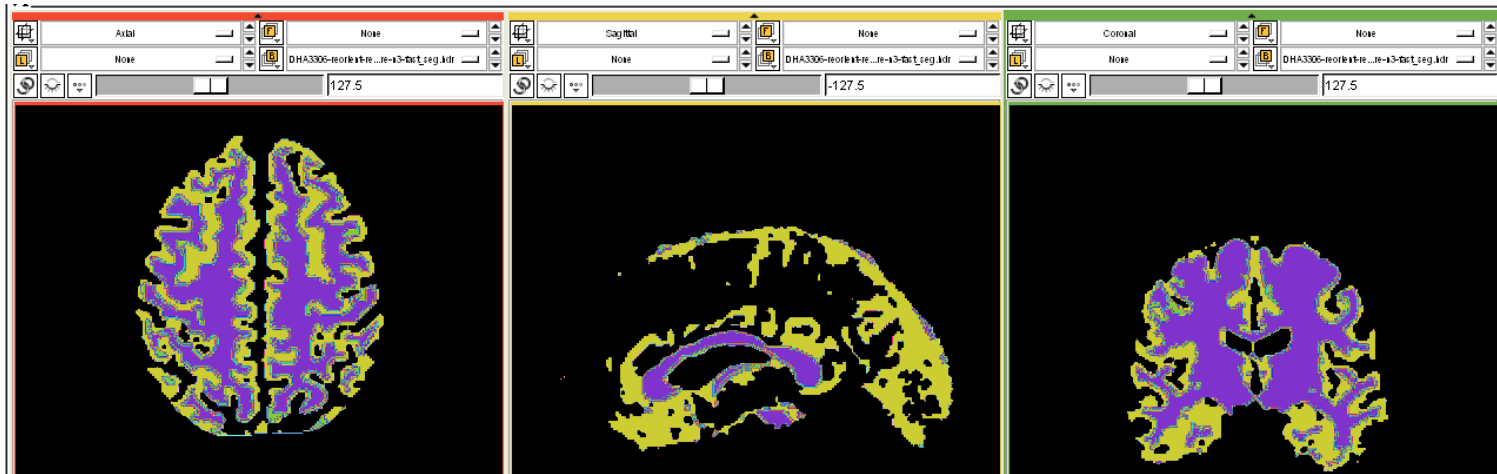
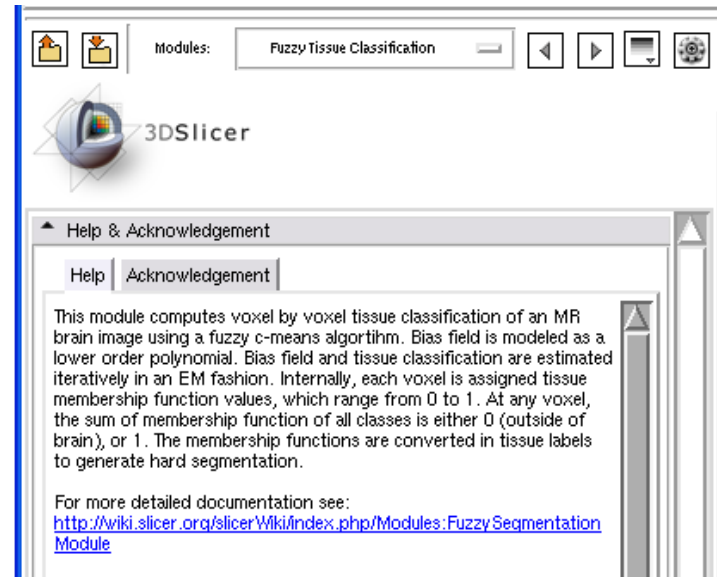
▲ Skull Stripper For Structural MR



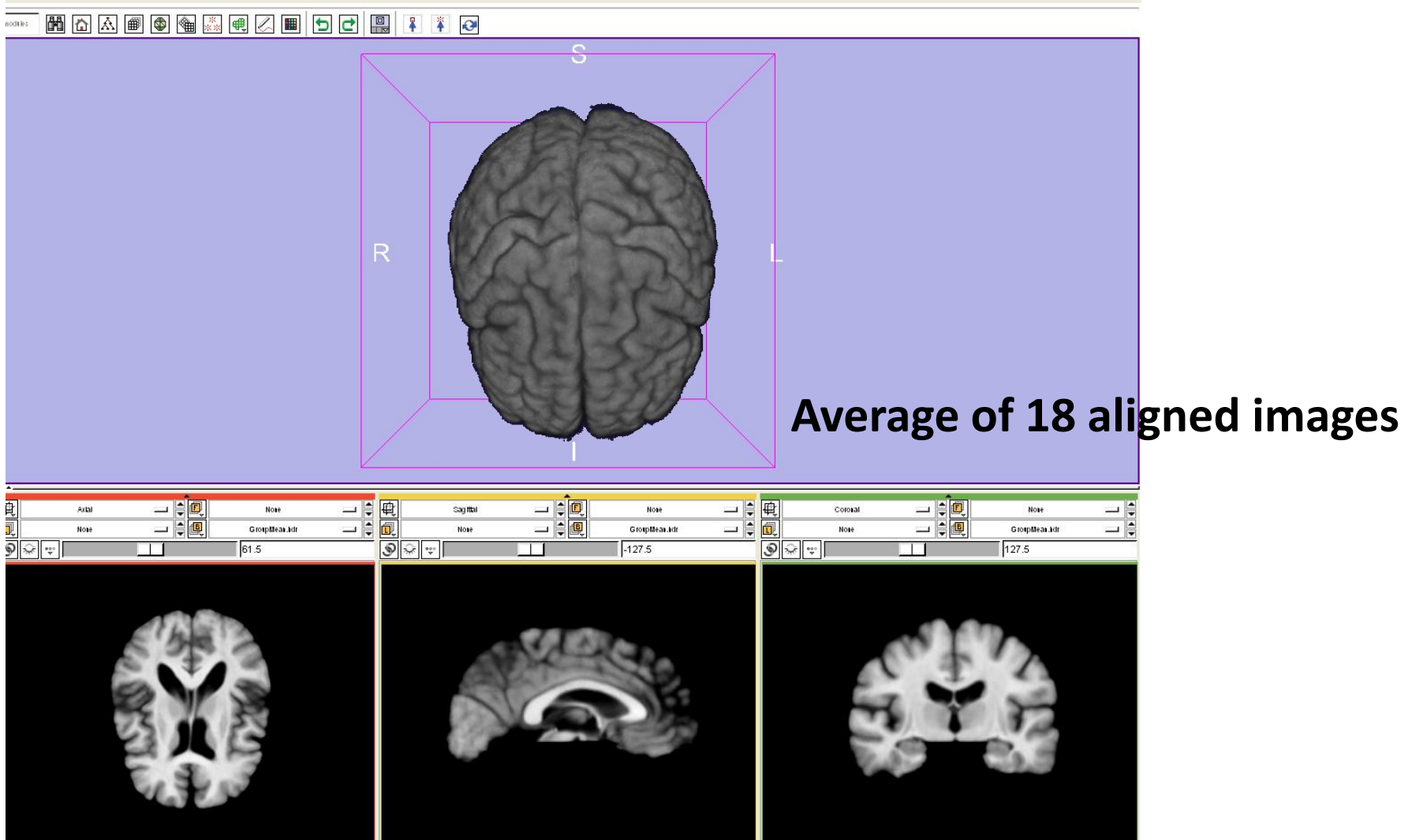
HAMMER in Slicer

Preprocessing step in Slicer

Fuzzy tissue segmentation module in Slicer, developed by Xiaodong Tao



HAMMER in Slicer



HAMMER in Slicer

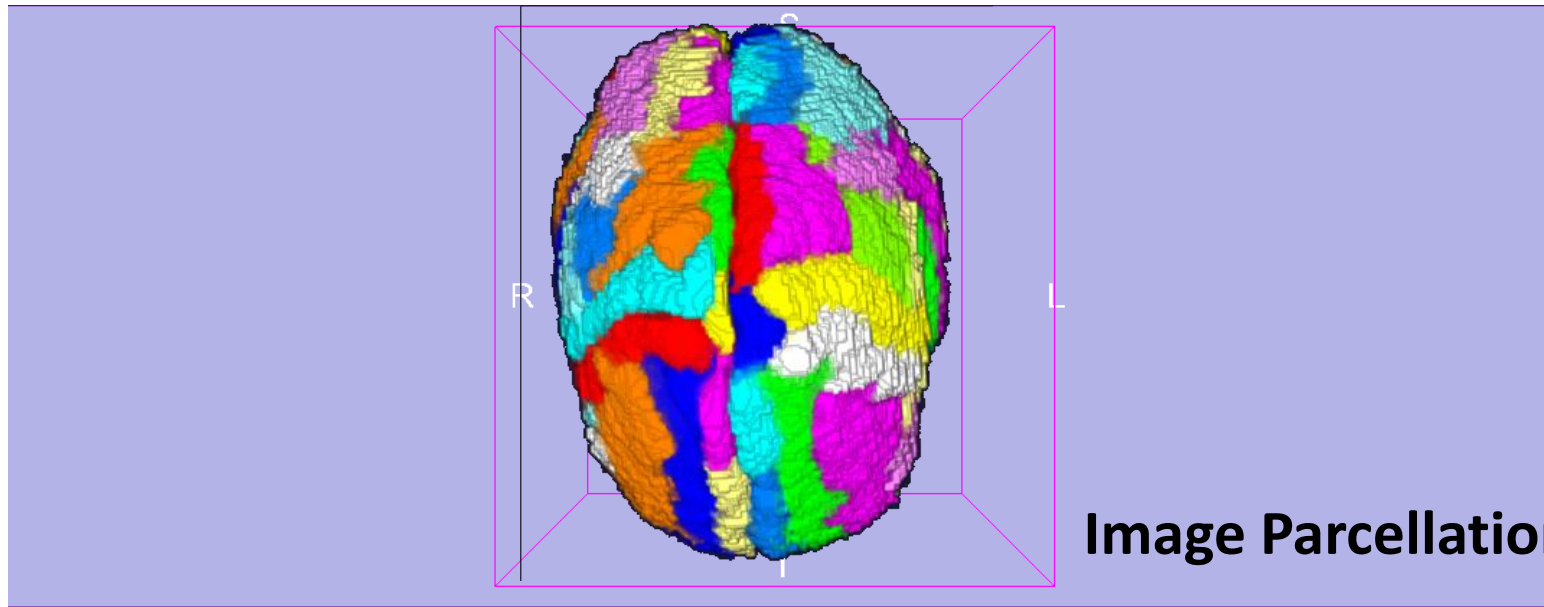
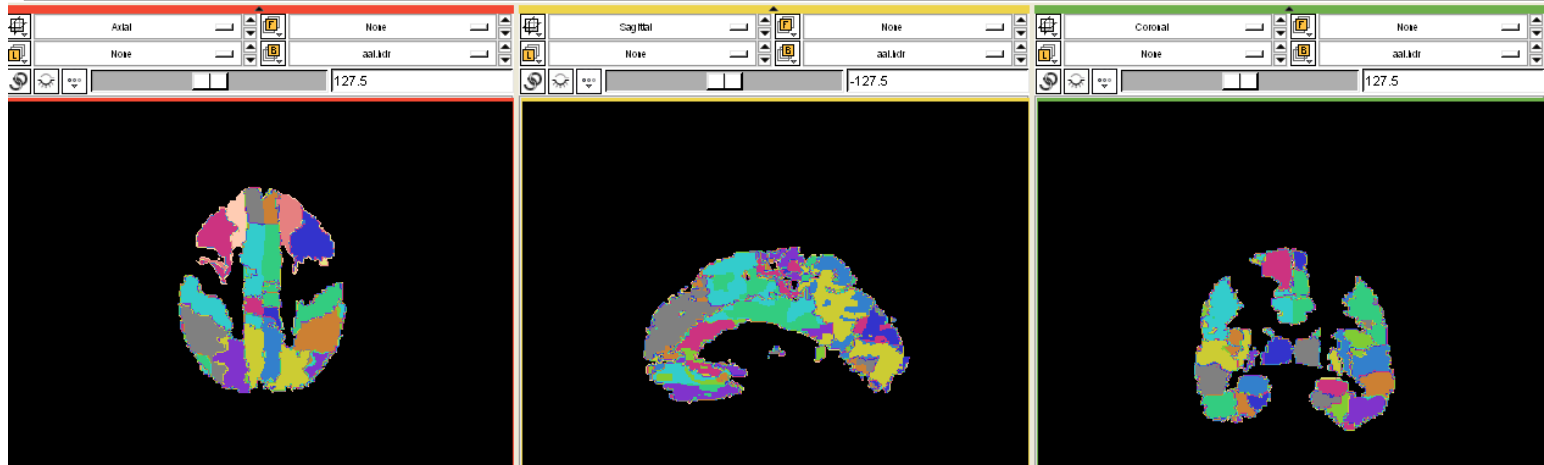
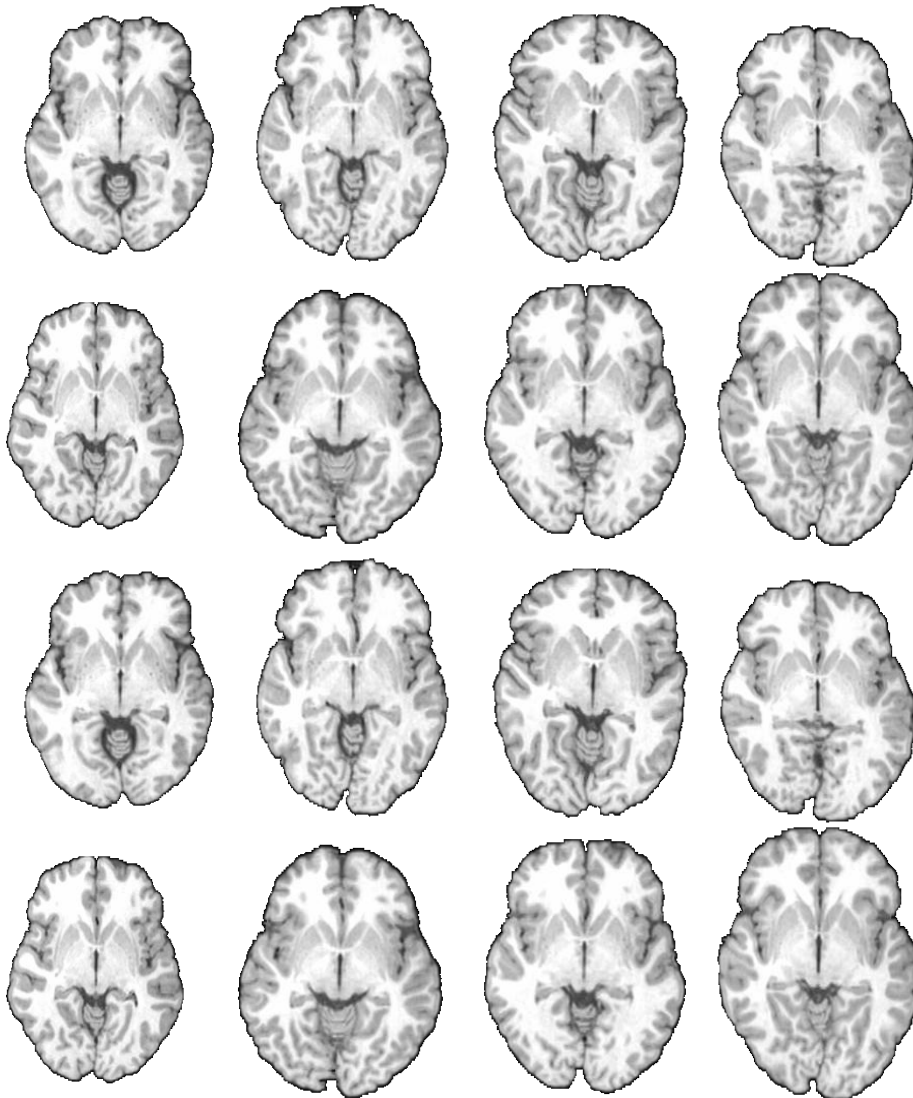


Image Parcellation Result

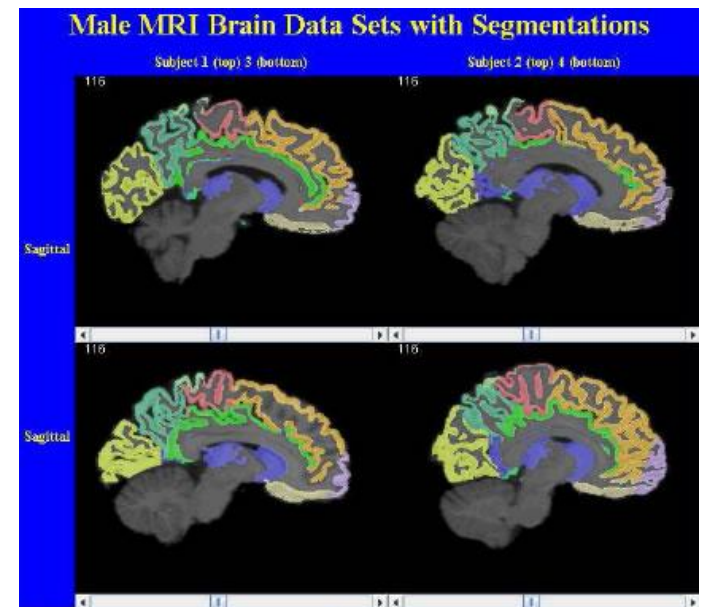


HAMMER in Slicer

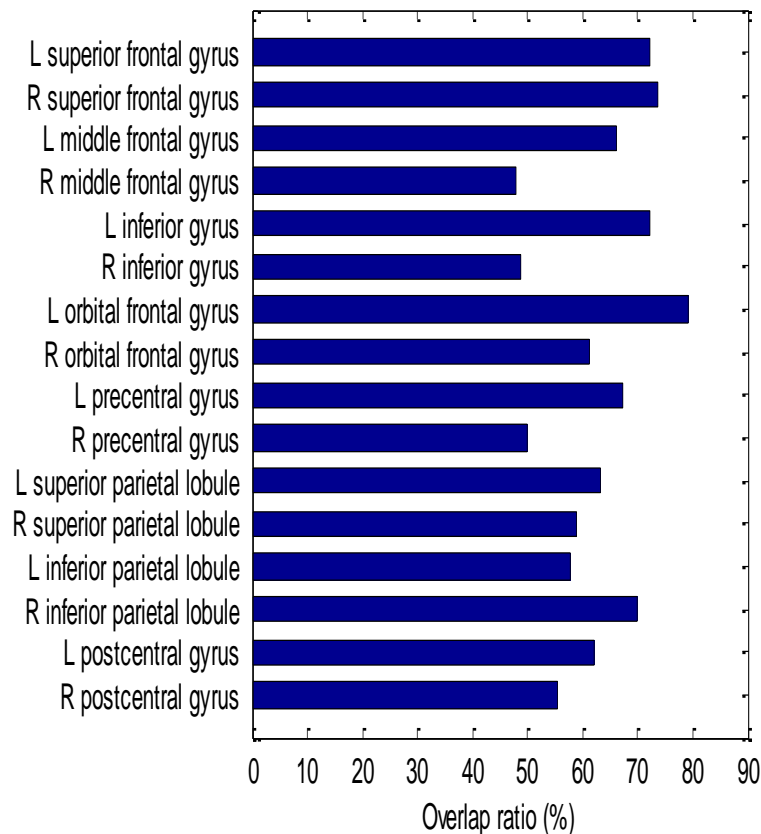
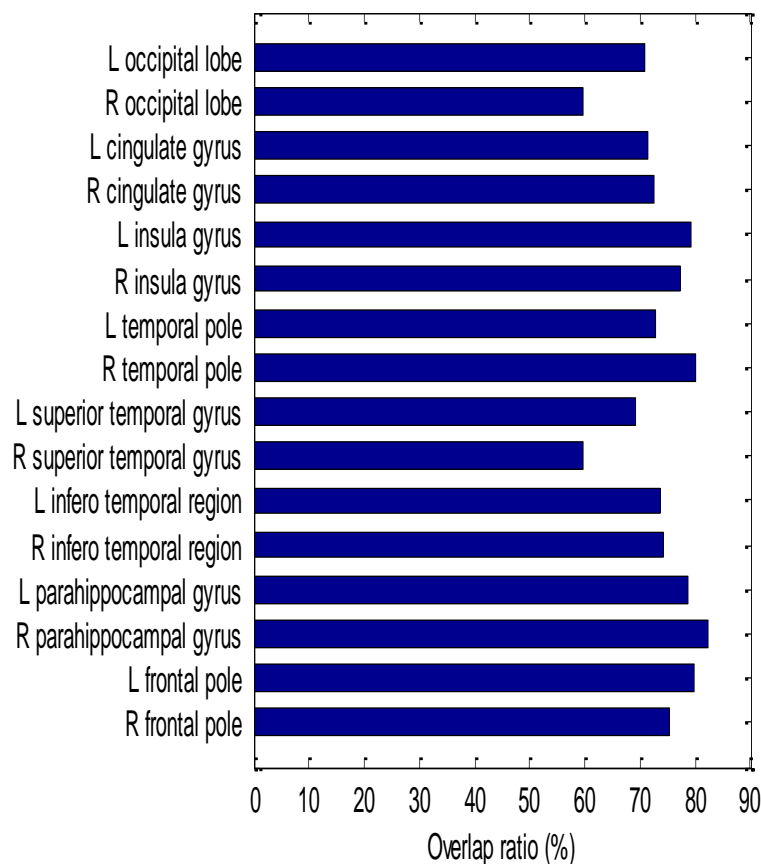


NIREP Dataset
16 subjects with manually
labeled 32 ROIs

<http://www.nirep.org>



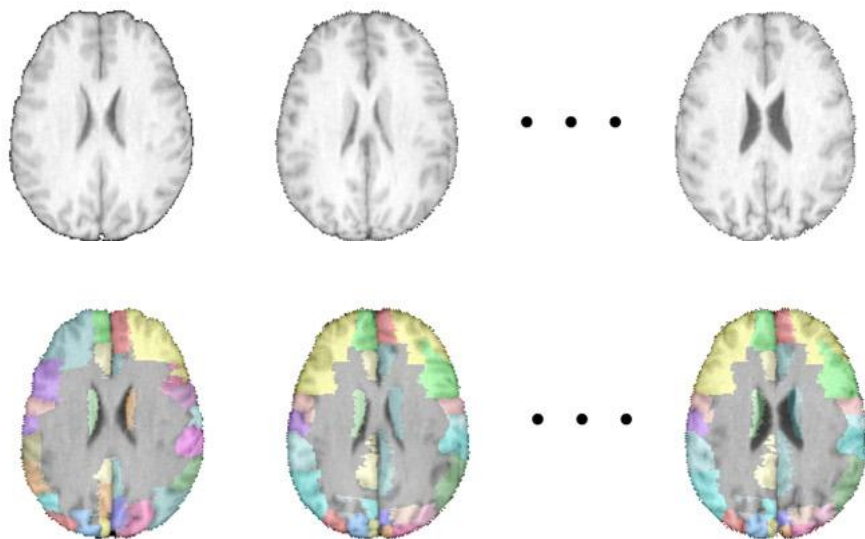
HAMMER in Slicer



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

HAMMER in Slicer

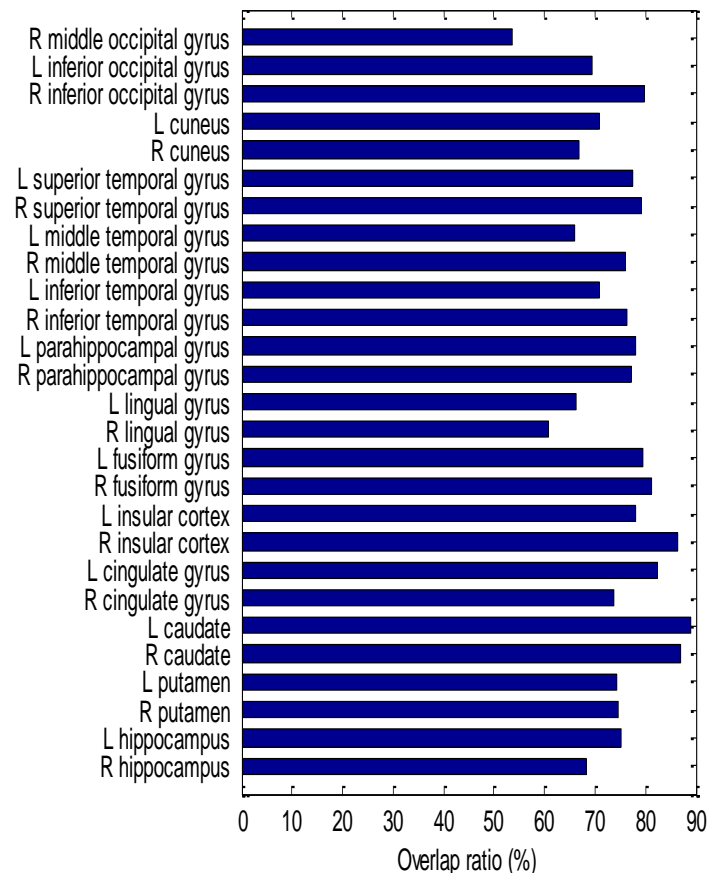
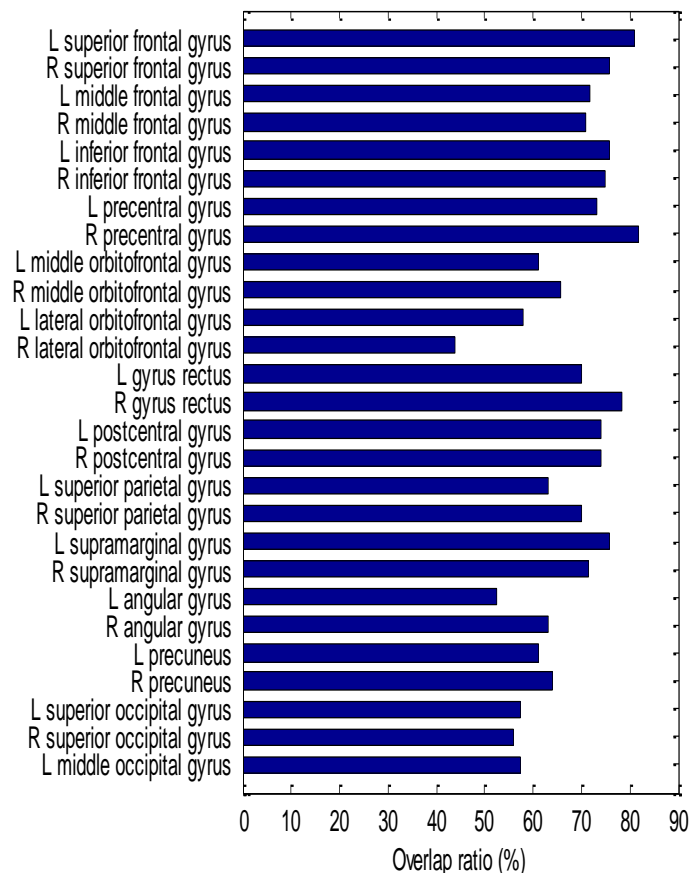
LONI LPBA40 Dataset 40 subjects with 54 manually labeled ROIs



Frontal lobe		Occipital lobe	
■	L superior frontal gyrus	■	L superior occipital gyrus
■	R superior frontal gyrus	■	R superior occipital gyrus
■	L middle frontal gyrus	■	L middle occipital gyrus
■	R middle frontal gyrus	■	R middle occipital gyrus
■	L inferior frontal gyrus	■	L inferior occipital gyrus
■	R inferior frontal gyrus	■	R inferior occipital gyrus
■	L precentral gyrus	■	L cuneus
■	R precentral gyrus	■	R cuneus
■	L middle orbitofrontal gyrus		
■	R middle orbitofrontal gyrus		
■	L lateral orbitofrontal gyrus	Temporal lobe	
■	R lateral orbitofrontal gyrus	■	L superior temporal gyrus
■	L gyrus rectus	■	R superior temporal gyrus
■	R gyrus rectus	■	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
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		

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

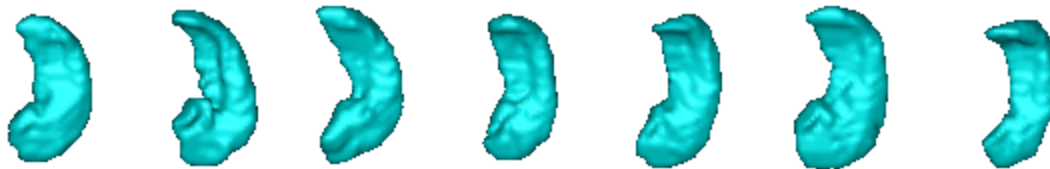
HAMMER in Slicer



Left hippocampus



Warped result of
left hippocampus



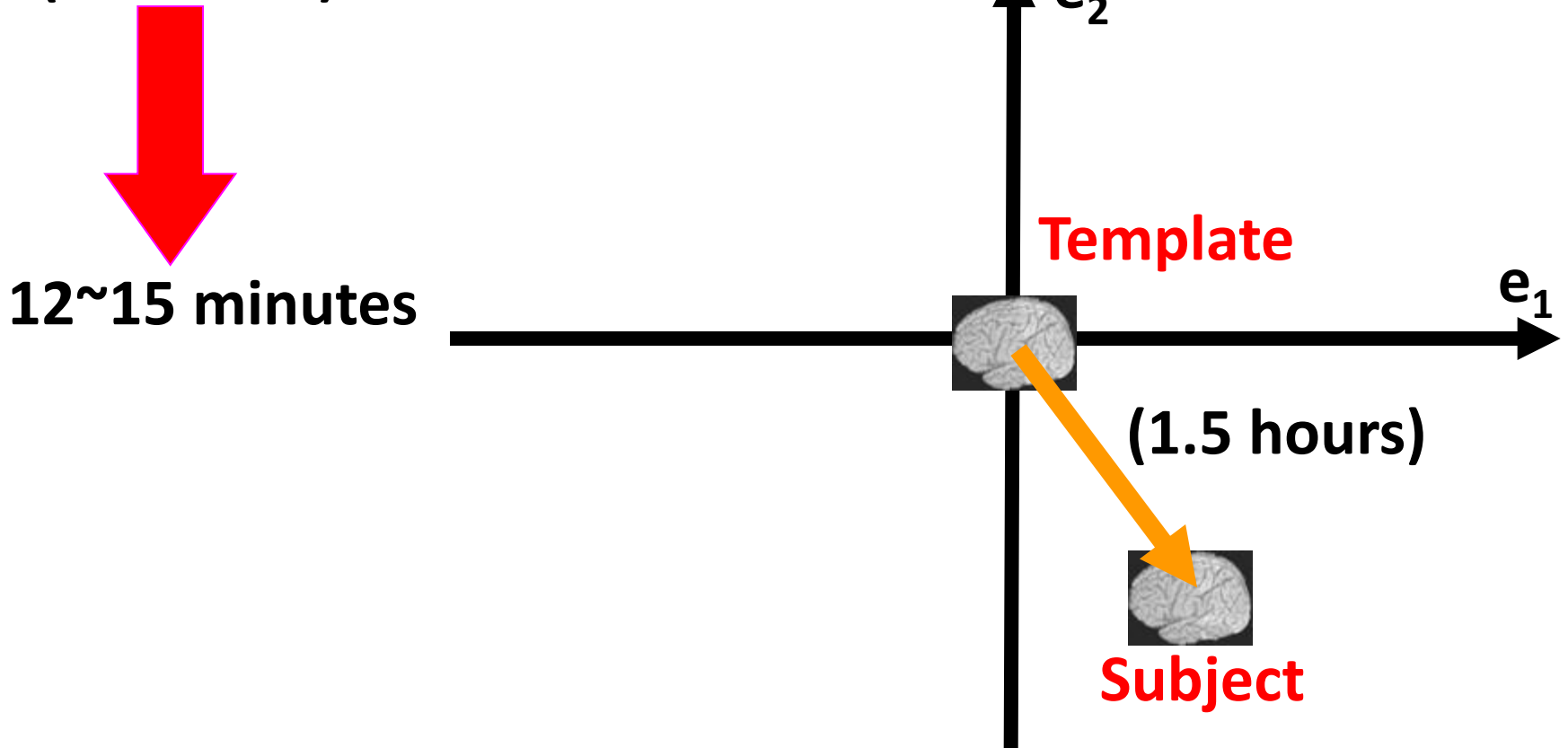
Right hippocampus



Warped result of
right hippocampus

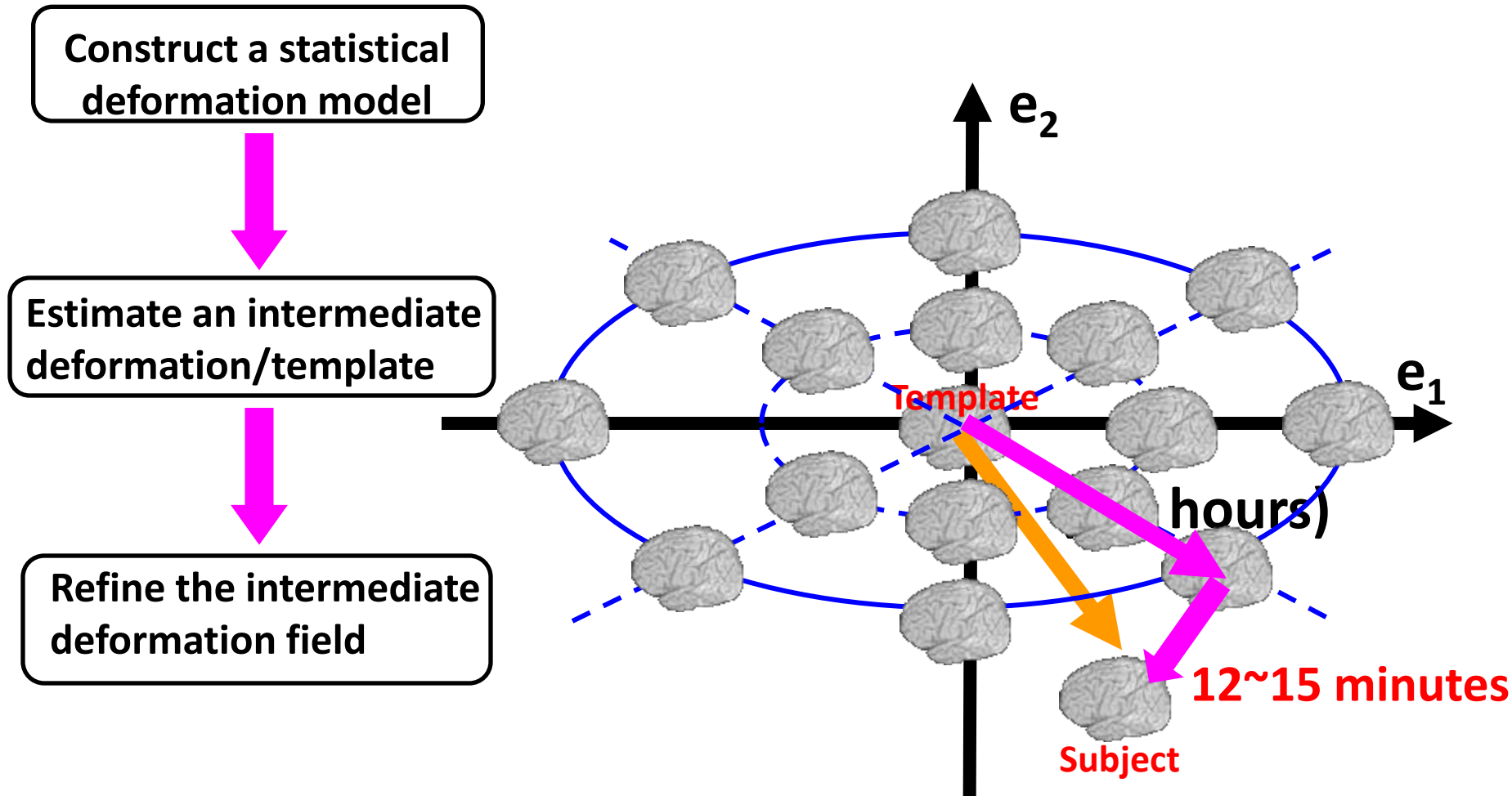
Further Improvements on HAMMER

RABBIT: To speed up our HAMMER registration algorithm
(1.5 hours)



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

Further Improvements on HAMMER

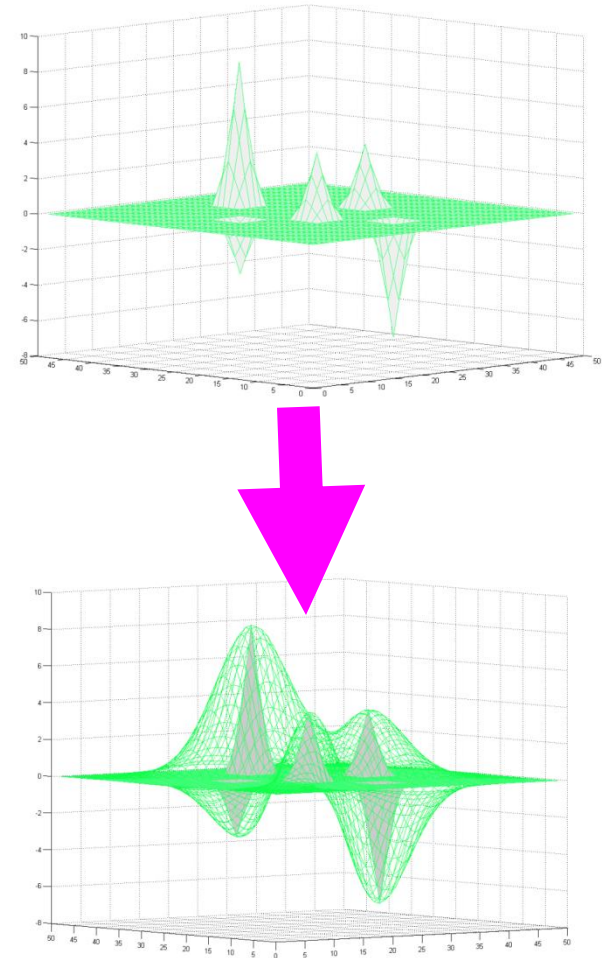


- Tang et. al., RABBIT: Rapid Alignment of Brains by Building Intermediate Templates. *Neuroimage*, 47(4):1277-87, Oct 1 2009.

Further Improvements on HAMMER

TPS-HAMMER:

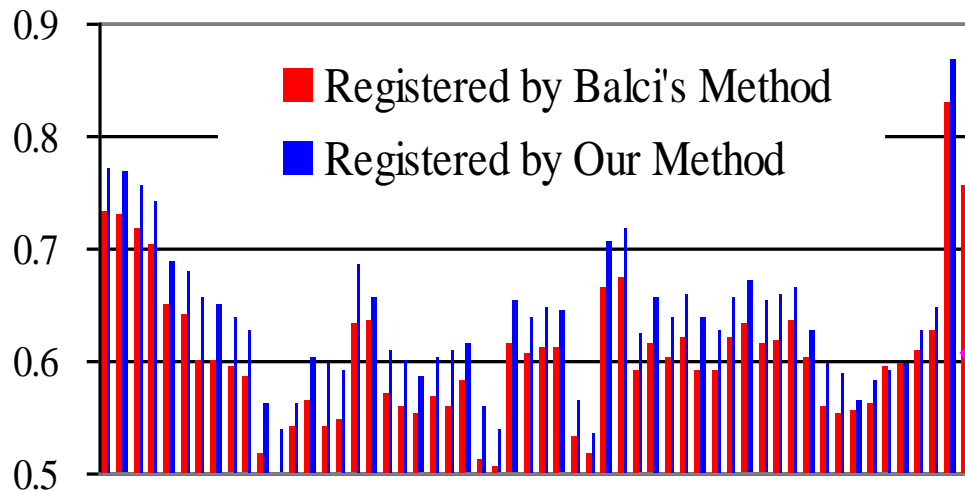
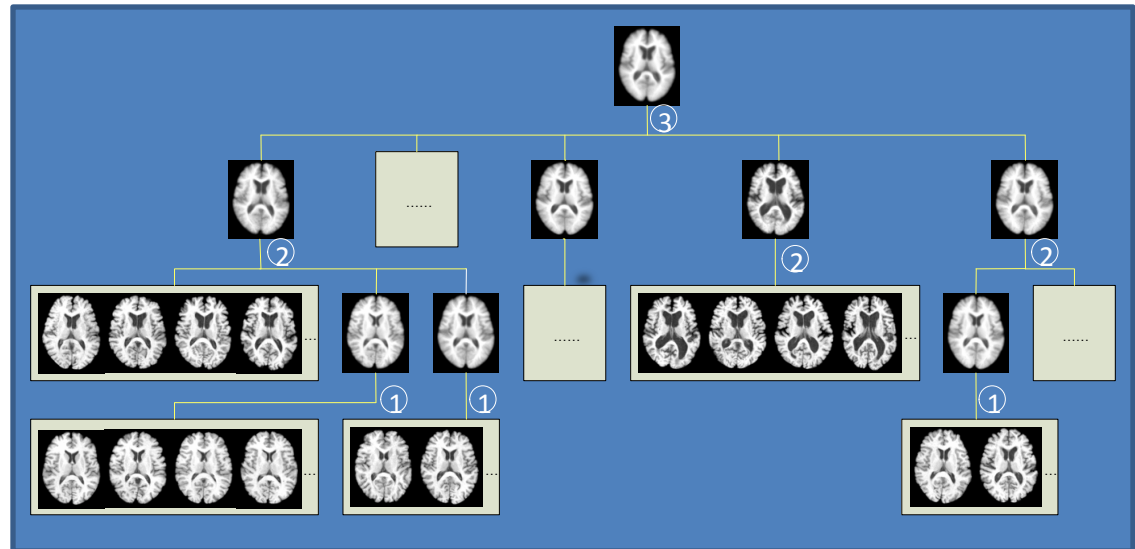
- Use soft correspondence detection to robustly establish correspondences for the driving voxels
- Use Thin Plate Splines (TPS) to effectively interpolate deformation fields, based on those estimated at the driving voxels



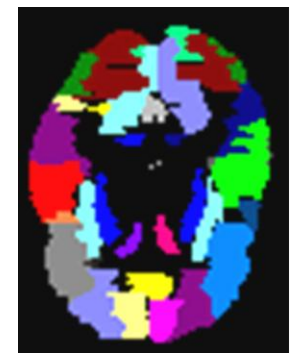
- Wu et. al., TPS-HAMMER: Improving HAMMER Registration Algorithm by Soft Correspondence Matching and Thin-Plate Splines Based Deformation Interpolation. *Neuroimage*, 49(3):2225-2233, Feb 2010.

Groupwise Registration

Hierarchical Groupwise registration:



6.0% increase for Dice ratio

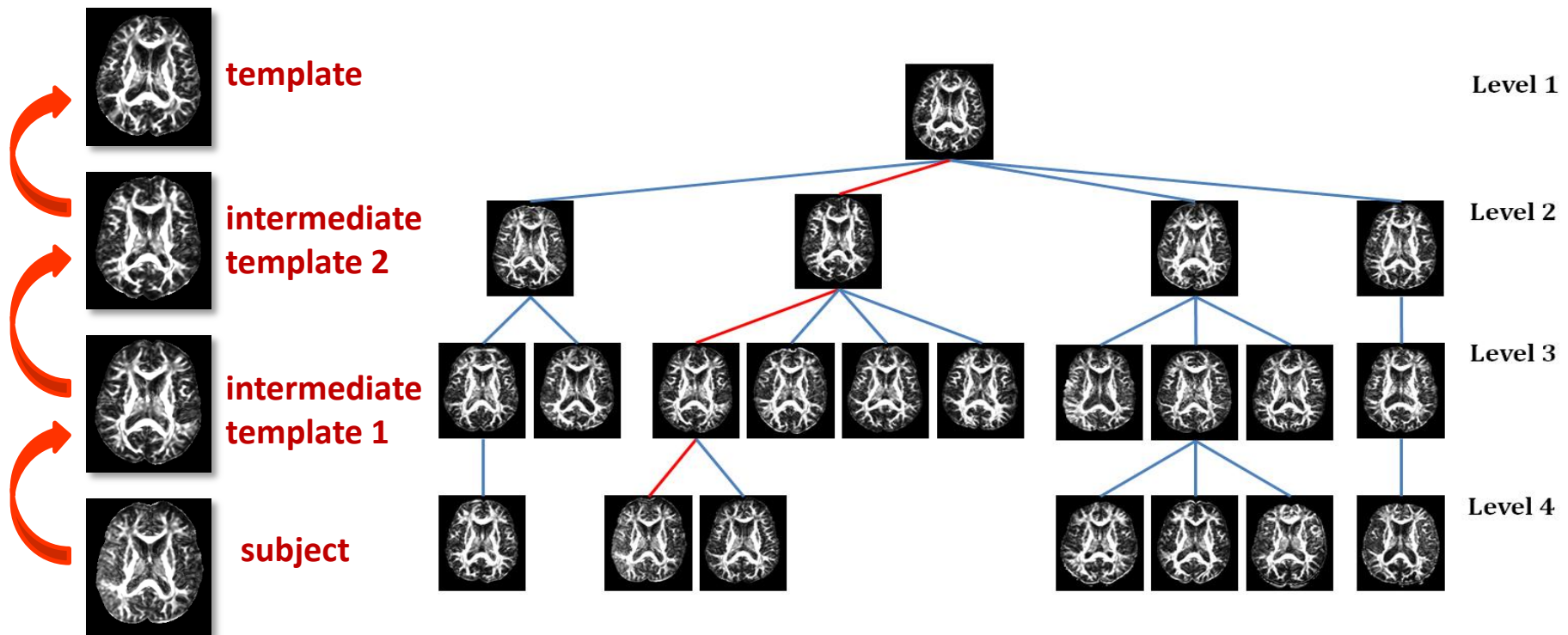


40 subjects with 54 manual ROIs

- 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:

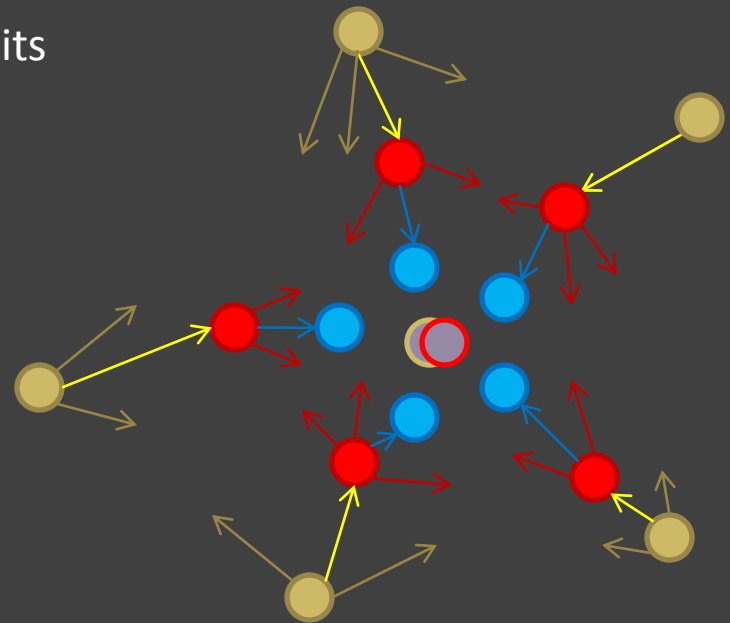


- Jia et al, "Intermediate Templates Guided Groupwise Registration of Diffusion Tensor Images", Revised for *Neuroimage*, 2010.

Groupwise Registration

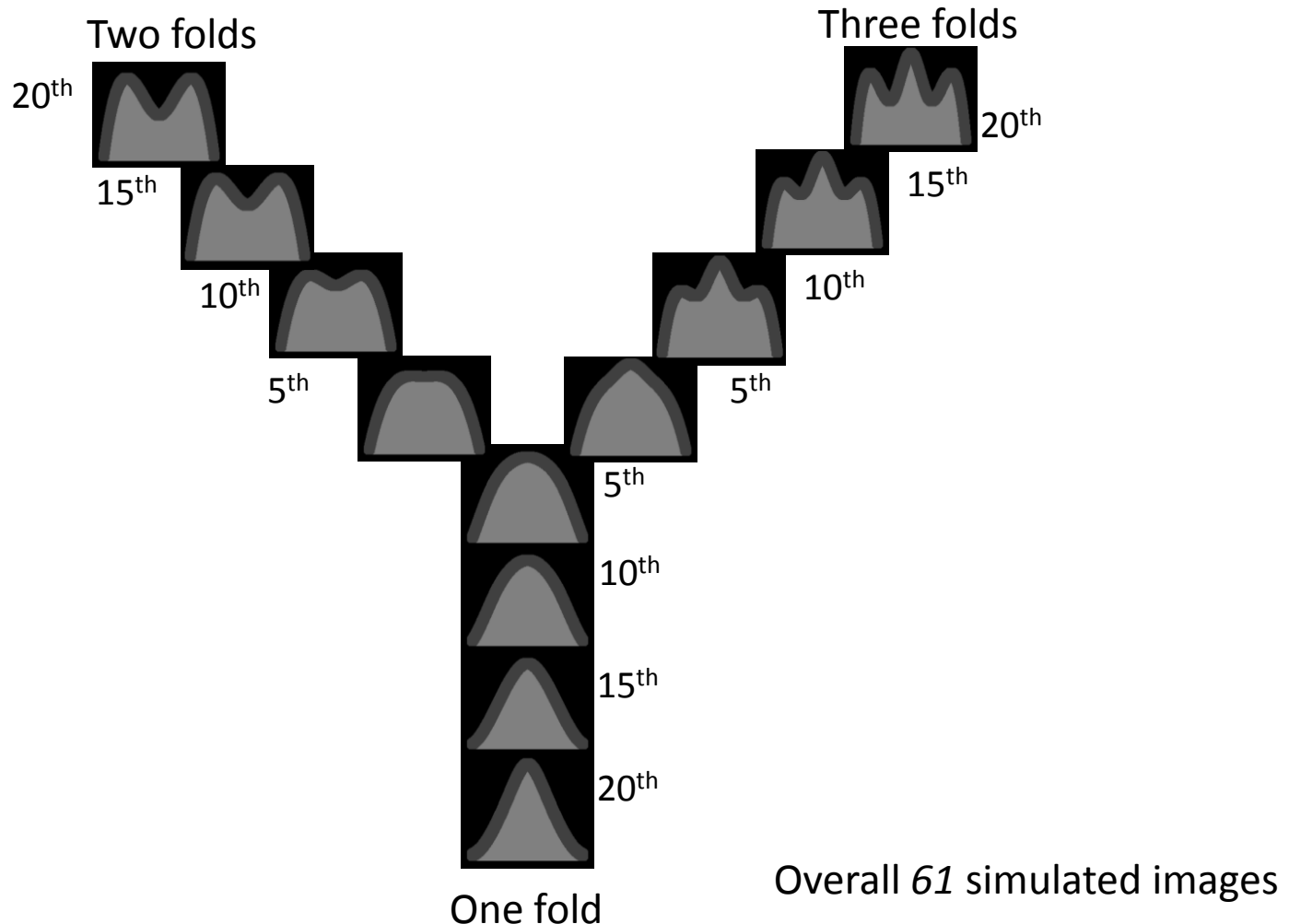
ABSORB:

- 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



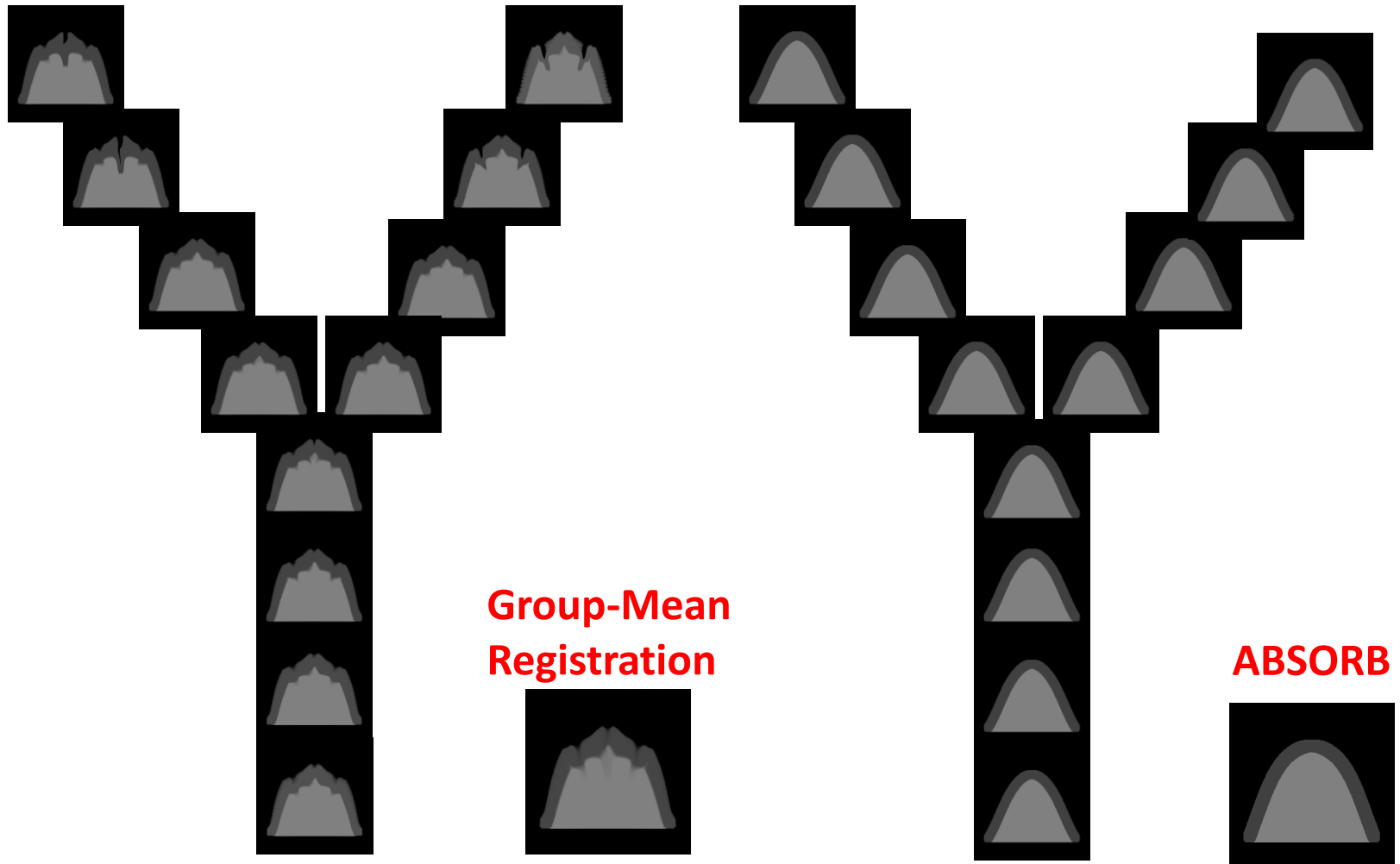
- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

Groupwise Registration



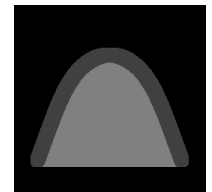
- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

Groupwise Registration



**Group-Mean
Registration**

ABSORB



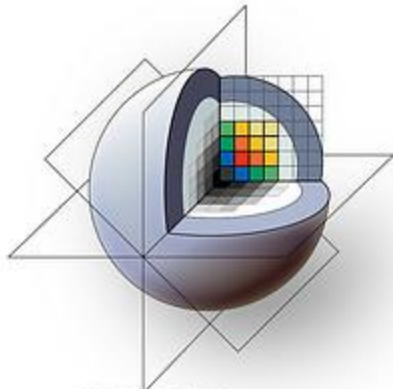
- Jia et al, "ABSORB: Atlas Building by Self-Organized Registration and Bundling", *NeuroImage*, 51(3): 1057-1070, Mar. 2010. **(free software package available in our web)**

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 Correspondence Detection", *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



3DSlicer



THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL