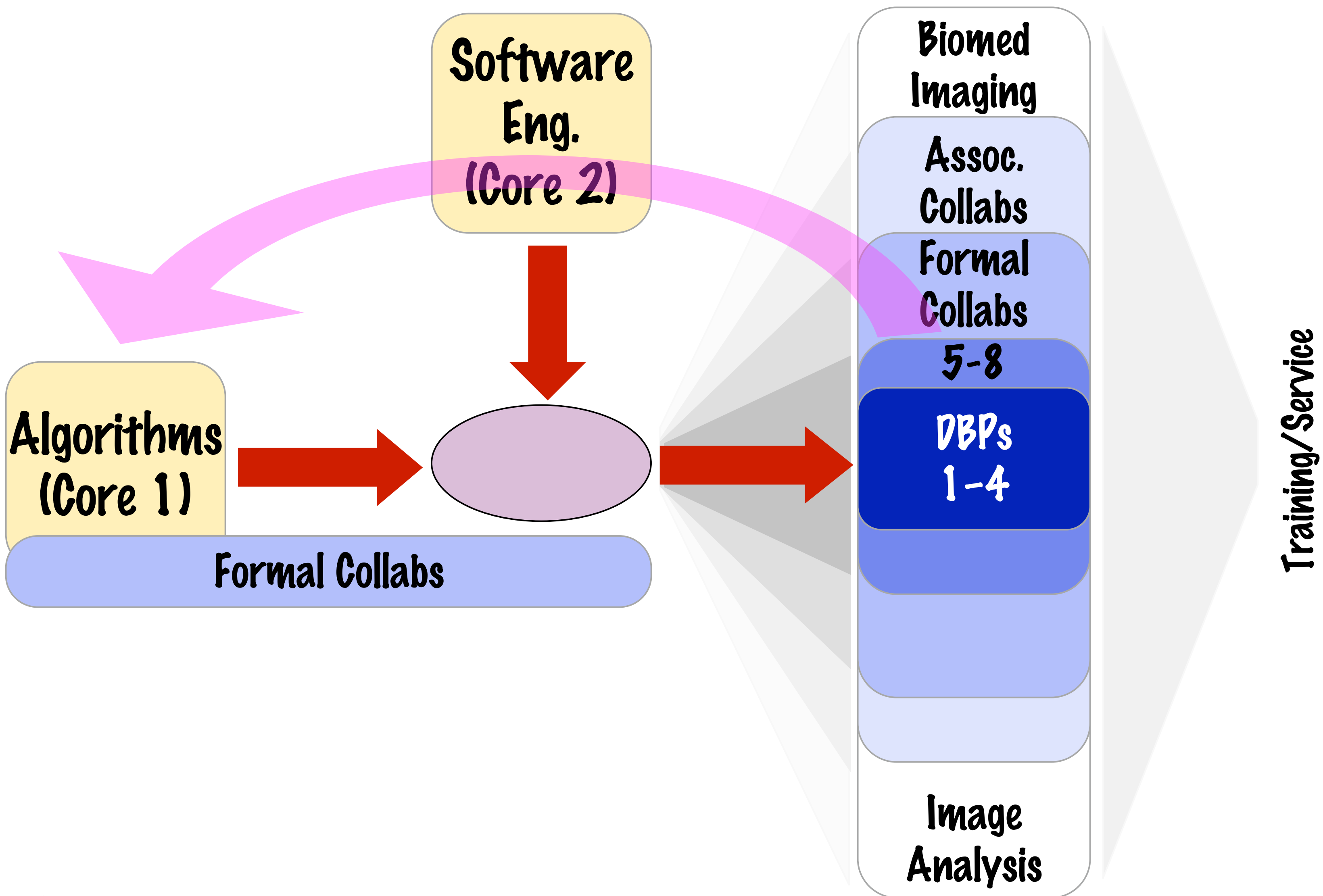
NA-MIC Highlights: From Algorithms and Software to Biomedical Science

Ross Whitaker

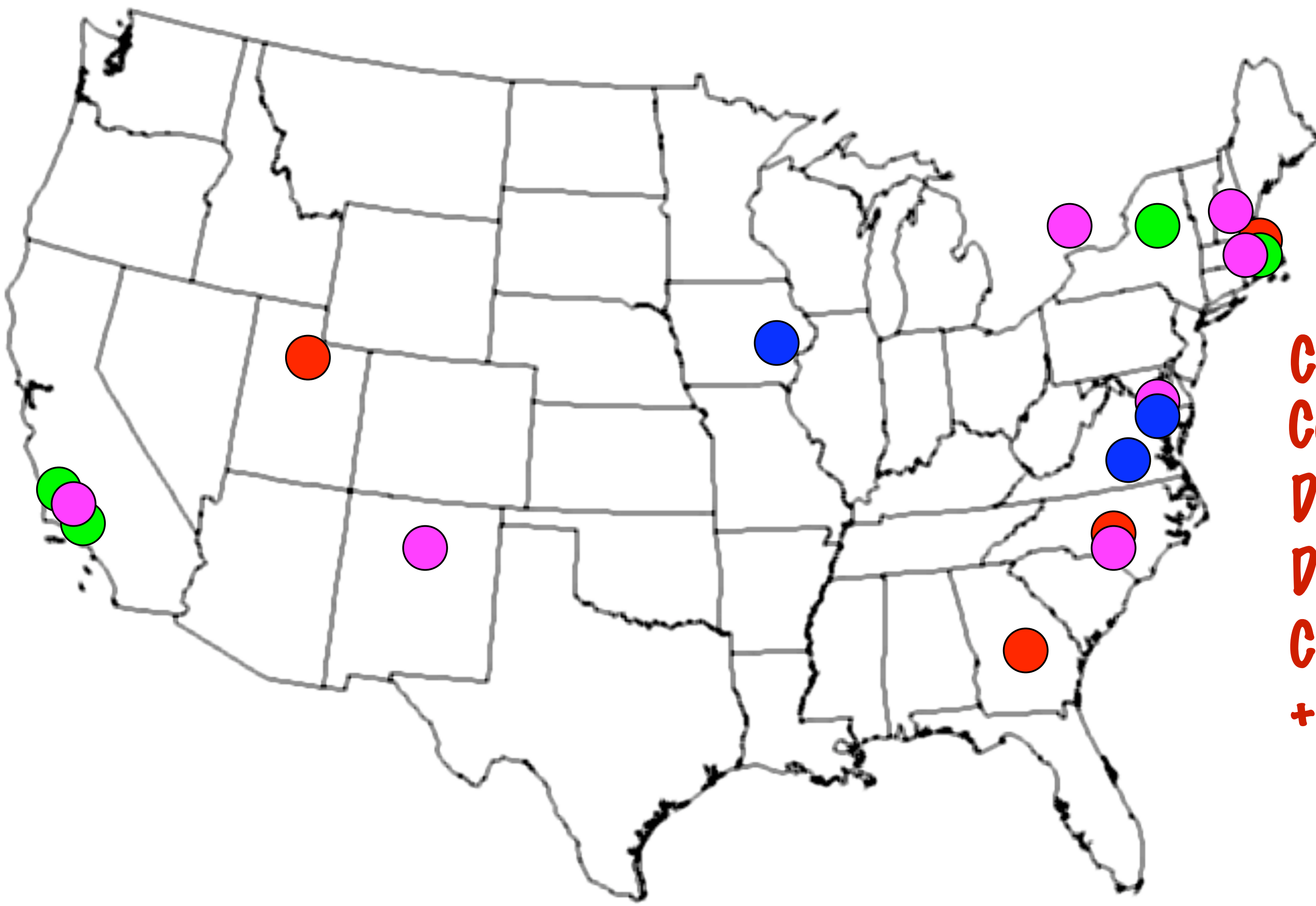
University of Utah

National Alliance for Biomedical Image Computing

Algorithms, Software, Science



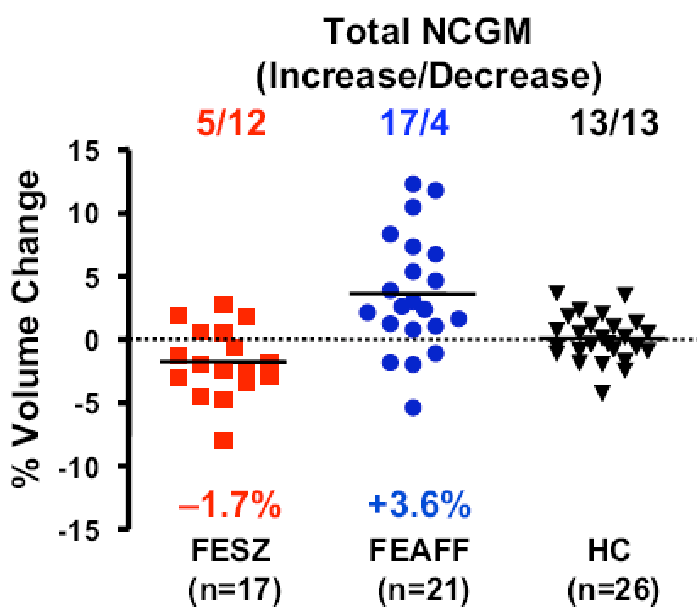
NA-MIC-A *National* Alliance

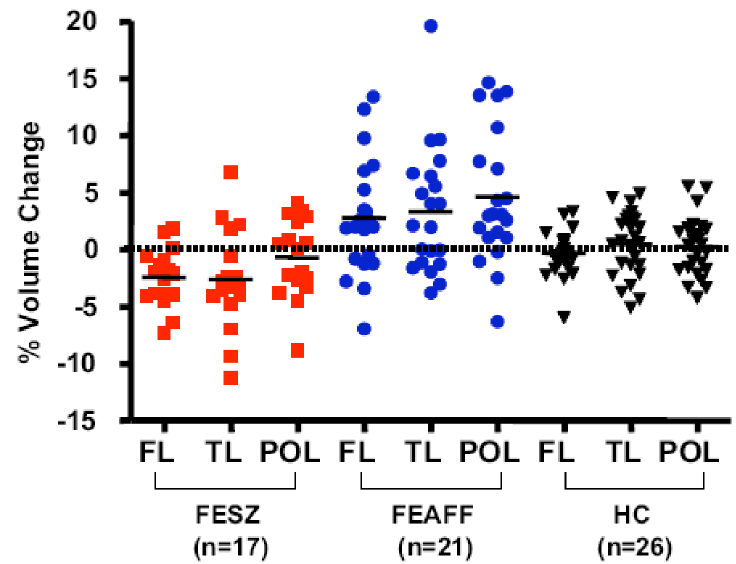


Core 1
Core 2
DBPs I
DBPs II
Collabs PAR
+ many others

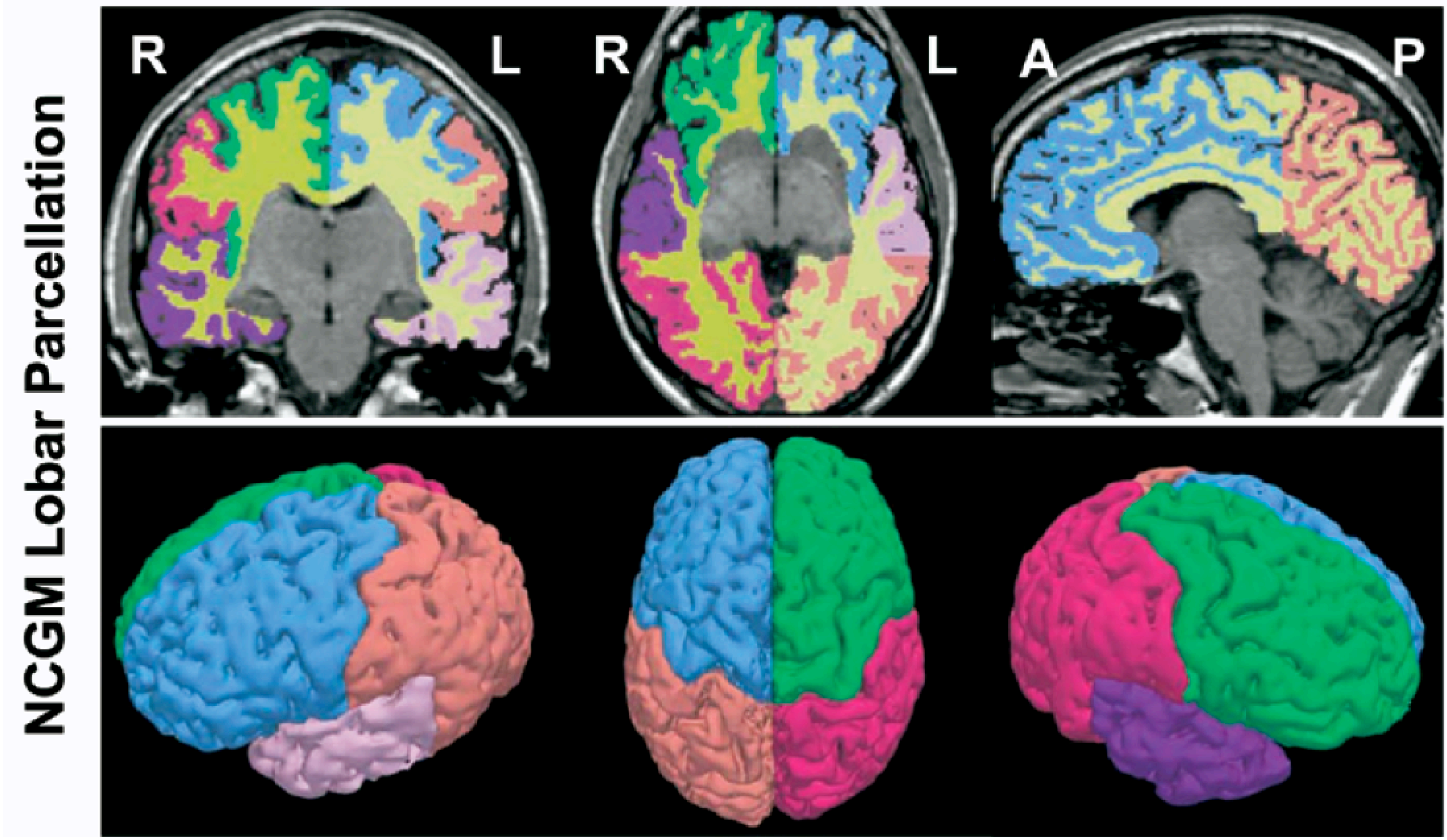
Schizophrenia-B&W, Shenton et al.

- M. 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.



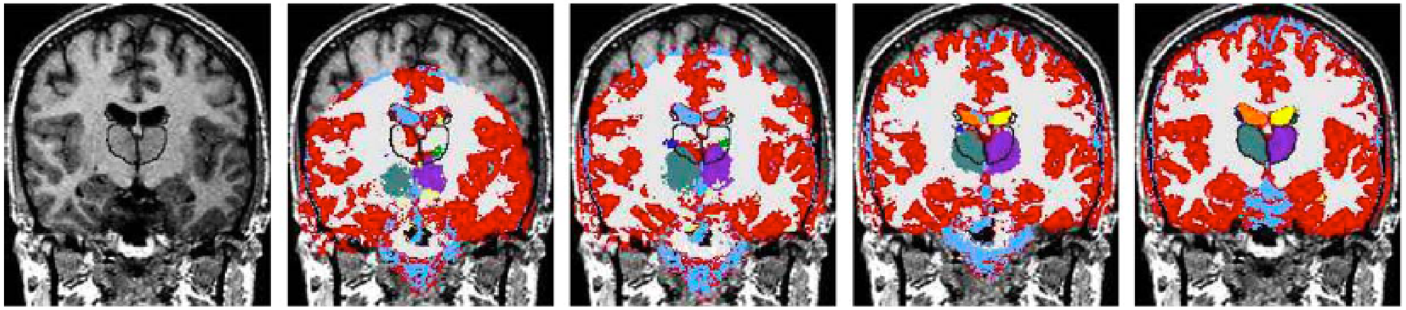


Segmentation: *EM Segmenter*



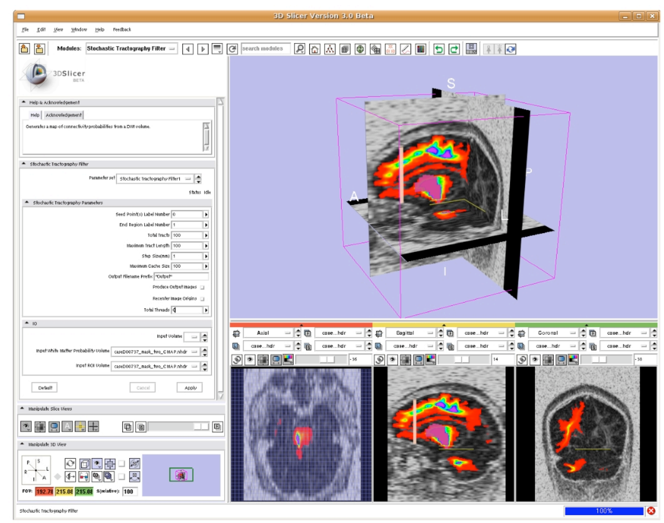
EM Segmenter

- Statistical methodology
  - Bayesian framework: data + atlases
- Validated
  - E.g. Pohl et al., "A bayesian model for joint segmentation and registration", NeuroImage, 2006
- Built on/within ITK
- Part of the *NA-MIC Kit*
- End-user application: *3D Slicer*



3D Slicer

- End-user application
- Visualization and analysis tools
- Modular architecture
  - ITK & VTK
  - Dozens of plug-ins already written
- Slicer 3.2 Released Aug 2008
- > 38,000 downloads in the past 12 months
  - Downloads ≠ users
  - Downloads -> activity



3D Slicer – Impact...

iShowU Edit Capture Help — Mon 9:50 AM

Slicer Community – SlicerWeb

http://www.slicer.org/pages/Slicer_Community

www.slicer.org

3D Slicer Enabled Research

3D Slicer is a free open source software package distributed under a BSD style license. The majority of funding for the development of 3D slicer comes from a number of grants and contracts from the National Institutes of Health (see Slicer Acknowledgments for more information).

We invite you to provide information on how you are using 3D Slicer to produce peer-reviewed research. Information about the scientific impact of this tool is helpful in raising funding for the continued support of this tool.

A COMPUTER MODELING TOOL FOR COMPARING NOVEL ICD ELECTRODE ORIENTATIONS IN CHILDREN AND ADULTS

Publication: Heart Rhythm. 2008 Apr;5(4):565-572. PDF

Authors: Matthew Jolley, Jeroen Stinstra, Steve Pieper, Rob Macleod, Dana H. Brooks, Frank Cecchin, John K. Triedman

Institution: Department of Cardiology, Children's Hospital Boston, Boston, MA, USA.

Background/Purpose: Use of implantable cardiac defibrillators (ICDs) in children and patients with congenital heart disease is complicated by body size and anatomy. A variety of creative implantation techniques has been used empirically in these groups on an ad hoc basis. OBJECTIVE: To rationalize ICD placement in special populations, we used subject-specific, image-based finite element models (FEMs) to compare electric fields and expected defibrillation thresholds (DFTs) using standard and novel electrode configurations. METHODS: FEMs were created by segmenting normal torso computed tomography scans of subjects ages 2, 10, and 29 years and 1 adult with congenital heart disease into tissue compartments, meshing, and assigning tissue conductivities. The FEMs were modified by interactive placement of ICD electrode models in clinically relevant electrode configurations, and metrics of relative defibrillation safety and efficacy were calculated. RESULTS: Predicted DFTs for standard transvenous configurations were comparable with published results. Although transvenous systems generally predicted lower DFTs, a variety of extracardiac orientations were also predicted to be comparably effective in children and adults. Significant trend effects on DFTs were associated with body size and electrode length. In many situations, small alterations in electrode placement and patient anatomy resulted in significant variation of predicted DFT. We also show patient-specific use of this technique for optimization of electrode placement. CONCLUSION: Image-based FEMs allow predictive modeling of defibrillation scenarios and predict large changes in DFTs with clinically relevant variations of electrode placement. Extracardiac ICDs are predicted to be effective in both children and adults. This approach may aid both ICD development and patient-specific optimization of electrode placement. Further development and validation are needed for clinical or industrial utilization.

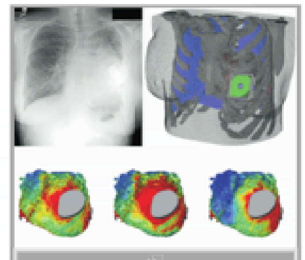


Figure 7: Patient-specific modeling in a patient with congenital heart disease.

Grant Support:
- NIH P41 RR12557
- NIH P41 RR13218
- NIH T32 HL07572
- CIMIT

TOWARDS SCARLESS SURGERY: AN ENDOSCOPIC ULTRASOUND NAVIGATION SYSTEM FOR TRANSGASTRIC ACCESS PROCEDURES

Publication: Comput Aided Surg. 2007 Nov;12(6):311-24. PDF

Authors: Raúl San José Estépar, Nicholas Stylopoulos, Randy Ellis, Eigil Samset, Carl-Fredrik Westin, Christopher Thompson, Kirby Vosburgh

Institution: Department of Radiology, Harvard Medical School and Brigham and Women's Hospital, Boston, MA, USA.

Background/Purpose: Scarless surgery is an innovative and promising technique that may herald a new era in surgical procedures. We have created a navigation system, named IRGUS, for endoscopic and transgastric access interventions and have validated it in in vivo pilot studies. Our hypothesis is that endoscopic ultrasound procedures will be performed more easily and efficiently if the operator is provided with approximately registered 3D and 2D processed CT images in real time that correspond to the probe position and ultrasound image. Materials and Methods: The system provides augmented visual feedback and additional contextual information to assist the operator. It establishes correspondence between the real-time endoscopic ultrasound image and a preoperative CT volume registered using electromagnetic tracking of the endoscopic ultrasound probe position. Based on this positional information, the CT volume is reformatted in approximately the same coordinate frame as the ultrasound image and displayed to the operator. Results: The system reduces the mental burden of probe navigation and enhances the operator's ability to interpret the ultrasound image. Using an initial rigid body registration, we measured the mis-registration error between the ultrasound image and the reformatted CT plane to be less than 5 mm, which is sufficient to enable the performance of novice users of endoscopic systems to approach that of expert users. Conclusions: Our analysis shows that real-time display of data using rigid registration is sufficiently accurate to assist surgeons in performing endoscopic abdominal procedures. By using preoperative data to provide context and support for image interpretation and real-time imaging for targeting, it appears probable that both preoperative and intraoperative data may be used to improve operator performance.

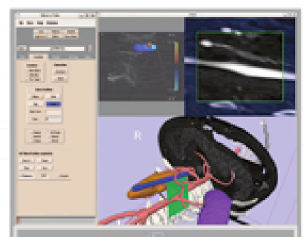
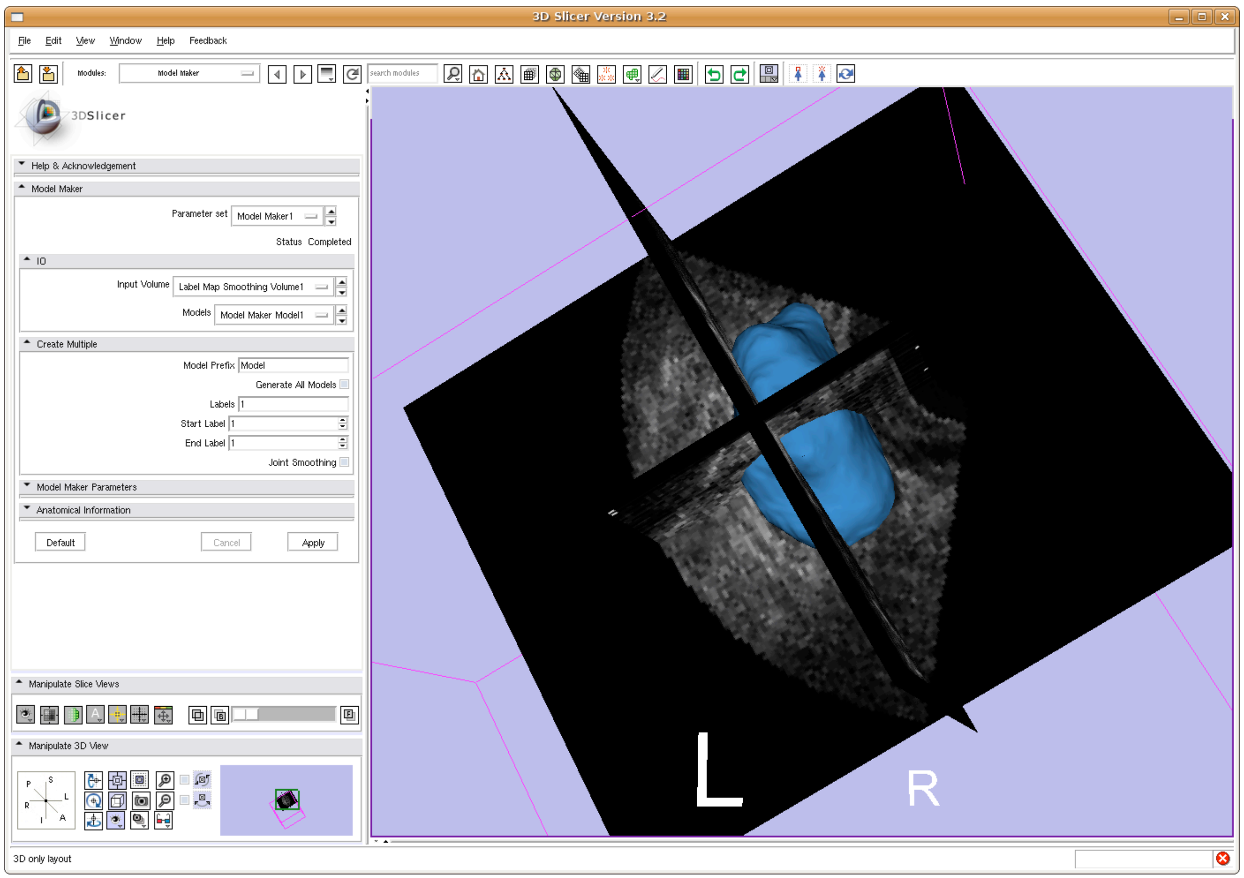


Figure 3: View of the system interface as presented to the clinician.

Grant Support:
- NIH P41-RR13218
- CIMIT

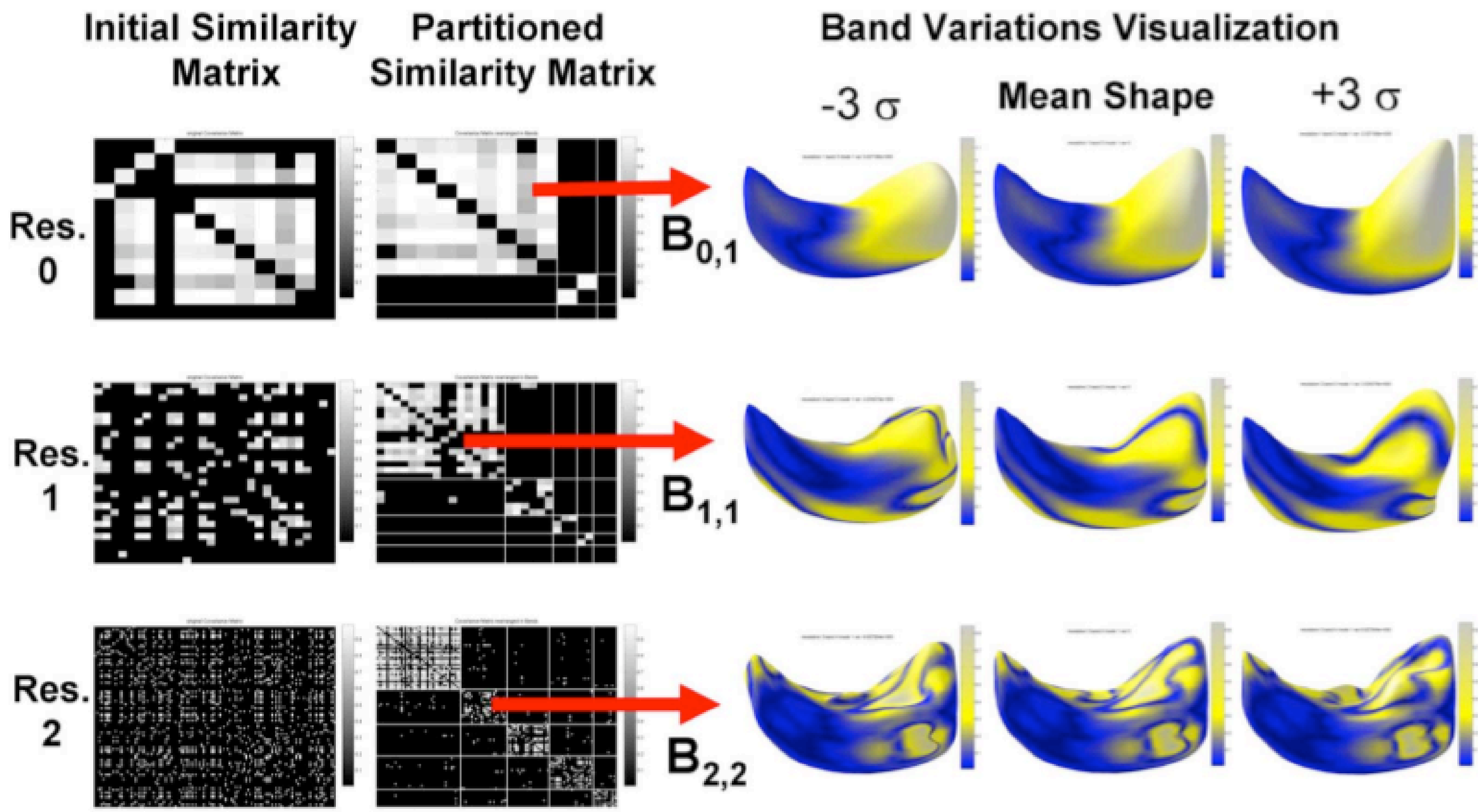
Random Walk to Optimize Deformable Models

- Prostate segmentation: JHU/Queens w/GaTech



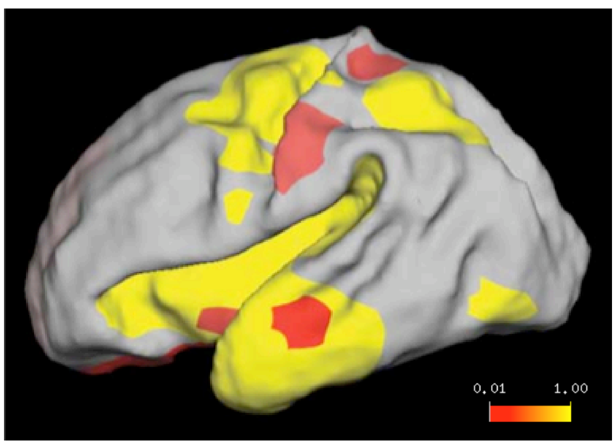
Wavelet Surface Representations - GaTech

- Multiscale + local for representation and analysis
- Nain et al., IEEE TMI 2007

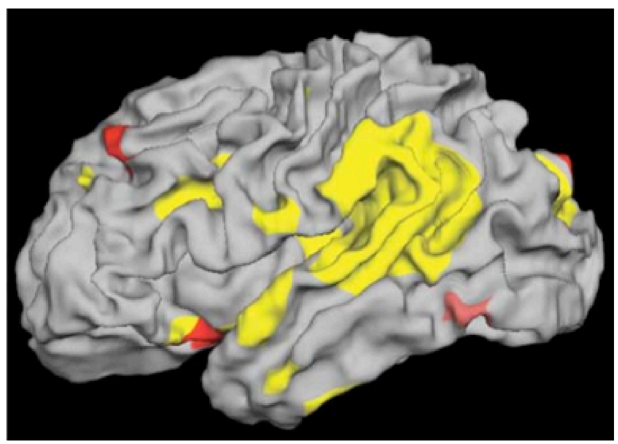


Spherical Wavelets for Shape Analysis
MIT, MGH

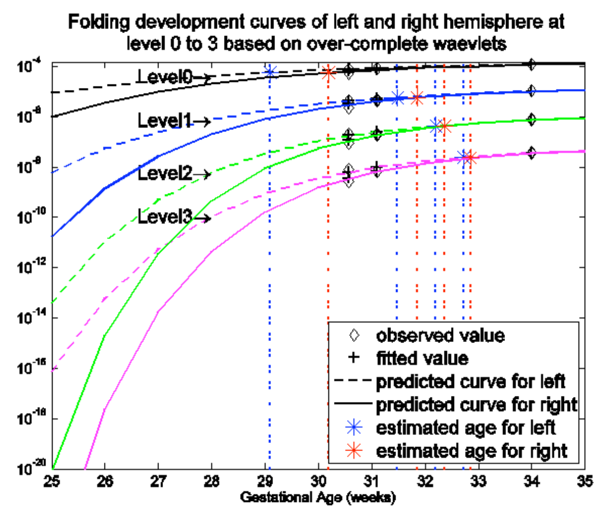
- Cortical folding in neonatal development
  - Yu et al., IEEE TMI, 2007
- Rate of cortical folding on cortex over time



0-33 weeks

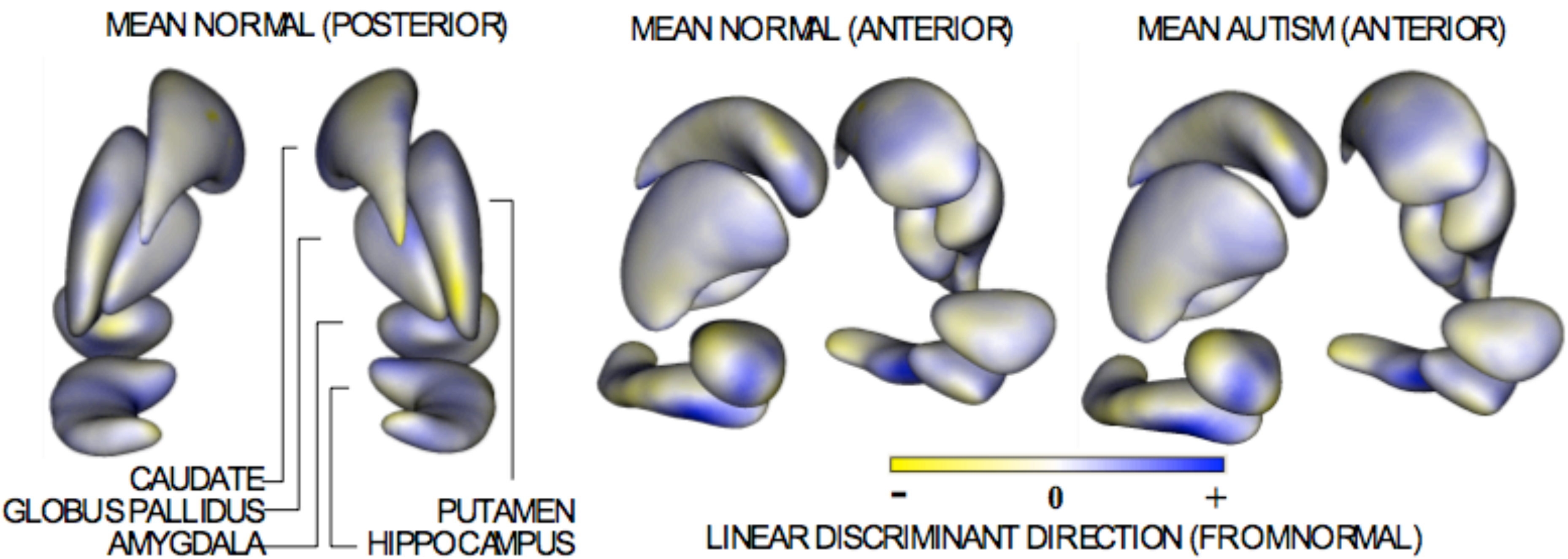


33-38 weeks



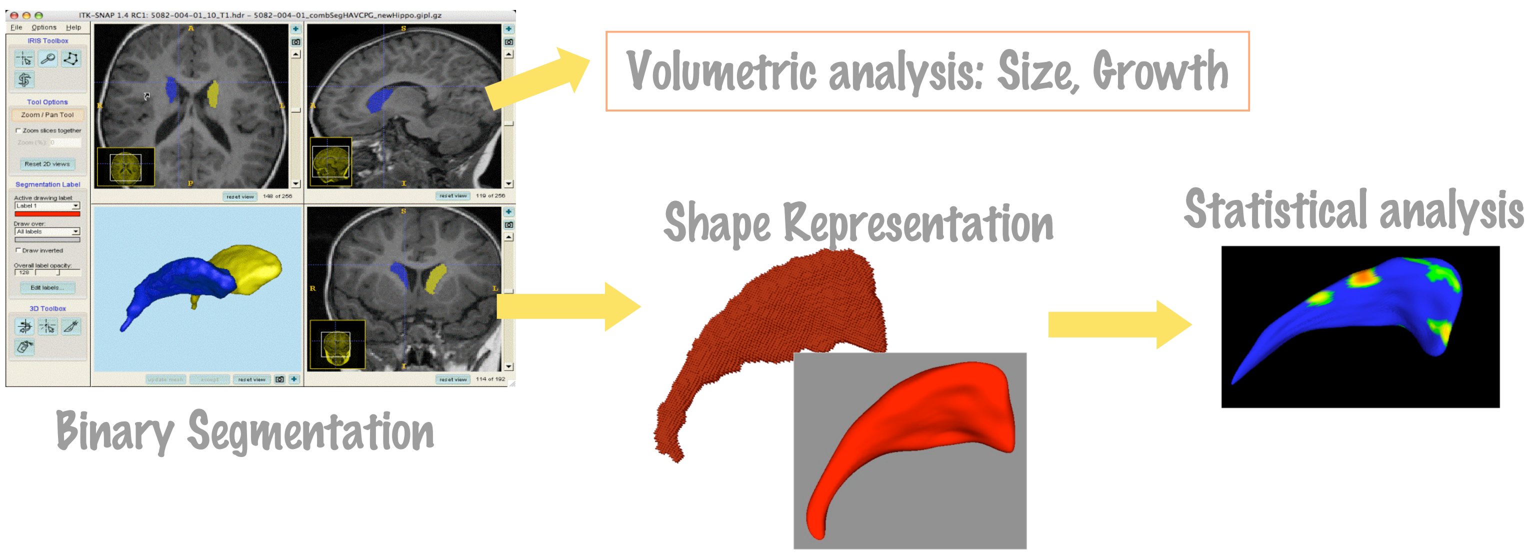
Hypothesis Testing on Shape Complexes in Autism

- Utah + UNC DBP – Joe Piven/Heather Hazlet
- Cates et al., MICCAI 2008
- Localize (previous) volume differences in caudate and amygdala
- Particle system for shape correspondence
- Pipeline: PCA, parallel analysis, permutation testing



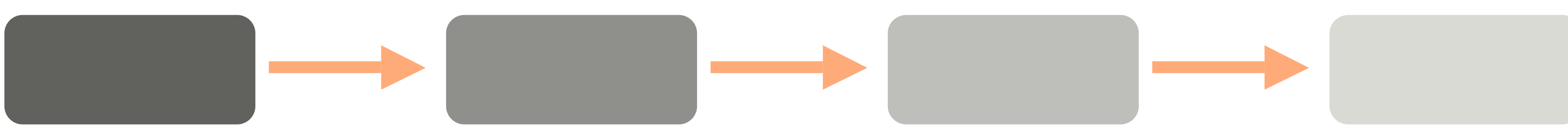
Statistical Shape Analysis Pipeline – UNC

- UNC NA-MIC Shape Analysis Toolbox
  - SPHARM-PDM, Hotelling T^2, permutation, FDR
  - MDL implementation with curvature
- ☆ New developments:
  - MANCOVA based hypothesis testing
  - Integration with ITK/Slicer
  - Incorporates other representations (GaTech, Utah)



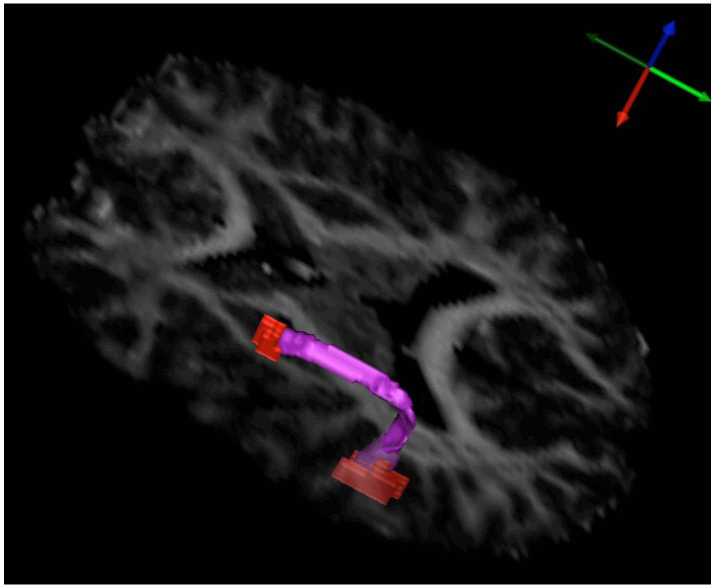
Software Infrastructure for Pipeline Processing of Images

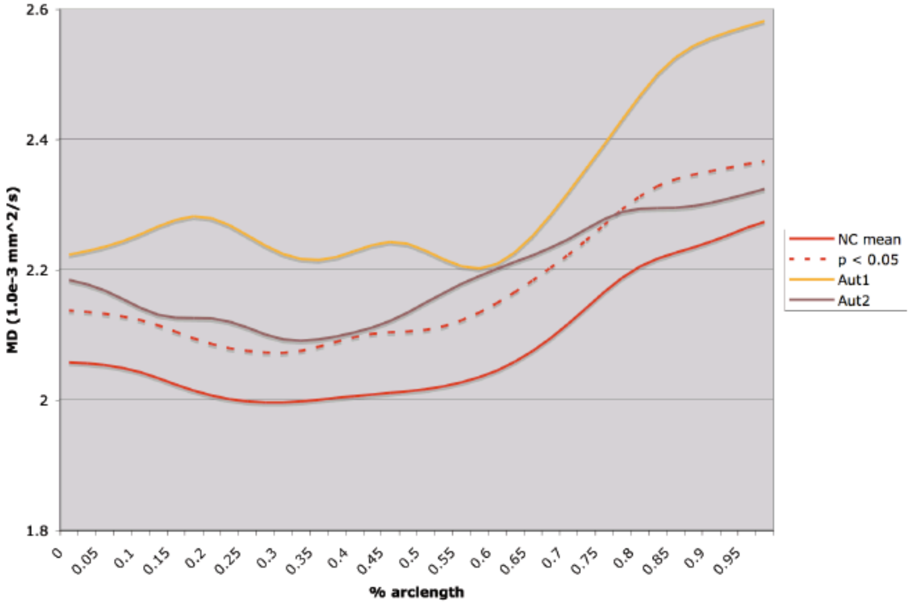
- *BatchMake* – Scripting language for batch processing of large datasets (Kitware)
  - Grid enabled (Condor)
  - GUI-based wizard
  - Integration into Slicer and NA-MIC kit
- *XNAT* – Archiving toolkit/API (WashU)
  - Distributed, security, quality control
  - Integrate into NA-MIC kit and BatchMake



DTI Analysis of the AF in Autism – Utah

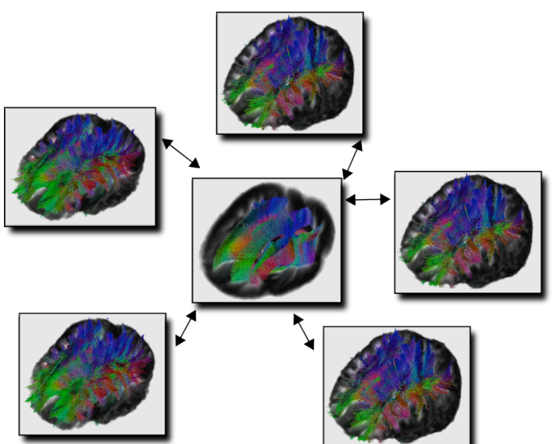
- W/Janet Lainhart, U. of Utah Autism Center
- Voxel-based characterization of white-matter tracts
  - *Optimal paths* framework
  - Arcuate Fasciculus – Wernicke's & Broca's
- ☆ Quantifiable diffusivity differences in AF between patients and NCs



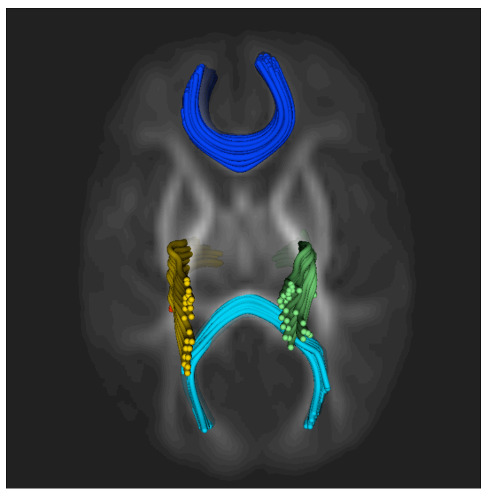


Atlas-Based DTI Analysis – Utah, UNC

- w/John Gilmore, UNC, Psychaitry
- ☆ Gilmore et al.: Bio Psych 2008, NeuroImage 2008
- Prenatal mild mentriculomegaly (MVM) predicts white-matter abnormalities in splenium
  - Reduced FA, increased diffusivity (Frobenius norm)
- Software ITK/NA-MIC



Atlas



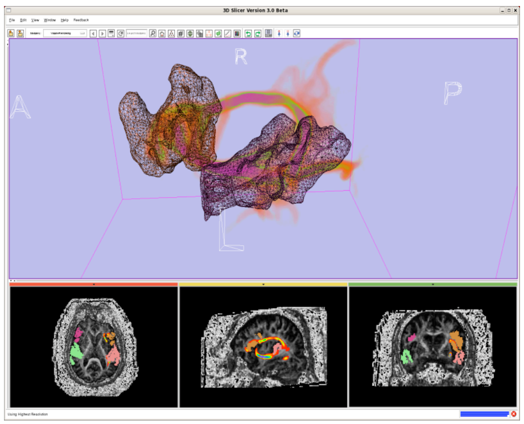
Tracts

Tract	p-value
Genu	.99
Splenium	**.0001**
Left cortico-spinal	.24
Right cortico-spinal	.80

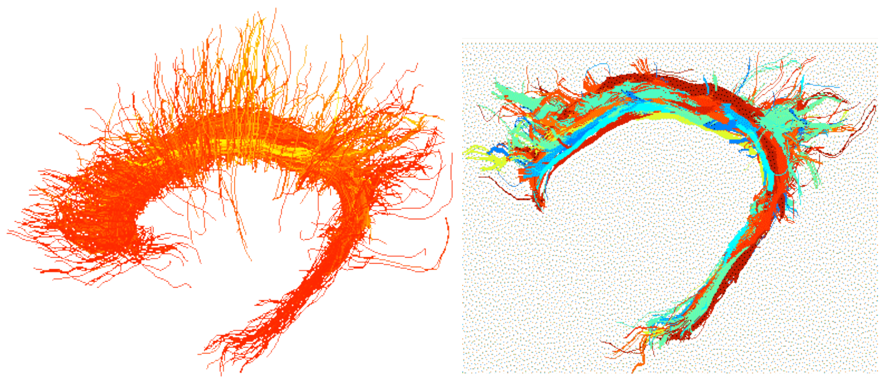
85 Controls, 13 MVMs

NA-MIC and DTI Analysis

- Other DTI work. E.g.
  - Harvard B&W – Stochastic Tractography
  - MIT – Tract clustering and data-driven fiber atlases

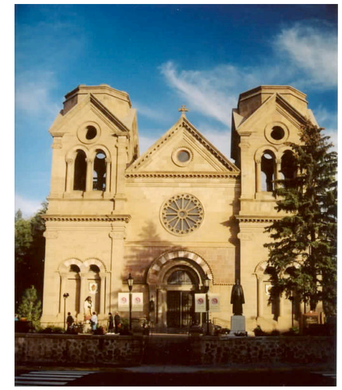


Stochastic Tractography in Slicer


Fiber Clustering and Atlas Building

- A comprehensive software infrastructure for DWI/DTI processing
  - DICOM files -> Visualization/Statistical Analysis
  - Integrate DWI and anatomical images
  - ITK & Slicer

Method Evaluation: The NA-MIC DTI Sante Fe Workshop



- Oct 2007
- ~25 participants
- Predefined datasets and tasks
  - DBP from Brigham and Women's (Kubicki)
- Technical meeting: compare and contrast differences of approaches/methods

Projects

Please add a page for your project in Engineering:Project:2006 AHM Programming:Name, and add a link here. After you have a reasonable definition of your project, please fill in this powerpoint template (thanks to Gordon Kindlmann in helping prepare the template), upload, and link to your project page. We will review these powerpoints in a tcon on Jan 5th, and also at the programming week itself.

1. Define Joint Registration and Segmentation Framework (Kilian Pohl- MIT/BWH)
2. Affine Invariant Anisotropic Smoothing ITK Filter (John Melonakos-GT, Delphine Nain-GT, Jim Miller-GE)
3. Rule Based Segmentation Slicer Module (John Melonakos-GT, Delphine Nain-GT, Ramsey Al-Hakim-GT, Shawn Lankton-GT, Alex Yarmakovich-Isomics)
4. Basic image processing filters for DTI (Saurav Basu-Utah, Casey Goodlett-UNC, Tom Fletcher-Utah, Karthik Krishnan-Kitware, Xiaodong Tao-GE)
5. Automated image mosaicking and feature tracking for Electron Microscopy data (Tolga Tasdizen-Utah, Liz Jurrus-Utah, Paul Koshevoy-Utah, Ross Whitaker-Utah)
6. Slicer 3

E, Jeff

uyash

Vincent

Oguz, Martin

Styner - UNC, Sebastien Barre - Kitware)

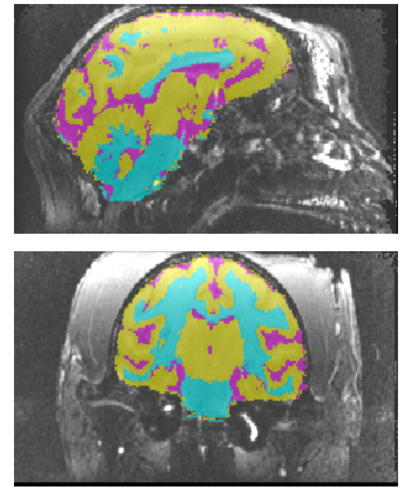
11. Improved DTMRI module tract display (Lauren O'Donnell - MIT, C-F Westin, BWH, Raul San Jose, BWH)
12. itku: Command-line ITK interface (Raul San Jose, Gordon Kindlmann - BWH)
13. Graphical framework to construct/ execute complex scientific analyses of data (Michael Pan, UCLA)
14. Simple to use UNC shape analysis LONI pipeline (Martin Styner, UNC)

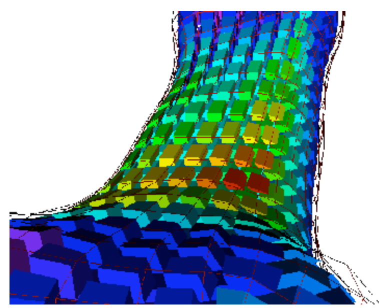
EM Segmenter

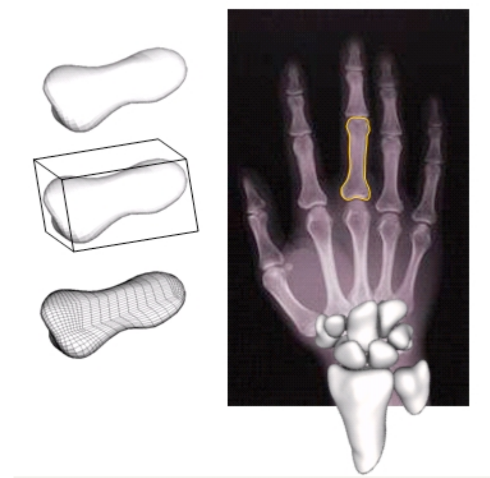
3DSlicer

EM Segmenter: New Collaborations

- Virginia Tech: Ch. Wyatt, Wake Forrest: J. Daunais
  - Alcohol and stress in R. monkeys
  - Structural and diffusion MRI
- Iowa: Kiran H. Shivanna, Vincent A. Magnotta, Nicole M. Grosland
  - Hex grid generation
  - Biomechanical simulation



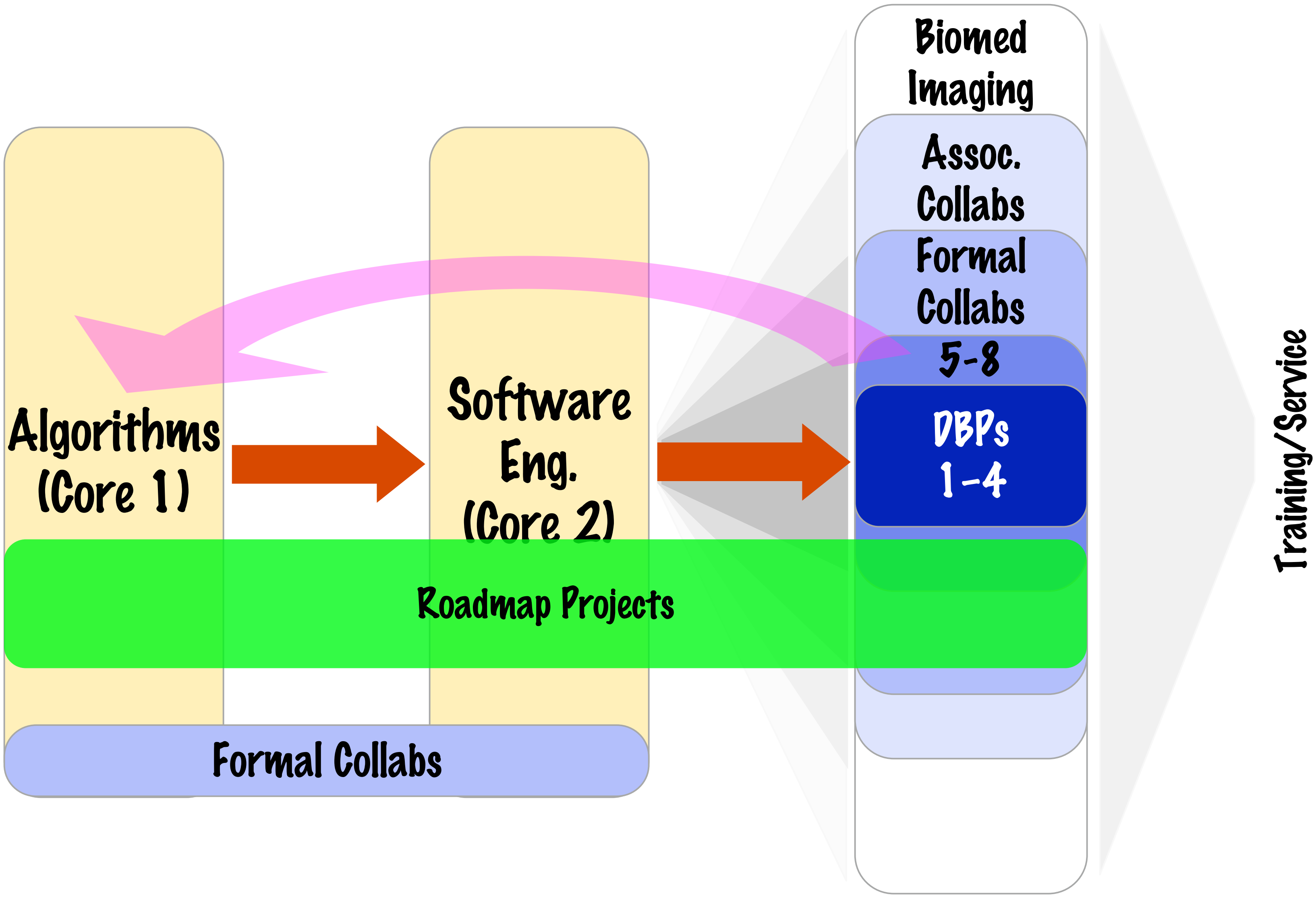




Thank you.

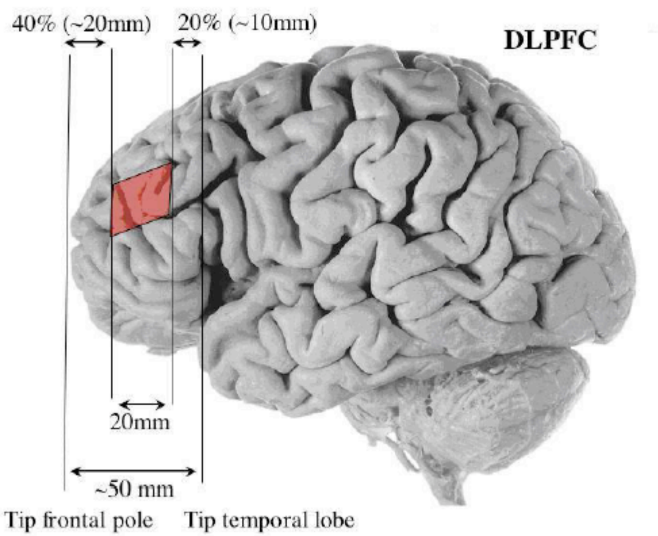
...and thanks to all our NA-MIC colleagues and collaborators.

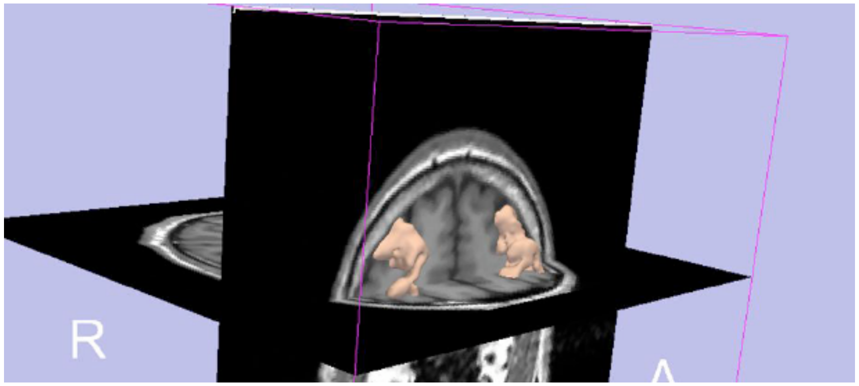
Algorithms, Software, Science

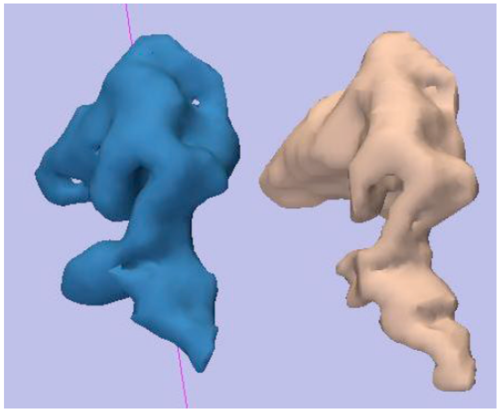


Segmentation: Rule-Based
GaTech, UC-Irvine

EM-Segmenter
tissue classifications ->
Cortical parcellations







R. Al-Hakim, et al. "A Dorsolateral Prefrontal Cortex Semi-Automatic Segmenter". SPIE Medical Imaging, 2006.