



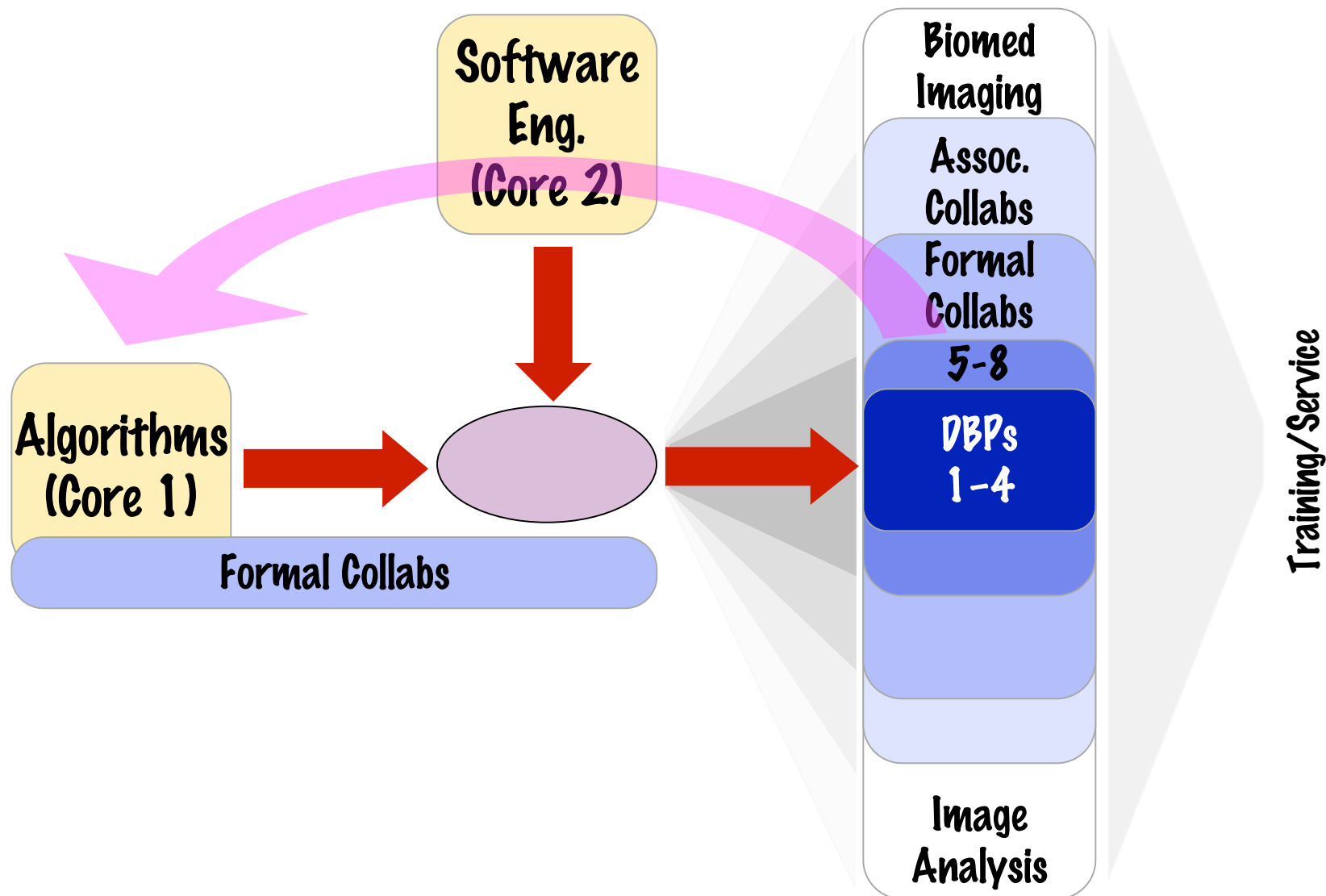
# NA-MIC Highlights: From Algorithms and Software to Biomedical Science

**Ross Whitaker**  
**University of Utah**

National Alliance for Biomedical Image Computing

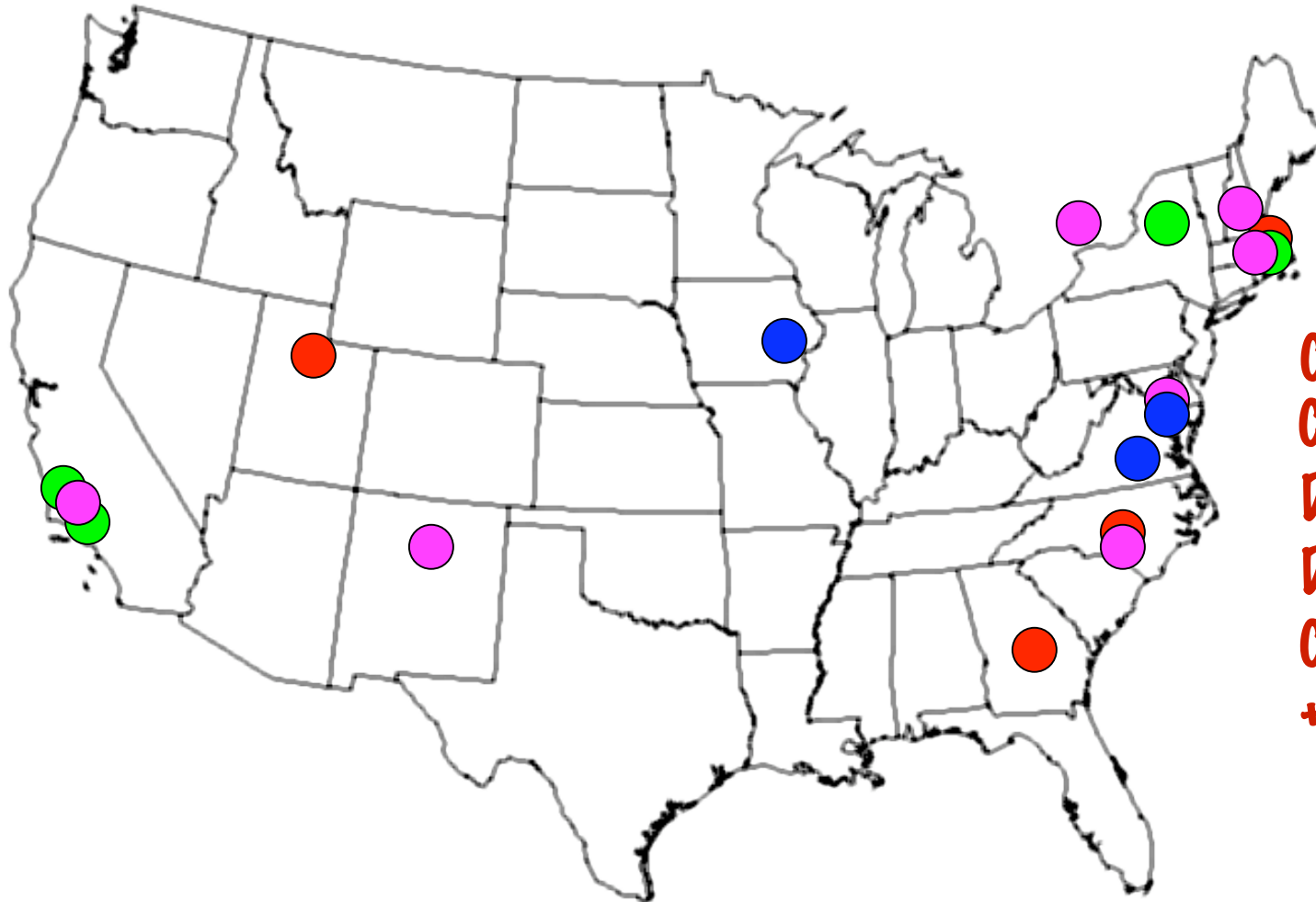


# Algorithms, Software, Science





# NA-MIC-A *National Alliance*

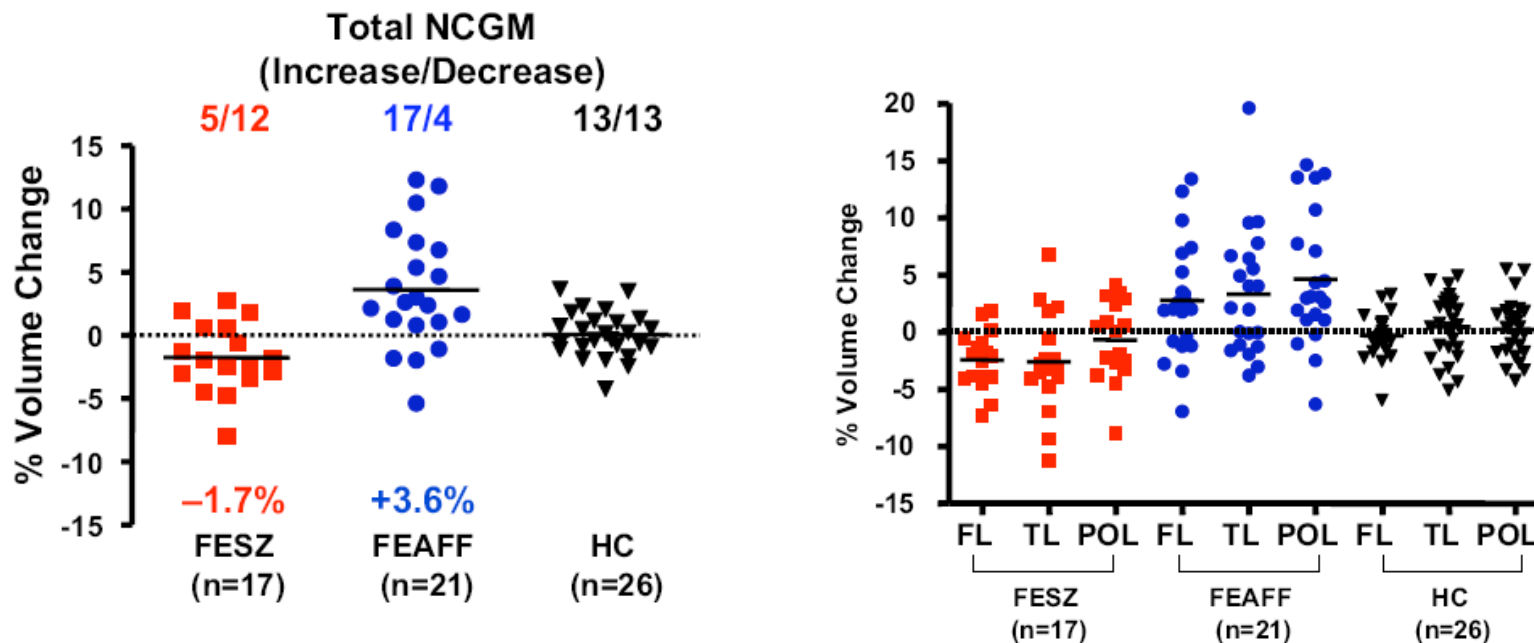


Core 1  
Core 2  
DBPs I  
DBPs II  
Collabs PAR  
+ many others



# 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.

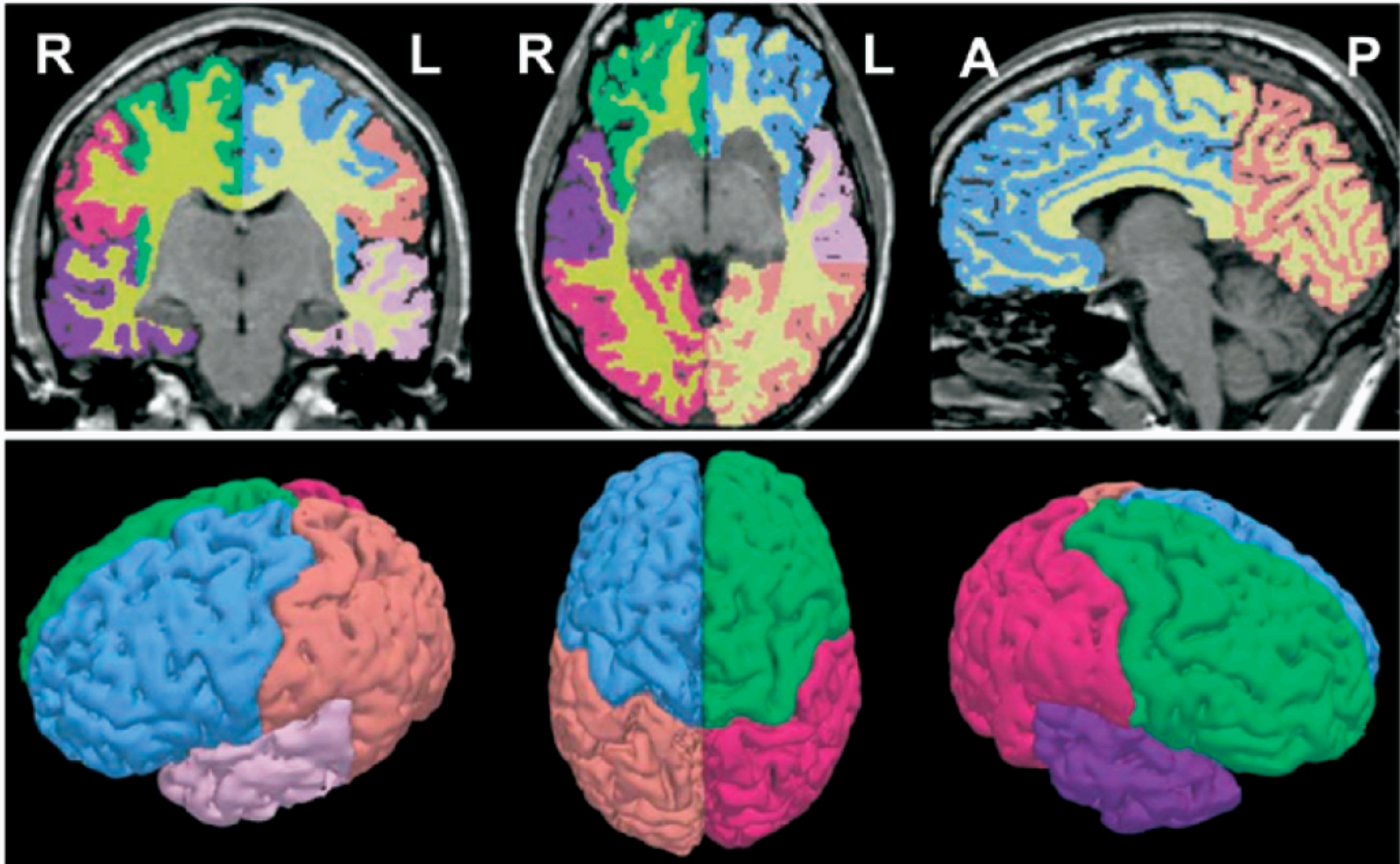






# Segmentation: *EM Segmenter*

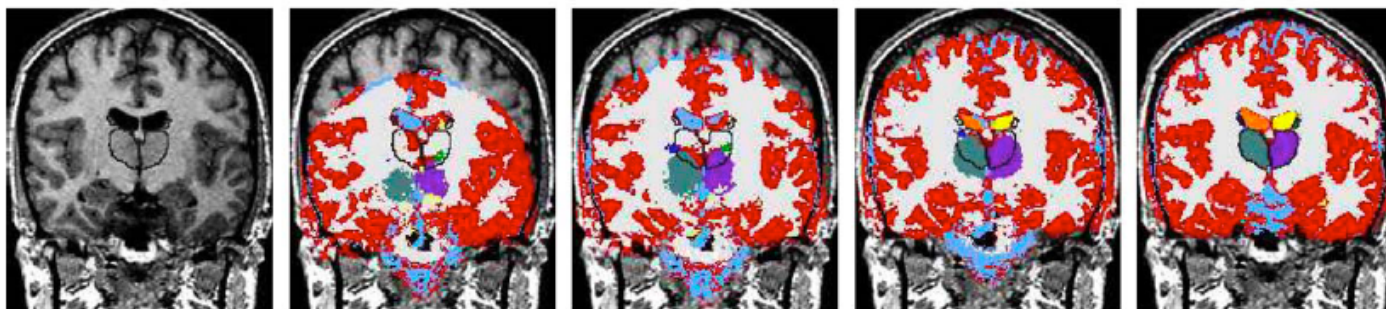
**NCGM Lobar Parcellation**





# 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

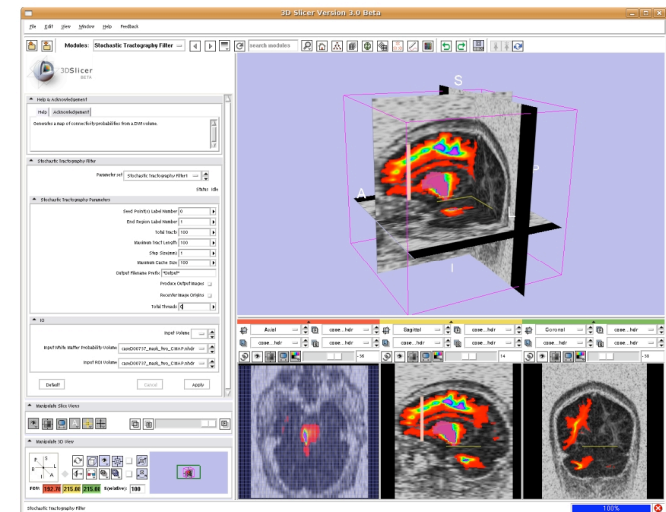


- End-user application
- Visualization and analysis tools
- Modular architecture
  - ITK & VTK
  - Dozens of plug-ins already written

★ Slicer 3.2 Released Aug 2008

★ > 5,000 downloads in the past 12 months

- Downloads ≠ users
- Downloads -> activity







# 3D Slicer - Impact...

iShowU Edit Capture Help  
Slicer Community - SlicerWeb  
http://www.slicer.org/pages/Slicer\_Community  
NAMIC wiki SIRIUS Player TVCG-reviews Salt Lake C. Underground Apple Yahoo! Google Maps YouTube Wikipedia News Popular

www.slicer.org  
3DSlicer  
Slicer Wiki  
About Slicer  
Home  
Introduction  
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Publication DB  
Image Gallery  
Slicer Community  
Source Code  
License  
Mailing Lists  
Web Archive

## 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 Sinstra, 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.

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

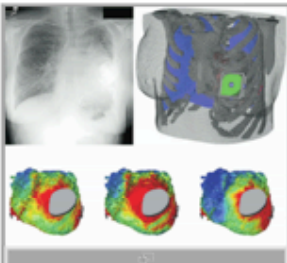


Figure 7. Patient-specific modeling in a patient with congenital heart disease.

### 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, Eglil 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.

**Grant Support:**  
NIH P41-RR13218  
CIMIT

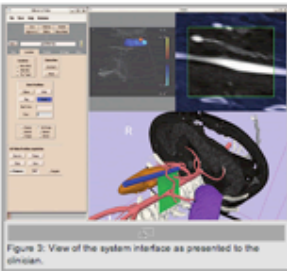
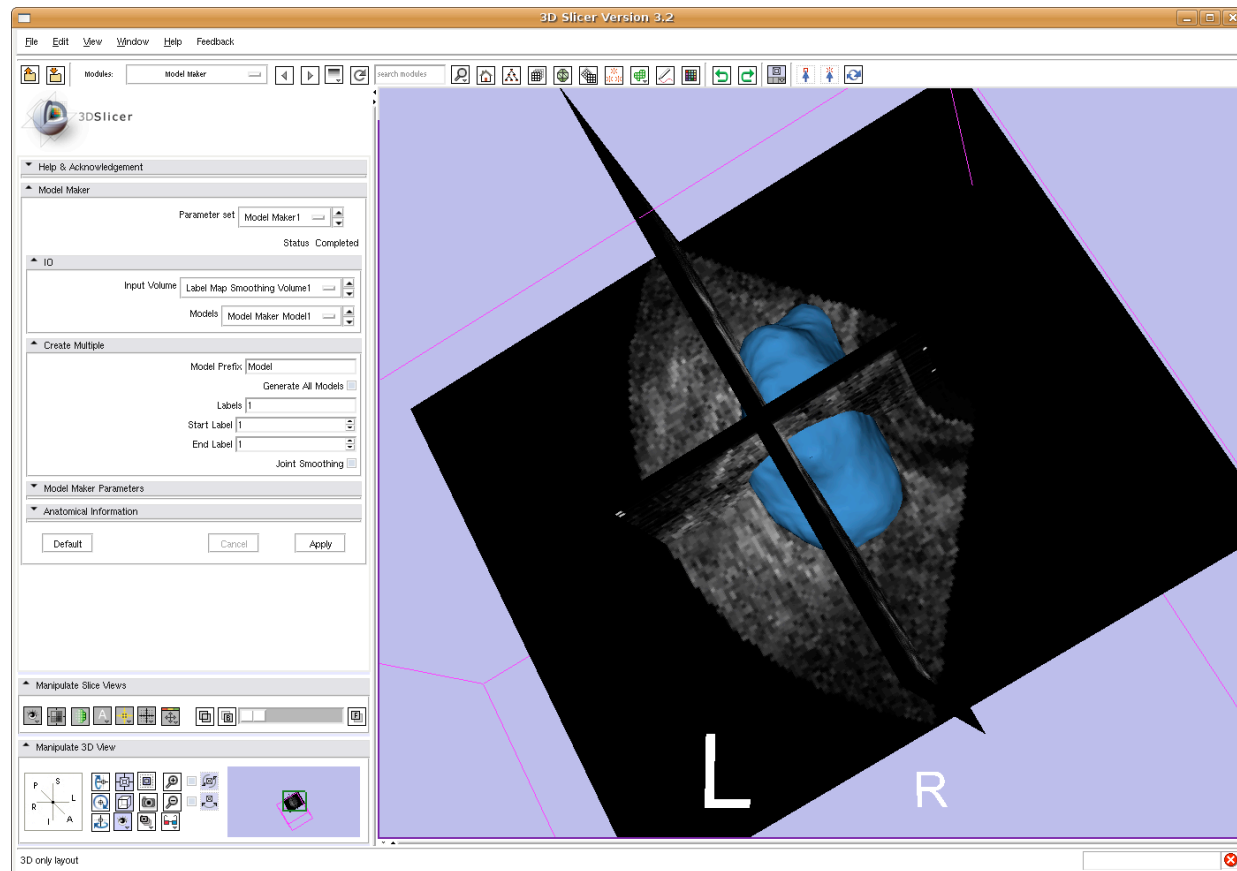


Figure 3. View of the system interface as presented to the clinician.



# Random Walk to Optimize Deformable Models

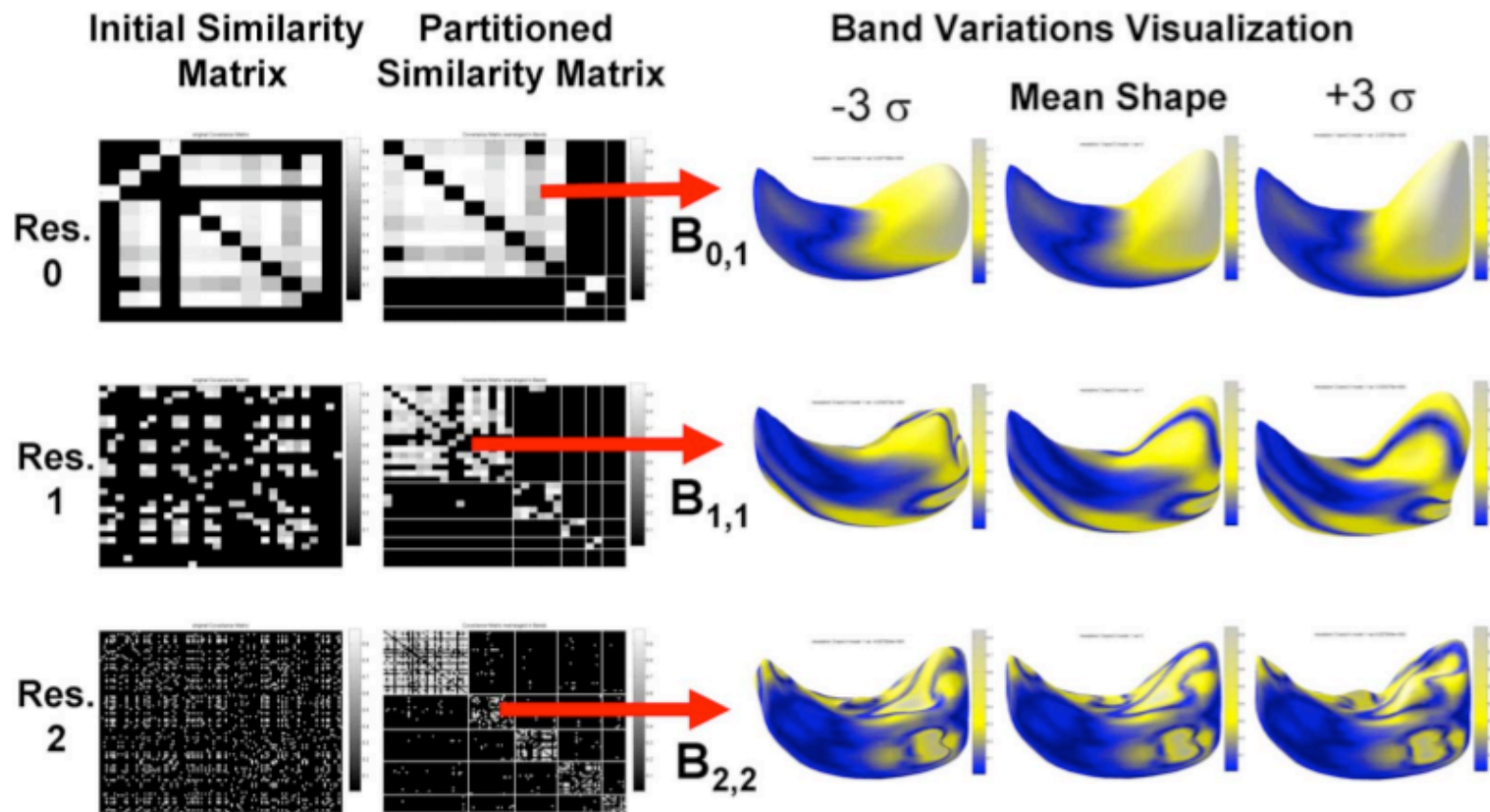
- Prostate segmentation: JHU/Queens w/GaTech





# Wavelet Surface Representations - GaTech

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

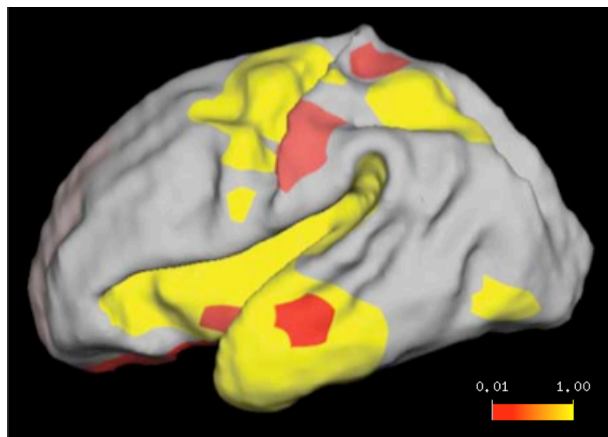




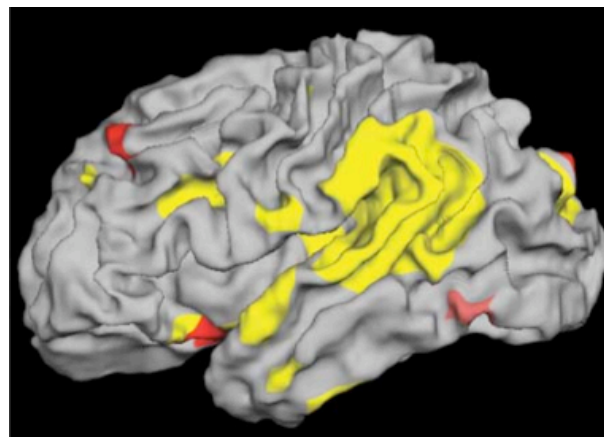
# Spherical Wavelets for Shape Analysis

## MIT, MGH

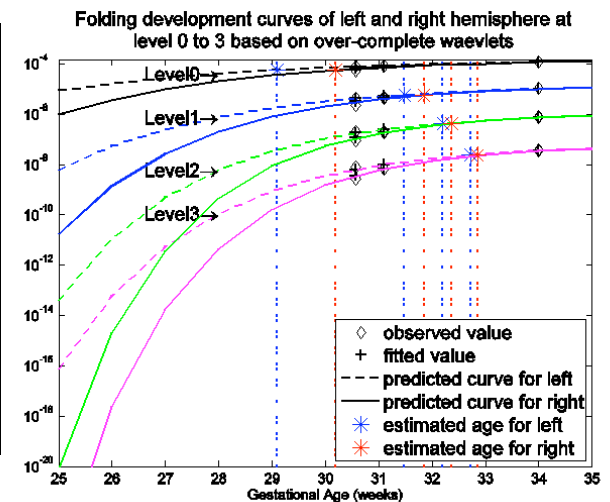
- Cortical folding in neonatal development
  - Yu et al., IEEE TMI, 2007
- Rate of cortical folding on cortex over time



0-33 weeks



33-38 weeks

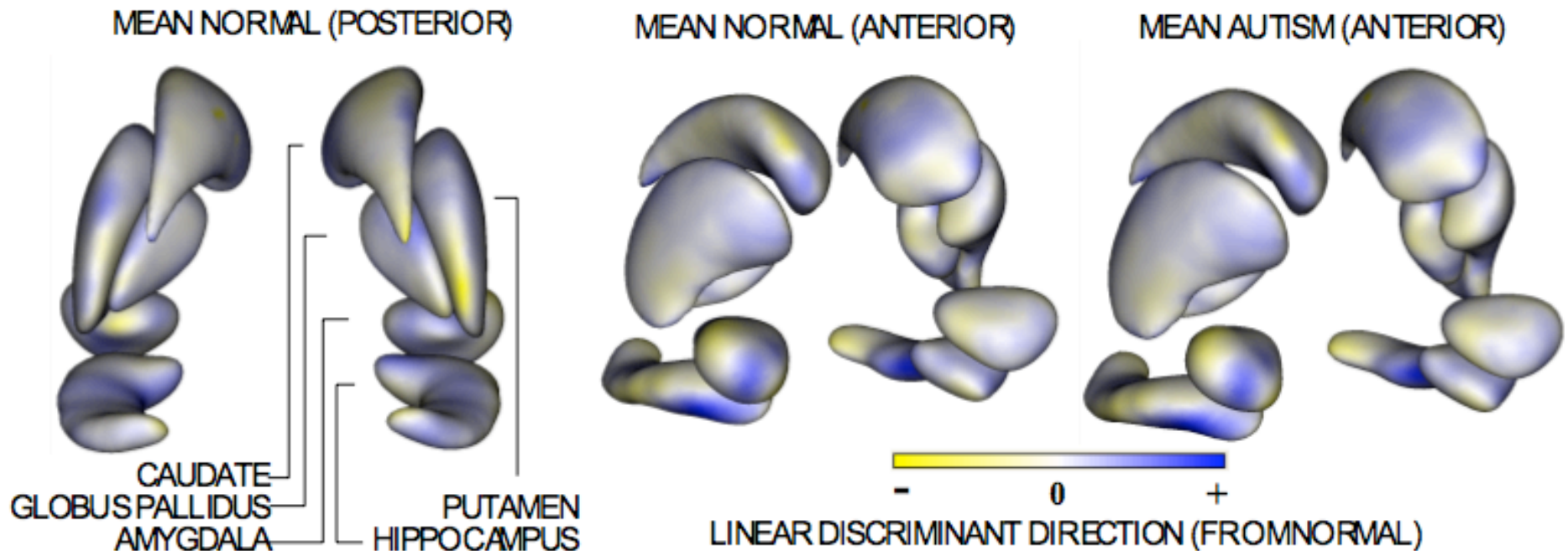






# Hypothesis Testing on Shape Complexes in Autism

- 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

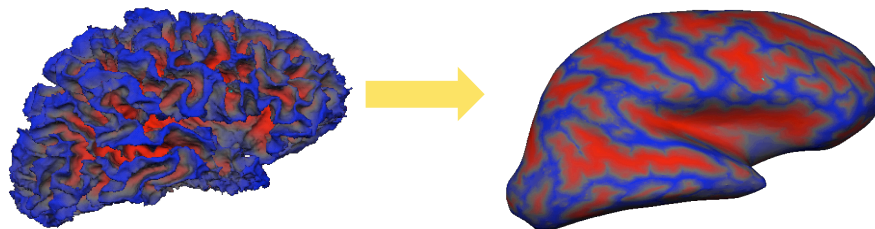
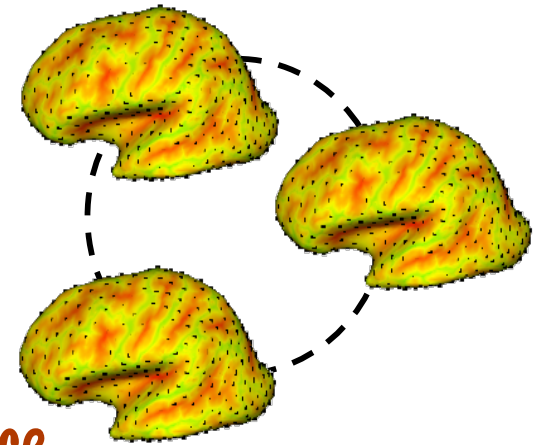






# Cortical Correspondence

- **Motivation: Cortical analysis of brain measures**
  - Cortical thickness in Autism
- **Need: local cortical correspondence**
  - Shape features essential, e.g. sulcal depth
- **Group-wise cortical correspondence**
  - UNC/Utah collaboration
- **Incorporation of shape & DTI for correspondence**
  - Probabilistic DTI connectivity



Sulcal Depth

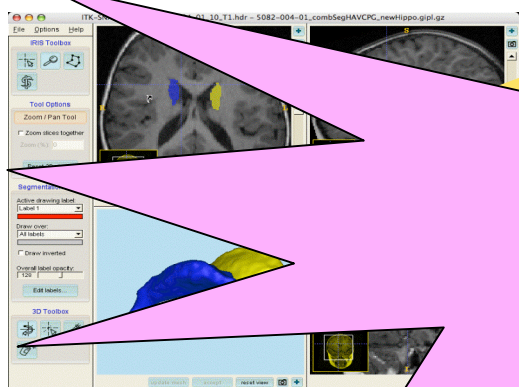


Prob Connectivity



# 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
  - Incorporates other representations (GaTech, Utah)



Binary Segmentation

Built on ITK

Analysis



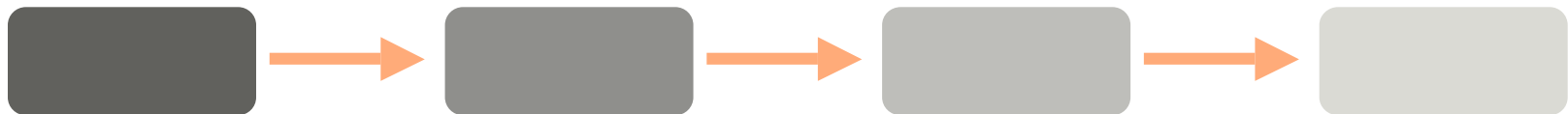
# ITK As An Algorithm Repository

- **Insight Toolkit**
  - Circa 1999 w/funding from NLM
    - ...and NIDCR, NEI, NINDS, NIMH, NIDCD, NCI, NSF
  - Multidimensional image analysis (VHP)
    - API (rather than an application)
    - Community supported and open source
    - Large data, threading, volumes, ...



## 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



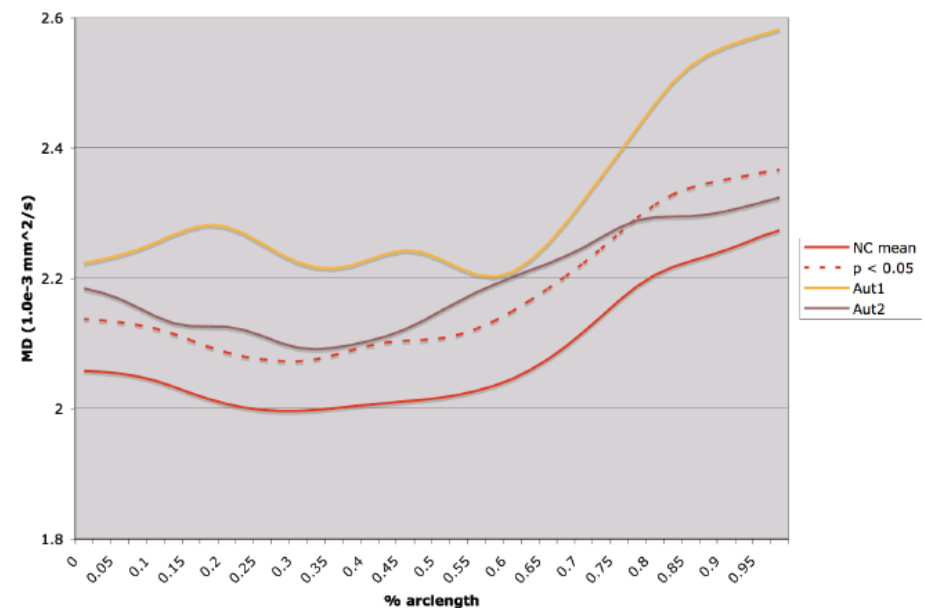
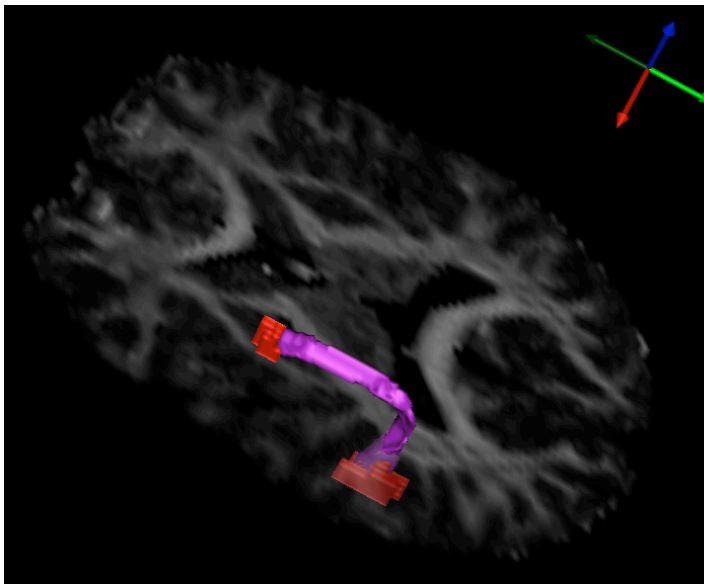


# DTI Analysis of the AF in Autism - Utah

- W/Janet Lainhart, U. of Utah Autism Center
- Voxel-based characterization of white-matter tracts
  - *Optimal paths* framework
  - Arcuate Fasciculus - Wernicke's & Broca's



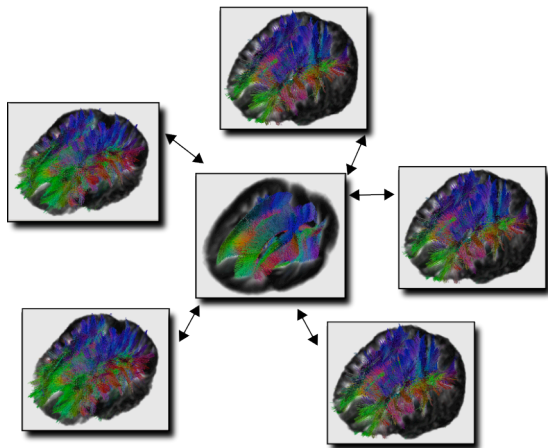
Quantifiable diffusivity differences in AF between patients and NCs



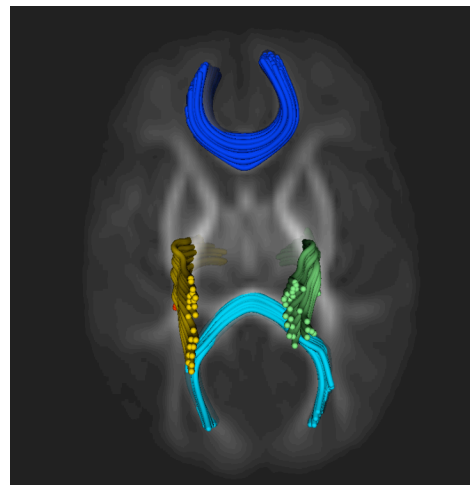


# Atlas-Based DTI Analysis – Utah, UNC

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



Atlas



Tracts

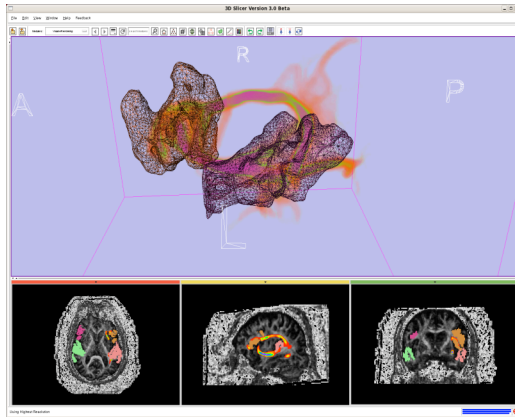
Tract	p-value
Genu	.99
Splenium	.0001
Left cortico-spinal	.24
Right cortico-spinal	.80

85 Controls, 13 MVMs

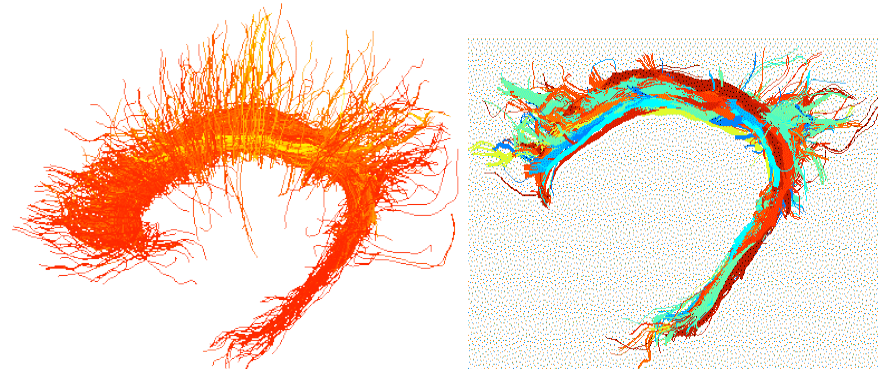


# NA-MIC and DTI Analysis

- 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

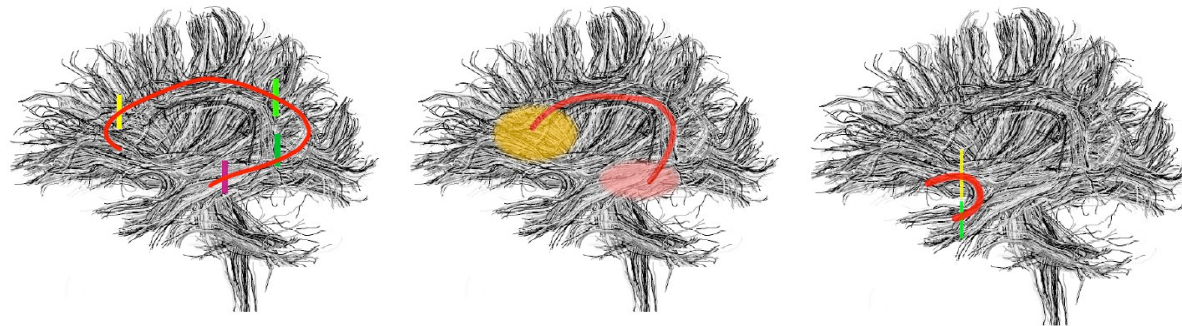
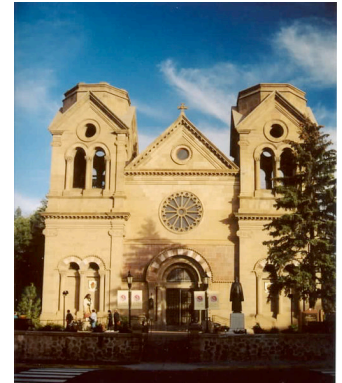
- A comprehensive software infrastructure for DWI/DTI processing
  - DICOM files -> Visualization/Statistical Analysis
  - Integrate DWI and anatomical images
  - ITK & Slicer





# 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

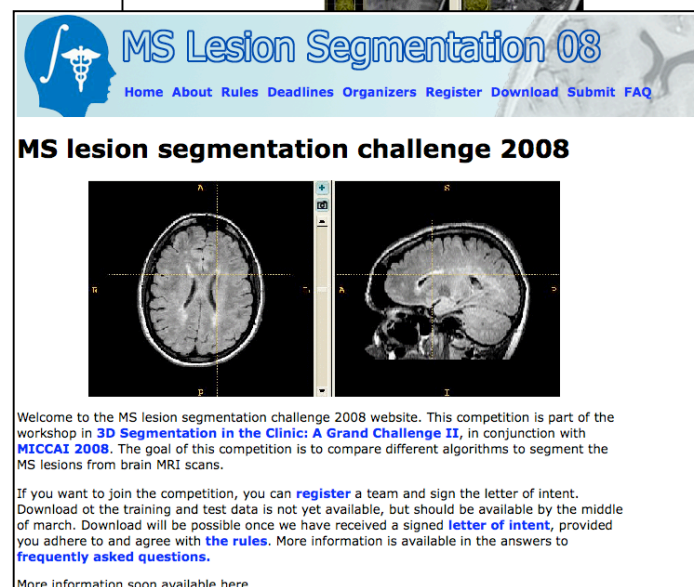
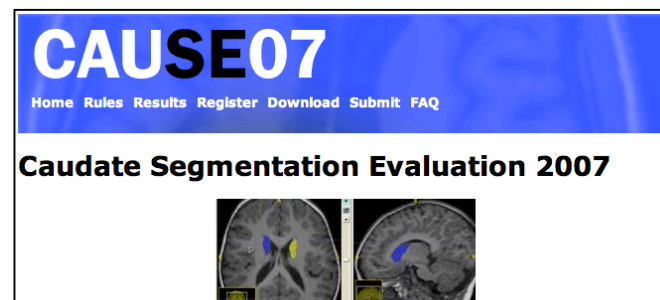






# Competitive Method Evaluation

- Tools/data for evaluation
- MICCAI workshops
  - 07: Caudate & liver segmentation
  - 08: Lesion segmentation
  - Largest MICCAI workshop
  - NAMIC: Co-sponsor
- Online evaluation continues
  - [www.cause07.org](http://www.cause07.org)
  - <http://www.ia.unc.edu/MSseq>
- Online proceedings
  - MIDAS journal, public



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## 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

# EM Segmenter



3DSlicer

GE, Jeff

uyash

Vincent

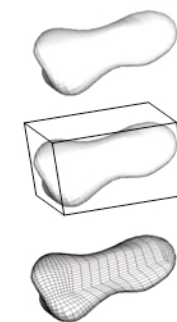
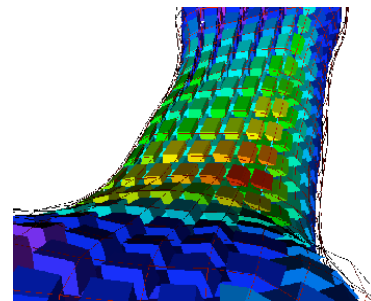
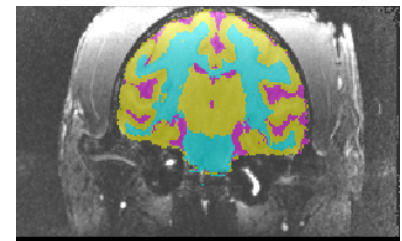
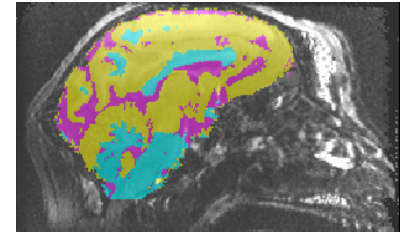
Oguz, Martin

11. Improved DTMRI module tract display (Lauren O'Donnell - MIT, C-F Westin, BWH, Raul San Jose, BWH)
12. itk: 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: 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



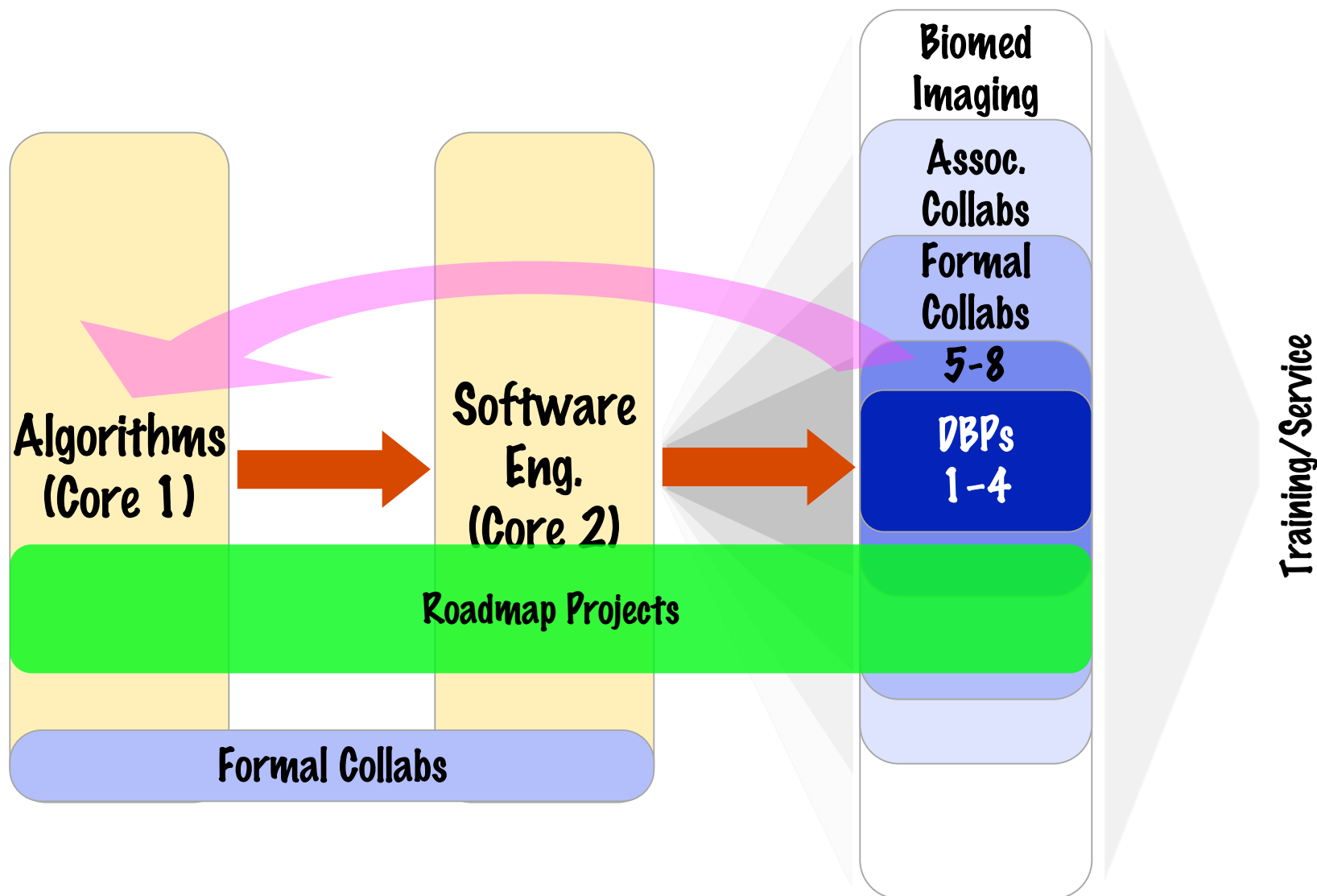


**Thank you.**

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



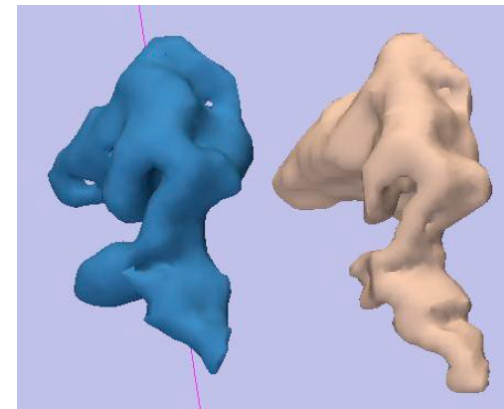
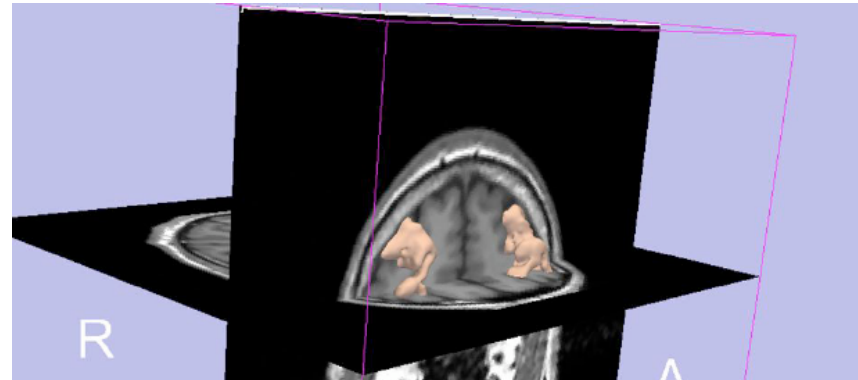
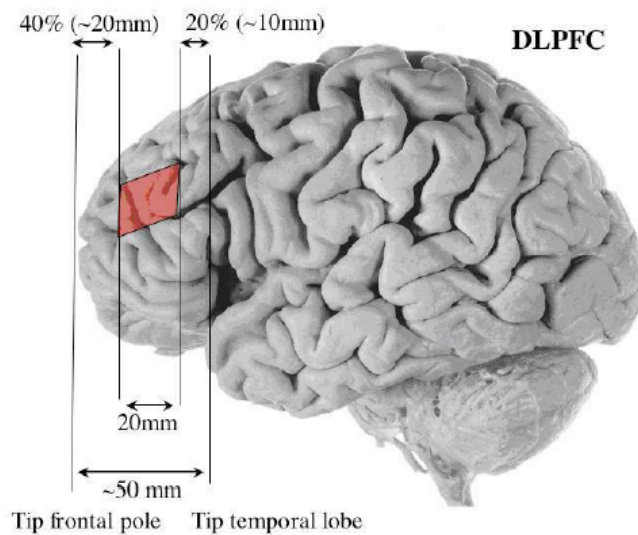
# Algorithms, Software, Science





# 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.**