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

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National Alliance for Biomedical Image Computing
Algorithms, Software, Science

- Algorithms (Core 1)
- Software Eng. (Core 2)
- Biomed Imaging
  - Assoc. Collabs
  - Formal Collabs 5-8
  - DBPs 1-4
- Image Analysis

Training/Service

NCBC EAB, January 2009
NA-MIC-A National Alliance

Core 1
Core 2
DBPs I
DBPs II
Collabs PAR
+ many others
Schizophrenia-B&W, Shenton et al.

Segmentation: EM Segmenter

NCGM Lobar Parcellation
EM Segmenter

- **Statistical methodology**
  - Bayesian framework: data + atlases

- **Validated**

- **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...

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 CD ELECTRODE ORIENTATIONS IN CHILDREN AND ADULTS


Authors: Matthew Jolley, Jeroen Strijkstra, Steve Pieper, Rob MacLeod, Dana H. Brooks, Frank Cechin, John K. Tiedman

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 have 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 conductivity. 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 subject-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 DFT 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 pattern-specific optimization of electrode placement. Further development and validation are needed for clinical or industrial utilization.

Grant Support:
- NIH P41 RR02557
- NIH P41 RR13218
- NIH T32 HL07822
- CMIT

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


Authors: Raúl San José Estépar, Nicholas Stylopoulos, Randy Ellis, Eigi Samset, Cari-Fredrik Weslin, Christopher Thompson, Kibby Visbourn

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 QUIVS, for endoscopic and transgastric access interventions and have validated it in vivo pilot studies. Our hypothesis is that endoscopic ultrasound procedures will be performed more easily and efficiently if the operator is provided with an integrated real-time 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 rendered using electromagnetic tracking of the endoscopic ultrasound probe position. Based on this positional information, the CT volume is reformat 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 infra-red rigid body registration, we measured the misregistration error between the ultrasound image and the reformatied CT plane to be less than 3 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 RR02557
- NIH T32 HL07822
- CMIT
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

![Wavelet Surface Representations Diagram](image)
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

Folding development curves of left and right hemisphere at level 0 to 3 based on over-complete wavelets

Observed value
Fitted value
Predicted curve for left
Predicted curve for right
Estimated age for left
Estimated age for right
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)

Built on ITK
**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


- Prenatal mild mentriculomegaly (MVM) predicts white-matter abnormalities in splenium
  - Reduced FA, increased diffusivity (Frobenius norm)

- Software ITK/NA-MIC

<table>
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<th>Tract</th>
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<tr>
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<td>Right cortico-spinal</td>
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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

• 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.ia.unc.edu/MSseg
- Online proceedings
  - MIDAS journal, public
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 icon on Jan 5th, and also at the programming week itself.

1. Define Joint Registration and Segmentation Framework (Kilian Pohl- MIT/BWH)
4. Basic image processing filters for DTMRI (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
7. Improved DTMR module tract display (Lauren O'Donnell - MIT, C-F Westin, BWH, Raul San Jose, BWH)
8. itk: Command-line ITK interface (Raul San Jose, Gordon Kindlmann - BWH)
9. Graphical framework to construct/ execute complex scientific analyses of data (Michael Pan, UCLA)
10. 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

Algorithms (Core 1) → Software Eng. (Core 2) → Formal Collabs

Roadmap Projects

Formal Collabs

Biomed Imaging

Assoc. Collabs

Formal Collabs

DBPs 1–4

5–8

Training/Service
Segmentation: Rule-Based
GaTech, UC-Irvine

EM-Segmen ter
tissue classifications ->
Cortical parcellations