TRD 3: Simulation and Estimation
Overall Approach

Heart vs Brain
Overall Approach

Stimulation

Source Localization
Original Aims

1. Bioelectric intrinsic source simulation and estimation for heart and brain
2. Electric/magnetic stimulation for heart and brain
3. Streamlined model-building
4. Quantification of uncertainty
Current Aims

1. Bioelectric intrinsic source simulation and estimation for heart and brain
2. Electric/magnetic stimulation for heart and brain
3. Streamlined model building
4. Quantification of uncertainty
Response to Reviews

“Enthusiasm for this TR&D was dampened, modestly, by a view that the inverse modeling for the brain work was much less mature than the heart work, and by questions regarding the ability of the applicants to move across multiple scales.”
Modeling Speedup & Stimulation

How does model-building speedup affect prediction accuracy?

IGA TRD tools will be used to study modeling tradeoffs.
SimEst TRD will reduce/delay effort on simulation aspects.
Progress
What Do Electrodes Tell Us?

Josh Blauer
(new) PhD
Voltage Mapping of Scar

Bipolar Amplitude (BPA)

Low  Bipolar Amp.  High

Voltage (mV)

0  1.5  3
Simulation of Scar Mapping

Non-excitable Lesions

Fiber Orientation & Anisotropy

Conductivity - Conduction Velocity
Active Evaluation of Substrate

Josh Blauer (new) PhD
Active Evaluation of Substrate
Clinical Feasibility Studies
Multimodal Evaluation of AF Substrate

Nathan Angel (new) PhD

Ravi Ranjan MD/PhD
Image Based Simulation of AF

Biophys J, 104(12):2764, 2013
T1 Mapping for Substrate
Where’s The EP Mapping?


Narayan S. et al, J Am Coll Cardiol 2012;60:
Integration of MRI with EAM
Dominant Frequency Analysis

Filtered Electrograms

FFT

9.75 Hz

7.90 Hz

1 second

4 Hz

20 Hz
High Dominant Freq. Near Fibrosis

MRI + DF Mapping

Average proximity 1.4 +/- 1.2 mm
Direct stimulation of the cortical surface can use clinically available electrodes and provide spatial specificity superior to scalp stimulation or other non-invasive measures.
Optimization of electrode design for delivery to deeper cortical layers including cortex in the sulci.
This project seeks to predict the impact of non-invasive brain stimulation, assess the change in brain state as the result of predicted impact, and relate this change in brain state to cognitive performance. We propose to use resting state network connectivity and FEM to predict the impact of TMS.

Can TMS selectively stimulate distinct cerebellar networks?
Halko Proposal: CIBC Role

NSF Collaborative Research: Changing Cognition Through Brain Networks

1) visual
2) motor
3) dorsal visual attention
4) ventral attention
5) limbic
6) fronto-parietal control
7) default network

fMRI based parcellation of cerebellum

Identify network stimulation strength

Individualized head model
Position coils
Stimulate target
Model induced currents
Supporting tDCS Collaborations

Kerstin Krauel + Tino Zaehle
- Modeling of current flow from tCS in patients with ADHS,
- Optimizing current delivery for rIFG for ADHS
- Auditory cortex stimulation

Bernhard Sabel
- Alternating current stimulation for vision restoration after optic nerve damage:
  - Randomized clinical trial underway

Paper under review in Frontiers of Cellular Neuroscience
Grant discussions ongoing

Paper under review in PLOS ONE,
From Summary Statement:

“Enthusiasm for this part of the project is driven to a great extent by opportunities resulting from establishing curated repositories of simulated, experimental and clinical data.”
Reproducible, community-based research

BrainStimulator: in beta release

See BrainStimulator Demo
Reproducible, community-based research

Newly formed **Consortium for Electrocardiographic Imaging (CEI)**

L. Wang, RIT

P. van Dam, Radboud, Netherlands

O. Doessel, KIT, Germany

R. MacLeod and D. Brooks
Reproducible, community-based research

Algorithm and Data Exchange Activities

Edgar database

March meeting in Germany

ISCE session in April

Hackathon at CinC
Comparison of Temporal Dimensionality Reduction Methods for Constrained Inverse in Cardiac Electrical Imaging

Quantitative Comparison of Two Cardiac Electrical Imaging Methods to Localize Pacing Sites


Jaume Coll-Font¹, Brittany Purcell², Jingjia Xu², Petr Stovicek³, Dana H Brooks¹, Linwei Wang²

¹ B-spiral group in the ECE dept. at Northeastern University, Boston (MA), USA
² Rochester Institute of Technology, Rochester (NY), USA
³ Charles University Hospital, Prague, Czech Republic
Mcaps Project

Medtronic cardiac arrhythmia potential simulation

Experiment Geometry

Geometry Scaling

Human Geometry

Experiment Time Signals

Time Scaling

Simulated Time Signals

Dog Geometry

Scaled to Human

Time Signal Scaling
Reviewer Concern

“The approach has one modest weakness in that the assignment of tissue conductivities appears to be based largely on regional differences in structure as identified in the images. In heart preparations, the arrangement of the myocytes and of the surrounding extracellular matrix both impact such conductivities, at least to the extent that conductivity measurements have been successfully employed. A more challenging issue that the applicants do not consider explicitly involves the distribution and type of gap junctions that form electrical connections between cells. Uncertainty quantification in terms of macroscopic impedance is clearly important for simulations to reflect the experimental or clinical arrangements. Strategies for consideration of any microscopic contributions to prescribed conductivities might also be expected to strengthen the approach. This will be important in continued movement across multiple scales.”
Planned Projects
Simulation Infrastructure

Complete new release of Forward/Inverse toolkit in SR5.
Complete new release of BrainSimulator.
Complete support for DBS pipeline in SR5.
Complete support for MATLAB and Python interfaces and migrate existing SR4 MATLAB code.
Begin to explore uncertainty quantification support.
Data Repository

Continue to review RedCap Interface to EDGAR.

Mine existing experimental files for EP data, including Bruno Taccardi legacy data.

Continue to expand use of XNAT for brain data.

Evaluate also for heart data applications.
Grant Proposals

Cardiac inverse problems (ECGI), perhaps involving CardioInsight but for sure CEI partners.

AF projects with Ravi Ranjan: mechanistic, ablation strategy, genetic animal model

Non-invasive neuromodulation studies in collaboration with NU (Dagmar, Deniz, Misha Pavel, others) and BIDMC and perhaps EGI
Support of Collaborators/DBPs

Trayanova: Continue with VEPL clinical testing

AFib: develop data merging tools for imaging, signal, and simulation studies.

Pasqual-Leone: optimizing tDCS and TMS lead sets, patient specific parameters.

Mcaps (Medtronic): complete experimental data phase and begin collaboration with CARP on simulation based datasets.

CardioInsight/Medtronic: develop validation strategies and data.