Cardiac Current Source Reconstructor

Introduction

The purpose of this project is primarily to reconstruct the Total Cardiac Vector (TCV) of the heart over a period of time using EIT and ECG data. While the intended use is to reconstruct the vector using both types of data, the Total Cardiac Vector can be reconstructed for a sufficient number of voltage measurements using only the ECG data. The TCV is defined to be the integral of, or the total, current density generated during depolarization and repolarization of the cardiac cells that cause the chambers of the heart to contract and relax pushing blood to the lungs and rest of the body:

$$\vec{M}(t) := \int_H J^H\left(\vec{x}, \overrightarrow{Q_0}\right) dH$$

where $\vec{M}(t)$ is the TCV computed at time t, H is the heart region inside the domain, $J^H\left(\vec{x}, \overrightarrow{Q_0}\right)$ is the current density supported inside the heart at a point $\vec{x}$ originating at point $\overrightarrow{Q_0} \in H$. The units of J^H is Amp x meters.

Project Description

The reconstructor algorithm works by taking the measured ECG and EIT voltages measured on a set of L electrodes by the ACT 5 EIT system produced by State University of New York at Albany and data taken at Colorado State University. Using the measured ECG voltages, $\vec{V} \in R^L$,the TCV is reconstructed by minimizing the l2 error norm between the measured voltages and predicted voltages, $\vec{U}$, generated using the Finite Element Method (FEM) by simulating forward data on the elementary basis vectors in R^3:

$$E(\vec{M}) = \left|\left|\vec{U} - \vec{V}\right|\right|_2$$

The predicted voltages, $\vec{U}$, is the resulting vector of the mapping G, that takes the source $\vec{M}$ to the voltages, $\vec{U}$. The columns of G are computed by simulating ECG voltages from a dipole of unit magnitude pointed in the elementary basis vectors. Using the measured EIT voltages, the conductivity is reconstructed at each sample and used in the algorithm to improve the accuracy of the reconstructor. The algorithm is written in Matlab and the FEM is solved using piecewise linear basis functions. Some issues to the project included the ability to quickly compute the dipole source origin as well as quickly simulate forward data using a variable cconductivity distribution. As this project is updated, these challenges will be addressed.

How to Use

The main program of this project is TCVR.mat. To run this file, the supplemental files provided in the include folder are needed. These include the files needed to construct the map G using the Finite

Element Method and determine the dipole source origin. When using this with EIT data, the ToDLeR conductivity reconstruction algorithm is used to reconstruct the piecewise constant conductivity. There are currently two methods of using the conductivity returned by the ToDLeR algorithm, one is to use the best fit constant conductivity fitted to the EIT data and the other is to use the variable conductivity projected from the Joshua Tree mesh to the FEM mesh used in the simulations. The first option, the constant conductivity that changes over time, is currently much faster than the variable conductivity.

Credits

The ACT 5 system was produced by Ahmed Abdelwahab, Omid Rajabi Shishvan, and Gary Saulnier at the State University of New York at Albany. The human subject data was taken by Nilton Barbosa da Rosa Jr. and Jennifer Mueller in association with Colorado State University. This project is a result of my PhD thesis “Linearized Conductivity Reconstructions and ECG Imaging” under the supervision of Dr. David Isaacson at Rensselaer Polytechnic Institute.