Body Surface and Intracardiac Mapping of SAI QRST Integral

Checkpoint Presentation

600.446: Computer Integrated Surgery II, Spring 2012

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Mentors: Dr. Larisa Tereshchenko, Dr. Fady Dawoud

Overview

- Introduction
- Motivation
- Quick Background
- Milestones
- Deliverables
- Technical Approach and Results
- Problems and Remaining Work
- References

Why?

- Physicians use electric potential maps of the heart to treat and diagnose arrhythmias
- Current method to map surface of heart is invasive and takes a long time
- Is there a better way to predict arrhythmias?
- We know that SAI QRST is a better clinical marker for a patient's risk of ventricular arrhythmias but don't understand what it means and how sensitive it is to lead placement

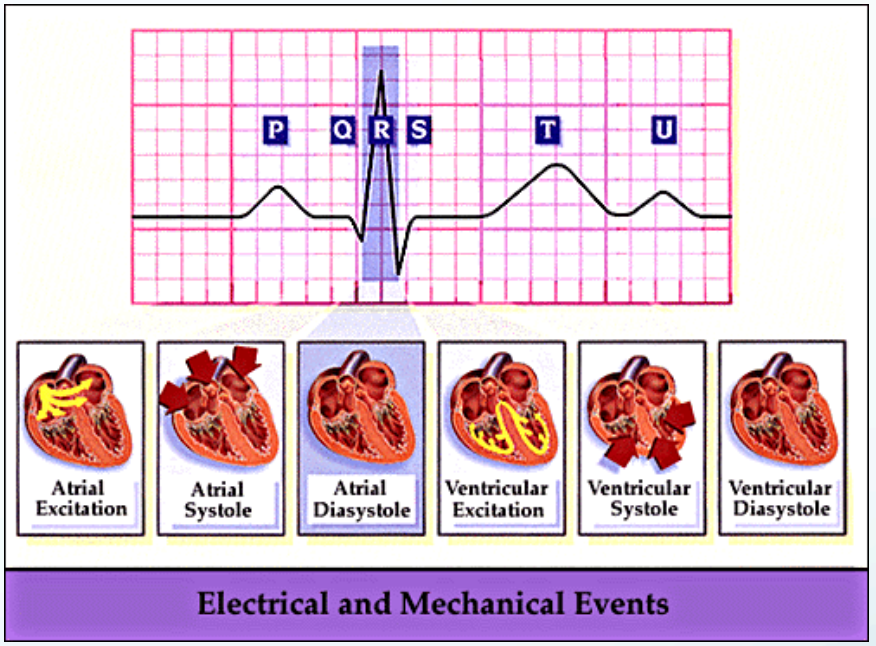
Background- Arrhythmias

- Approximately 350,000 people die of sudden cardiac death every year in the United States [1]
- Half of all deaths caused by heart disease are sudden death [1]
- Known that ventricular arrhythmias are linked to sudden death
  - Ventricular Tachycardia: rapid coordinated contraction of the ventricles
  - Ventricular Fibrillation: rapid uncoordinated contraction of the ventricles
  - Often Ventricular Tachycardia leads to Ventricular Fibrillation which can quickly lead to sudden cardiac death

1. Lloyd-Jones D, Adams R, Carnethon M, et al. Heart disease and stroke statistics—2009 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 2009;119:480

Background-ECGs and QRST

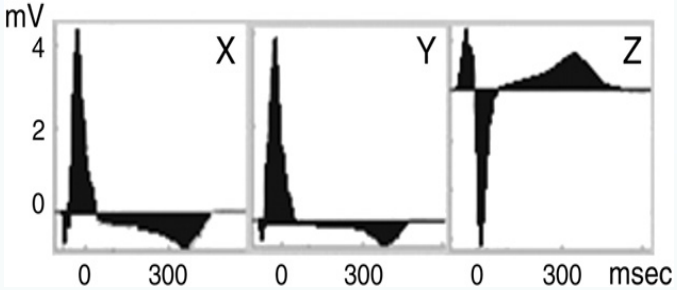
- ECGs are regularly used by doctors to diagnose patients with heart problems
- Normal ECG waveform:
  - P – depolarization as signal moves through atria
  - QRS – depolarization as signal moves through ventricles
  - T – repolarization of ventricles



Ecg_em_events.html. Photograph. EHSL. Web. 22 Feb. 2012. <http://library.med.utah.edu/kw/ecg/mml/ecg_em_events.html>.

Background – SAI QRST

- Sum Absolute Integral QRST (SAI QRST) - absolute area under the QRST regions of the ECG



- Large group (n=355) studies show that SAI QRST is a very good predictor of risk for ventricular arrhythmia[2]

2. Tereshchenko LG, Cheng A, Fetics BJ, et al. A new electrocardiogram marker to identify patients at low risk for ventricular tachyarrhythmias : sum magnitude of the absolute. Journal of Electrocardiology 2011;44(2):208-216

Re-cap of Progress

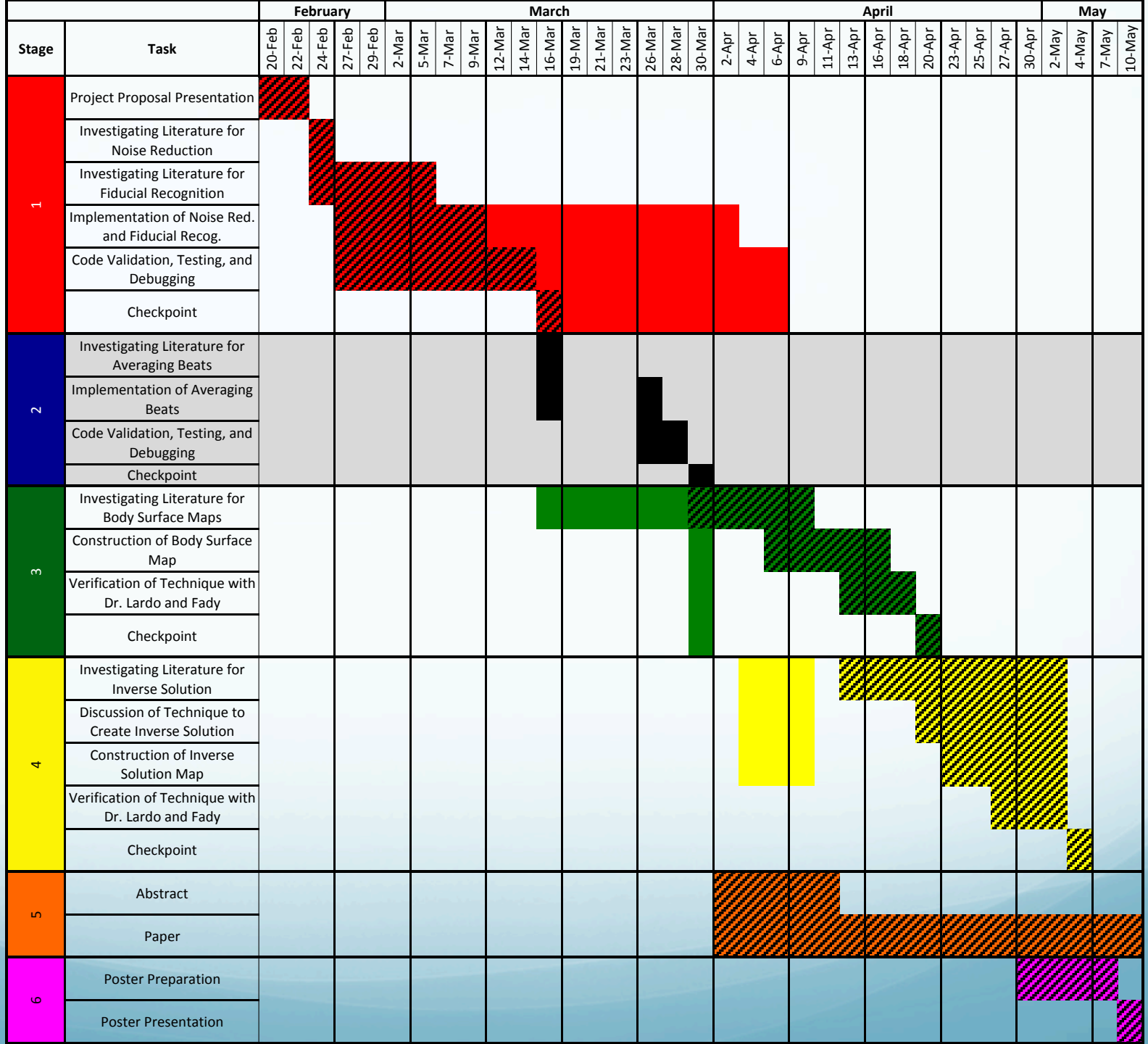
Planned Milestones

- ☐ Automatically detecting fiducial points (85% complete)
  - ☑ Criteria: graphical confirmation that our method finds the correct fiducial point
- ☑ Averaging the sum absolute and native integrals for each lead
  - ☑ No longer necessary as we already have averaged data
- ☑ Calculating sum absolute and native integrals of QRST interval
  - ☑ Criteria: graphical confirmation that our method is calculating the correct integrals
- ☑ Constructing body surface map
  - ☑ Criteria: confirmation of methods and results with our mentors
- ☐ Constructing inverse heart map (0% complete)
  - ☐ Criteria: confirmation of methods and results with our mentors

New Milestones

- ❑ Abstract Submission (50% complete)
  - ❑ We have completed the preliminary analysis but would like to have more complete data for our mentor to include in the submission
- ❑ Paper Submission (0% complete)

Gantt Chart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1
Project Proposal Presentation
Investigating Literature for Noise Reduction
Investigating Literature for Fiducial Recognition
Implementation of Noise Red. and Fiducial Recog.
Code Validation, Testing, and Debugging
Checkpoint
2
Investigating Literature for Averaging Beats
Implementation of Averaging Beats
Code Validation, Testing, and Debugging
Checkpoint
3
Investigating Literature for Body Surface Maps
Construction of Body Surface Map
Verification of Technique with Dr. Lardo and Fady
Checkpoint
4
Investigating Literature for Inverse Solution
Discussion of Technique to Create Inverse Solution
Construction of Inverse Solution Map
Verification of Technique with Dr. Lardo and Fady
Checkpoint
5
Abstract
Paper
6
Poster Preparation
Poster Presentation

Deliverables

OLD

- Minimum
  - Semi-automatically pre-processing 120-lead ECG data
  - Automatically detecting fiducial points
  - Calculating the sum absolute QRST integral
  - Averaging the sum absolute QRST integral for each lead
- Expected
  - In addition to above, constructing a body surface map of the sum absolute QRST integral
- Maximum
  - In addition to above, constructing a map of the heart using the inverse solution

NEW

- Minimum
  - Semi-automatically pre-processing 120-lead ECG data
  - Automatically detecting fiducial points
  - Calculating the sum absolute QRST integral
  - Averaging the sum absolute QRST integral for each lead
  - ⬆ In addition to above, constructing a body surface map of the sum absolute QRST integral
- Expected
  - ⬆ In addition to above, constructing a map of the heart using the inverse solution
- Maximum
  - Abstract to Heart Failure Society
  - Paper

Technical Approach:

- Borrowed heavily from Zong's Computers in Cardiology (2003 and 2006)
- 2003 algorithm (for QRS detection):
  - Tested against MIT-BIH Arrhythmia database
  - Sensitivity of 99.65 %
  - Accuracy of 99.77%

Zong W, Moody B, Jiang D. A Robust Open-source Algorithm to Detect Onset and Duration of QRS Complexes. Computers in Cardiology 2003;30:737-740

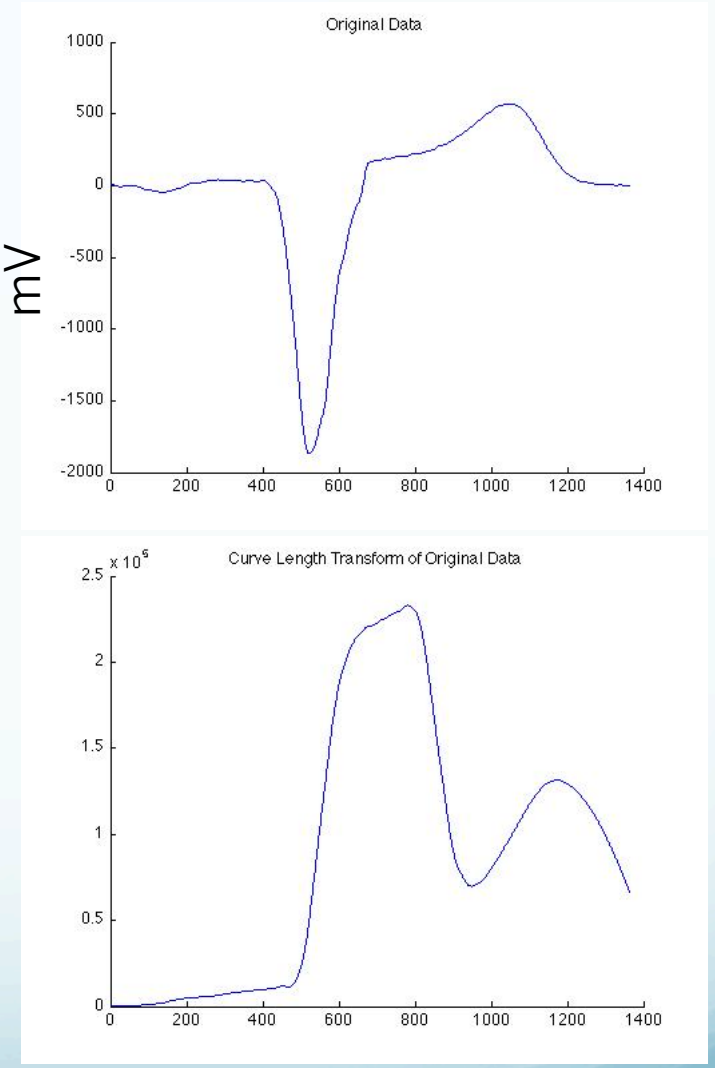
Low-pass filter

- Ideal band-pass filter is 5-15 Hz
- Only low-pass filter necessary
  - Curve length suppresses very low frequency
- Difference equation (for low-pass filter):
- $y(n) = 2y(n-1) – y(n-2) + x(n)-2x(n-5)+x(n-10)$

Curve-length Transformation

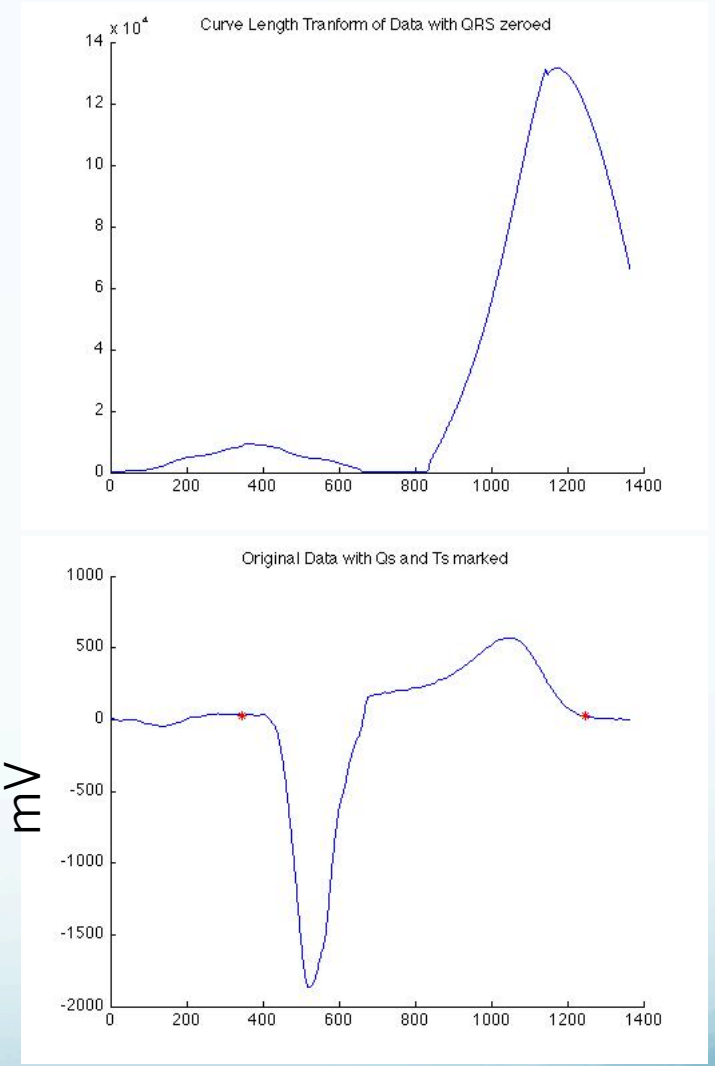
- Window for transform ≈ QRS width
- QRS should yield maximal curve length

$$L(w,i) = \sum_{k=i-w}^{i} \sqrt{\Delta t^2 + \Delta y_k^2}$$



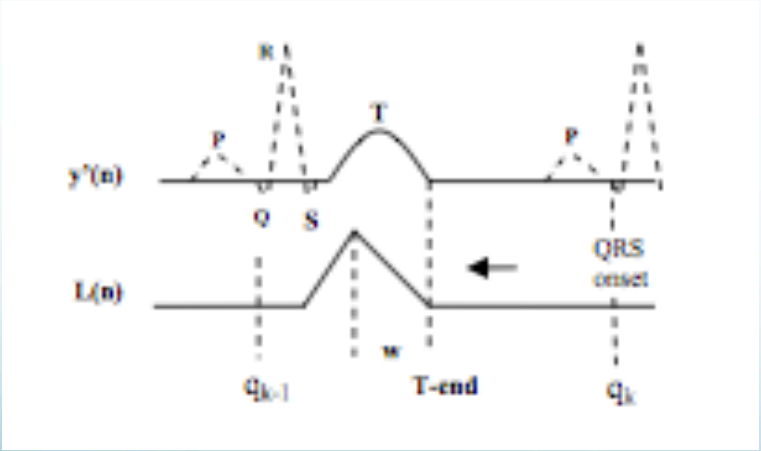
Finding Q and S

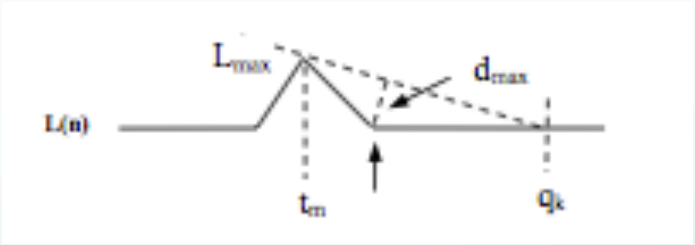
- When LT crosses threshold (t_i)
- Search backwards 125ms min LT (L_{min})
- Search forwards 125ms max LT (L_{max})
- $L_{diff} = L_{max} - L_{min}$
- Backwards until $Q_{si} = L_{min} + L_{diff}/100$
- Forwards until $S_{si} = L_{max} - L_{diff}/20$
- Adjustment of -20/+20 samples for beginning/end
- 500 ms “eye-closing” period



End of T-search

- Currently working on it
- Old method of zeroing out QRS and feeding the ECG did not work
- New method:

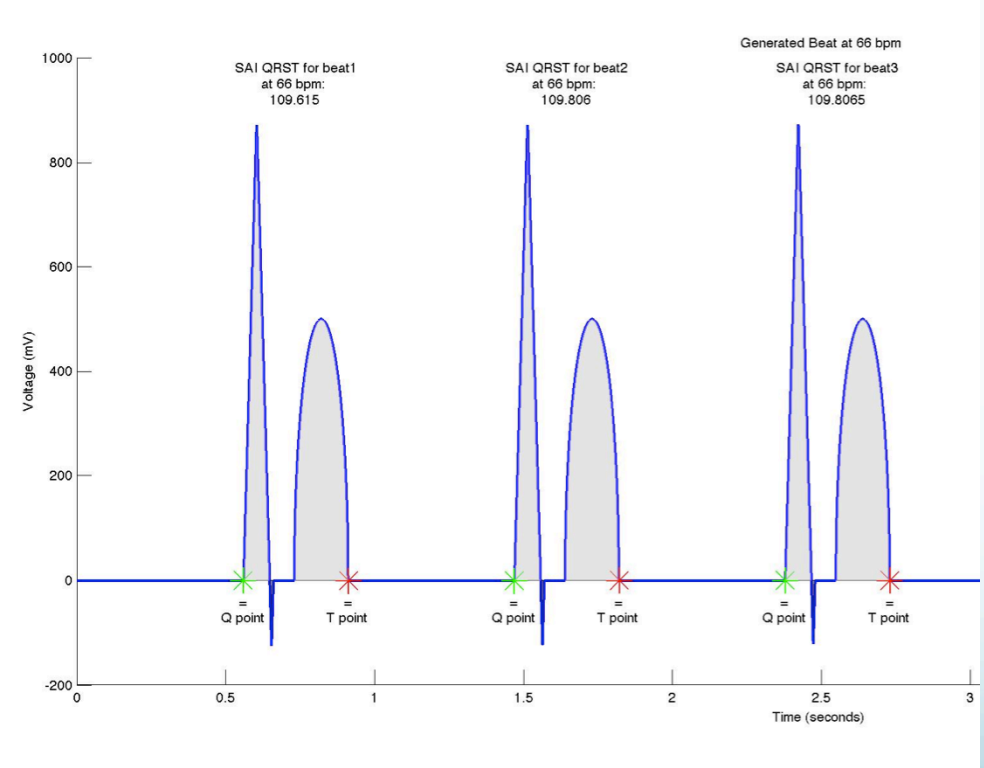




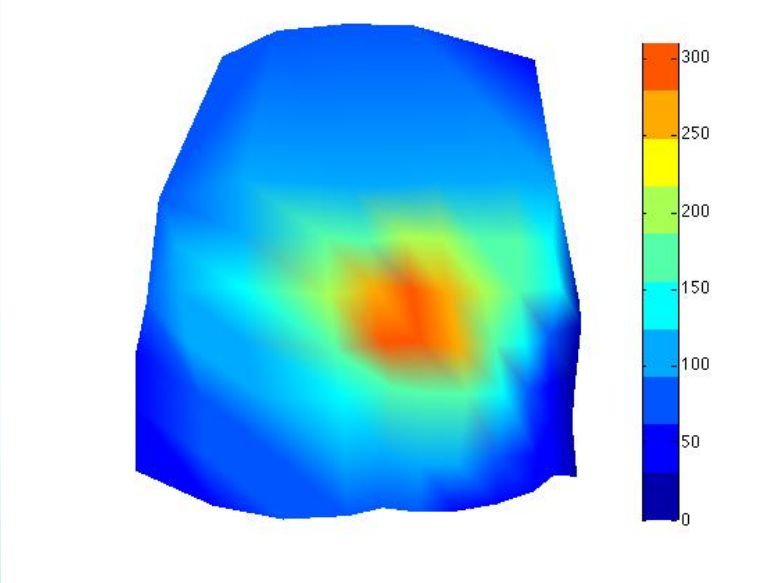
Zong W, Saeed M, Heldt T, America N, Manor B. A QT Interval Detection Algorithm Based on ECG Curve Length Transform Materials and methods. Computers in Cardiology 2006:377-380.

SAI QRST and Body Surface Mapping

- Based on the detected Q and T points calculating the integral is pretty rudimentary



mV•ms



Remaining Work

- Debugging the T-wave detection
- Validation of results
- Intracardiac Mapping

Dependencies

- IRB Approval
  - Mentors need IRB approval to release data
  - Status: Resolved
- Data Source
  - See above
  - Status: Resolved
- Weekly support meetings with Dr. Tereshchenko
  - Assistance with first two stages of project
  - Status: Resolved
- Packages to help solve the inverse problem and create body surface and heart maps
  - Turned out to just be a bunch of plotting features in MATLAB
  - Status: Resolved
- Meetings with Dr. Lardo or Fady for help with constructing body surface and heart maps
  - Fady will be primary contact and provide assistance with constructing these maps
  - Status: Resolved

Updated Goals

- Same as before
  - Automatically detecting fiducial points
  - Calculating sum absolute ~~and native integrals~~ of QRST interval
  - ~~Averaging the sum absolute and native integrals for each lead~~
  - Constructing body surface map
  - Constructing inverse heart map
- New Goals
  - Preliminary Data and Abstract to Heart Failure Society (April 11th)
  - Paper about what we learned about SAI QRST and lead placement (TBD)

Management Plan

- Everything remains the same as planned
  - Mentors:
    - Weekly Meetings with Dr. Tereshchenko: Fridays 3-4:30pm
    - Dr. Lardo – as needed (most likely not)
    - Fady Dawoud – as needed
  - Markus and Sindhoora: working together on all aspects of the project

References

Remains the same as before

- 1. Ghosh S, Silva JN a, Canham RM, et al. Electrophysiologic substrate and intraventricular left ventricular dyssynchrony in nonischemic heart failure patients undergoing cardiac resynchronization therapy. Heart rhythm : the official journal of the Heart Rhythm Society 2011;8(5):692-9.
- 2. Ambroggi LD, Corlan AD. Body Surface Potential Mapping. In: Comprehensive Electrocardiology., 2011:1376-1413.
- 3. Rudy Y. Cardiac repolarization : Insights from mathematical modeling and electrocardiographic imaging (ECGI). HRTHM 2009;6(11):S49-S55.
- 4. Wang Y, Cuculich PS, Zhang J, Desouza KA, Smith TW, Rudy Y. Noninvasive Electroanatomic Mapping of Human Ventricular Arrhythmias with Electrocardiographic Imaging (ECGI). 2011;84.
- 5. Tereshchenko LG, Cheng A, Fetics BJ, et al. A new electrocardiogram marker to identify patients at low risk for ventricular tachyarrhythmias: sum magnitude of the absolute. Journal of Electrocardiology 2011;44(2):208-216.
- 6. Tereshchenko LG, Cheng A, Fetics BJ, et al. Ventricular arrhythmia is predicted by sum absolute QRST integral but not by QRS width. Journal of Electrocardiology 2010;43(6):548-552.
- 7. Sornmo L, Laguna P. ELECTROCARDIOGRAM (ECG) SIGNAL PROCESSING. Wiley Encyclopedia of Biomedical Engineering 2006:1-16.
- 8. Zong W, Saeed M, Heldt T, America N, Manor B. A QT Interval Detection Algorithm Based on ECG Curve Length Transform Materials and methods. Computers in Cardiology 2006:377-380.
- 9. Zong W, Moody B, Jiang D. A Robust Open-source Algorithm to Detect Onset and Duration of QRS Complexes. Computers in Cardiology 2003;30:737-740.

Questions?