Implementation of Body Surface Potential Map of QRST Integral

600.446: Computer Integrated Surgery II, Spring 2012

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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 diagnose arrhythmias?

Current Methods for 3-D Mapping of Heart

3-D Electrical Mapping of the Heart. YouTube. YouTube, 02 Sept. 2010. Web. 22 Feb. 2012. http://www.youtube.com/watch?v=Ivqa1xQkxzU (last ~15 seconds were cut)

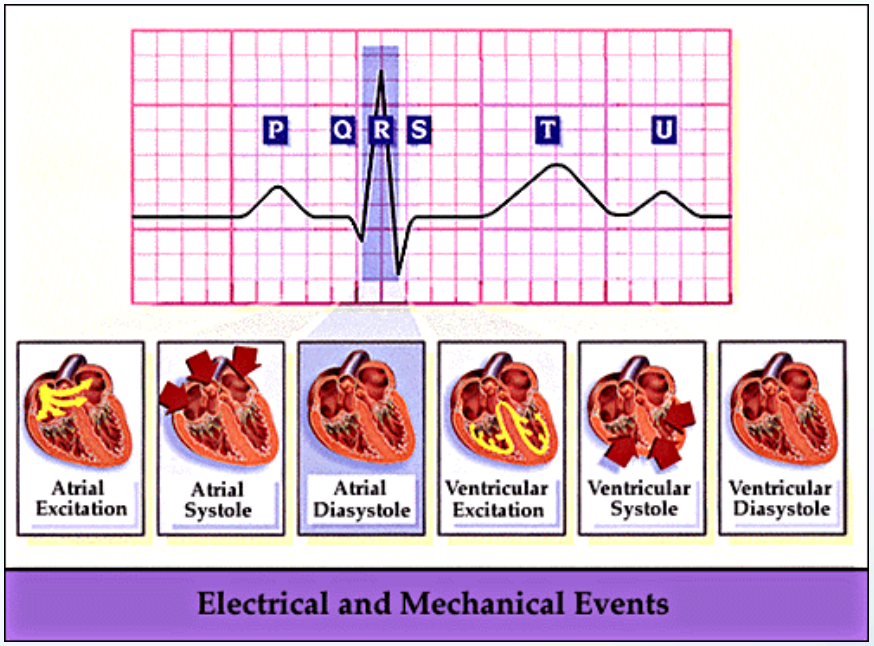
Background- Arrhythmias

- 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

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

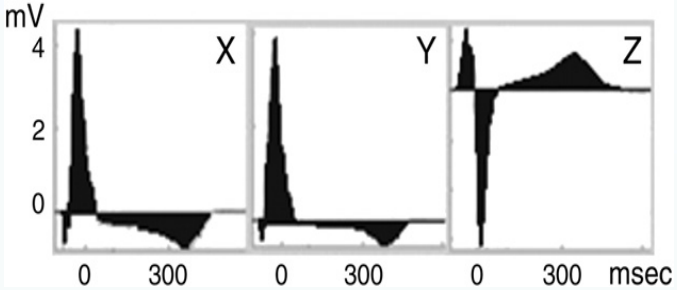
- ECGs are regularly used by doctors to diagnose patients with heart problems
- Normal ECG waveform:
  - P – depolarization as signal moves through atria
  - QRS – depolarization as signal moves through ventricles
  - T – repolarization of ventricles



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

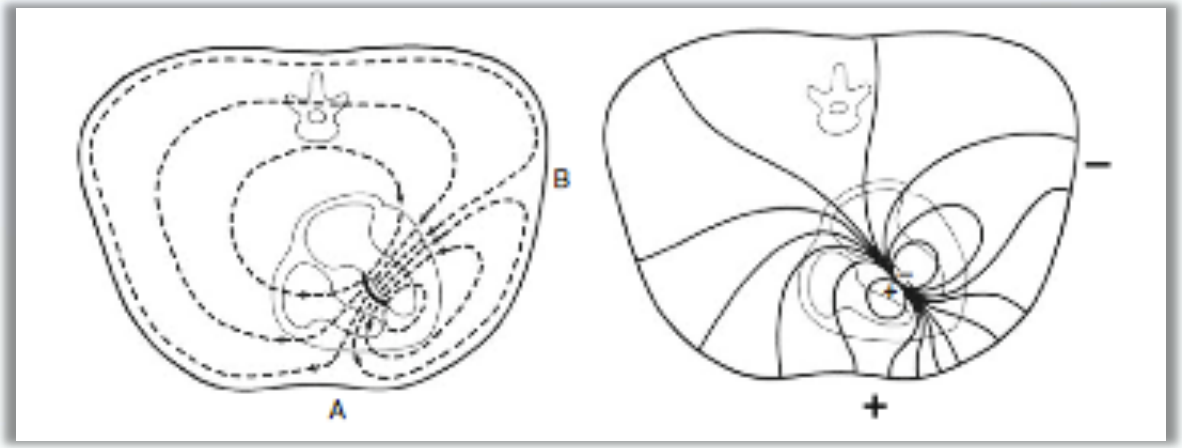
- Sum Absolute Integral QRST (SAI QRST) - absolute area under the QRST regions of the ECG

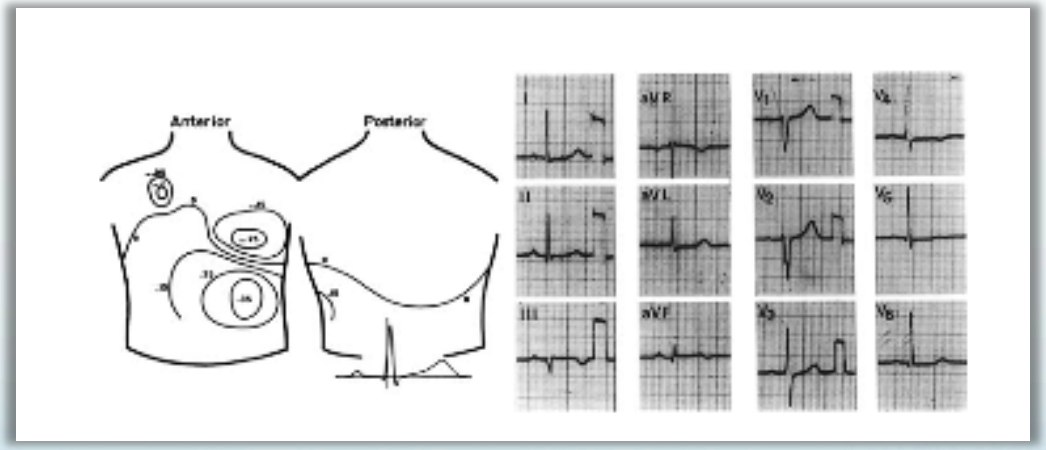


- Large group (n=355) studies that SAI QRST is a very good predictor of risk ventricular arrhythmia in conventional ECGs [2]

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

Background-
Body Surface Potential Maps (BSPM)





Ambroggi LD, Corlan AD. Body Surface Potential Mapping. In: Comprehensive Electrocardiology., 2011:1376-1413.

Background-Inverse Solution

- Map the surface of the heart from the ECGs recorded from surface of the body
- Re-creates heart map "comparable" to the ones you get from mapping with a catheter [3]
- Non-invasive
- Computationally challenging: depends on patient's geometry

3. Wang Y, Cuculich PS, Zhang J, Desouza KA, Smith TW, Rudy Y. Noninvasive Electroanatomic Mapping of Human Ventricular Arrhythmias with Electrocardiographic Imaging (ECGI). Science Translational Medcine 2011;84

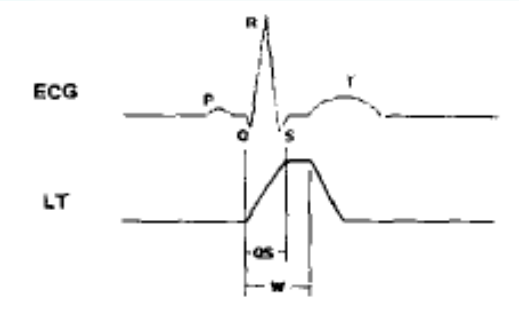
Our Idea (Motivation)

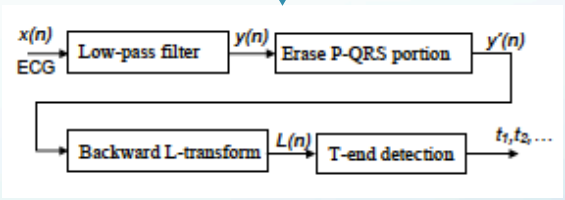
- Combine SAI QRST and BSPM to provide a better way to predict ventricular arrhythmias
- Potential applications:
  - Cardiac Resynchronization Therapy
  - Prognostic and diagnostic information
  - Non-invasive mapping of a new marker of cardiac disease

Technical Approach (1)

- In order to even begin dealing with our 120-lead ECG data, we will need to develop a way of automatically detecting the fiducial points of each ECG signal and based of these points calculate the sum absolute and native integrals of the QRST interval.

- To accomplish this task, we plan on using the following 3 steps[4].
  1. PQ junction detection[5]
  2. Automatic lead detection
  3. T-wave end detection





4. 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.
5. 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

Technical Approach (2)

- Having determined the sum absolute and native integrals of the QRST integral for each beat, we will then average across the beats to give us our averaged sum absolute integral for the individual leads.
- After calculating the sum absolute integrals, we will then calculate a body surface map based on the sum absolute QRST intervals
- Finally, with the help of our mentor we will attempt to solve the inverse problem and create a map of the heart based of the body surface map

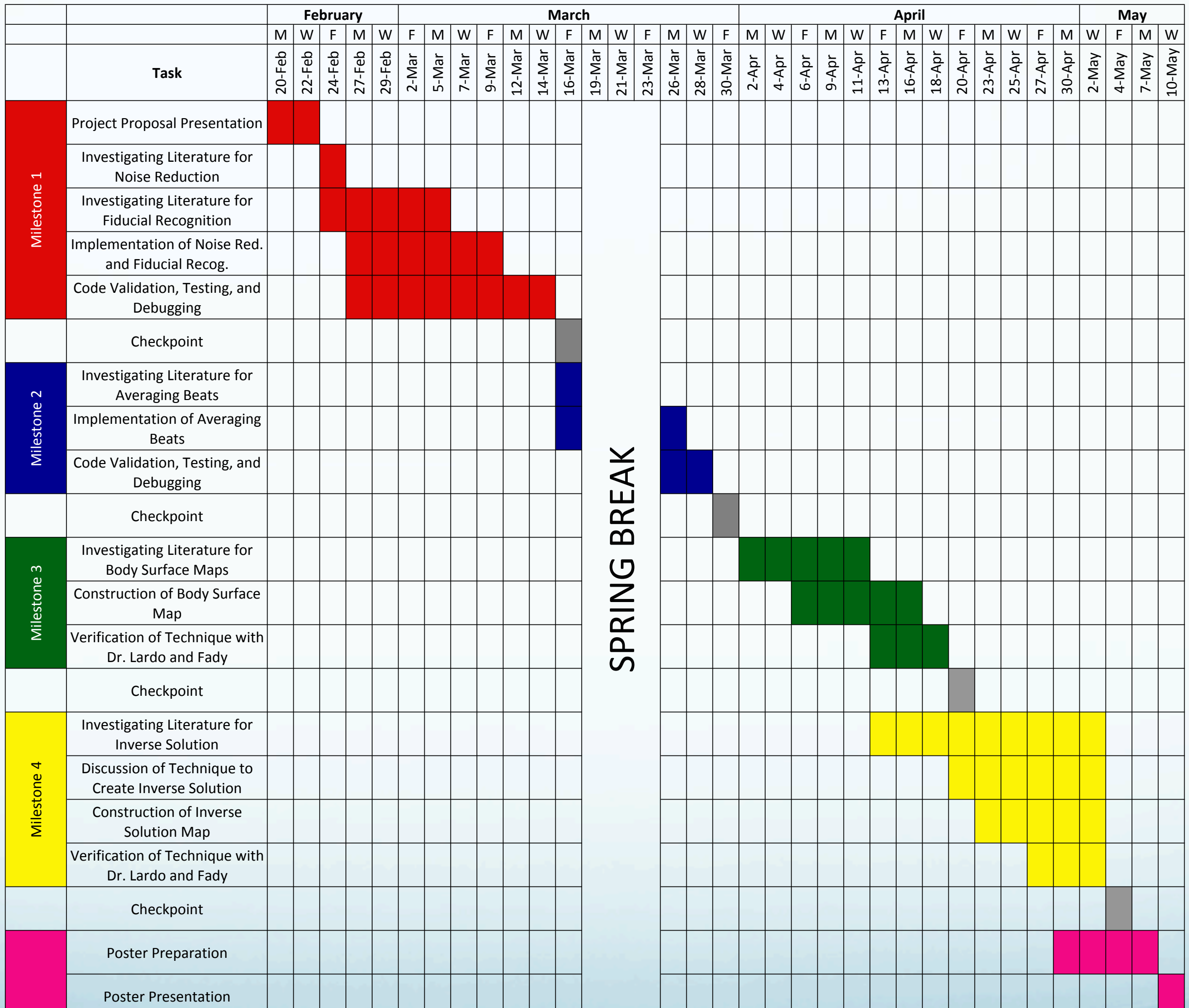
Deliverables

- 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

Milestones

- Automatically detecting fiducial points
  - Criteria: graphical confirmation that our method finds and labels the correct fiducial point
- Calculating sum absolute and native integrals of QRST interval
  - Criteria: graphical confirmation that our method is calculating the correct integrals
- Averaging the sum absolute and native integrals for each lead
  - Criteria: see if averaging works for test data
- Constructing body surface map
  - Criteria: confirmation of methods and results with our mentors
- Constructing inverse heart map
  - Criteria: confirmation of methods and results with our mentors

Gantt Chart


February
March
April
May
Task
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Milestone 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
Milestone 2
Investigating Literature for Averaging Beats
Implementation of Averaging Beats
Code Validation, Testing, and Debugging
Checkpoint
Milestone 3
Investigating Literature for Body Surface Maps
Construction of Body Surface Map
Verification of Technique with Dr. Lardo and Fady
Checkpoint
Milestone 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
Poster Preparation
Poster Presentation
SPRING BREAK

Management Plan

- Mentors:
  - Weekly Meetings with Dr. Tereshchenko: Fridays 3-4:30pm
  - Dr. Lardo - pending
  - Fady Dawoud – pending
- Markus and Sindhoora: working together on all aspects of the project
- Additional Tasks:
  - Markus: time management (making sure project keeps rolling)
  - Sindhoora: communications with mentors

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
  - When we reach Stage 3 (projected March 20), we can acquire these from Fady
  - Status: Pending
- Meetings with Dr. Lardo or Fady for help with constructing body surface and heart maps
  - Fady (Dr. Lardo's PhD student) will be primary contact and provide assistance with constructing these maps
  - Status: Pending

Reading List

- 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.