Technical Developments to Enable Electrical Impedance Tomography (EIT) Measurement of Blood Flow to Monitor Cardiac Output Key Engineering Contributions

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Outline

- Introduction
- Problem
- Contributions
- Results
- Conclusion
- Future Work
Introduction

- Heart Disease: “is a group of conditions affecting the structure and functions of the heart.”

- Examples:
  - Angina
  - Arrhythmia
  - Atrial fibrillation
  - Coronary Artery Disease (CAD)
  - Etc.
Introduction (2)

- CAD
  - Most common form of heart disease
  - Occurs when arteries in the heart are blocked
  - Complications include
    - Angina (chest pain) due to lack of oxygen to the heart
    - Heart Attack due to part heart muscle death from lack of oxygen
Introduction (3)

- **Gold Standard for Diagnosis of CAD**
  - Angiography
    - Catheter inserted (groin or arm)
    - Guided through artery to a position near the heart
    - Contrast agent is administered through catheter
    - X-rays are taken in conjunction with release of contrast agent
  - Cardiac CT
    - Intravenous pump hookup
    - Contrast agent administered
    - X-ray images are taken in conjunction with the release of contrast agent
EIT

- Experimental imaging technique where changes inside the body can be imaged using a set of electrodes on the surface
- Advantages: Portable, non-ionizing, high acquisition rates, relatively inexpensive
- Disadvantages: Low resolution, high sensitivity to electrode movement, imaging anomalies are not well understood, use of ill conditioned problem to calculate images
The goal of this thesis is to develop a collection of Electrical Impedance Tomography (EIT) techniques to allow for monitoring of cardiac output and other parameters of heart function.
Contributions

- EIT Protocol
- Hardware Toolset
- Software Toolset
Contributions (CT Protocol)
Contributions (EIT Protocol)

EIT Protocol

1. Request Consent
2. 4 EIT Electrodes Placed on Patient
3. EIT Prep
   - Remaining 12 EIT electrodes placed on patient in circular plan around 9th intercostal space
   - One ground electrode placed on left abdomen
   - 2 ECG electrodes placed on patient (one right below the right clavicle, and the other just below the left clavicle) ground remains the same as EIT
   - Hooked up to EIT system
   - Hooked up to ECG amplifier
   - CT breathing protocol reiterated
4. Check impedance of EIT electrodes and act accordingly
5. EIT and ECG acquisition
   - EIT and ECG data simultaneously acquired
6. If electrode impedances are below threshold

*1 (link from CT Protocol)
Contributions (Hardware Toolset)
Contributions (Hardware Toolset) (2)
Contributions (Hardware Toolset) (3)
Contributions (Software Toolset)
Contributions (Software Toolset) (2)
Contributions (Software Toolset) (3)
Results (Simulation)
## Results (Simulation) (2)

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$SNR = 20dB$
Results (Human Experiment)

- Subject #1
Conclusion

- Goal of this thesis was to design a toolset to enable the measurement of EIT cardiac parameters
- The results are promising
- A colleague is taking over this work
Future Work

- Compare EIT and CT Blood flow
- Test toolset on patients at UOHI
- Tweak EIT and Software Protocol as needed
- Include other EIT methods to improve cardiac EIT imaging
- Try several EIT systems
- Increase number of patients imaged with final hardware/software toolset
Thank You

- Questions
Results (Human Experiment) (2)

- Subject #2
Results (Human Experiment) (3)

- Subject #3
## Results (Simulation) (2)

### $SNR = \infty$

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Contributions (Software Toolset) (4)

Start

1. Calculate Matrix B
   \[
   \left( \frac{(J\Sigma_{\text{op}} + \Sigma_{\text{in}})}{B} \right)^{-1}
   \]

2. Matrix Multiply B and C
   \[
   \left( \frac{J\Sigma_{\text{op}}^T + \Sigma_{\text{in}}}{C} \right)^{-1}
   \]

3. Calculate Matrix A
   \[
   \left[ \frac{\Sigma_{\text{op}} J^T}{A} \right]_{\text{top}}
   \]

4. Multiply Matrix A with Product from Step 2 (BC)
   \[
   \left[ \frac{\Sigma_{\text{op}} J^T}{A} \right]_{\text{top}} \left( \frac{J\Sigma_{\text{op}}^T + \Sigma_{\text{in}}}{B} \right)^{-1}
   \]

End

Repeat Steps 3 and 4 for all iterations of x