Inverse Problems & Applications

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Systems and Computer Engineering, Carleton University, Ottawa

Inverse Problems . . . *Plato's cave*

Plato's cave ... Shadows on the wall

Source: iamcriselleeee.files.wordpress.com/2013/11/cave-2.jpg

Inverse Problems

Forward Problem: *Forms* $\Rightarrow$ *Shadows*

Inverse Problems

Forward Problem:	*Forms* $\Rightarrow$ *Shadows*
Inverse Problem:	*Shadows* $\Rightarrow$ *Forms*

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- Ill-conditioned
  Sensitivity to some movements is low

Inverse Problems

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  Sensitivity to some movements is low
- Ill-posed
  Some movements don't change shadows

Inverse Problems

Forward Problem: *Forms* $\Rightarrow$ *Shadows*
Inverse Problem: *Shadows* $\Rightarrow$ *Forms*

- Ill-conditioned
  Sensitivity to some movements is low
- Ill-posed
  Some movements don't change shadows
- Noisy
  Flickering light

Inverse Problems

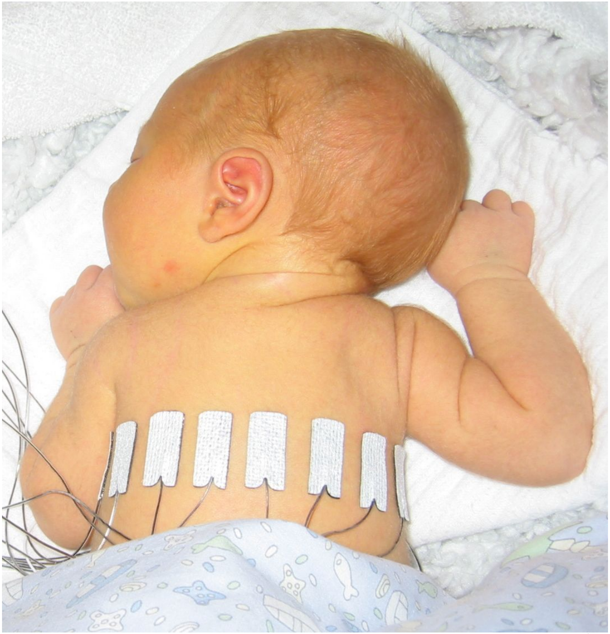
Techniques: to calculate stable & meaningful parameters in the presence of inversion difficulties
Examples

- Image deblurring / restoration
- Medical imaging
- Geophyical imaging
- Model parameter fitting
- Reconstruction with imcomplete/noisy data

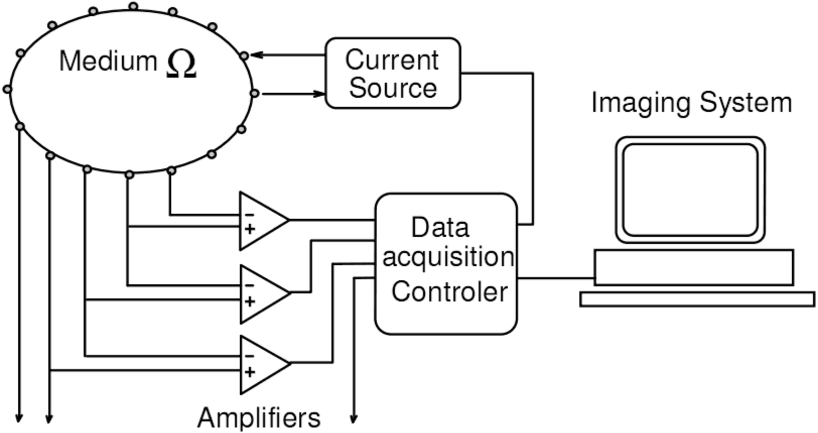
Electrical Impedance Tomography

10-day old healthy baby with EIT electrodes

Source: eidors3d.sf.net/data_contrib/if-neonate-spontaneous



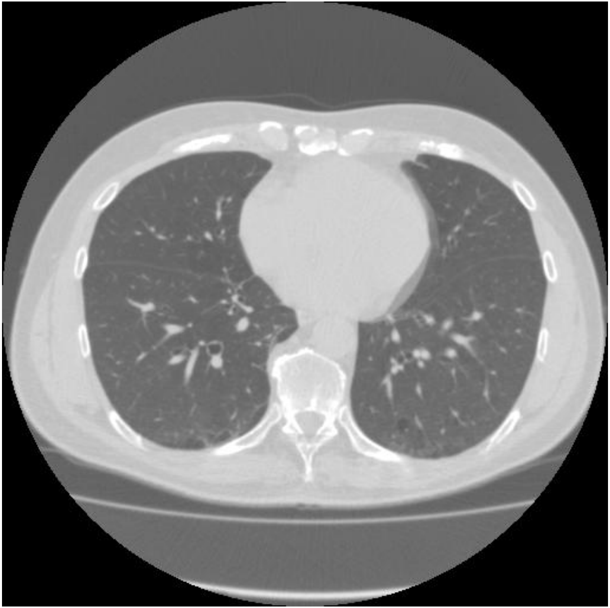
Electronics – Block Diagram



Current Propagation

Healthy Adult Male
CT slide at heart

Source: eidors3d.sf.net/tutorial/netgen/extrusion



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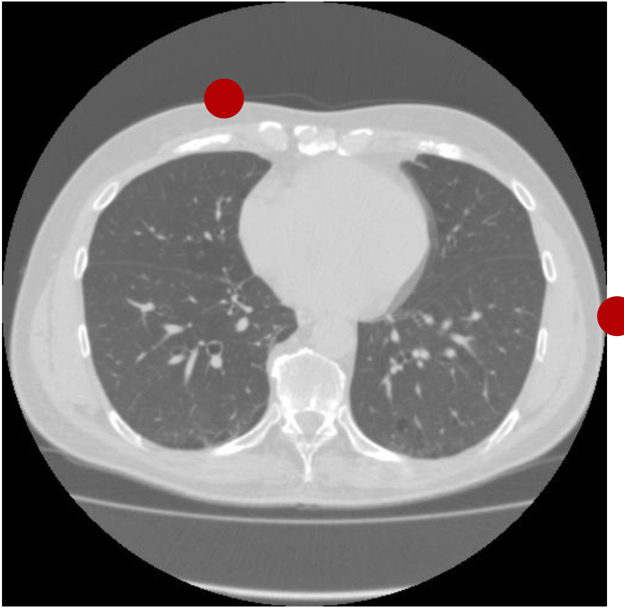

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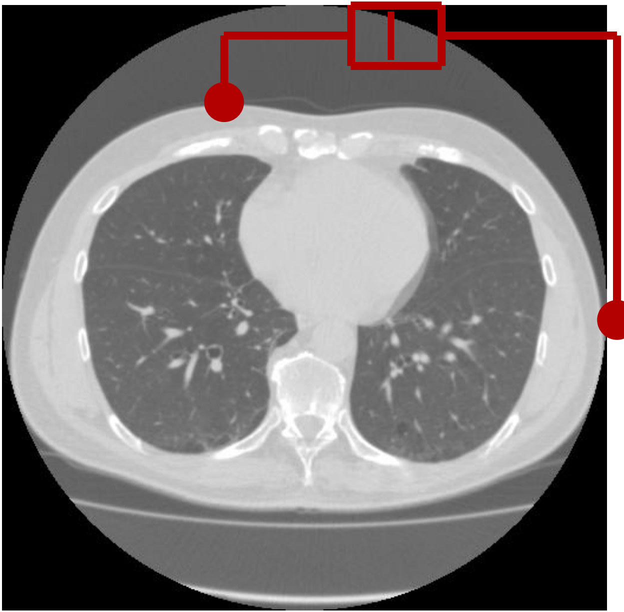

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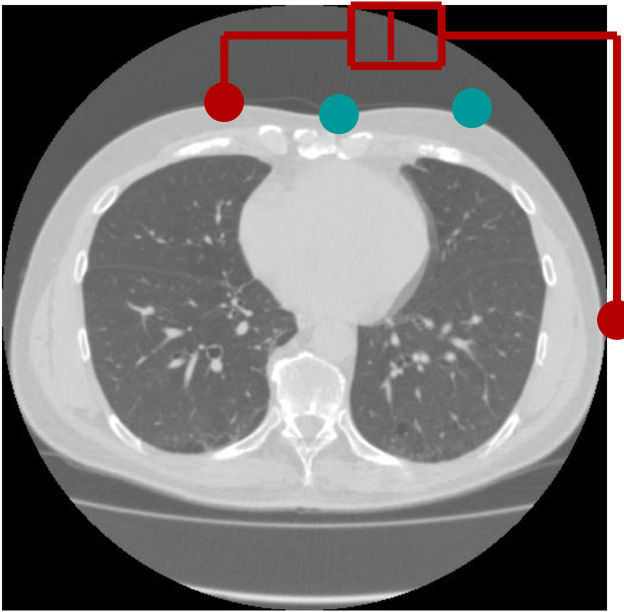

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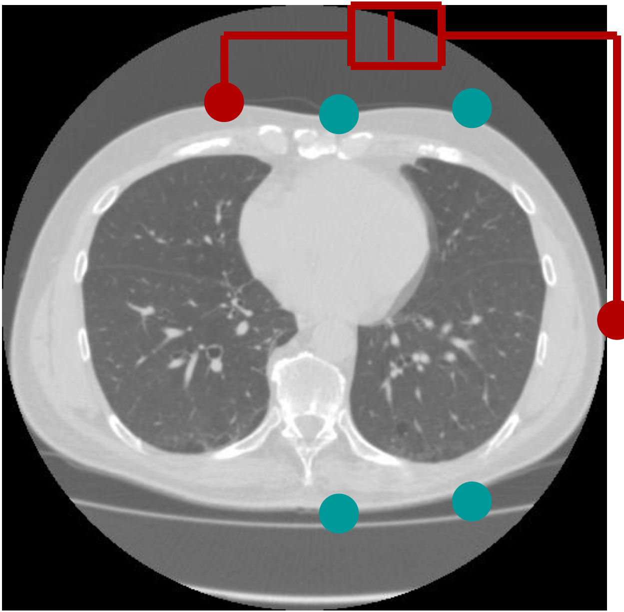

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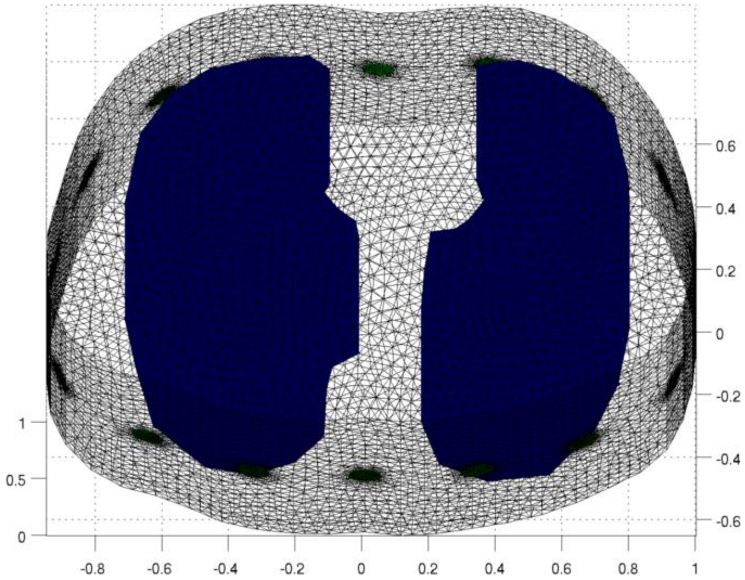
Finite Element Modelling



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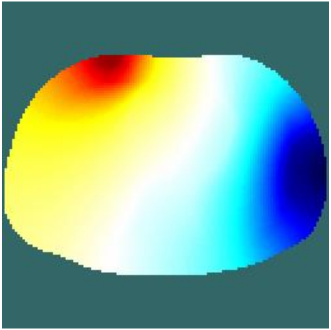
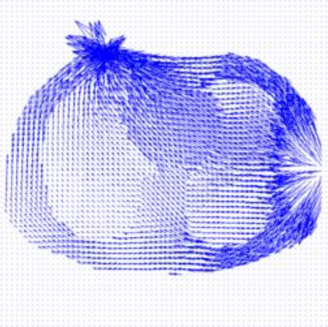


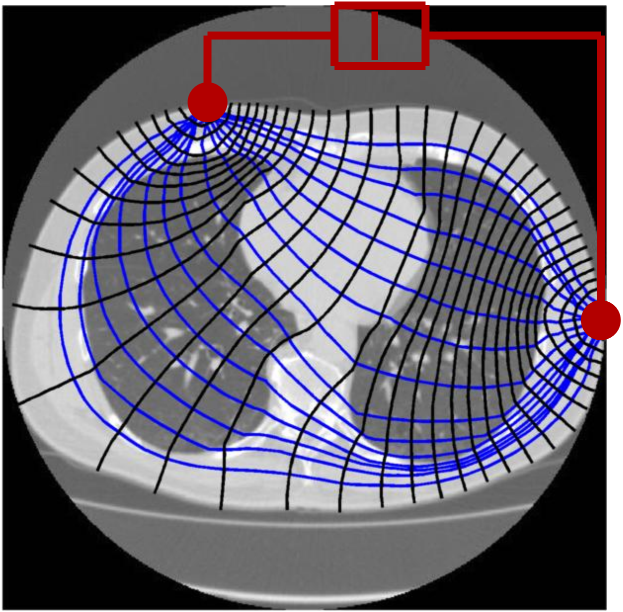
Simulated Voltages



Voxel Currents

Thorax Propagation

CT Slice with simulated current streamlines and voltage equipotentials



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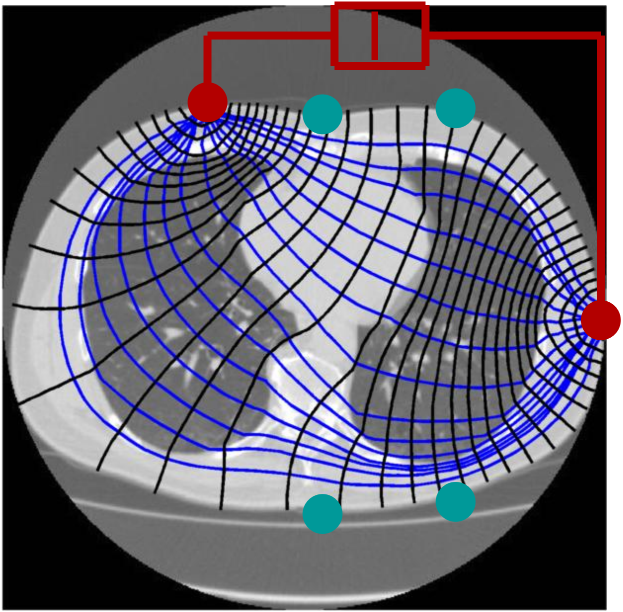
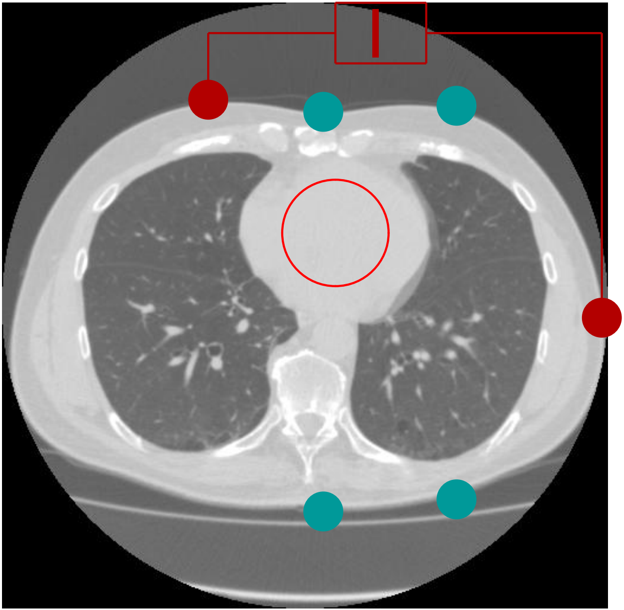


CT Slice with simulated current streamlines and voltage equipotentials

Changing Conductivity

Heart receives blood (diastole) and is more conductive



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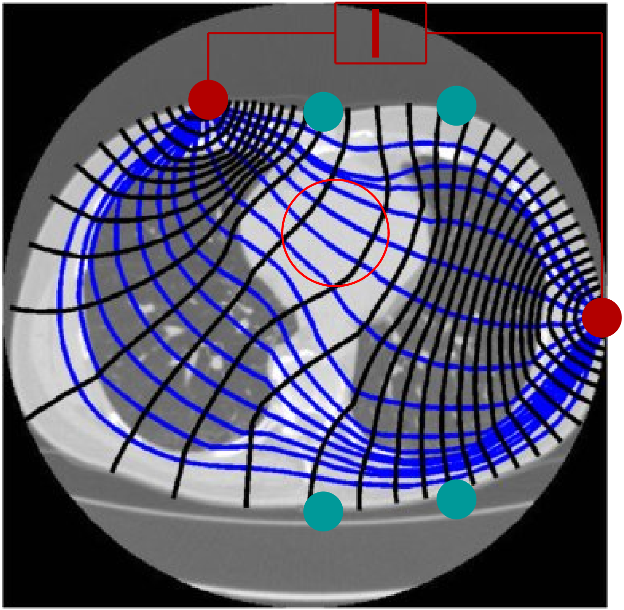

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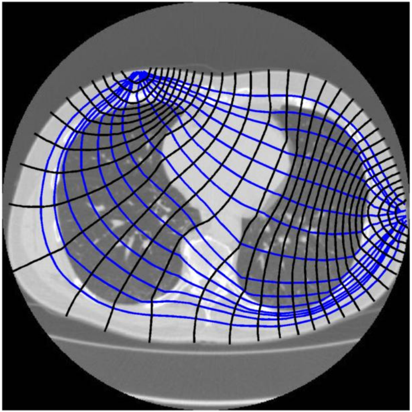
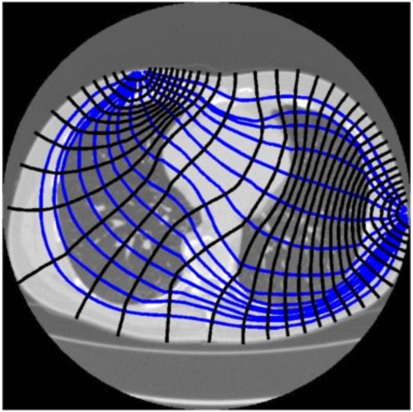
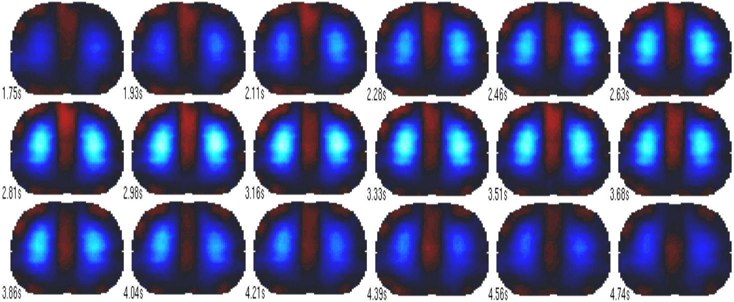
Changing Conductivity



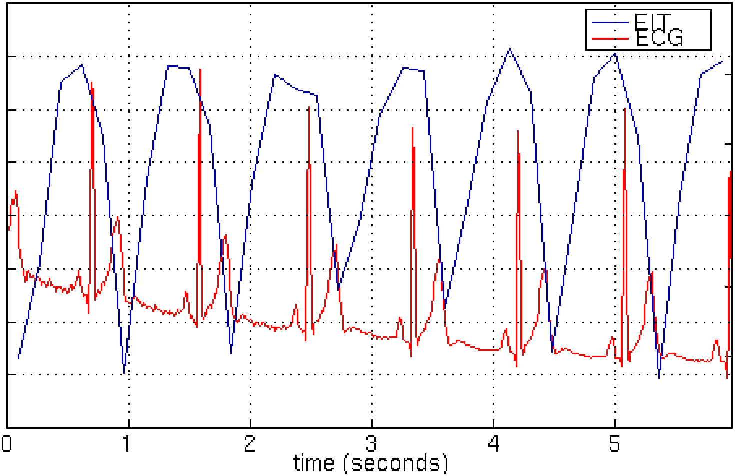


Application: Breathing



Chest images of tidal breathing in healthy adult

Application: Heart



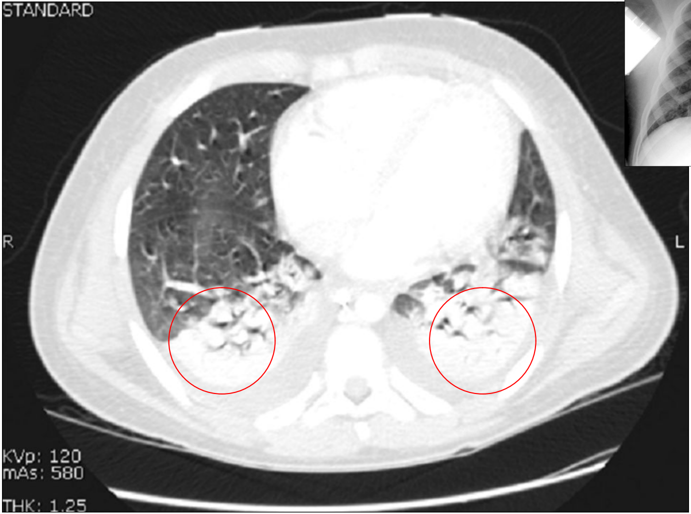
EIT Signal in ROI around heart (and ECG)

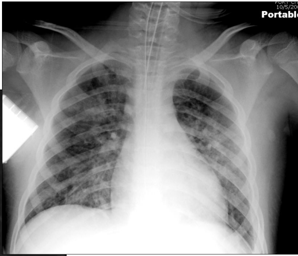
Mechanical Ventilation

Mechanical Ventilator with EIT monitor

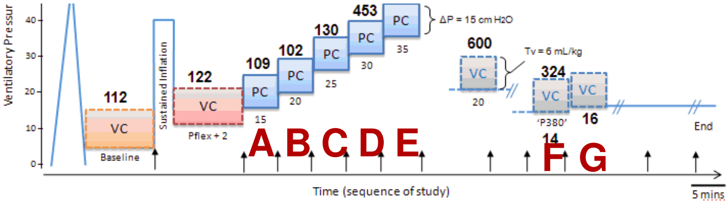
Source: Swisstom.com

Acute Respiratory Distress Syndrome (ARDS)





EIT + Lung State



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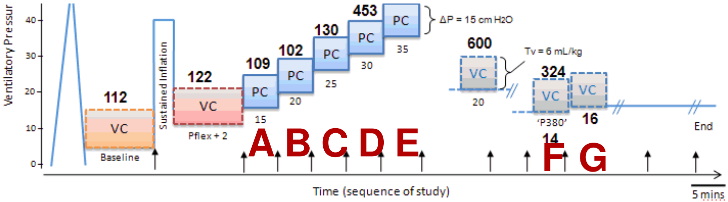

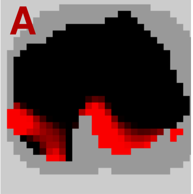

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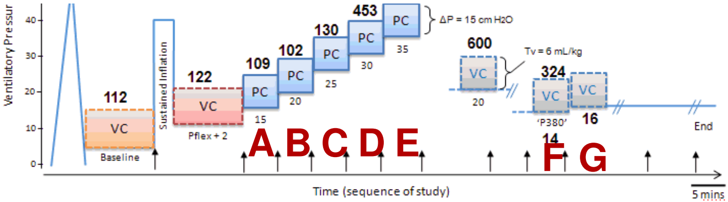

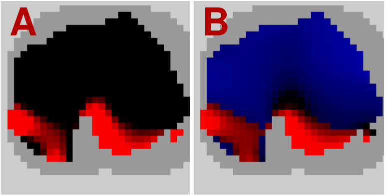

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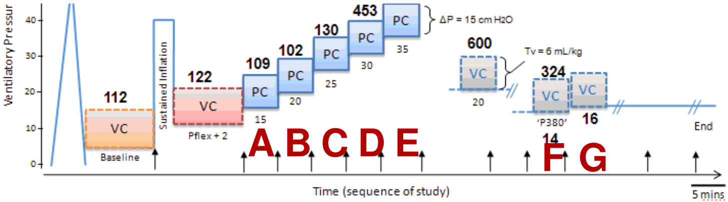

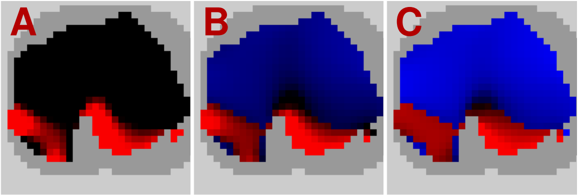

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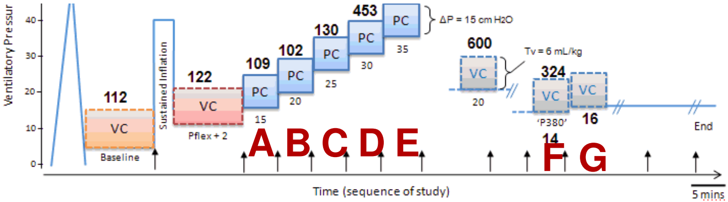

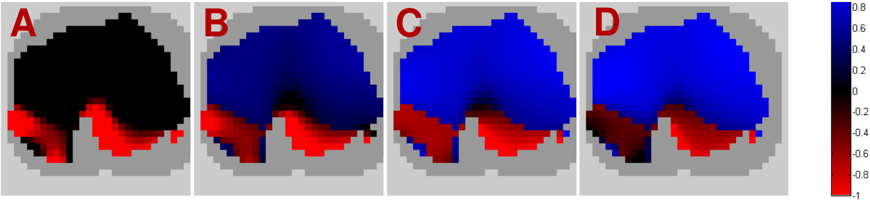

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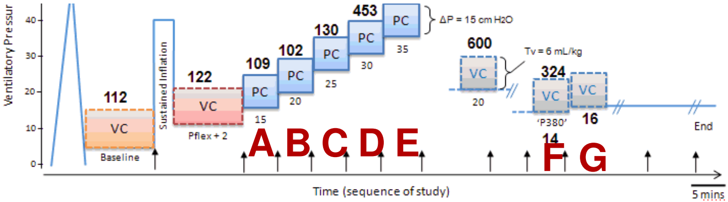

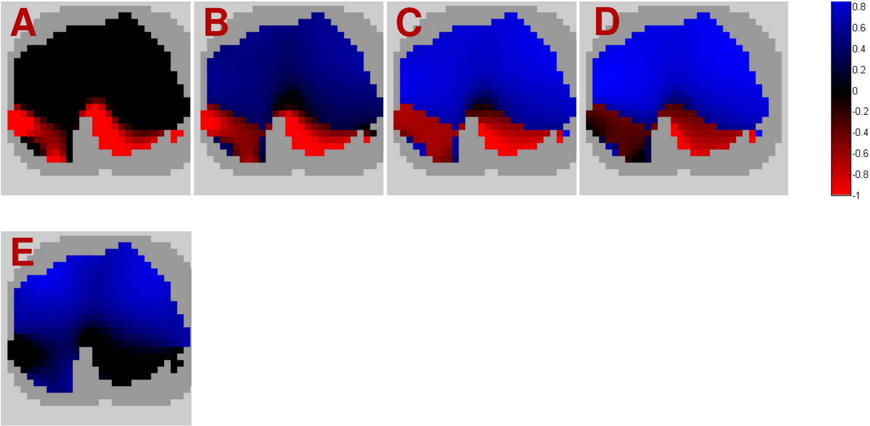

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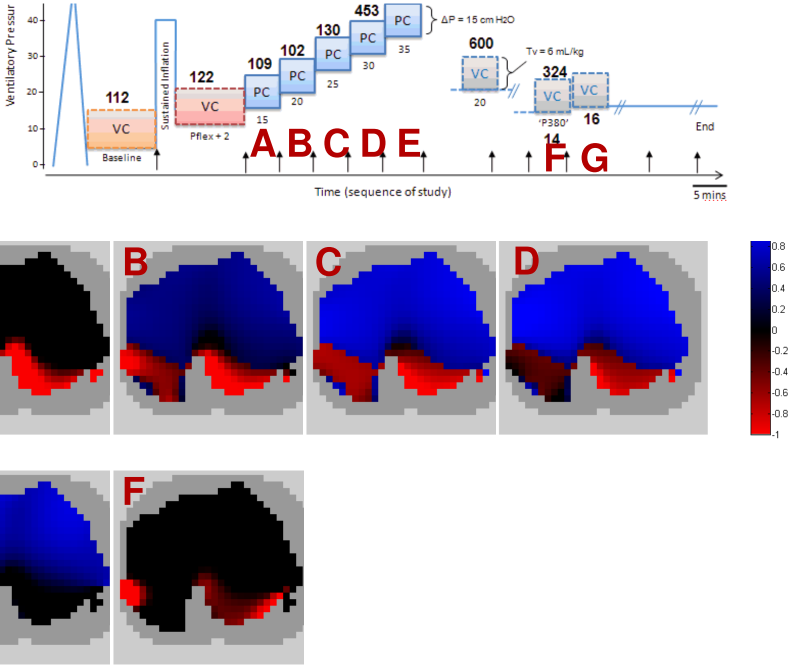

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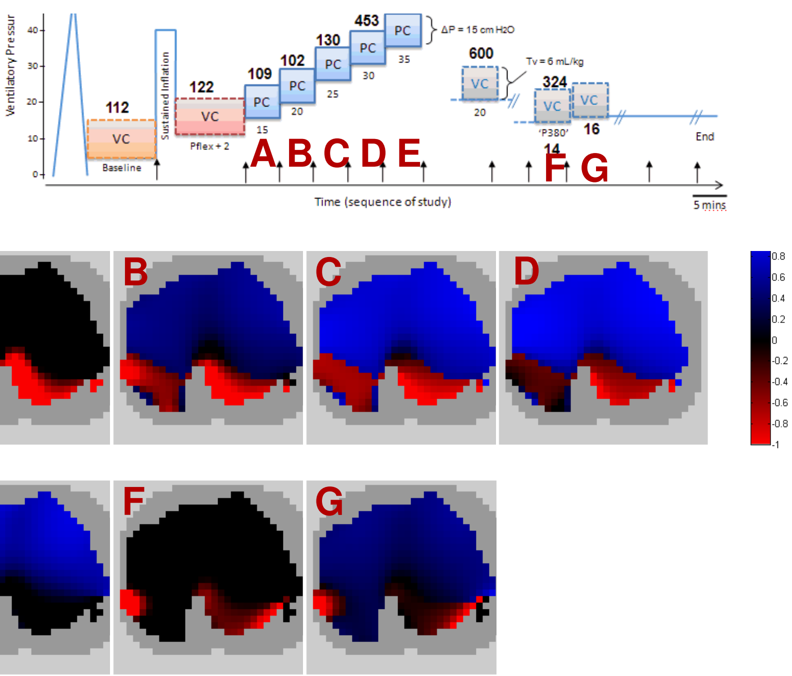


EIT for Brain Imaging

Applications:

- Epileptic foci
- Stroke (Ischaemic vs. Haemoragic)
- Fast Neural Imaging

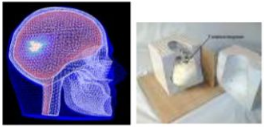
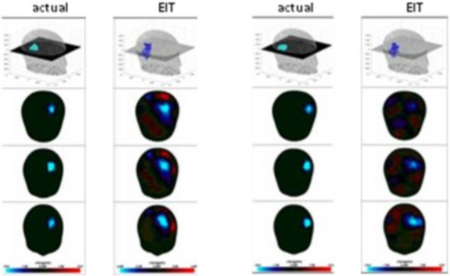


Fig. 2. Left : Finite element of the head used to produce images. Right: Example of EIT images produced in a saline filled tank

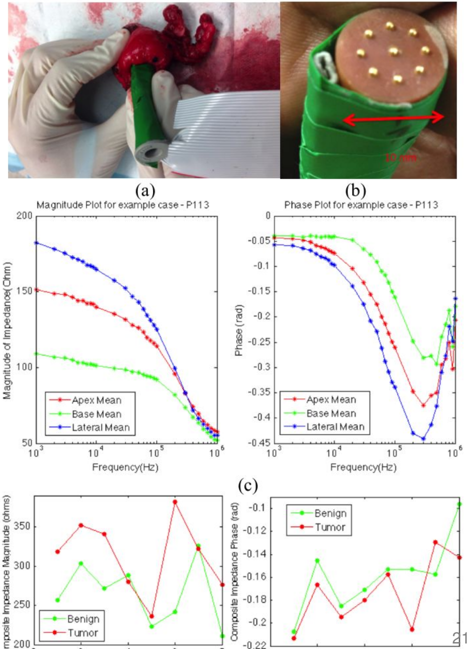


Source: Holder, www.ucl.ac.uk/medphys/research/eit/pubs/brain_EIT_over

EIT for Cancer Imaging: Breast/Prostate

- Cancerous tissue has different electrical properties
- Image tissue
- Image increased vascularization

Source: Khan, Mahara, Halter *et al*, Conf. EIT, 2014



Non-medical applications

- Flow in pipes
- Mixing tanks
- Imaging metalic ores
- Hydro-geology

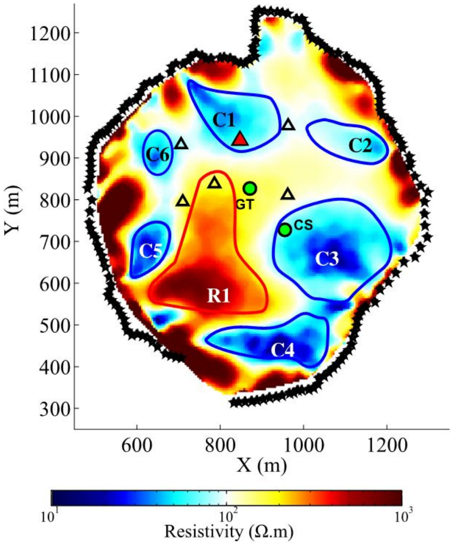
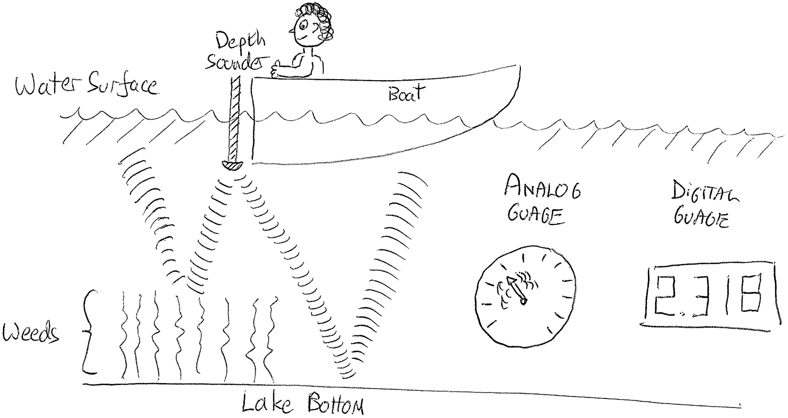


Figure shows resistivity in a cross-section of La Soufrière de Guadaloupe volcano.

Source: N. Lesparre *et al*, Conf. EIT, 2014

Data Quality

Data Quality



Depth Sounder – with analog and digital guages

What's the problem?

With strong priors and complex algorithms, algorithms give us pretty pictures, even when they are irrelevant.

Question:

- how can we know when to trust a pretty picture?
- how can we know when the data are junk?

Data Quality Measure: Concept

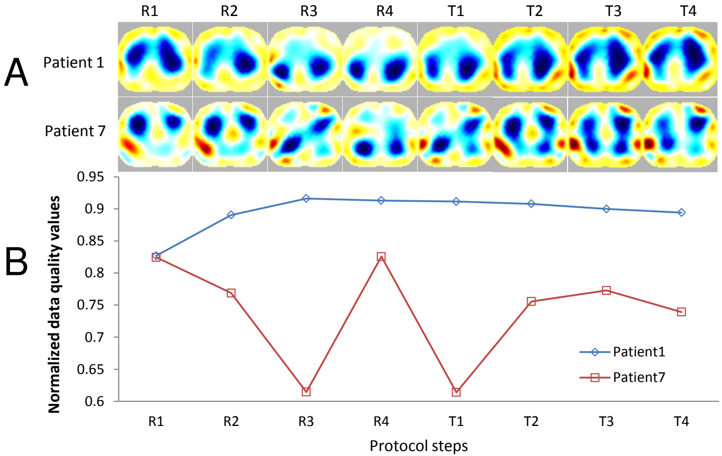
- *Concept:* High Quality Data is Consistent
- *Idea:* Use IP to predict each data point from all others

$$\boxed{\begin{matrix}\text{Original}\\ d\end{matrix}} \Rightarrow \boxed{\begin{matrix}\text{Remove } i\\ d^{(i)}\end{matrix}} \Rightarrow \boxed{\begin{matrix}\text{Solve}\\ \hat{m}^{(i)}\end{matrix}} \Rightarrow \boxed{\begin{matrix}\text{Predict}\\ \hat{d}^{(i)}\end{matrix}}$$

- Calculate error

$$\epsilon_i = d_i - \hat{d}_i^{(i)}$$

Example: Data quality measures



Clinical data and data quality metric for each stage of the protocol (R1–R4 — recruitment: PEEP⇑, T1–T4 — titration: PEEP⇓). *A*: EIT images *B*: Calculated data quality.

Perspectives

- Data analysis is hard
- powerful algorithms are useful
- we live in a world of big data
- complex systems fail in complex ways
- users like pretty pictures

So … the situation will get worse

Solutions?

Solutions?

Solutions?

$\Rightarrow$

Solutions?

$\Rightarrow$

Solutions?

$\Rightarrow$

Thus, we need

Solutions?

$\Rightarrow$

Thus, we need

- Open Data

Solutions?

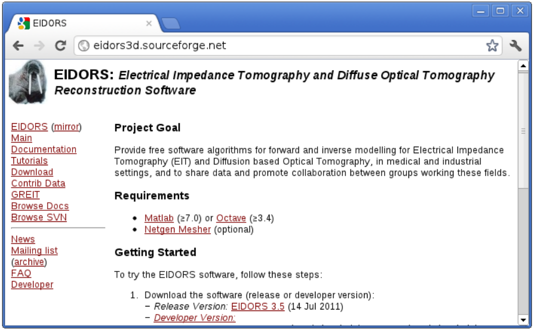
$\Rightarrow$

Thus, we need

- Open Data
- Open source analysis

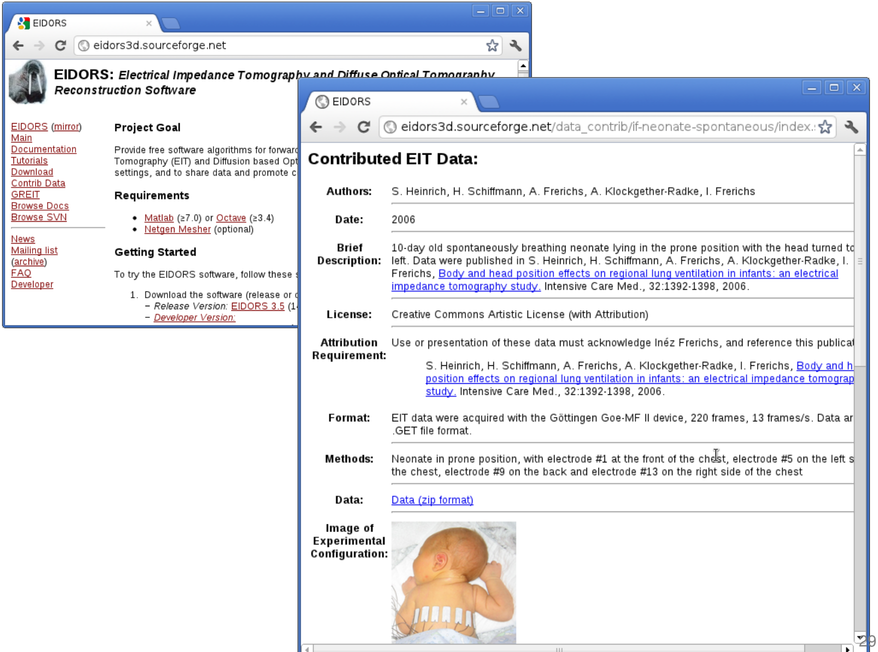
For EIT . . .

For EIT . . .



EIDORS
eidors3d.sourceforge.net
EIDORS: Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software
EIDORS (mirror)
Main
Documentation
Tutorials
Download
Contrib Data
GREIT
Browse Docs
Browse SVN
News
Mailing list (archive)
FAQ
Developer
Project Goal
Provide free software algorithms for forward and inverse modelling for Electrical Impedance Tomography (EIT) and Diffusion based Optical Tomography, in medical and industrial settings, and to share data and promote collaboration between groups working these fields.
Requirements
Matlab (≥7.0) or Octave (≥3.4)
Netgen Mesher (optional)
Getting Started
To try the EIDORS software, follow these steps:
1. Download the software (release or developer version):
– Release Version: EIDORS 3.5 (14 Jul 2011)
– Developer Version:

For EIT . . .


EIDORS
eidors3d.sourceforge.net
EIDORS: Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software
EIDORS (mirror)
Main
Documentation
Tutorials
Download
Contrib Data
GREIT
Browse Docs
Browse SVN
News
Mailing list (archive)
FAQ
Developer
Project Goal
Provide free software algorithms for forward
Tomography (EIT) and Diffusion based Opt
settings, and to share data and promote c
Requirements
Matlab (≥7.0) or Octave (≥3.4)
Netgen Mesher (optional)
Getting Started
To try the EIDORS software, follow these
1. Download the software (release or d
– Release Version: EIDORS 3.5 (1
– Developer Version:
EIDORS
eidors3d.sourceforge.net/data_contrib/if-neonate-spontaneous/index.
Contributed EIT Data:
Authors: S. Heinrich, H. Schiffmann, A. Frerichs, A. Klockgether-Radke, I. Frerichs
Date: 2006
Brief Description: 10-day old spontaneously breathing neonate lying in the prone position with the head turned to left. Data were published in S. Heinrich, H. Schiffmann, A. Frerichs, A. Klockgether-Radke, I. Frerichs, Body and head position effects on regional lung ventilation in infants: an electrical impedance tomography study. Intensive Care Med., 32:1392-1398, 2006.
License: Creative Commons Artistic License (with Attribution)
Attribution Requirement: Use or presentation of these data must acknowledge Inéz Frerichs, and reference this publicat
S. Heinrich, H. Schiffmann, A. Frerichs, A. Klockgether-Radke, I. Frerichs, Body and h position effects on regional lung ventilation in infants: an electrical impedance tomograp study. Intensive Care Med., 32:1392-1398, 2006.
Format: EIT data were acquired with the Göttingen Goe-MF II device, 220 frames, 13 frames/s. Data ar .GET file format.
Methods: Neonate in prone position, with electrode #1 at the front of the chest, electrode #5 on the left s the chest, electrode #9 on the back and electrode #13 on the right side of the chest
Data: Data (zip format)
Image of Experimental Configuration:

Carleton UNIVERSITY

Traffic jam on the way to Carleton