The Effect of Shape Deformation on Two-Dimensional Electrical Impedance Tomography

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Electrical Impedance Tomography

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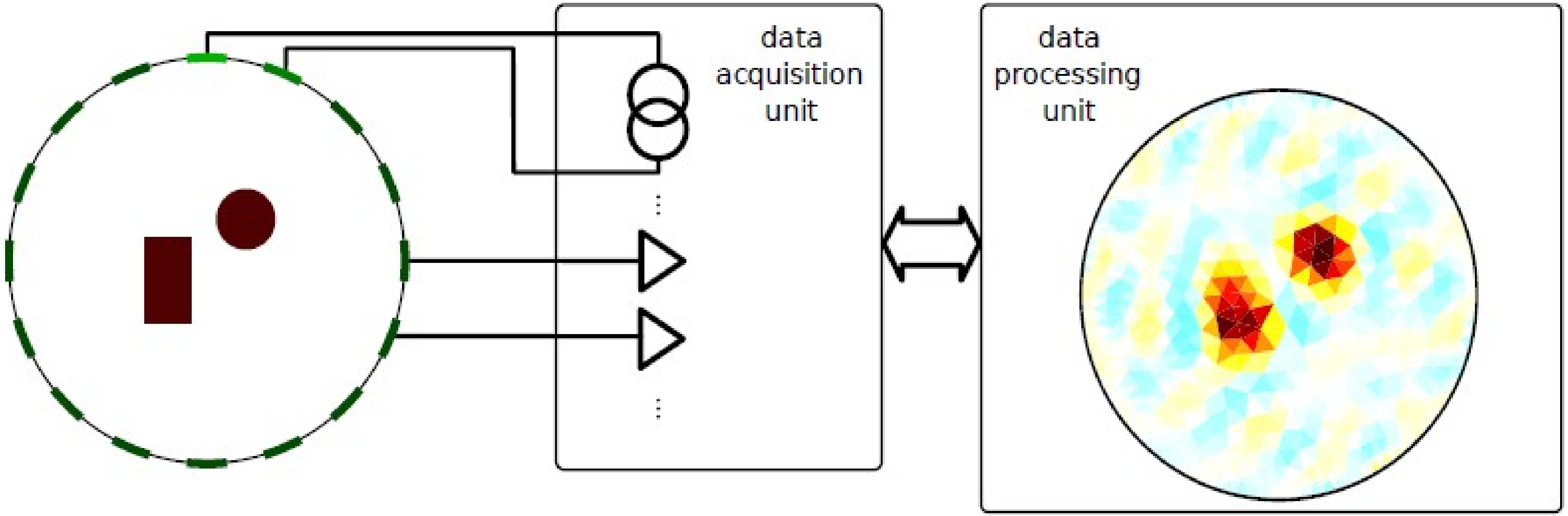
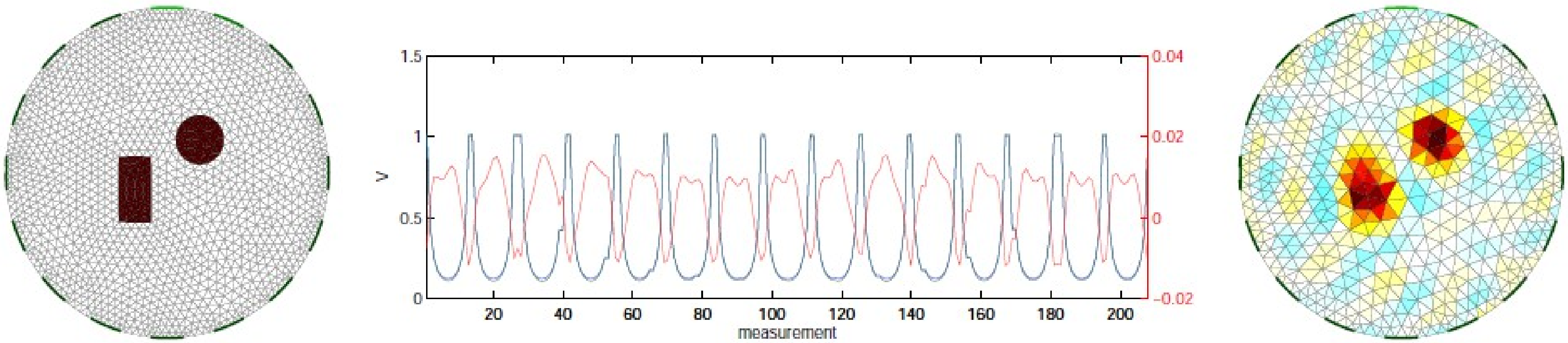


The Tools



(a) forward (b) voltage measurements (c) inverse

- Finite Element Method
- Inverse Problem

(a) forward (b) inverse

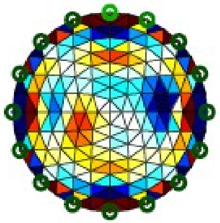
Shape Deformations

- Using Difference EIT, most unknowns do not affect image quality as long as they are not changing:
  - e.g. contact impedance,
  - electrode location, or
  - electrode area[1]
- ... but what happens when the body *is* deforming?

[1] Barber & Brown, *Errors in reconstruction of resistivity images using a linear reconstruction technique*, 1988, Clin. Phys. Physiol. Meas

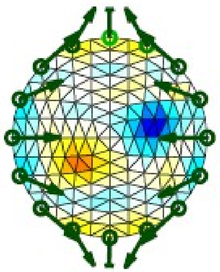
Shape Deformations

- Many shape deformations result in artifacts[2]



(b)

- Some deformations can be reconstructed if conductivity is isotropic[3]



(c)

- Conformal changes are interesting:
  - Isotropic conductivities remain isotropic under conformal deformations[4]

[2] A Adler et al, *Impedance imaging of lung ventilation: do we need to account for chest expansion?*, 1996, IEEE BME

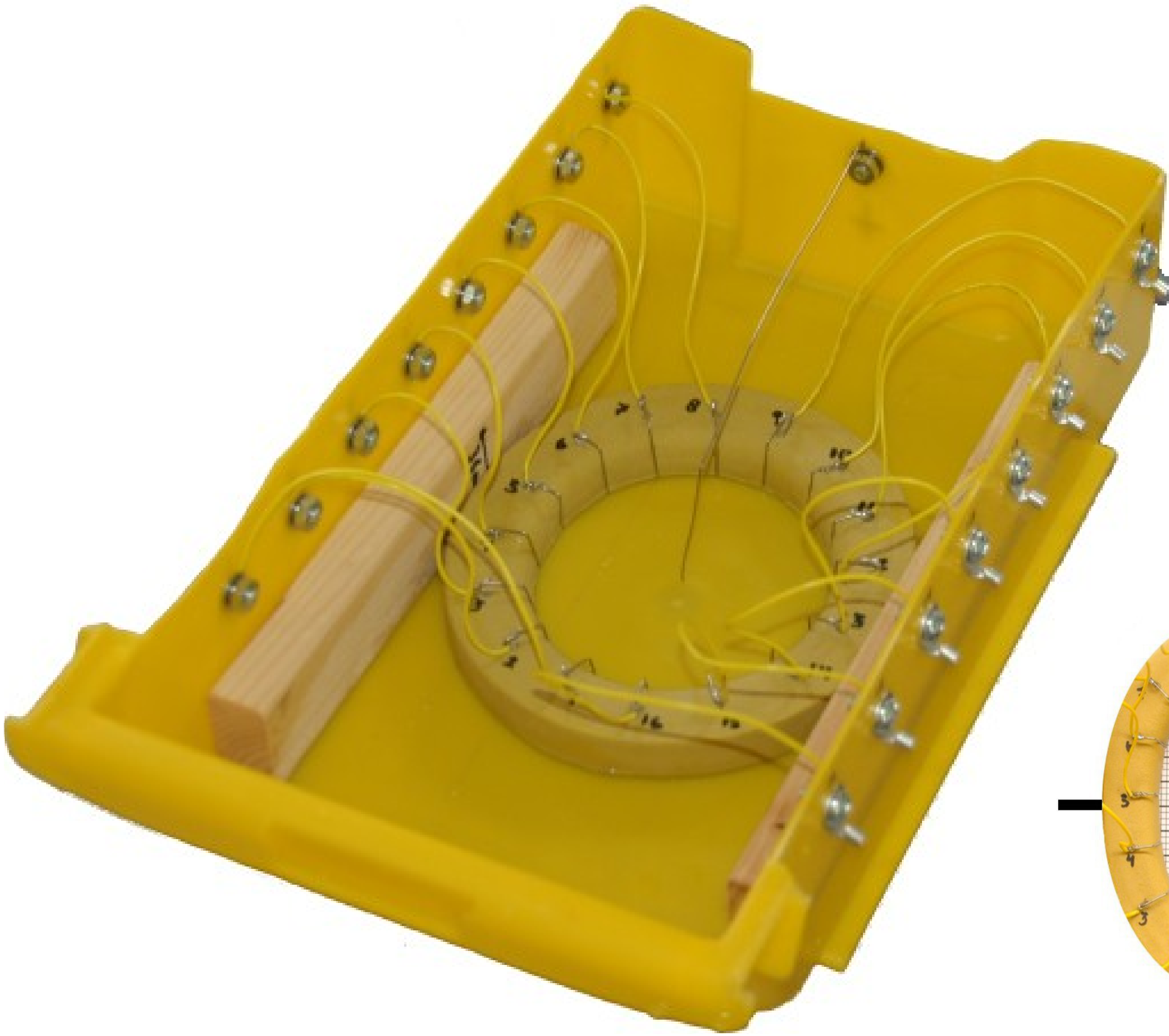
[3] M. Soleimani, et al,, *Imaging of conductivity changes and electrode movement in EIT*, Physiol. Meas., May 2006.

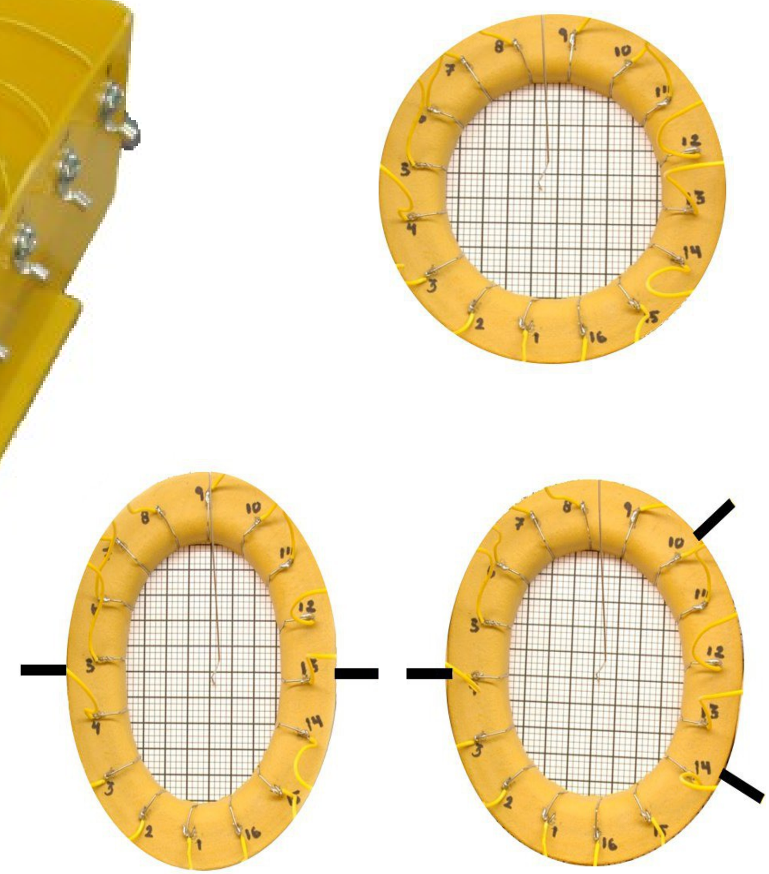
[4] WRB Lionheart, *Boundary Shape and Electrical Impedance Tomography*, 1998, IOP Journal Inv. Problems

Contributions

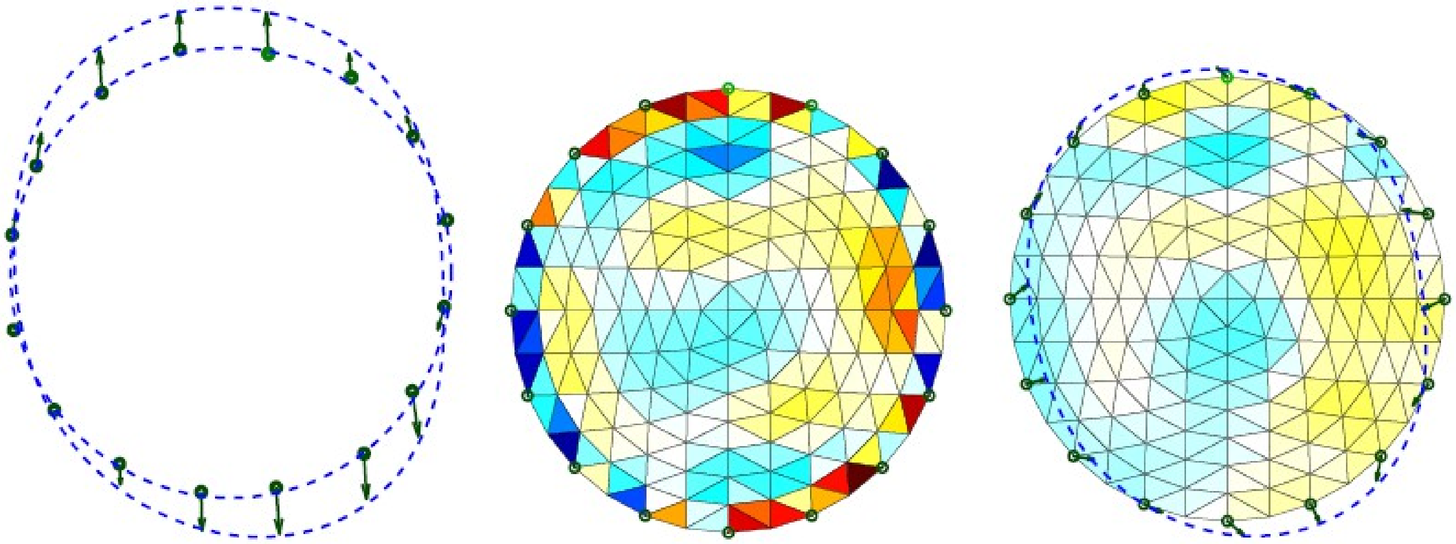
i. Phantom
ii. Simulated Deformations
iii. FEM Deformations
iv. Conformal Motions
v. Electrode Models

i. Phantom

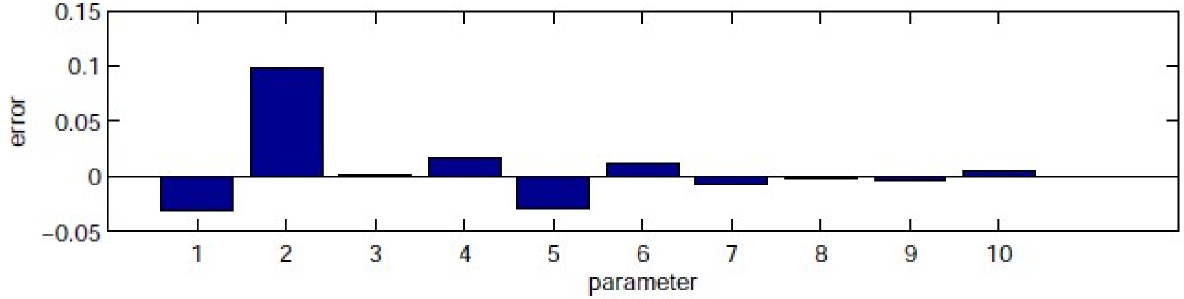




i. Phantom



(a) true displacements (b) naive reconstruction (c) movement reconstruction



(d) parameter error

$$\theta' = \theta + \theta_k$$

$$r' = r \sum_{n=0}^{N} a_n \cos(n\theta') + b_n \sin(n\theta')$$

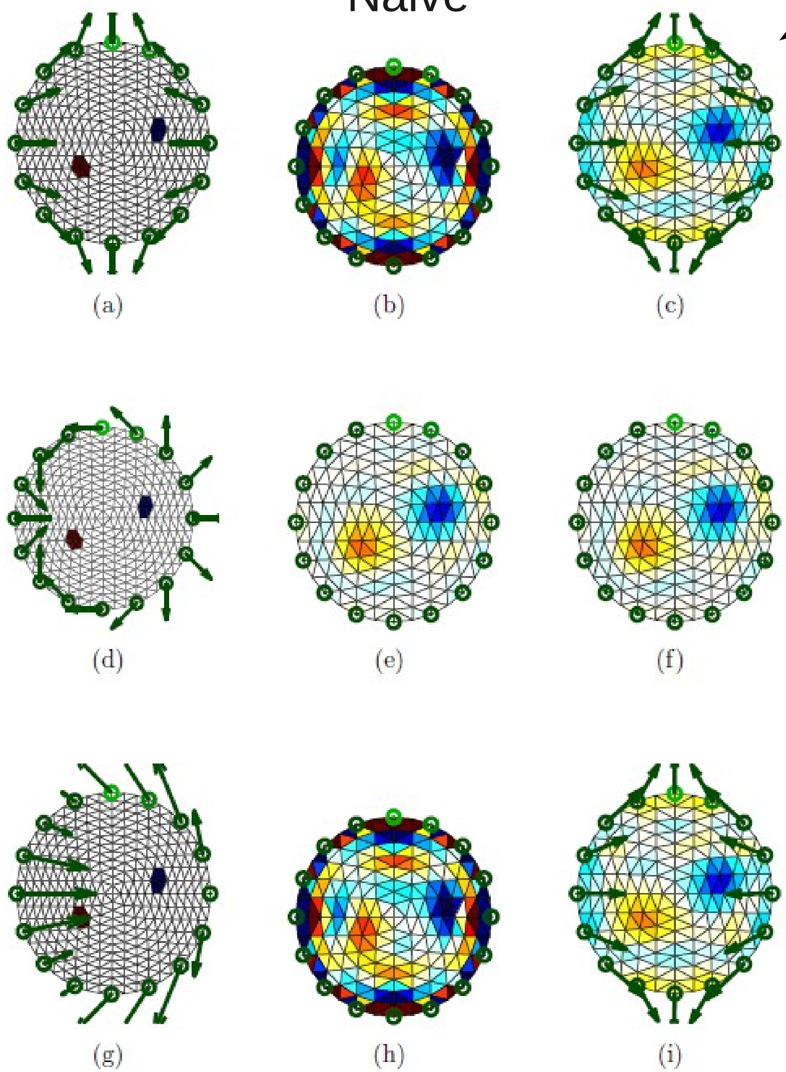
1: θ_k, 2: a_0, 3,4: a_1,b_1, 5,6: a_2,b_2, 7,8: a_3,b_3, 9,10: a_4,b_4

ii. Simulated Deformations

Forward Model

Naive

Reconstruction
(including Electrode Movement)



Non-Conformal

$z \to 0.99x + i1.01y$

Conformal

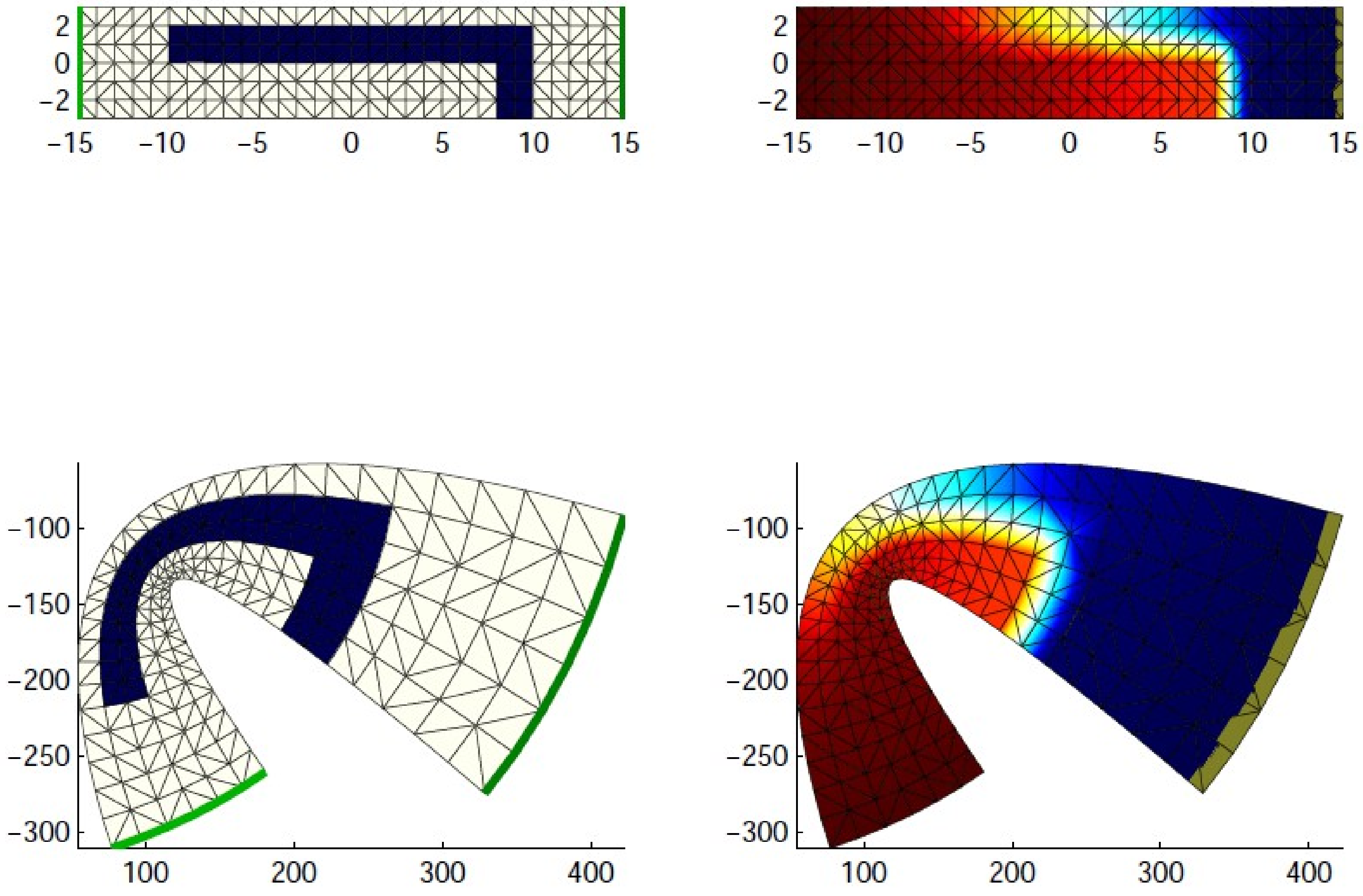
$z \to z + 0.01z^2$

Combined

iii. FEM Deformations

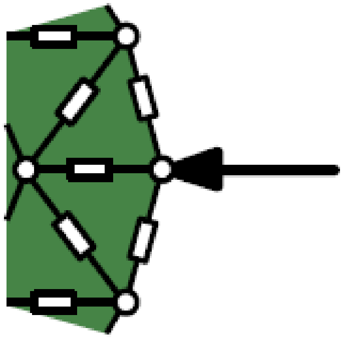
- If the EIT measurements don't change after a shape deformation, explains how conductivity must have changed
- If the conductivity is isotropic then, *iff* the shape change is conformal will the reconstructed conductivity be isotropic
- In the isotropic case, showed solution converges for a conformal shape change

iv. Conformal Motions

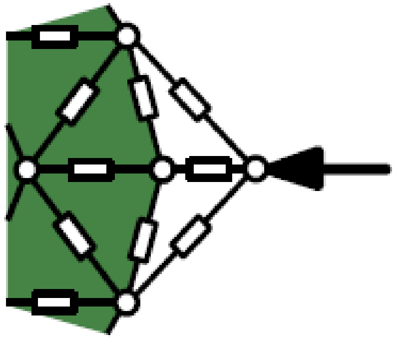


$$z \to \exp((z - 20 - \mathrm{i}80)/100) \cdot (z + \mathrm{i}20) \cdot (z - \mathrm{i}10),$$

v. Electrode Models



Point Electrode Model



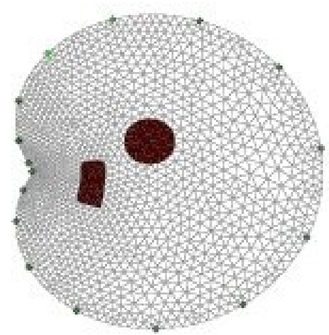
Complete Electrode Model

- With respect to conformal deformations:
  - PEM does not introduce artifacts.

    What about CEM?

Summary

- Two-dimensional reconstructions can have undetected conformal deformations
  - It is not possible to reconstruct boundary deformation solely from voltages
- Measurement noise can be used to approximate electrode area & contact impedance errors



$z = x + iy;\ z \to z + 0.4z^2$

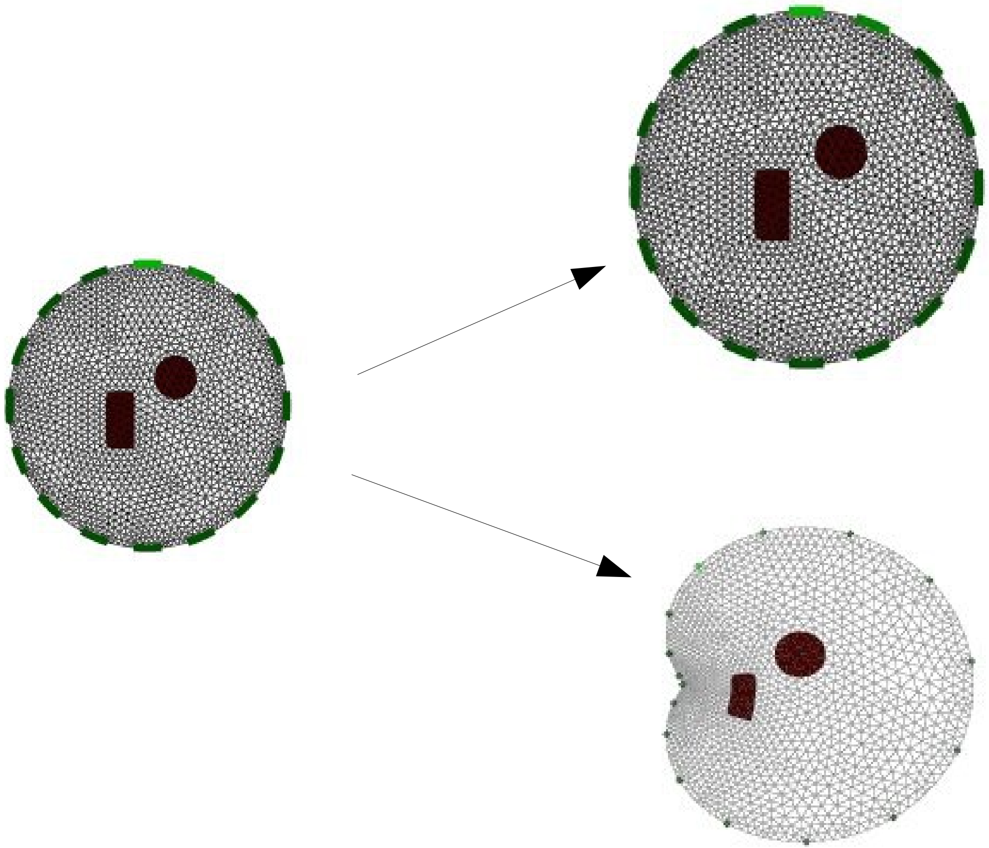
Future Work

- Deformation decomposition: Conformal/Non-Conformal
- Electrodes:
  - Simultaneous contact impedance reconstruction
  - Detect conformal changes when electrodes are of fixed size
- Extend this work to three-dimensions

Thank You

Questions?

v. Electrode Models



Dilation

Complex

$z = x + iy;\ z \to z + 0.4z^2$

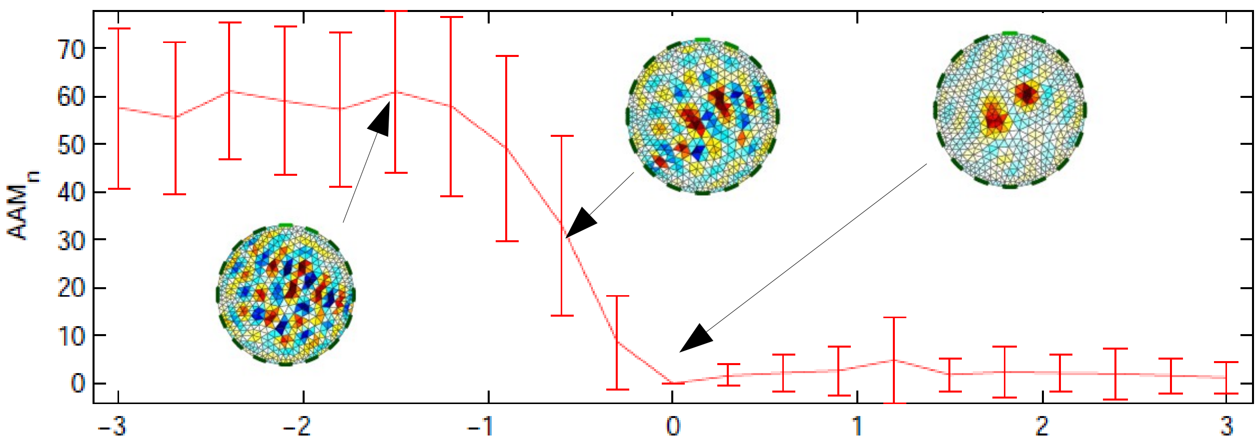
v. Electrode Models

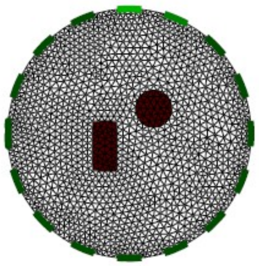
Table 1 : Electrode Model Behaviour under Deformation

	Deformation			
Model	Domain	Electrode	AAM_n	Comment
PEM	dilation	matching	0	
	complex		0.0807	
	dilation	fixed	0	
CEM	dilation	matching	0.0010	
	complex		2.013	artifacts (deformed)
	dilation	fixed	5.5	artifacts (ringing)

$$AAM_n = \sum \left[\frac{\mathbf{c}_1 - \mathbf{c}_0}{\mathbf{c}_0} \right]^2$$

v. Electrode Models





$$\mathrm{AAM}_n = \sum \left[\frac{\mathbf{c}_1 - \mathbf{c}_0}{\mathbf{c}_0} \right]^2$$

$$z_c = 10^{\mathcal{N}(\mu, \sigma^2)}$$

$$3 \leq \mu \leq 3$$

$$\sigma^2 = |\mu|$$