Electrical Impedance Tomography for Deformable Media

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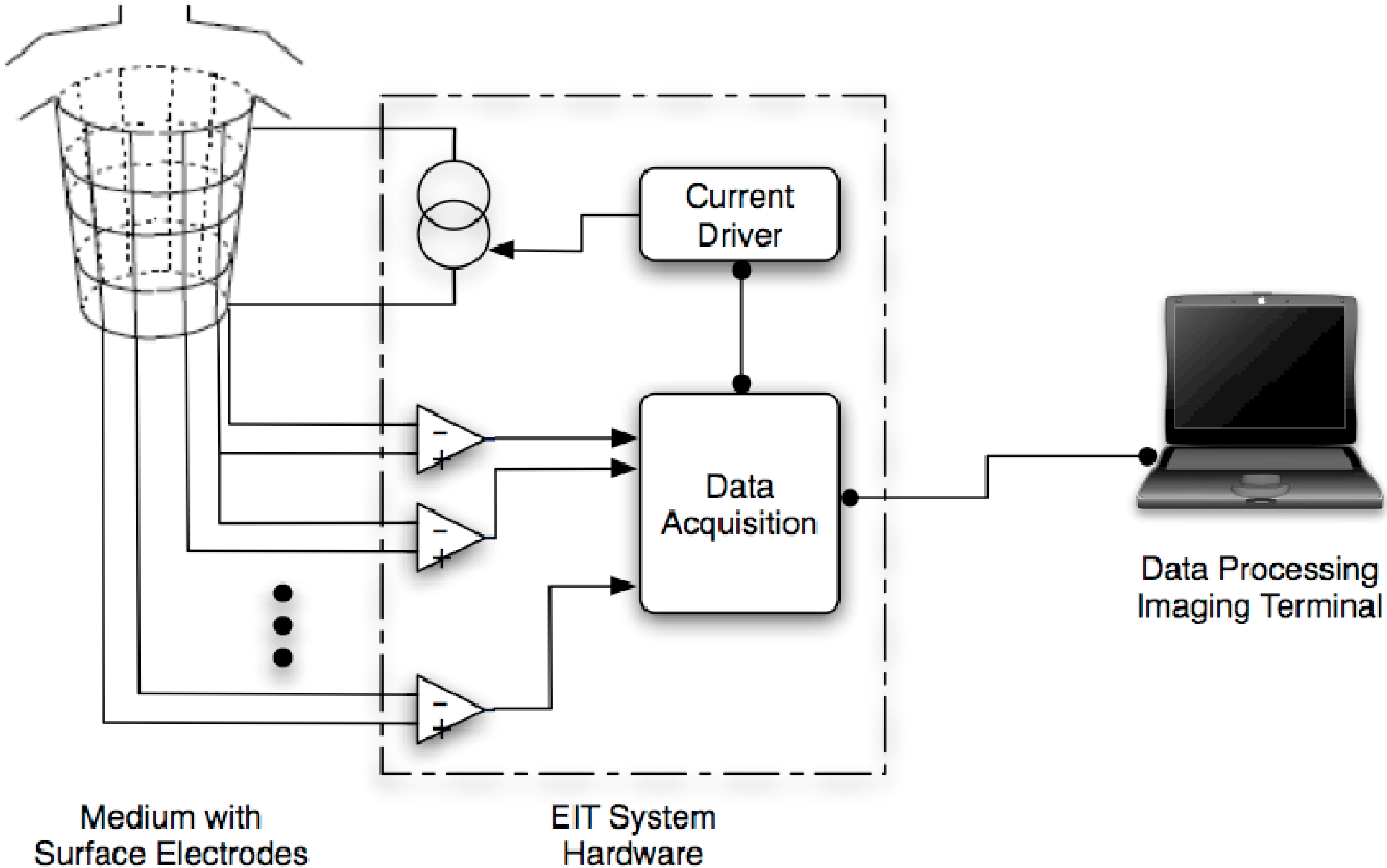
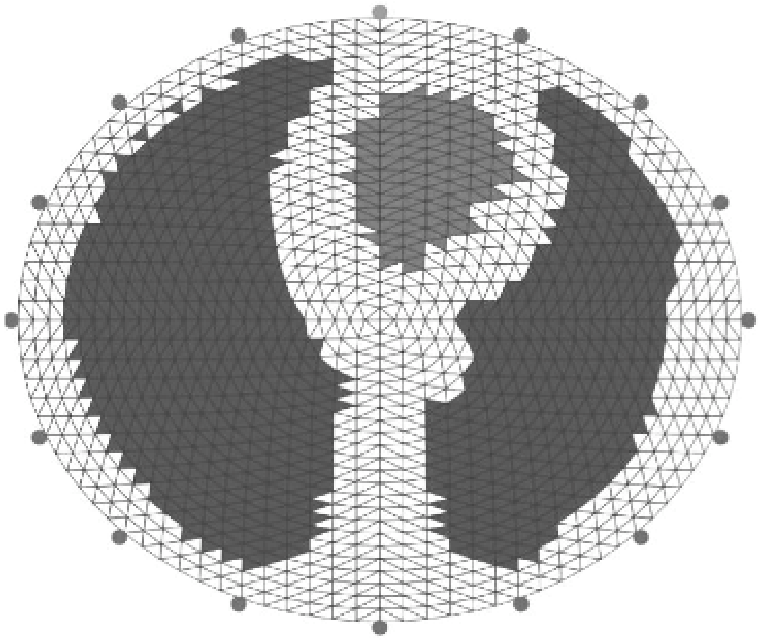
Outline

- Electrical impedance tomography
- Image variability from boundary deformation
- Electrode displacement regularization
- Imaging of deformable media
- Conclusion

Electrical impedance tomography

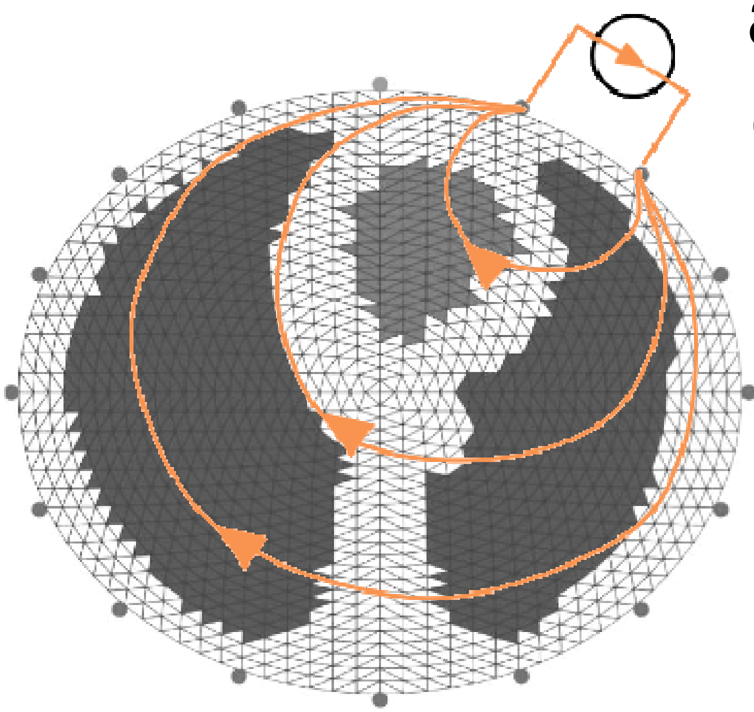


Electrical impedance tomography

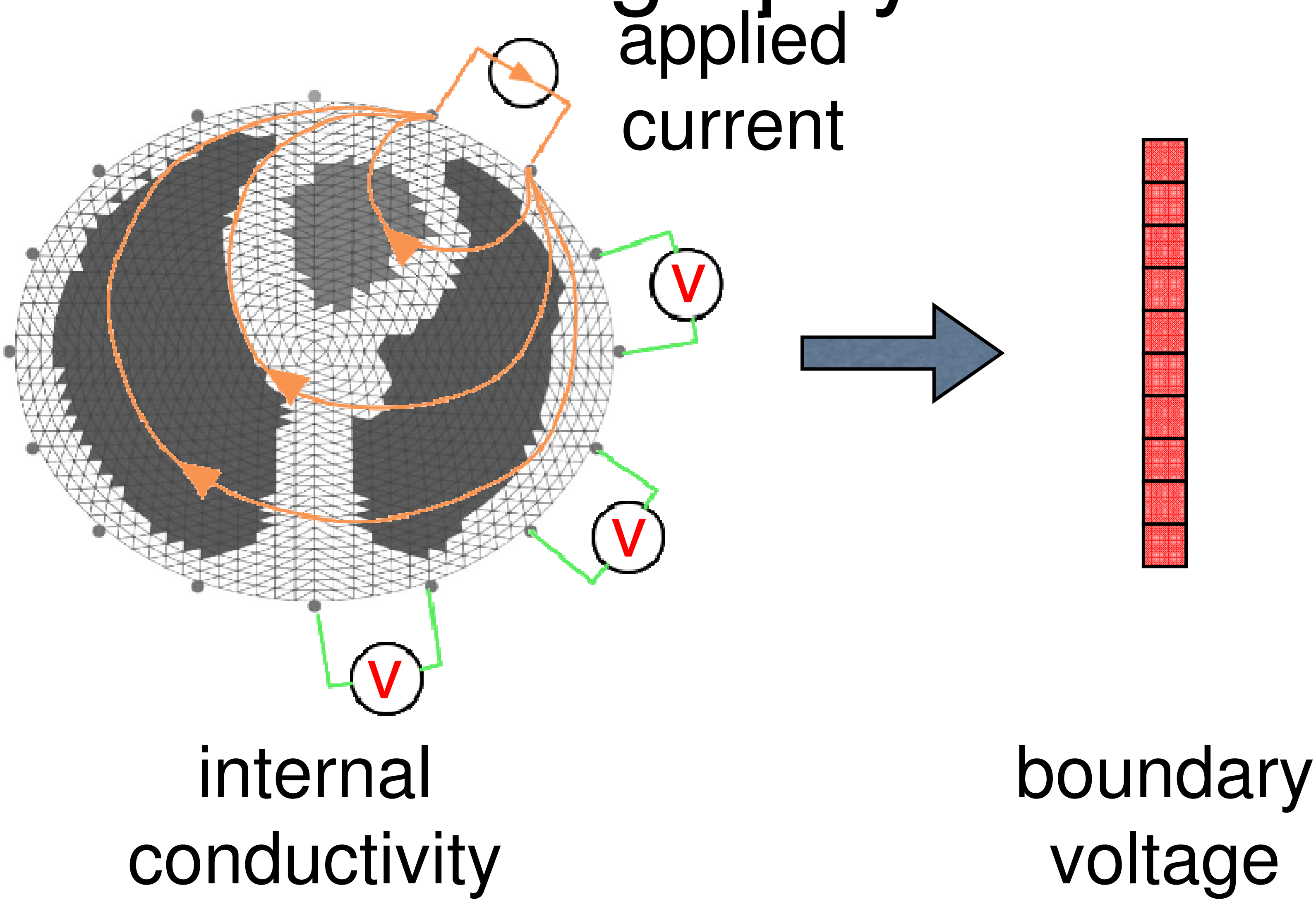


internal
conductivity

Electrical impedance tomography



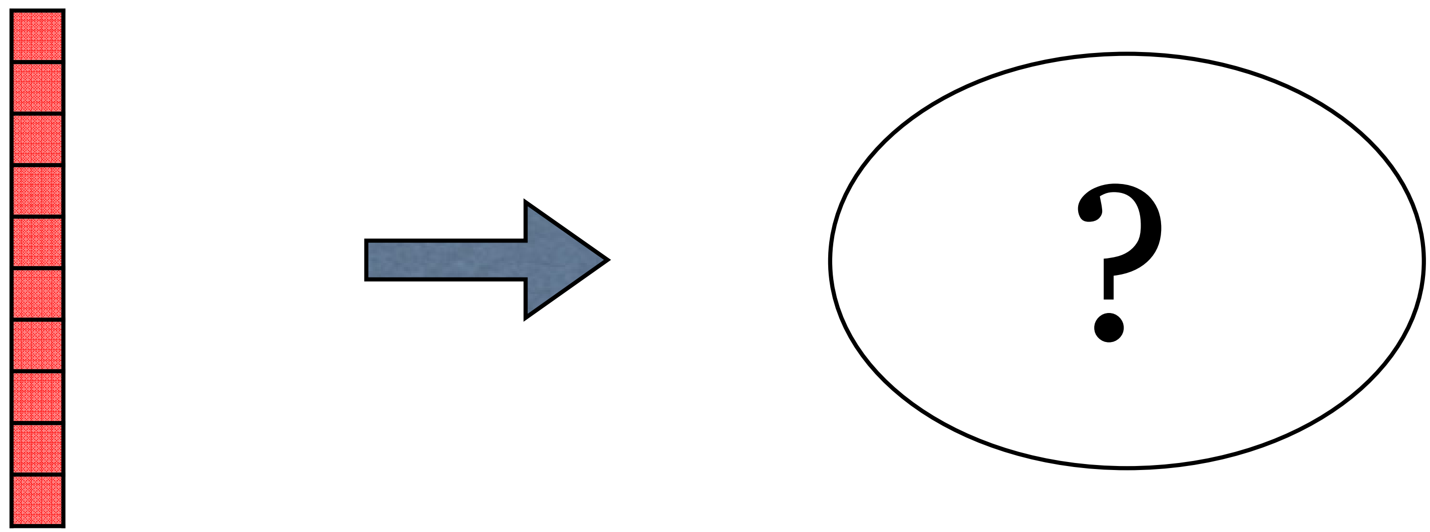
Electrical impedance tomography



Electrical impedance tomography

inverse problem

- non-linear
- unstable
- not unique



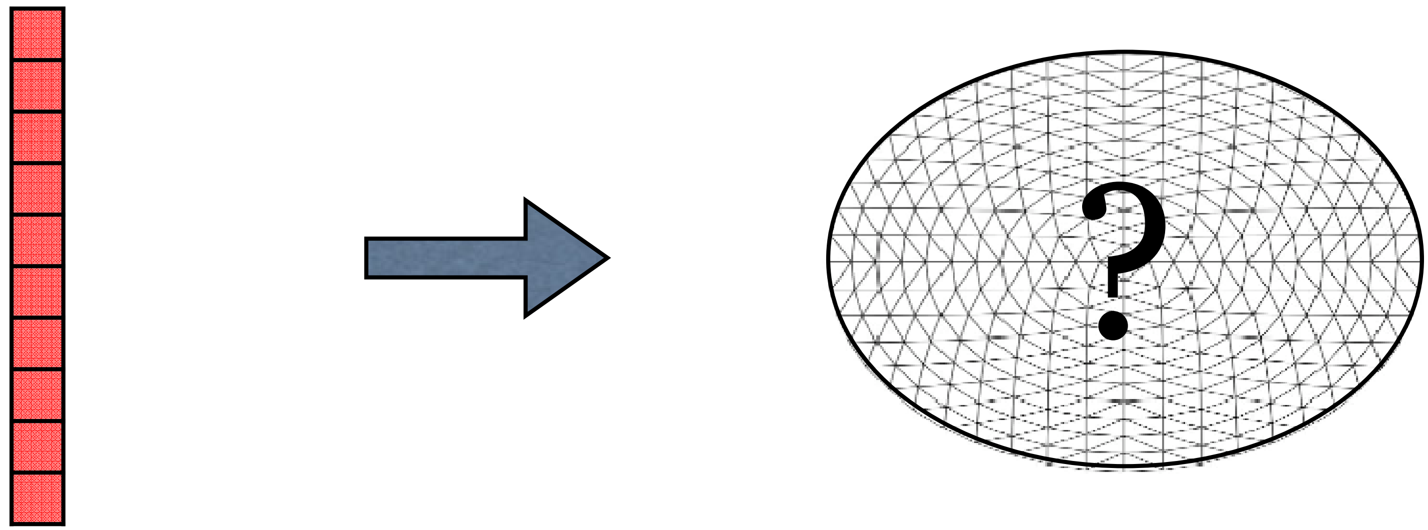
boundary voltage

internal conductivity

Electrical impedance tomography

inverse solution

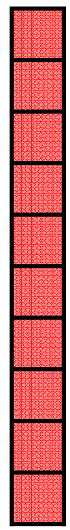
1. discretize
2.
3.



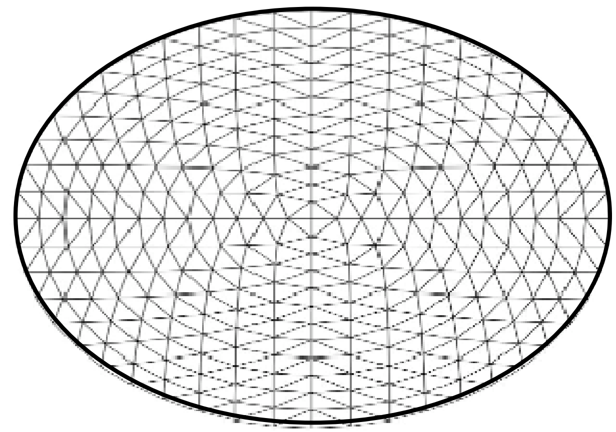
Electrical impedance tomography

inverse solution

1. discretize
2. linearize
3.



$\times \; f(J) \; =$



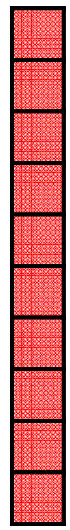
boundary voltage

internal conductivity

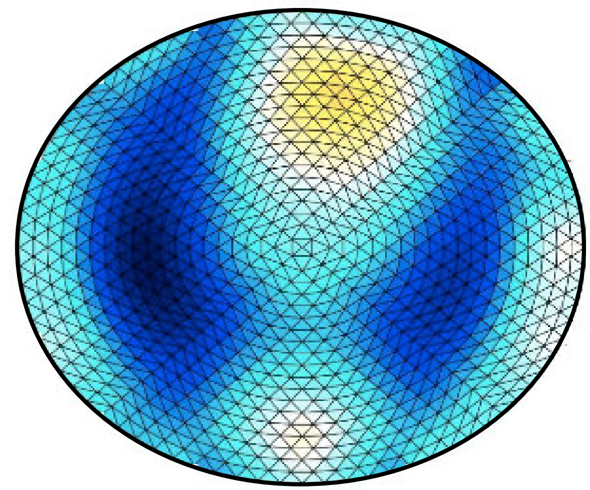
Electrical impedance tomography

inverse solution

1. discretize
2. linearize
3. regularize



$$\times\, f(J,R) =$$



boundary voltage

internal conductivity

Boundary deformation

Thesis motivation

- the body is soft and is always in motion
- body motion causes EIT errors because:
  the boundary deforms
  the electrodes move
- monitoring may require movement
  e.g., breathing to monitor lung ventilation

Boundary deformation

adapted from http://www.brendoman.com/media/ (Oct. 12, 2006)

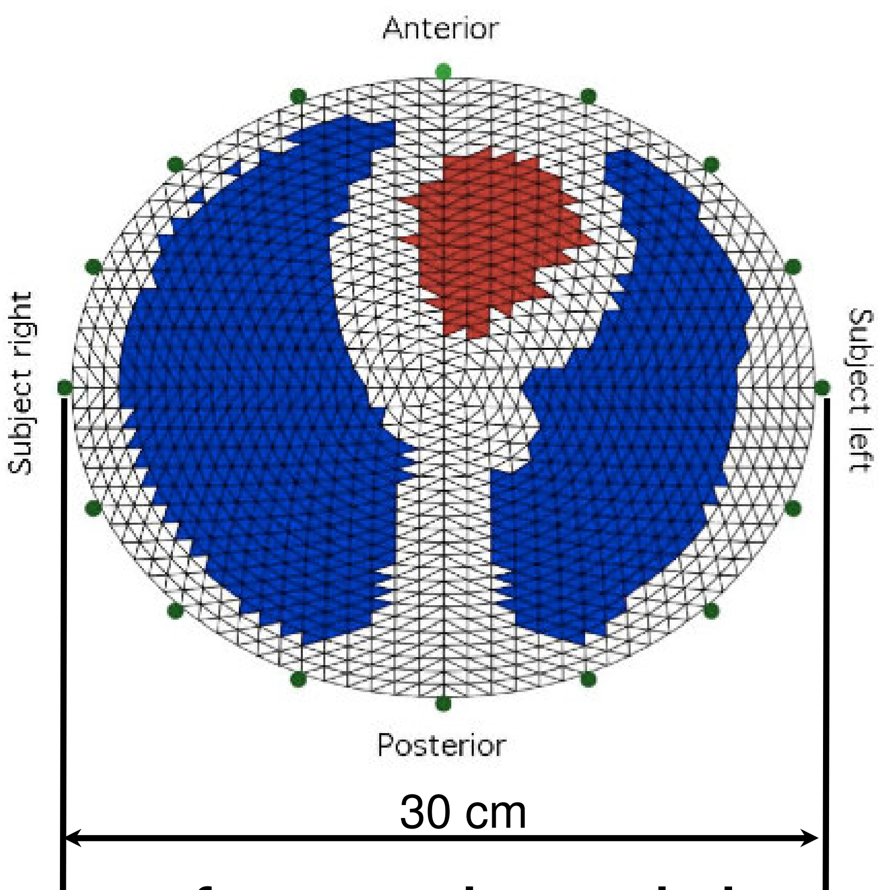
Boundary deformation

A study of deformation

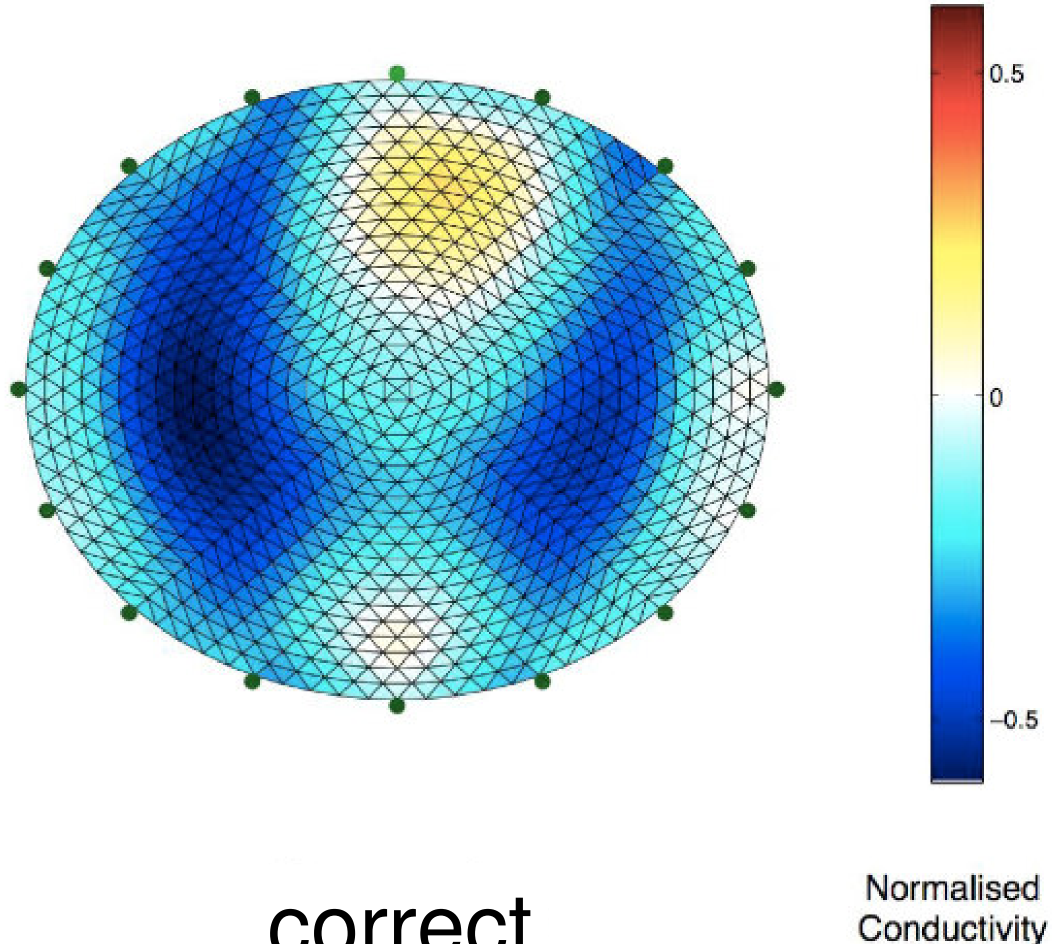
- simulated EIT measurements to determine how much error is introduced from
  1. boundary deformation
  2. electrode displacement along boundary

- analysed results by
  1. inspection
  2. error measurement

Boundary deformation

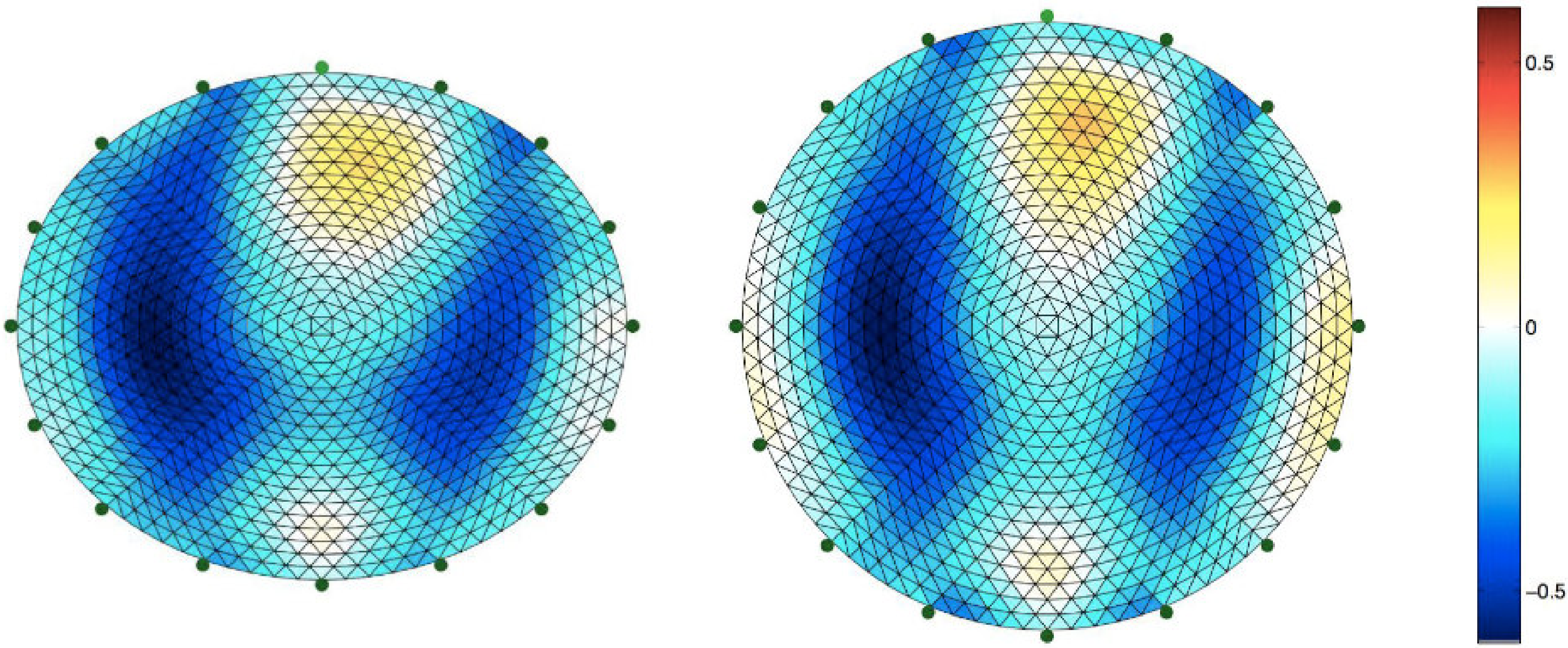


forward model



correct

Boundary deformation

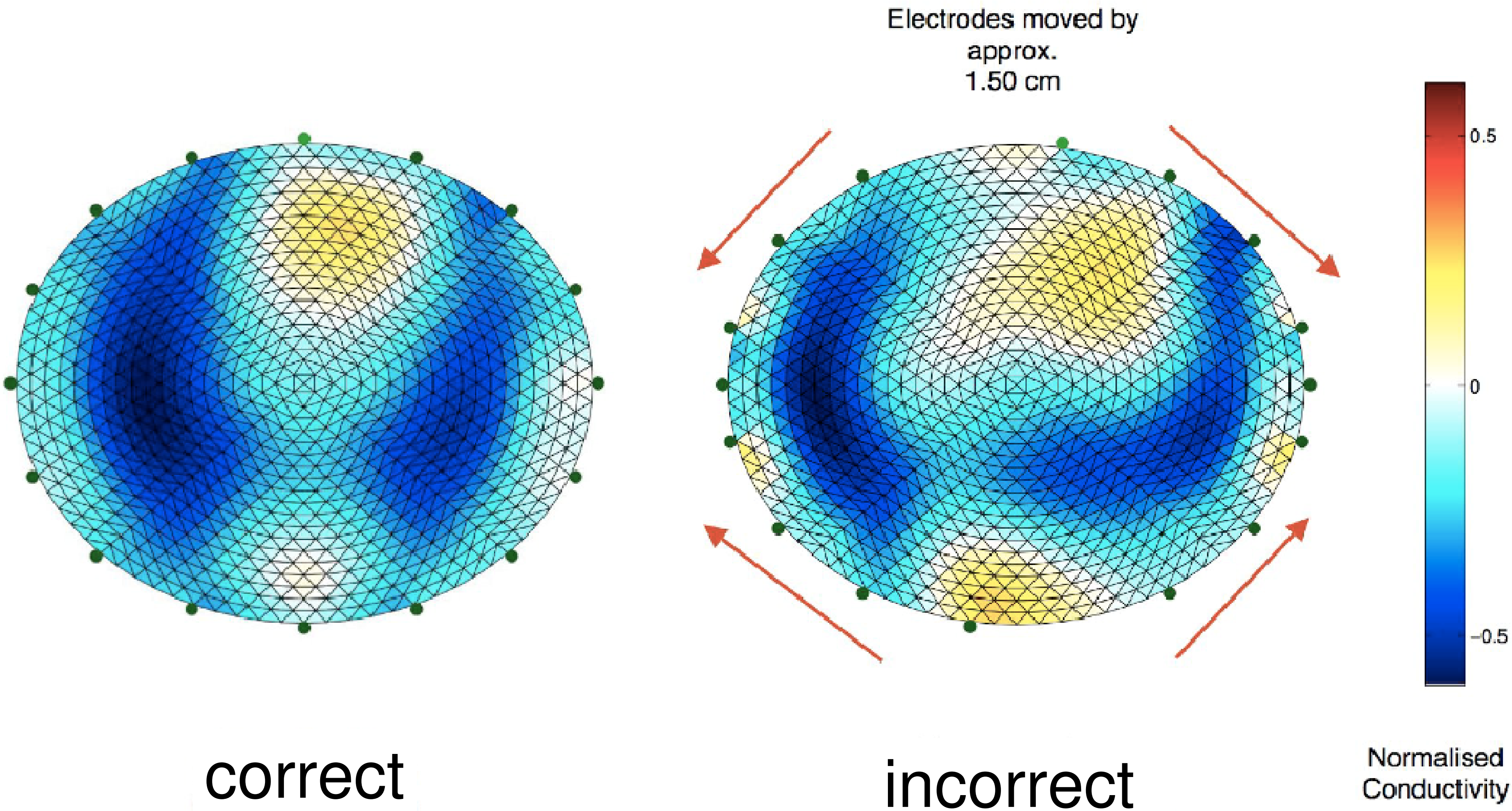


correct

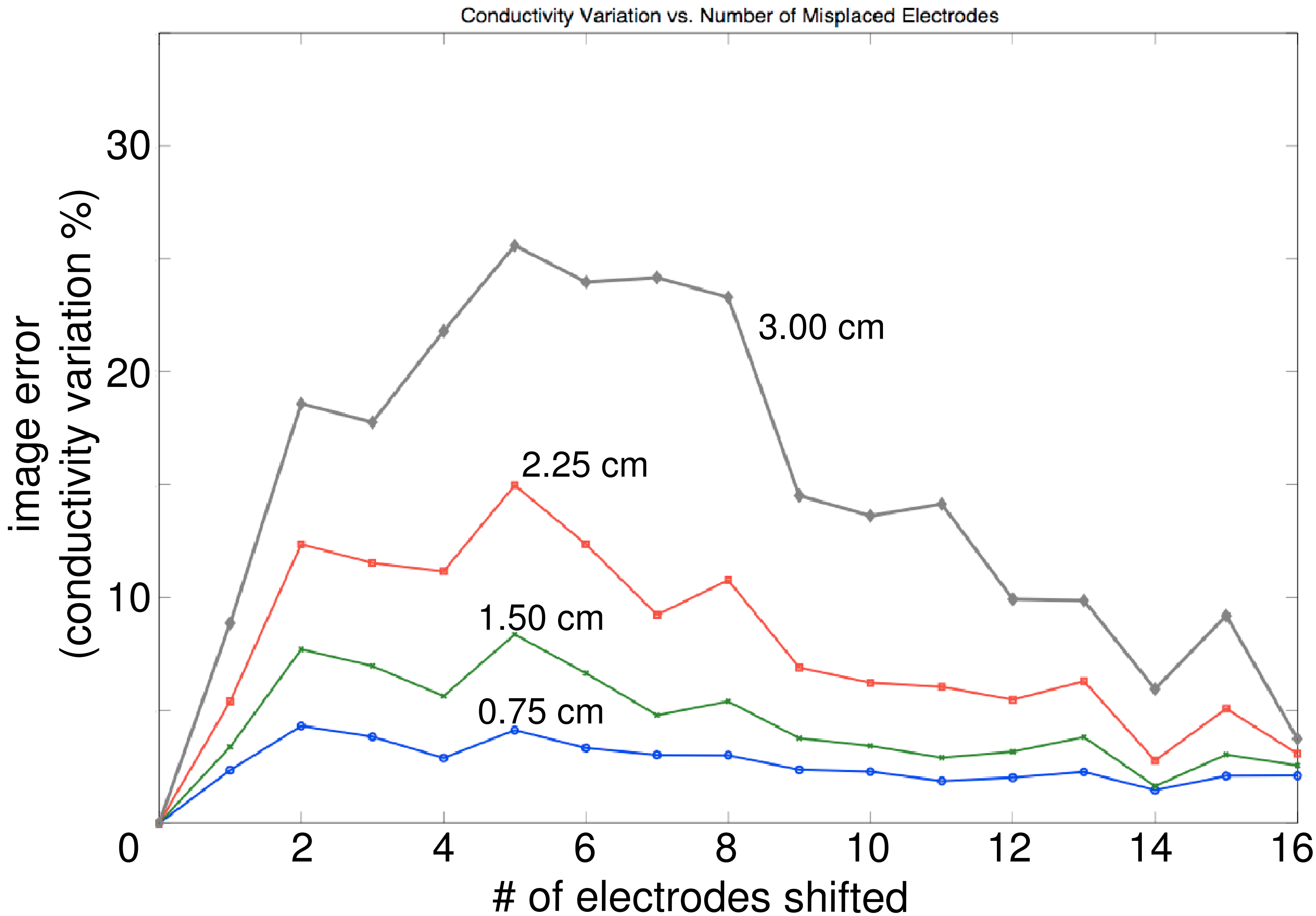
incorrect

Normalised Conductivity

Boundary deformation



Boundary deformation

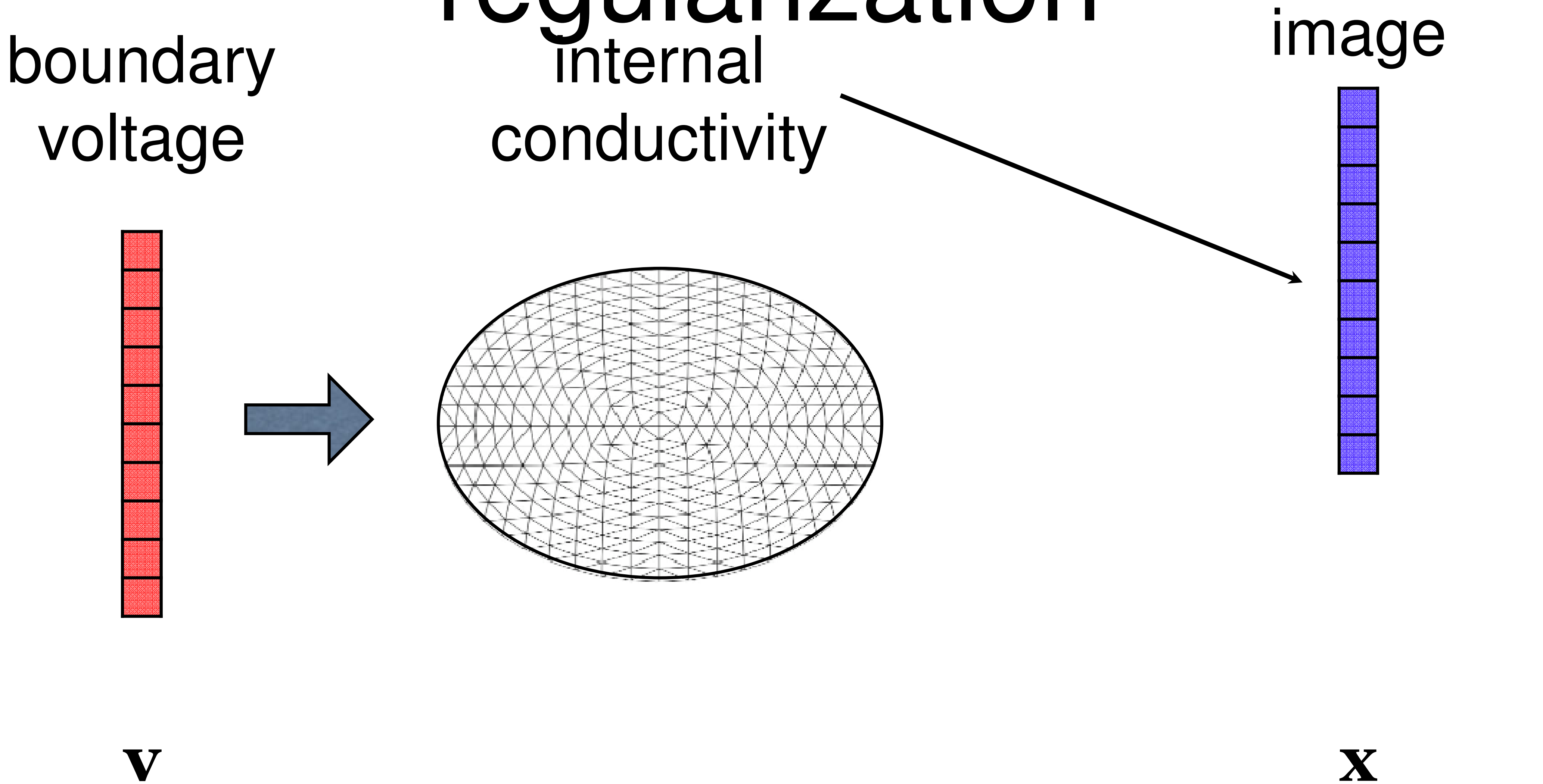


Displacement regularization

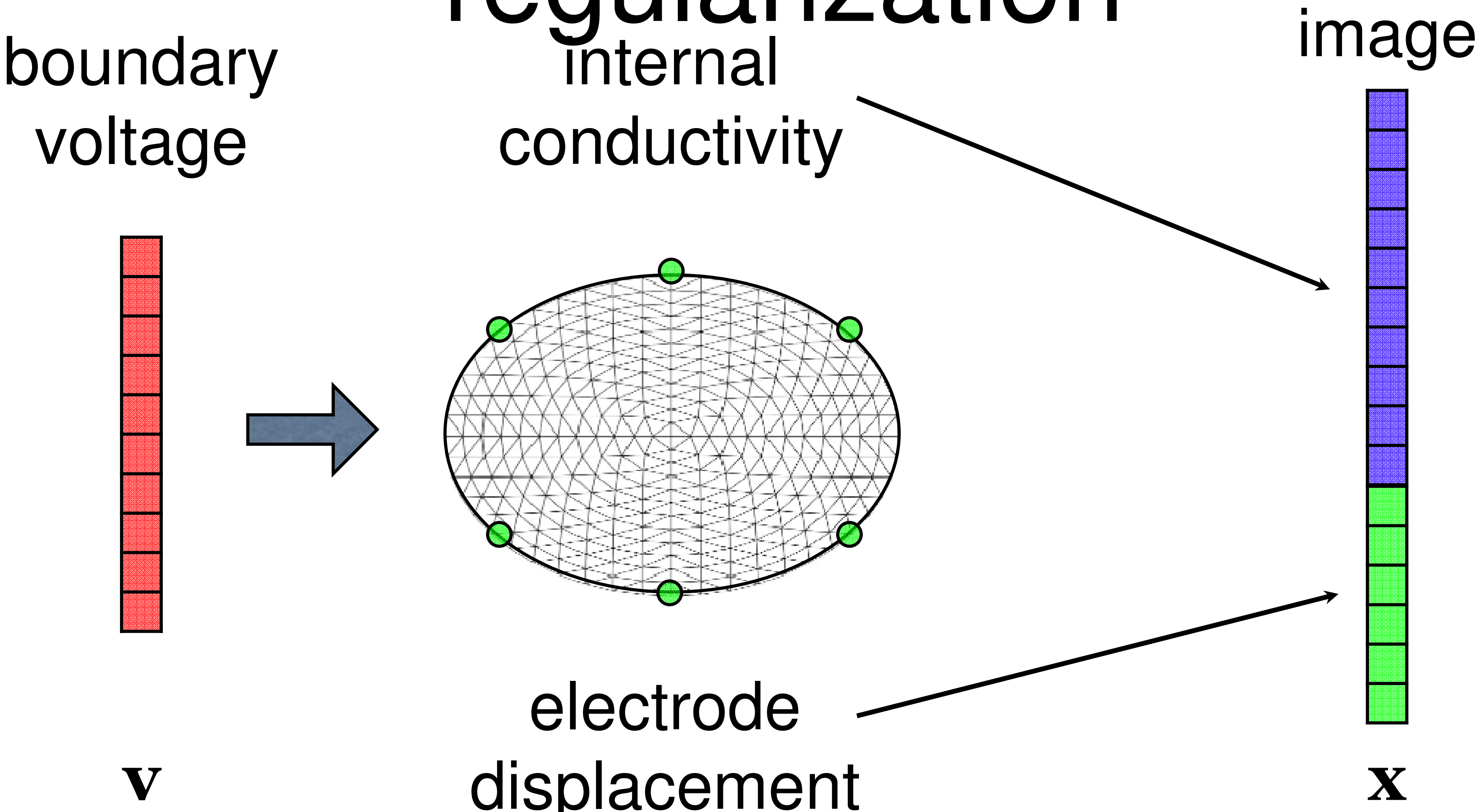
The proposed solution includes an electrode displacement parameter into the inverse problem

- define the system model
- define the augmented regularization matrix
- define the augmented Jacobian matrix

Displacement regularization



Displacement regularization



Displacement regularization

$$\mathbf{x} = f(J,R)\,\mathbf{v}$$

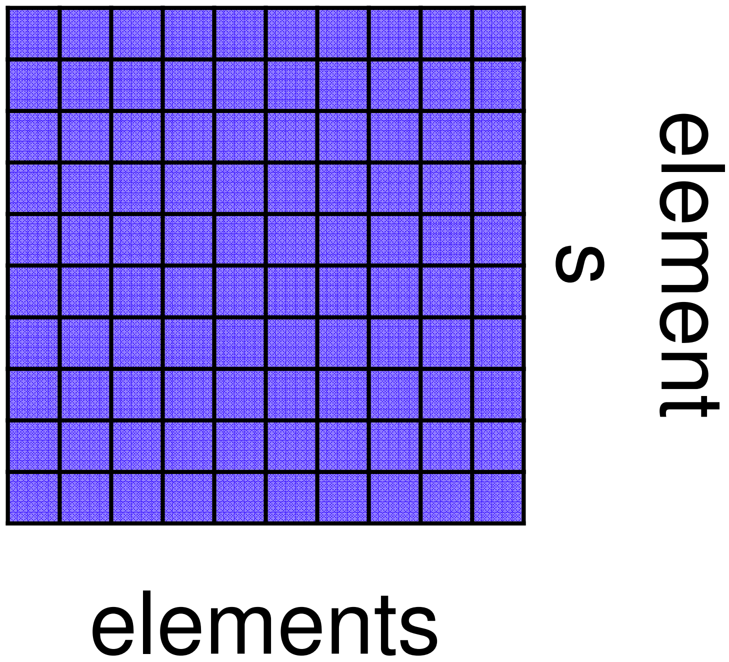
$$\mathbf{x} = (J^T J + \lambda^2 R)^{-1} J^T \mathbf{v}$$

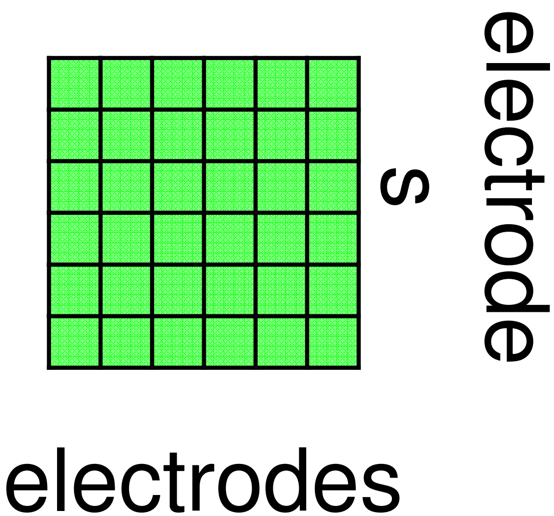
Displacement regularization

Building R -- *a priori* claims

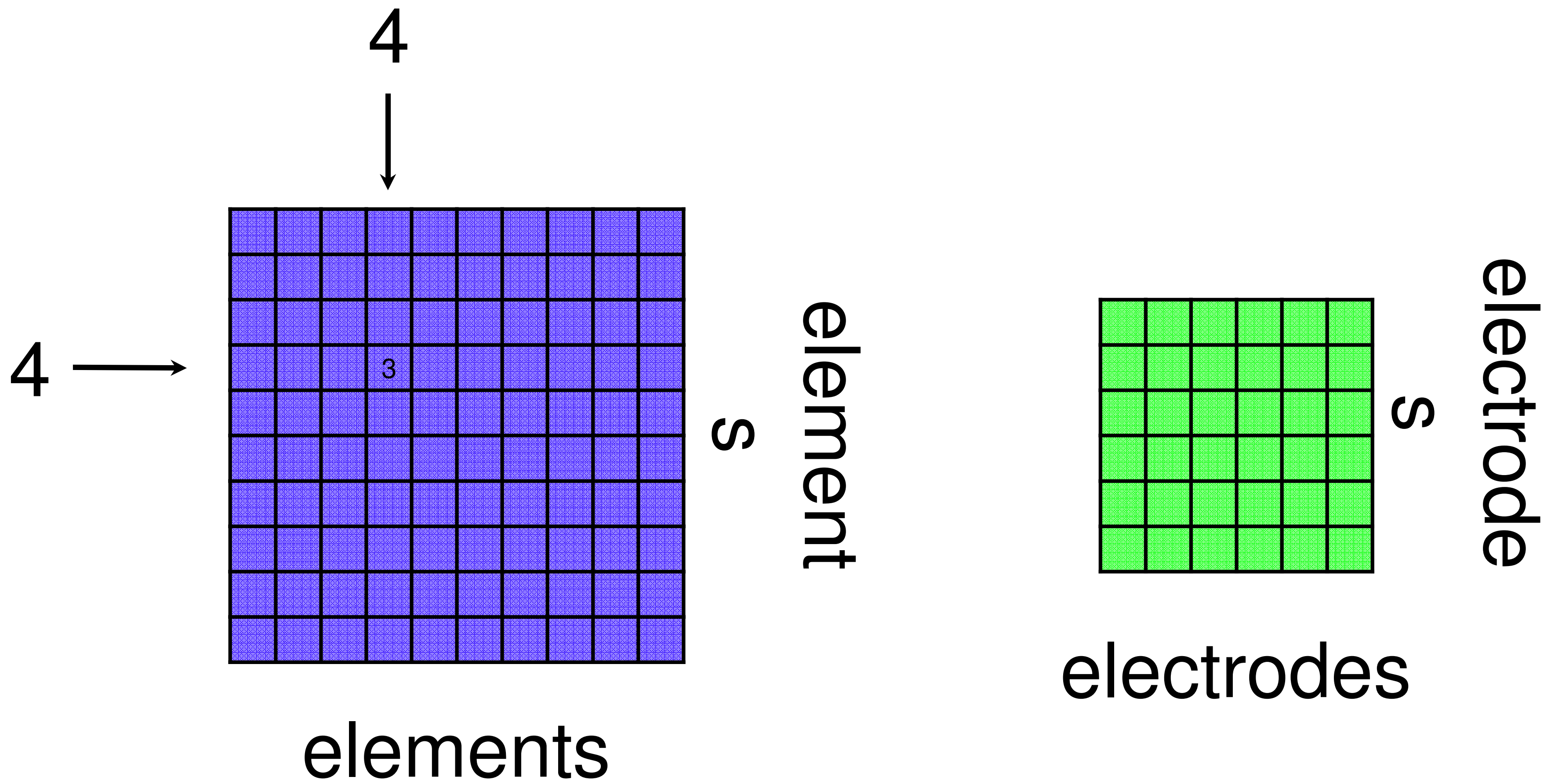
- conductivity distribution is smooth
- adjacent electrode displacements are correlated

Displacement regularization

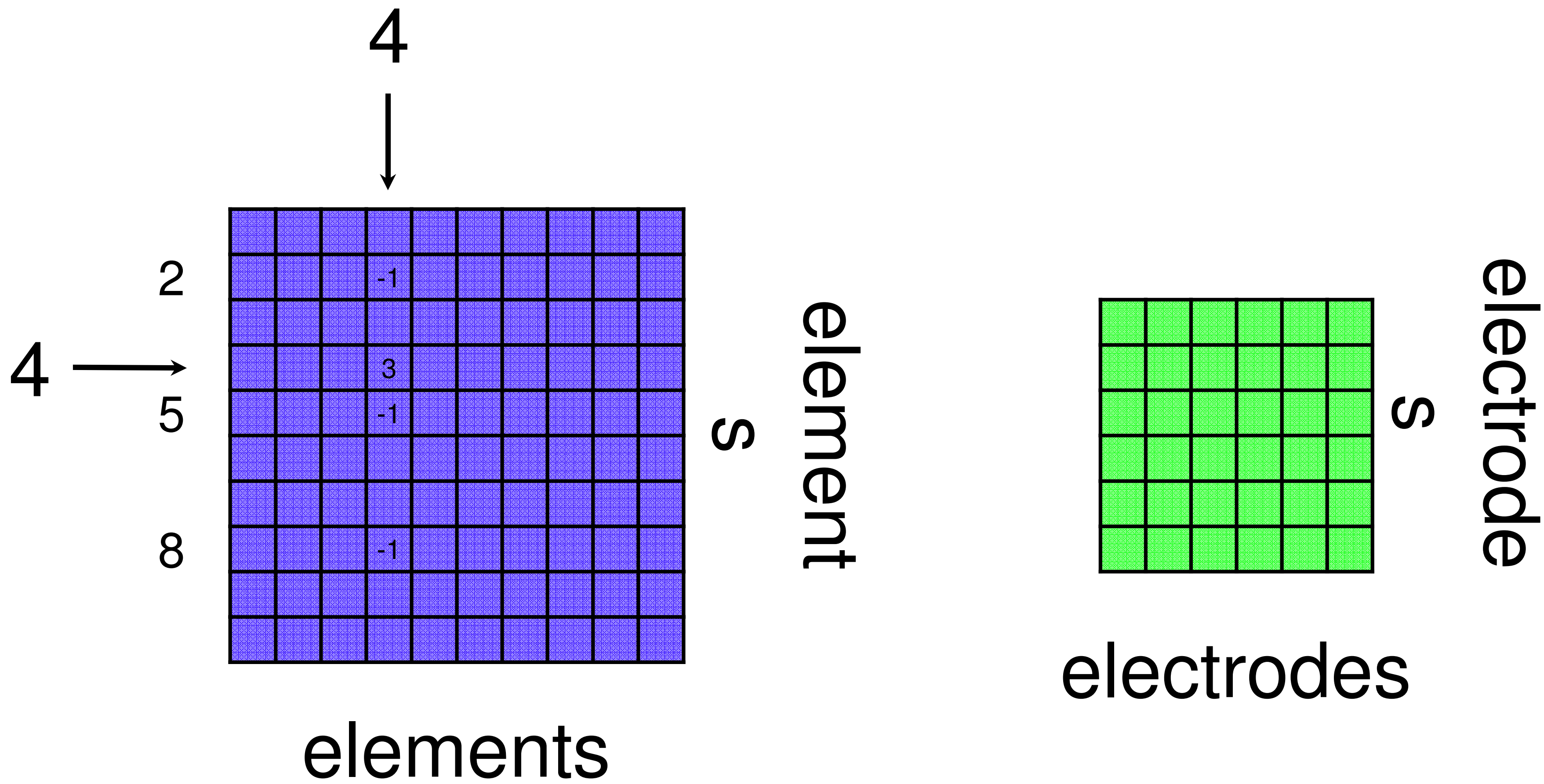




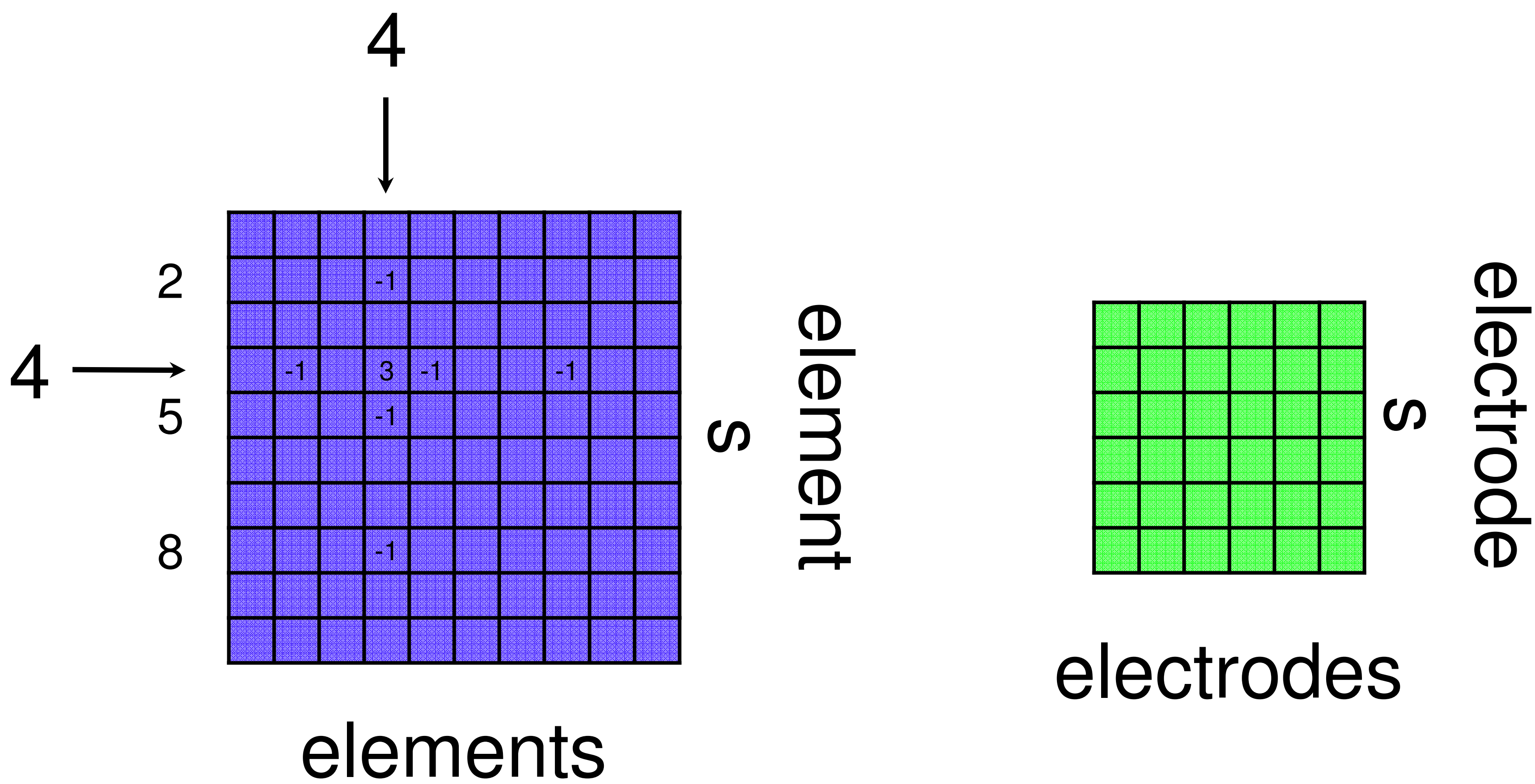
Displacement regularization



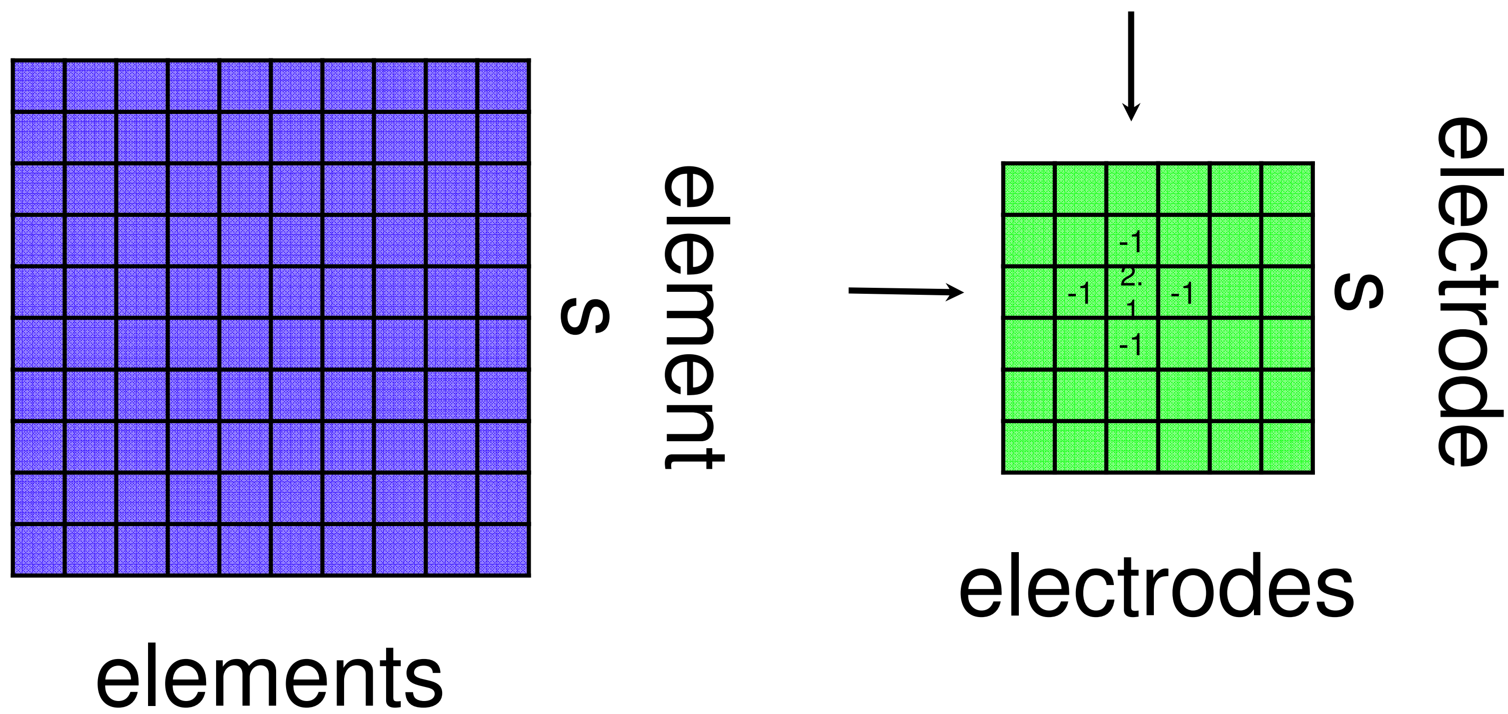
Displacement regularization



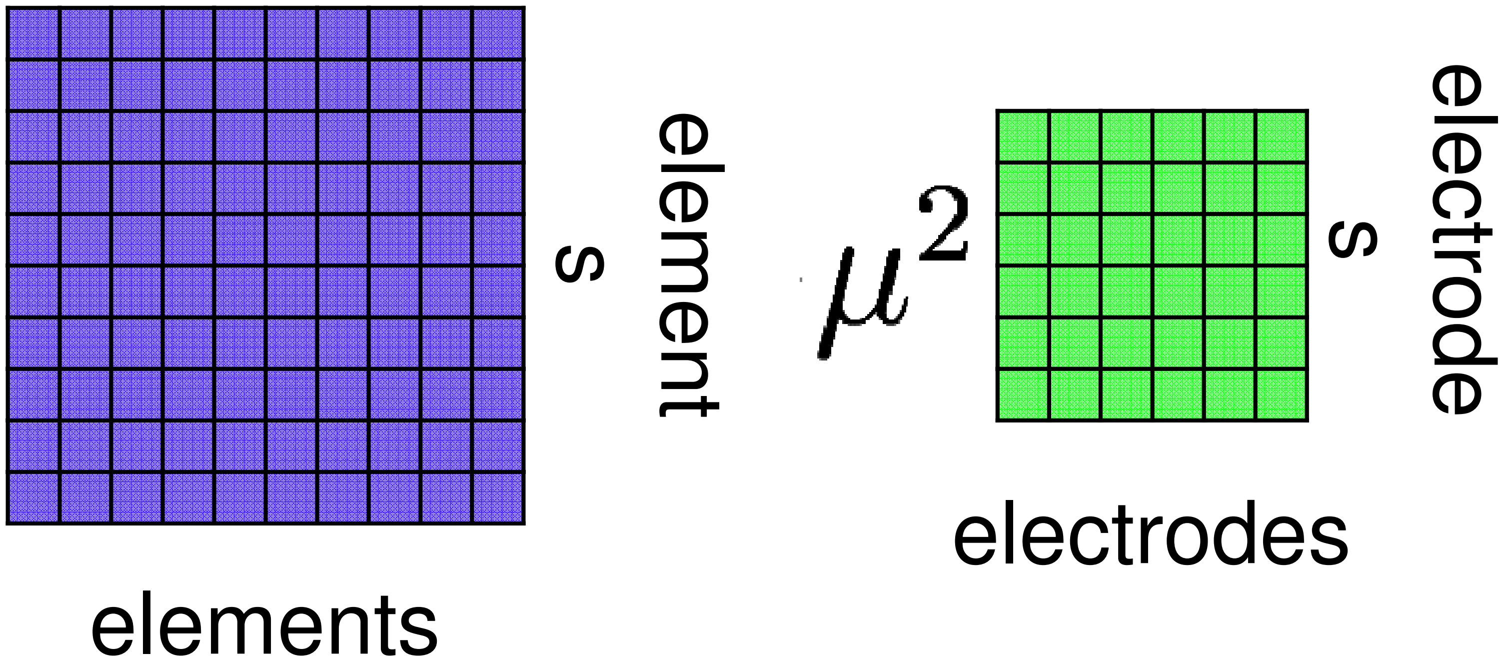
Displacement regularization



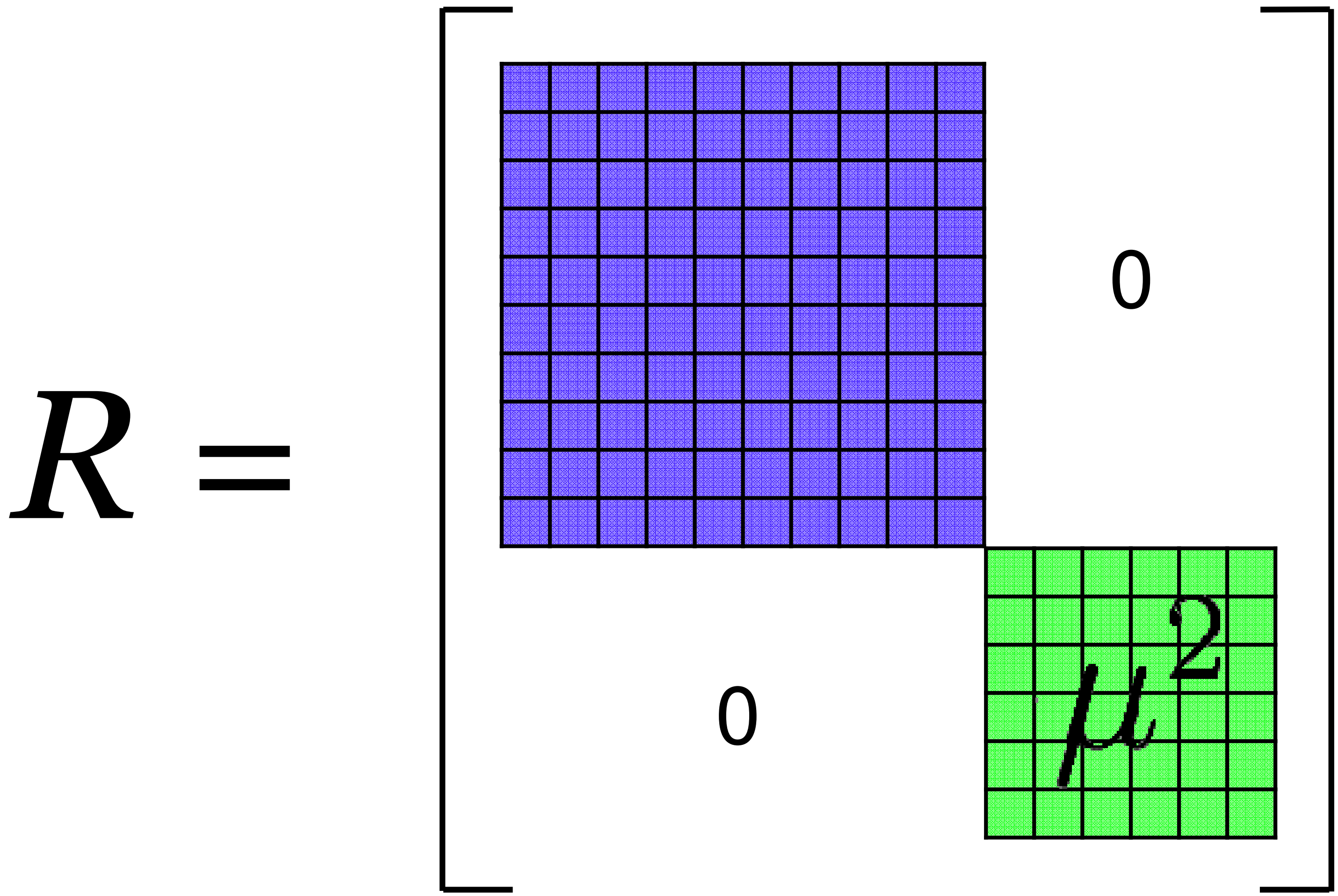
Displacement regularization



Displacement regularization



Displacement regularization

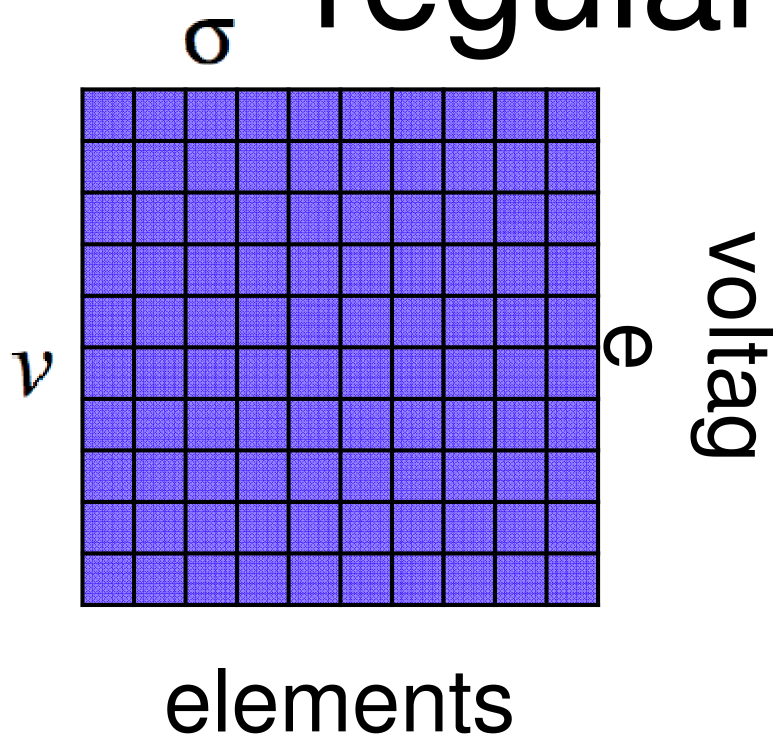


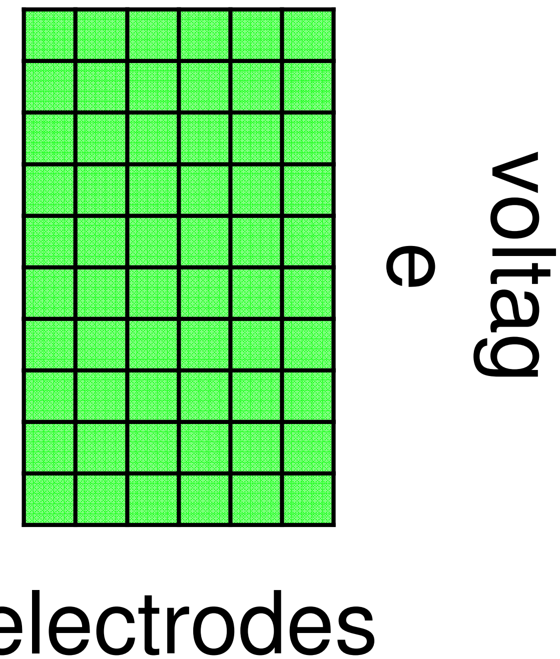
Displacement regularization

Building J -- sensitivity to input change

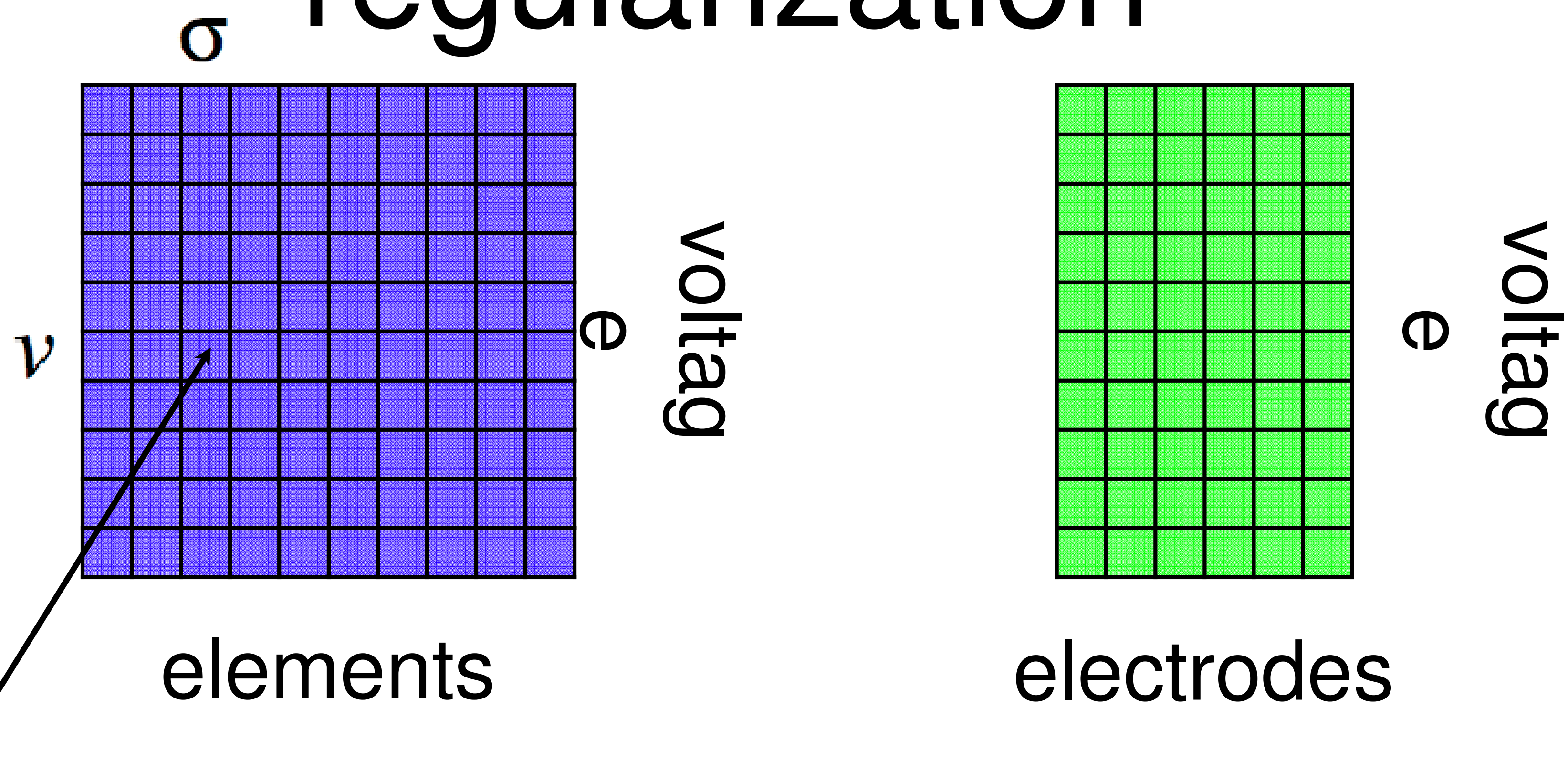
- conductivity change will affect boundary voltage
- displacements will affect boundary voltage

Displacement regularization



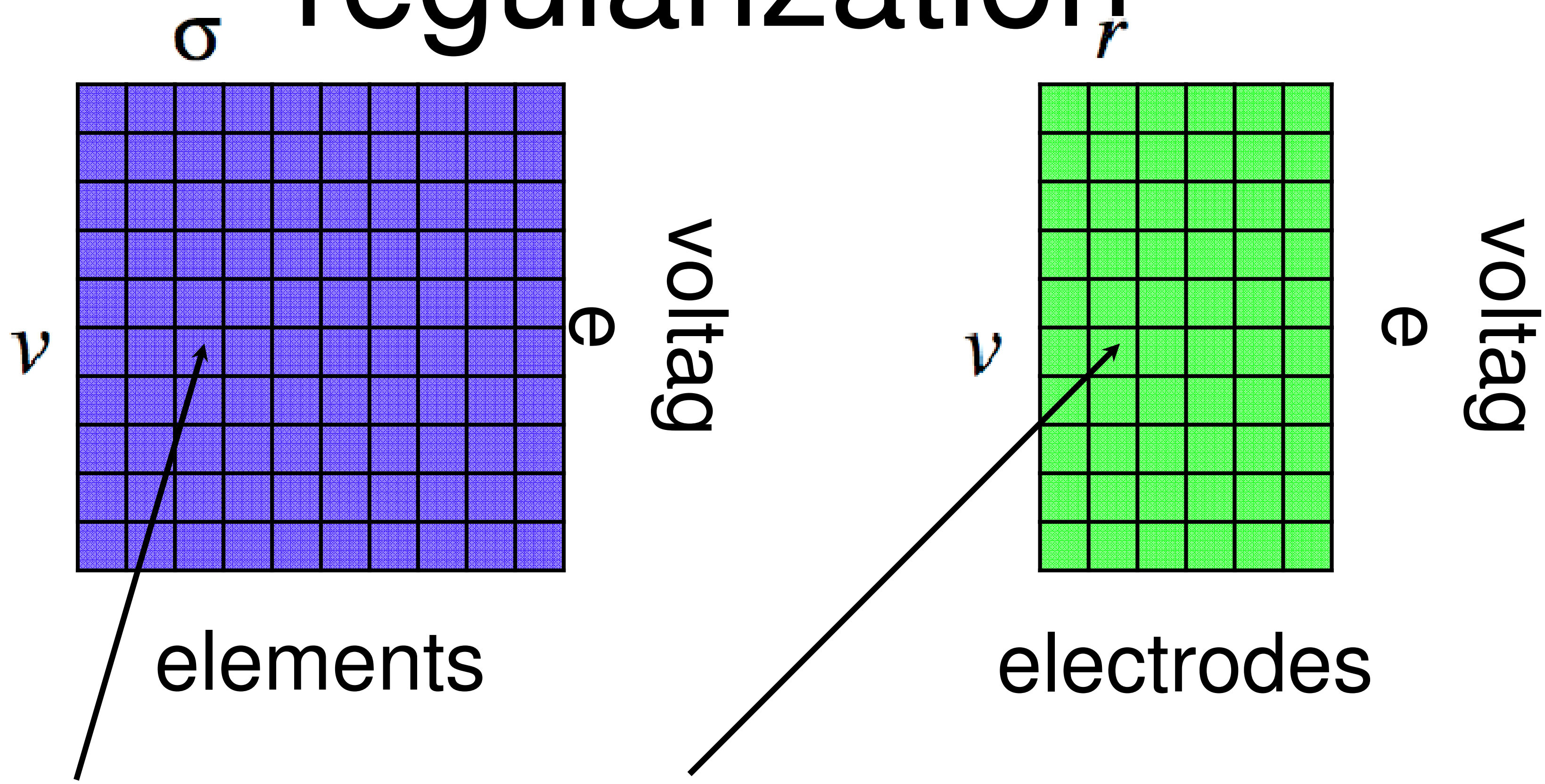


Displacement regularization



$$\frac{\partial v}{\partial \sigma} \approx \frac{v(\sigma + \Delta\sigma) - v(\sigma)}{\Delta\sigma}$$

Displacement regularization

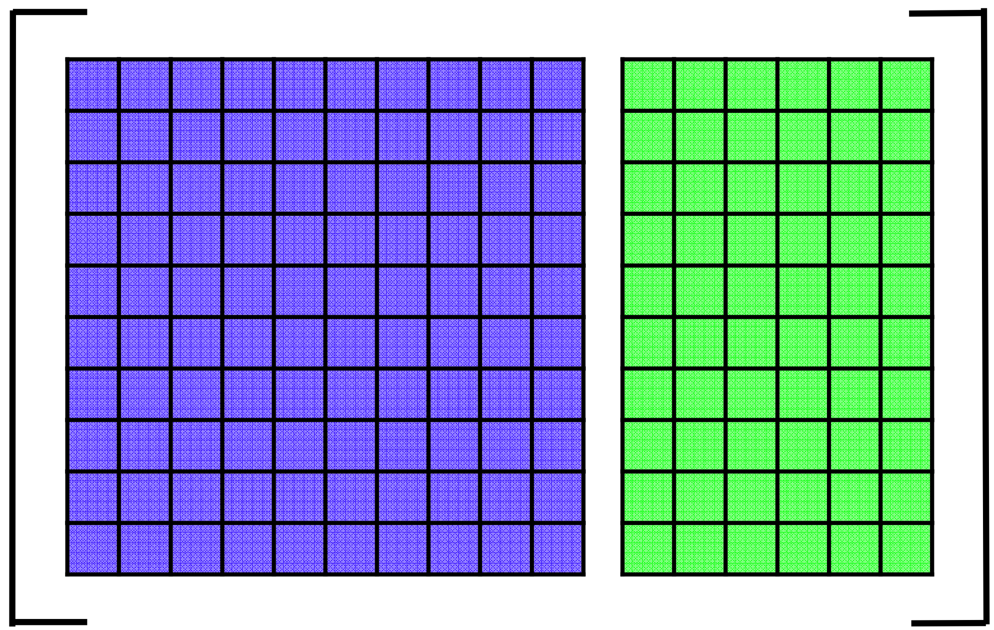


$$\frac{\partial v}{\partial \sigma}$$

$$\frac{\partial v}{\partial r}$$

Displacement regularization

$J =$

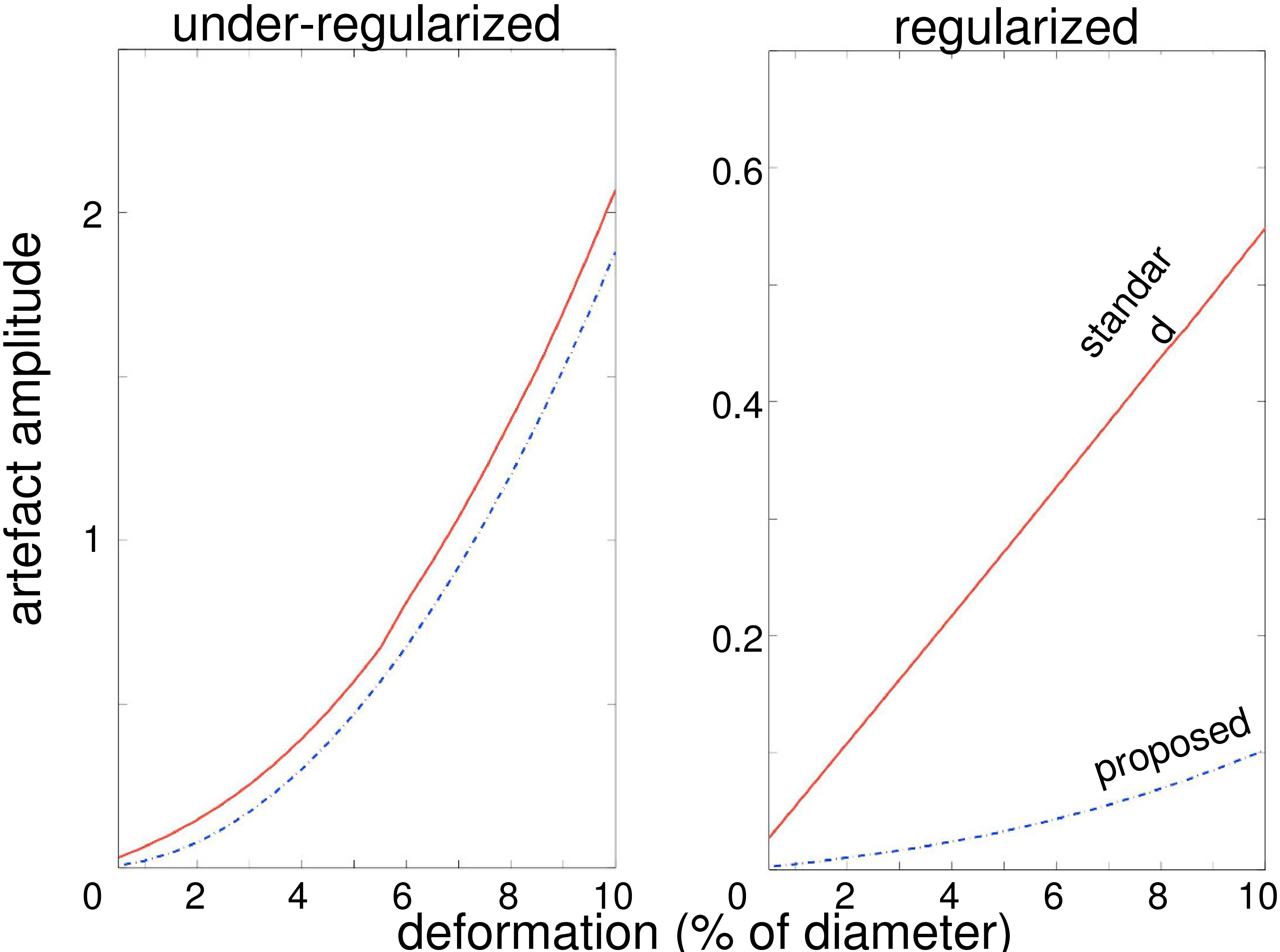


Algorithm performance

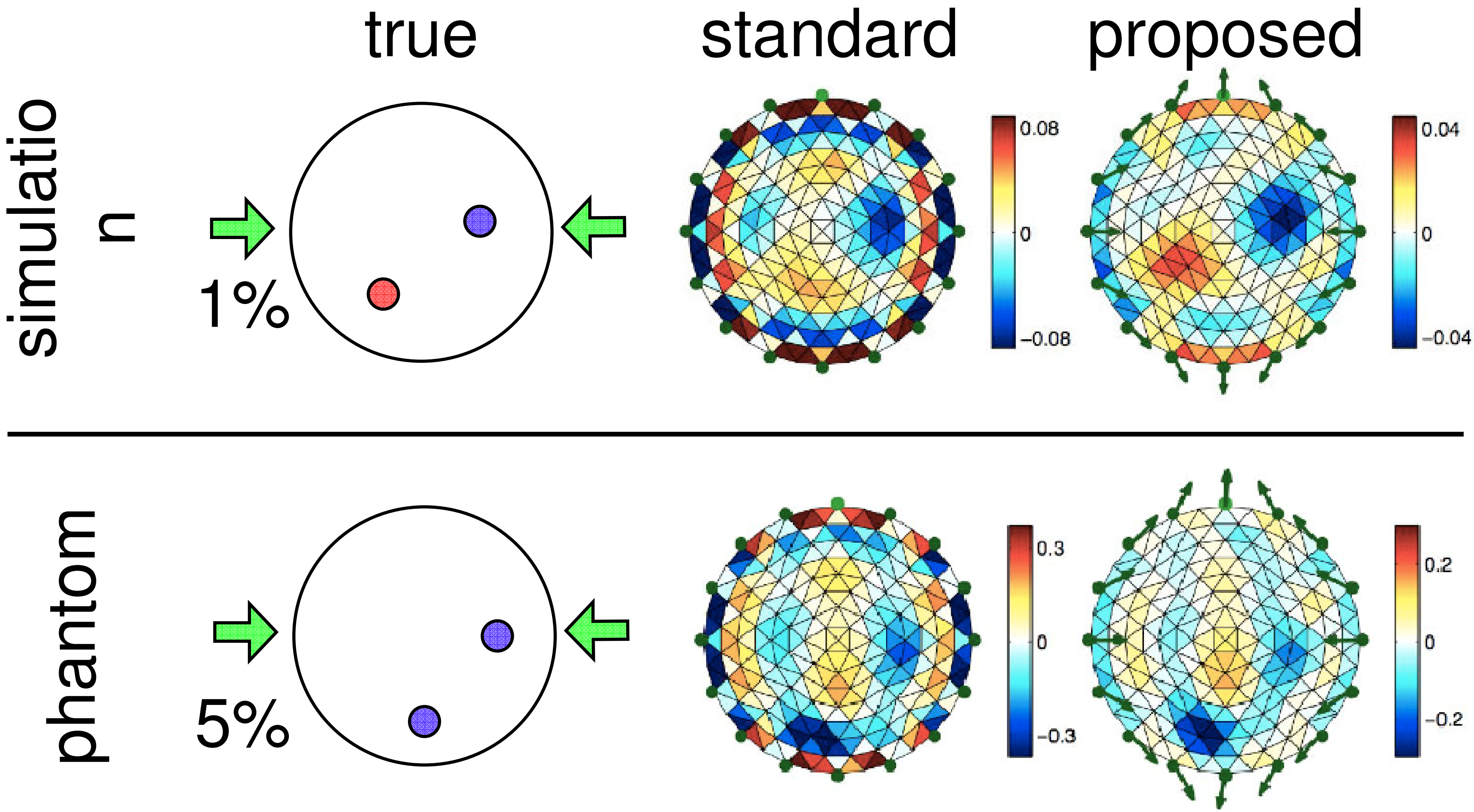
Results of a comparison to the standard algorithm

- no change in position accuracy
- marginal improvement in image resolution
- large improvement in artefact reduction
- calculates electrode displacements

Algorithm performance

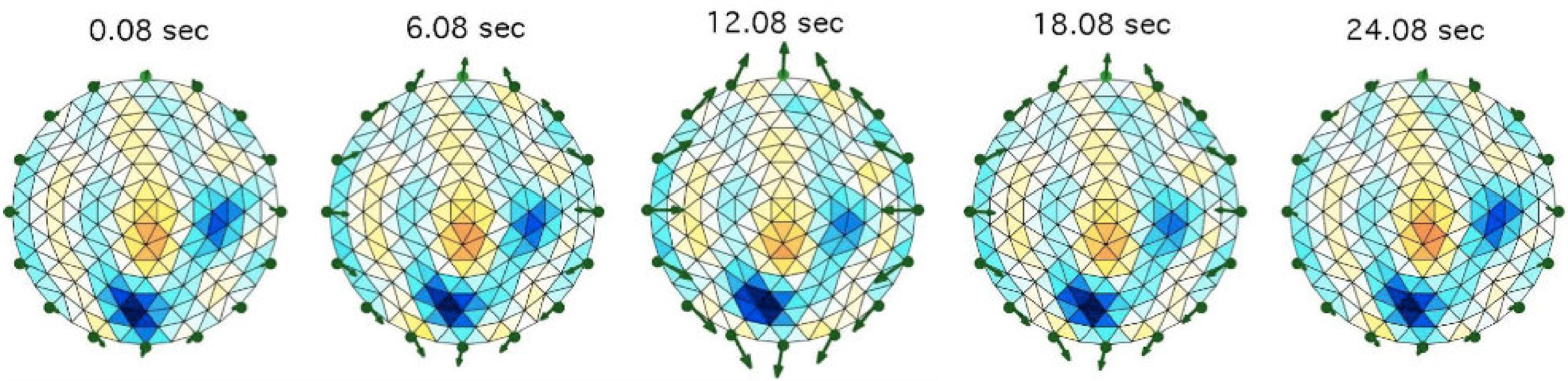


Imaging deformable media



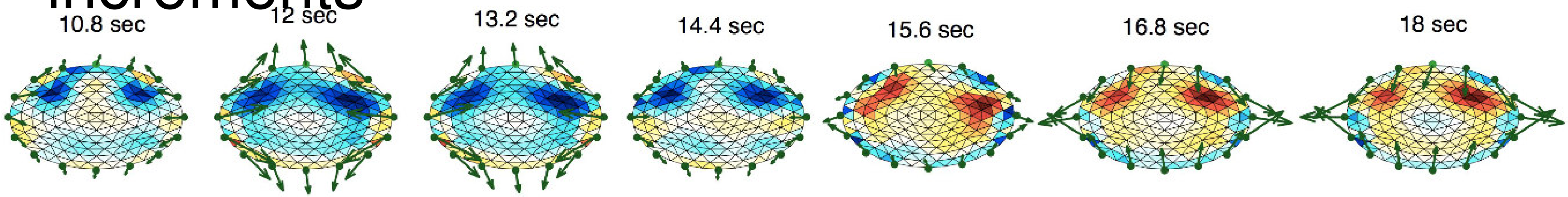
Imaging deformable media

Phantom time series:
- 6 sec. increments
- periodic 5% deformation

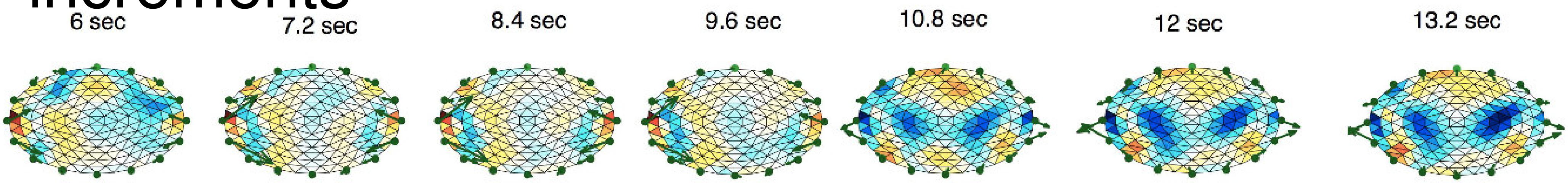


Imaging deformable media

Human TLC-RC breathing: 1.2 sec. increments



Human “paradoxical” breathing: 1.2 sec. increments



Conclusion

This thesis

- studied & quantified the effect of boundary deformation
- proposes an algorithm that compensates & calculates electrode displacement
- provides evidence supporting the use of EIT for deformable media

Contributions

journal

Soleimani, M., **Gomez-Laberge, C.**, and Adler, A. (2006) Imaging of conductivity changes and electrode movement in electrical impedance tomography. Physiological Measurement. 27:S103-S113

conferences

Gomez-Laberge, C., and Adler, A. (2006) Imaging of electrode movement and conductivity change simulations in electrical impedance tomography. In Proceedings IEEE CCECE. Ottawa, Canada.

McLeod, C., **Gomez-Laberge, C.,** and Adler, A. (2006) Reduction of electrode position errors in clinical imaging. In Conference 7th Biomedical Applications of Electrical Impedance Tomography. Seoul, South Korea.