

# Application of Electrical Impedance Tomography to Robotic Tactile Sensing

MASc Defence

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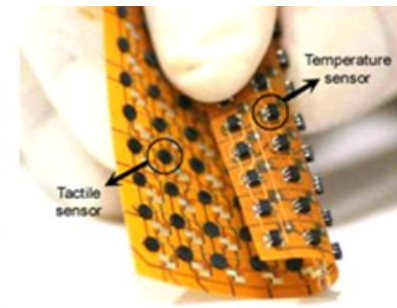
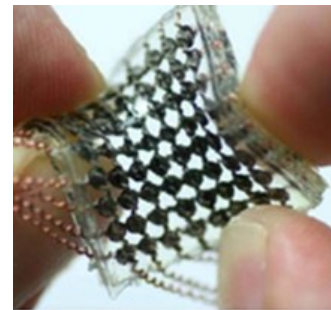
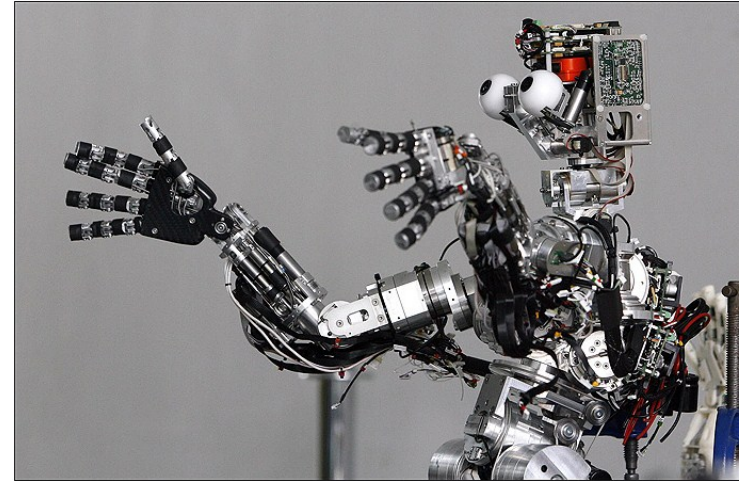
25/7/2012

# Outline

- ▶ Motivation
- ▶ Pressure Distribution Sensor
- ▶ Equipment and Samples
- ▶ Flexible Sensor Assessment
- ▶ Stretchable Tactile Sensor
- ▶ Conclusion
- ▶ Future Works

# Motivation

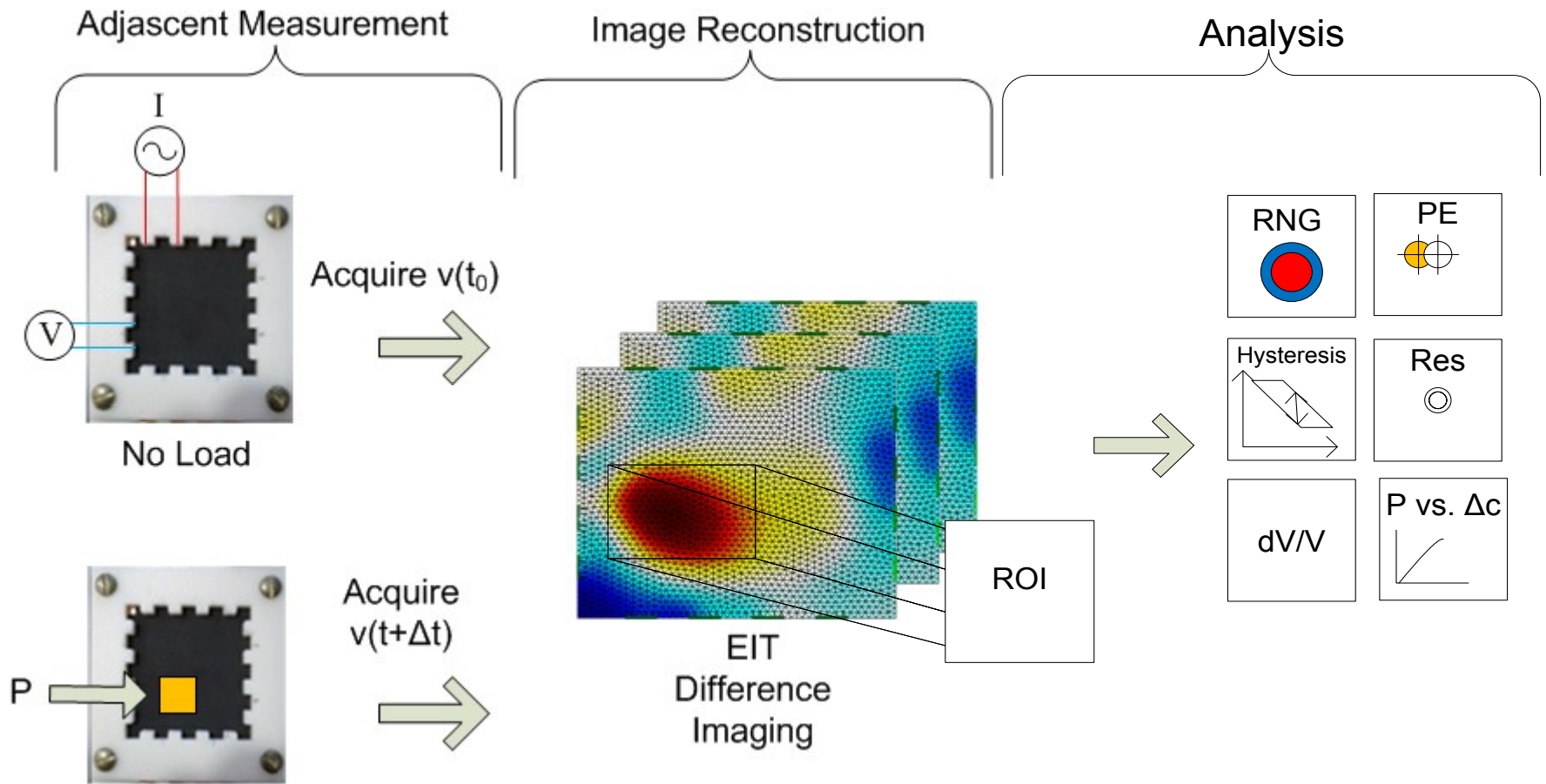
- ▶ Eliminate wires within active sensor area
- ▶ Reduce overall wiring complexity
- ▶ Enhance flexibility and stretch potential
- ▶ Single sensing element for complex geometric part coverage



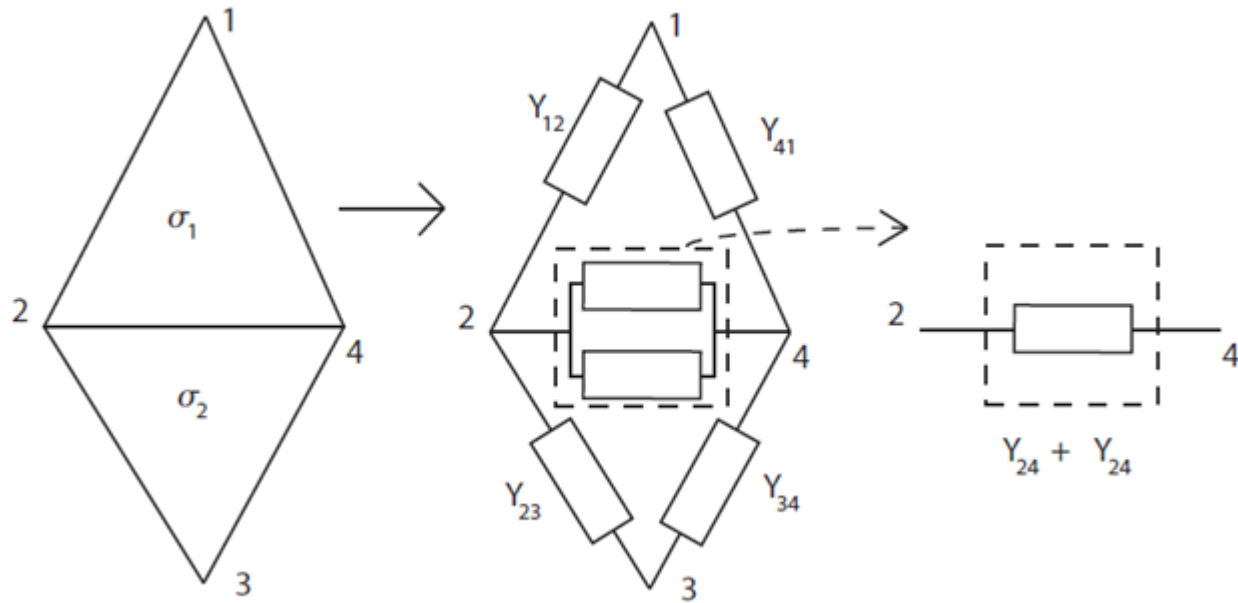
# Research Objectives

- ▶ Assess the accuracy and reliability of 2D EIT for pressure sensing
- ▶ Test different materials for compatibility
- ▶ Allow for integration over complex geometries

# EIT Pressure Sensing Method



# Discretization Approach



B. M. Graham, "Enhancements in Electrical Impedance Tomography (EIT) Image Reconstruction for 3D Lung Imaging," Carleton University, 2007.



# EIT Difference Imaging

- ▶ General form:

$$\mathbf{z} = \mathbf{H}\mathbf{x} + \mathbf{n}$$

- ▶ Jacobian:

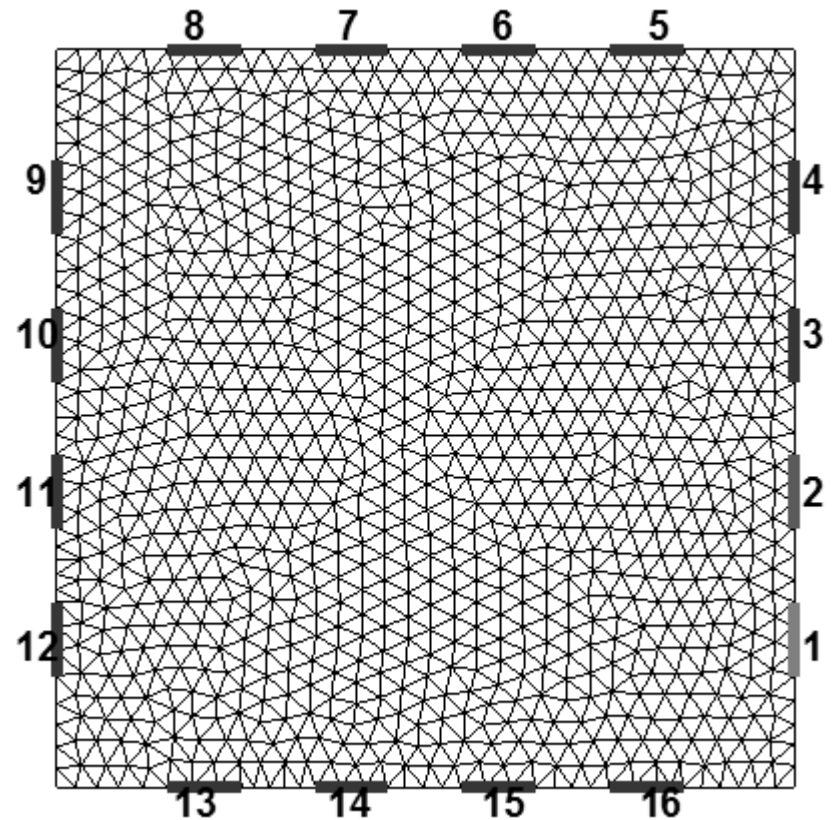
$$\mathbf{H} = \mathbf{T} \left[ \mathbf{Y}^{-1}(\sigma) \frac{\partial}{\partial \sigma} \mathbf{Y}(\sigma) \mathbf{Y}^{-1}(\sigma) \mathbf{I} \right]$$

- ▶ Regularized solution:

$$\mathbf{x} = (\mathbf{H}^T \mathbf{H} + \lambda^2 \mathbf{R}^T \mathbf{R})^{-1} \mathbf{H}^T \mathbf{z}.$$

# EIT Forward Model and Configuration

- ▶ EIDORS
- ▶ Adjacent stimulation
- ▶ Distmesh used for mesh generation
- ▶ 16 electrodes
- ▶ Laplacian regularization method

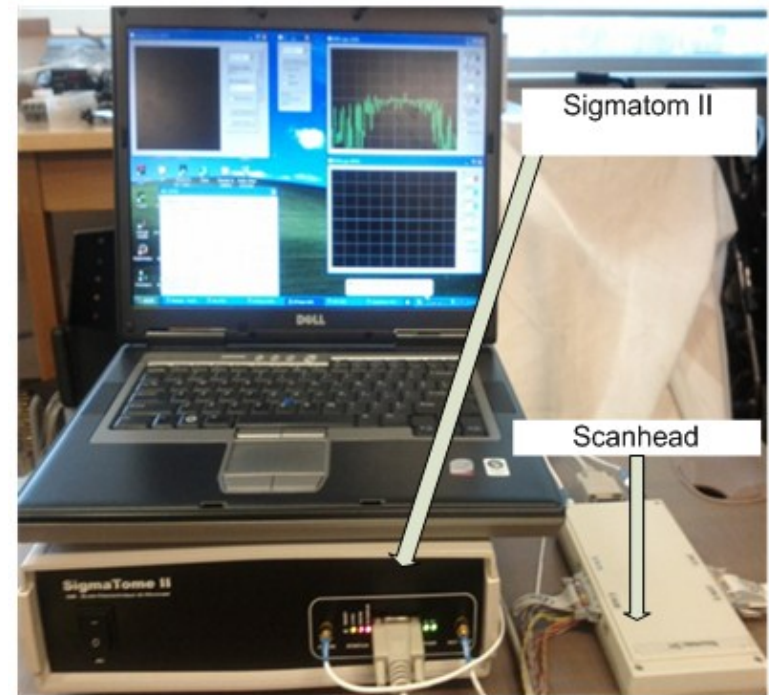


Mesh of 4078 Elements and 2075 Nodes



# Equipment

- ▶ SigmaTom II
  - Frequency 12.5–100kHz
  - Amplitude 0–4mA
  - 208 measurements/frame
- ▶ MLP-25
  - Nonlinearity 0.1% of R.O.
  - Hysteresis 0.1% of R.O
  - Excitation Voltage 10 VDC

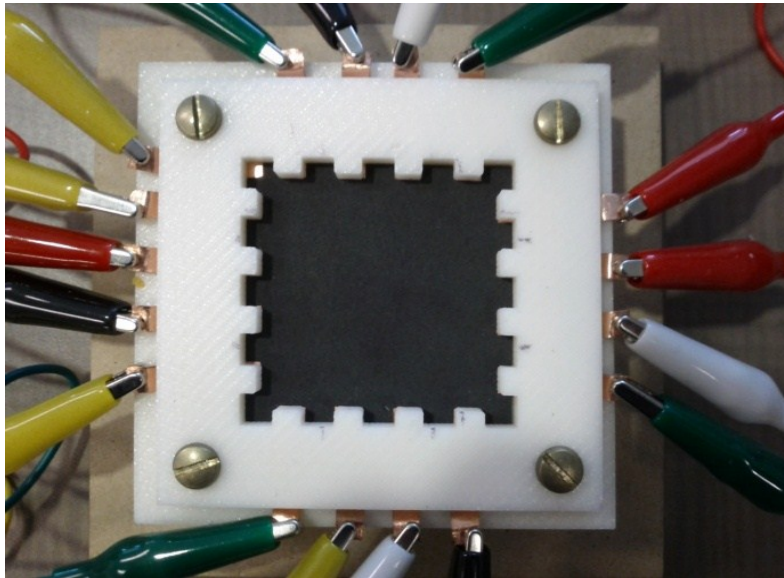


EIT System

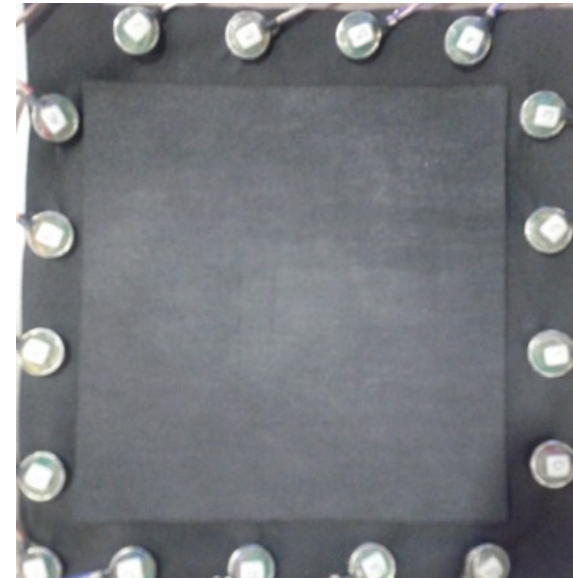


MLP-25 Load Cell

# Flexible Sample Materials



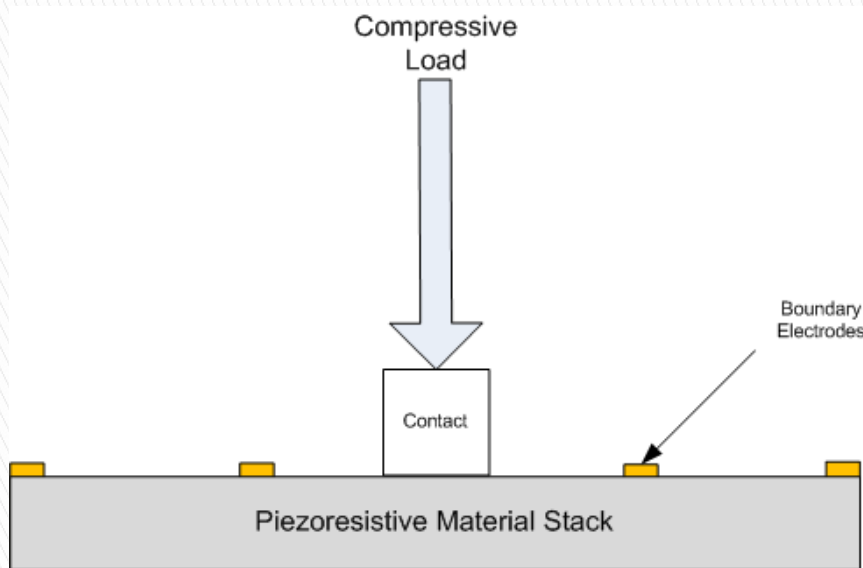
Sample #1: Conductive Polymer stacked with copper (5cm\*5cm)



Sample #2: Two layers of non-woven conductive fabric (21cm\*21cm)

# Experiments and Performance Metrics

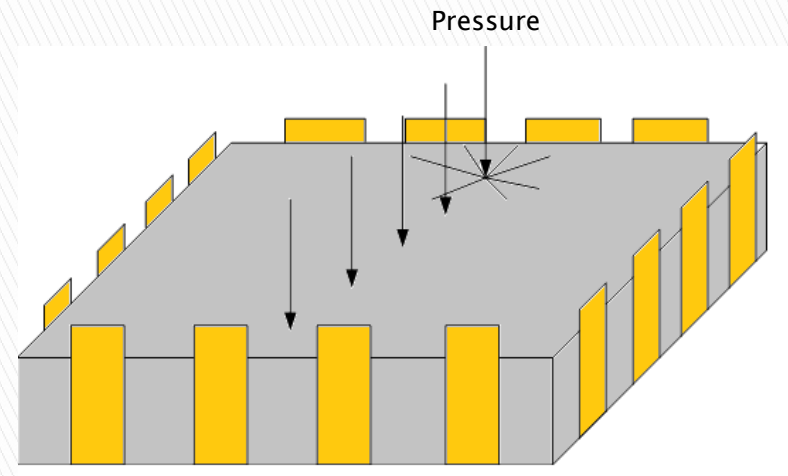
## ▶ Static Compression Test



Fixed location varying load

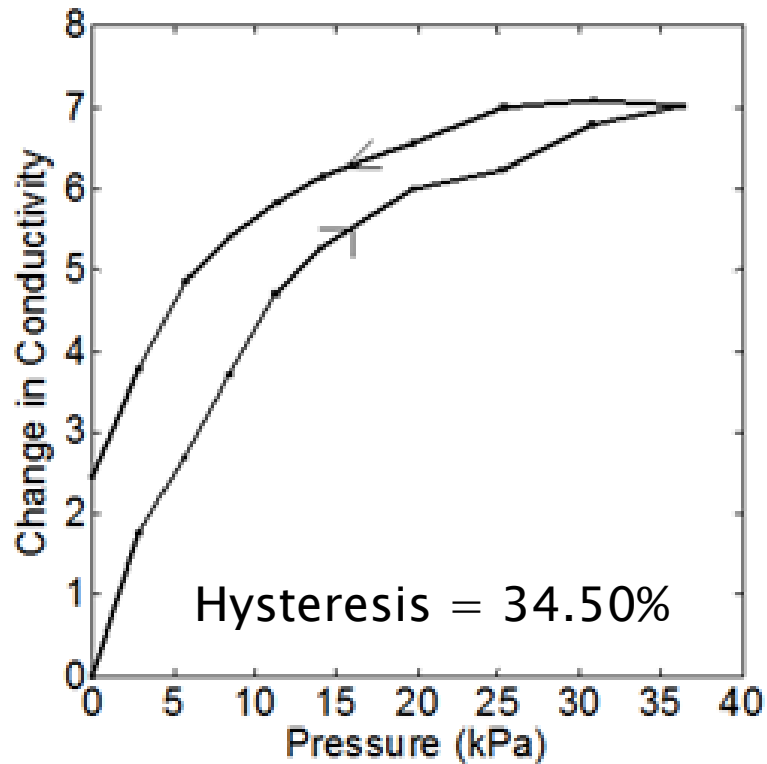
## ▶ Pressure Map Test

- Position Error (PE)
- Resolution (RES)
- Ringing (RNG)

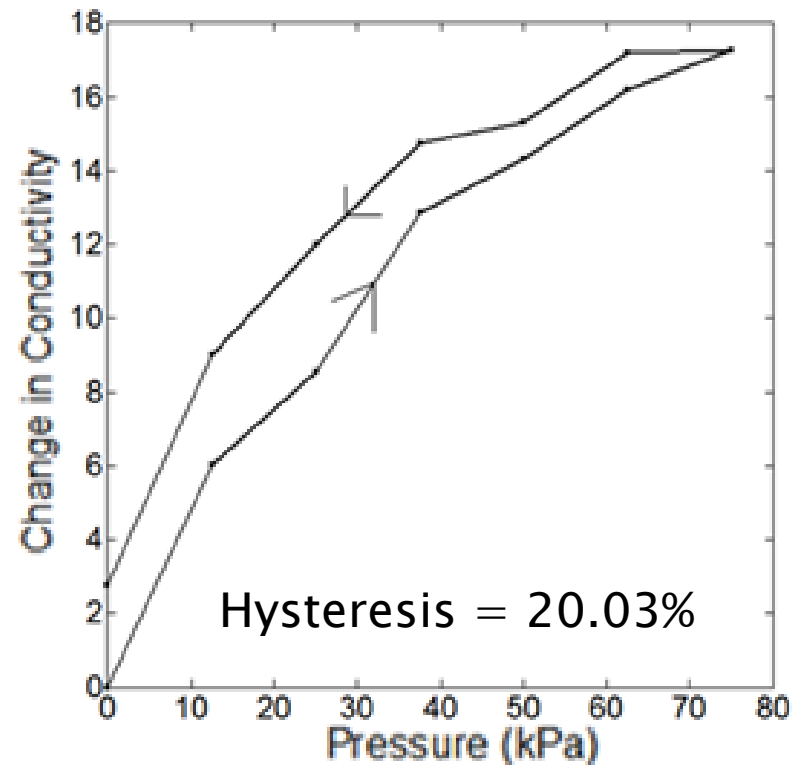


Fixed load varying location

# Flexible Sensor Pressure Response

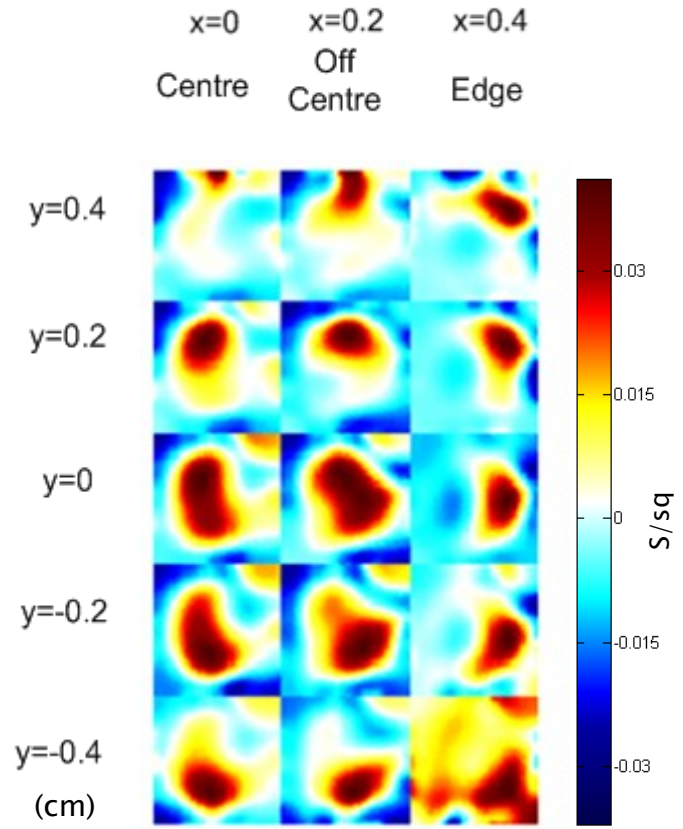
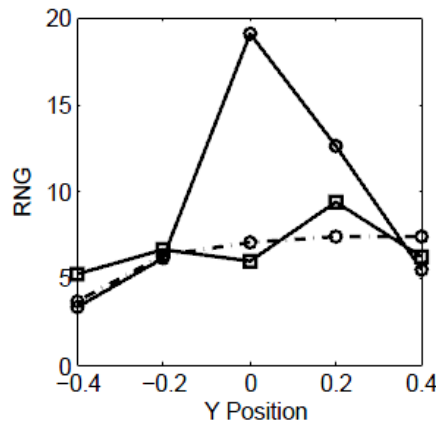
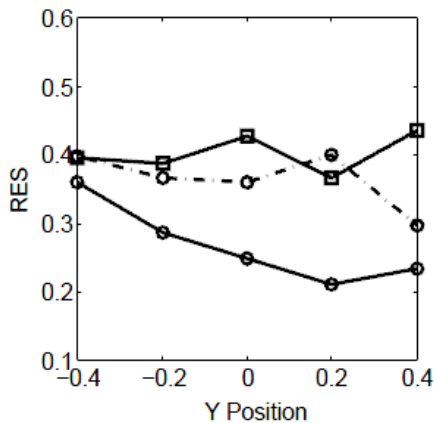
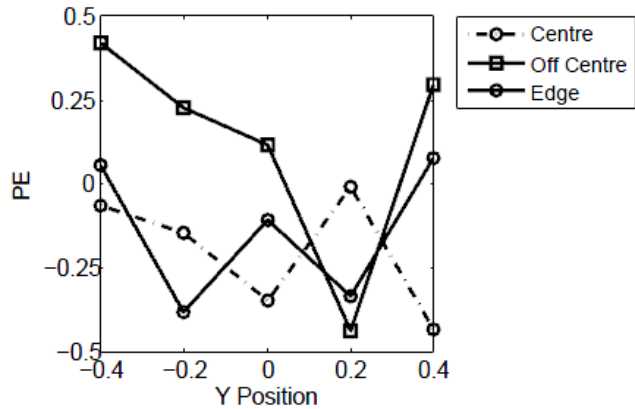


Conductive Polymer



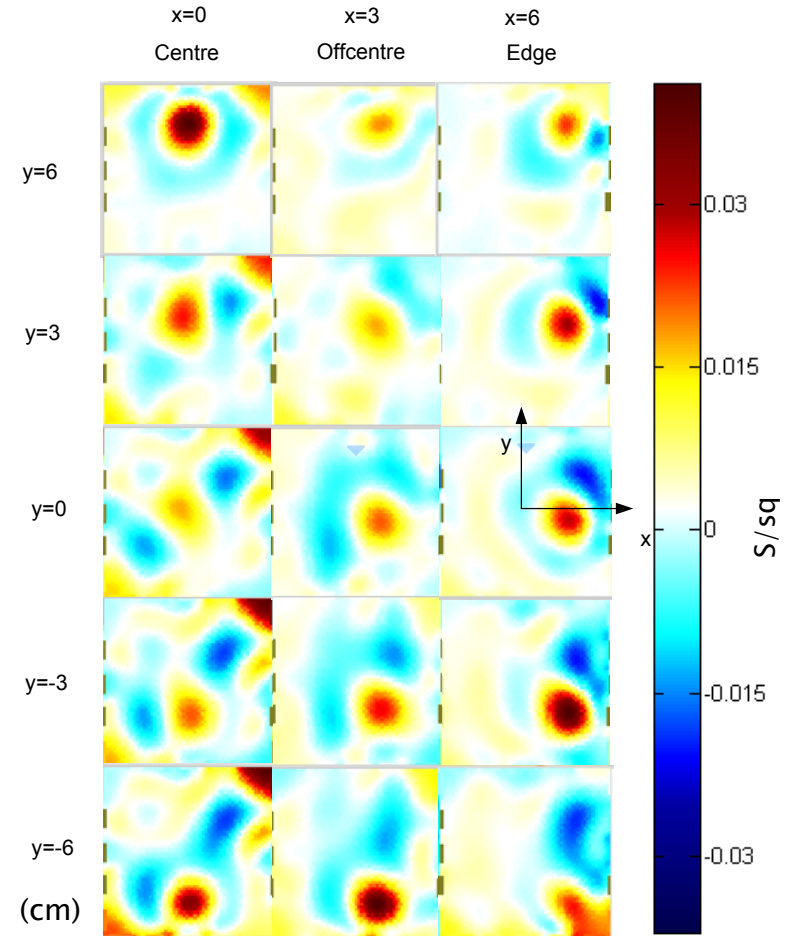
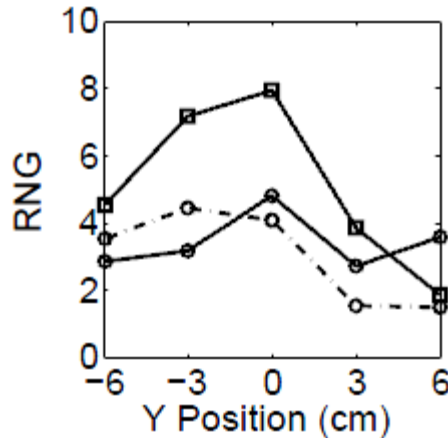
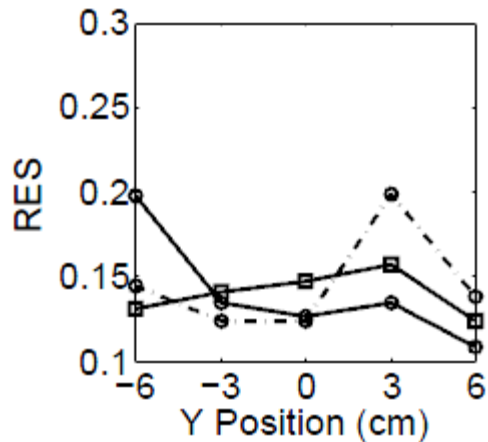
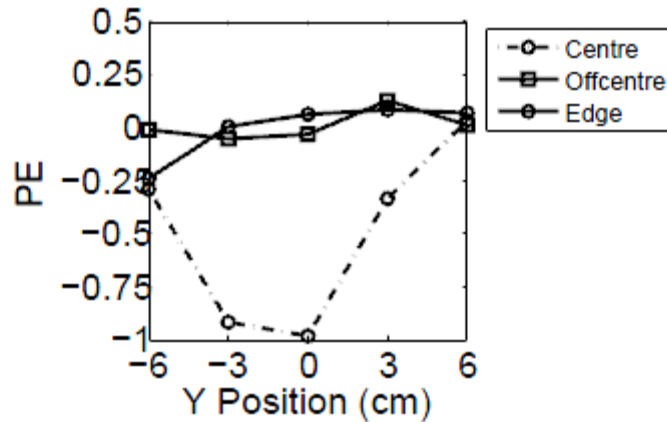
Non-woven fabric

# Sample #1 Image Analysis





# Sample #2 Image Analysis





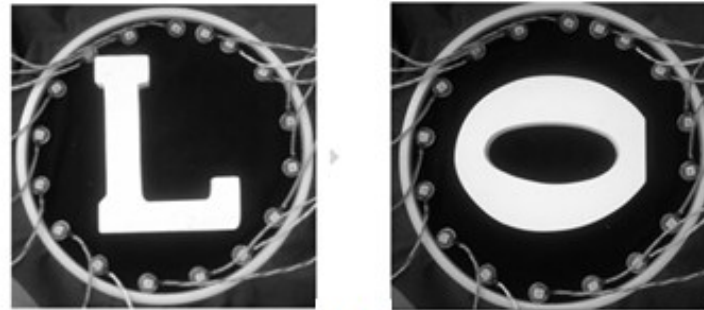
# Stretchable Tactile Sensor

- ▶ Stretchable, woven, conductive fabric
- ▶ Cover complex geometric features using single element
- ▶ Allow for complex surface modelling in EIT imaging

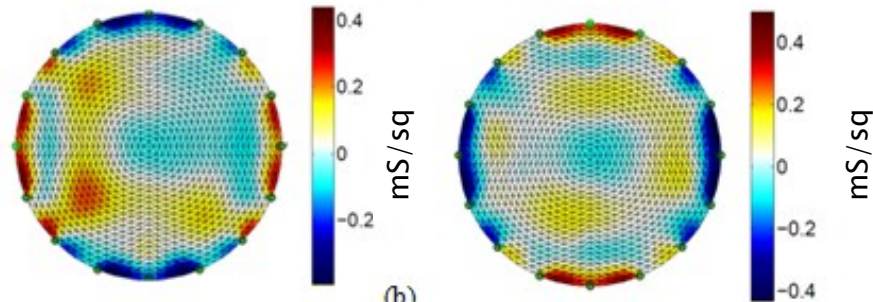


Woven fabric in fixture

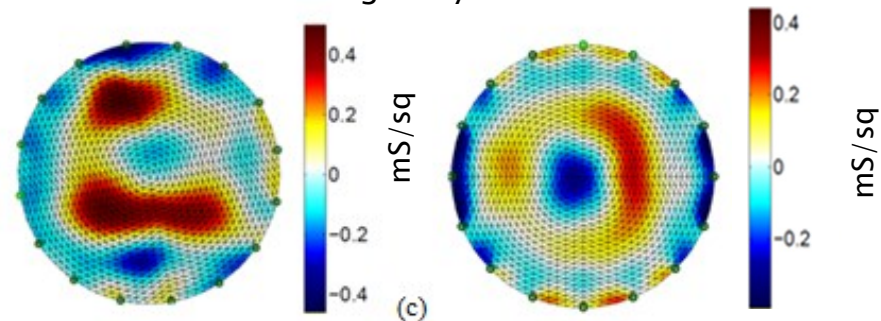
# Results: Feature Recognition



(a)

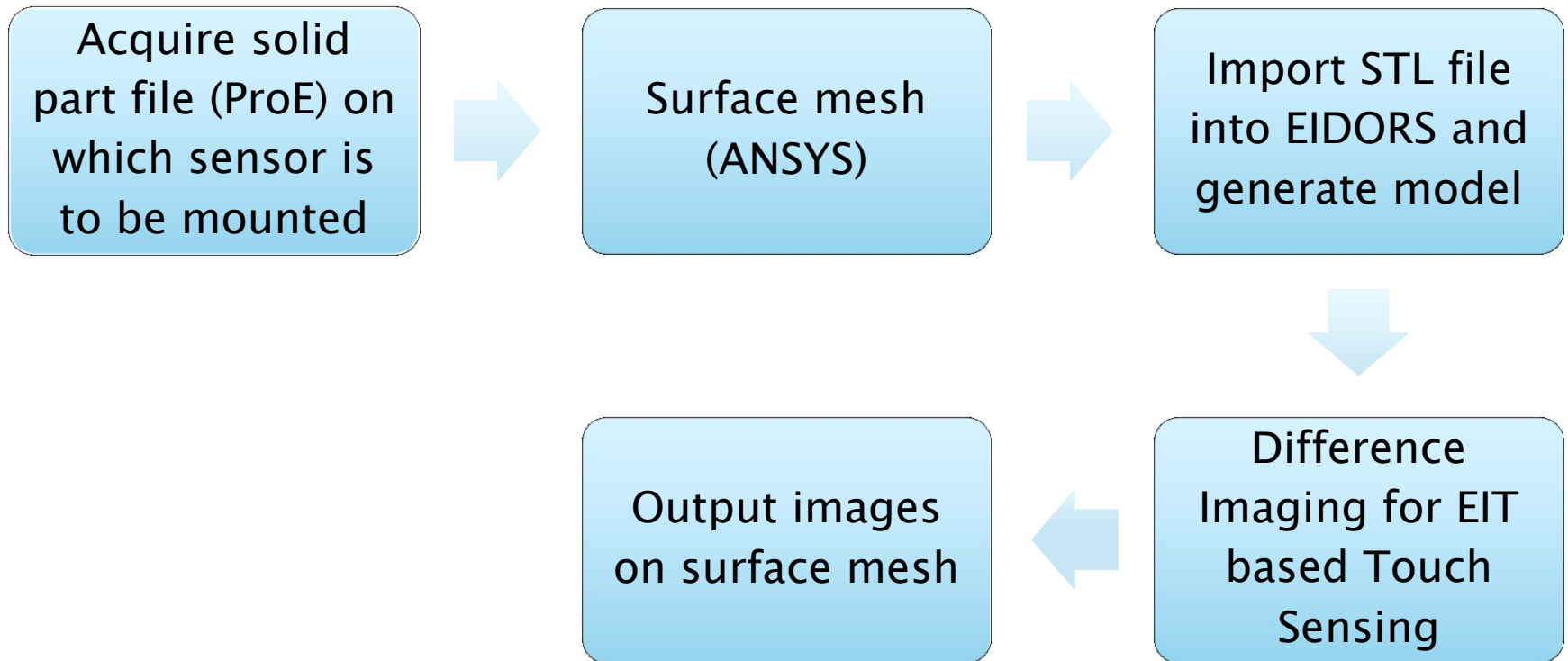


Single Layer



Dual Layer

# Procedure for Complex Geometry Implementation



# Complex 3D Geometry

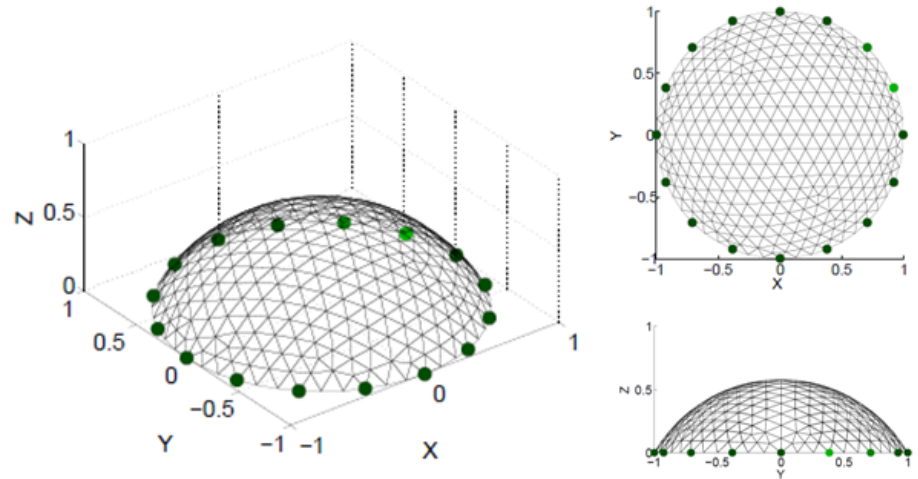
- ▶ System matrix modification in EIDORS
- ▶ Testing using hemisphere shaped part



HDF Part



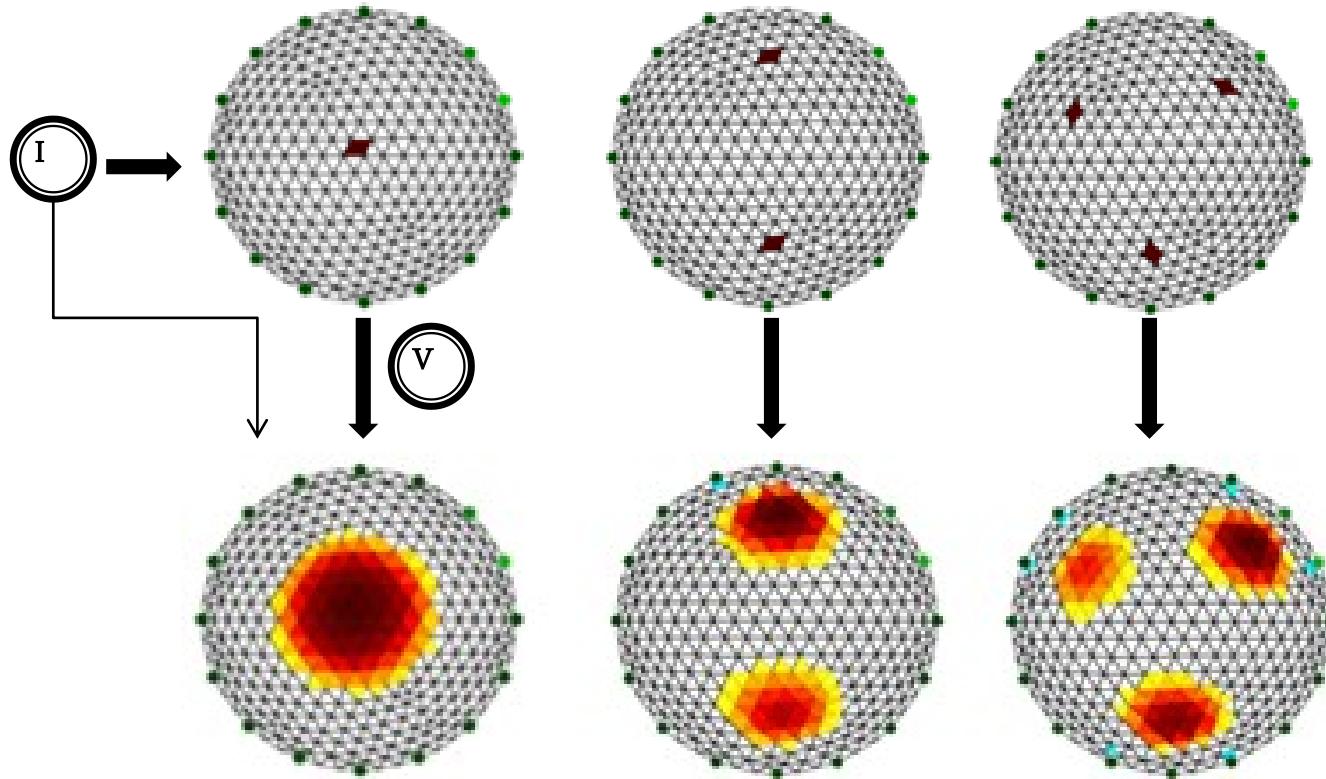
Mounted Sensor  
 $\varnothing=210\text{mm}$



Normalized Forward Model

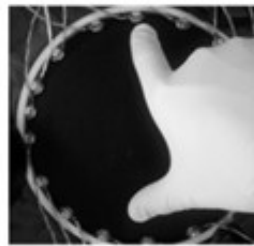
# Simulated Pressure Distribution

Forward Problem

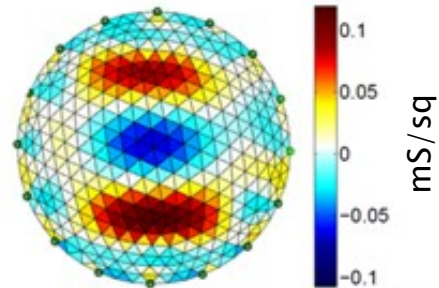


Inverse Problem

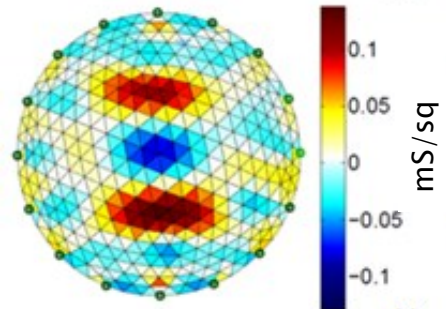
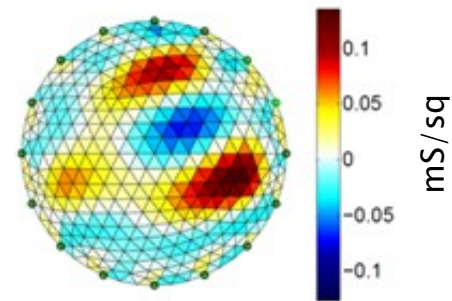
# Results: Multi-touch under stretch



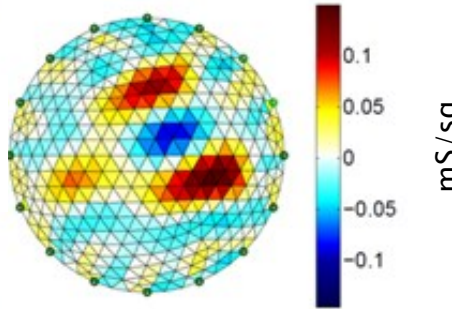
(a)



(b)



(c)





# Contributions

- ▶ 2D EIT pressure sensor using a *Conductive Polymer* and *non-woven* fabric
- ▶ Novel EIT complex geometry surface modelling
- ▶ Stretchable touch sensor
  - Multi-touch
  - Feature recognition

# Conclusion

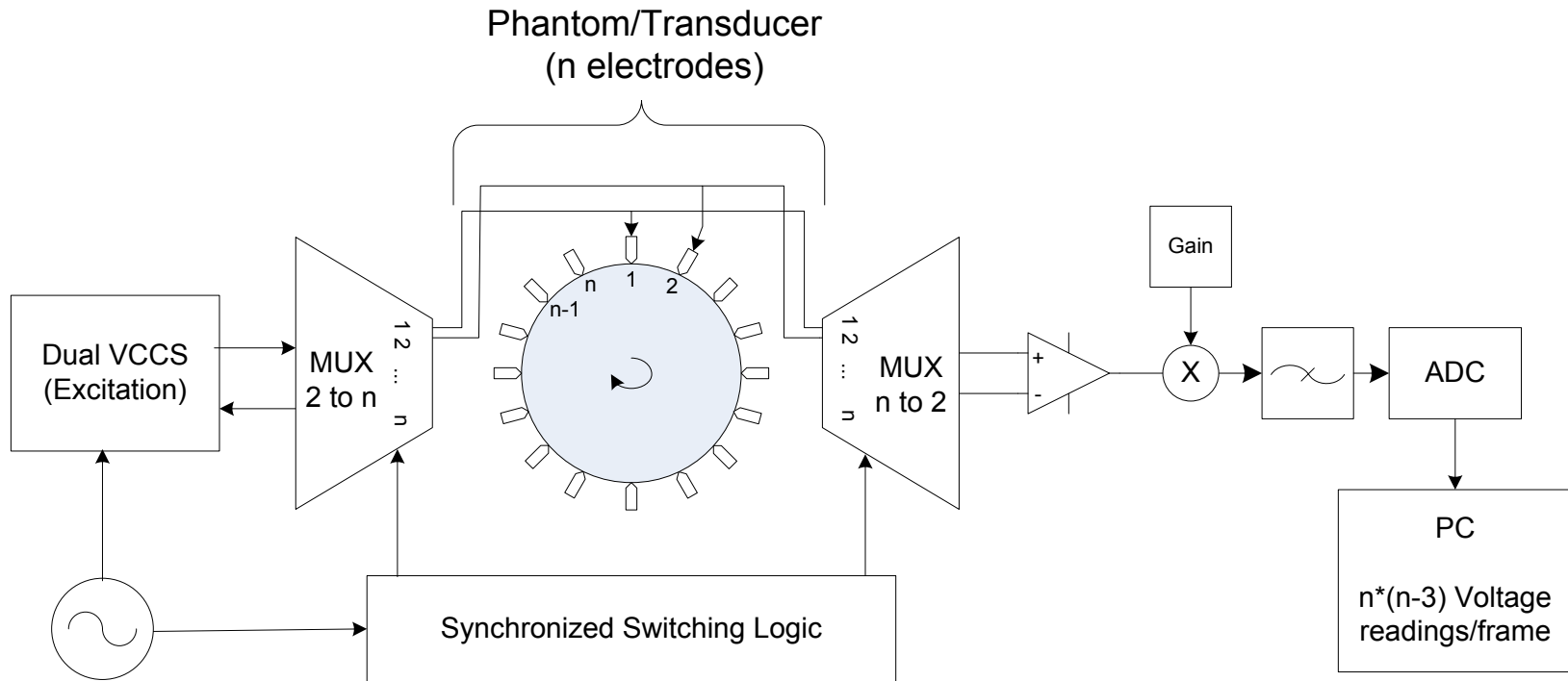
- ▶ EIT is capable of effective pressure and touch sensing via 2D and 3D surface models
- ▶ Hysteresis is a significant impediment to the design
- ▶ Position error is mainly caused due to shape deformations and image artefacts

# Future Works

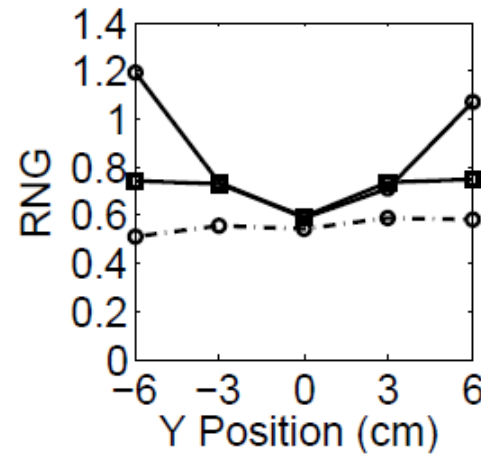
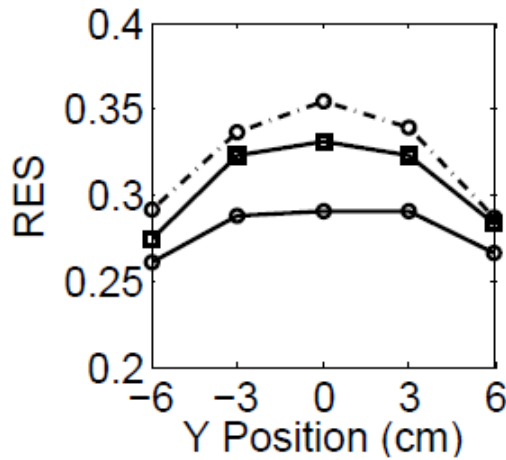
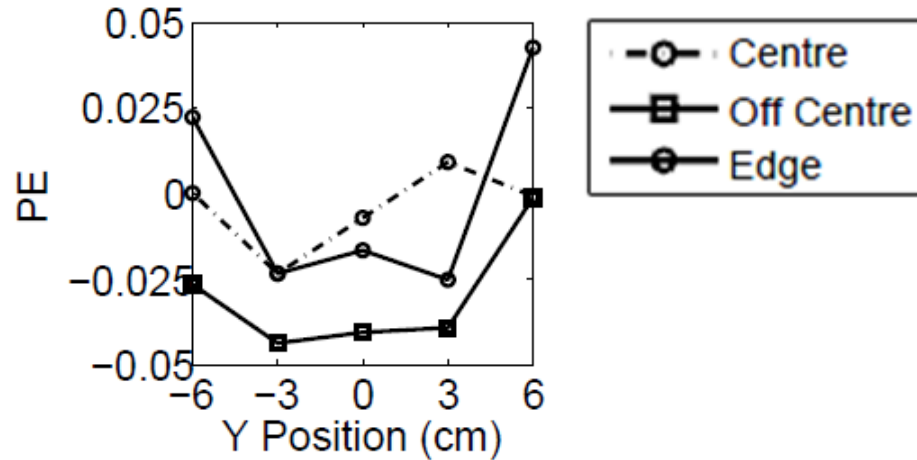
- ▶ Investigate alternative electrode mounting and stimulation methods
- ▶ Real-time compact hardware setup
- ▶ Apply a real-time Preisach hysteresis compensator

Questions?

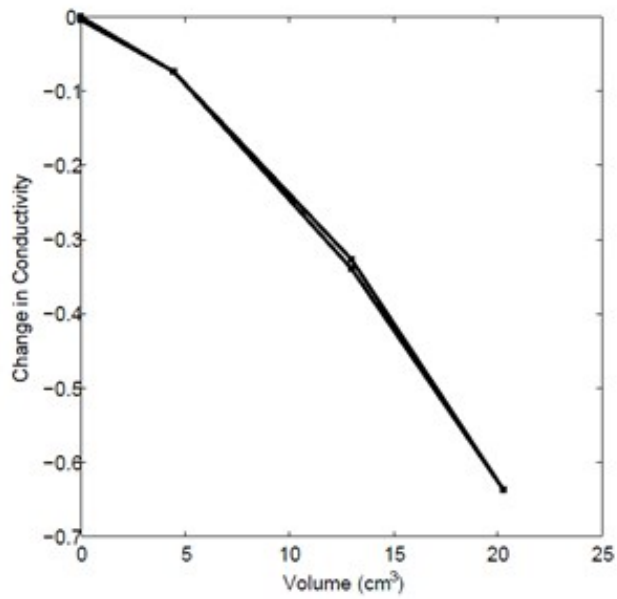
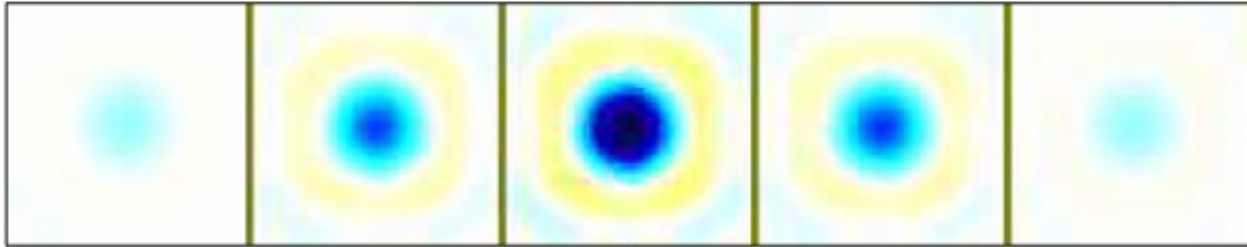
# EIT Hardware Architecture



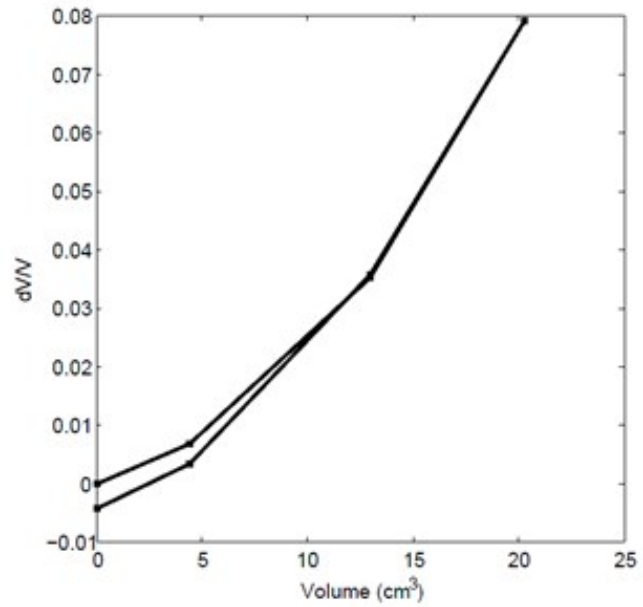
# Benchmarking







(b)



(c)