Electrical Impedance Tomography

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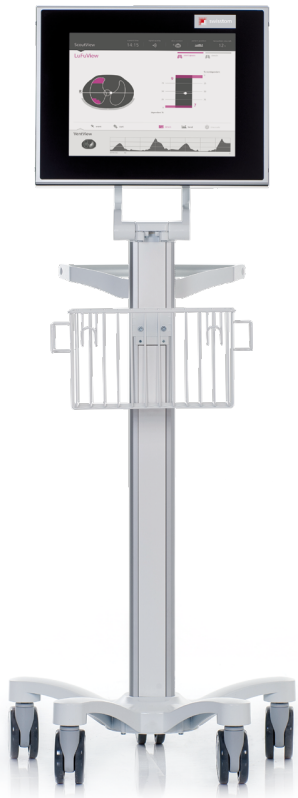
Apr 4, 2018

Electrical Impedance Tomography

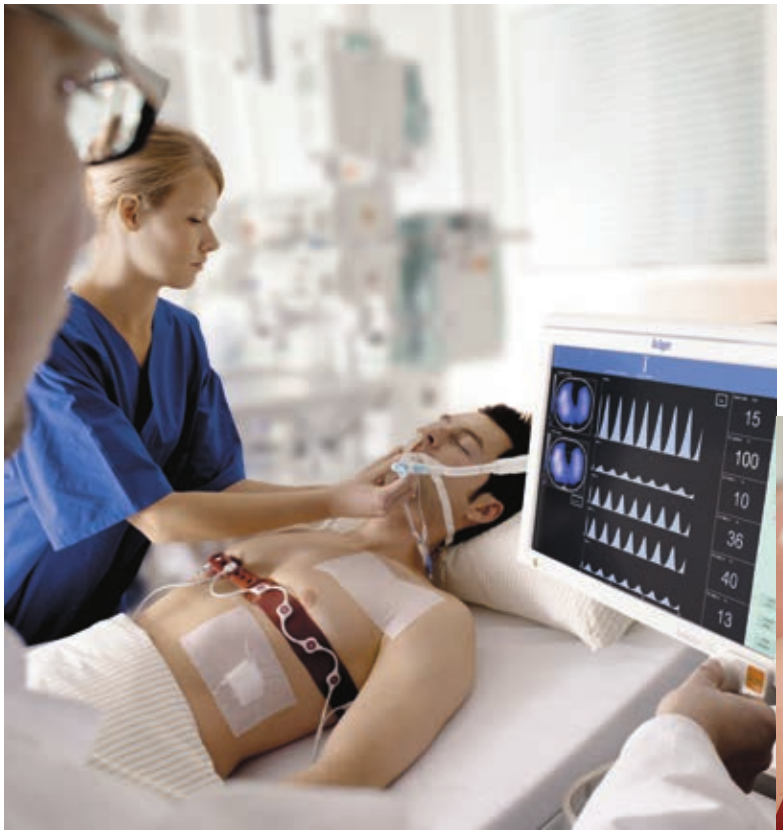


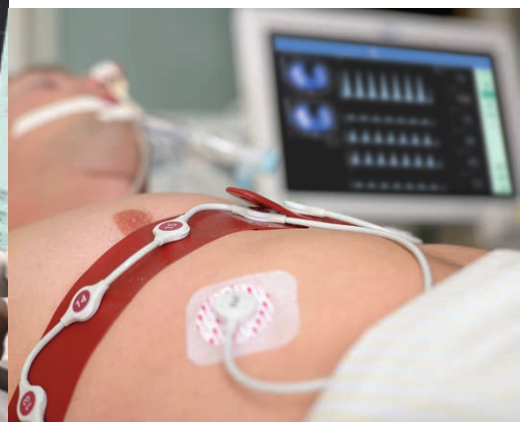
Typical EIT Bedside Equipment; Ventilator Management

Swisstom BB2

images from Swisstom BB2 brochure, retrieved Apr 3, 2018

Electrical Impedance Tomography





Typical EIT Bedside Equipment; Ventilator Management

Dräger Pulmovista 500

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images from Dräger Pulmovista 500 brochure, retrieved Apr 3, 2018

Electrical Resistivity Tomography

Typical ERT Survey Equipment
ABEM Terrameter LS

Guideline Geo, technical specs retrieved Feb 22, 2018

PBG Geophysical Exploration Ltd., image retrieved Feb 22, 2018

Electrical Resistivity Tomography

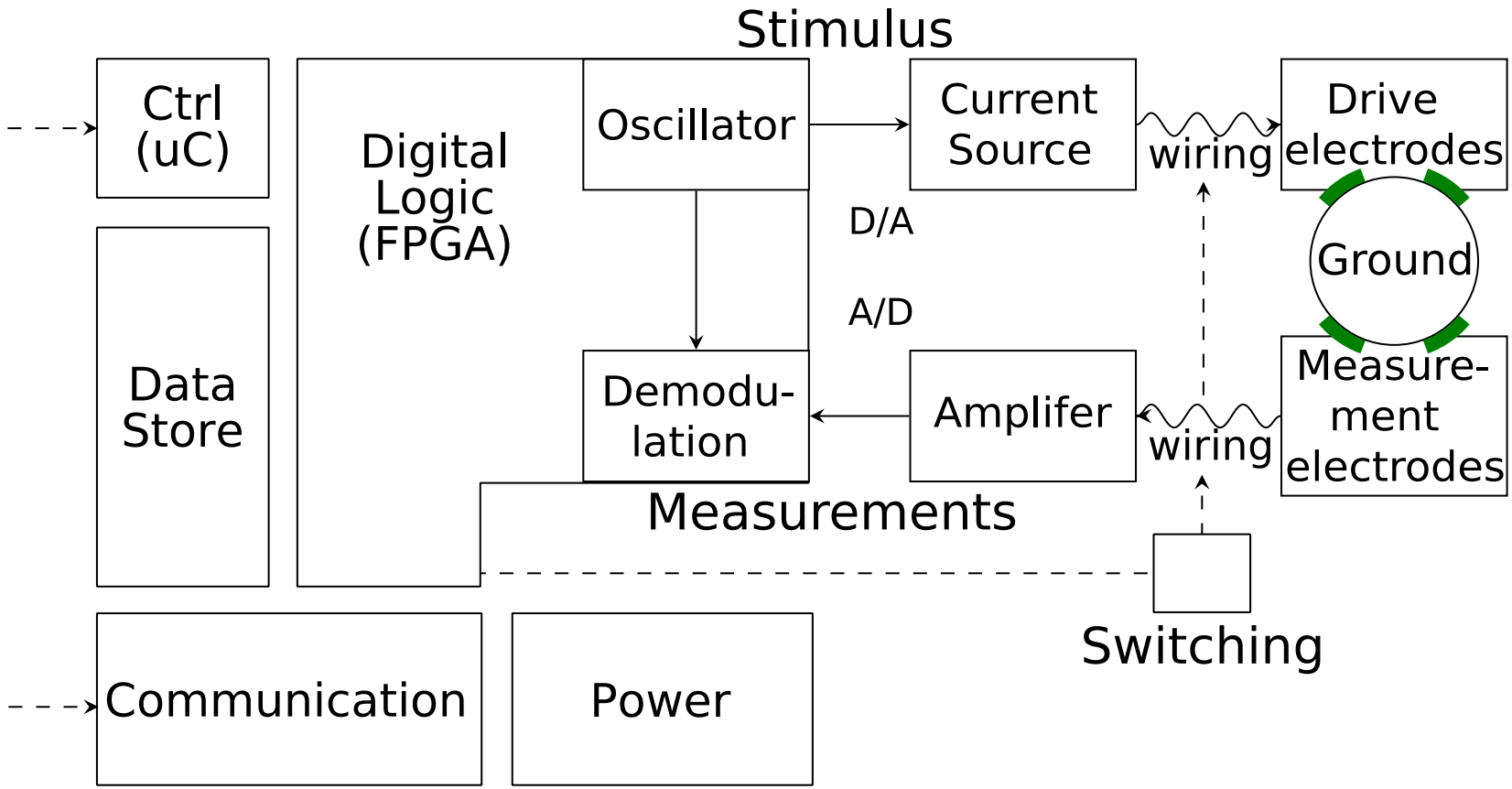
Long-term remote monitoring

slow moving landslide at Hollin Hill, UK with colleagues from the British Geological Survey
daily measurements 2008–present

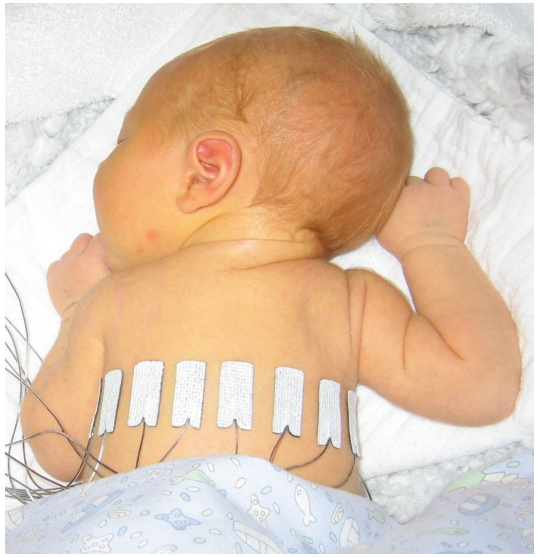
Automated Landslide Electrical Resistivity Tomography (ALERT) system

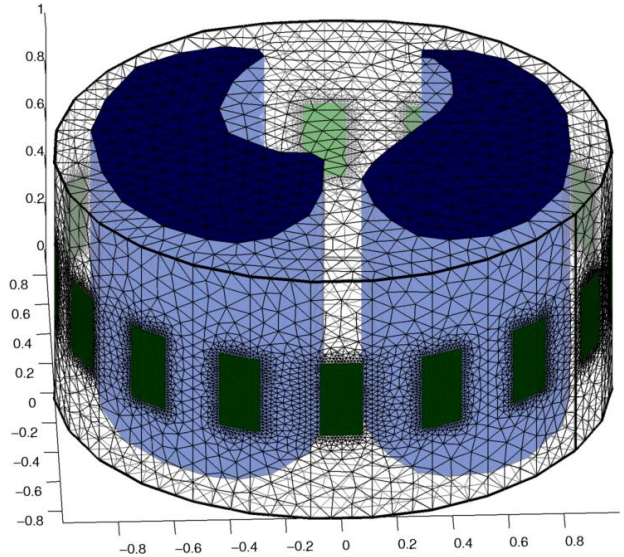
A. Boyle, 2018

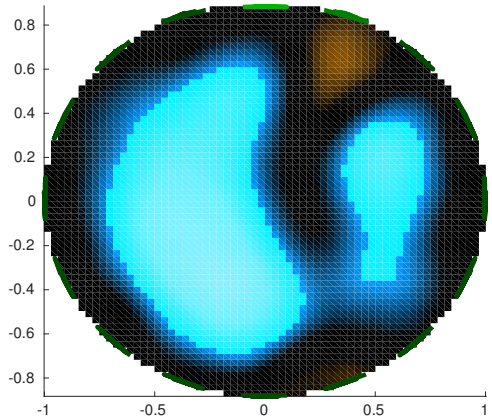
Electrical Resistivity Tomography



Electrical Impedance Tomography







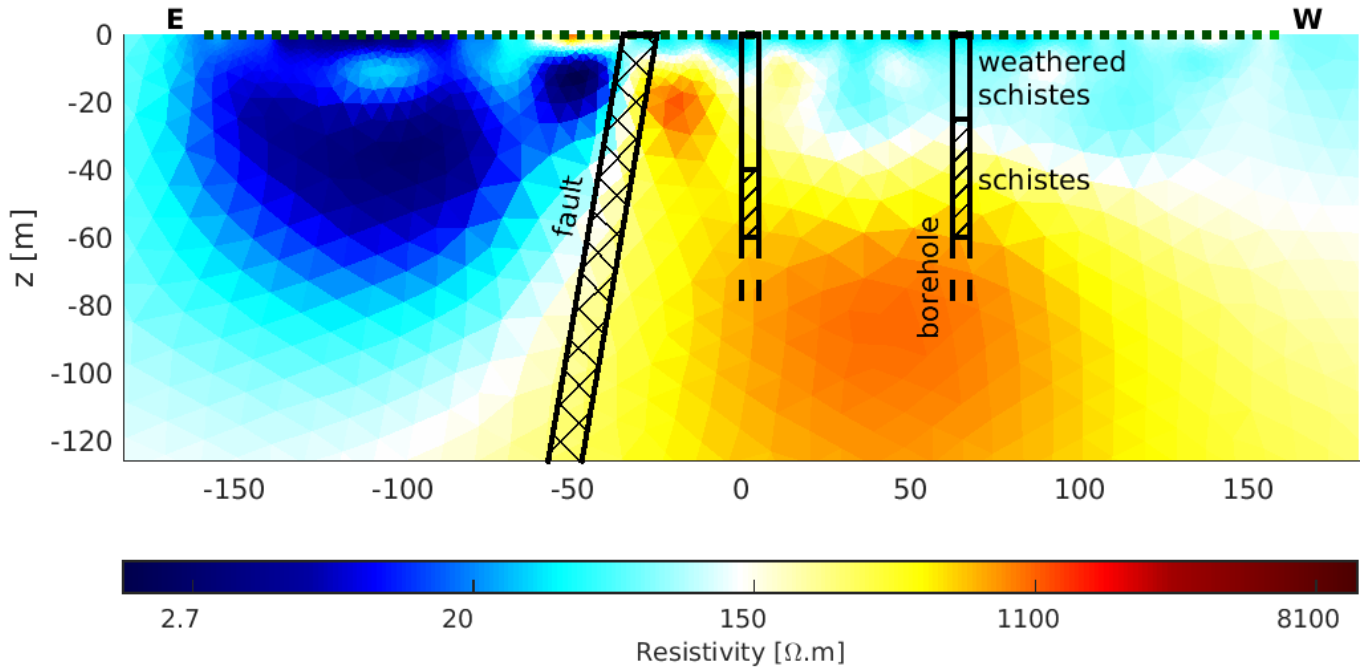
Typical EIT Reconstruction

Neonate Lungs

EIDORS tutorial: GREIT Reconstruction for an neonate human thorax geometry

A. Boyle, 2018

Electrical Resistivity Tomography



Typical ERT Survey

Pont-Péan, France

A. Boyle, *Geophysical Applications of Electrical Impedance Tomography*, PhD thesis, 2016

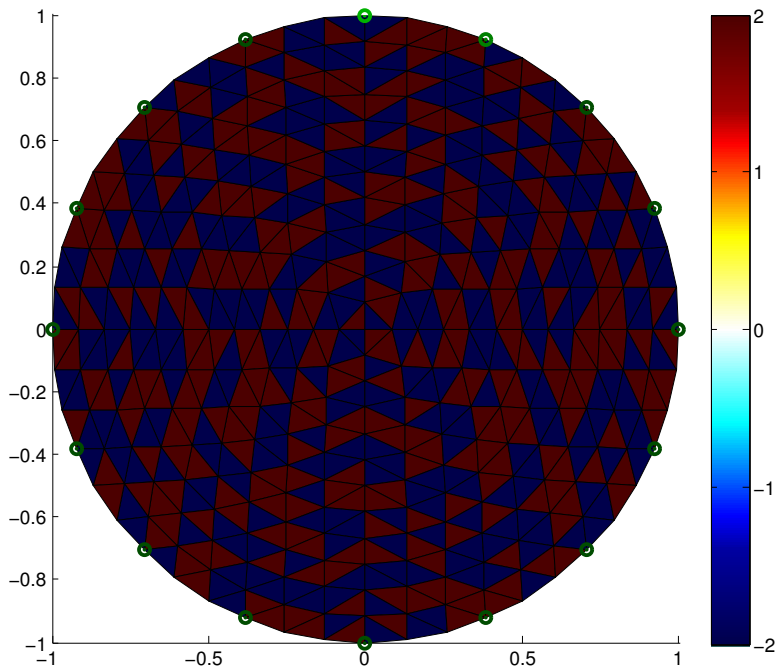
Methods

Absolute imaging problem; large conductivity contrasts
... a Gauss-Newton nonlinear iterative solver

$$\min_x ||\mathbf{Ax} - \mathbf{b}||_2^2 \tag{1}$$

$$\delta \mathbf{x}_n = -(\mathbf{J}_n^\mathsf{T} \mathbf{J}_n)^{-1} (\mathbf{J}_n^\mathsf{T} \mathbf{b}) \tag{2}$$

$$\mathbf{x}_{n+1} = \mathbf{x}_n + \alpha_{n+1}\ \delta \mathbf{x}_{n+1} \tag{3}$$



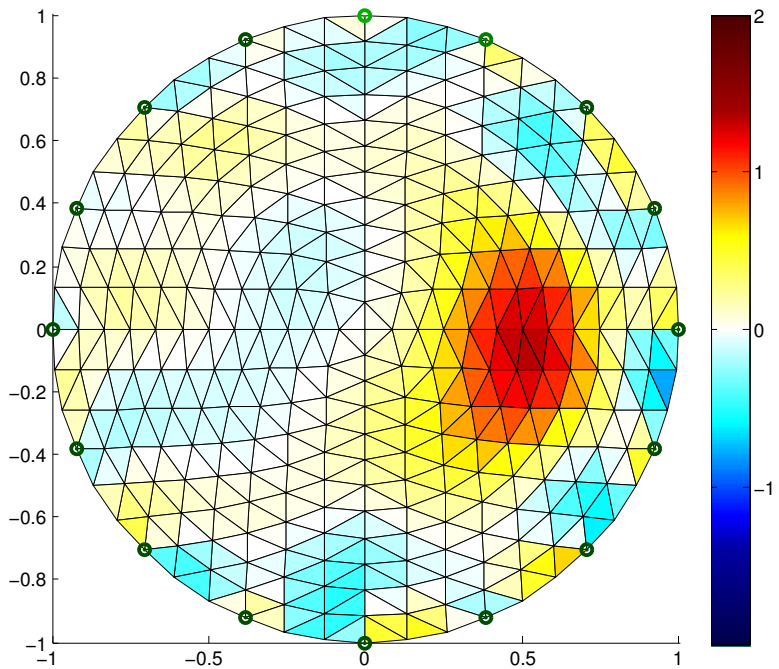
Methods

Absolute imaging problem; large conductivity contrasts
... a Gauss-Newton nonlinear iterative solver

$$\min_x ||\mathbf{Ax} - \mathbf{b}||^2_{\mathbf{W}} + ||\lambda \mathbf{R}(\mathbf{x} - \mathbf{x}_*)||^2_2 \quad (1)$$

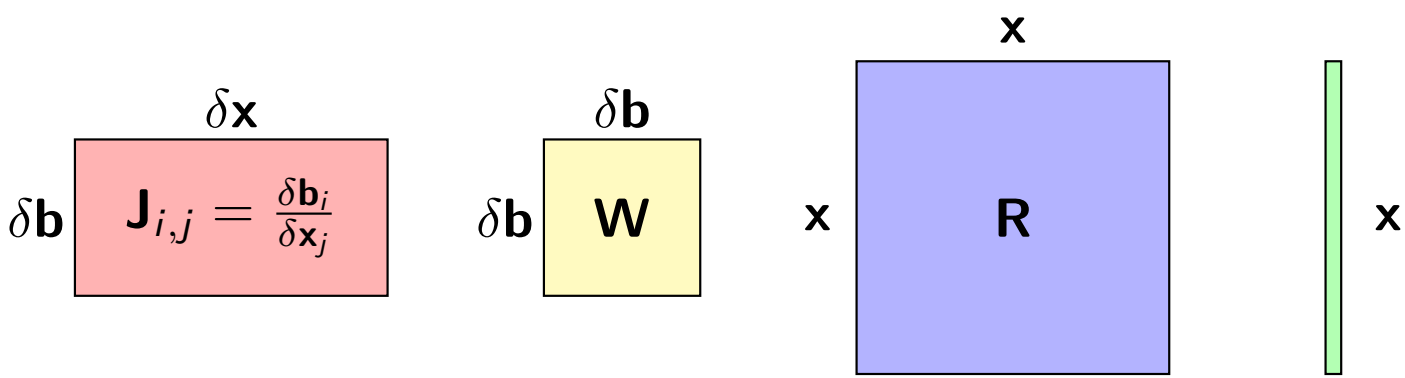
$$\delta \mathbf{x}_{n+1} = -(\mathbf{J}_n^\mathsf{T} \mathbf{W} \mathbf{J}_n + \lambda^2 \mathbf{R}^\mathsf{T} \mathbf{R})^{-1} (\mathbf{J}_n^\mathsf{T} \mathbf{W} \mathbf{b} - \lambda^2 \mathbf{R}^\mathsf{T} \mathbf{R}(\mathbf{x}_n - \mathbf{x}_*)) \quad (2)$$

$$\mathbf{x}_{n+1} = \mathbf{x}_n + \alpha_{n+1}\, \delta \mathbf{x}_{n+1} \quad (3)$$

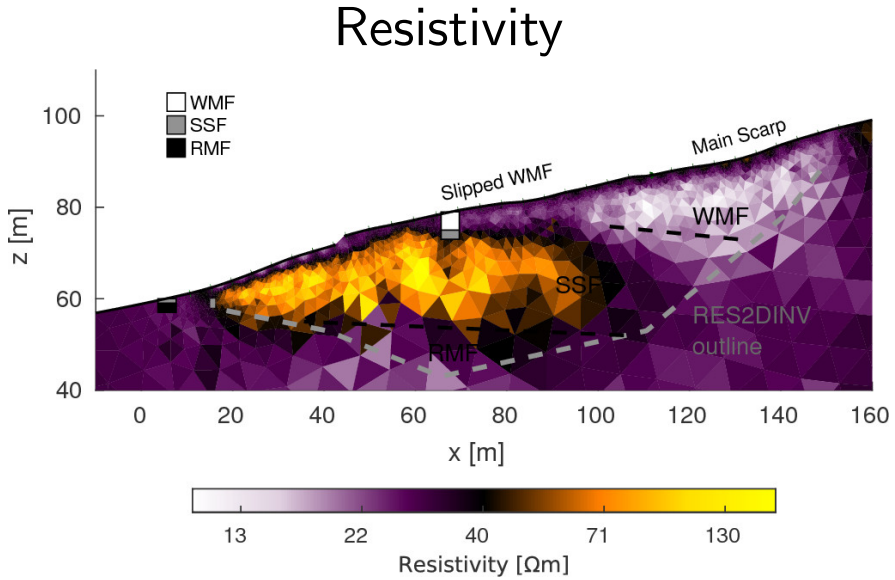


Methods

$$\delta \mathbf{x}_{n+1} = -(\mathbf{J}_n^{\mathsf{T}} \mathbf{W} \mathbf{J}_n + \lambda^2 \mathbf{R}^{\mathsf{T}} \mathbf{R})^{-1} (\mathbf{J}_n^{\mathsf{T}} \mathbf{W} \mathbf{b} - \lambda^2 \mathbf{R}^{\mathsf{T}} \mathbf{R} (\mathbf{x}_n - \mathbf{x}_*))$$



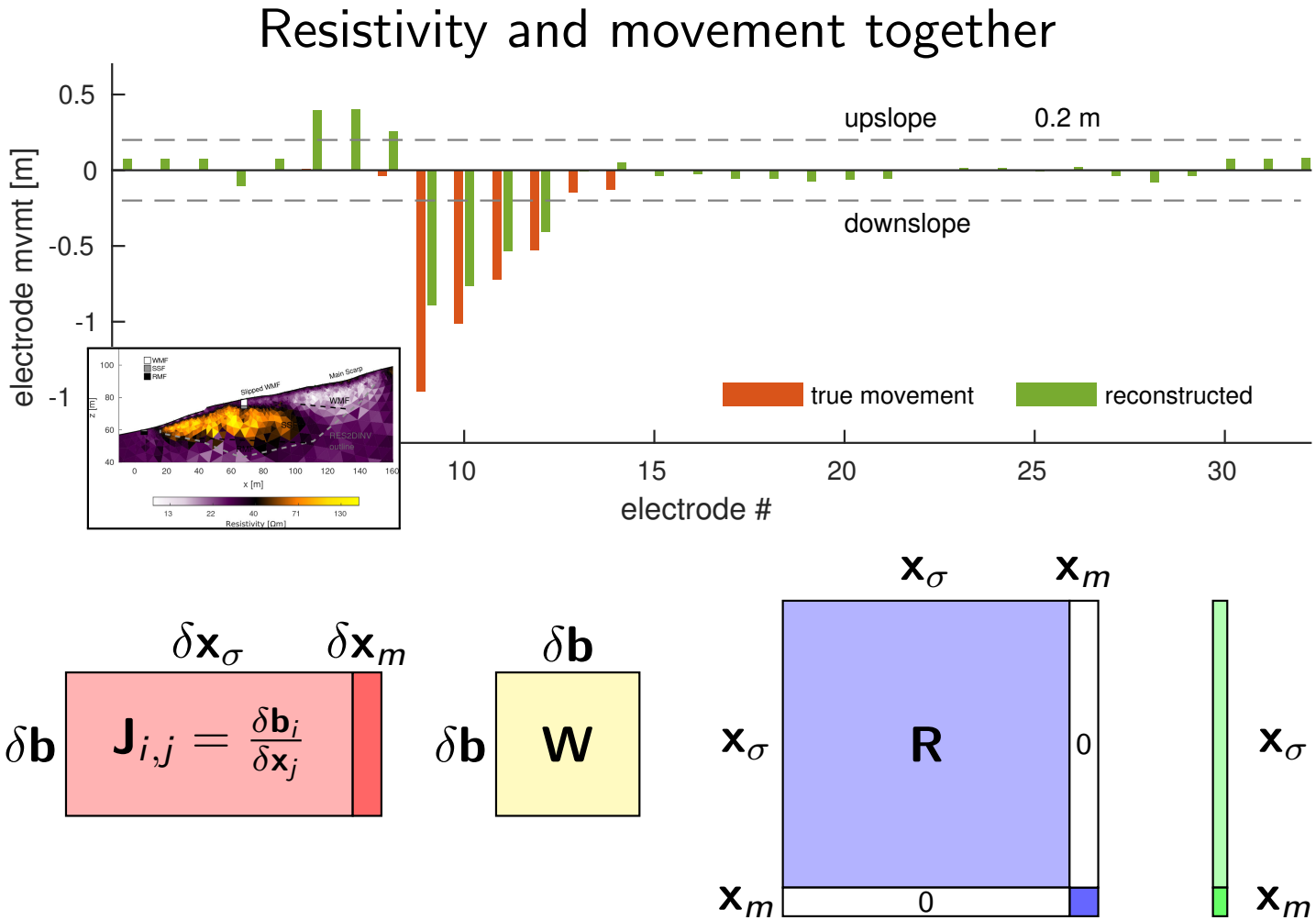
Methods



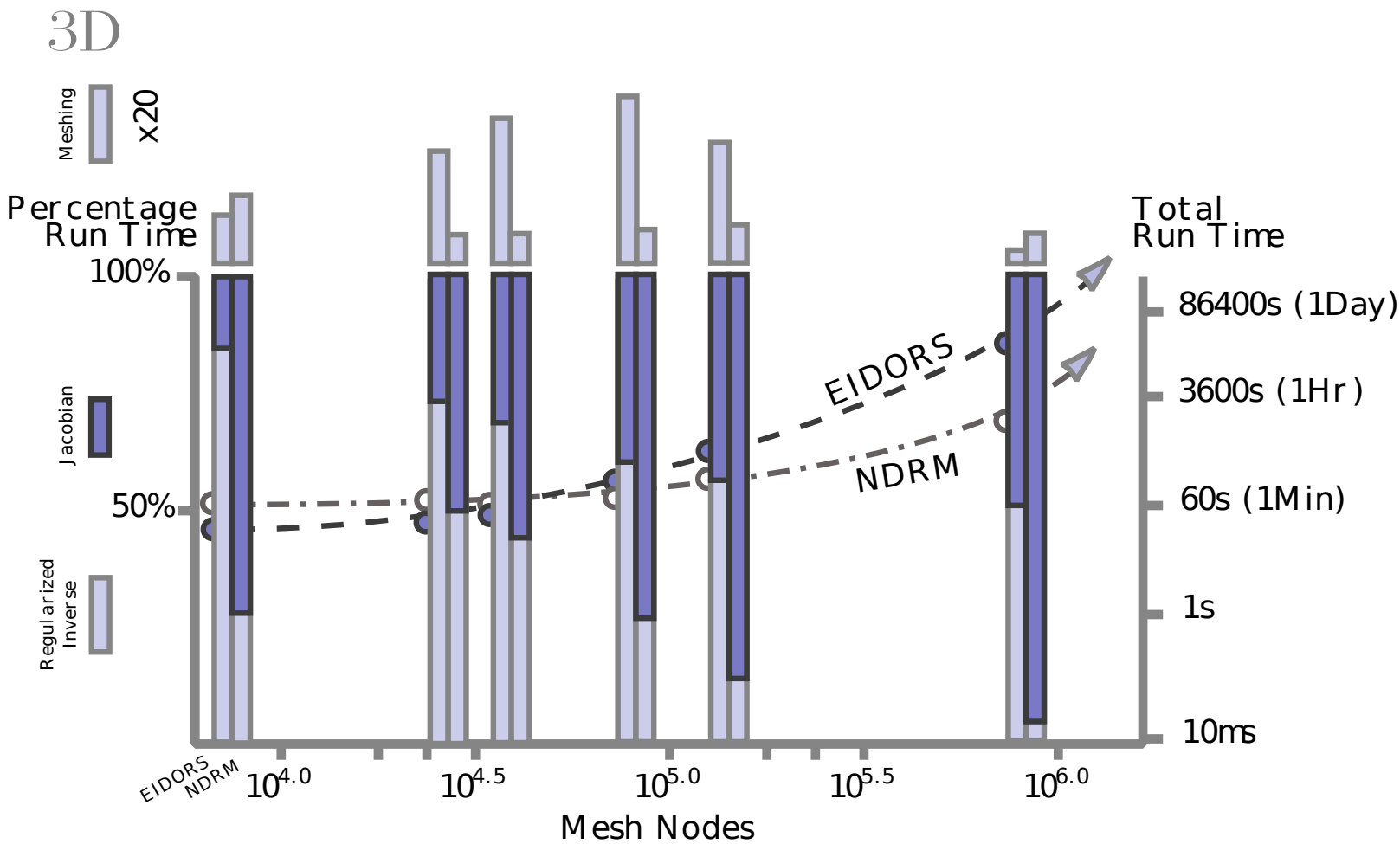
$$\delta\mathbf{b} \overbrace{\boxed{\mathbf{J}_{i,j} = \frac{\delta \mathbf{b}_i}{\delta \mathbf{x}_j}}}^{\delta\mathbf{x}} \quad \delta\mathbf{b} \overbrace{\boxed{\mathbf{W}}}^{\delta\mathbf{b}} \quad \mathbf{x} \overbrace{\boxed{\mathbf{R}}}^{\mathbf{x}} \quad \mathbf{x}$$

A. Boyle, P. Wilkinson J. Chambers, P. Meldrum, S. Uhlemann A Adler, Jointly reconstructing ground motion and resistivity for ERT-based slope stability monitoring, *Geophysical Journal International*, 212(2), 2018

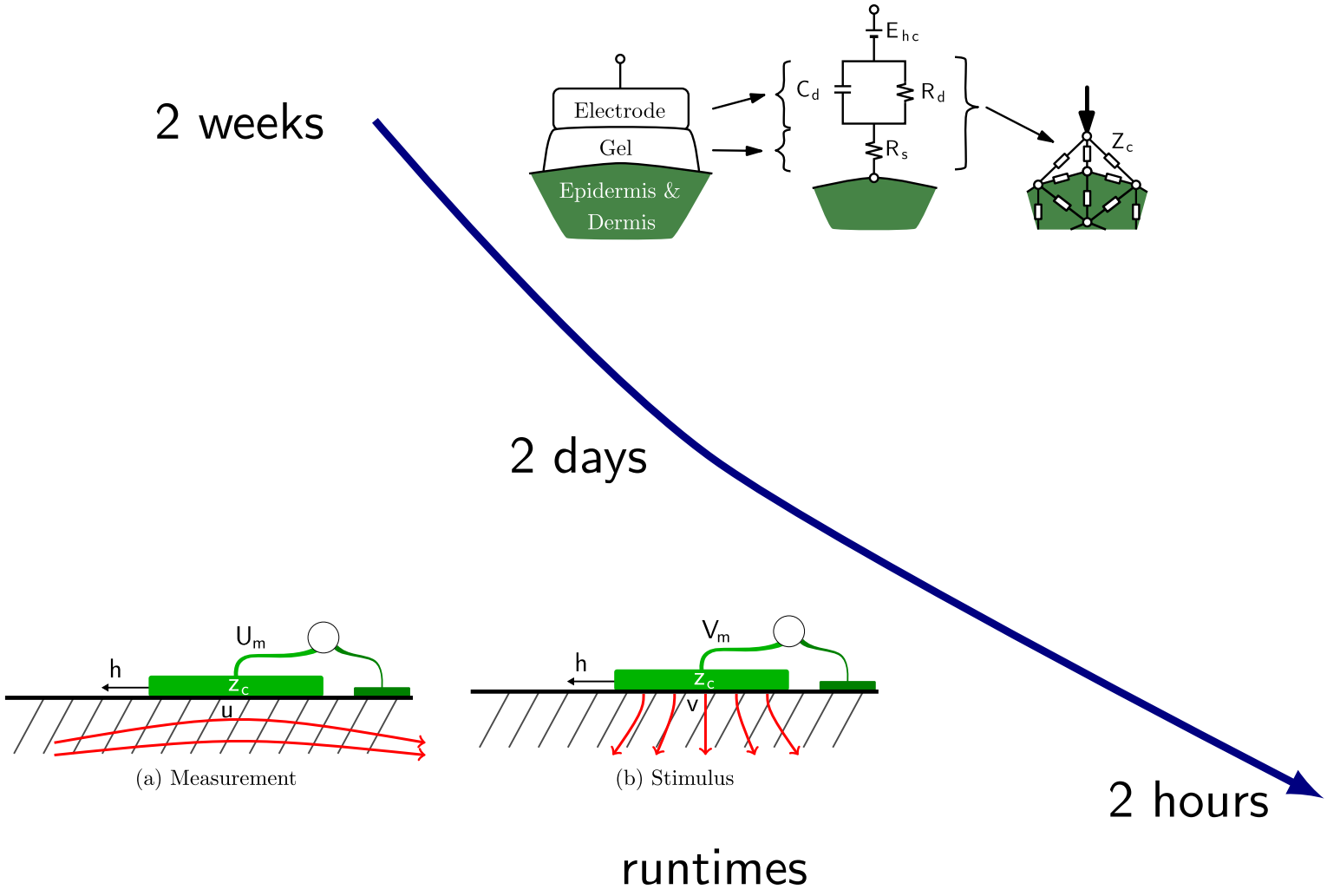
Methods



A Boyle, P Wilkinson J Chambers, P Meldrum, S Uhlemann, A Adler, Jointly reconstructing ground motion and resistivity for ERT-based slope stability monitoring, *Geophysical Journal International*, 212(2), 2018



A Boyle, A Borsic, A Adler, Addressing the Computational Cost of Large EIT Solutions, *Physiological Measurement*, 33(5), 2012



(a) Measurement

(b) Stimulus

A Boyle, A Adler, Impact of Electrode Area, Contact Impedance and Boundary Shape on EIT Images, *Phys. Meas.*, 32(7), 2011

A Boyle, M Crabb, M Jehl, W Lionheart, A Adler, Methods for Calculating the Electrode Position Jacobian for Impedance Imaging, *Phys. Meas.*, 38(3), 2017

Average 565 derailments per year, 80 with dangerous goods (Canada, 2010-2015)[2]
Gogama clean-up costs will be "in the millions" – MPP F. Gelinas[3]

[1] Transportation Safety Board of Canada, *Railway Investigation Report R13E0069*, Apr 2013

[2] Transportation Safety Board of Canada, *Statistical Summary - Railway Occurrences 2015*, Feb 2016

[3] M. Stackelberg, CBC News, *Ontario bills CN $350K for Gogama derailment clean-up*, Dec 2015

Mount Polley Mine, Likely, BC: spilled 4,500,000 m^3 of tailings[4] with clean up costs of \$200–500 mil.[5] (2014)
46 "dangerous or unusual occurances" 2000–2012 in BC[6]; 2–5 "major" tailings dam failures per year[7]

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[4] Indep. Expert Eng. Invest. & Review Panel, *Report on Mount Polley Tailings Storage Facility Breach*, 2015

[5] CBC News, *Mount Polley mine tailings spill*, Aug 2014

[6] G. Hoekstra, Vancouver Sun, *Liberals keeping dangerous occurrences at B.C. tailings ponds a secret*, Aug 2014

[7] M. Davies, et al., *Mine Tailings Dams: When Things Go Wrong*, AGRA Earth & Env. Ltd, 2002

What is the Systems Problem?

Long-term remote monitoring is a

- hard systems problem, and
- vital for Canada

Long-term, reliable remote monitoring can mitigate risks and enable timely response

flickr: druclimb, Toe of the Katzie Glacier, near Vancouver, BC, 2008

Could manage *ground stability* risks with

- a tool for real-time monitoring (prediction) of movement
- robust, reliable, informative reconstructions

Tool of choice:

Electrical Resistivity Tomography
Electrical Impedance Tomography

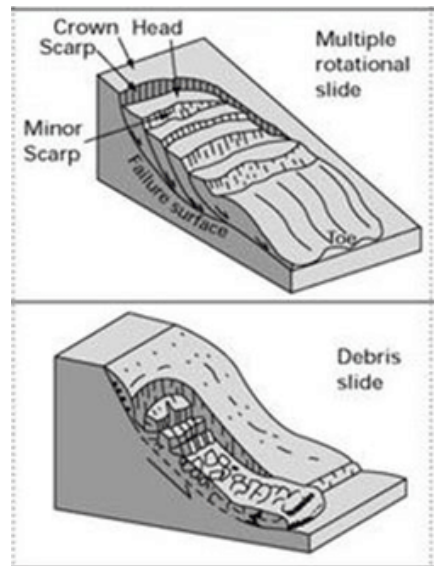


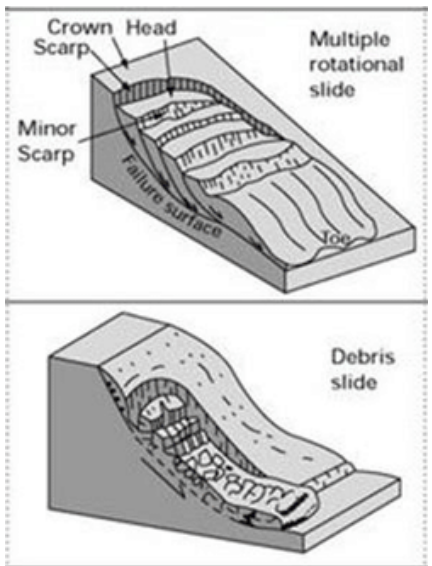
image: A Pitasi, Phd Thesis, Mediterranean University of Reggio Calabria, 2016

Could manage *ground stability* risks with

- a tool for real-time monitoring (prediction) of movement
  electrode movement & resistivity
- robust, reliable, informative reconstructions
  instrument, data, algorithm, implementation

Tool of choice:

Electrical Resistivity Tomography
Electrical Impedance Tomography



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