Distinguishability in EIT

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Distinguishability Question:
Based on $\Delta v$, can we tell if $\Delta \sigma$ occurred?
What is the significance of the test?
Detection Strategy

Use linear Reconstruction

Perform multiple measures

Including noise

Sum image in ROI => x
How to interpret

• Signal to noise ratio
  – This is an image SNR
  – We can calculate a Noise Figure (NF) as

$$ SNR_{\text{image}} = \frac{\bar{x}}{\sigma_x} $$

$$ NF = \frac{SNR_{\text{image}}}{SNR_{\text{data}}} $$

• Hypothesis test z-score
  – Determine \( p(\text{distinguishability}) \)

$$ z = \frac{\bar{x}}{\sigma_x} $$

• \( SNR / z \) depends on
  – Size of signal (\( \Delta \sigma / \text{stimulation current} \))
  – Data noise (for each channel)
  – Reconstruction algorithm

Want to avoid this dependence
Distinguishability from EIT data

- Equivalent to classic distinguishability formulations (Isaacson 86, Lionheart 01)
- Given a large ROI

\[ z = \frac{\bar{x}}{\sigma_x} = \frac{\bar{x}}{\sqrt{R_{ROI}^t \Sigma_n R_{ROI}}} = \bar{x} \sqrt{J_{ROI}^t \Sigma_n^{-1} J_{ROI}} \]

- \( R \) = reconstruction matrix,
- \( J \) = jacobian,
- \( \Sigma_n \) = channel noise

Doesn't depend on reconstruction
Distinguish current patterns

- Using the change in transfer impedance matrix ($T_\Delta$)

$$\Delta V = MT_\Delta C$$

- Measurements (differential)  
  - Current Patterns

- Noise norm for each current pattern

$$z = \bar{x} \sqrt{\| \cdot \|^2 + \| \cdot \|^2 + \cdots}$$

$$= C^tT_\Delta M^t\Sigma^{-1}MT_\Delta C$$
Choose current patterns

Why not just use the best pattern?

• Electrical safety constraint
  – Total current => bipolar drive
  – Current/electrode => Walsh patterns

• Need good distinguishability throughout the region of interest
  – For each pattern, for each region
    • Calculate $z$
  – Choose set of patterns which are globally optimal
Distinguishability for one pattern

Bipolar stimulation patterns

SNR

SNR order

Element has highest SNR for this pattern than any other
Distinguishability for pattern set

SNR order for complete Sequence of bipolar stimulation patterns

All Meas

Stim: [1-2]

Stim: [1-3]

Stim: [1-4]

No Meas on driven electrodes

Stim: [1-2]

Stim: [1-3]

Stim: [1-4]
For 16 electrodes

SNR:

- All Meas
- No stim meas

SNR order:

- All Meas
- No stim meas
Choosing optimal patterns

• For a given choice of region of interest, compare regions in terms of SNR
Distinguishability Question:
Based on $\Delta v$, can we tell if there are two or one objects? How close?
Detection Strategy #2

- SNR depends on noise and on resolution
- Idea: use same calc as for #1, but replace \( J_{\text{ROI}} \) by \( J_1 - J_2 \).