Selection of Stimulus and Measurement Schemes
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Abstract: The performance of an EIT system is determined by its ability to detect contrasting changes in a Region of Interest (ROI) (the sensitivity), while not being sensitive to those outside the ROI (the specificity). We propose a framework to measure system performance and show that this can be implemented as a minimax function over a Fisher linear discriminant on the system sensitivity.

1 Introduction

EIT uses patterns of current stimulation and voltage measurement (stim & meas patterns) to create images, and it is clear that the choice of stim & meas patterns is critical to the quality of the reconstructed images. Optimal $L_1$, $L_2$, and $L_\infty$-norm schemes have been considered for circular, two-dimensional domains \cite{1, 2}. Constructing optimal patterns that maximize the distinguishability of a conductivity contrast with a constrained total stimulation power ($L_2$-norm) results in trigonometric patterns which use many stimulus electrodes simultaneously \cite{3}. A restriction to pair-wise stimulus and measurement electrodes, common to many EIT hardware implementations, results in schemes such as the adjacent-drive and opposite-drive stim & meas patterns.

Sensitivity to a conductivity contrast, the Jacobian $J$, can be expressed as the change in a measurement $\delta V_m$ with respect to a small conductivity change $\delta \sigma$, as with the adjoint method

$$J_{i,j} = \frac{\delta V_m}{\delta \sigma_{i,j}} = \int_{\Omega} \sigma \nabla u \cdot \nabla v$$ \hspace{1cm} (1)

for a voltage distribution between stimulus electrodes $u$ and the voltage distribution if measurement electrodes were used as stimulus electrodes $v$.

In this work, we develop a generalization of the “distinguishability” approach and show how this can be interpreted as considering sensitivity and specificity across ROIs to achieve an appropriate trade-off between the two criteria.

2 Conceptual Approach

Our conceptual approach is shown in fig. 1. Here, we seek image contrast changes in a “true” ROI, $T$, while not being confused by changes in nearby “false” ROIs, $F_1$, $F_2$, $F_3$. If the EIT system makes measurements, $m_1$, $m_2$, then, including noise, the detected changes from each ROI are shown. Using Linear Discriminant Analysis (LDA), an optimal decision boundary can be defined, and a probability of error, $p(\epsilon)$, of false detection is calculated. The quality of the pattern is defined by the maximum error probability. Stim & meas patterns can then be compared, where the best pattern minimizes the maximum probability of error $p(\epsilon)$.

3 Example

As an example, a set of regions (red circles) in an inhomogeneous half-space with 4 electrodes (green circles) are considered (fig. 2). An initial stimulus and measurement pair can be selected based on minimizing the maximum distinguishability $z$ \cite{4}, but further choices are needed to balance sensitivity and specificity.

4 Discussion

The selection of optimal strategies has previously been focused largely on sensitivity. We propose an approach that can be used to select optimal stim & meas patterns that capture the trade-off between sensitivity and specificity.

In the limit, sensitivity is the Jacobian $J$ at a point on the domain. We observe that the concept of specificity is then intimately related to the partial derivatives of the Jacobian

$$\partial_{x_j} J = \nabla (\sigma \nabla u \cdot \nabla v)$$ \hspace{1cm} (2)

reflecting the variation in sensitivity between nearby points.

References
\begin{enumerate}
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