EIT Spatial Filtering in realistically shaped head models

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Abstract: We demonstrate the use of Spatial Filtering in EIT (EIT-SF) to estimate the time course and position of localized conductivity changes in the brain, when modelling ischemic stroke and neuronal activation. We compare the solutions obtained for three head models. Results support the use of EIT-SF to localize and characterize dynamic conductivity changes in the human brain.

1 Introduction

We showed in a previous study [1] that Electrical Impedance Tomography Spatial Filtering (EIT-SF) is able to localize a conductivity change within the brain. In this work we extend the results to estimate the time evolution of the conductivity change and analyze the use of approximate head models.

2 Methods

2.1 Simulated Signals

We simulated two different, dynamic, conductivity changes: a linear decrease up to 30% of the baseline conductivity (simulating ischemic stroke) [2], and a gaussian shaped pulse with a maximum of 10% of the baseline conductivity (simulating neuronal activity) [3]. Signals were simulated on a head model built from Magnetic Resonance images of a subject. The conductivity changes $\delta\sigma(t)$ were assigned to a $1cm$ radius sphere (Vol $\approx 4.22cm^3$) near the motor cortex (P1), the superior temporal gyrus (P2), and the insula (P3) (see Fig. 1a). We assumed 64 electrodes and 63 alternating current injection pairs (the Cz electrode fixed), resulting in a signal vector $y(t)$ of 3906 elements per each of the 21 simulated snapshots. The forward problems, i.e the computation of the electric potentials at the sensor positions, were calculated using the Finite Element Method, for a current of $100\mu A$. White additive gaussian noise (WGN) $n(t)$ with different standard deviations (Std Dev) was added to the signals to simulate noisy measurements. The model for a conductivity change $\delta\sigma(t)$ at position $\vec{x}_i$ is:

$$y(t) = l(\vec{x}_i)\delta\sigma(t) + n(t), \tag{1}$$

where $l(\vec{x})$ is the forward problem solution for a unitary conductivity change at position $\vec{x}$.

2.2 Linearly Constrained Minimum Variance (LCMV) filter

From the simulated signals, we performed the localization and time course estimation with three different head models: individual-specific (M1), atlas-based (M2), and three-shell concentric spherical (M3) models. The LCMV filter multiplies the signal by a weight vector $w(\vec{x})$ such that the output $w(\vec{x})^T y(t)$ is the unbiased estimator of $\delta\sigma(t)$ at position $\vec{x}$ with minimum variance. The LCMV filter is [1, 4]:

$$\widehat{\delta\sigma(t,\vec{x})} = w(\vec{x})^T y(t) = \frac{l(\vec{x})^T C_y^{-1} y(t)}{l(\vec{x})^T C_y^{-1} l(\vec{x})}, \tag{2}$$

where C_y stands for the sample covariance matrix of $y(t)$. For each situation we computed the Conductivity Change Index (CCI) (based on [4]) to study the localization, as the norm of $l(\vec{x})$ is a function of the position $\vec{x}$:

$$\text{CCI}(\vec{x}) = \frac{w^T(\vec{x}) C_y w(\vec{x})}{w^T(\vec{x}) w(\vec{x})}. \tag{3}$$

For M1 and M3, we performed a 9 parameter linear registration (translation, rotation, and scaling) to M2, adopting the electrode positions as the registration marks.

2.3 Results

The results are shown in Fig. 1. The localization errors were below $8.5mm$ for the M1 model ($0.1\mu V$ noise Std Dev), and the error when localizing with an approximate model was below $16mm$. The dispersion depends on the noise as depicted in Fig. 1a.

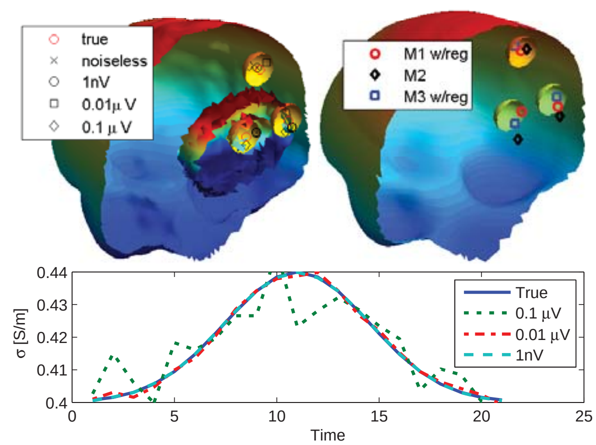

Figure 1: (a) Localization of the linear conductivity change using M1 for different noise levels. Two isosurfaces indicating dispersion are also displayed for the $0.1\mu V$ and $0.01\mu V$ noise Std Devs. (only P3). (b) Same localization but using the three models with registration to M2 and noiseless signals. (c) Normalized outputs for the gaussian pulse at P2 and with M2.

3 Conclusions

EIT-SF was used to successfully locate a conductivity change and to estimate its time course, even without using the individual-specific geometry. This suggests that EIT-SF is a promising technique to study ischemic stroke and neuronal activity.

References

[1] Fernández-Corazza M, von Ellenrieder N, Muravchik CH. *J Phys Conf Ser* **407**(1), 2012. Pp. 012023

[2] Horesh L. *Some Novel Approaches in Modelling and Image Reconstruction for Multi-Frequency Electrical Impedance Tomography of the Human Brain.* Ph.D. thesis, University College London, 2006

[3] Abascal JFP, Arridge SR, Atkinson D, et al. *NeuroImage* **43**(2):258 – 268, 2008

[4] Sekihara K, Nagarajan SS. *Adaptive Spatial Filters for Electromagnetic Brain Imaging*. Springer, Berlin, 2008

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