Temporal Reconstructions in EIT

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Abstract: EIT shows potential for monitoring fast changing conductivity profiles, such as heart and lung physiology and chemical processes. In such cases, the measurements which constitute an EIT frame are not taken simultaneously. Several approaches have been proposed to interpret such data, but have not been systematically compared. We formulate and compare temporal EIT solvers on simulation data.

1 Introduction

Electrical Impedance Tomography (EIT) has relatively low spatial resolution; however, it has a high temporal resolution, which offers the possibility to capture rapid physiological changes [1]. Thus EIT is used in applications where the underlying conductivity change is rapid compared to the frame rate. In this case, the data within a single EIT frame will not represent the same conductivity distribution. Measurement data $\mathbf{d}_i$ is measured at time t:

$$\mathbf{d}_i = \mathbf{J}_i \mathbf{m}(t) + \mathbf{n} \tag{1}$$

where $\mathbf{J}_i$ is the i^{th} row of the Jacobian (sensitivity) matrix, $\mathbf{m}(t)$ is the conductivity matrix at time t, and $\mathbf{n}$ is additive zero-mean noise, with covariance $\Sigma_\mathbf{n}$. Measurements made at nearby points – in both space and time – will "see" a more similar conductivity distribution than those further apart, and this is represented by a space-time covariance matrix, $\Sigma_\mathbf{m}$.

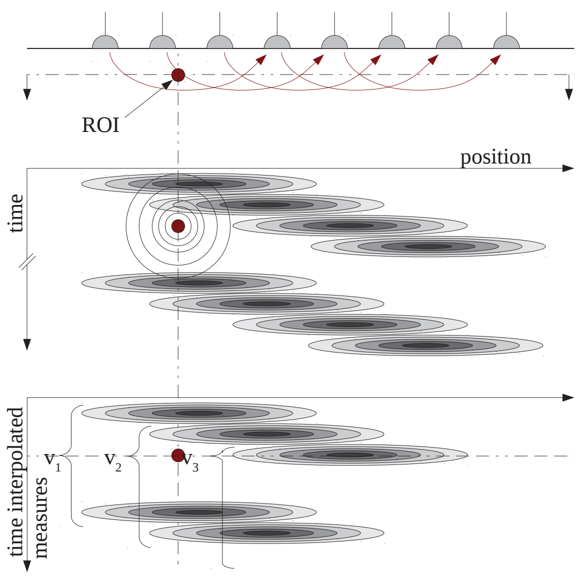

Figure 1: Block diagram of a geophysical EIT system with a temporal effect. *Top:* a ROI in a horizontal plane underneath a series of surface electrodes is imaged. *Middle:* a repeated set of measurements is made, and the sensitivity in space and time is illustrated. Temporal reconstruction uses a covariance matrix in space and time around the ROI (shown). *Bottom:* time interpolation reconstruction first calculates interpolated data (shown) before a traditional reconstruction.

2 Methods

Several approaches to account for temporal effects have been proposed, but have not been systematically compared. Our goal is to develop a framework for such comparison.

Using a Wiener filter formulation, EIT image reconstruction seeks to estimate an image $\hat{\mathbf{m}}$ where

$$\hat{\mathbf{m}} = \Sigma_\mathbf{m}\mathbf{T}^t\mathbf{J}^t(\mathbf{J}\mathbf{T}\Sigma_\mathbf{m}\mathbf{T}^t\mathbf{J}^t + \Sigma_\mathbf{n})\mathbf{F}\mathbf{d} \tag{2}$$

where $\mathbf{T}$ and $\mathbf{F}$ represent the temporal and interpolation filters. Fig. 1 illustrates a simple case of EIT measurements in one spatial dimension and time. Proposed approaches are:

- *Temporal ignorance* (not shown). Assuming that temporal effects are negligable. ($\mathbf{T}$ and $\mathbf{F}$ are both identity)
- *Temporal reconstruction* [2], in which the regularization prior is modelled based on the temporal and spatial effects in $\Sigma_\mathbf{m}$. ($\mathbf{T}$ represents the temporal covariance, while $\mathbf{F}$ is identity)
- *Temporal interpolation* [3], in which measurements are interpolated (using Fourier or linear schemes) to the reconstruction time of interest and then reconstructed using an algorithm without temporal information. ($\mathbf{F}$ is the interpolating filter, $\mathbf{T}$ is identity)
- *Kalman filtering* [4] (not shown).

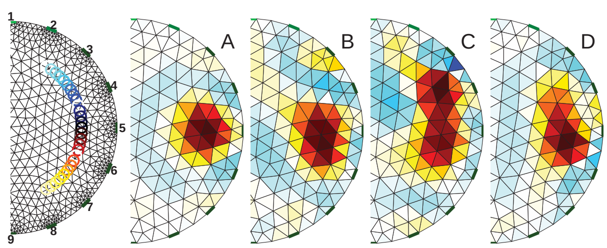

Figure 2: Simulation and Reconstruction images (on circular domain, half shown). *Left*: Simulation matrix, with an object moving from top (blue) to bottom (red) during three acquisition frames; the first acquisition of each frame is marked white; *A:* Reconstruction of a frame of data with the object still at 90° (reference image); *B:* Temporal ignorance; *C:* Linear temporal interpolation; *D:* Temporal reconstruction [2].

3 Discussion

When changes are fast, the EIT measurement frame conflates data from differing distributions. We seek to develop a framework to compare approaches to compensate for this effect. We simulate a relatively fast moving target, and, in this test scenario, images C and D correctly position the target, while B and D have the best spatial localization.

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