Temporal effects in EIT image reconstructions

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Abstract: Most EIT image reconstruction algorithms do not account for temporal effects such as non-instantaneous acquisition of data frames and temporal correlation between successive EIT images. We have recently published a framework for assessing the performance of reconstruction algorithms accounting for temporal effects. Results of applying this framework to five reconstruction algorithms and three types of EIT data frame will be presented.

1 Introduction

Most EIT image reconstruction algorithms assume that the conductivity distribution does not change during the acquisition of an EIT data frame and that there is no correlation between successive EIT images. In practice however, these assumptions hold only approximately as the heart is beating and the lungs are breathing during data acquisition and successive EIT images are correlated, especially at high frame rates. Some methods based on the Kalman filter [1], temporal EIT reconstruction [2] and interpolation of EIT measurements [3] have been proposed in the literature to account for those temporal effects. Recently, we have published a paper describing a comparison framework for temporal EIT image reconstructions [4]. By applying this comparison framework to different scenarios and reconstruction algorithms, we were able to visualize some artifacts and interesting results related to temporal effects in EIT image reconstructions.

2 Methods

Simulations are performed on a cylindrical geometry inside which a small spherical conductive target is inserted whose conductivity σ is varied as a function of time in the following manner:

$$\sigma(t_\mathrm{m}) = 1 - \frac{\cos(2\pi f_{\mathrm{c/m}} t_\mathrm{m} + \phi)}{2} + 0.01 \qquad (1)$$

where t_m is time expressed as measurement number, $f_{\mathrm{c/m}}$ is the frequency expressed in cycles per measurement, and ϕ is the phase shift between the conductivity variation and the instant corresponding to the first EIT measurement of the first EIT frame. The conductivity of the background cylinder is unity and kept constant over time. Since an EIT frame is composed of n_m measurements, the frequency expressed in cycles per frame $f_{\mathrm{c/f}}$ is equal to $n_\mathrm{m} \times f_{\mathrm{c/m}}$. Five figures of merit (FOM) are then defined [4]: temporal amplitude response (TAR), position error (PE), resolution (RES), shape deformation (SD), and ringing (RNG). The means and standard-deviations of each FOM are calculated over a number of complete cycles of equation (1).

3 Results

Simulations have been performed for three different types of EIT data frame: 1) perfect, 2) realistic and 3) interpolated [3], using five different image reconstruction algorithms: 1) backprojection, 2) Gauss-Newton, 3) GREIT [5], 4) Kalman filter [1], and 5) temporal reconstruction algorithm [2].

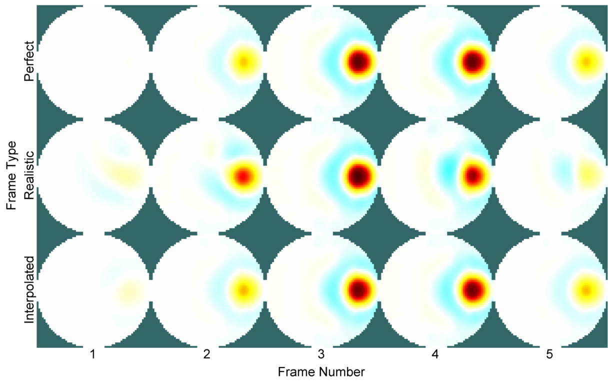

Figure 1: Images reconstructed on a sinusoidally varying conductivity target using the GREIT reconstruction algorithm and three different types of EIT data frame.

Figure 1 shows images reconstructed with the GREIT algorithm for three different types of EIT data frame: 1) perfect (top row), 2) realistic (middle row), and 3) interpolated (bottom row). The simulation parameters were: $f_{\mathrm{c/f}} = 0.2$, $\phi = 0$, number of cycles = 4 and sphere is located $2/3$ of the radius from the medium center. Ringing and shape deformation artifacts can clearly be observed while using realistic data frames (middle row) especially when the amplitude of the conductivity target is smaller. In this particular scenario, using interpolated frames reduces those observed artifacts.

4 Conclusions

Temporal artifacts and FOM worsening have been observed down to frequency as low as 50 times lower than the frame rate. FOM variations have been observed mainly as a function of type of EIT data frame, reconstruction algorithm, hyperparameter values, conductive target location, $f_{\mathrm{c/f}}$ and ϕ. Using the same framework, variations as a function of SNR have also been observed mainly as a function of reconstruction algorithm and type of EIT data frame. So far, no technique for accounting for temporal effects can be declared a clear winner as each performed best in some scenarios and worst in others. The framework is a nice tool to observe temporal effects and provide a reasonable explanation for previously observed image artifacts. It also provides a very useful tool for designing the next generation of algorithms accounting for temporal effects.

References

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