Statistical and deterministic approaches for electrode movement in lung EIT

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Abstract: Electrode movement can be a challenging issue in EIT modelling. In cases where the imaged region is changing, such as lung EIT, small artefacts may arise. To cope with this artefacts some deterministic and statistic approaches are available in the literature. In this work both are compared against expected electrode movement in lung EIT imaging.

1 Introduction

In lung EIT monitoring electrodes will slightly move from their position due to breathing. The mismatch between the simulated model and the real geometry of the patient can lead to some artefacts in image reconstruction. To account for the electrode movement a deterministic approach using an extended Jacobian and a statistical approach using approximation error models is available in the literature [1] [2]. The objective of the study is to compare both approaches in a realistic scenario.

2 Methods

2.1 Reconstruction algorithms

The inverse problem solution is expressed using an statistical approach as the Maximum A Posteriori (MAP). The error between the measured voltage V and approximated voltage (by the known model) $U_h(\sigma,\widetilde{\gamma})$ (where σ is conductivity and $\widetilde{\gamma}$ approximated boundary condition) is defined as η. If the prior and noise covariance matrix are defined as Γ_σ and $\Gamma_{\eta|\sigma}$ respectively and their Cholesky factors are L_σ and $L_{\eta|\sigma}$. The solution of the most likely conductivity values that maximizes the posterior distribution is described as

$$\sigma_{MAP} = \arg\min_{\sigma} \Big\{ ||L_{\eta|\sigma}(V - U_h(\sigma,\widetilde{\gamma}) - \eta_{*|\sigma})||^2 + ||L_\sigma(\sigma - \sigma_*)||^2 \Big\}. \quad (1)$$

This specific MAP description is generally refereed as MAP with approximation error model (MAP-AEM), as it includes the errors that are present in the system as noise.

The statistical approach to deal with predictable errors is to model the expected noise mean and standard deviation off-line[1]. Alternatively, an extended sensitivity matrix can be built in order to have a deterministic linear approximation of the movement of the electrodes with respect to the measured voltages [2].

2.2 Simulations

To compare the results, the electrode movement created by human breathing is simulated[3]. Additionally statistical modelling of standard deviation and mean of the noise are preformed. Then image reconstruction using the statistical and deterministic approach is performed.

2.2.1 Results

To evaluate the quality of the resulting images some performance figures are used, modified from the GREIT parameters [4] and image processing literature [5]. The robustness is the evaluated property in this work, therefore the coefficient of variation of the parameters for the whole breathing cycle is calculated, as in table 1.

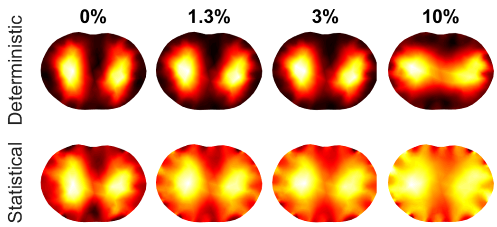

Figure 1: Deterministic (top) and statistical (bottom) approaches against amount of electrode movement in breathing. Movement of 0%, 1.5%, 3% and 10% o the boundary size.

3 Conclusions

This paper compares the statistical and deterministic approaches for electrode movement due to breathing. The AEM seems to have worse performance in general. A critical evaluation of AEM based method and deterministic method will be presented.

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References

[1] Kaipio JP, Kolehmainen V, Somersalo E, et al. *Inverse Problems* **16**(5):1487, 2000

[2] Soleimani M, Gómez-Laberge C, Adler A. *Physiol Meas* **27**(5):S103, 2006

[3] Zhang J, Qin L, Allen T, et al. *Open Biomed Eng J* **15**(7):109–15, 2013

[4] Adler A, Arnold J, Bayford R, et al. *Physiol Meas* **30**(6):S35, 2009

[5] Burger W, Burge MJ. *Principles of Digital Image Processing, Fundamental techniques*. Springer, 2009

Table 1: Mean and standard deviation of the coefficient of variation in performance figures of statistical and deterministic method.

	TA	RES	SD	RNG	Corr.	Mutual info.	Sharp.
Determ.	$12.6e^{-3} \pm 1.5e^{-3}$	$11.6e^{-3} \pm 1.6e^{-3}$	1.16 ± 0.11	0.26 ± 0.03	$16.1e^{-3} \pm 1.7e^{-3}$	$4.9e^{-3} \pm 0.5\, e^{-3}$	$21.5e^{-3} \pm 2.8e^{-3}$
MAP-AEM	0.1 ± 0.01	$43e^{-3} \pm 7.6e^{-3}$	0.8 ± 0.2	0.42 ± 0.06	0.19 ± 0.02	0.12 ± 0.01	0.33 ± 0.049