Region of Interest Guided Stimulation Pattern Selection Strategy for Electrical Impedance Tomography

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Abstract: The proposed method identifies an optimal set from all possible combinations of stimulation patterns for a fixed number of electrodes. The reconstructions using the optimal set achieve better localization within the region of interest compared to the common stimulation patterns.

1 Introduction

In electrical impedance tomography, stimulation patterns highly influence the attainable spatial resolution and distinguishability in a reconstruction [3]. Typically, these patterns are decided based on personal experiences and simulations. In this paper, we propose a methodology to select stimulation patterns such that we obtain high quality reconstructions in our region of interest (ROI).

2 Method

The proposed method has three steps. Given N electrodes, the number of possible pair-drive stimulation configurations are $N(N-1)/2$. We quantify the importance of each pair-drive for reconstructing a point target x (one mesh-element) in the ROI by calculating the goodness score

$$GS_k = \|\Sigma_k \, V_k^\top x\|_2 \tag{1}$$

where we use the SVD decomposition of the sensitivity matrix defined for the k^{th} pair-drive, *i.e.*, $J_k = U_k \Sigma_k V_k^\top$. In (1), we measure how well the basis functions represent the point-target, weighted with the singular values.

Now, we build an optimal stimulation set starting with the highest scored pair-drive. We add high scoring pair-drives one by one in the set until the criteria holds:

$$\text{Rank}(\bar{J}) \leq \lfloor s \, \text{Rank}(J) \rfloor \tag{2}$$

where the sensitivity matrix $\bar{J}$ is built with pair-drives in the optimal set and J with all $N(N-1)/2$ pair-drives. At each step, we eliminate high scoring pair-drives if they do not increase the rank of $\bar{J}$. It is likely that high scoring pair-drive sensitivity matrices are linearly dependent to each other.

The tuning parameter $s \in (0, 1]$ enables us to choose only the most important pair-drives if a high frame rate is desired for data acquisition. For $s = 1$, the optimal $\bar{J}$ is similar to J in the sense of the number of linearly independent vectors in the sensitivity matrix. The value of s can also be adjusted by analyzing the singular values of J.

In the last step, we repeat the first two steps for a number of targets covering the entire ROI. The union of optimal sets, identified for each point-target, is the final optimal set that we use for reconstruction of an object in the ROI.

3 Experiments

We define an ellipsoid ROI of semi-axis $(0.2, 0.2, 0.5)$cm at origin $(0, 0.5, 0)$ inside a cylinder of radius 1cm and height 1.4cm. Total $N = 2\times16$ electrodes are placed at two planes $z = \pm0.3$cm. We take single-ended measurements with respect to a reference electrode for each stimulus pair. We apply current stimulus at all electrodes but the reference electrode. Hence, the total stimuli are $S = (N-1)(N-2)/2$.

We reconstruct a 2D slice at $z = 0$ of a spherical target with 10% contrast of radius 0.15cm placed at $y = 0.5$cm and multiple heights h; see Fig. 1 for reconstructions with full stimulus patterns, popular skip-4 square pattern, and three patterns obtained with the proposed approach.

Measurements are with noise of variance 10^{-8}. We calculate regularization parameters λ using the image signal to noise ratio (SNR) measure with SNR = 0.5 [1].

The reconstructions are highly localized near to the reconstruction plane with both full and the proposed stimuli compared to the skip-4 pattern; as also illustrated through the GREIT resolution measure (lower is better) [2]. But, with the target further away from the reconstruction plane, performance decreases with a reduced number of patterns.

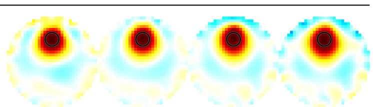
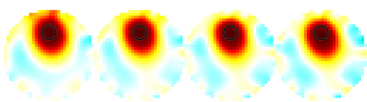
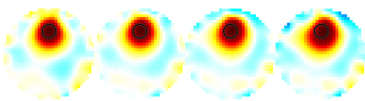
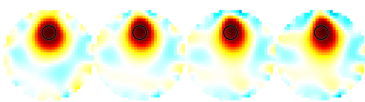
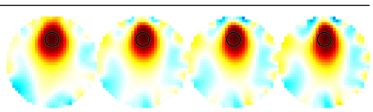
h from center	0.0	0.2	0.4	0.6
full pattern, S = 465, λ = 0.0738				
resolution	0.366	0.371	0.375	0.392
skip-4 square, S = 30, λ = 0.0769				
resolution	0.525	0.505	0.479	0.491
s = 1.0, S = 140, λ = 0.0737				
resolution	0.40	0.397	0.402	0.435
s = 0.6, S = 81, λ = 0.0737				
resolution	0.424	0.397	0.399	0.417
s = 0.2, S = 29, λ = 0.0727				
resolution	0.488	0.428	0.434	0.455

Figure 1: Reconstructions with five stimulation patterns. Black circle represents the ground-truth target position.

4 Conclusion

We proposed a method to obtain stimulation patterns targeting a specific ROI. Our results shows that highly localized reconstructions are possible through optimally selected stimulation patterns. Future work involves improving the method by removing redundancy in the optimal set.

References

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[3] A. Adler *et.al.*, *Physiol. Meas.*, 32(7):731-744 2011.