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Do we need to enforce the homogeneous Neumann condition on the torso for solving the inverse electrocardiographic problem?

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Introduction

- Robust calculations of the inverse electrocardiographic problem may require accurate specification of boundary conditions at the torso and cardiac surfaces [1].

\[ \text{div}(\phi) \mid _{\Omega_i} \]

Under:

- Dirichlet conditions: \( \phi \mid _{\Gamma_i} \)

(1)

- Homogeneous Neumann conditions: \( \partial_n \phi = 0 \) on \( \Gamma_i \)

The aim of the inverse problem is to find \( \phi \mid _{\Omega_i} \)

The classical formulation of the ECGI inverse problem with the method of fundamental solution (MFS) involves a linear system [2]. That can be split into two submatrices:

\[ (MFS) \]

The contribution of the submatrix \( B \) for convex optimization [3]. We solve this problem with SDPT3, a primal-dual path-following algorithm available on CVX package.

\[ \text{This is a saddle-point problem and we can introduce its Lagrangian} \]

\[ \text{The solution is found by solving the block linear system} \]

We solve this problem with SDPT3, a primal-dual path-following algorithm available on CVX package for convex optimization [3].

Compared with the standard MFS.

Results

- The respective contribution of \( B_0 \) and \( B_1 \) depends only on the geometry and location of sources (for which we used a fixed rule defined in [2]).

Comparison between the reconstructions

- The best activation time and CC maps were achieved by \( \lambda = 0 \) (MFS without Neumann conditions) and \( \lambda = 0.5 \) (Standard MFS).

Conclusions

- The results of MFS without Neumann condition are in better agreement with the original data. Furthermore, removing the Neumann conditions reduces the forward and inverse computational cost, since the size of the linear system is divided by 2 and the normal vectors do not need to be computed. The ill-posedness of the problem is reduced and consequently the problem is less sensible to the regularization.

- The Lagrange multipliers of method 2 were significantly higher on the electrodes on the front of the torso than on the ones on the back. This seems to indicate that partial or weighted Neumann conditions (depending on the position of the electrodes) can be explored further in order to refine the inverse problem and improve the resolution of the ECGI problem.

- Note that the results presented here only apply to the MFS method. However, preliminary work seems indicate that homogeneous Neumann conditions at the torso surface have a positive impact on the boundary element method.

- Finally, we used only 5 ventricular databases obtained by a numerical model. The case of complex atrial activations, and clinical data must be considered for a complete evaluation of the techniques proposed.

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References


