Flexible Numerical Platform for Electrical Impedance Tomography

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Abstract

Electrical impedance tomography (EIT) consists in probing biological tissues with low amplitude alternating electrical fields through surface electrodes, and analyzing the response of the medium to reconstruct its electrical characteristics. EIT has been considered for a wide range of clinical applications, the most promising being continuous pulmonary function monitoring.
In the EIT reconstruction process, numerical modeling enables (i) measurement prediction: it computes the expected voltages at the different detectors for each source, i.e. the projections; (ii) sensitivity analysis: it establishes how each elementary volume in the imaging domain will contribute to the measurements. Both constitute the forward problem, and are required for parameter estimation (the inverse problem).
For accurate forward modeling in EIT, the complete electrode model (CEM) has to be taken into account. It is usually presented as non-easily implementable in standard finite element method (FEM) libraries. This aspect together with the low requirements on the modeling (simple geometry, large regions of conductivity changes, real domain computations, first order shape functions, isotropy) has motivated the development of custom-built FEM packages. While these codes may be tuned for specific applications, focusing for instance on real-time capabilities, the exploration of new features proves tough to implement and debug.

In this work, the CEM is reviewed, and a means of implementing it into Comsol Multiphysics is proposed. Built-in parametric sweep allows addressing of the different electrode combinations, and the Livelink for Matlab provides flexibility for more intricate source-detector configurations. A method to perform the sensitivity analysis thereafter is also put forward. This defines a forward solver for EIT. Then, two options can be considered: (i) any EIT inversion algorithm can rely on this solver to fit the model to the data, e.g. running studies from Matlab; (ii) built-in Comsol Optimization module can perform the parameter estimation.
As for the forward problem predictions, a comparison is carried out against a standard EIT library in 2D and 3D. Results suggest that the proposed workflow is consistent and match those of previously developed libraries. Then, both options to recover the conductivity of the medium from data are explored. Eventually, reconstructions performed against in vitro data are presented to point out the completeness of the proposed numerical framework.
The Comsol Multiphysics environment hence suits the requirements for EIT forward modeling. Further, it offers the possibility, without necessitating numerous developments, to explore more sophisticated models that are able to take into account adaptive high density geometrically

accurate meshes, higher order shape functions, complex domain computations, complicated geometries, anisotropy, and to extend towards multimodality imaging.

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