Application of a Fast Parallel EIT Forward Solver to Study the Feasibility of Stroke Type Detection

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Abstract: We present an application of a newly developed fast parallel EIT forward solver (PEITS) implemented in C++. Its features are summarised and the installation, configuration and interface to Matlab are demonstrated. An application of the solver to a feasibility study of stroke type differentiation is illustrated. We found that precise positioning of the electrodes is critical for obtaining good images of stroke.

1 Introduction

Most research groups in EIT currently use the Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software EIDORS [1], which is programmed in Matlab. EIDORS provides many useful features, such as 2D and 3D forward simulations and an extensive collection of reconstruction algorithms, visualisation functions and more. Horesh et al. [2] adapted EIDORS with different preconditioners and more efficient routines, resulting in a version called SuperSolver. For large meshes, however, Matlab suffers from a lack of efficient parallel programming possibilities, which makes the computation of forward solutions a lengthy task. Last year we presented the implementation of a fast parallel forward solver using the complete electrode model, which is now available for free download [3].

2 Methods

2.1 Running PEITS

Used on a workstation or computer cluster, the *P*arallel *EIT S*olver (PEITS) reduces the computation times for the forward solutions and the Jacobian matrix significantly on large finite element meshes. A typical EIT application with 60 forward solutions and around 1000 protocol steps (i.e. 1000 lines in the Jacobian matrix) can be solved on 40 processors in 78 seconds on a 2 million element mesh, and in less than 18 minutes on a 15 million element mesh. Even on one processor we found PEITS to be twice as fast as an optimised version of EIDORS for an application on 2 million elements. This comes at the expense of less flexibility with regards to different applications, e.g. parallel current injection is not yet supported. PEITS is currently only supported on UNIX systems, where it can be easily installed following the guidelines on the website [3].

2.2 Feasibility Study

We are presenting the application of PEITS in a simulation study determining the main error sources in frequency-difference EIT imaging of stroke [4]. This study required 31 forward solutions on a 5 million element mesh for 12 different frequencies for each studied situation. In total this added up to more than 5000 forward solutions. On all 16 cores of a workstation with two 2.4GHz Intel Xeon CPUs with eight cores and 20MB cache each, the computation time for all forward solutions was around 300 minutes. The results of the study show that the precise positioning of electrodes is critical for good image quality. Even electrode misplacements as small as 1.3mm can lead to an image deterioration that makes the detection of a stroke impossible.

For the study, forward solutions were simulated on a fine 5 million element mesh with various errors on electrode position, electrode contact impedance and tissue conductivity at different frequencies. For the reconstruction the we used the frequency-difference fraction reconstruction method presented in [5] on a coarse 180k element mesh. The mesh we used included a scalp layer, a skull layer and a brain layer. We chose this simplified head geometry because we intend to reproduce the study in a tank and confirm our simulation results with experimental data.

3 Conclusions

We illustrate an application of a new fast parallel solver for the forward problem in EIT. It significantly reduces the time needed for simulation studies and EIT reconstructions on large finite element meshes. A feasibility study of frequency-difference EIT on a realistic head mesh has shown that it is very important to measure the electrodes positions with an accuracy of less than 1mm.

References

[1] Adler A, Lionheart W. *Physiological measurement* **27**(5):S25–42, 2006
[2] Horesh L, Schweiger M, Bollhöfer M. *Int J Inf Syst . . .* **2**(4):532–556, 2006
[3] Jehl M, Dedner A, Betcke T, et al. http://users.dune-project.org/projects/dune-peits/wiki, 2014
[4] Malone E, Jehl M, Arridge S, et al. *Submitted to Physiological Measurement* 2014
[5] Malone E, Sato Dos Santos G, Holder D, et al. *IEEE Transactions on Medical Imaging* 1–12, 2013