Efficient numerical methods for computer-assisted TMS & conductivity estimation

Nele De Geeter

Supervisors: Guillaume Crevecoeur, Luc Dupré

I. Introduction

Eddy-current simulations are needed for a wide spectrum of biomedical applications. Techniques whereby eddy currents interact with the biological system are Transcranial Magnetic Stimulation (TMS) and Induced Current - Magnetic Resonance Electrical Impedance Tomography (IC-MREIT).

II. Efficient numerical solver

A widely applied method for simulating the eddy currents is the impedance method. It discretizes the geometry into voxels and assigns material properties, represented as impedances, to each of them. This leads to a 3D network of impedances with the time-varying magnetic induction in each voxel as source model. However, the linear system of equations that have to be solved is ill-conditioned, leading to a long convergence time and an inaccurate solution or even in some situations to no solution at all. Therefore, we introduce an independent impedance method, whereby a set of independent equations is identified by defining independent loops in the 3D circuit using graph theory [1]. This improves the conditionality and speeds up the numerical convergence.

Computer-assisted TMS: TMS has become an important tool for the diagnosis and treatment of neurological diseases and psychiatric disorders. External coils are positioned above the head and create rapidly changing magnetic fields. These time-varying applied fields induce eddy currents and stimulate the human brain in a non-invasive way. However, the precise interaction mechanism of electric currents with the neurological system is still an open question and needs to be answered [2].

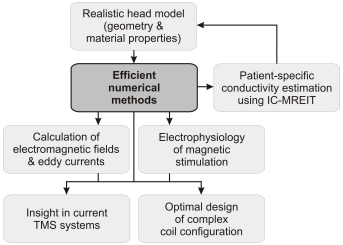

Figure 1. Overview of the objectives of this research.

IC-MREIT: IC-MREIT is a non-invasive technique for conductivity estimation. The MR scanner induces eddy currents into the brain which generate a magnetic field, measured by the MR scanner and function of the conductivity values. We propose a low-parametric procedure using a priori information, obtained by T1-weighted MR images, so to circumvent the ill-posedness of traditional IC-MREIT.

III. Conclusions

In this research, an efficient 3D eddy-current solver is proposed for bio-electromagnetic calculations. It is a useful tool for accurate and fast TMS simulations and conductivity estimation.

References

[1] N. De Geeter, G. Crevecoeur, and L. Dupré, "An efficient 3D eddy-current solver using an independent impedance method for transcranial magnetic stimulation", *IEEE Trans. Biomed. Eng.*, accepted for publication.

[2] T.A. Wagner, M. Zahn, A.J. Grodzinsky, and A. Pascual-Leone, "Three-dimensional head model simulation of transcranial magnetic stimulation", *IEEE Trans. Biomed. Eng.*, vol.51, pp.1586-1594, 2004.

N. De Geeter is with the Department of Electrical Energy, Systems & Automation, Ghent University, Gent, Belgium. E-mail: Nele.DeGeeter@UGent.be.