Summary

The Boundary Element Method (BEM) is widely used as a key computational technique to infer knowledge about the human cerebral activity, and in particular, to solve the forward problem of electroencephalography. Despite the many advantages that explain the popularity of the BEM, several challenges impede its application. Notably, the composite head medium has an electrically inhomogeneous and anisotropic conductivity profile, which, in the absence of specific treatment, can only be coarsely approximated by the standard BEM. Furthermore, the time and memory costs for a standard, non-accelerated numerical method become prohibitively large for dense meshes, which hamper the use of the BEM in high-resolution imaging applications.

This thesis presents a new inhomogeneity and anisotropy-handling formulation which addresses the modeling deficiencies of the BEM in bioelectromagnetic brain modeling. This is achieved by complementing the classical surface integral equations of the BEM with volume and wire integral equations that leverage the specific structure of the different head tissues. Then, a new algebraic fast solver method based on the adaptive cross approximation algorithm is developed to improve the computational complexity of the formulation. This acceleration method introduces and leverages a spanning tree of the set of quadrature points, allowing the single compression of several block matrices together and improving the overall computational cost of the proposed formulation. Finally, we investigate the application of the proposed techniques to an inverse problem of conductivity estimation in the context of electrical impedance tomography. We show in particular that they enable a higher flexibility in the modeling of the problem unknowns while retaining the advantages of BEM formulations.