BEM-FMM toolkit with adaptive mesh pre-refinement (*b*-refinement) for EEG forward modeling

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Introduction

This toolkit augments a fast-multipole-method-accelerated boundary element method (BEM-FMM) [1][2] by adaptive mesh pre-refinement (*b*-refinement) [3] to accurately solve an EEG forward modeling problem on a realistic head model with approximately 1 M facets. On standard server hardware (3 GHz CPU), the solution can typically be obtained in just over 1 minute. AMR increases the model size by 10% to 15%. For a detailed explanation of the method and accuracy benchmarks, please see [3]. If you use this toolkit in your research, please also cite [3].

This toolkit is made available under GNU GPLv3.

Quick Start Guide

To function, this toolkit requires MATLAB R2023a or newer with the Parallel Computing Toolbox and the Statistics and Machine Learning Toolbox. If you use this toolkit in your research, please cite [yet to be published].

Scripts are to be executed *sequentially*, without clearing the MATLAB workspace in between.

1) Download the contents of the GitHub repository to the local machine
2) Open MATLAB to the main folder.
3) Construct and prerefine the head model by:
   a. Changing MATLAB's working directory to the "Model" subfolder
   b. Executing model1_setup_base_model.m
   c. Executing model2_add_AMR.m.
4) Change the working directory to the main folder
5) Execute bem1_setup_solution.m to initialize parameters for the integrals and solver
6) Compute head model self-interaction integrals by executing bem2_setup_integrals.m.
7) Solve the forward problem by executing bem3_charge_engine.m
8) Observe fields on the scalp surface by executing:
   a. bem3_surface_field_b.m for the magnetic field
   b. bem3_surface_field_c.m for the charge density distribution
   c. bem3_surface_field_p.m for the potential distribution

To obtain a solution using the base 1M facet model without adaptive *b*-refinement, follow the same process but exclude (3c).

References

[1] Makarov SN, Noetscher GM, Raij T, Nummenmaa A. A Quasi-Static Boundary Element Approach with Fast Multipole Acceleration for High-Resolution Bioelectromagnetic Models. IEEE Trans Biomed Eng. 2018 Mar 7. doi: 10.1109/TBME.2018.2813261.

[2] Makarov SN, Hamalainen M, Okada Y, Noetscher GM, Ahveninen J, Nummenmaa A. Boundary Element Fast Multipole Method for Enhanced Modeling of Neurophysiological Recordings. IEEE Trans Biomed Eng. 2021 Jan;68(1):308-318. doi: 10.1109/TBME.2020.2999271.

[3] (Awaiting publication)