Universität Rostock Traditio et Innovatio

Bachelor or Master's Thesis

A boundary element approach for the computation of electric fields in cell cultures

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Predicting the electric field in cell cultures [1] is challenging: due to the large number of cells (> 10 000), standard finite element approaches result in an (ill-conditioned) linear system of equations with several millions of unknowns, which are cumbersome to solve. Since we are typically interested in computing the potential on the surface of the cells, a high resolution discretization of the surface is necessary. This can lead to non-uniform meshes that are additionally challenging for standard finite element approaches.

In this thesis, we will investigate an approach based on the boundary element method [2], [3]. In contrast to the finite element method, only the surface of the cells will be discretized, which drastically reduces the computational cost while yielding higher accuracy compared to a finite element approach. An open source framework (bempp-cl) shall be used, which allows to conveniently use integral operators [4].

This thesis can be conduced either as a master's thesis or as a bachelor's thesis with a more limited scope.

Tasks:

- Establishment of mathematical formulation;
- Implementation using bempp-cl;
- Validation using analytical formulae;
- Benchmarking against finite element code;
- Analysis of large problems on university cluster.

Prerequisites: Interested in bridging theory and experiments. Solid mathematical background and programming skills, preferably in Python. Experience with UNIX-like operating systems (Linux, MacOS, etc.) is a plus.

References

[1] A. Tveito, K.-A. Mardal, and M. E. Rognes, *Modeling Excitable Tissue: The EMI Framework*. 2021.

[2] S. A. Sauter and C. Schwab, *Boundary Element Methods*, ser. Springer Series in Computational Mathematics 39. Berlin: Springer, 2011, 561 pp.

[3] A. Di Biasio and C. Cametti, "Effect of shape on the dielectric properties of biological cell suspensions," *Bioelectrochemistry*, vol. 71, no. 2, pp. 149–156, Nov. 1, 2007.

[4] T. Betcke, M. W. Scroggs, and W. Śmigaj, "Product algebras for Galerkin discretisations of boundary integral operators and their applications," *ACM Transactions on Mathematical Software*, vol. 46, no. 1, 4:1–4:22, Mar. 20, 2020.