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SIMULATING CARDIAC FUNCTION WITH CELLULAR AND SUBCELLULAR RESOLUTION

TRACK NUMBER 500 (COMPUTATIONAL APPLIED MATH) OR 1700 (NUM METH & ALGO IN SCI & ENG) OR 1800 (SCI COMP)

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ABSTRACT

The electric excitation of the myocardium is a pivotal mechanism for sustaining proper cardiac function. Related diseases such as arrythmias or atrial fibrillation have major impact on heart failure and infarction, and thus are a significant source of mortality in developed countries. Numerical simulation of cardiac excitation mechanisms helps understanding of disease onset and progression, and is therefore an invaluable tool for improving diagnosis and therapies.

Established models such as the bidomain and monodomain models homogenize the myocardium for describing the electrical activation in terms of a reaction-diffusion system. While they are very successful in reproducing many effects and mechanisms, some aspects caused by heterogeneous microstructure of the myocardium cannot be captured. This includes heterogeneity on the cellular scale as present in fibrosis, spatial distribution of ion channels and gap junctions, or shape and interconnection of myocytes.

For that reason, detailed models representing the discrete cellular structure of the myocardium have recently gained attention. The most prominent example is the EMI model [1], representing all myocytes as individual subdomains, and treating the nonlinear dynamis of ion channels only on the membranes, i.e. the subdomain interfaces. These models are also used, with different ion dynamics, for describing neural activation with subcellular resolution.

Further modeling directions are towards detailed models of single myocytes, the impact of cellular resolution on mechanics, or gap junction function.

Such models pose new challenges for simulation: significantly increased size due to increased resolution, dimension-heterogeneous structure, and only piecewisely continuous solutions. They call for new or adapted approaches for numerical simulation with a perspective towards high performance computing.

This minisymposium will present a forum for presenting new results and methods for simulating EMI and similar models in relevant areas such as space and time discretization approaches, adaptivity, heterogeneous model coupling, iterative solvers, or domain decomposition preconditioners. Potential contributions include, but are not limited to, new finite volume schemes for EMI models, boundary element and static condensation approaches, stabilized explicit Runge-Kutta schemes, spatial adaptivity with SDC time stepping, BDDC and block preconditioners adapted to the EMI geometry, or high-performance GPU implementation of preconditioned Krylov solvers.

REFERENCES

[1] A. Tveito, K.-A. Mardal, M.E. Rognes. Modeling Excitable Tissue: The EMI Framework. Simula Springer Briefs on Computing 7, 2021.