15th International Conference on Domain Decomposition Methods
July 21-25, 2003, Berlin, Germany

A Parallel Solver for Reaction-Diffusion Systems in Computational Electrocardiology

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Abstract: In this work, a parallel solver for numerical simulations in computational electrocardiology in three dimensions is introduced and studied. The solver is based on the anisotropic Bidomain cardiac model, consisting of a system of degenerate parabolic reaction-diffusion equations describing the intra and extracellular potentials of the myocardial tissue.
This model includes intramural fiber rotation and anisotropic conductivity coefficients, that can be fully orthotropic or axially symmetric around the fiber direction. In case of equal anisotropy ratio, this system reduces to the simpler anisotropic Monodomain model, consisting of one reaction-diffusion equation describing the transmembrane potential only. These cardiac models are coupled with a membrane model for the ionic currents, consisting of a system of ordinary differential equations that can vary from the simple FitzHugh-Nagumo (FHN) model to the more complex Luo-Rudy phase I (LR1) model.
The solver employs structured isoparametric Q_1 finite elements in space and a semi-implicit adaptive method in time. Parallelization and portability are based on the PETSc parallel library.
Large-scale computations with up to $O(10^7)$ unknowns have been run on parallel computers, simulating excitation and repolarization phenomena in three dimensional domains.

Type of contribution: Talk
Location: Lecture Room, **Time:** Monday, 21 July, 11:00

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