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High performance computing for computational electrocardiology. Part I: motivation and mathematical models.

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Life sciences could benefit immensely from the massive growth of HPC processing power occurred in the last ten years. Indeed, complex biological systems are described by sophisticated mathematical models, whose solution requires highly scalable solvers. In particular, for what concerns cardiac electrophysiology, the simulation of the electrical excitation of the heart muscle, and the subsequent contraction-relaxation process, represents a challenging computational task. In the present talk, we will describe the main mathematical model of the cardiac electrical and mechanical interactions, the so-called cardiac electro mechanical coupling model. This model consists of a system of non-linear partial differential equations (PDEs), constituted by four sub-models: the quasi-static anisotropic finite elasticity equations describing the macroscopic deformation of the cardiac tissue; the active tension model, i.e. a system of ordinary differential equations (ODEs) describing the intracellular calcium dynamics and the consequent generation of the cellular force; the anisotropic Bidomain model, i.e. a system of degenerate parabolic reaction-diffusion PDEs describing the electrical current flow through the tissue; the membrane model, i.e. a stiff system of ODEs describing the bioelectrical activity of the membrane of cardiac cells. We will finally present the results of three-dimensional simulations of the full cardiac excitation-contraction process.

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