Microanatomically realistic Bidomain Models of the entire Heart  
A largescale parallel Computing Approach

Within the last decade, computer models of the cardiac activation process have become an indispensable complementary tool to electrophysiological experiments for the investigation of phenomena like the formation of arrhythmias (arrhythmogenesis) and their termination with electrical shocks (defibrillation).

In recent years, computer models of atria and ventricles of different species have been developed, however, most of these models used a computationally significantly less demanding monodomain simplification which does not capture electrophysiologically important mechanisms. State of the art models are a trade-off capturing either the anatomical gross anatomy at a limited spatial resolution or they represent particular regions of limited size, but incorporate microscopical details. Many questions of major importance in cardiac electrophysiology, however, require both macroscopic accuracy, microstructural details and the use of a bidomain formulation.

To develop virtual heart simulators which allow bidomain studies using both microscopically and macroscopically accurate computational grids for species ranging from the mouse to humans, major methodological improvements are key to succeed. In this presentation, several techniques will be suggested demonstrating a viable approach to develop cardiac simulators which come closer to a “Virtual Heart”. Three key techniques will be presented: 1) The use of largescale parallel computing approaches and efficient solvers for the elliptic problem associated with te bidomain equations, 2) Multi-modal imaging techniques allowing to combine image stacks obtained with different imaging modalities like MRI and serial histological sectioning, and 3) Advanced meshing methods which allow an automatic adaptive mesh generation to obtain smooth representations of cardiac surfaces and to reduce the computational burden by decreasing the spatial resolution with distance to epicardial and endocardial surfaces.