Modelagem Computacional

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Universidade Federal de Juiz de Fora

Workshop on Computational Modeling of the Heart

November 19, 2010

Graduate Program in Computational Modeling
Universidade Federal de Juiz de Fora, Brazil

Organization:
Prof. Dr. Rodrigo Weber dos Santos, Pós Graduação em Modelagem Computacional, UFJF

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Support:
Universidade Federal de Juiz de Fora. Pós-Graduação em Modelagem Computacional. Instituto de Ciências Exatas. Faculdade de Engenharia. CAPES/MEC.

Program

Location: Anfiteatro Escadinha – Faculdade de Engenharia - UFJF

14:00-15:00

Prof. Dr. Gernot Plank, University of Graz, Austria

“Modeling Cardiac Electrophyiology at the Organ Scale in the Peta (Exa) FLOPS Computing Age”

Research in cardiac electrophysiology aims at developing anatomically realistic and biophysically detailed computer models of integrated cardiac function. The computational cost of these simulations is high due to the spatio-temporal characteristics of electrical impulse propagation in the heart. Transients in the heart are fast, requiring high temporal resolution, and wavefronts are steep, necessitating fine spatial resolution. Combined, these two factors result in large systems of equations that have to be solved thousands of times in order to simulate a single heart beat. Despite a steep increase in the available compute power, execution times remain to be significant when engaging such detailed models. Next generation HPC resources promise to deliver much better performance in the PetaFLOPS or even ExaFLOPS range, but current trends clearly indicate that performance gains can only be expected from engaging a much larger number of compute cores. This necessitates strongly scalable numerical techniques which can take advantage of tens of thousands of cores. This talk will give an outline of these challenges and present first results which enabled the simulation of a single human heart beat in less than 5 minutes using 16 thousand cores on a current national supercomputing facility.

15:00-15:30

MSc. Bernardo Rocha, LNCC

“Accelerating Cardiac Simulations Using Graphics Processing Units”

The modeling of the electrical activity of the heart is of great medical and scientific interest, because it provides a way to get a better understanding of the related biophysical phenomena, allows the development of new techniques for diagnoses and serves as a platform for drug tests. Cardiac electrophysiology may be simulated by solving a partial differential equation coupled to a system of ordinary differential equations describing the electrical behavior of the cell membrane. The numerical solution is, however, computationally demanding because of the fine temporal and spatial sampling required. The demand for real time high definition 3D graphics made the new graphic processing units (GPUs) a highly parallel, multithreaded, many-core processor with tremendous computational horsepower. It makes the use of GPUs a promising alternative to simulate the electrical activity in the heart. The aim of this work is to study the performance of GPUs for solving the equations underlying the electrical activity in a simple cardiac tissue. In tests on 2D cardiac tissues with different cell models it is shown that the GPU implementation runs 20 times faster than a parallel CPU implementation running with 4 threads on a quad–core machine, parts of the code are even accelerated by a factor of 180.

15:30-16:00

Bernardo Lino, UFJF

“Quantitative Modeling of Cardiac Electromechanics”

The objective of this work is the study and development of new models for the electromechanical coupling of cardiac cells and tissues, in particular for the left ventricle, which is the main structure responsible for pumping blood to the body. This work can be divided in two main steps:

1) The development of a new model for the electromechanics of human left ventricle cardiac myocytes, based on the coupling of two existing models, one for the electrophysiology and another for the myofilament active force generation. On the development of this model optimization techniques like genetic algorithms where used for the parameter adjustment to reproduce the few experimental data available in the literature.

2) This model was embedded in larger scale electromechanical simulations, i.e. tissue level. This work treats the numerical and methodological problems that the coupling brings. Furthermore, we analyze the influence of the mechanical deformation in important eletrophysiological features, such as the waveforms of ventricular electrograms.

16:00-16:30

Ricardo Silva Campos, UFJF

"A Numerical Method with Adaptive Time Step for Solving Cardiac Cell Models”

At cellular level, the electrical activity of the heart may be simulated by solving a system of ordinary differential equations (ODEs). Because the biophysical processes underlying this phenomenon are nonlinear and change very rapidly, the ODE system is challenging to solve numerically. The aim of this work is to implement an explicit numerical method with adaptive time steps, in order to speed up cardiac simulations. The method consists in calculating each iteration with two different numerical methods, the Euler and the Runge Kutta 2nd order methods. The next time step size is estimated by calculating the relative error between the solutions obtained by the two methods. This scheme allows the use of small time steps when the solution is more sensitive but larger steps when the solution does not significantly changes between time steps. Comparing to traditional fixed time step methods, we obtained speedups between 3 and 50, for the simulation of different cardiac cell models.