GPU-based High Performance Wave Propagation Simulation of Ischemia in Anatomically Detailed Ventricle

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Action potential propagation simulation of ischemia in 3D anatomically detailed ventricle is valuable in studying the mechanisms and dynamics of ischemia-induced re-entry and arrhythmia. However, such simulations are computationally intensive, which make efficient numerical solution urgently necessary. In this work, using Graphic Processing Unit (GPU) based high performance computing, we study the action potential propagation simulation of ischemia from three aspects: anatomically detailed electrophysiology modeling, GPU based efficient simulation, and rendering of simulation results, which are further explained as follows: (1) We adopt Ten Tusscher (2006)'s electrophysiologically detailed cell model for human ventricular cells, and refer to the recent electrophysiological data to determine the influence of mild or severe ischemia. Based on the cell model, we present an integrative model of the anatomically detail human ventricle, where the data are provided by the Visible Human Project. (2) Using NVIDIA Tesla C1060 and CUDA (Compute Unified Device Architecture), we explore GPU computing system to accelerate the cardiac electrophysiology simulation. Owing to the spatial locality of cardiac tissue, we take advantage of texture memory which can improve performance and reduce memory traffic. To deal with the no-flux boundary conditions automatically, we choose the phase-field method by introducing an auxiliary field. (3) We adopt the GPU ray casting algorithm to simultaneously render the simulation results from GPU, and thus avoid the GPU-CPU data transfer in conventional CPU based simulation. Simulation results show that hyperkalaemia has significant effect on the spatial heterogeneities of the action potential propagation, and the more severe of the ischemia, the more instability of spiral waves. Moreover, the simulation speed of our GPU based method can be over 20 times faster than that of conventional CPU based method. At last, by directly using GPU, the proposed method has the advantage of showing the simulation results on the fly.