An Adaptive Step Size GPU ODE Solver for Simulating Electric Cardiac Activity

Victor M Garcia, Alejandro Liberos, Andreu M Climent*, Antonio Vidal, Jose Millet and Alberto Gonzalez

DSIC
Universitat Politecnica de Valencia

Simulation of electric cardiac activity requires the solution of a large system of ordinary differential equations (ODEs). Depending on the mathematical model, 15 to 40 differential equations must be solved for each node, and a realistic model may include millions of nodes. Consequently, the computing power needed to simulate just a few seconds of cardiac activity is huge. Graphic Processing Units (GPU) have emerged as a powerful and economical option to solve these mathematical models. However, GPUs are relatively difficult to program, therefore only fixed step ODE solvers have been developed. In this study, an adaptive step solver implemented in CUDA language is presented. Specifically, a second order explicit method has been developed. The calculations were split in two computing kernels, a large kernel to compute the data for all cells and a small kernel to compute the new time step. The performance of the method was tested by using a mathematical model of 300 human atrial cells. The presented methodology was compared with an Euler fixed step solution implemented in a CPU and in the same GPU (e.g. GPU-NVIDIA-Fermi). Different implementations were tested by simulating 10 second of the model; the execution time and the root mean square error introduced by the adaptive method were measured. The CPU solution with a fixed step of 0.005ms needed 2077 seconds in a Dual-Core CPU 3GHz with RAM 4GB. Fixed step and adaptive step GPU solutions needed 118 and 92 seconds respectively. The mean error introduced by the adaptive method was 0.2 ± 1.3mV. Results presented in this study show that a robust adaptive step ODE solver can be implemented in a GPU. As expected, GPU implementations achieved much better performance than CPU solutions. In added, the presented adaptive methodology achieved a computation time reduction up to a 20% versus a fix step implementation.