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The Instabilities of Spiral Waves Due to Their Chirality in Anisotropic Cardiac Tissue Using CUDA

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Heart disease is the predominant cause of death in the industrialized countries. Half of cardiac conditions, particularly those involving ventricular fibrillation (VF), result in cardiac arrest and death. Ventricular tachycardia (VT) is associated with several reentrant or spiral electrical waves that rotate at a different frequency other than the pacing frequency of the sinoatrial node. This electrical wave results in fast contractions and reduced efficiency in pumping blood. The process by which VF develops, progresses, and can terminate are not clear. Hence, a combination of experimental, theoretical and computational work is required to have a better understanding of the electrical dynamics.

In the past decades, the fast development of optical mapping technique enables the visualization of electrical signals on tissue surface, however the signals inside the tissue remain undetectable. Therefore, in this study, we approach the problem using mathematical models, which enable us to investigate the complex dynamics of the reentry waves intramurally.

Several physiological conditions have been proposed to initiate VF. Such conditions include electrical conduction blocks and spiral wave phase singularity twisting. We explored the effect of the chirality of the spiral wave on the stability of the system by focusing on quantifying spatio-temporal chaos and spiral wave breakup as a function of spatial properties such as the thickness of the tissue and the rotation of the myocardium fiber. We restricted our work to studying the dynamics of phenomenological models such as the 3V-Fenton-Karma and the 4V-Bueno-Orovio cardiac models because of their simplified equations, reduced set of parameters, and realistic dynamics.

To achieve real-time 3D simulations with anisotropic conductivity, we used high performance GPU (graphic processing units) programing library CUDA (Compute Unified Device Architecture). The use of GPU's allows us to obtain results with a much higher resolution (domains of 256^3 and 512^3 grid points) and at a speed 10 to 100 times faster than standard serial implementations. In addition, we tested the performance of parallel implicit and explicit numerical solvers and compare them to their serial counterparts.