Automatic Location of Phase Singularities in Cardiac Spiral-wave Reentry Simulation

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Cardiac fibrillation is one of the leading causes of death in the industrialized world. Cardiac arrhythmias can be sustained by a number of reentry or spiral waves of electrical activity, and thus tachycardia or even cardiac fibrillation may be produced. Spiral waves continuously propagate into recovered tissue and rotate around a central core. Spiral-wave reentry could be unstable, and spiral waves can break up to multiple spiral waves, which are similar to wave fronts observed during cardiac fibrillation.

The identification of phase singularities (PSs) is essential in defining spiral waves and analyzing the mechanisms underlying cardiac fibrillation both in experimental and in mathematical models.

In this paper, we propose an automatic method based on Iyer and Gray to identify the PS in two-dimensional cardiac tissue. The monodomain model was used to study the propagation of action potential, and two cell models were selected to test the method for PSs location, one is the human atrial appendage cell model and the other is atrial fibrillation-induced electrical remodeling cell model. The proposed method is compared with the methods used by Fenton as well as by Karma in performances of efficiency, accuracy and parameter sensitivity. The results showed that our method is more time-saving and less parameter sensitive than the previous methods. Furthermore, the detecting progress of the proposed method is automatic and can accurately detect the PSs without changing any parameters for different heart cell models, which is especially important for 3D whole heart simulation. The proposed method would be useful for understanding of the initiation, termination and interaction of spiral waves in atrial and ventricular fibrillations.