Special Program in Applied Mathematics and Applied Mechanics

Quadratic Adaptive Algorithm for Solving Cardiac Action Potential Models

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In this talk, I will give a short introduction to the numerical simulation of cardiac cell models and present a new adaptive integration method for computing cardiac action potential models. Time steps are adaptively chosen by solving a quadratic formula involving the first and second derivatives of the membrane action potential. To improve the numerical accuracy, we devise an extremum-locator (el) function to predict the local extremum when approaching the peak amplitude of the action potential. In addition, the time step restriction (tsr) technique is designed to limit the increase in time steps, and thus prevent the membrane potential from changing abruptly. The performance of the proposed method is tested using the Luo-Rudy phase 1 (LR1), dynamic (LR2), and human O'Hara-Rudy dynamic (ORd) ventricular action potential models, and the Courtemanche atrial model incorporating a Markov sodium channel model. Numerical experiments demonstrate that the action potential generated using the proposed method is more accurate than that using the traditional Hybrid method, especially near the peak region. The traditional Hybrid method may choose large time steps near to the peak region, and sometimes causes the action potential to become distorted. In contrast, the proposed new method chooses very fine time steps in the peak region, but large time steps in the smooth region, and the profiles are smoother and closer to the reference solution. In the test on the stiff Markov ionic channel model, the Hybrid blows up if the allowable time step is set to be greater than 0.1 ms. In contrast, our method can adjust the time step size automatically, and is stable. Overall, the proposed method is more accurate than and as efficient as the traditional Hybrid method, especially for the

human ORd model. The proposed method shows improvement for action potentials with a non-smooth morphology, and it needs further investigation to determine whether the method is helpful during propagation of the action potential.

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