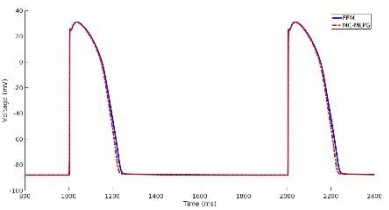
A novel paradigm for in silico simulation of cardiac electrophysiology through the Mixed Collocation Meshless Petrov-Galerkin Method

Konstantinos A. Mountris, Carlos Sanchez, Esther Pueyo

Aragon Institute of Engineering Research, University of Zaragoza, IIS Aragon, Spain

Computational simulations of cardiac tissue electrophysiology involve high computational load, due to their inherent complexity and the limitations of the employed numerical methods, the most commonly used being the Finite Element Method (FEM). To reduce this complexity, we propose the use of the Mixed Collocation Meshless Petrov-Galerkin (MC-MLPG) method. MC-MLPG is a truly meshless method, where meshless basis functions are used to interpolate voltage and current flux by using nodal collocation.

A 0.48 cm x 0.48 cm piece of human ventricular epicardial tissue was simulated based on the monodomain reaction-diffusion model. Propagation of the cardiac action potential (AP) was solved by considering the operator splitting method, where the MC-MLPG was used to solve the diffusion term, with a space resolution of 0.008 cm. The O'Hara-Rudy AP model was used to represent cellular electrophysiology. Time integration was performed explicitly with a time step of 0.01 ms. The tissue was stimulated at its bottom edge by periodic stimuli of twice diastolic threshold amplitude delivered at CL=1000 ms. Fiber orientation was set parallel to the Y-axis, with conductivity coefficients set at ky=0.0013 mS and kx=0.00052 mS. Conduction velocity (CV), maximum voltage derivative (dVdtMax), AP duration at 90% (APD90), 50% (APD50), and 20% (APD20) repolarization were evaluated at the center of the tissue after steady-state was reached for baseline conditions. Comparison with a FEM simulation was performed using the Elvira software.



Action potential simulation. (cont.) FEM, (dashed) MC-MLPG.

For both MC-MLPG and FEM simulations, CV was 66.7 cm/s. Differences in dVdtMax were negligible (0.57%). Differences in APD90, APD50 and APD20 were 4.41%, 3.30% and 2.24%, respectively.

The MC-MLPG method represents a promising alternative to FEM for cardiac electrophysiology simulations. MC-MLPG does not involve any mesh requirements and is well suited for massive parallelization.