

Simulation of Fractionated Electrograms at Low Spatial Resolution in Large-Scale Heart Models

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Computation of extracellular potentials from transmembrane potentials is a common problem in cardiac electrophysiology. It is part of many bidomain reaction-diffusion models, and is also used to compute (intracardiac) electrograms from membrane potentials simulated by monodomain models. Computation of electrograms requires the solution of an elliptic boundary-value problem which, when discretized, can be written as a system of linear equations. Because extracellular potentials must be solved at a spatial resolution of 0.2 mm or better to avoid spike artefacts, these linear systems can have tens or hundreds of millions of equations for a whole-heart model. Such large systems are hard to solve and require in the order of 10-100 GB memory. Faster and less memory-intensive solutions are often desirable.

Artefacts in low-resolution solutions are related to the restriction operator that is used to translate the source data from the high-resolution to the low-resolution mesh. Typically, this restriction is done by injecting transmembrane potentials. We propose to use transmembrane current as a source, with trilinear weighting rather than simple injection.

We tested this method in a large-scale model of the human ventricles, which consisted of 90 million nodes at 0.2-mm resolution. A good visual match was obtained between electrograms computed at 1-mm and at 0.2-mm resolution, even in regions where strong sub-millimeter heterogeneity in tissue conductivity was present. Peak potential values were well reproduced, but the slope of steep deflections was underestimated at low resolution. The solution at low resolution was more than proportionately faster than that at high resolution.

Our method is easy to implement in an existing bidomain solver and is useful to rapidly compute electrograms intended for visual inspection at thousands of sites simultaneously. The scheme may also be valuable as a restriction operator in multigrid methods.