# Simulation of Cardiac Action Potential Propagation using Hybrid Models

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Mathematical models of the cardiac action potential include complex biophysically-derived ionic models, simpler generic ionic models, and phenomenologically-derived models that caricature the action potential and its propagation. Complex models are computationally demanding. To investigate spatiotemporal behaviours (e.g. reentrant arrhythmias), simpler models are more computationally effective. However, these can be insufficiently rich to represent many dynamics and pathological states.

In this study we investigate the use of hybrid models as an efficient approach to cardiac tissue simulation. Small regions of tissue modelled at a biophysically-detailed level can be embedded within a larger system (e.g. whole ventricles) represented using a simpler action potential model. Thus a region of specific interest (e.g. tissue affected by ischemia) can be realistically modelled, but with computational requirements greatly reduced for the surrounding tissue. As a case study, we consider a hybrid system in which Luo-Rudy (LR1) model cells are embedded within a surrounding tissue employing the 3-variable Fenton-Karma model.

The validity of the hybrid approach is dependent upon the method used to couple cells across the interface of the two model regions. A simple approach to inter-model coupling is to allow normal (intra-model) diffusive cell-cell coupling to apply unaltered across the interface. We show that such an approach fails to cope adequately with the different action potential morphologies of the component models; e.g., instead of being preserved, the embedded Luo-Rudy model's action potential includes features characteristic of the Fenton-Karma model.

We develop an alternative method in which inter-model coupling is dependent upon the discrete action potential phase (resting - stimulated - upstroke plateau recovery) of interface cells. Our method is shown to perform well in simulations of propagation in 1D and 2D hybrid models. We conclude by considering further development of methods to support hybrid modelling, and possible future applications.