INVERSE MODELING FOR CARDIAC ELECTROPHYSIOLOGY WITH FAST EIKONAL APPROXIMATION

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ABSTRACT. Heart failure is a clinical syndrome, affecting 2% of the general population, in which heart disease is accompanied by subcellular abnormalities that cause progressive deterioration of the heart muscle. The nature of these disorders differs greatly between patients. Accurate characterisation of these disorders is necessary to understand the problem and to design the best therapy.

Over the last decade, multiscale patient-specific modeling has been proposed by several groups to better understand the underlying mechanisms of heart failure. Unfortunately, a large set of parameters with great uncertainty is involved. Restricting our attention to electrophysiology only, this includes the position of early activation sites and possible local conductivity abnormalities. These are fundamental for the correct setup of patient-specific models with left bundle branch block (LBBB).

The aim of this work is twofold: define an inverse model to identify the early activation sites and the local conductivities, and solve it very efficiently by means of a reduced model for the bidomain equation.

More specifically, the inverse model aims to minimise the mismatch between simulated times and activation times measured with an endocardial catheter using an electroanatomical mapping system, by optimising the local conductivity and the number and position of early activation sites. The methodology is also extended to make use of noninvasive measure such as the surface ECG.

The forward modelling of the activation times is based on the eikonal equation [1]. The main advantage of this approach is the greatly reduced computational cost associated with the solution of the forward problem. The basic idea under which the eikonal model is developed is to focus on the geometrical side of action potential propagation instead of its local generation. Moreover, we found that the eikonal model provides a reliable approximation of the activation time and the ECG for the LBBB patients.

The numerical solution of the anisotropic eikonal equation is carried out on GPUs. Since the *de facto* standard fast-marching method is not suitable for this type of architecture, we opted for a simple Jacobi iteration of a local variational principle, which has been proven to converge to the correct viscosity solution [2]. On a single high-end GPU, we are able to solve the full activation sequence and the ECG on a 1 mm resolution in less than 5 seconds.

For the localisation of early activation sites in LBBB patients from sparse endocardial activation measurements, we propose a localisation algorithm based on the shortest path equivalence of eikonal solutions. The methodology, already tested on 4 patient-specific datasets, reports very convincing results, which can be obtained in few minutes.

REFERENCES

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