Multi-scale and Multi-physics Visualization

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1 Introduction

Accurate computational models of physiology require the coupling of different physical processes that occur across a wide range of spatial scales. The interpretation and analysis of the calculated results of these models require the integrated visualization of these multi-scale and multi-physics processes. A number of different strategies for doing this are presented for a model of the heart left ventricle.

2 Heart ventricular visualization

To model a heart ventricle, computational models for the mechanics of the heart tissue, the cellular potential chemistry and the electrical propagation through the tissue have been coupled together. The mechanical behaviour has a relatively long time scale as the heart beats, whereas the changes in electrical potential occur very rapidly as the activation wave propagates. The interaction of these two behaviours is important.

The gross mechanical behaviour of the heart is represented well by the deforming geometry. However, to understand the mechanical model more analysis is required. The strain tensor provides useful information and much work has been presented on using deforming glyphs to display such tensor fields. The relationship of the strain tensor field to the underlying physical microstructure can be seen by representing the fibrous structure with streamribbons aligned in the sheet planes. To represent the electrical wavefront, isoelectric surfaces can be drawn in the tissue volume. The time course of potential and individual ionic currents at a single material location is important. One strategy to enable these quantites to be shown throughout the volume is to have an interactive “point of interest” which the investigator can move and watch the change in the signal plots. Figure 1 shows a visualization where the signal plots for several material locations are shown overlaid at the side. The balls on these plots indicate the corresponding point on the chart to the currently displayed geometrical position. Isoelectric surfaces are shown embedded in the geometry.

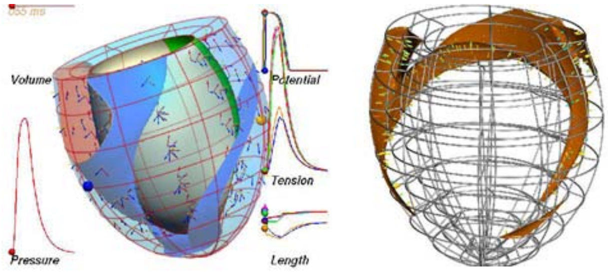

Figure 1. Visualization of coupled electromechanics in a heart ventricle.

To display similar information incorporated in a geometrical solution, graphs can be billboarded at multiple locations throughout the model. Representing the potential with colour and showing a recent time history which scrolls along allows the time course of one parameter to be visualized without axes.

When visualizing the activation wavefront the rapid onset is essentially instantaneous. Streaklines which track the gradient of potential along the wavefront generate a series of snakes which track along with the isoelectric surfaces. However, on these snakes, the length and colour can encode further information about the activation, such as exaggerating the duration so it can be seen or showing the peak potential.

The variation between the potential behaviour at various locations in the heart can be hard to perceive from the raw potential information. Displaying derived quantities such as the spatial variation in restitution, or shifting the potential time course at individual locations so that activation times coincide, reveals the variation in the cellular potential behaviour.

3 Conclusion

Some methodologies for visualizing multi-scale and multi-physics solutions for a model of a heart ventricle have been described. These are crucial to the development, understanding and interpretation of such models.