Segmentation Uncertainty Quantification in Cardiac Propagation Models

Jess Tate, Nejib Zemzemi, Shireen Elhabian, Beáta Ondrušová
Machteld Boonstra, Peter van Dam, Dana Brooks, Akil Narayan, Rob MacLeod

Cardiac simulation continues to increase in relevance in research and the clinic for predicting arrhythmias and guiding treatments. A key part of patient-specific simulations is segmentation of cardiac geometry, a subjective and error-prone procedure that plays a fundamental role in propagation modeling, simulating ECG from cardiac sources, and ECGI (estimating cardiac sources from ECGs). In this study we quantify the dependence of a cardiac propagation model on from segmentation variability.

We used statistical shape modeling and a polynomial Chaos (PC) to capture segmentation variability dependence and applied its affects to a propagation model. The shape model was constructed from 15 segmentations of the same subject and includes five modes of shape variability. The shape model was sampled across these modes using weighted Fekete sampling; an isotropic, homogeneous Eikonal propagation model was constructed from the sampled shape and evaluated. PC was used to estimate the statistics of the model output distribution from the multiple solutions.

The predicted uncertainty due to segmentation shape variability was distributed near the base of the heart and near high amplitude torso potential regions. While the uncertainty of the activation patterns predicted by the model was not enough to alter the main propagation pathways, some activation sequences showed higher uncertainty than others, in particular the sinus and LV stimulation patterns. The uncertainty predicted in body surface potentials (BSPs) is generally low; however, the anterior areas with high spatial gradients showed high uncertainty.

Our results provide insight into the response of cardiac propagation models to segmentation variability. While, in general, the model is relatively robust to shape variability, existing errors have significant downstream effects if the propagation model is used to feed further computations, such ECGI computations.

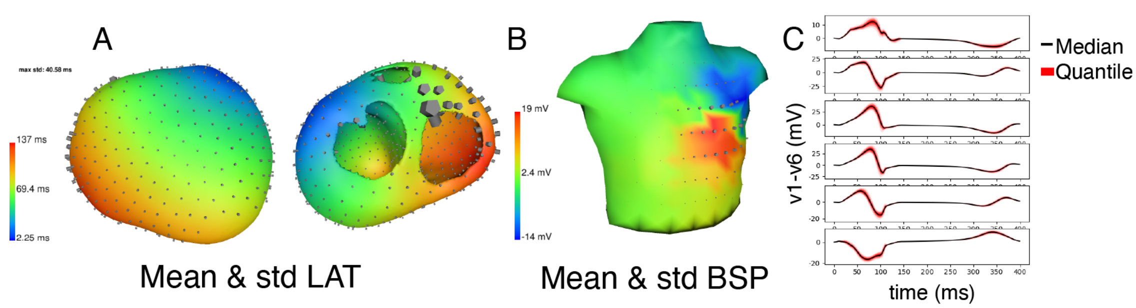

Figure 1: Spatial and temporal distribution of predicted variability from segmentation uncertainty. A) local activation time (LAT) mean (colormap) and standard deviation (cylinder size). B) body surface potential (BSP) mean (colormap) and standard deviation (cylinder size). C) Precordial ECG median and 8 quantile bands.