A Cardiac Shape Model for Segmentation Uncertainty Quantification

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As the use of cardiac simulation becomes increasingly more common, so does the need to fully quantify uncertainty of simulation methods. Segmentation of cardiac geometry is a key, yet possibly error-prone part of patient-specific simulations, such as ECG imaging. In this study, we improved open our previous shape analysis of ventricular segmentation variability by creating a unified shape space including both the epicardium and endocardium.

We used the ShapeWorks software tool to statistically quantify the segmentation variability of patient using four strategies: standard, multidomain, hybrid multidomain, and geodesic distance. Researchers within the Consortium for ECG Imaging (CEI), supplied nine ventricular segmentations from a single patient CT scan. ShapeWorks was used to compute correspondence points on all surfaces using the four strategies then to compute the shape space for each set of correspondences using Principal Component Analysis (PCA). The computed shape space is then used as the basis to create a parameterized shape model which can reconstruct any ventricular shape within the space.

Only the multidomain and hybrid multidomain strategies produced a shape model with all nine segmentations. The hybrid multidomain produced the most consistent correspondence points and captured slightly more of the total variability with the same number of PCA axes (93 % with five axes, compared to 91 %). The geodesic distance strategy produced a shape model with a subset of the four segmentations most similar in shape. Each shape models captured spatially dependent characteristics of the segmentation variability, including wall thickness, annular diameter, and basal truncation.

Our results demonstrate multiple strategies to generate a ventricular shape model of segmentation variability for use in uncertainty quantification of simulation pipelines. While the multidomain hybrid approach arguably represents the segmentation dataset with highest fidelity, the other strategies may be useful for applications with sparse meshing requirements.

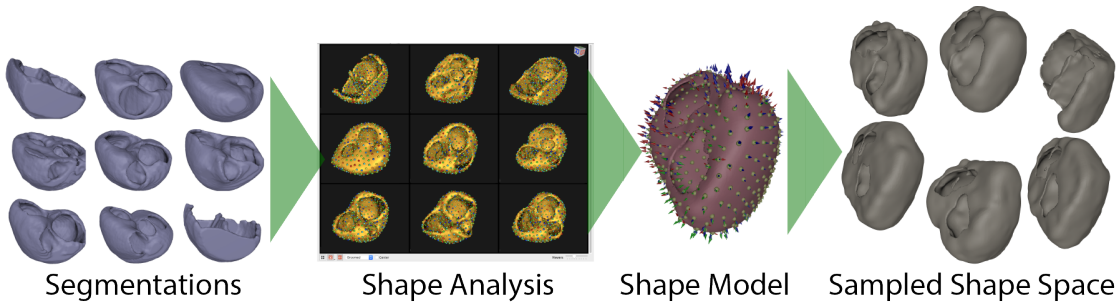

Figure 1: Shape analysis pipeline. ShapeWorks generates the shape model, which can be used in simulation pipelines.