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Image-based numerical simulation of heart model with prescribed displacements along the heart surface

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It is a need to have accurate numerical models for better understanding of heart behaviour in cardiomyopathy and other heart diseases. These computational models can include variety of different processes such as transport, electrophysiology and muscle mechanics [1]. In this work we focus on deformations of the heart walls, in order to get the displacements field of the insides of the heart. Displacements of the parts of the heart's epicardium can be concluded from imaging, but insides of the heart are harder to track without use of numerical models.

In our methodology we track motion of heart along some curve, based on images. We generate finite element model, prescribe displacements in appropriate nodes of outer surface and then we use mesh-based shape deformation method called polyharmonic deformations. This method is used to propagate prescribed deformations to the rest of the model smoothly, where shape deformation problem is reduced to quadratic energy minimization problem [2]. After mesh is deformed, we pass the motion of the selected nodes in time to the finite element solver which provide us complete displacement and stress field of continuum. Using this approach we can run image-based simulation relying on realistic conditions and generate complex deformation patterns in the patient-specific heart model.

Developed methodology is used to track the displacements of endocardium, given the displacements of the epicardium taken from 2D cardiac images. Methodology is tested with respect to real 3D heart model, with using linear elastic and recently developed orthotropic material model based on Holzapfel experiments. This approach has potential to be used in coupled solid-fluid simulation of whole heart in order to give accurate prediction of heart beat for different heart diseases.

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