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MYOCARDIAL MATERIAL PARAMETER ESTIMATION FROM 2D IMAGING DATA

Anastasia Nasopoulou, David Nordsletten, Steven Niederer, Pablo Lamata

King's College London, United Kingdom
anastasia.nasopoulou@gmail.com, david.nordsletten@kcl.ac.uk, steven.niederer@kcl.ac.uk, pablo.lamata@kcl.ac.uk

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Summary: Myocardial material parameter estimation is a necessary step towards both the estimation of the material stiffness of the myocardial wall (a recommended biomarker for cardiac disease stratification), and the generation of predictive cardiac biomechanical models of clinical value. Currently the process of estimating myocardial material parameters relies on 3D models of the myocardium and therefore requires the use of costly and time consuming 3D imaging protocols (i.e. from magnetic resonance or computer tomography), which are not universally available bedside. Conversely, 2D ultrasound images are rapidly obtainable and ubiquitous in clinical practice, thus providing motivation for the development of a parameter estimation strategy from 2D images presented in this study.

The proposed methodology builds up from recent work [1], where a novel energy based cost function was introduced in order to address the known problem of parameter 'coupling', whereby multiple parameter combinations can provide equally valid solutions in the inverse problem. Using long axis images of the myocardium and cavity pressure measurements, the formulation of the virtual work principle over a myocardial 'slice' allows for unique estimation of the parameter set.

The methodology was tested against two synthetic data sets of the left ventricle in diastole; one comprising of pressure, 2D geometry and 3D deformation data (mimicking the availability of 3D speckle tracking data) and another where the deformation data are 2D instead. For both data sets a popular transversely isotropic material model [2] was used and the ground truth parameters were recovered, demonstrating the feasibility of the technique. The accompanying sensitivity analysis to data noise and sources of data-model incompatibility (i.e. choice of reference frame, fitted microstructural profile in the model, offset in imaging plane) demonstrated a sufficiently robust behavior of the method, identifying the quality of the deformation data as the most critical factor for accuracy. As a next step, the pipeline is applied to clinical data from heart failure patients.

References

[1] Nasopoulou et al. Improved identifiability of myocardial material parameters by an energy-based cost function. BMMB (2017).
[2] Guccione et al. Passive material properties of intact ventricular myocardium determined from a cylindrical model. J Biomech Eng (1991).