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Research paper

Myocardial transversely isotropic material parameter estimation from in-silico measurements based on a reduced-order unscented Kalman filter

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ABSTRACT

Parameter estimation from non-invasive measurements is a crucial step in patient-specific cardiac modeling. It also has the potential to provide significant assistance in the clinical diagnosis of cardiac diseases through the quantification of myocardial material heterogeneity. In this paper, we formulate a novel Reduced-order Unscented Kalman Filter (rUKF) applied to the left ventricular (LV) nonlinear mechanical model based on cubic-Hermite finite elements. Material parameters in the widely-employed transversely isotropic Guccione's constitutive law are successfully identified for both homogeneous and heterogeneous cases. We conclude that the four parameters in Guccione's law can be uniquely and correctly determined in-silico from noisy displacement measurements of material points located on the myocardial surfaces. The future application of this novel and effective approach to real clinical measurements is thus promising.

1. Introduction

The measurement of regional myocardial function and contractility are vital for the assessment of heart diseases. From these measurements, the quantification of local myocardial stiffness provides significant values for the diagnosis assistance from the investigation of diastolic dysfunction (Wang and Nagueh, 2009) to better selection of patient candidates with infarcted or hibernating tissue for further therapy (Nagel and Schuster, 2010).

Accordingly, the model-based parameter estimation from non-invasive clinical measurements of the cardiac function has been an active research area. Various frameworks and methods has been proposed (Sermesant et al., 2006; Moireau et al., 2008; Sermesant et al., 2006). In Sermesant et al. (2006), a variational data assimilation method was employed to

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