Advanced Statistical Inference of Myocardial Stiffness: A time series Gaussian Process approach of emulating Cardiac Mechanics for real-time clinical decision support

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Abstract:
Our work is primarily motivated to determine the passive stiffness of the myocardium from the measurement of the left ventricle (LV) volume at various time points, which is crucial for diagnosing cardiac physiological conditions. Although there have been significant advancements in cardiac mechanics modelling, the tasks of inference and uncertainty quantification of myocardial stiffness remain challenging, with high computational costs preventing real-time decision support. We adapt Gaussian processes to construct a statistical surrogate model for emulating LV cavity volume during diastolic filling to overcome this challenge. As the LV volumes, obtained at different time points in diastole, constitute a time series, we apply the Kronecker product trick to decompose the complex covariance matrix of the whole system into two separate covariance matrices, one for time and the other for biophysical parameters. To proceed towards personalized health care, we further integrate patient-spec
ific LV geometries into the Gaussian process emulator using principal component analysis (PCA). Utilizing a deep learning neural network for extracting time-series left ventricle volumes from magnetic resonance images, Bayesian inference is applied to determine the posterior probability distribution of critical cardiac mechanics parameters. Tests on real-patient data illustrate the potential for real-time estimation of myocardial properties for clinical decision-making. These advancements constitute a crucial step toward clinical impact, offering valuable insights into posterior uncertainty quantification for complex cardiac mechanics models.