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PARAMETRIC MODEL ORDER REDUCTION USING POD FOR COUPLED NONLINEAR CARDIAC MECHANICS

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Cardiac mechanics simulations consist of solving large-deformation, materially nonlinear, elastodynamic boundary-value problems coupled to zero-dimensional models of hemodynamics. The needed huge number of DOFs and challenges solving such coupled nonlinear problems make the solution computationally expensive and limit the models' use in clinical practice. In addition, cardiac models rely on a large set of patient-specific parameters, describing constitutive behavior, hemodynamics, boundary conditions, or local fiber orientation [1]. Just one solution of one example does not at all meet clinical demands.
Hence, we propose a coupled reduced order model (ROM) of the structural domain using proper orthogonal decomposition (POD) based on snapshots obtained from the coupled full order model (FOM). We demonstrate the computational speedup for a patient-specific four-chamber cardiac geometry with about one million structural degrees of freedom using a high performance computing C++ environment. Furthermore, we provide a quantitative comparison of several subspace interpolation methods [2] for parametric model order reduction (pMOR) to demonstrate the ability to evaluate the ROM at parameter sets without prior FOM knowledge. Finally, we show the application of cardiac pMOR to inverse analysis and uncertainty quantification.
Using POD for cardiac pMOR shows good approximation of the displacements as well as of scalar cardiac quantities, such as ejection fraction, left ventricular pressure, and atrioventricular plane displacement, while achieving considerable speedups over the FOM.

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