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LARGE-SCALE OPTIMIZATION FOR NON-INVASIVE TESTING WITH DISCONTINUOUS GALERKIN METHODS

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Non-invasive testing is an important method to determine the characteristics of engineering systems without disassembling or damaging them. One non-invasive test of interest is determining unknown external conditions on a system from a few recordings with the intent to reconstruct loads at other locations within the system. An example of this is the application of acoustic energy to satellites in an attempt to assess the structural modes and to ensure that the system can withstand critical loads during deployment [1]. The interior structure of these systems is often known but material properties (including attenuative and anisotropic materials) may be unknown and require determination. Once the numerical model has been calibrated, accurate predictions can be made for a range of different operating conditions to assess the performance of components throughout the system. Another use of non-invasive testing is defect detection in an engineering system, such as miss-assembly, manufacturing defect and material deterioration (aging), thus requiring the determination of both the interior structure and the material properties.

The nature of such optimization problems however raises numerous challenges, including the requirement of addressing many inversion parameters, incorporating complex physics, dealing with sparse measurements, and optimization machinery (such as sensitivities, globalization, check-pointing). Furthermore, various engineering systems require the resolution of complicated dynamics and consequently this motivates the use of higher-order discretization schemes.

To this end, we present a numerical framework that includes large-scale optimization and is built on the Discontinuous Galerkin (DG) discretization approach [2, 3]. Although our framework is capable of simulating a range of physics, we focus here on wave propagation for non-invasive testing. Our PDE constraints consist of the first-order wave equations with a modal representation. The code supports arbitrary quadrature order, local polynomial order refinement, and non-conformal hanging-node topologies. A variety of time integrators and numerical fluxes are also available. Corresponding adjoint-based sensitivities are implemented in addition to gradient equations that both support a range of optimization methods, including nonlinear conjugate gradient and Gauss Newton. Line search and trust region methods are implemented to provide the necessary globalization guidance.

Additionally, we will present simulations and inversions for some non-invasive tests. Our target article contains multiple components at different sizes with varying material properties, including attenuative and anisotropic. Not only do we require a higher-order discretization to capture all the dynamical features but we also need to simulate a wide range of frequencies. These mechanisms pose complicated issues in our optimization formulation including necessary parameterizations to map physically interpretable properties to material coefficients in the PDE formulation. In the case of attenuation, the mapping requires the solution of a least-square problem.

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