The Coupled Photoacoustic Imaging Problem: Inverse Solution and a Time-Explicit Hybridizable Discontinuous Galerkin Formulation

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ABSTRACT

Photoacoustic imaging is a medical imaging technique combining diffuse optical tomography and ultrasonography. Within an illuminated object of interest, optical energy is converted to heat via the photoacoustic effect. The accompanying thermal expansion initiates pressure waves which are subsequently detected at the object's boundary. By use of back projection formulas or physically motivated reconstruction algorithms, the recorded acoustic signals allow for conclusions on the underlying optical and mechanical properties [1].

In this presentation, a reconstruction algorithm is proposed which optimizes the spatially varying material properties subject to the relevant physical phenomena namely diffusive light propagation, photoacoustic energy conversion, and acoustic wave propagation.

For the efficient simulation of acoustic wave propagation, the hybridizable discontinuous Galerkin (HDG) method, as presented in [2], is used. In contrast to conventional discontinuous Galerkin (DG) methods, HDG significantly reduces the number of global unknowns to be solved for implicit time integration schemes by introducing the trace field as new variable. The HDG formulation is especially well suited for high-order polynomial bases and hence competitive to e.g. partition of unity or ultra weak variational methods and superior to the standard continuous Galerkin method for wave propagation problems. A newly developed formulation using an explicit time stepping scheme in combination with the HDG numerical flux functions from [2] is based on a two step update procedure for the trace and interior field.

The proposed reconstruction algorithm incorporates the solution of the primal optical and acoustic problem with standard finite elements and the HDG method, respectively, and the solution of the adjoint problem in order to be able to calculate a gradient of the objective function.

A quantitative comparison of the performance of implicit and explicit time integration using HDG spatial discretization for acoustic wave propagation is provided. Also, an example for a reconstruction procedure with experimentally obtained data is provided to verify the applicability of the algorithm.

REFERENCES

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