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Scientific Computing Seminar

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Data-to-Born transform for imaging with waves

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1:30 PM- 2:30 PM
Room 646   PGH

Abstract:

We introduce a novel algorithm for nonlinear processing of full waveform multiply scattered data. The algorithm is motivated by the applications of imaging with waves. It is formulated for a general hyperbolic system that applies to both acoustic, elastic and electromagnetic waves in a scattering medium modeled by an unknown coefficient, the reflectivity. In imaging one seeks to invert the nonlinear mapping from the reflectivity to the collected data. Many existing imaging approaches (Kirchhoff, reverse time migration - RTM, etc.) ignore this nonlinearity, i.e., operate under the assumption that the single scattering (Born) approximation is accurate. This leads to image artifacts when multiple scattering is significant.

The proposed algorithm transforms the full waveform multiply scattered data to the data that the same medium would produce if the waves in it propagated in the single scattering (Born) regime, hence the name Data-to-Born (DtB) transform. Since the DtB transform acts in the data space only, it can be used as a pre-processing step for any linear imaging (Kirchhoff, RTM) or inversion (e.g., least-squares RTM) method.

The DtB transform is based on a reduced order model (ROM) defined by a finite dimensional projection of the wave equation propagator that has three important properties. First, it is data driven, meaning that it is computed from the measured waveform data alone, with no a priori knowledge of the medium. Second, it can be factorized in two operators that have an approximately affine dependence on the unknown reflectivity. This allows to compute the Frechet derivative of the reflectivity-to-data mapping which gives the Born approximation. Third, the algebraic nature of ROM computation and differentiation makes the DtB transform applicable to both scalar (acoustic) and vectorial (elastic, and also electromagnetic) wave data without any specific modifications. The theoretical considerations are illustrated with an array of numerical experiments.

- This is a joint work with with L. Borcea, V. Druskin, and M. Zaslavsky.