Incorporating Multiple Scattering in Imaging with Iterative Born Methods

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Diffraction tomography gives a Fourier relation between the scatterer illuminated by a set of transmitters and the scattered field collected by a set of receivers. This linear relationship can be exploited in a more flexible way using iterative optimization methods with freedom on the locations of the transmitters and receivers, and their radiation patterns. The optimization process requires matrix-vector multiplications (MVMs) in each iteration, corresponding to the solutions of forward scattering problems. We can perform the MVMs with $\mathcal{O}(N)$ or $\mathcal{O}(N \log N)$ computational complexity using fast algorithms, where N is the number of pixels in the computational imaging domain. Usually, the scatterer is illuminated from different angles, and the cost is multiplied with the number of illuminations.

Many well-known linear methods (including some diffraction tomography algorithms) that take into account only the first-order scattering mechanism break down when multiple-scattering effect is strong. This is because they omit those higher-order terms that represent the multiple-scattering phenomenon. Iterative Born methods, however, employ a rigorous formulation to resolve the non-linear relationship between the object and the scattered field with successive linearizations. There are several versions of Born methods and their variations that have been proposed in the last three decades.

The computational burden of iterative Born methods is immense. Therefore obtaining real-life images is either impossible or impractical with conventional computational approaches, and previous research on Born methods was limited in terms of real-life applications. As a remedy, our research effort makes use of fast algorithms and parallel supercomputing for solving large and realistic multiple-scattering problems for obtaining physically meaningful images. There are two parallelization challenges here: the first one is the parallelization of independent scattering solutions, and the second one is the parallelization of forward-scattering solver itself. We tackle the both challenges. This report focuses on our philosophy for efficient utilization of frameworks with hundreds of computing nodes with heterogeneous CPU+GPU architectures.

In this study, application to ultrasound imaging is considered. Tomographic reconstructions under several scenarios are presented, including those with full-angle and limited-angle observations of the scatterer. The scattered field data is obtained from numerical experiments as well as from a medical ultrasound scanner. A preprocessing procedure is proposed for calibration of the real-world and computational environments. The real-world data is obtained with L9-4 array connected to a SonixDAQ and SonixRP platform and the tomographic reconstructions are obtained on NCSA Blue Waters.