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3D PDE-based Contrast Source Inversion for Biomedical and Agricultural Applications

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1 Extended Abstract

Since its inception 20 years ago, contrast source inversion (CSI) [1] has been successfully applied to a wide variety of tomographic imaging applications and modalities that include microwaves, seismics and ultrasound. Ever-improving computing hardware has more recently permitted CSI-based imaging to be applied to fully three-dimensional problems, clearing the way for advancing new applications or investigating the capabilities of new hardware systems that necessarily require three dimensional field simulation and imaging. Two such applications are considered herein. First is microwave breast imaging within a hardware system that exploits an irregular metallic boundary to improve sensitivity while reducing modelling error [2]. Second is radio wave imaging of stored grain [3], the goal being to monitor the electrical properties of grain while it is stored inside a large metallic grain bin, where bin geometries and the possible distributions of electrical constitutive parameters require three-dimensional modelling capabilities. CSI requires a forward solver capable of accurately reconstructing the fields from estimates of the constitutive parameters, and has been previously implemented using integral equations [1, 4] (possibly using numerical Green's functions) and partial differential equation (PDE) based models including both the finite element method (FEM) [5] and more recently, the discontinuous Galerkin method (DGM) [6]. As the capabilities of forward solvers advance, the CSI cost functional can be adjusted and/or augmented to make use of additional features. For example, CSI can be readily formulated for both electric and magnetic field measurements for both electric and magnetic targets if provided with an appropriate forward solver [4]. The forward solver approach most naturally suited to the two applications considered herein is a PDE-based model, where inhomogeneous backgrounds and irregular boundary conditions can be easily accounted for.

In this work, we present an overview of our work on PDE-based CSI inversion for biomedical and agricultural applications. We first summarize applied results obtained with a 3D parallel FEM-CSI algorithm, and then we introduce a 3D parallel DGM-CSI implementation. DGM-CSI enables a number of new modelling capabilities as it supports simultaneous electric and magnetic field simulations from electric and magnetic targets, high-order expansions of unknowns, and high-order inhomogeneous background representations. Results will be presented for both synthetic and experimental datasets for the biomedical and agricultural applications considered.

References

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