Large-Scale Inverse Scattering Solutions for Retrieving 3-D Electromagnetic Properties from Magnetic Resonance Imaging

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In this work we develop a fast method for retrieving electromagnetic properties, including dielectric constant, conductivity and magnetic permeability, from magnetic resonance imaging (MRI).

Traditionally, MRI images are related to T1 and T2 variations in the tissue. Since 1991, MRI-based electrical properties tomography (EPT), a non-invasive technique for characterizing electrical conductivity and permittivity of human tissues, has been developed for the diagnosis of cancer and specific absorption rate (SAR) quantification, based on the distortion of radiofrequency (RF) magnetic field in MRI. The conventional EPT assumes low contrasts, thus the inverse problem is linear and is limited in accuracy. For high-contrast tissues, such conventional techniques do not work.

In this work, the volume integral equation (VIE) method is utilized to reconstruct the electrical properties because of its flexibility in handling complex high-contrast inhomogeneous scatterers without approximations. Unfortunately, for the MRI problem, the number of unknowns in the inverse problem can easily exceed several millions; such large-scale problems are also nonlinear, thus requiring iterative solutions. In this work, to speed up the forward modeling, the stabilized biconjugate gradient fast Fourier transform (BCGS-FFT) method is used to solve the volume integral equation. To speed up the inversion, a Born-type iterative method together with a conjugate-gradient fast Fourier transform (CG-FFT) method is incorporated to solve the inverse problem. The numerical results have demonstrated that the inversion method based on the positive rotating magnetic field of MRI is capable of reconstructing high-spatial-resolution electrical properties mapping of inhomogeneous human tissues with over 8 million complex unknowns in the nonlinear inverse problem. New applications of this MRI-based electrical property retrieval will be discussed.