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The Contrast Source Inversion (CSI) method is a widely exploited inversion tool in microwave imaging, as it allows quantitative reconstructions of dielectric properties inside the Domain of Interest (DOI). Here, the CS algorithm is proposed for medical imaging. The goal is to develop a device that can detect and monitor a brain stroke, thanks to the difference in dielectric properties between the healthy brain tissues and the stroke area. This kind of device could further support the clinician and be a complementary tool to already used systems, such as computerized tomography (CT) and magnetic resonance imaging (MRI). In the CSI method, two variables are defined: the dielectric contrast between the target and the background medium, and the contrast source, which plays the role of auxiliary variable and allows mitigating the inherent non-linearity of the problem. For each antenna, the contrast source variable links the total radiated field with the dielectric contrast in each DOI position. The inverse scattering problem solution is obtained by minimizing a cost functional and then, updating the dielectric contrast and the contrast source variable accordingly. The cost functional encompasses the difference in the measurement domain between the measured data and the predicted data, obtained through the numerical model, as well as the residual computed for the contrast source/contrast pair in the DOI [1].
Due to the iterative nature, the computational cost is a significant drawback, especially when dealing with real-world scenarios. In such cases, a 3-D vectorial formulation of the underlying inverse scattering problem is indeed required. Moreover, the considered scenario has a pretty complex geometry, and, to optimize the number of unknowns, it needs a non-uniform discretization [2]. For these reasons, we propose an efficient implementation of the CS algorithm using the finite element method (FEM) to discretize the DOI. The FEM solver allows to work with a conformal, but non-uniform mesh. The discretization strategy herein proposed aims to speed up and simplify the 3-D algorithm implementation by expressing the variables as linear combinations of scalar coefficients and vectorial basis function, thus avoiding the difficulties of an implementation with vectorial coefficients. This description facilitates the CS inversion algorithm, which can work by updating only the variables' scalar coefficients under investigation. Besides being very efficient from the computational point of view, this kind of implementation leads to a low discretization error and, consequently, the CS cost functional can be easily minimized. To further increase the convergence rate, the proposed CS-FEM implementation also takes advantage of the Subspace-Based Optimization Method (SOM). In SOM, the contrast source's stable part is estimated, thus reducing the auxiliary variable research space [3]. The described algorithms will be applied to experimental data, obtained with the measurement system in [4], where the human head tissues are mimicked with 3-D printed anthropomorphic phantoms filled with proper liquid mixtures.

References

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