Three Dimensional Level Set Method for Microwave Imaging

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Microwave imaging has potential for use in many different applications, including cancer screening and diagnostics, hemorrhagic stroke detection, and real-time monitoring and guidance of thermal therapies. This methodology is non-invasive and requires an inversion algorithm which includes a forward solver to obtain the electric field distribution and a level set optimization to recover the dielectric distribution, which has only one kind of inhomogeneity. Since the level set optimization requires the adjoint field computation, which is computationally expensive, it is necessary to investigate methods that can reduce such computational burden. In this paper, prior knowledge is assumed of the dielectric constant and conductivity, and that the total electric fields do not change much for the few voxel updates. Such assumptions lead to the simplification of the adjoint field computation. In this case, the adjoint field turns into the transpose of the coefficient matrix present in the linear system given by the Volume Electric Field Integral Equation. The adjoint field is used to compute the direction that minimizes the error using a level set formulation that recovers the shape and position of the object, which may be non-connected. Each iteration of the inversion algorithm consists of one forward run (Finite-Difference-Time-Domain) to compute the total electric field and some level set iterations. In order to verify the accuracy of this methodology, tests were performed on several synthetically generated cases using a variety of dielectric contrasts, shapes and positions. Tests were also performed on various anatomically realistic numerical phantoms found in the literature (e.g. Wisconsin Numerical Breast Phantom Repository: `https://uwcem.ece.wisc.edu`). The results showed that the methodology was able to recover the shape and position of the object in each of these cases with a satisfactory resolution.

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