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Integration of a Fuzzy Logic System with the Contrast Source Inversion Method - A Numerical Validation

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The electric properties of an unknown region cannot be determined with arbitrary accuracy when the scenario is probed by means of electromagnetic waves. In fact, different corrupting factors (i.e., the measurement errors and the environmental noise) and the intrinsic ill-posedness of the problem highly affect the performances of whatever reconstruction technique. Moreover, the limited amount of information on the scenario under test collectable from scattering experiments is an additional limiting factor to be carefully taken into account addressing practical applications like sub-surface inspection, medical imaging or non-destructive testing. In order to overcome such intrinsic drawbacks, the use of suitable strategies is mandatory. As far as the presence of noise in the data and the measurement errors are concerned, a possible countermeasure has been proposed and validated in [1], where an innovative fuzzy-logic-based [2] strategy has been presented. The fuzzy system (FLS) is able to provide two series of coefficients used as weighting parameters in the cost function, defined when recasting the inverse scattering problem in term of an optimization one. Thanks to the FLS, a direct (and expensive) estimation of the noise or *a priori* assumptions on the level of noise are avoided, but the corruptions and the errors in the scattering data are taken into account in an unsupervised fashion.

Concerning the mathematical formulation, in [1] the problem has been stated in terms of contrast and field unknowns. In this contribution, maintaining the same FL approach for estimating the noise impact, the data and state equations have been redefined in terms of contrast function and contrast sources. Such a formulation has been proposed in [3] (*Contrast Source Inversion method*, CSI) and it is based on the modified gradient method and on the source-type integral equation method. It has been proved to be a very powerful algorithm, showing robustness to noise and computational efficiency. Moreover, in [4], a regularization term based on the minimization of the total variation (TV) of the scenario has been proposed to further enhance the quality of the reconstructions. Successively, to avoid the calibration of any artificial parameter, the regularization has also been proposed as a multiplicative factor of the original cost functional.

In this work, selected results from extensive numerical simulations will be presented to assess the performances of an integrated inversion scheme based on the CSI method and the Fuzzy Logic Systems. The results will also highlight the interaction effects between the fuzzy regularization coefficients and the regularization approach based on the total variation for both single and multiple-frequency data sets.

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