Deep Learning Augmented Inverse Scattering Algorithm

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Microwave imaging is a widely used technology with applications ranging from geophysical exploration to medical imaging and landmine clearance. It involves the reconstruction of a target's dielectric profile from measurements of scattered electromagnetic (EM) fields produced upon illumination of the target by fields from known sources. The measured scattered fields are processed by an inverse scattering (IS) algorithm to estimate the target's shape and/or dielectric profile. Unfortunately, the scattered EM field data does not uniquely determine the target, i.e. the IS problem is *ill-posed*. Furthermore, the relationship between the scattered EM fields and the target shape and/or dielectric profile are *non-linear*. As a result, IS algorithms often converge slowly and/or get stuck in weak local optima. To remedy this situation, a plethora of IS preconditioners and penalty function-based regularizers, and different IS algorithms have been developed. Unfortunately, these efforts only have yielded limited progress in the reconstruction of arbitrarily shaped targets. In recent years, significant research efforts have been devoted to the development of application-specific reconstruction schemes that leverage machine learning methods. Current literature abounds with applications of artificial neural networks (and support vector machines) to the EM IS problem. The main idea behind these methods is to train a neural network with measurements (input) and dielectric profiles of "known" investigation domains (output) during an offline stage and then to use the trained neural network to predict the shape and/or dielectric profile of the "unknown" target during the online stage.

In this study, an iterative computational methodology that combines a deep learning convolutional neural network (CNN) (Lecun et al., *Proc. IEEE.*, 86(11), 2278 - 2324, 1998) and a distorted born (DB) IS algorithm (Chew and Wang, *EEE Trans. Med. Imag.*, 9(2), 218-225, 1990) is proposed. The method iteratively refines an initial guess of the target's shape and/or dielectric profile until the scattered field data matches that of the true profile to a prescribed threshold. The iterative procedure involves two steps: (i) a prescribed number of DB IS iterations are executed; (ii) the DB IS dielectric profile prediction is fed into the CNN, which in turn produces an improved reconstruction of the true dielectric profile. The method results in more accurate reconstructions than stand-alone DB IS schemes because the CNN injects information about the (restricted class of) objects being imaged to the IS algorithm that is unknown to the scheme with or without a classical regularizer.

The efficacy and accuracy of the method are demonstrated by reconstructing dielectric profiles of targets encountered in through the wall imaging (TWI). The CNN is trained to predict TWI dielectric profiles by using a large set of randomly and synthetically generated TWI dielectric profiles (output) and their DB IS reconstructions (input). The CNN extracts features of the EM scattering that are specific to DB IS reconstructed TWI dielectric profiles and uses them to predict locations of the walls. The wall locations are then used to generate the target's dielectric profile. In the TWI context, the method has been shown very effective in accelerating the convergence and accuracy of reconstructions of IS algorithms.