Deep Learning Augmented Inverse Scattering Algorithms for Through-the-Wall Imaging

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Inverse scattering (IS) algorithms are used in many microwave tomography applications ranging from through-the-wall imaging (TWI) to breast cancer detection and non-destructive testing. These algorithms process electromagnetic (EM) fields scattered from unknown targets to estimate their shape and/or dielectric profile. Due to the ill-posedness of IS problem and the non-linear relationship between a target's properties and the EM fields it scatters, IS algorithms often converge slowly and reconstruct the shape and/or dielectric profile of the target inaccurately. To tackle these issues, significant research efforts have recently been devoted to the development of deep learning-augmented reconstruction schemes that improve the convergence and accuracy of the IS algorithms (Gomez et al., USNC/URSI Nat. Radio Sci. Meeting, 2016) (Wei and Chen, *IEEE Trans. Geosci. Remote Sens.*, 57(4), 1849-1860, 2019) (Li et. al., *IEEE Trans Antennas Propagat.*, 67(3), 1819-1825, 2019). The core idea of these schemes is (i) to train a deep neural network with the dielectric profiles of "known" scatterers (output) and their inaccurate reconstructions generated by IS algorithms (input) during the offline stage and (ii) to predict the dielectric profiles of "unknown" scatterers from inaccurate IS reconstructions and/or scattered field measurements during the online stage.

In this study, we compare the performance of three different deep learning-augmented IS algorithms for TWI applications. These algorithms leverage (i) traditional convolutional neural networks (CNN) (Y. LeCun et al., *Nature*, 521(7553), 436–444, 2015), (ii) U-nets (R. Olaf et al., *Int. Conf. Med. Image Comp. Comp Ass. Interv.*, 234-241, 2015), and (iii) Mask Regional CNNs (H. Kaiming et al., Proc. *IEEE Inter. Conf. Comp. Vision*, 2961-2969, 2017) to extract features of the dielectric profiles generated by the distorted Born IS (DB-IS) algorithm (Chew and Wang, *IEEE Trans. Med. Imag.*, 9(2), 218-225, 1990). During the offline stage, the algorithms are trained using a large set of synthetically and randomly generated TWI dielectric profiles (output) and their inaccurate DB-IS reconstructions (input) generated after a prescribed number of DB-IS iterations. During the online stage, the trained deep neural networks are used to predict the dielectric profile within the 'unknown' investigation domain (output) for a given DB-IS-generated inaccurate dielectric profile. All three algorithms yield more accurate reconstructions compared to the stand-alone DB-IS algorithm. In the talk, the accuracy comparisons and limitations of these three algorithms for the TWI application as well as the training sets will be presented.