Convolutional Neural Networks for Imaging of Micro-structures

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Abstract— The characterization of micro-structures from electromagnetic field widely attracts attention. The work focuses on the imaging of sub-wavelength micro-structures, which is in some way linked with the question of super-resolution, since the elements of the considered structures may exhibit special features arising from such sub-wavelength dimensions [1]. This means that traditional first-order imaging approaches relying on backpropagation as developed under many guises will fail. So, the convolutional neural networks are proposed to solve the problem, which is already used to solve the inverse scattering problem [2] in many applications.

The micro-structure is composed of a grid-like set of circular cylindrical dielectric rods, and some rods are missing in the structure, the goal of the research is the localization of missing rods. The micro-structure is put in the region of interest, and a set of transmitter and receiver turns around on a circle at 36 positions (the interval between two positions is 10 degrees), the radius of the operation circle is 20 wavelengths from the center of the region of interest, the structure is illuminated by the in-going wave generated by the transmitter, then the scattered field is collected by the receiver. From the collected scattered field, the distribution of the permittivity of the micro-structure can be reconstructed, then the localization on missing rods in the structure can be realized.

There are lots of different methods to realize the reconstruction procedure, the non-iterative method like back-propagation, or the iterative method like contrast source inversion [3]. A binary contrast source inversion (CSI) is proposed to solve the problem, it transfers the conventional CSI to deal uniquely for binary case, by representing the permittivity with sigmoid function, where the missing rod in the structure is '0' case and the normal rod is '1' case. But the main drawback of the iterative optimization method is the time consuming burden and it is not suitable for real time reconstruction.

Methodologies based on artificial neural network are proposed to realize the localization of missing rods in the structure. The convolutional neural networks have significant achievement in many areas. It has strong modeling capabilities, and real-time localization can be achieved with a well-trained network. The structure of CNN [4] that we use is based on U-net architecture, which contains three main parts: the convolutional layers, batch normalization layer, rectified linear function and the max-pooling; full-connected layers as the second part; and the de-convolutional layers with the sigmoid function as the third part. The network can realize the mapping from the scattered field to the distribution of the permittivity.

The corresponding experiment in an anechoic chamber is also being carried out with carefully designed prototypes, and we should notice that the number of experimental data is much smaller than the number of simulated data, so we can't use the experimental data to train the network directly, and with the presence of experimental noise, the performance of the model that is trained based on the simulated data can't be guaranteed.

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