Target Counting and Location Detection in Electromagnetics Using Artificial Intelligence

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Introduction

Here, we showcase an application of neural networks (NNs) to solve an inverse problem in electromagnetics. Identical targets are randomly distributed into an area of known dimensions. The electromagnetic (EM) field measured at a finite number of points along the perimeter of the area is then fed into a convolutional neural network (CNN) designed to predict either (i) the number of the targets or (ii) the location of the targets. Counting the targets is posed as a supervised classification problem with a known upper limit to the number of targets, and an accuracy of 96% has been achieved for the case where the number of the targets is known to be less than 10. A number of approaches have been taken to improve the network performance including frequency variation analysis and appending channels to the input vector corresponding to the EM field measurements acquired by illuminating the same target distribution with additional PW angles of incidence.

Methods

A randomized target distribution (RTD) is introduced into a box, and subsequently illuminated with a monochromatic plane wave (PW) at a given angle of incidence. The EM field is then measured by 40 antennas uniformly spaced along the perimeter of the square, and then fed into a CNN which outputs the class probabilities. In the counting scenario, each class corresponds to a target number, and in the location detection scenario, each class corresponds to a cell in the 2D mesh grid over the distribution area.

Results

• Major factors which give rise to incorrect predictions are identified by analyzing the target distributions.
• The failure analysis has been utilized to improve the performance of CNN.
• Prediction accuracies as high as 96% have been achieved as a result of the failure analysis.

Evaluation of CNN performance trained on 270,000 samples containing up to 10 targets. All RTDs are illuminated with a PW at f = 10 MHz and at an angle of incidence of 0 – 45 degrees. The training process involved online-testing (evaluation) of the CNN on another independent 30,000 samples to monitor the generalization capability of the CNN. After the training and the online-testing processes are completed, a set of 300,000 new samples were generated for final performance evaluation. Operating the trained CNN on each sample returns an output vector from which the predicted number of targets can be obtained. Within the set of 300,000 new samples, an overall accuracy of 89% is achieved. Panel (a) shows the accuracies achieved when performed on the corresponding bar. Panel (b) represents the output vector of probabilities averaged over all samples within the i-th subset for n ∈ {1,...,N}.

Conclusions

Here, the convolutional neural networks are shown to be capable of solving inverse problems, namely counting and tracking objects based on electromagnetic field measurements by antennas surrounding those objects. Failure analysis, as briefly shown here, is an effective tool in enhancing the CNN performance to an extent where CNN predictors could outperform RADARS.

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For further information

Below are the resources to learn about convolutional neural networks (CNNs) in detail:


References


Network performance is evaluated on EM field measurement under illumination frequencies ranging from 10 to 100 MHz. This suggests that 10 MHz illumination leads to maximum learning. Lower frequencies lead to a very low contrast in antenna readings, which results in instability in training the CNN.

• Target location detection

Our tracking CNN is capable of predicting the location of only one target. The predictor outputs the probability that the target can be found within any given cell of the mesh grid the area is divided into.

• Frequency sweep analysis

The CNN performance with an input vector containing the separately-measured EM field due to three additional illumination angles.