Deep Neural Network Representations of Transient Electrodynamic Phenomena

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With the exponential growth in computing power and unprecedented availability of data, the machine learning and data-driven technology is emerging as one of the key disruptive developments for achieving progress in the simulation-driven discovery. In this paper, we demonstrate the feasibility of utilizing time-domain datasets obtained from simulations/measurements to develop predictive physical models based on deep neural networks.

The network architecture comprises a convolutional encoder, a vanilla recurrent neural network (RNN) and a convolutional decoder. The convolutional encoder takes the time sequences of EM field data as inputs. Through the multilayer convolutional operations, the spatial domain is successfully compressed. The features extracted by the encoder are fed to the RNN. Subsequently, the hidden state of the RNN is recursively updated for a specific number of times to produce a stack of representations of the temporal field evolution. Finally, the stack of updates is fed to the decoder to construct complete future time steps of the electromagnetic (EM) fields.

The training stage can be viewed as teaching machine electromagnetic physics. It is divided into three Phases. In Phase I, we aim to teach the network to emulate the physics of wave propagation in homogeneous media by varying only the incident angles. In Phase II, we include different sizes of perfect electric conducting (PEC) circles and squares in the simulation domain. The network is expected to learn the physics of wave reflection, diffraction, and creeping wave phenomena. In Phase III, we place randomly distributed, multi-scale PEC objects in the simulation domain.

The proposed network can be used to learn representations of transient electrodynamic phenomena, which can then be utilized as a data-driven predictive model in simulating transient problems.