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Construction of deep neural networks using a time-delayed system

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We present a method for folding a deep neural network of arbitrary size into a single system with multiple time-delayed feedback loops [1]. This single-neuron deep neural network contains only a single nonlinearity and appropriately adjusted modulations of the feedback signals. The network states emerge in time as a temporal unfolding of the dynamics. By adjusting the modulations within the feedback loops, we adapt the network's connection weights. These connection weights are determined via a back-propagation algorithm. Our approach can fully represent standard deep neural networks (DNN), encompasses sparse DNNs, and extends the DNN concept toward dynamical systems implementations. The new method, which we call folded-in-time DNN (Fit-DNN), exhibits promising performance in a set of benchmark tasks.

[1] F. Stelzer, A. Röhm, R. Vicente, I. Fischer, S. Yanchuk, Deep neural networks using a single neuron: folded-in-time architecture using feedback-modulated delay loops, *Nat. Commun.*, **12**(2021), No. 1, 5164.