# Lyapunov-derived Control and Adaptive Update Laws for Inner and Outer Layer Weights of a Deep Neural Network

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**Abstract**: Lyapunov-based real-time update laws are well-known for neural network (NN)-based adaptive controllers that control nonlinear dynamical systems using single-hidden-layer NNs. However, developing real-time weight update laws for deep NNs (DNNs) remains an open question. This paper presents the first result with Lyapunov-based real-time weight adaptation laws for each layer of a feedforward DNN-based control architecture, with stability guarantees. Additionally, the developed method allows nonsmooth activation functions to be used in the DNN to facilitate improved transient performance. A nonsmooth Lyapunov-based stability analysis proves global asymptotic tracking error convergence. Simulation results are provided for a nonlinear system using DNNs with leaky rectified linear unit (LReLU) and hyperbolic tangent activation functions to demonstrate the efficacy of the developed method.