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Fluctuations and concentration in two-layer neural networks

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We study the learning dynamics of wide two-layer neural networks trained by stochastic gradient descent (SGD), aiming to understand *quantitatively* how network width shapes both the typical training trajectory and the variability of the final predictor.

We adopt an *interacting particle* viewpoint in which neurons evolve under SGD as a large coupled system. As the width grows, this collective dynamics is well approximated by a deterministic *mean-field* limit, which provides an analytically tractable description of how the parameter distribution (and hence predictions) evolves during training.

We then quantify finite-width effects through two complementary results. First, we characterize *fluctuations* around the mean-field limit: after the natural rescaling, we show that the deviations converge to a Gaussian limiting process, yielding an explicit description of the variability induced by training randomness. Second, we establish finite-width *concentration inequalities*, uniform over training time, which control with high probability how close a width- N network remains to its mean-field proxy.

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