Artificial Neural Networks: Tricks of the Trade and Neural Smithing

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Introduction to Machine Learning

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So now we can train ANNs with backprop, so we are done, right? Machine learning is solved, class finally dismissed?

So now we can train A… …prop,

so w… …t?

Mac… …solved, class

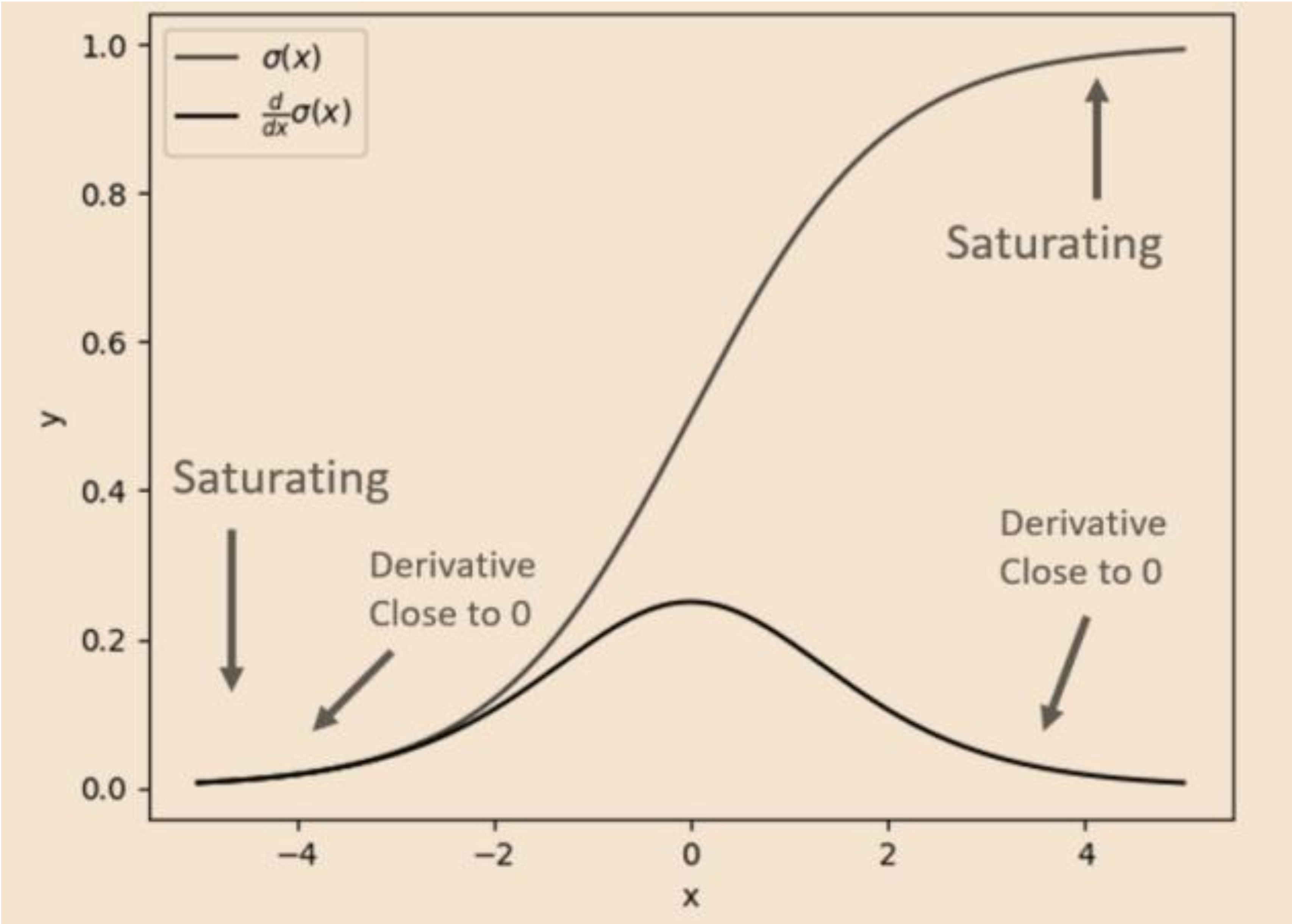
…y dismissed?

WRONG!

The Vanishing Gradient Problem

- Solving credit assignment problem with back-propagation (backprop) too difficult
  - Difficult to know how much importance to accord to remote inputs (Bengio et al., 1994)
  - Information passed through chain of multiplications back through network – ***vanishing gradients***
    - Any value slightly less than 1 in Hadamard product, derivative signal quickly shrinks to useless values (near zero)
  - Learning long-term dependencies in temporal sequences becomes near impossible
- Complementary problem: ***exploding gradients***
  - Any value greater than 1 in Hadamard product, derivative signal increases dramatically (numerical overflow)

The Logistic Sigmoid and Its Derivative:

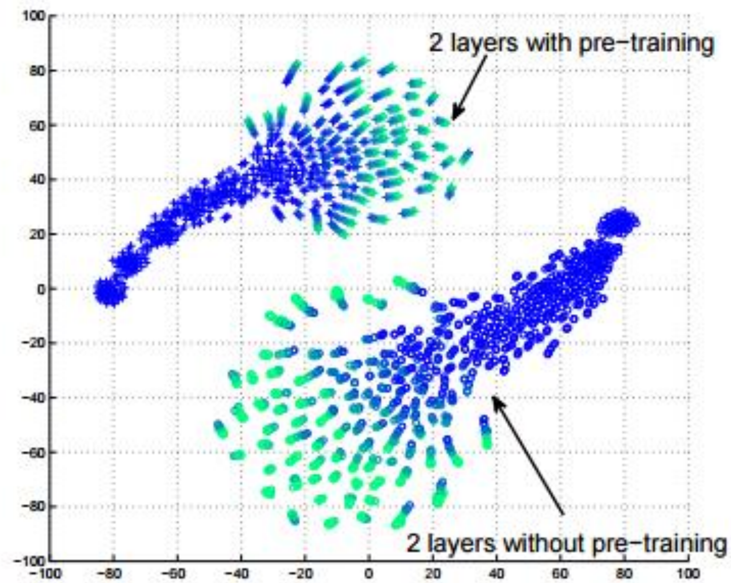


How to make those gradients work for you!

THE IMPORTANCE OF STARTING OUT RIGHT: INITIALIZATION

Why do we care how parameters are initialized?

- Initialization affects final performance
  - Will put closer to some spots in function space and farther from others



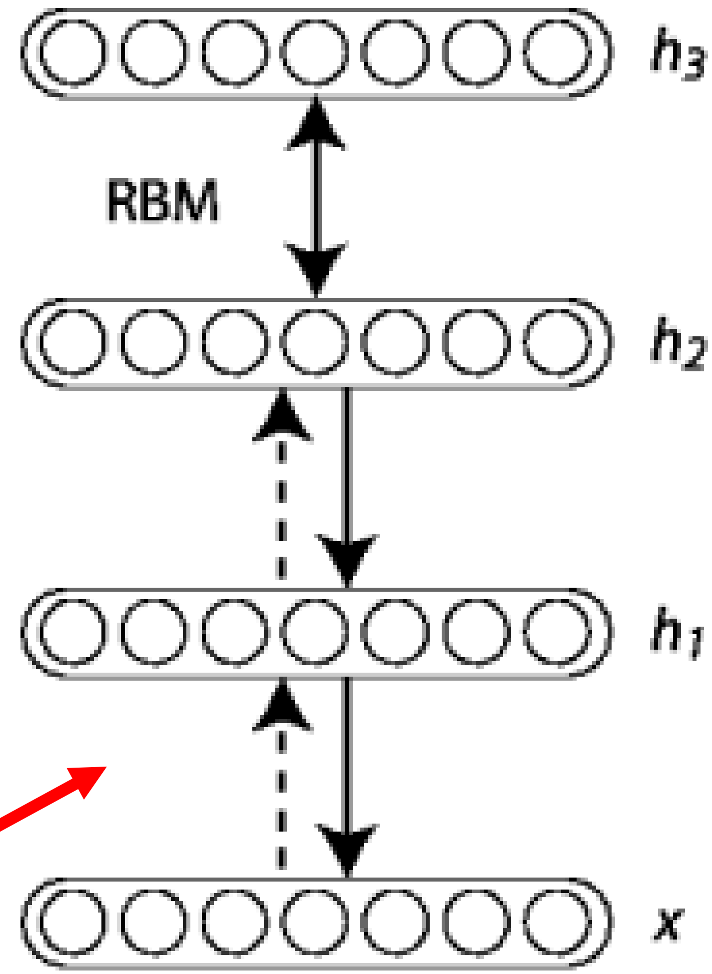
- Where we end up in function space will often correlate w/ our error performance

Figure 5: 2D visualizations with tSNE of the functions represented by 50 networks with and 50 networks without pre-training, as supervised training proceeds over MNIST. See Section 6.3 for an explanation. Color from dark blue to cyan and red indicates a progression in training iterations (training is longer without pre-training). The plot shows models with 2 hidden layers but results are similar with other depths.

"Why Does Unsupervised Pre-training Help Deep Learning?", Erhan et al. 2010 http://jmlr.org/papers/volume11/erhan10a/erhan10a.pdf

Pre-Training: Learning Your Initialization

- General idea:
  - Train another model, e.g., ***deep belief network*** →
  - Dump its parameters into the one you care about
  - Fine-tune final model



- Unsupervised generative models were largely useful for this

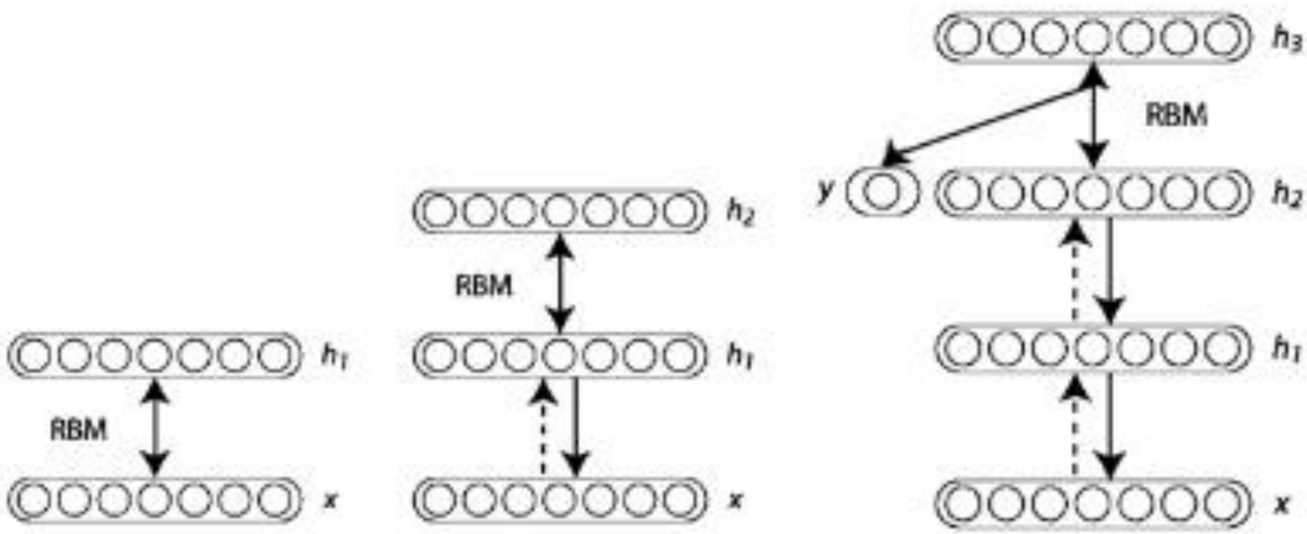
This is used something called a harmonium, a small non-backprop trained generative network!

$$P(x, h^1, \ldots, h^\ell) = \left(\prod_{k=0}^{\ell-2} P(h^k | h^{k+1}) \right) P(h^{\ell-1}, h^\ell)$$

With: $P(h^{k-1} | h^k)$, $P(h^{\ell-1}, h^\ell)$, $x = h^0$

Pretraining: Stacked (Neural) Models

- Iterative pre-training construction of **Deep Belief Network (DBN)** (Hinton et al., 2006)



(a) RBM for $\mathbf{x}$ (b) RBM for $\mathbf{h}^1$ (c) RBM for $\mathbf{h}^2$ and y

from: Larochelle et al. (2007). An Empirical Evaluation of Deep Architectures on Problems with Many Factors of Variation.

White Board Time!

A Simple (Denoising) Autoencoder

Research Efforts in Pre-Training

Pre-training works! (Erhan et al., 2010), but…

- 2-stage learning (Bengio et al., 2007)
  - Step 1: (Greedy) unsupervised pre-training
    - Deep Belief Networks: Contrastive Divergence (CD-k) or SML/PCD
    - ***Stacked Denoising Autoencoders***: Back-propagation w/ cross-entropy loss
  - Step 2: Supervised fine-tuning
    - 1) Toss old model, dump parameters into MLP
    - 2) (Gentle) back-propagation fine-tuning

So…

- Hybrid, single-stage training (Larochelle et al., 2012; Ororbia et al., 2015)
  - Why not learn a generative & discriminative model at same time?

OR…Smarter Random Initializations

- Classical approaches
  - Sample from *~U(-a, a)*, where is *a* small scalar
  - Sample from *~N(0, a)*, where is *a* small standard deviation
- Fan-in-Fan-out (number inputs, number output)
  - Calibrate by variances of neuronal activities
- Simple distributional schemes
  - Fan-in/Fan-out Uniform
  - Fan-in/Fan-out Gaussian (good for ReLU activations)
- Orthogonal Initialization
  - Use Singular Value Decomposition (***SVD***) to find initial weights
- Identity Initialization / Constraint (for RNNs)
  - Does not always work unless constraint is enforced

QUESTIONS?