Advanced Machine Learning

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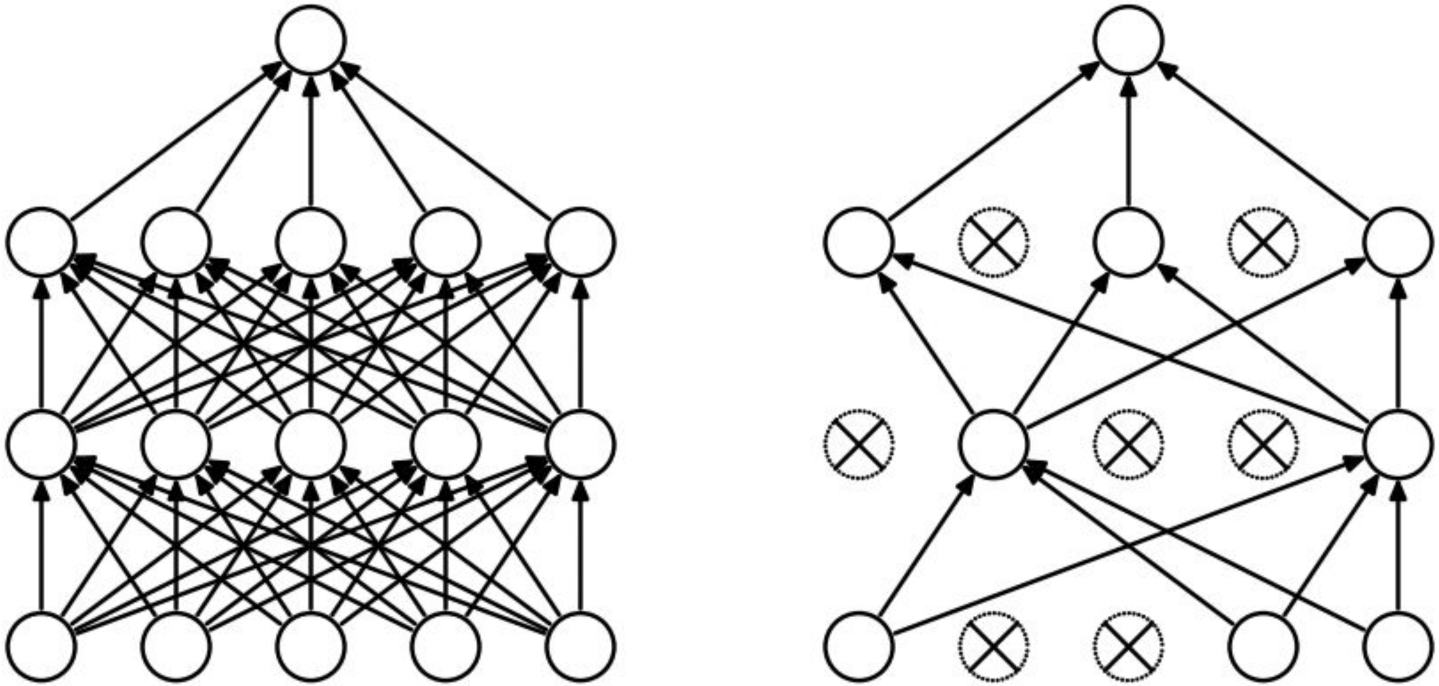
Dropout



(a) Standard Neural Net (b) After applying dropout.

Srivastava, Nitish, et al. "Dropout: a simple way to prevent neural networks from overfitting." *The journal of machine learning research* 15.1 (2014): 1929-1958.

Why should we use dropout?

To make an ensemble of neural networks, they should either have

1. Different architectures
   - Finding optimal hyperparameters for each architecture is a daunting task
   - Training each large network requires a lot of computation
2. Be trained on different data
   - There may not be enough data available to train different networks on different subsets of the data

Dropout is a technique that addresses both these issues

Srivastava, Nitish, et al. "Dropout: a simple way to prevent neural networks from overfitting." *The journal of machine learning research* 15.1 (2014): 1929-1958.

Implementing Dropout

In a neural network with *L* hidden layers and no dropout, the feed-forward operation can be described as:

$$\begin{aligned} z_i^{(l+1)} &= \mathbf{w}_i^{(l+1)} \mathbf{y}^l + b_i^{(l+1)}, \\ y_i^{(l+1)} &= f(z_i^{(l+1)}), \end{aligned}$$

where ***z*** is the input into a layer, ***y*** is the output from a layer, ***w*** and ***b*** are the weights and biases of a layer, and ***f()*** is the activation function

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Implementing Dropout

With dropout, the feed-forward operation becomes:

$$
\begin{aligned}
r_j^{(l)} &\sim \mathrm{Bernoulli}(p), \\
\widetilde{\mathbf{y}}^{(l)} &= \mathbf{r}^{(l)} * \mathbf{y}^{(l)}, \\
z_i^{(l+1)} &= \mathbf{w}_i^{(l+1)} \widetilde{\mathbf{y}}^{l} + b_i^{(l+1)}, \\
y_i^{(l+1)} &= f(z_i^{(l+1)}).
\end{aligned}
$$

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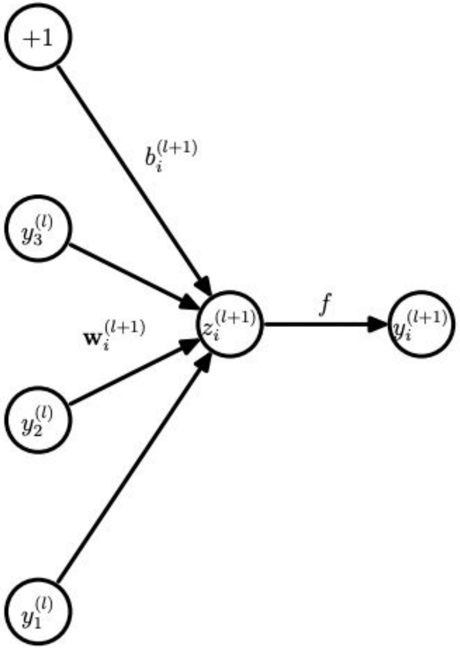
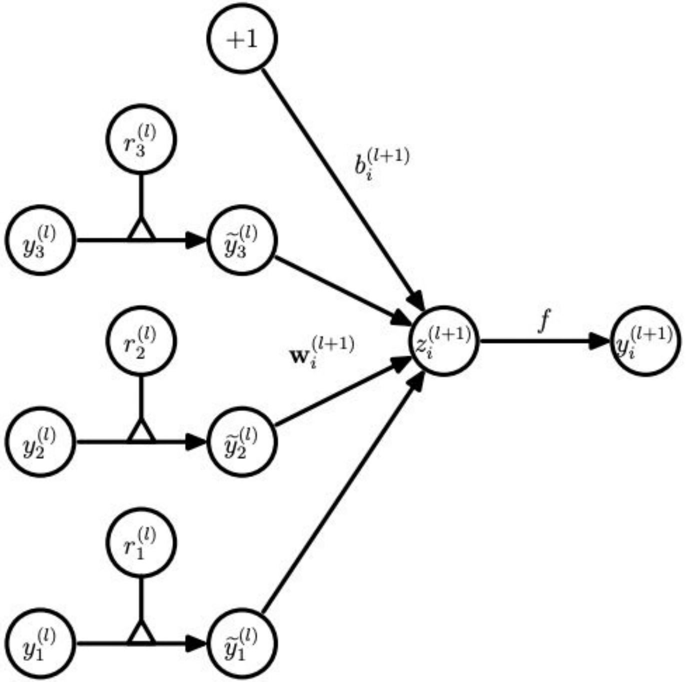
Implementing Dropout



(a) Standard network



(b) Dropout network

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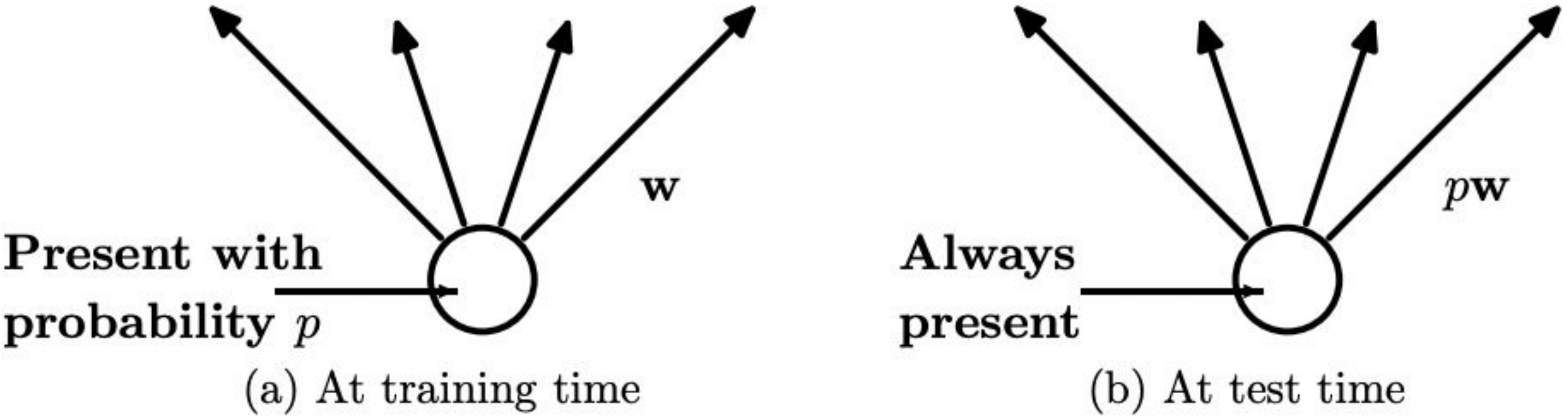
Implementing Dropout - Inference time

At inference time, it is not feasible to explicitly average the predictions all the different models like we do with bagging. So, we use scaling:



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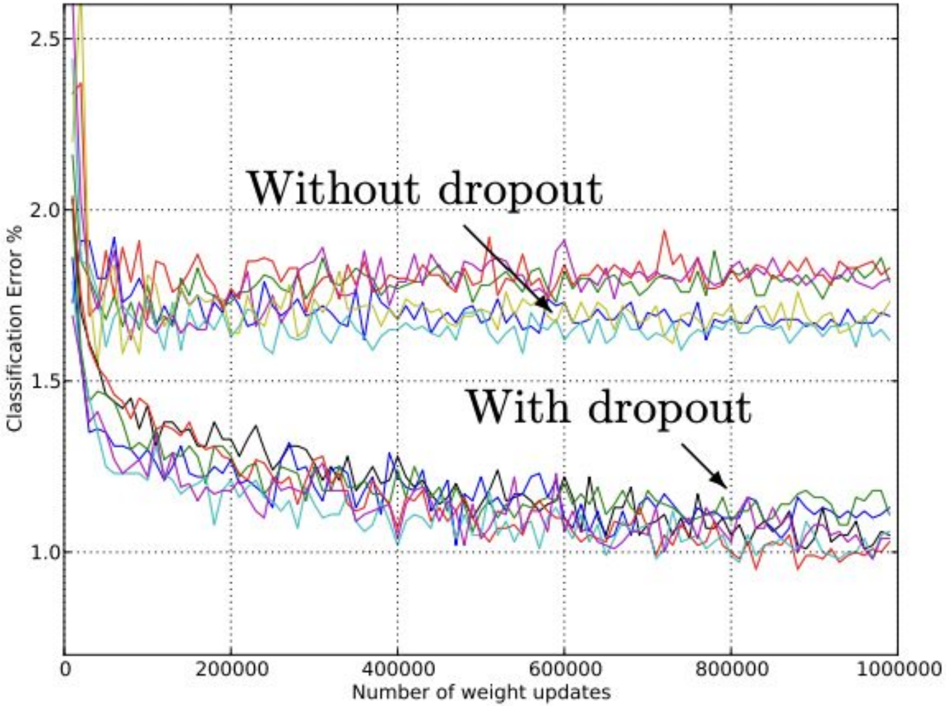
Implementing Dropout - Results



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Implementing Dropout - Results

Method	Test Classification error %
L2	1.62
L2 + L1 applied towards the end of training	1.60
L2 + KL-sparsity	1.55
Max-norm	1.35
Dropout + L2	1.25
Dropout + Max-norm	**1.05**

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Advantages of Dropout

1. Computationally cheap

- During training, dropout requires only *O(n)* computations per example per update, to generate *n* random numbers and multiply them
- During testing, the cost of dividing the weights (scaling) is a single operation per example

Advantages of Dropout

2. It works well with nearly any model

Method	Phone Error Rate%
NN (6 layers) (Mohamed et al., 2010)	23.4
Dropout NN (6 layers)	21.8
DBN-pretrained NN (4 layers)	22.7
DBN-pretrained NN (6 layers) (Mohamed et al., 2010)	22.4
DBN-pretrained NN (8 layers) (Mohamed et al., 2010)	20.7
mcRBM-DBN-pretrained NN (5 layers) (Dahl et al., 2010)	20.5
DBN-pretrained NN (4 layers) + dropout	**19.7**
DBN-pretrained NN (8 layers) + dropout	**19.7**

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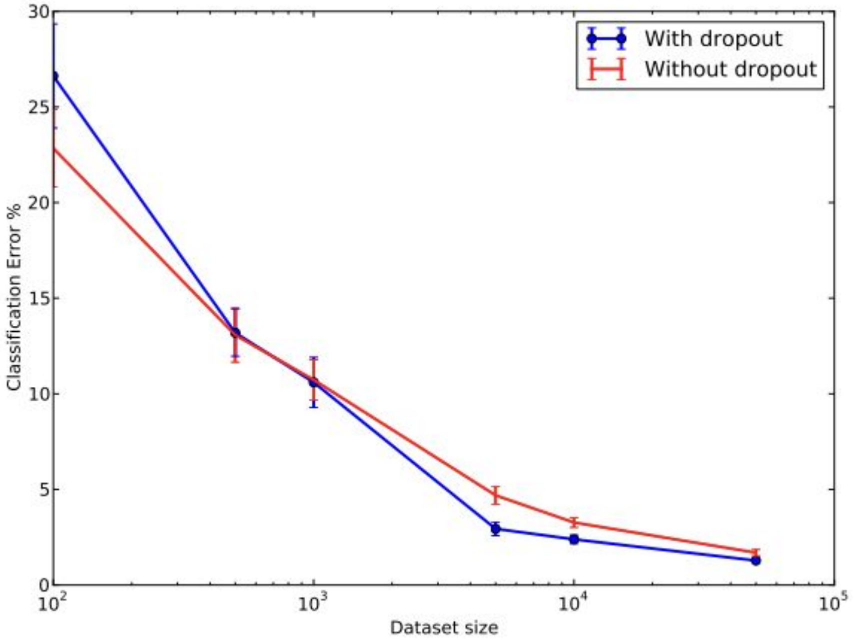
Limitations of Dropout

1. Works better with larger training datasets



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Limitations of Dropout

2. The cost function (or loss function) isn't well-defined