ImageNet Classification with Deep Convolutional Neural Networks

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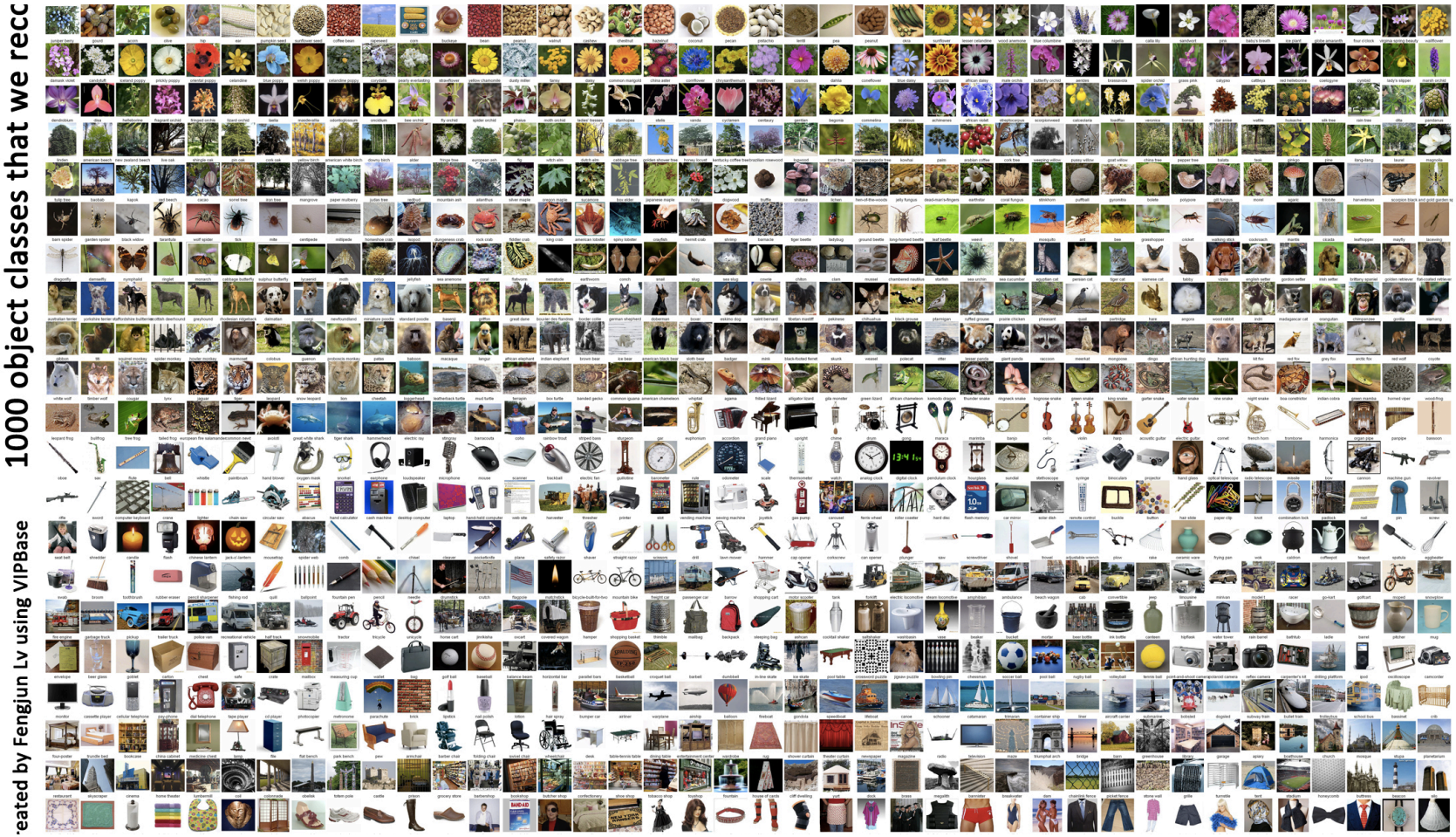
Problem: Large-Scale object class definition



rtesy of ImageNet (http://www.image-net.org/challenges/LSVRC/2010/index)

Motivation

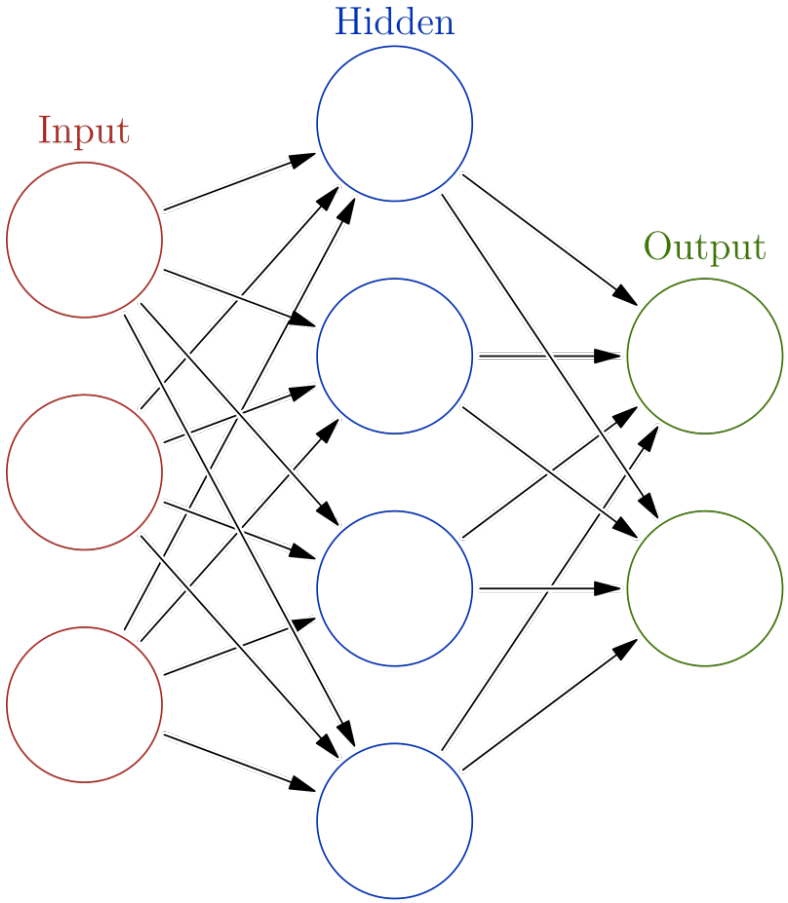
- Number of image classes close to the scale of what a human can differentiate
- A large amount of data means algorithms need to be scalable

Key Contributions

- Efficient method to learn parameters of a convolutional net
- Amazing benchmark results

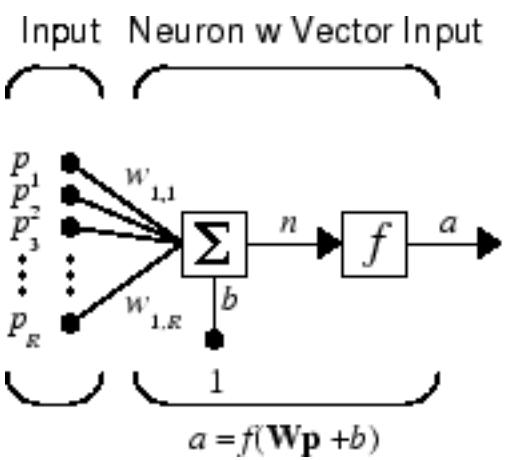
Background

- Neural Network



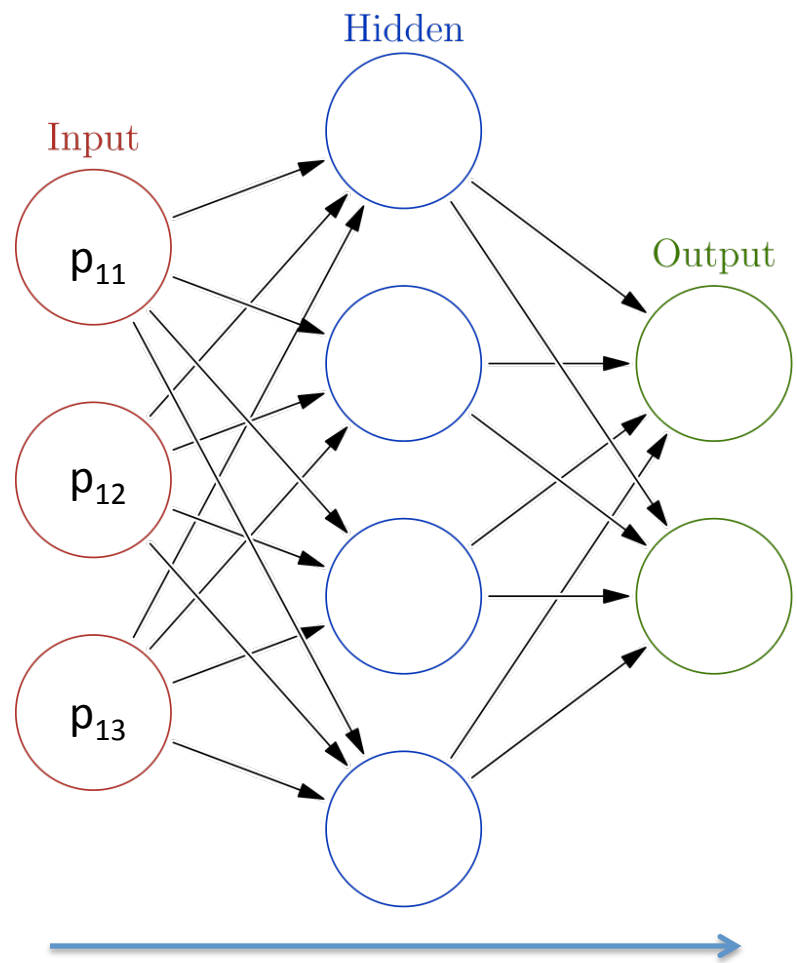
Background: Fully Connected NN

- Forward Propagation
- $n_2 = W_{21}\, p_1 + b_1$
- $a_2 = f(n_2)$



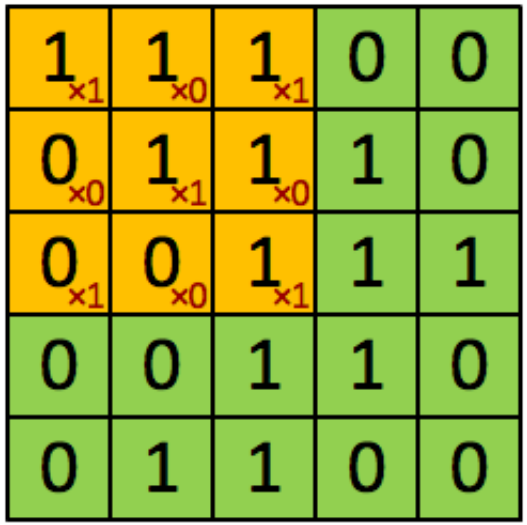
Where

R = number of elements in input vector

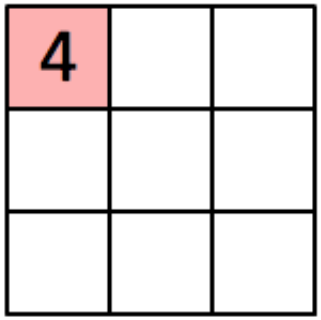


Background: Convolutional NN

- Same as fully connected but with constraints



Image

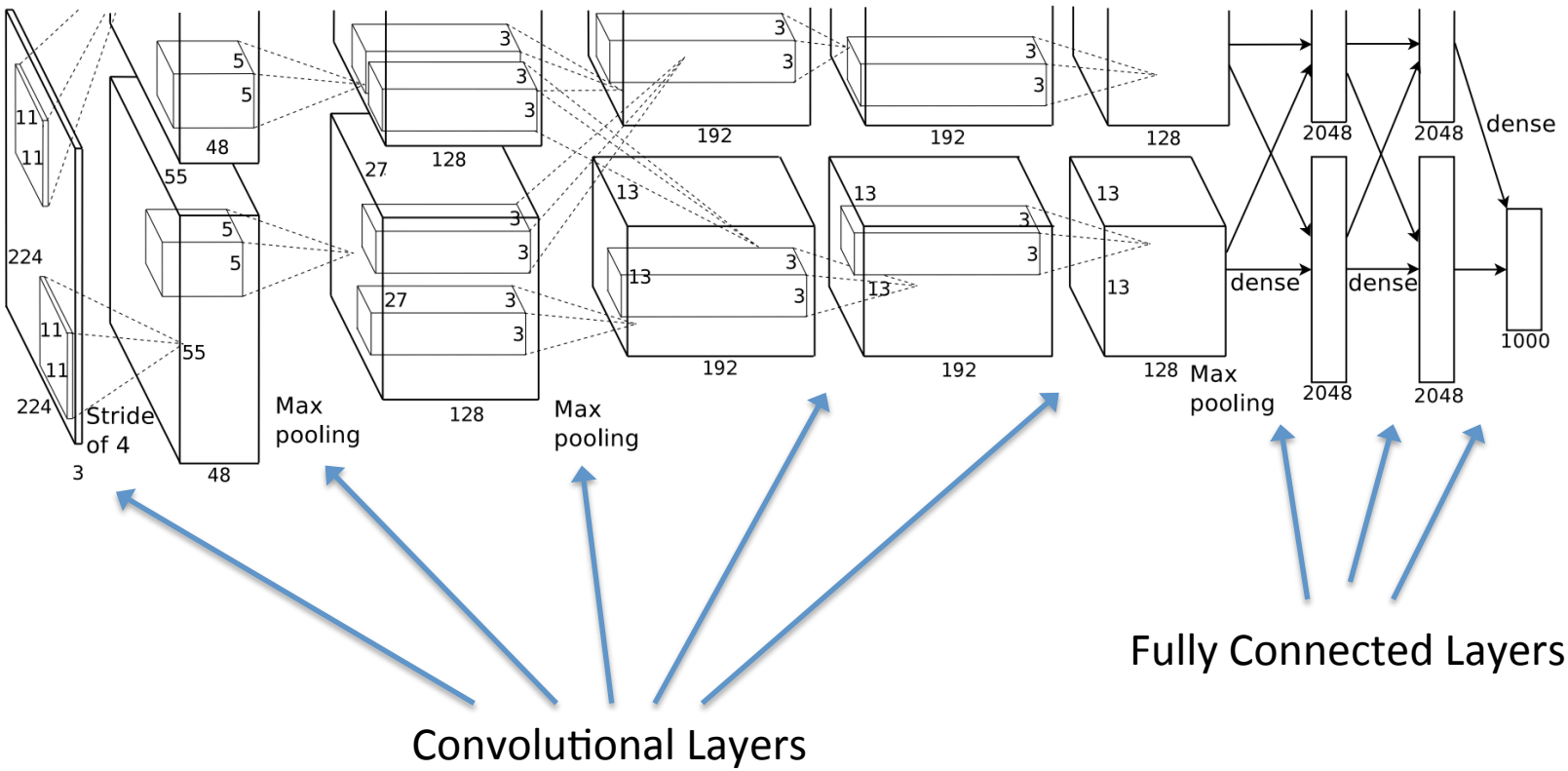


Convolved Feature

Background: history

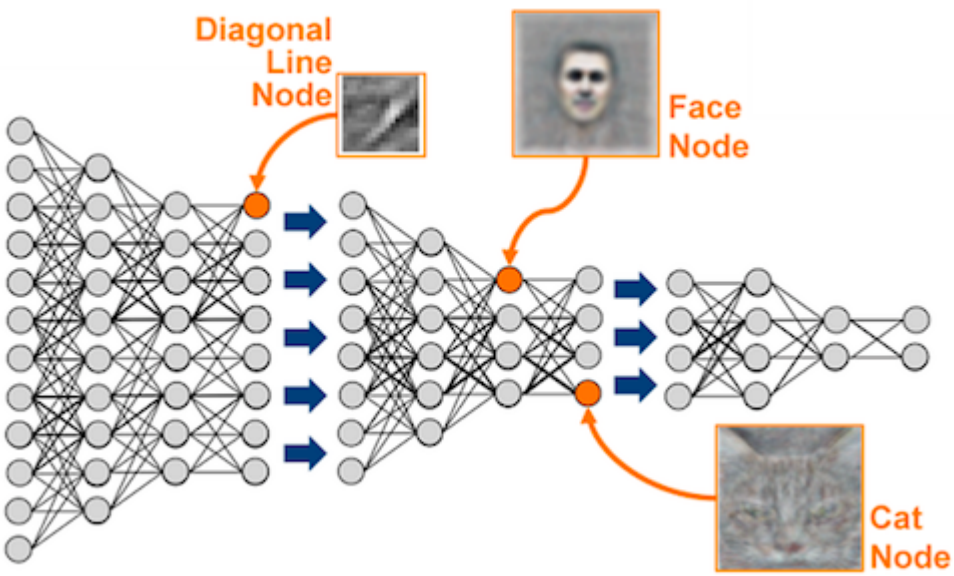
- Convolutional Neural Nets are old
  - Invented in 1980 by Kunihiko Fukushima
- Technology and dataset sizes limited learning

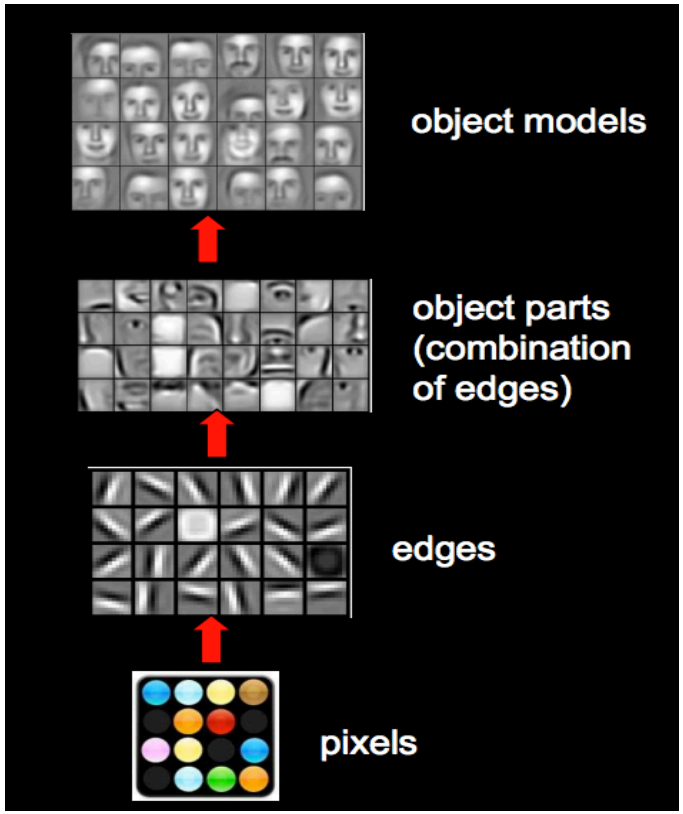
Overview of Implementation



Why Deep?

- Learn feature hierarchies

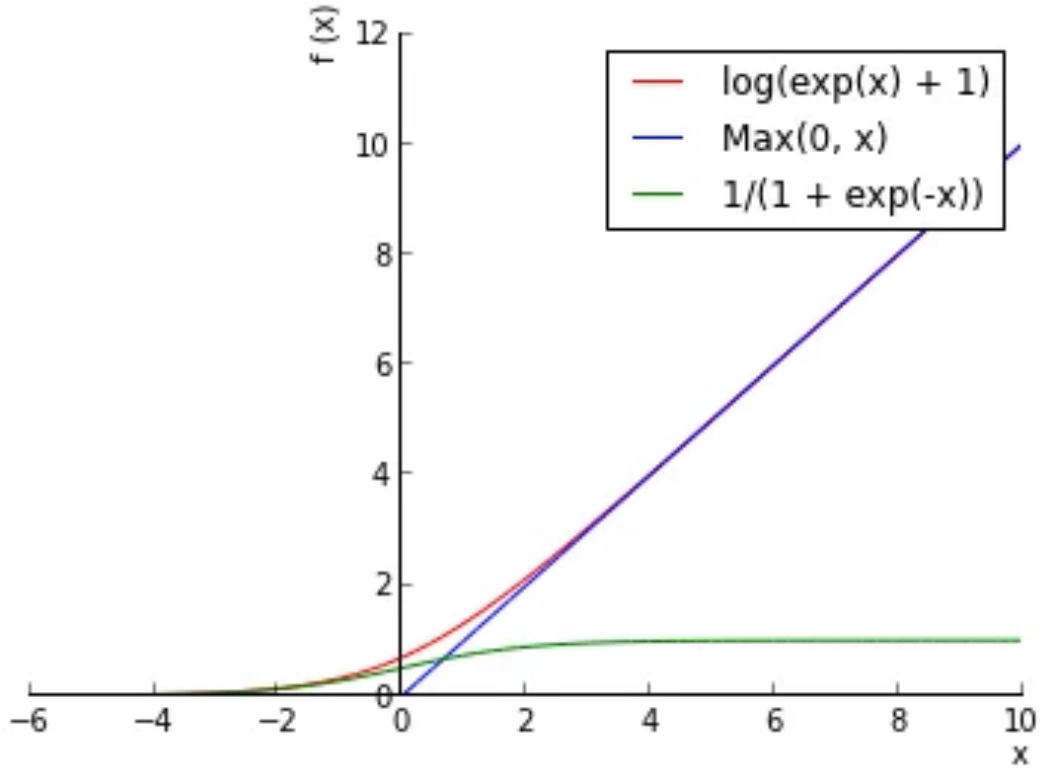




http://icml2011speechvision.files.wordpress.com/2011/06/visionaudio.pdf

Optimizations to speed up training

- Use Rectified Linear Units: f(x) = max(0,x)



Optimizations to speed up training

- Train with two GPUs
- Overlap pooling
- Local response normalization

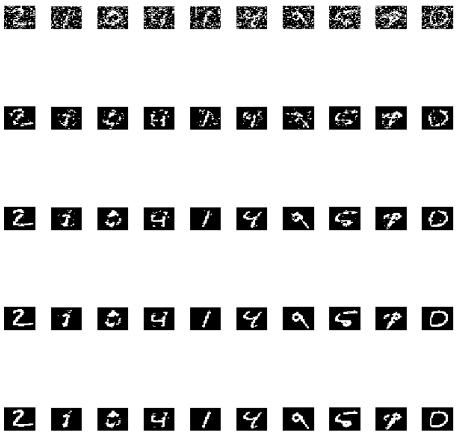
$$b^i_{x,y} = \frac{a^i_{x,y}}{\left(k + \alpha \sum_{j=\max\left(0, i-\frac{n}{2}\right)}^{\min\left(N-1, i+\frac{n}{2}\right)} \left(a^j_{x,y}\right)^2\right)^\beta}$$

Combating overfitting

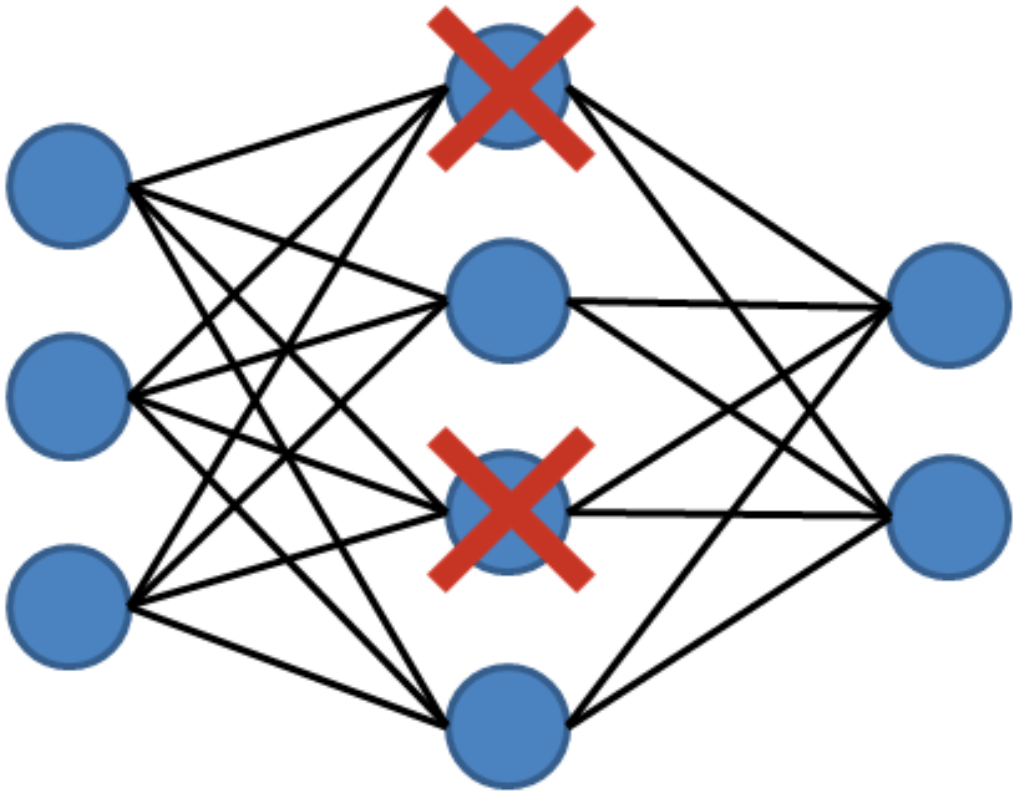
- Many parameters -> can easily overfit
  - Data augmentation
  - Dropout

Data Augmentation

- Create fake "new data"
  - Adding Noise
  - Sampling random 224x224 Patches
  - Horizontal Reflection



Dropout



Learning

- Backpropagation/ Stochastic Gradient Descent
  - Glorified chain rule
- Used a momentum method to update weights

$$
\begin{aligned}
v_{i+1} &:= 0.9 \cdot v_i - 0.0005 \cdot \epsilon \cdot w_i - \epsilon \cdot \left\langle \frac{\partial L}{\partial w}\Big|_{w_i} \right\rangle_{D_i} \\
w_{i+1} &:= w_i + v_{i+1}
\end{aligned}
$$

v_{i+1} = Momentum at iteration i+1	.0005 = weight decay
w_{i+1} = weight at iteration i+1	.9 = friction coefficient
ε = learning rate	
L = cost function	

Strengths

- Great benchmark results
- Takes raw data as input
  - Learns own features
- (Empirically,) accuracies don’t seem to have plateaued yet.
  - 2014 paper achieves 10% error rate

Weaknesses

- Relatively slow to train
- A lot of hyper parameters
  - Number of layers, number of neurons/ layer, etc.

Experimental Results

Model	Top-1	Top-5
Sparse coding [2]	*47.1%*	*28.2%*
SIFT + FVs [24]	*45.7%*	*25.7%*
CNN	**37.5%**	**17.0%**

Table 1: Comparison of results on ILSVRC-2010 test set. In *italics* are best results achieved by others.

Model	Top-1 (val)	Top-5 (val)	Top-5 (test)
SIFT + FVs [7]	—	—	*26.2%*
1 CNN	40.7%	18.2%	—
5 CNNs	38.1%	16.4%	**16.4%**
1 CNN*	39.0%	16.6%	—
7 CNNs*	36.7%	15.4%	**15.3%**

Table 2: Comparison of error rates on ILSVRC-2012 validation and test sets. In *italics* are best results achieved by others. Models with an asterisk* were "pre-trained" to classify the entire ImageNet 2011 Fall release. See Section 6 for details.


sea slug
sea slug
flatworm
coral reef
sea cucumber
coral
swimming trunks
swimming trunks
short pants
maillot
maillot
bikini
stupa
stupa
palm
fountain
pine
mosque
megalith
megalith
castle
stone wall
church
cliff
mushroom
agaric
mushroom
jelly fungus
gill fungus
dead-man's-fingers
hair spray
HAARSPRAY
taft
hair spray
lotion
lighter
lipstick
nail polish
hen-of-the-woods
hen-of-the-woods
coral
coral fungus
lichen
polypore
tumble-dryer
Select programme
A
dishwasher
washer
tumble-dryer
photocopier
CD player

phaius

- celandine
- lesser celandine
- celandine poppy
- four o'clock
- toadflax

electric range

- electric range
- microwave
- dishwasher
- tumble-dryer
- file

banana

- hand glass
- toothbrush
- lipstick
- Band Aid
- persimmon

football helmet

- crash helmet
- soccer ball
- football helmet
- earphone
- hard hat

mushroom

- bolete
- gill fungus
- mushroom
- polypore
- agaric

scale

- armchair
- breastplate
- padlock
- stinkhorn
- cuirass

polyp

- polyp
- sea anemone
- coral
- sea slug
- flatworm

Madagascar cat

- squirrel monkey
- spider monkey
- titi
- indri
- howler monkey

The End

- Questions?