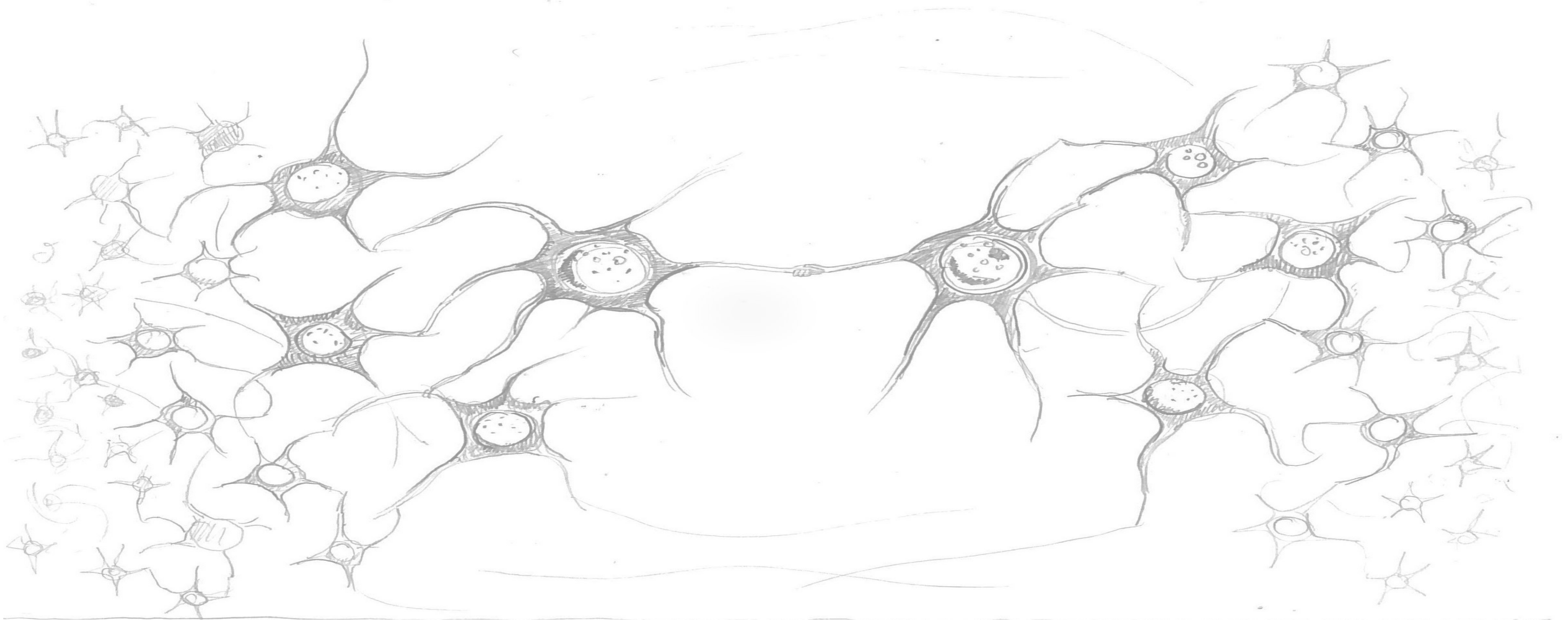
Navigating the Neural Net Terrain

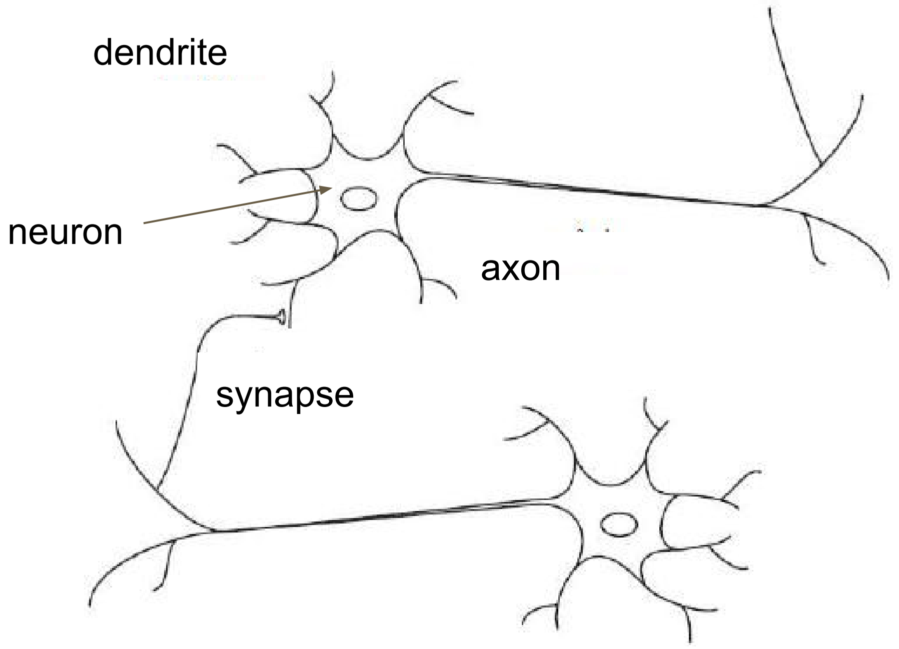
A 45 min. Tour



Julia Lintern

Sept. 7, 2016

The Brain Analogy
(our cartoon neuron)

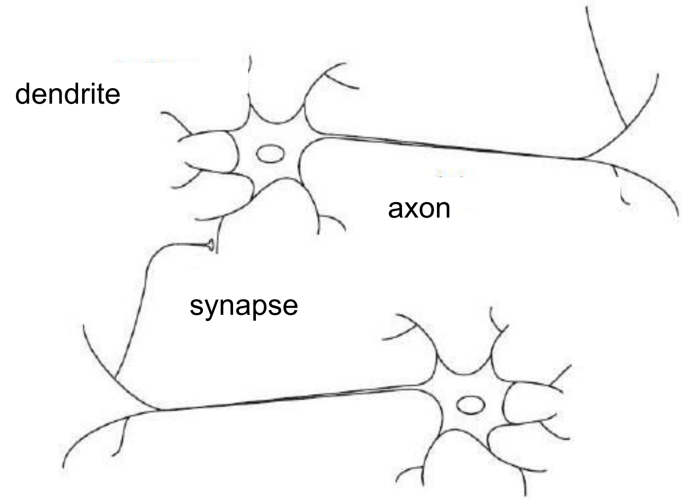


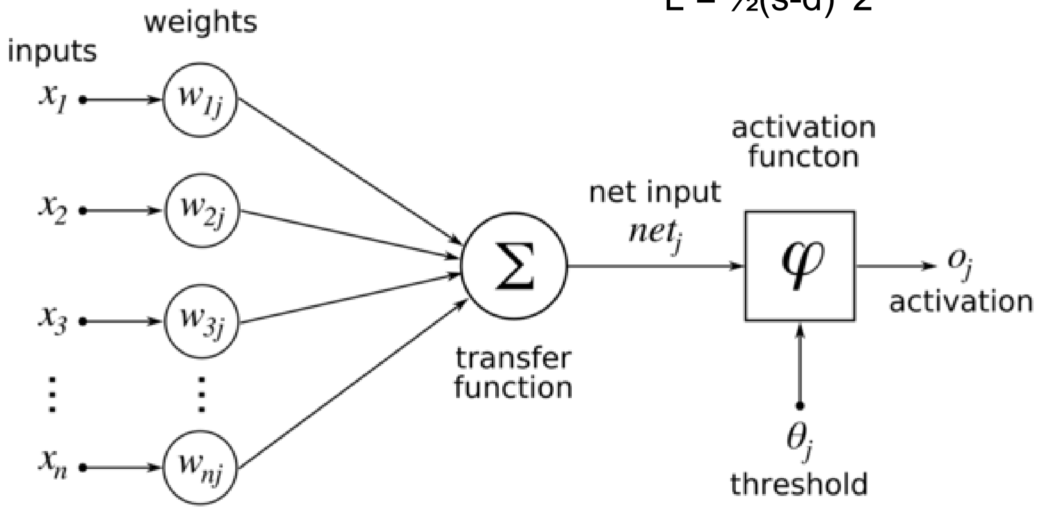
The Brain Analogy

(cartoon neuron & mathematical neuron)

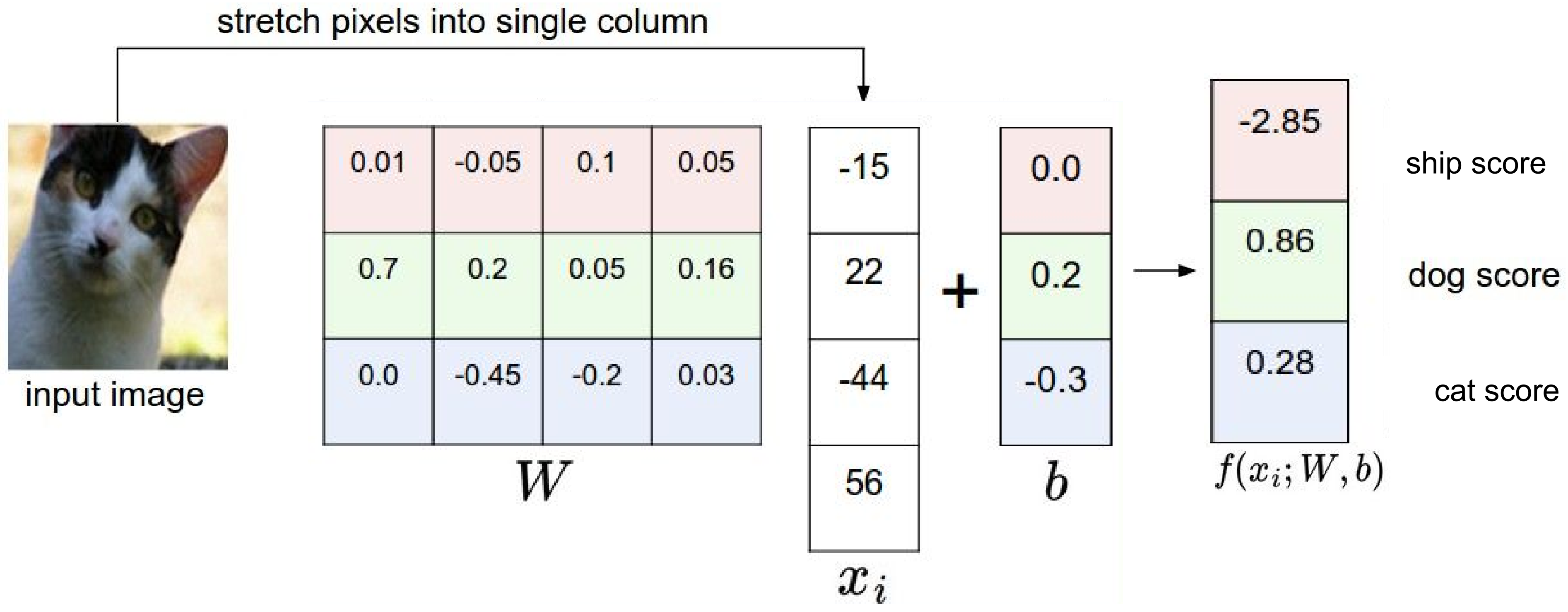
$s = f(x,w)$

$L = \frac{1}{2}(s-d)^2$

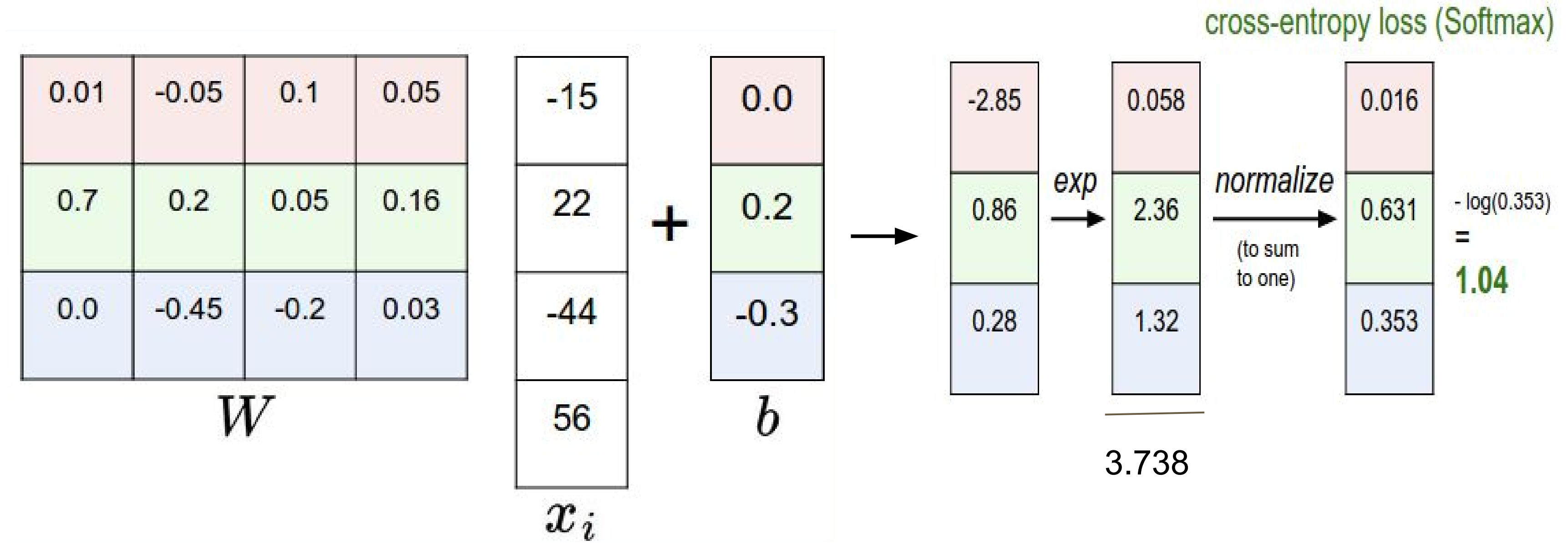




The Linear Classifier Analogy



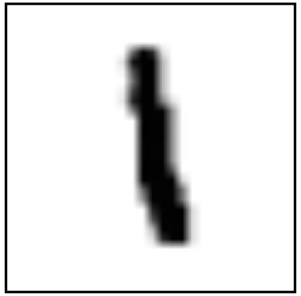
Losses:
Softmax (Cross-Entropy) Loss



Softmax: $f_j(z) = \frac{e^{z_j}}{\sum_k e^{z_k}}$

Cross-Entropy $L_i = -\log\left(\frac{e^{z_j}}{\sum_k e^{z_k}}\right)$

The Linear Classifier Analogy: MNIST data set

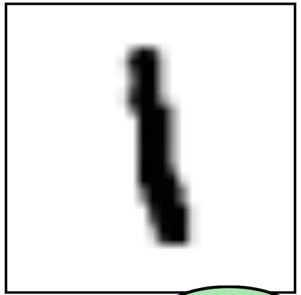


$$\cong \begin{bmatrix}
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&.6&.8&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.5&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.7&0&0&0&0&0\\
0&0&0&0&0&0&0&1&1&0&0&0&0&0\\
0&0&0&0&0&0&0&.9&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&.3&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{bmatrix}$$

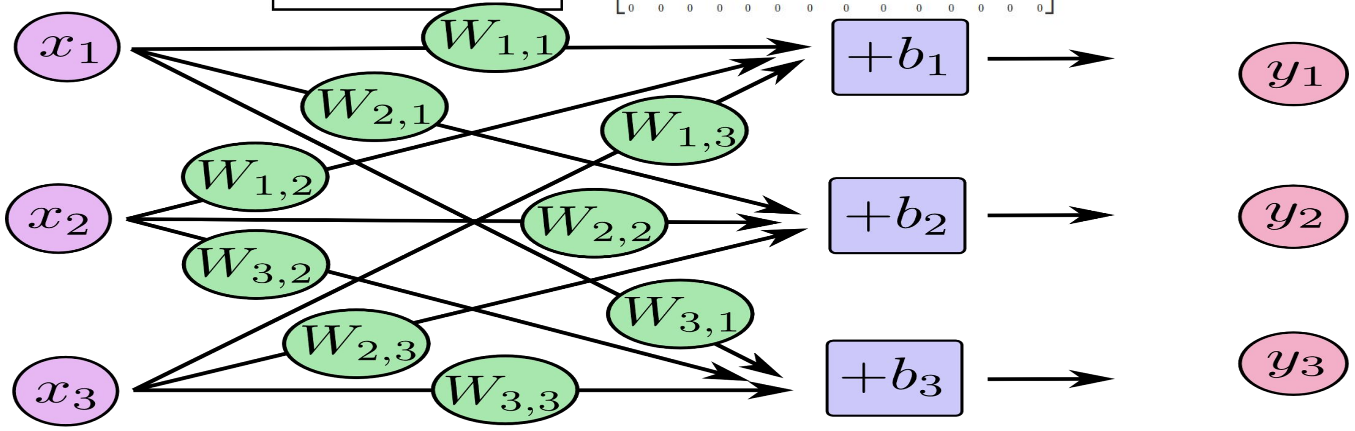
$$\begin{pmatrix}
W_{1,1}x_1 + W_{1,2}x_2 + W_{1,3}x_3 + b_1\\
W_{2,1}x_1 + W_{2,2}x_2 + W_{2,3}x_3 + b_2\\
W_{3,1}x_1 + W_{3,2}x_2 + W_{3,3}x_3 + b_3
\end{pmatrix} = \begin{bmatrix} y_1\\ y_2\\ y_3 \end{bmatrix}$$

1) Add up evidence of input being in a certain class Evidence = $\sum W_{i,j}x_j + b_i$

The Linear Classifier Analogy: MNIST data set



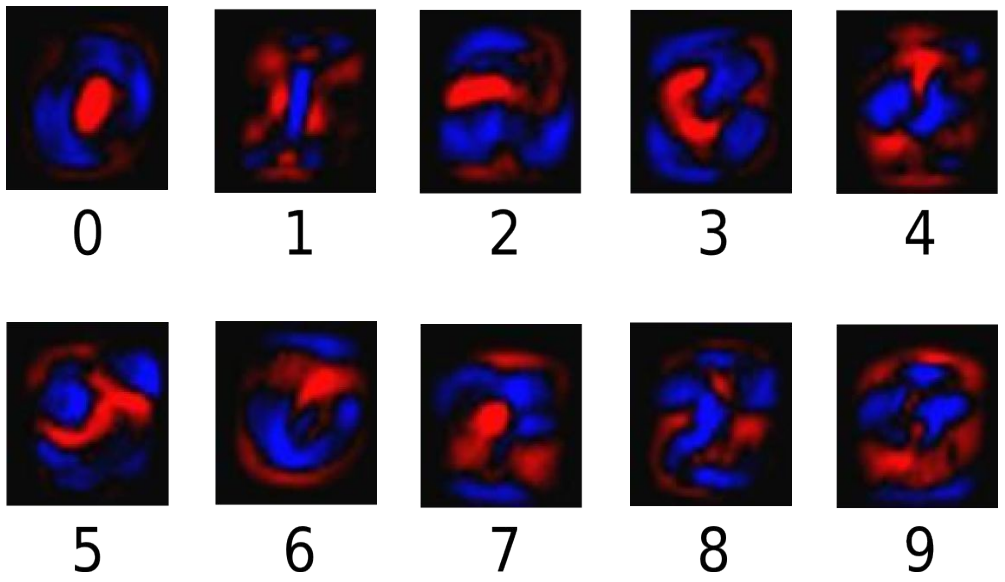
$$\approx \begin{bmatrix}
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&.6&.8&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.5&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.7&0&0&0&0&0\\
0&0&0&0&0&0&0&1&1&0&0&0&0&0\\
0&0&0&0&0&0&0&.9&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&.3&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{bmatrix}$$



1) Add up evidence of input being in a certain class Evidence = $\sum W_{i,j}x_j + b_i$

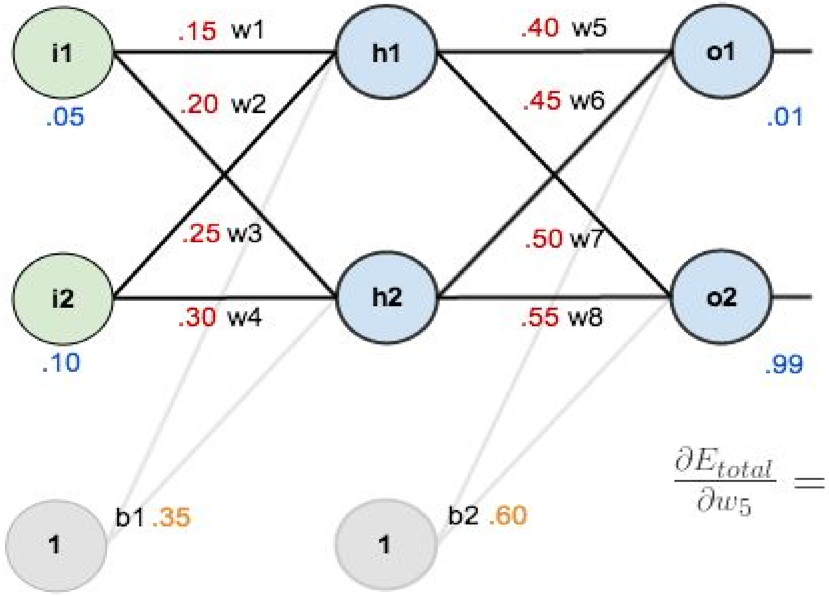
The Linear Classifier Analogy: MNIST data set

$W \simeq$



BackPropagation

How do we get there?

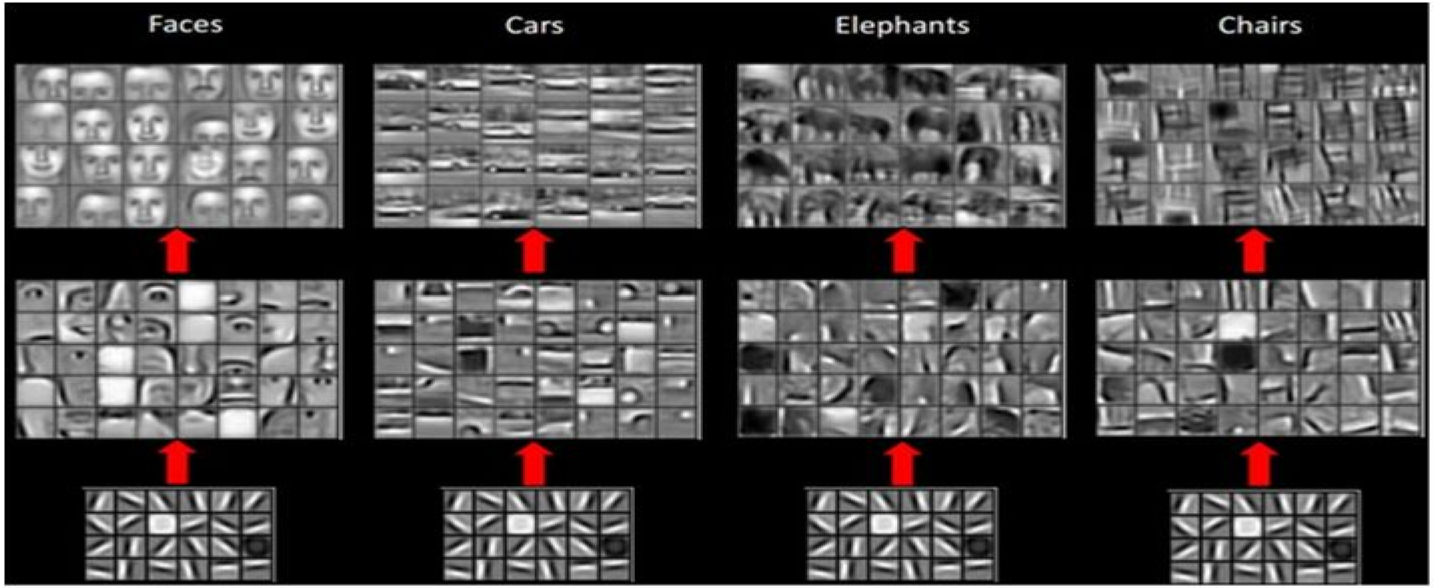


$$\frac{\partial E_{total}}{\partial w_5} = \frac{\partial E_{total}}{\partial out_{o1}} * \frac{\partial out_{o1}}{\partial net_{o1}} * \frac{\partial net_{o1}}{\partial w_5}$$

Chain Rule!

Convolutional Neural Nets

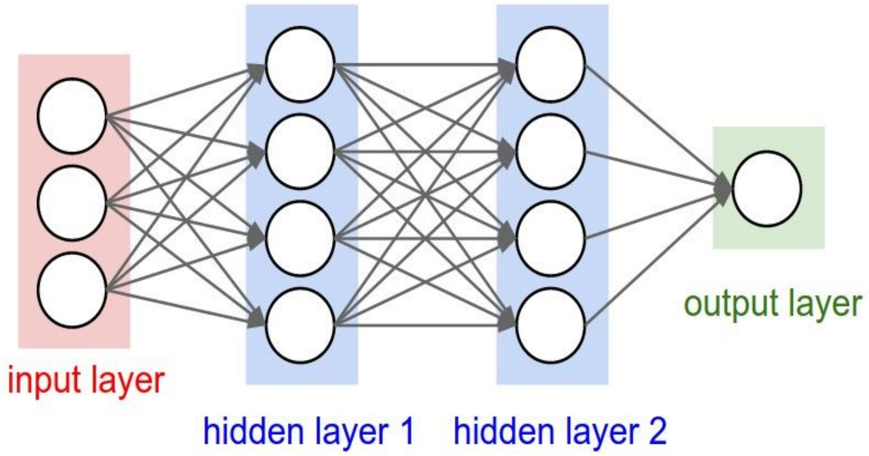
Very similar to Neural Nets.. But how are they different ?

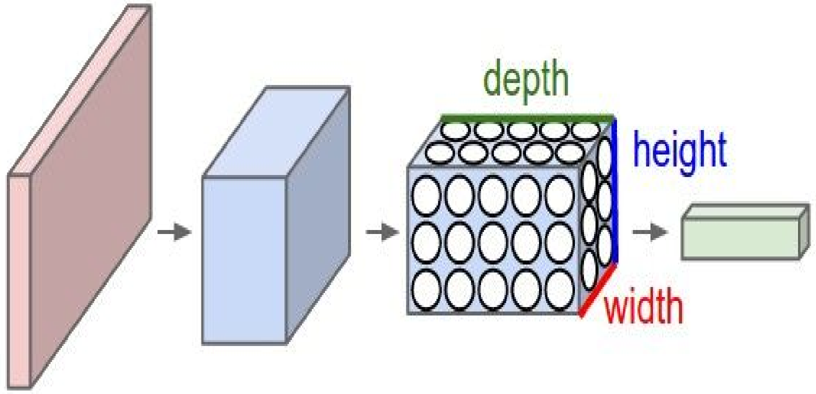


Convolutional Neural Nets

Vs. Neurals Nets

- Input is an image: Leverage 3D Structure
- Fully Connected ?   Not really





The CNN Family

Winners of the ILSVRC ImageNet challenges

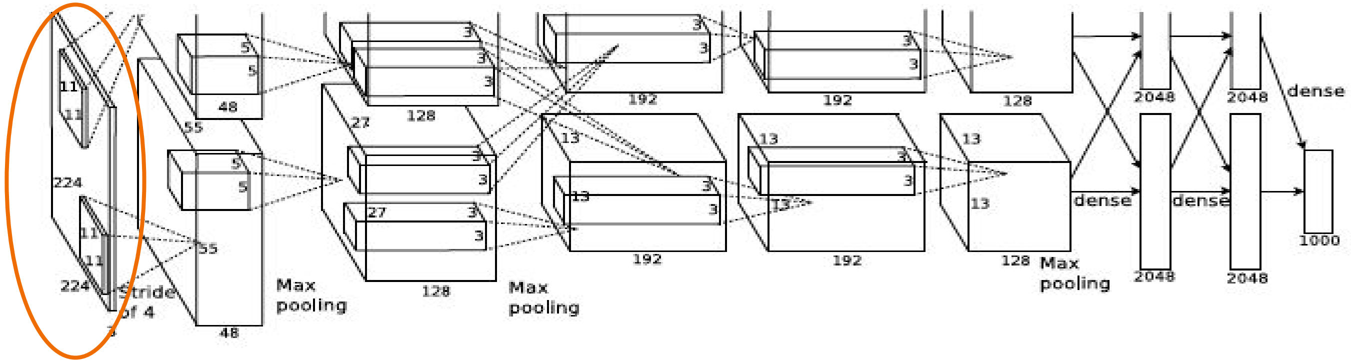
AlexNet (2012, Krizhevsky): Popularized CNNs - 1st to incorporate consecutive convolutional layers

GoogleNet / Inception (2014, Szegedy): Drastically reduced the # of parameters used (from 60 million to 4 million)

ResNet (2015, Kaiming He): Residual Network : famous for skip-connections and heavy use of batch-normalization; also removes some fully connected layers (at end of network)

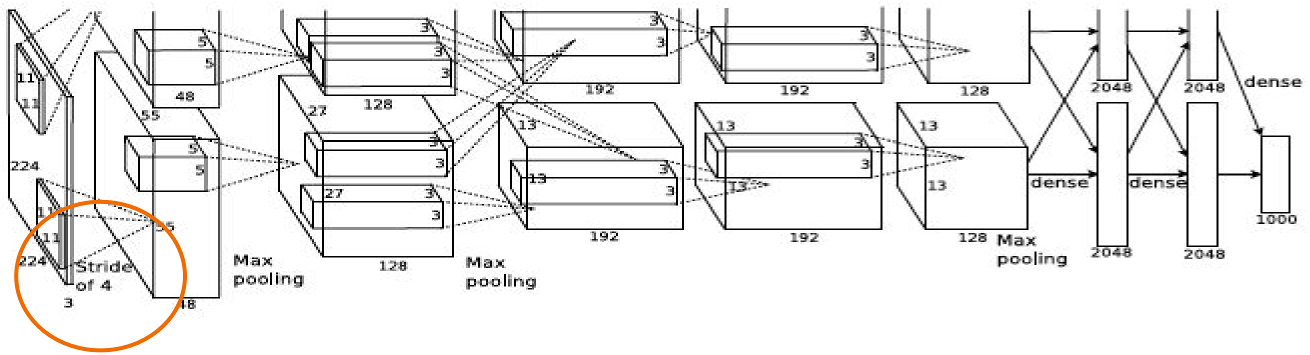
Convolutional Neural Nets : Architecture

1) **Input Layer: Raw pixel values of the image (ex: 224 x 224 x 3 (3 ~ color channels (RGB))**
2) Conv Layer
3) Pool Layer
4) ReLU Layer
5) FC (Fully Connected Layer)



Convolutional Neural Nets : Architecture

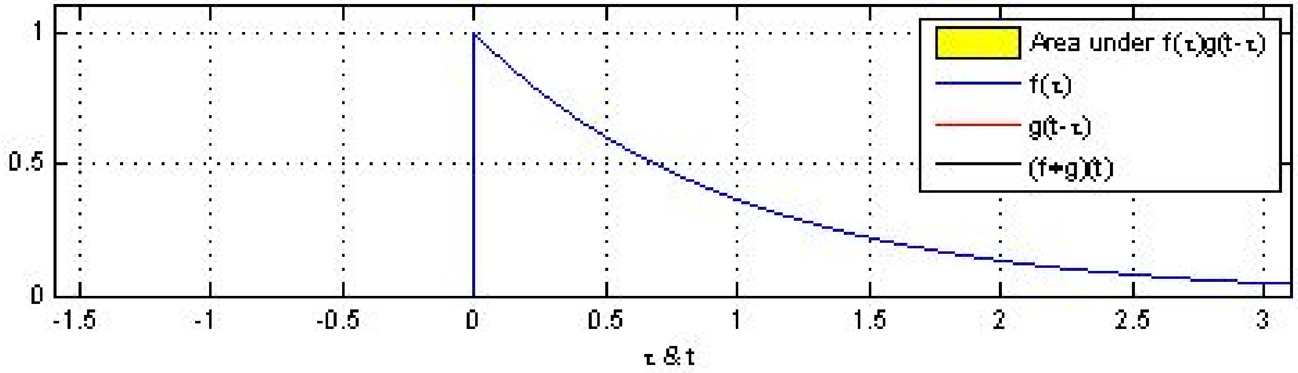
1) Input Layer: Raw pixel values of the image
2) **Conv Layer: Dot product between weights and the small region of input volume (ex: 11 x 11 x 3 filters)**
3) Pool Layer
4) ReLU Layer
5) FC (Fully Connected Layer)



Convolutional Neural Nets : Architecture

What is a Convolution?

$$f*g = \int f(t - \tau)g(\tau)d\tau$$



Convolutional Neural Nets : Architecture

What is a Convolution?

$$\begin{array}{|ccc|c}\cline{1-3} 1&1&1&0\\ 1&1&1&0\\ 1&1&1&0\\ \cline{1-3}\end{array} \qquad \begin{array}{|ccc|}\hline 1&1&1\\ 1&-8&1\\ 1&1&1\\ \hline\end{array} \longrightarrow 0$$

$$\begin{array}{c|ccc|}\cline{2-4} 1&1&1&0\\ 1&1&1&0\\ 1&1&1&0\\ \cline{2-4}\end{array} \qquad \begin{array}{|ccc|}\hline 1&1&1\\ 1&-8&1\\ 1&1&1\\ \hline\end{array} \longrightarrow -3$$

Convolutional Neural Nets : Architecture

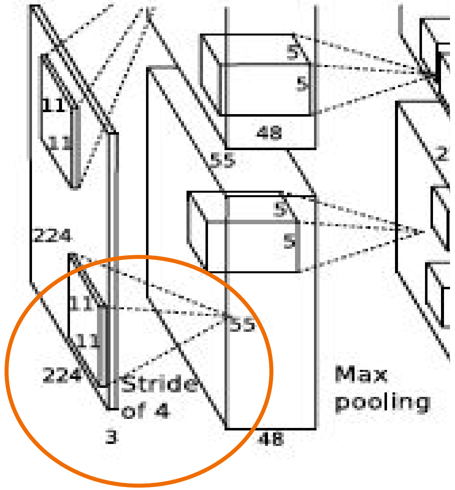
What is a Convolution?

Convolutional Layer: **(W-F + 2P)/S +1**

- **W : Input Volume size**
- **F: Receptive Field size of the Conv Layer Neuron**
- **P: Zero- Padding**
- **S: Stride**

(224 - 11 +2(3))/4 + 1 = 55

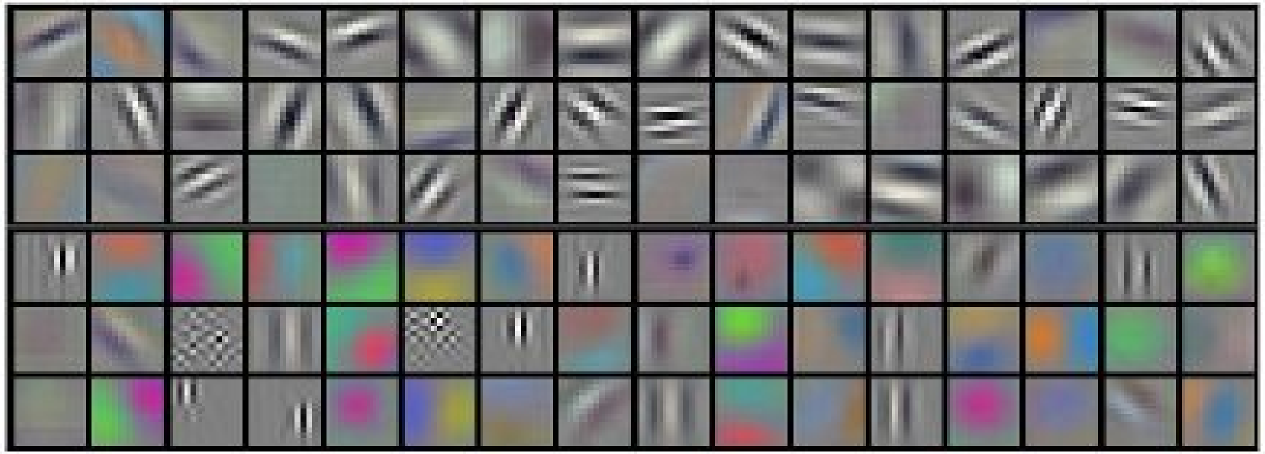
Conv Layer Output ~ 55 x 55 x 96 (ie : 55^2 neurons in each layer)



Convolutional Neural Nets : Architecture

What is a Convolution?

Voila. We have 96 filters.



Convolutional Neural Nets : Architecture

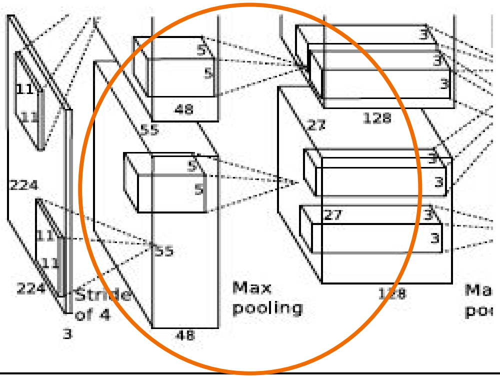
1) Input Layer
2) Conv Layer
3) **Pooling Layer: Performs downsampling operation**
4) ReLU Layer
5) FC (Fully Connected Layer)

$$\begin{array}{ccc} 12 & 23 & 9 \\ 8 & 11 & 13 \\ 22 & 5 & 10 \end{array} \longrightarrow \boxed{23}$$

Our Eqn : O = (W- F)/S +1

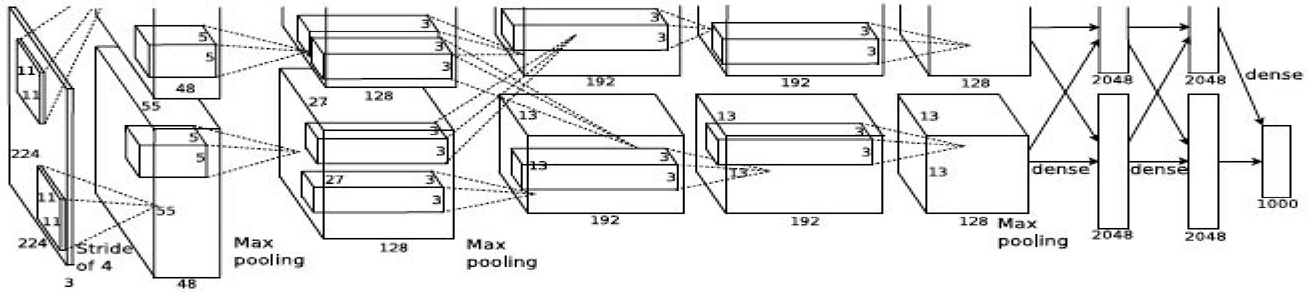
AlexNet: use 3 x 3 MaxPooling w/ stride = 2

O =(55-3)/2 + 1 = 27



Convolutional Neural Nets : Architecture

1) Input Layer: Raw pixel values of the image
2) Conv Layer:
3) Pool Layer:
4) **ReLU Layer: Apply an elementwise activation function (ex : max(0,x) thresholding output dimension ~ same as input)**
5) FC (Fully Connected Layer)

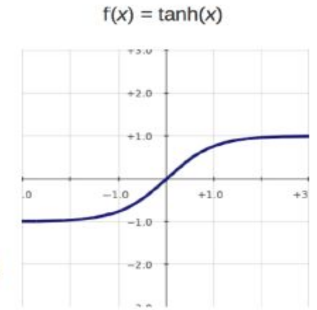


*The ReLU non-linearity is applied to the output of every convolutional and fully-connected layer.

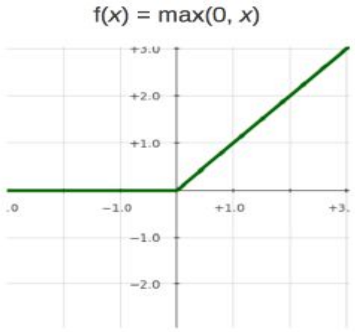
Convolutional Neural Nets : Architecture

ReLU Layer:

Tradionally:
f(x) = tanh(x) or fx= (1+e-x)^-1 (Very slow to train)

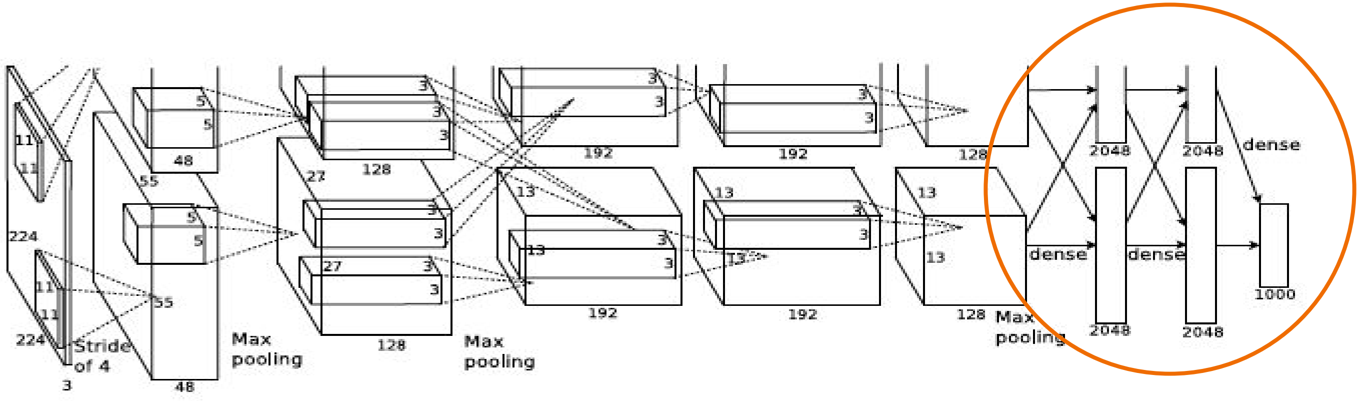


Now:
f(x) = max(0,x) (Faster to train)



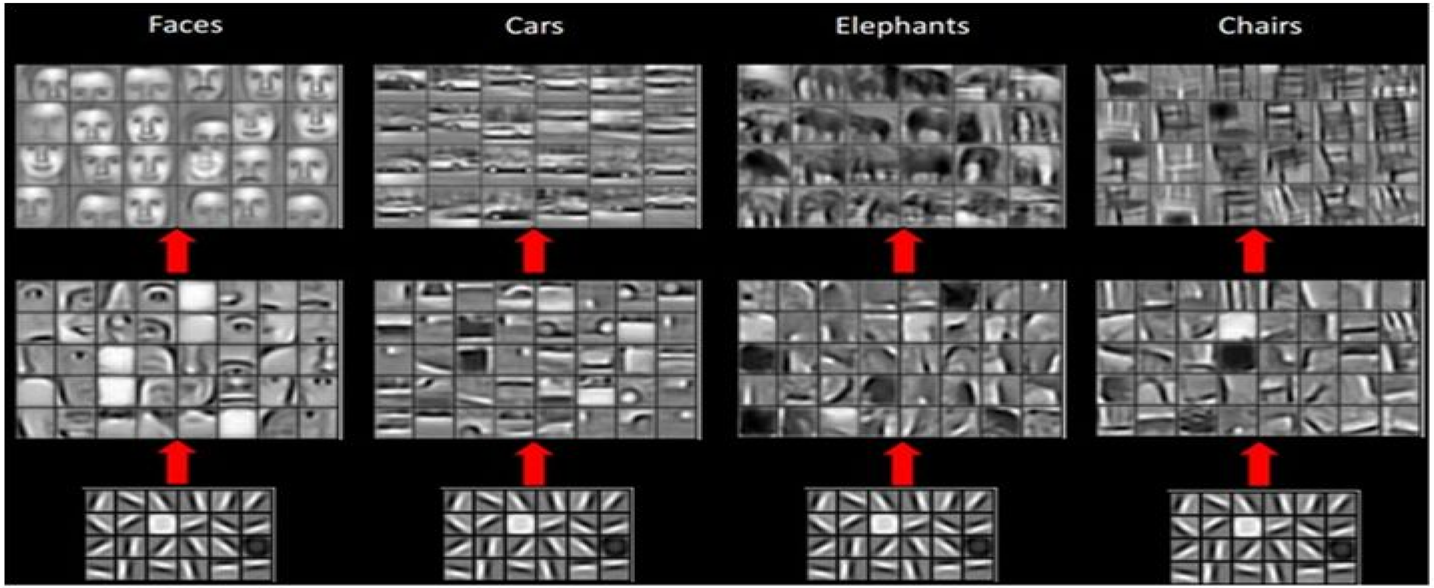
Convolutional Neural Nets : Architecture

1) Input Layer: Raw pixel values of the image
2) Conv Layer:
3) Pool Layer:
4) ReLU Layer:
5) **FC (Fully Connected) Layer : Each neuron will be connected to all activations of the previous volume. The output layer will compute class scores (ex: [1 x 1 x 1000])**



Convolutional Neural Nets : Architecture

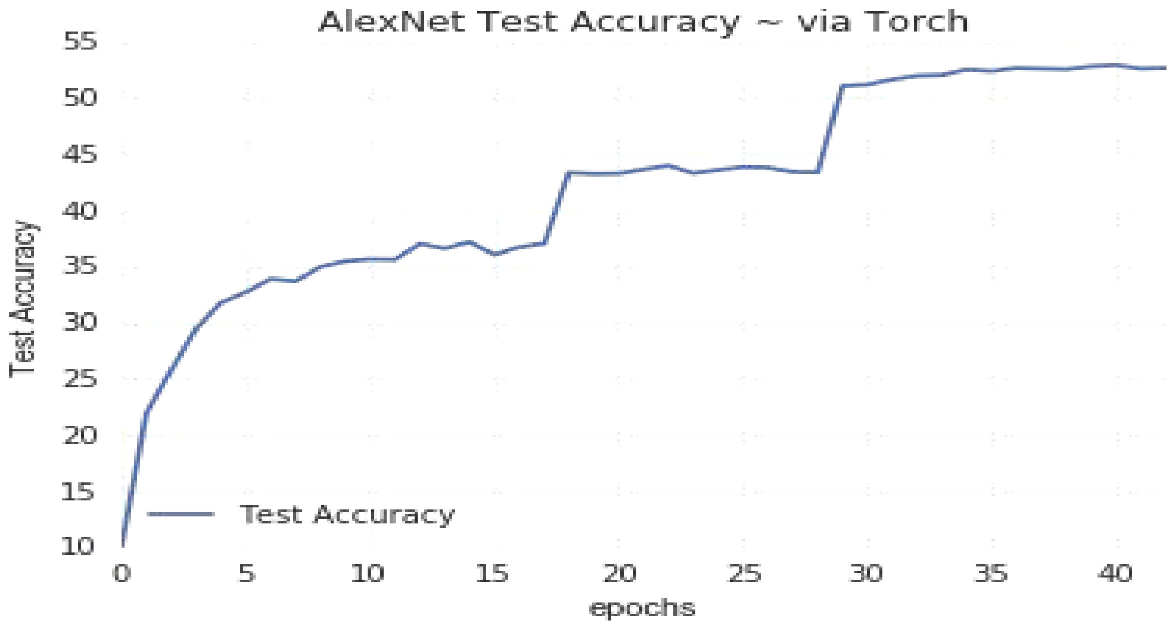
\



Working with Behold.ai

How long does it take to train AlexNet to achieve 50% accuracy ?

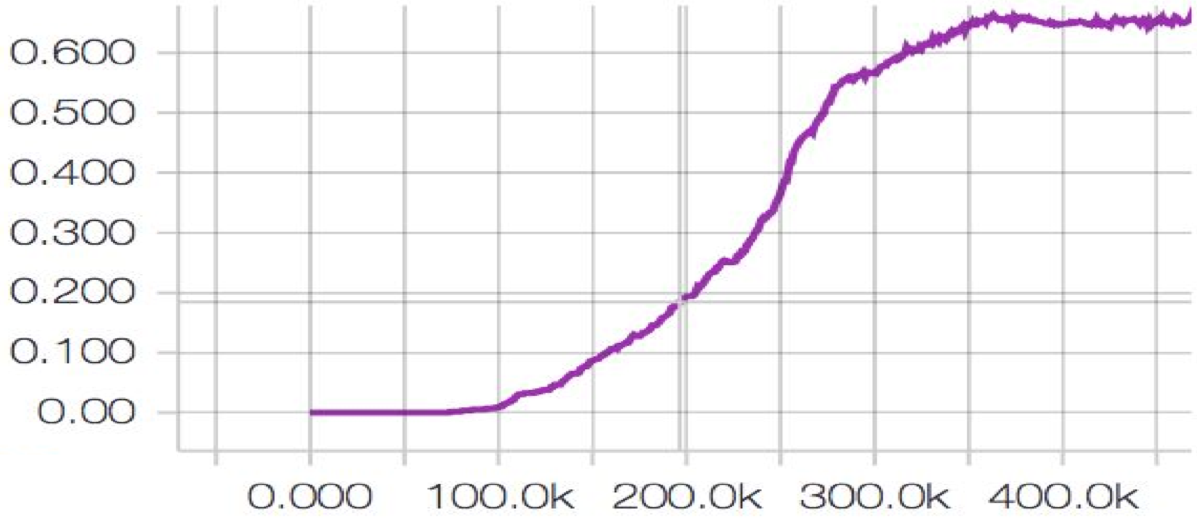
First: via Torch



Working with Behold.ai

How long does it take to train Inception-V3 to achieve 50% accuracy?

Then: via TensorFlow



Working with Behold.ai

Torch:

- + Fast. Easy to integrate with GPUs
- + Many modular pieces that are easy to combine
  https://github.com/soumith/imagenet-multiGPU.torch/blob/master/models/alexnet.lua
- - Written in Lua

TensorFlow:

- + Written in python & numpy
- + Tensorboard for visualization
- - Latest releases can be buggy (difficult to integrate GPUs)
- - Can be many x slower than Torch

https://console.aws.amazon.com/ec2/v2/home?region=us-east-1#LaunchInstanceWizard:

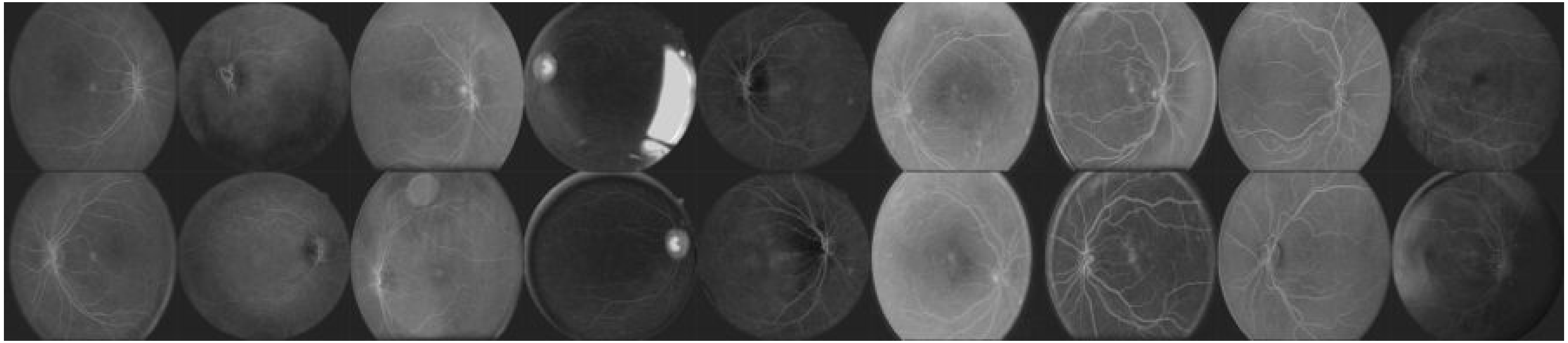
Working with Behold.ai

Can I leverage the AlexNet model and retrain it on a new dataset?

Train Retinopathy data via AlexNet on Torch

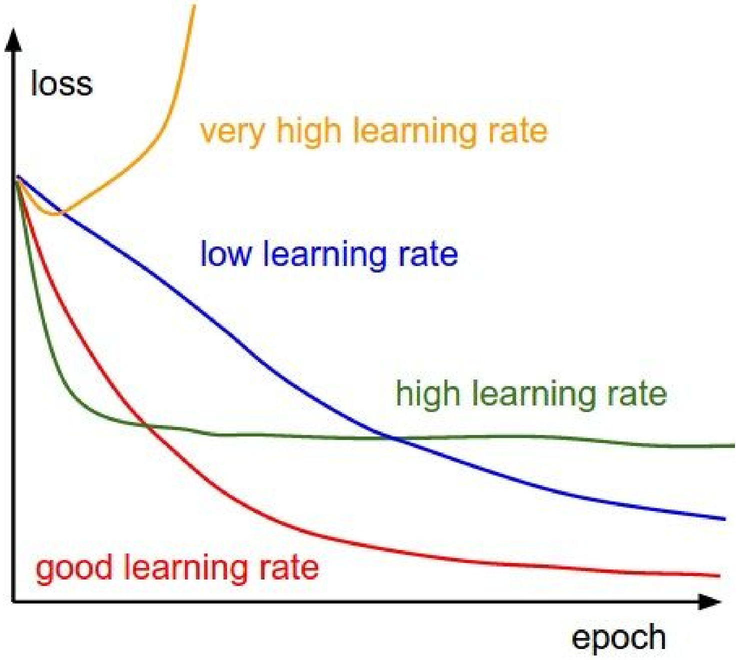
Kaggle Dataset:

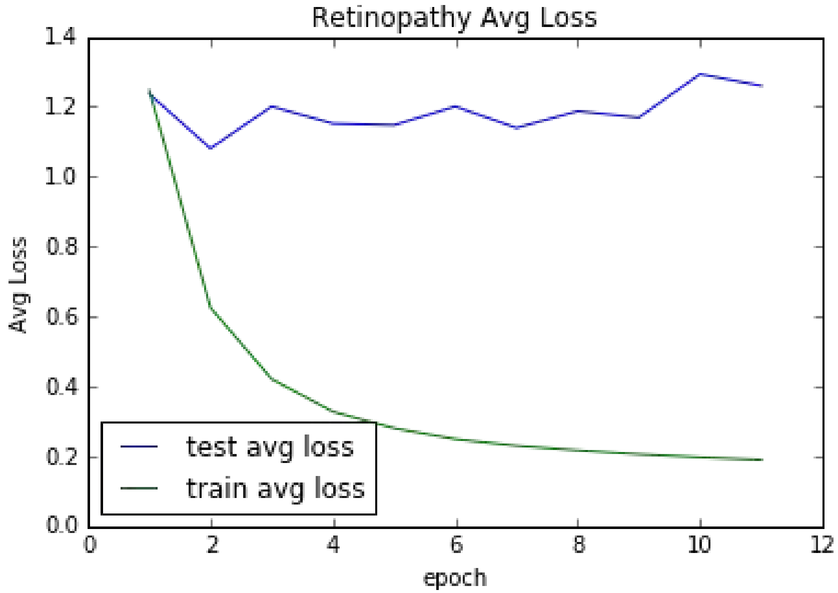
Diabetic Retinopathy Detection



Learning from the Learning Process

1) Loss functions

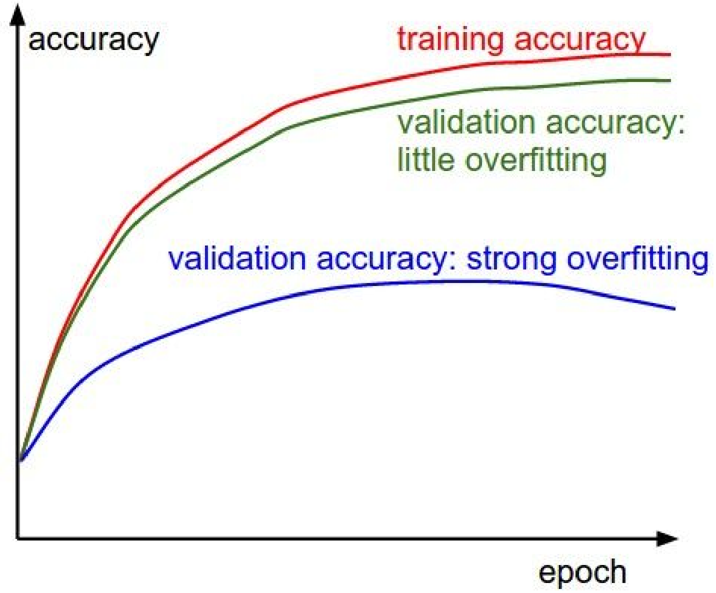


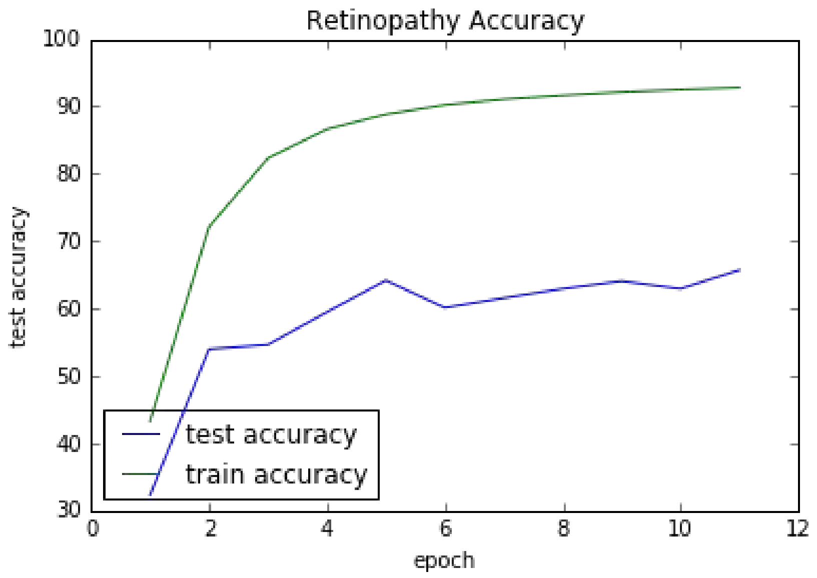


* Tip: Change the learning rate!

Learning from the Learning Process

2) Accuracy





* Tip: Increase L2 weight penalty , Increase Drop-Out, More Data (possibly with jitter) - -try batch norm ?

Learning from the Learning Process:

3) Weight Ratios

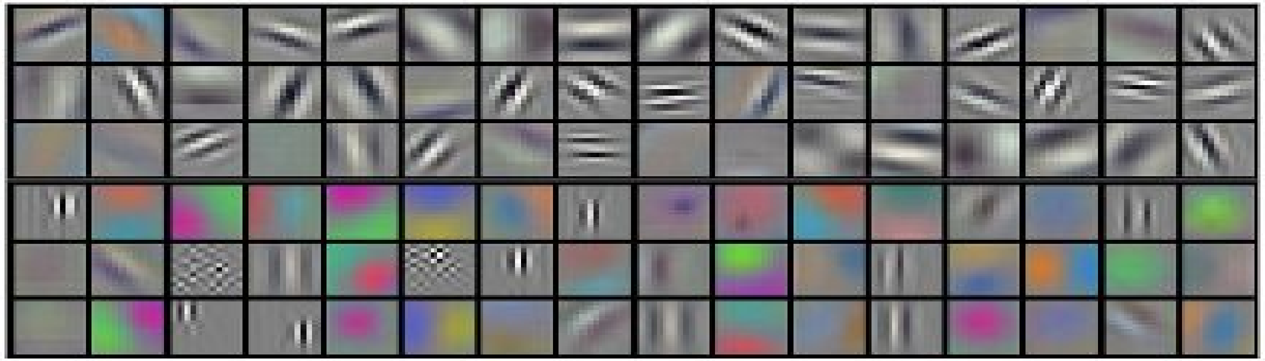
- update / weight ratio : should be roughly about 1e-3

(larger ~ learning rate may be too, too much lower ~ learning rate may be too low)

4) First-layer Visualizations

Visualized weights from the 1st layer of the network:

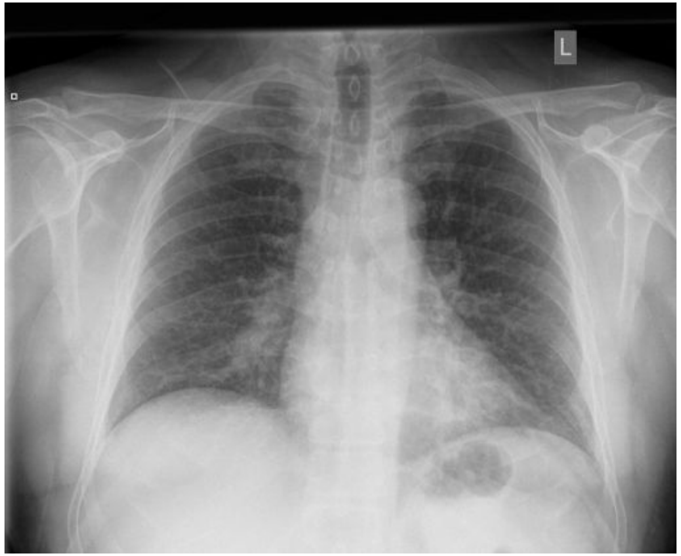
(smooth, diverse features indicate that training is going well)



Working with Behold.ai

Can I leverage the Inception model to decipher different diseases via Tensorflow?

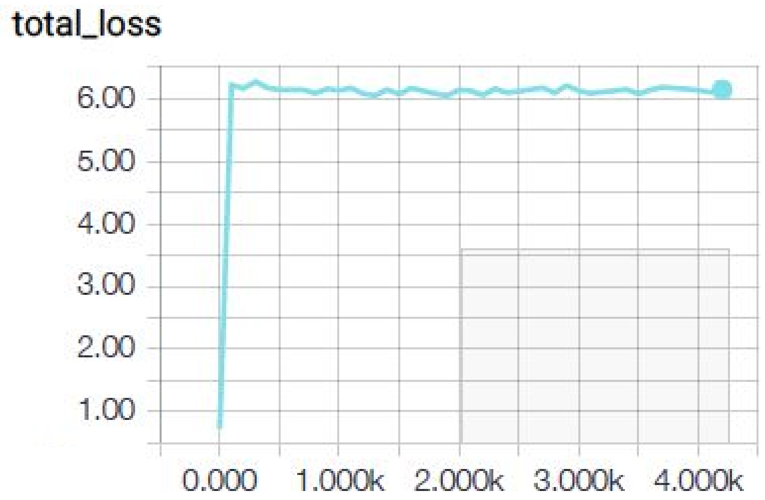
Train XRAY data via TF's Inception-V3



Opacity

Working with Behold.ai

Train XRAY data via TF's Inception-V3

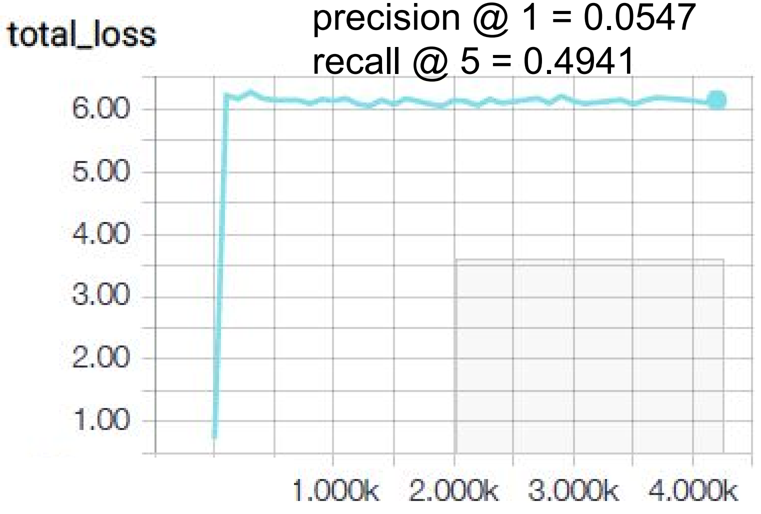


precision @ 1 = 0.0547
recall @ 5 = 0.4941

Working with Behold.ai

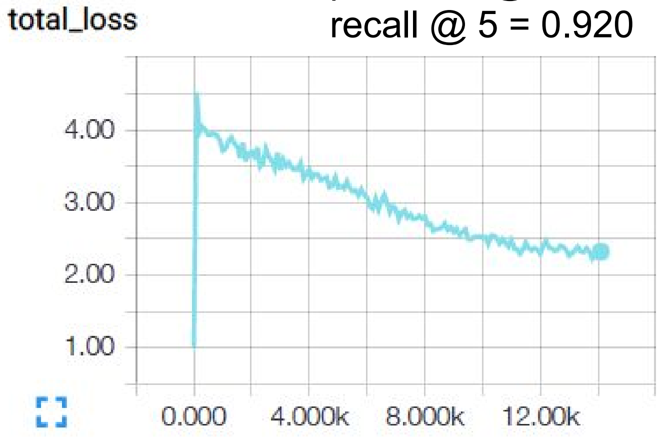
Train XRAY data via TF's Inception-V3

precision @ 1 = 0.0547
recall @ 5 = 0.4941



Train using Inception-V3 from scratch

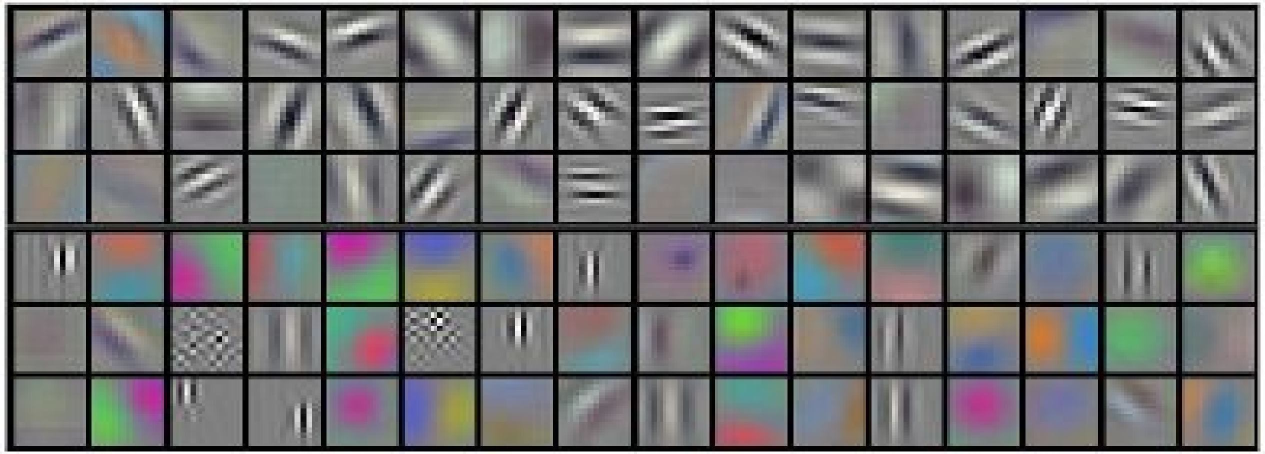
precision @ 1 = 0.587
recall @ 5 = 0.920



Retrain using Inception-V3 from existing model

Working with Behold.ai

Why did that work so well ???



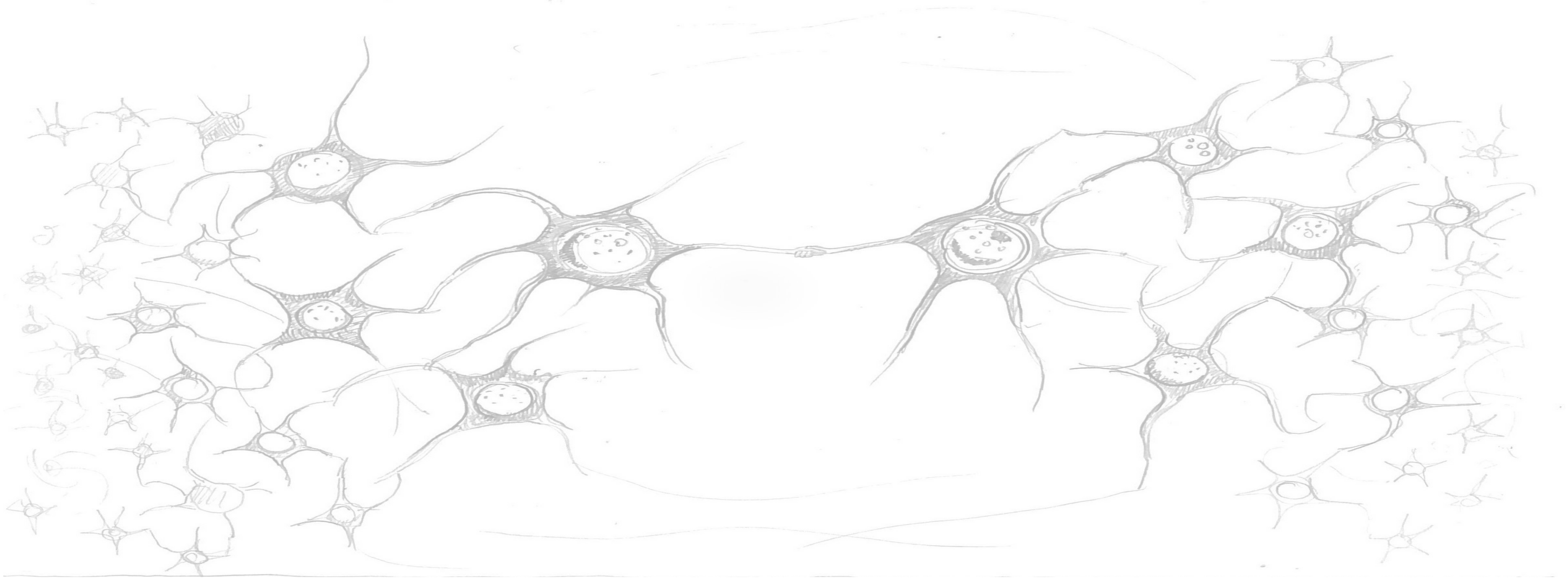
A quick quick look at TensorFlow

- Tensorflow is based on the concept of a computational graph with nodes & edges.
- The output of one operation is fed as input into the next operation.
- TF has it’s own ‘version’ of things:

  Ex: input=tf.constant(5), why ?

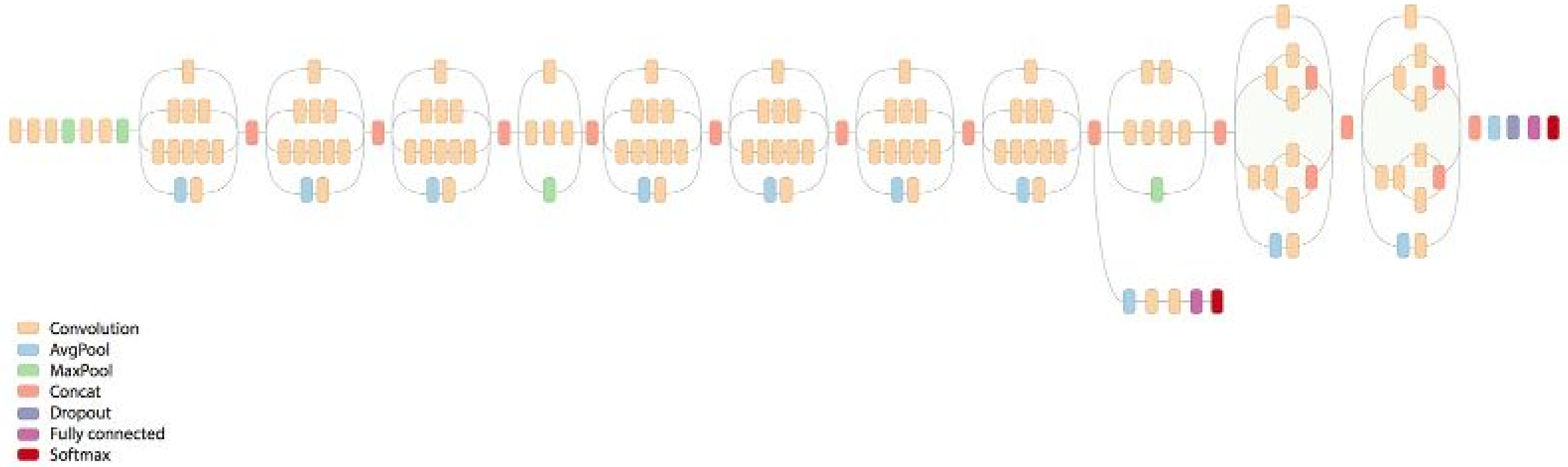
http://localhost:8888/notebooks/tensorflow_final.ipynb

Thank you!

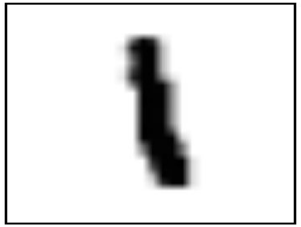


julialintern.com

Appendix


Convolution
AvgPool
MaxPool
Concat
Dropout
Fully connected
Softmax

The Linear Classifier Analogy: MNIST data set



$$\simeq \begin{bmatrix}
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&.6&.8&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.7&1&0&0&0&0&0&0\\
0&0&0&0&0&0&.5&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.4&0&0&0&0&0\\
0&0&0&0&0&0&0&1&.7&0&0&0&0&0\\
0&0&0&0&0&0&0&1&1&0&0&0&0&0\\
0&0&0&0&0&0&0&.9&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&.3&1&.1&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0\\
0&0&0&0&0&0&0&0&0&0&0&0&0&0
\end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{softmax}\left(\begin{matrix} W_{1,1}x_1 + W_{1,2}x_2 + W_{1,3}x_3 + b_1 \\ W_{2,1}x_1 + W_{2,2}x_2 + W_{2,3}x_3 + b_2 \\ W_{3,1}x_1 + W_{3,2}x_2 + W_{3,3}x_3 + b_3 \end{matrix} \right)$$

1) Add up evidence of input being in a certain class Evidence = □ $W_{i,j}x_j + b_i$

2) Convert evidence into probabilities using softmax (illustrate on board)

Softmax: $f_j(z) = \frac{e^{z_j}}{\sum_k e^{z_k}}$ *Cross-Entropy* $L_i = -\log\left(\frac{e^{z_j}}{\sum_k e^{z_k}} \right)$