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Hyperparameter tuning

Tuning process

Hyperparameters

→ α

β 0.9

$\beta_1, \beta_2, \epsilon$
0.9 0.999 10^{-8}

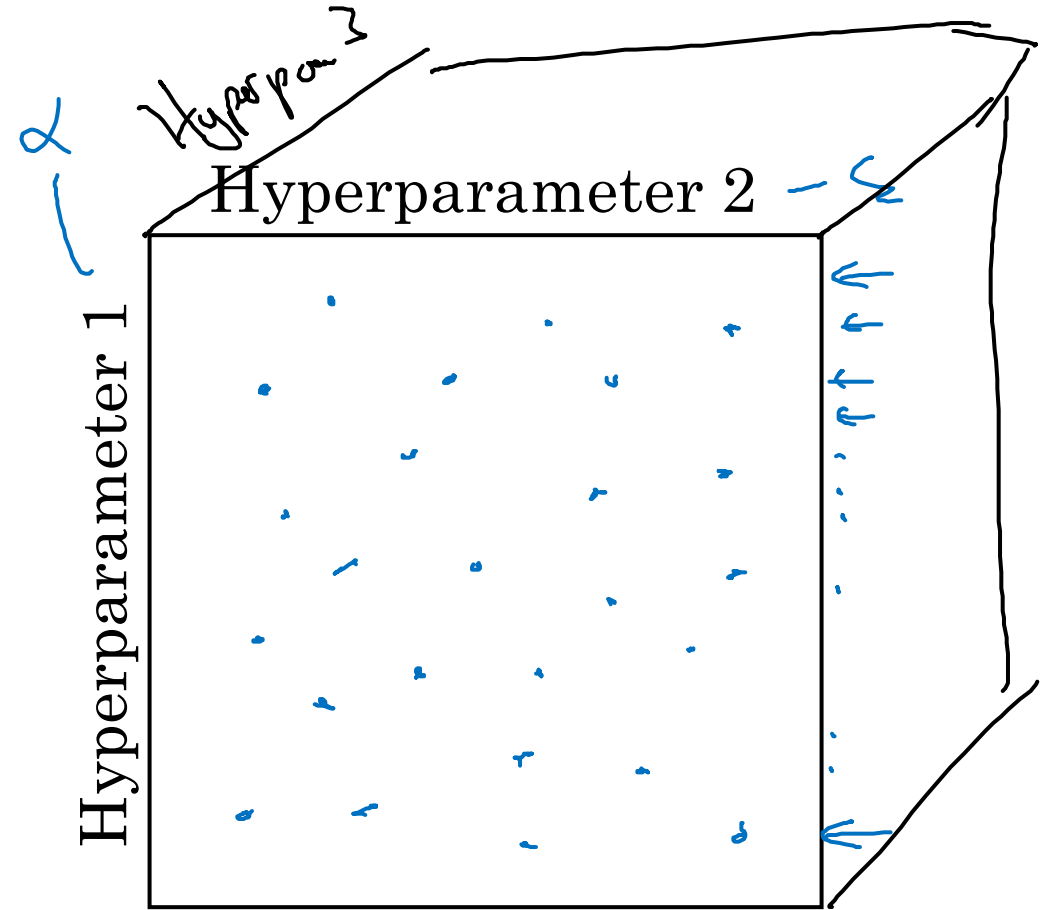
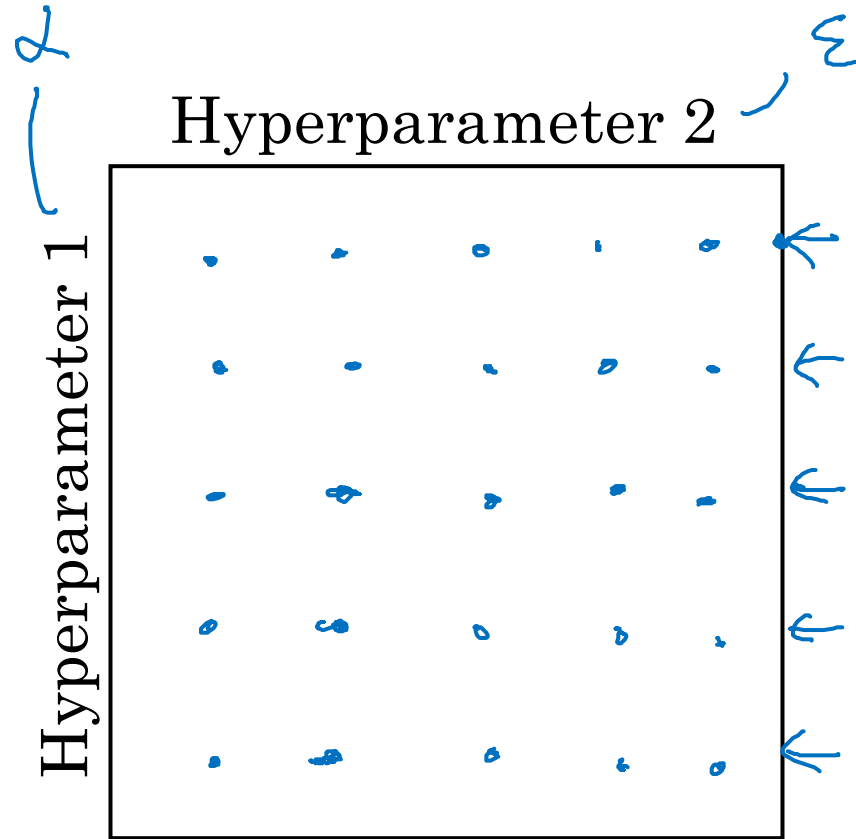
layers

hidden units

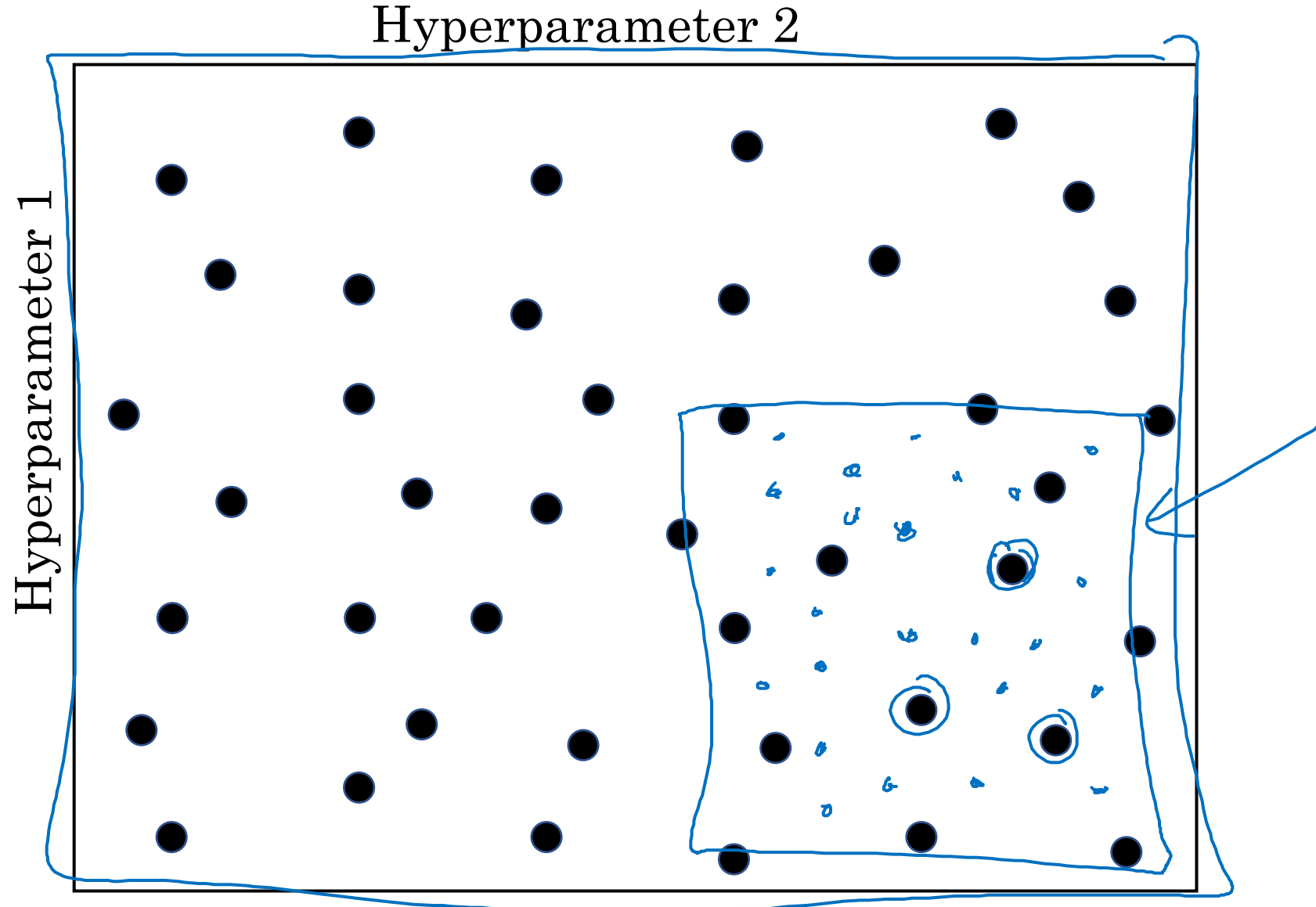
learning rate decay

mini-batch size

Try random values: Don't use a grid



Coarse to fine





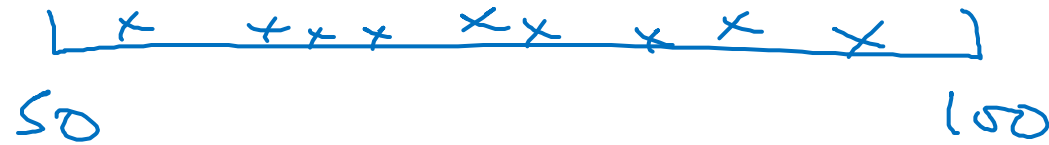
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Hyperparameter tuning

Using an appropriate
scale to pick
hyperparameters

Picking hyperparameters at random

→ $n^{\text{test}} = 50, \dots, 100$

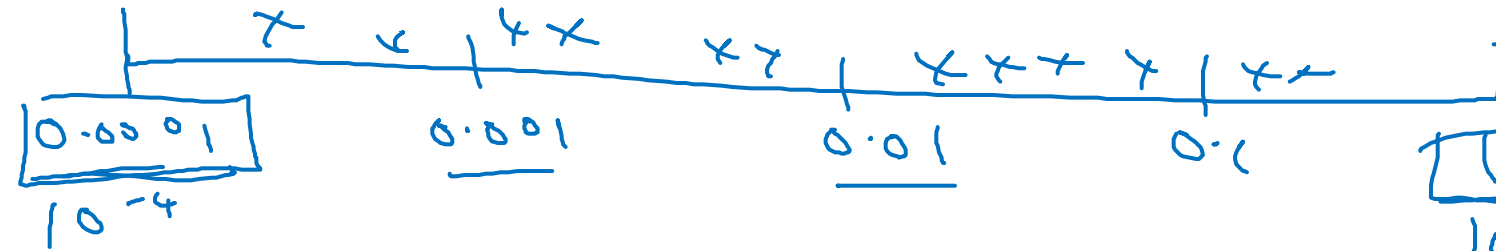
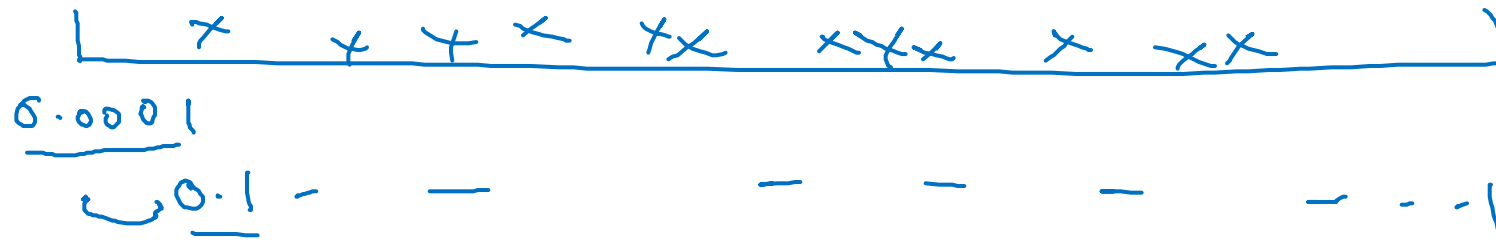


→ #layers $L : 2 - 4$

2, 3, 4

Appropriate scale for hyperparameters

$$\alpha = 0.0001, \dots, 1$$



$$10^a$$

$$a = \log_{10} 0.0001$$

$$= -4$$

$$r = -4 * \text{np.random.rand}()$$

$$\alpha = 10^r$$

$$r \in [-4, 0]$$

$$10^{-4} \dots 10^0$$

$$b = \log_{10} 1$$

$$= 0$$

$$\underline{10^a \dots 10^b}$$

$$\underline{\frac{r \in [a, b]}{[-4, 0]}}$$

$$\underline{\alpha = 10^r}$$

Hyperparameters for exponentially weighted averages

$$\beta = 0.9 \quad \dots \quad 0.999$$

\downarrow \downarrow
 10 1000

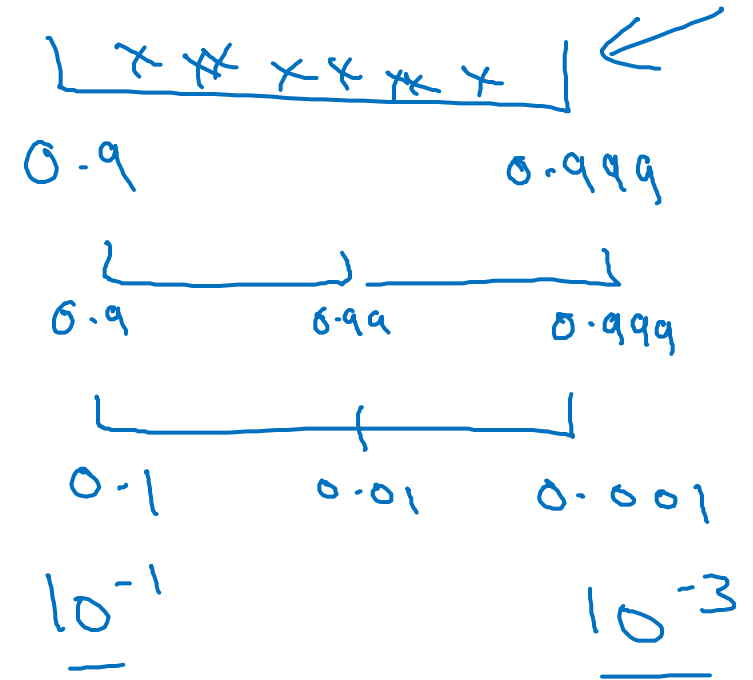
$$1 - \beta = 0.1 \quad \dots \quad 0.001$$

$$\beta: 0.999 \rightarrow 0.9995 \quad \} \sim 10$$

$$\beta: 0.999 \rightarrow 0.9995$$

~ 1000 ~ 2000

$$\frac{1}{1 - \beta_K}$$



$$r \in [-3, -1]$$

$$1 - \beta = 10^r$$

$$\beta = 1 - 10^r$$

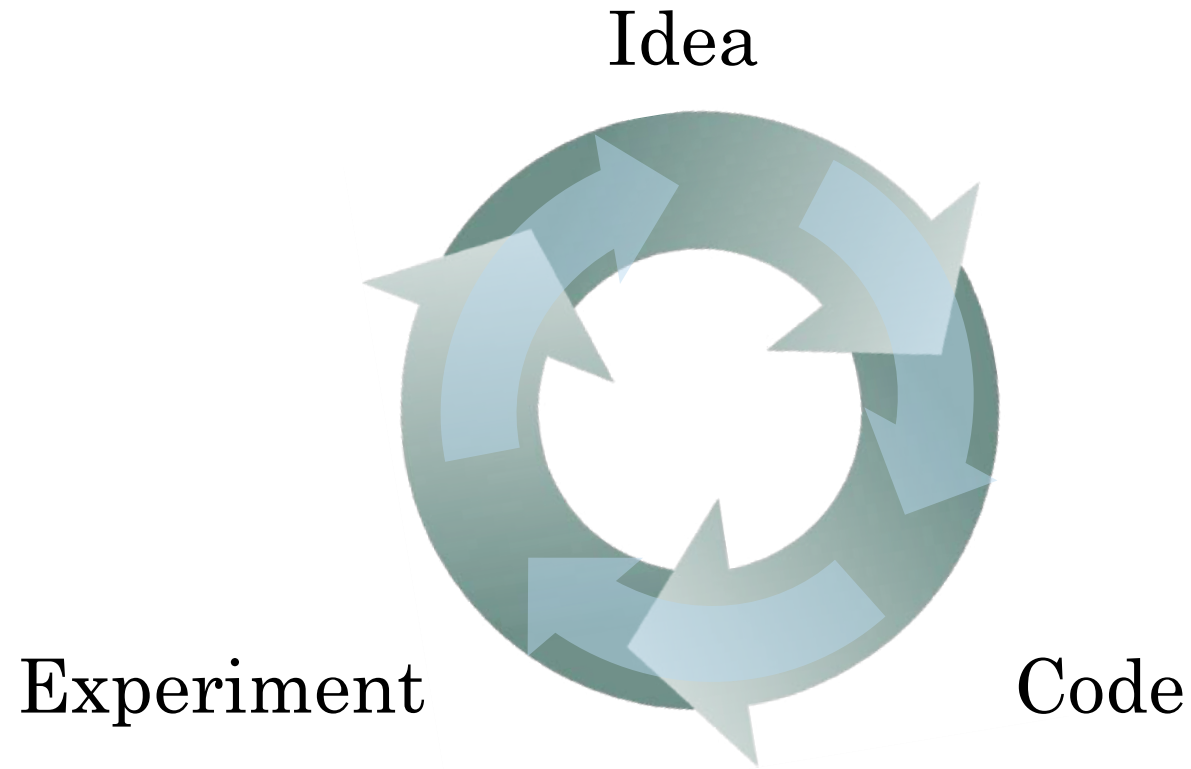


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Hyperparameters tuning

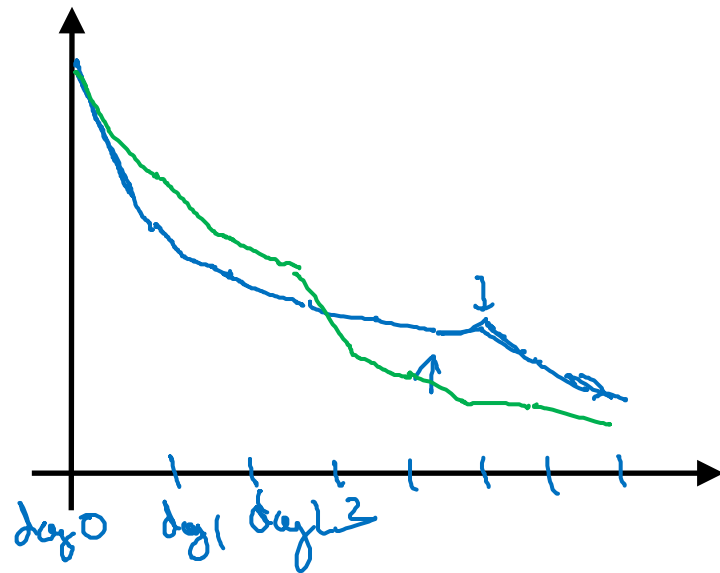
Hyperparameters
tuning in practice:
Pandas vs. Caviar

Re-test hyperparameters occasionally



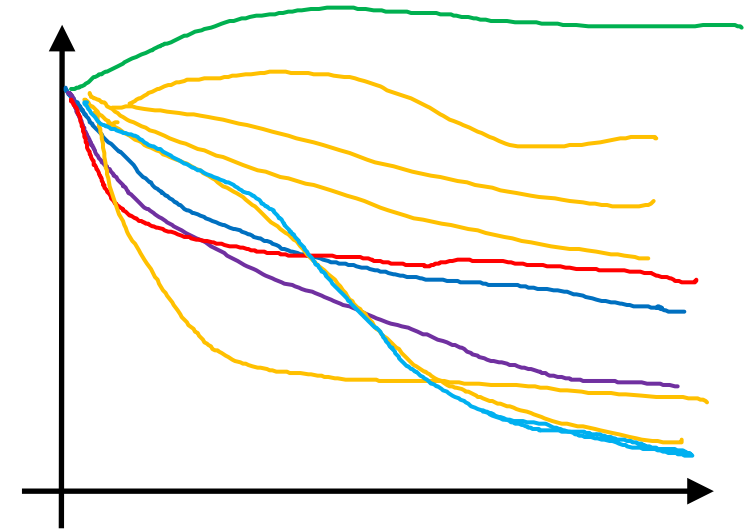
- NLP, Vision, Speech,
Ads, logistics,
- Intuitions do get stale.
Re-evaluate occasionally.

Babysitting one model



Panda ↵

Training many models in parallel



Caviar ↵

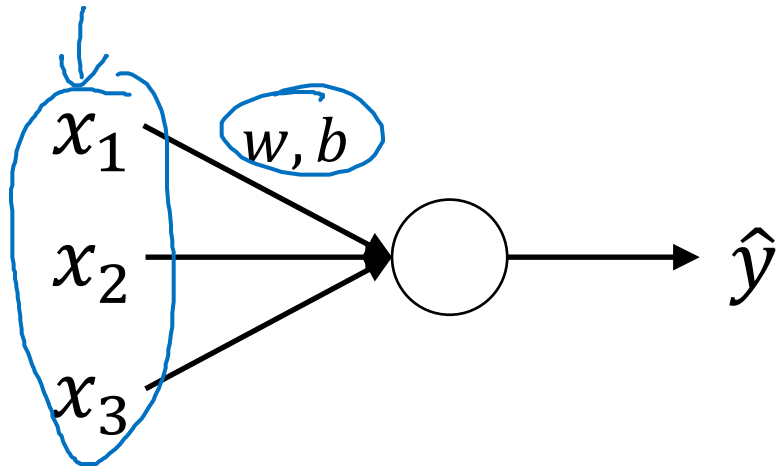


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Batch Normalization

Normalizing activations
in a network

Normalizing inputs to speed up learning

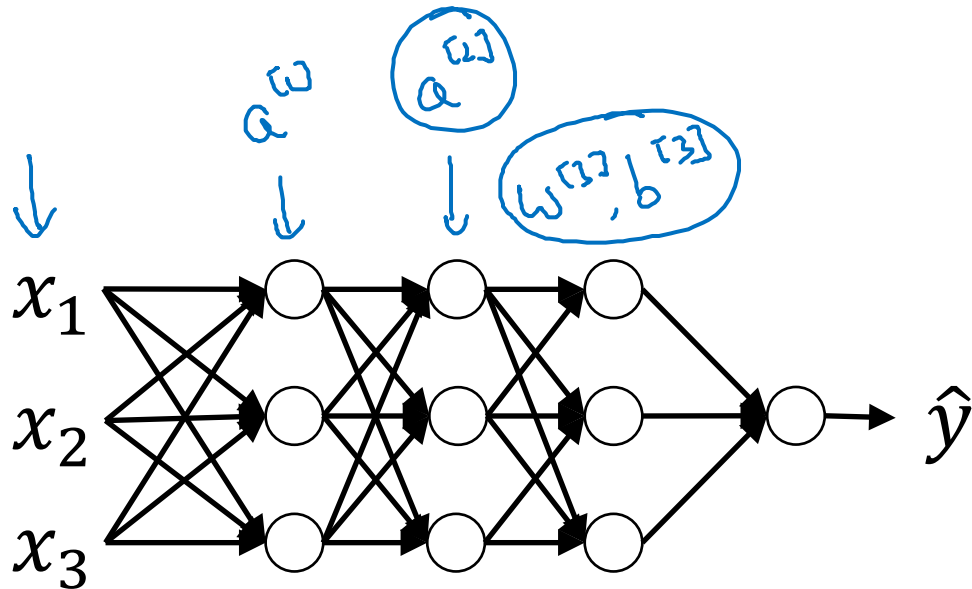
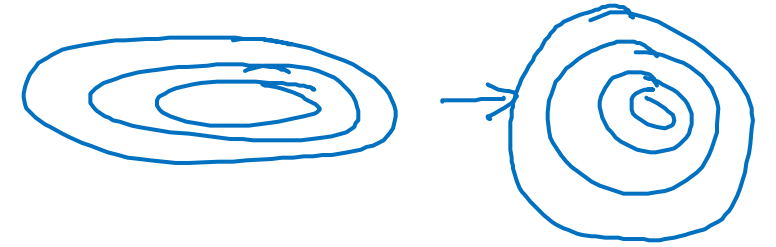


$$\mu = \frac{1}{n} \sum_i x^{(i)}$$

$$X = X - \mu$$

$$\sigma^2 = \frac{1}{n} \sum_i x^{(i)2} \quad \leftarrow \text{element-wise}$$

$$X = X / \sigma^2$$



Can we normalize $\frac{a^{[2]}}{w^{[1]}, b^{[1]}}$ so as to train faster

Normalize $\frac{z^{[2]}}{\uparrow}$

Implementing Batch Norm

Given some intermediate values in NN

$z^{(1)}, \dots, z^{(m)}$
 $z^{[l]}(i)$

$$\begin{aligned} \mu &= \frac{1}{m} \sum_i z^{(i)} \\ \sigma^2 &= \frac{1}{m} \sum_i (z^{(i)} - \mu)^2 \\ z_{\text{norm}}^{(i)} &= \frac{z^{(i)} - \mu}{\sqrt{\sigma^2 + \epsilon}} \\ \hat{z}^{(i)} &= \gamma z_{\text{norm}}^{(i)} + \beta \end{aligned}$$

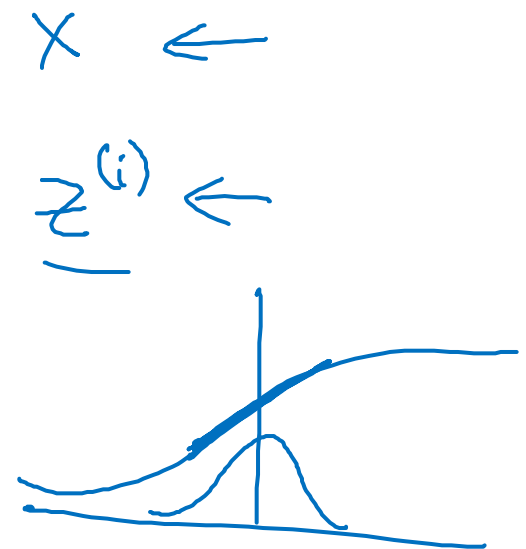
If

$$\gamma = \sqrt{\sigma^2 + \epsilon}$$

$$\beta = \mu$$

then $\hat{z}^{(i)} = z^{(i)}$

learnable parameters of model.



Use $\hat{z}^{[l]}(i)$ instead of $z^{[l]}(i)$.

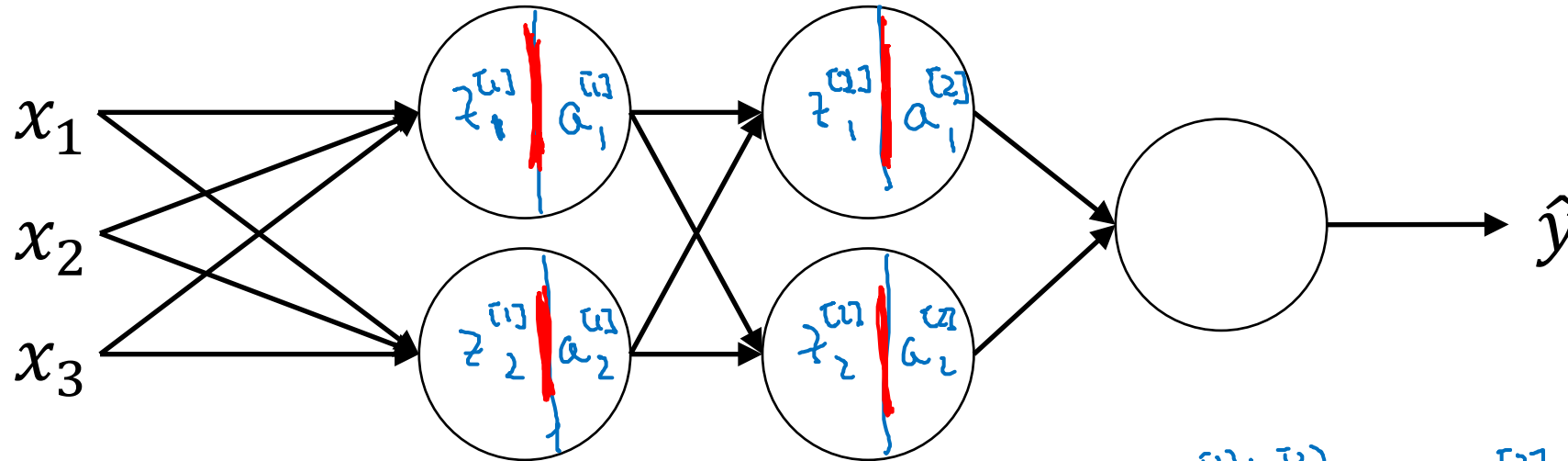


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Batch Normalization

Fitting Batch Norm
into a neural network

Adding Batch Norm to a network



$$X \xrightarrow{W^{[1]}, b^{[1]}} \underline{z^{[1]}} \xrightarrow[\text{Batch Norm (BN)}]{\beta^{[1]}, \gamma^{[1]}} \underline{z^{[1]}} \rightarrow a^{[1]} = g(z^{[1]}) \xrightarrow{W^{[2]}, b^{[2]}} \underline{z^{[2]}} \xrightarrow[\text{BN}]{\beta^{[2]}, \gamma^{[2]}} \underline{z^{[2]}} \rightarrow a^{[2]} \rightarrow \dots$$

Parameters: $\left\{ W^{[1]}, b^{[1]}, W^{[2]}, b^{[2]}, \dots, W^{[L]}, b^{[L]} \right\}$
 $\rightarrow \underline{\beta^{[1]}, \gamma^{[1]}, \beta^{[2]}, \gamma^{[2]}, \dots, \beta^{[L]}, \gamma^{[L]}}$
 $\rightarrow \underline{\beta}$

$$d\beta^{[L]} \quad \beta = \beta - \alpha d\beta^{[L]}$$

tf.nn.batch-normalization ←

Working with mini-batches

$$\underline{X^{[1]}} \xrightarrow{W^{[1]}, b^{[1]}} \underline{z^{[1]}} \xrightarrow[\text{BN}]{\beta^{[1]}, \gamma^{[1]}} \underline{\tilde{z}^{[1]}} \rightarrow g^{[1]}(\tilde{z}^{[1]}) = a^{[1]} \xrightarrow{W^{[2]}, b^{[2]}} \underline{z^{[2]}} \rightarrow \dots$$

$$\boxed{X^{[2]}} \rightarrow \underline{z^{[2]}} \xrightarrow[\text{BN}]{\beta^{[2]}, \gamma^{[2]}} \underline{\tilde{z}^{[2]}} \rightarrow \dots$$

$$X^{[3]} \rightarrow \dots$$

Parameters: $W^{[l]}, \cancel{b^{[l]}}, \beta^{[l]}, \gamma^{[l]}$

\uparrow \uparrow \uparrow
 $(n^{[l]}, 1)$ $(n^{[l]}, 1)$ $(n^{[l]}, 1)$

\uparrow
 $(n^{[l-1]}, 1)$

$$\rightarrow \underline{z^{[l]}} = W^{[l]} a^{[l-1]} + \cancel{b^{[l]}}$$

$$z^{[l]} = W^{[l]} a^{[l-1]}$$

$$\rightarrow \tilde{z}^{[l]} = \gamma^{[l]} z_{\text{norm}}^{[l]} + \boxed{\beta^{[l]}}$$

Implementing gradient descent

for $t = 1 \dots \text{num Mini Batches}$

Compute forward pass on $X^{\{t\}}$.

In each hidden layer, use BN to replace $\underline{z}^{\{t\}}$ with $\underline{\hat{z}}^{\{t\}}$.

Use backprop to compute $\underline{dw}^{\{t\}}$, ~~$\underline{db}^{\{t\}}$~~ , $\underline{dp}^{\{t\}}$, $\underline{df}^{\{t\}}$

Update params
$$\left. \begin{aligned} w^{\{t\}} &:= w^{\{t-1\}} - \alpha dw^{\{t\}} \\ \beta^{\{t\}} &:= \beta^{\{t-1\}} - \alpha dp^{\{t\}} \\ f^{\{t\}} &:= \dots \end{aligned} \right\} \leftarrow$$

Works w/ momentum, RMSprop, Adam.

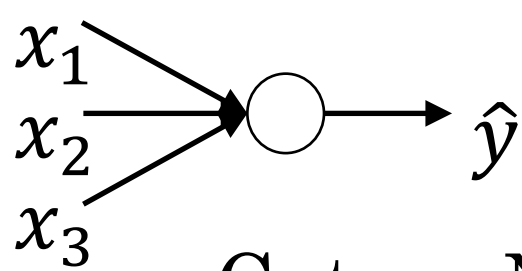


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Batch Normalization

Why does
Batch Norm work?

Learning on shifting input distribution

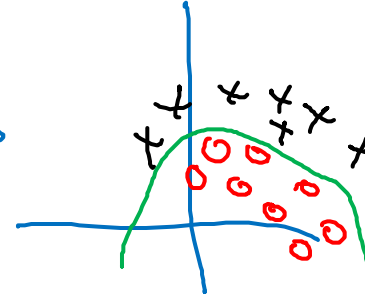
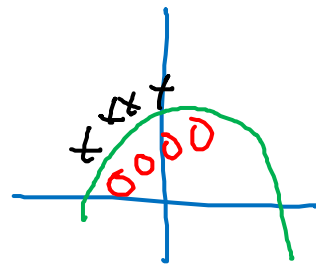


Cat

Non-Cat

$y = 1$

$y = 0$



$y = 1$

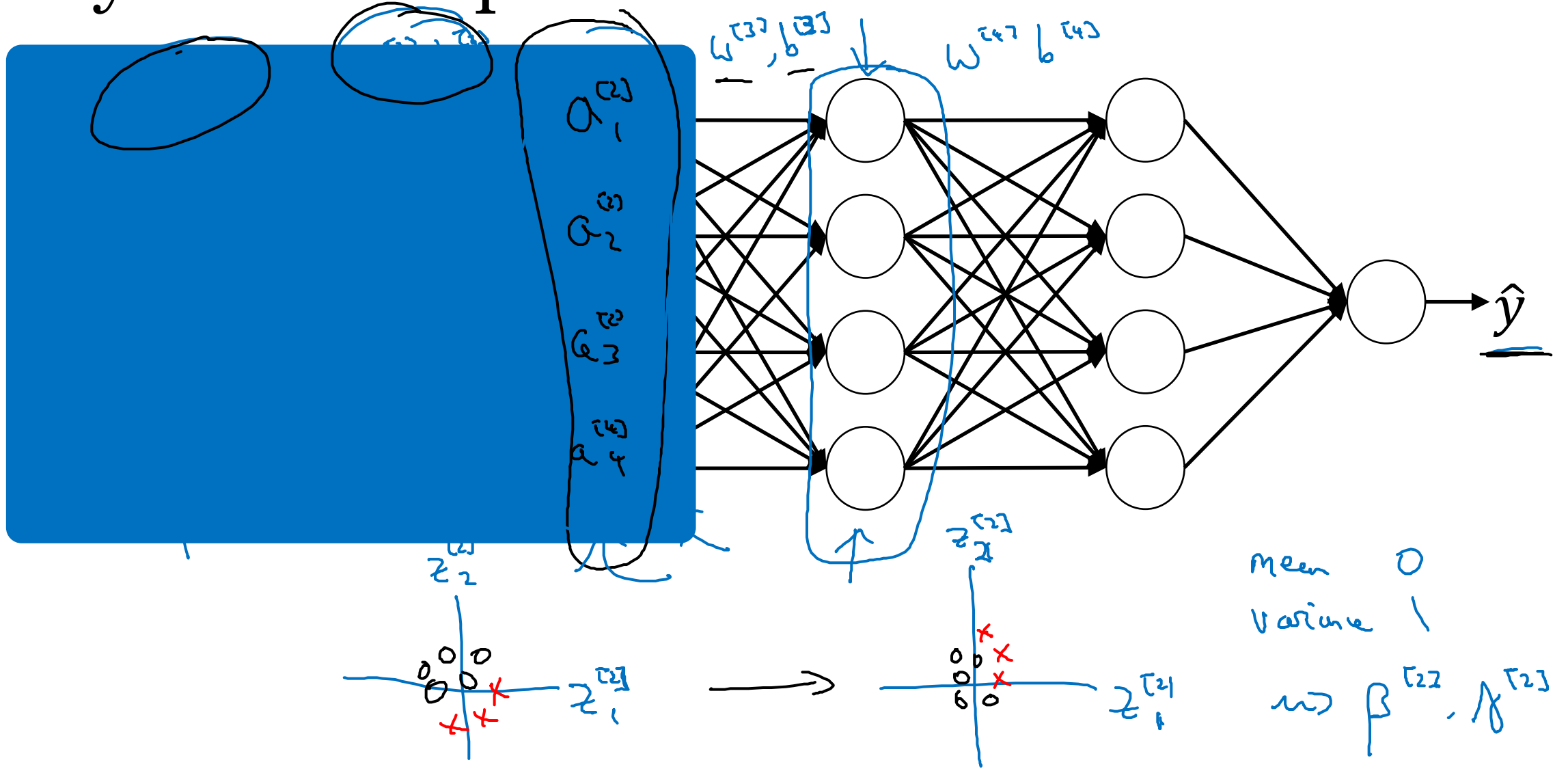
$y = 0$



"Covariate shift"

$\underline{x} \rightarrow y$

Why this is a problem with neural networks?



Batch Norm as regularization

- Each mini-batch is scaled by the mean/variance computed on just that mini-batch.
- This adds some noise to the values $z^{[l]}$ within that minibatch. So similar to dropout, it adds some noise to each hidden layer's activations.
- This has a slight regularization effect.

mini-batch : 64 \longrightarrow 512



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Multi-class classification

Softmax regression

Recognizing cats, dogs, and baby chicks



3



1



2



0



3



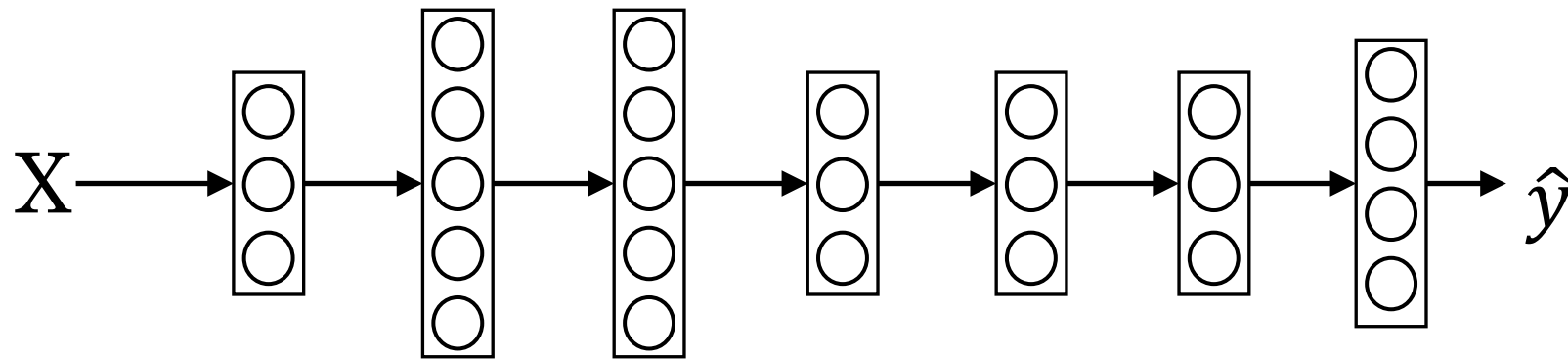
2



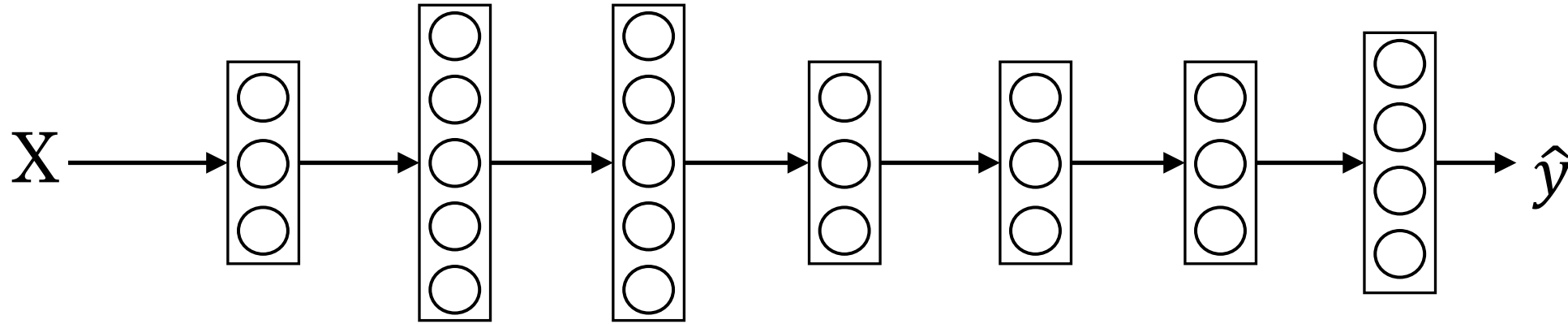
0



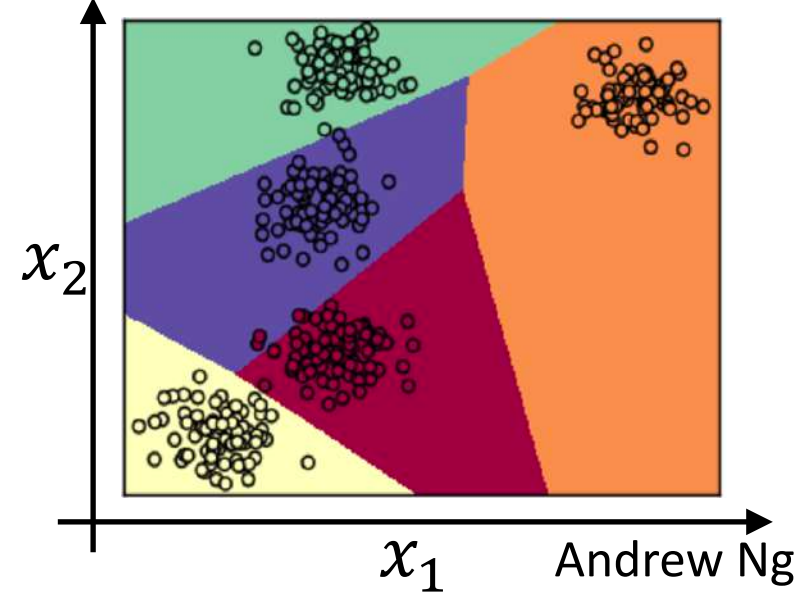
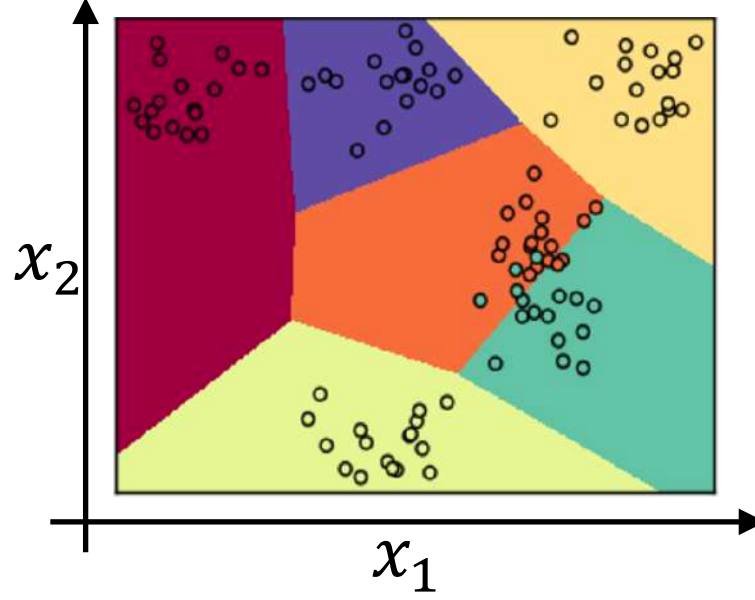
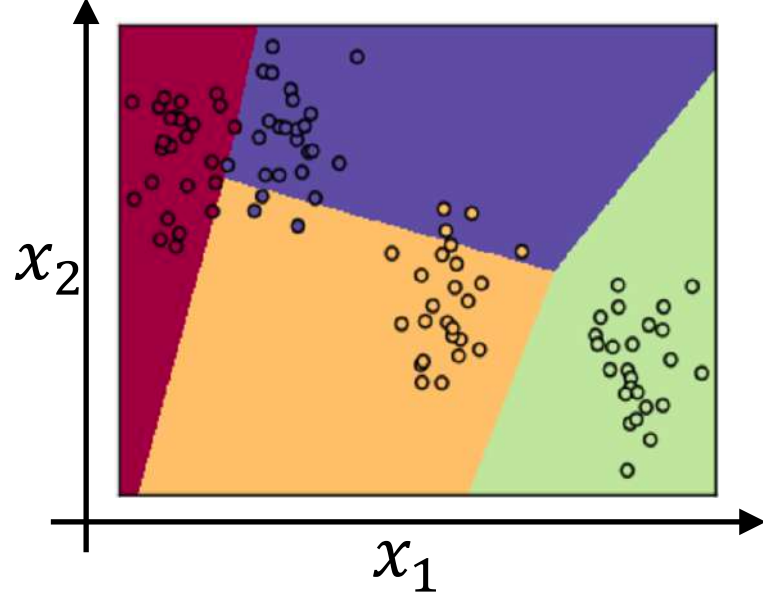
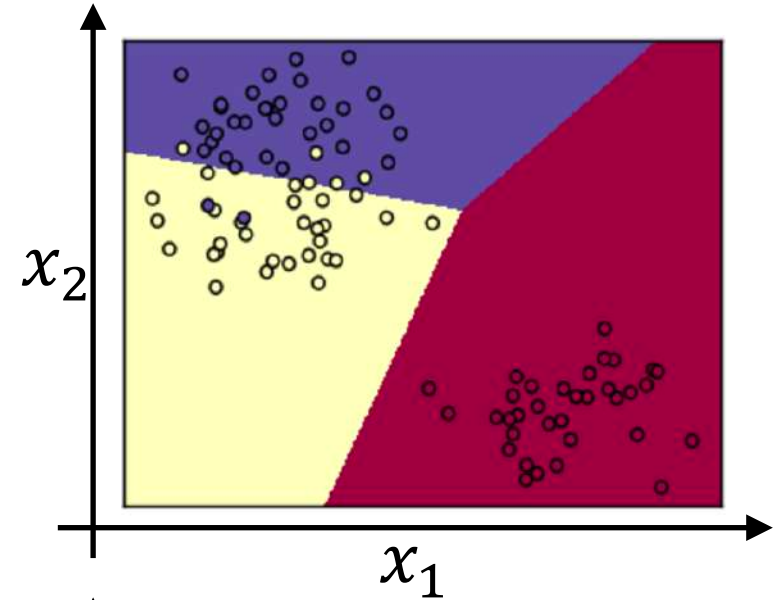
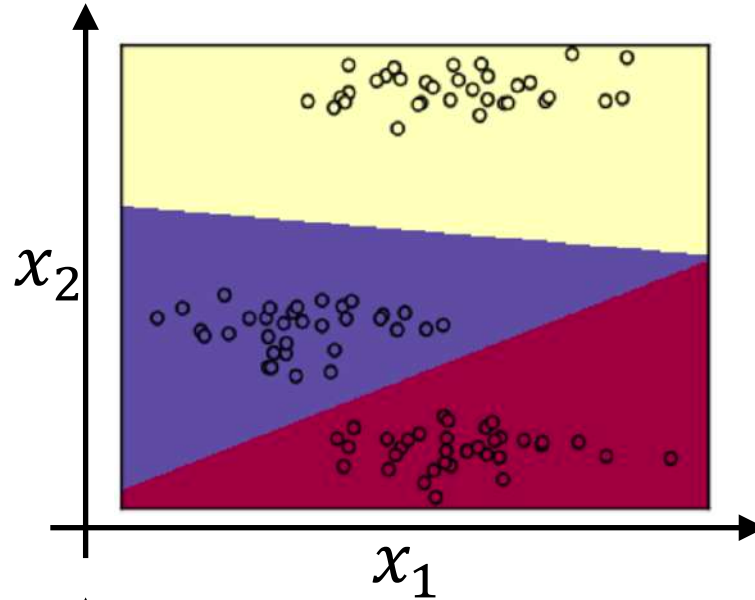
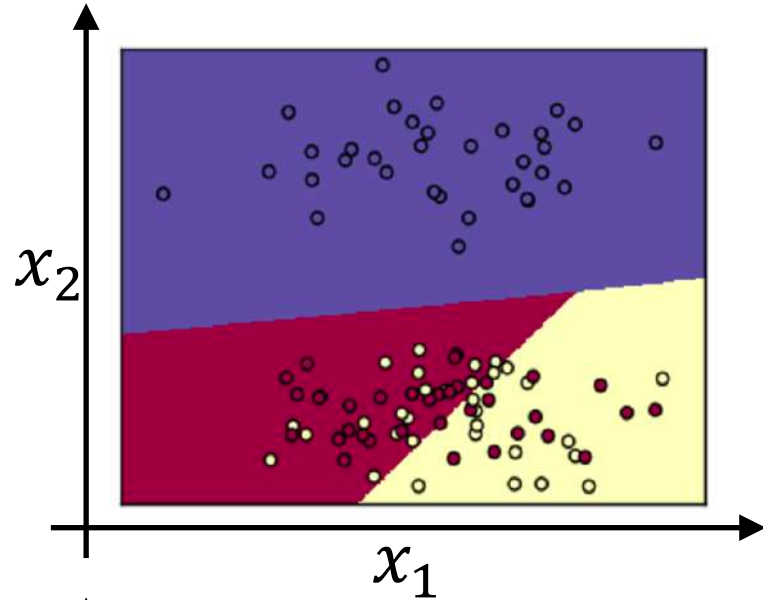
1



Softmax layer



Softmax examples





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Programming Frameworks

Deep Learning frameworks

Deep learning frameworks

- Caffe/Caffe2
- CNTK
- DL4J
- Keras
- Lasagne
- mxnet
- PaddlePaddle
- TensorFlow
- Theano
- Torch

Choosing deep learning frameworks

- Ease of programming (development and deployment)
- Running speed
- - Truly open (open source with good governance)



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Programming Frameworks

TensorFlow

Motivating problem

$$\begin{aligned} J(w) &= \boxed{w^2 - 10w + 25} \\ &\quad \swarrow \\ &\quad (w-5)^2 \\ &\quad w=5 \end{aligned}$$

$$\begin{aligned} J(w, b) \\ \uparrow \quad \uparrow \end{aligned}$$