Artificial Intelligence and Machine Learning

Neural Networks

Lecture Outline

- Logistic Regression Review
- Neural Networks
  - Forward pass
  - Backward pass

Review: Logistic Regression

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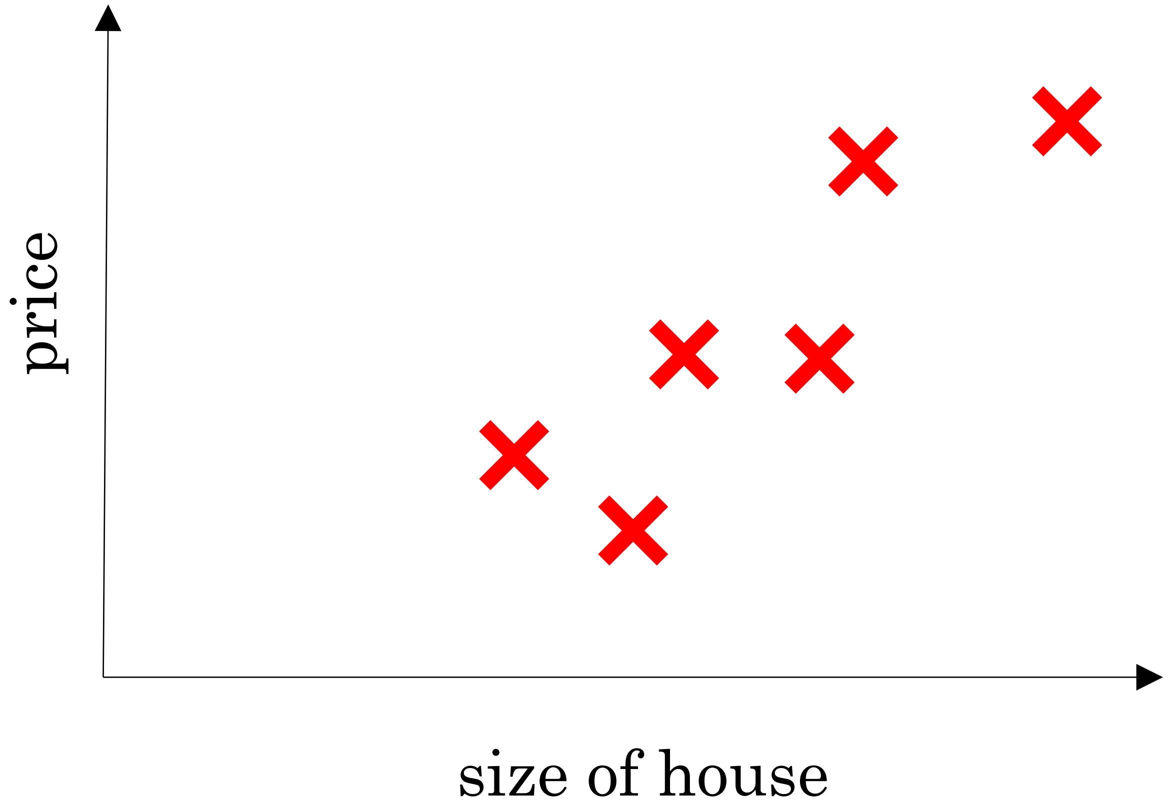
Introduction to Deep Learning

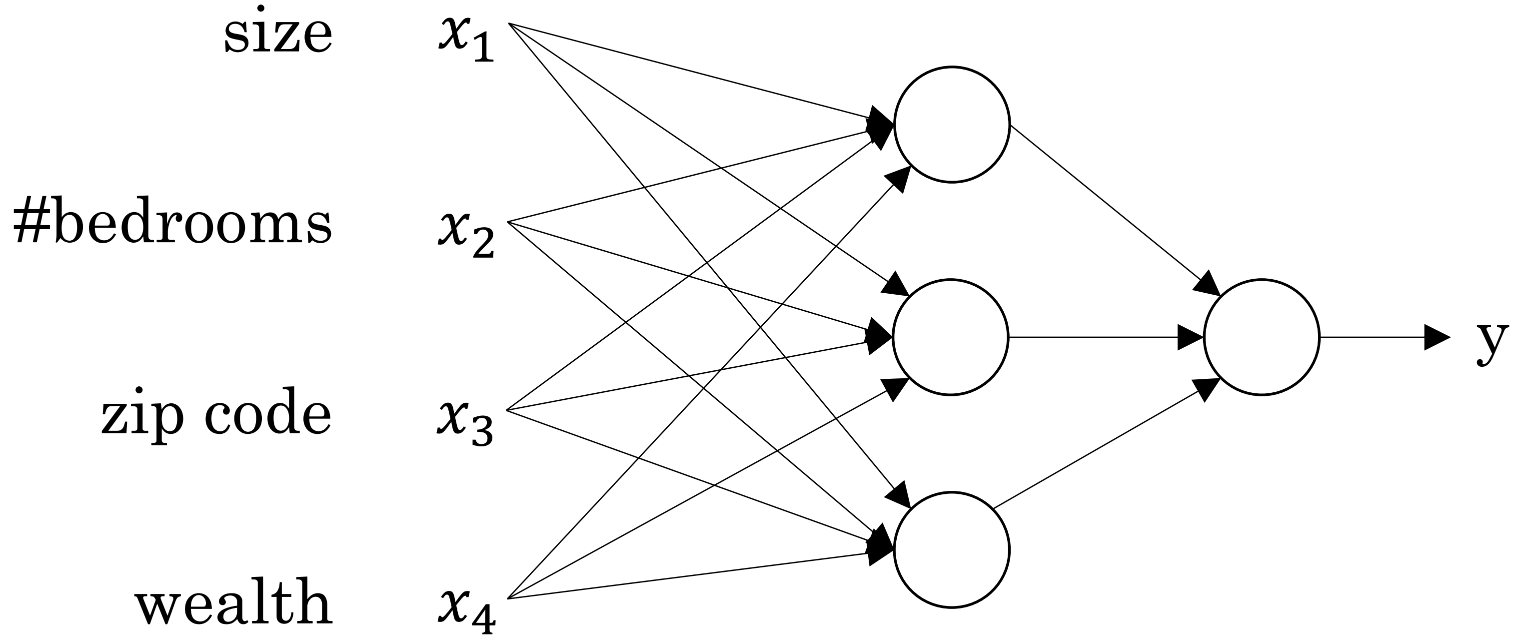
What is a Neural Network?

Housing Price Prediction



Housing Price Prediction

Housing Price Prediction



Introduction to Deep Learning

Supervised Learning with Neural Networks

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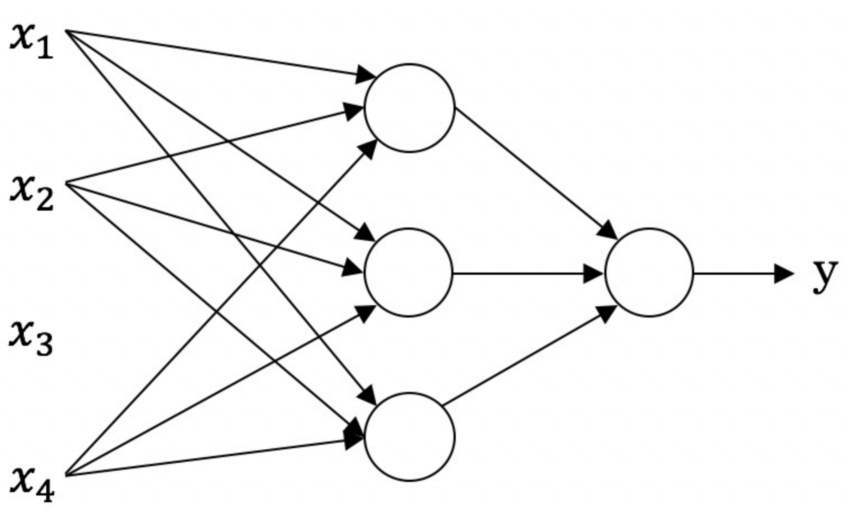
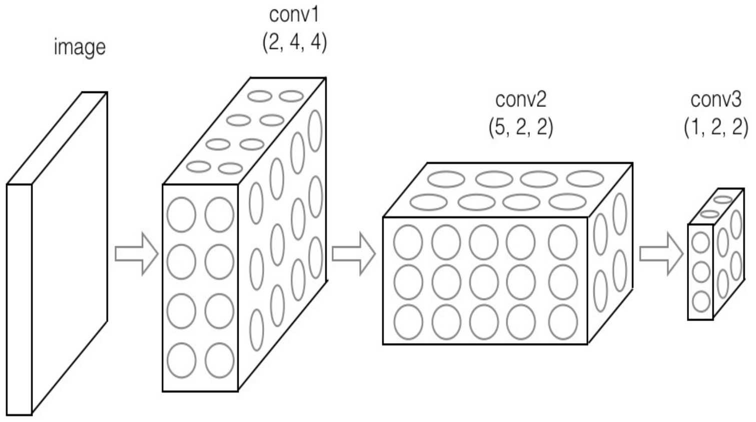
Supervised Learning

Input(x)	Output (y)	Application
Home features	Price	Real Estate
Ad, user info	Click on ad? (0/1)	Online Advertising
Image	Object (1,…,1000)	Photo tagging
Audio	Text transcript	Speech recognition
English	Chinese	Machine translation
Image, Radar info	Position of other cars	Autonomous driving

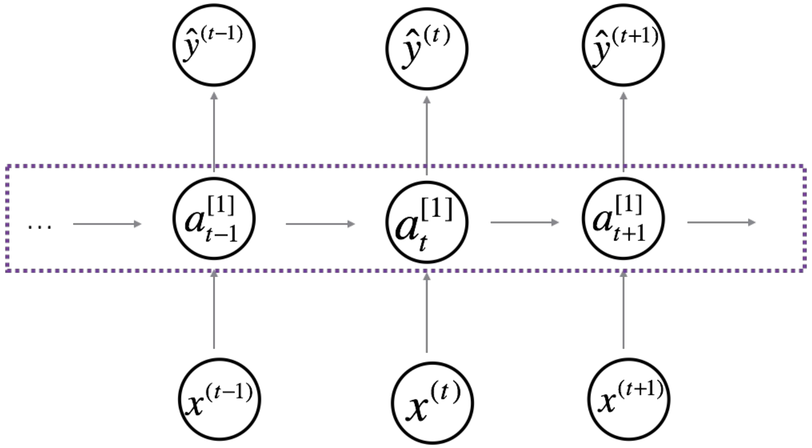
Neural Network examples



Standard NN



Convolutional NN



Recurrent NN

One hidden layer Neural Network

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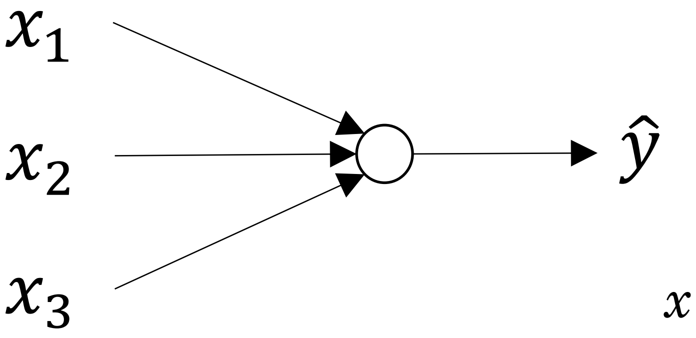
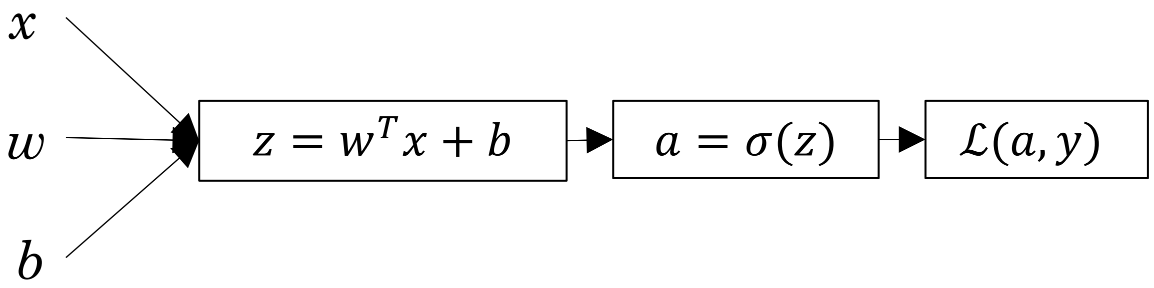
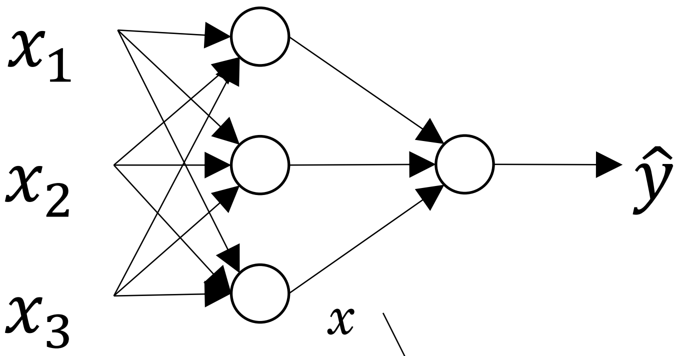
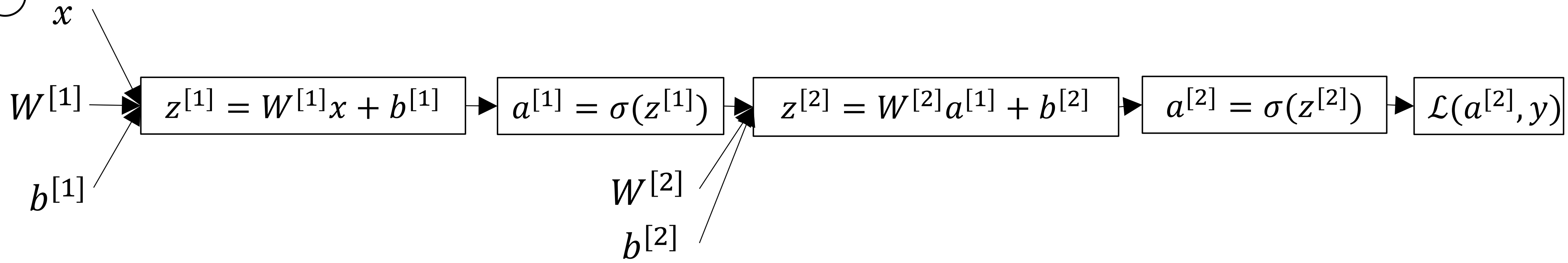
Neural Networks Overview

What is a Neural Network?









One hidden layer Neural Network

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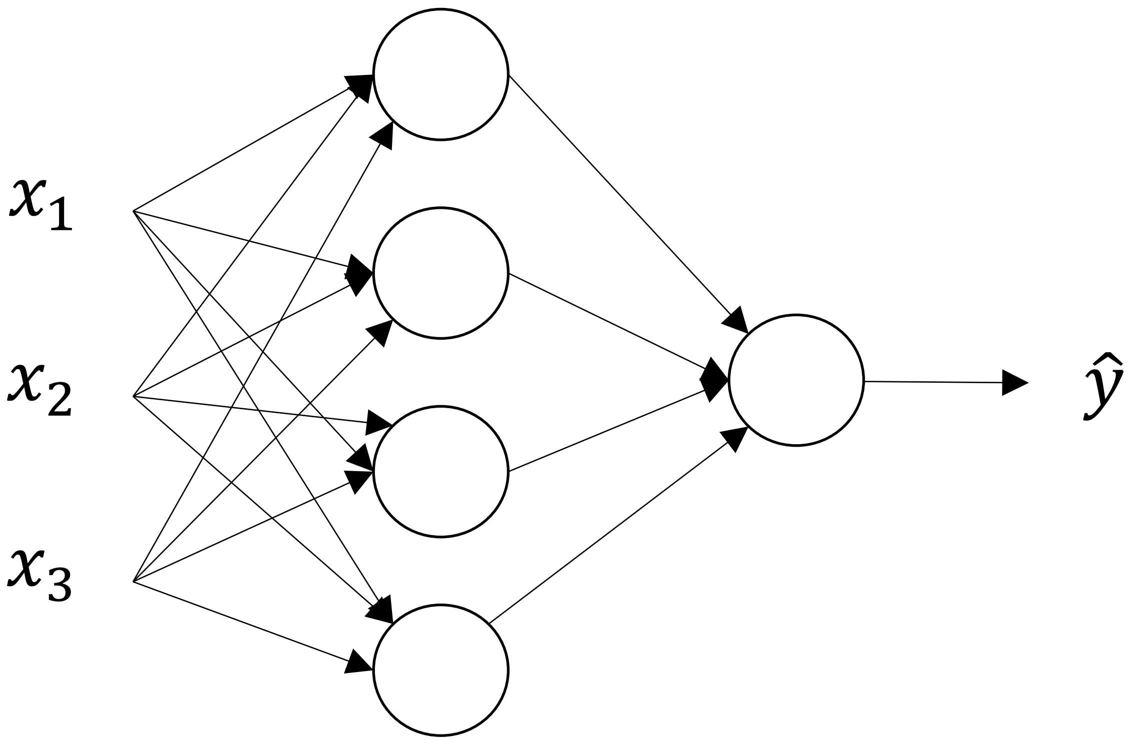
Neural Network Representation

Neural Network Representation



One hidden layer Neural Network

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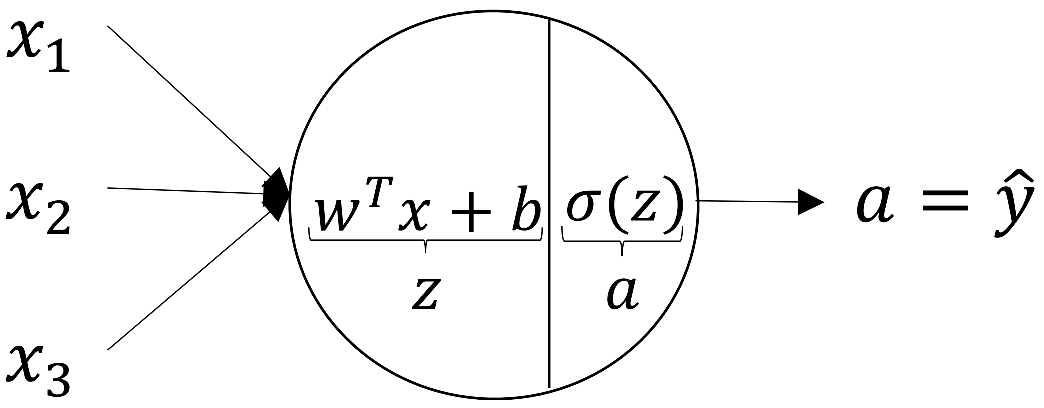
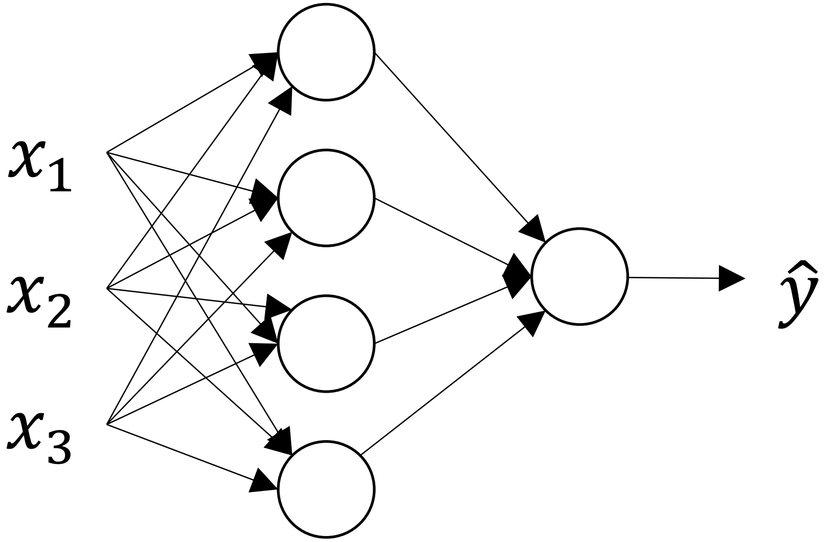
Computing a Neural Network's Output

Neural Network Representation

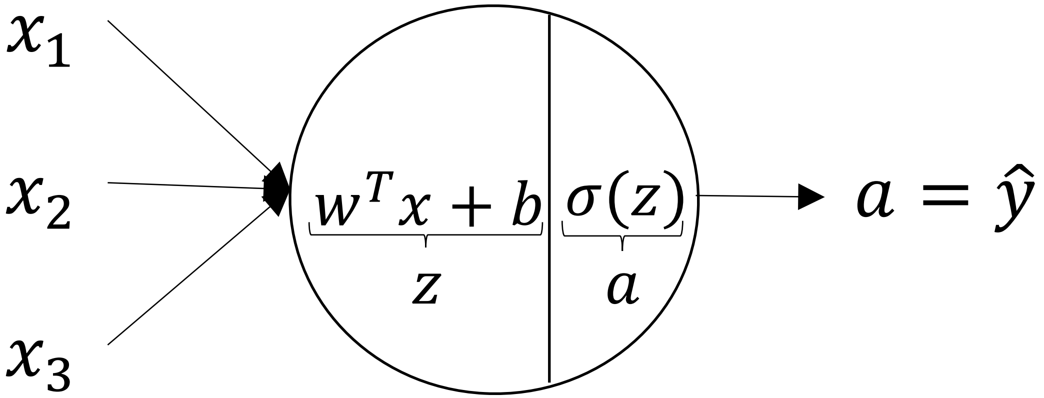


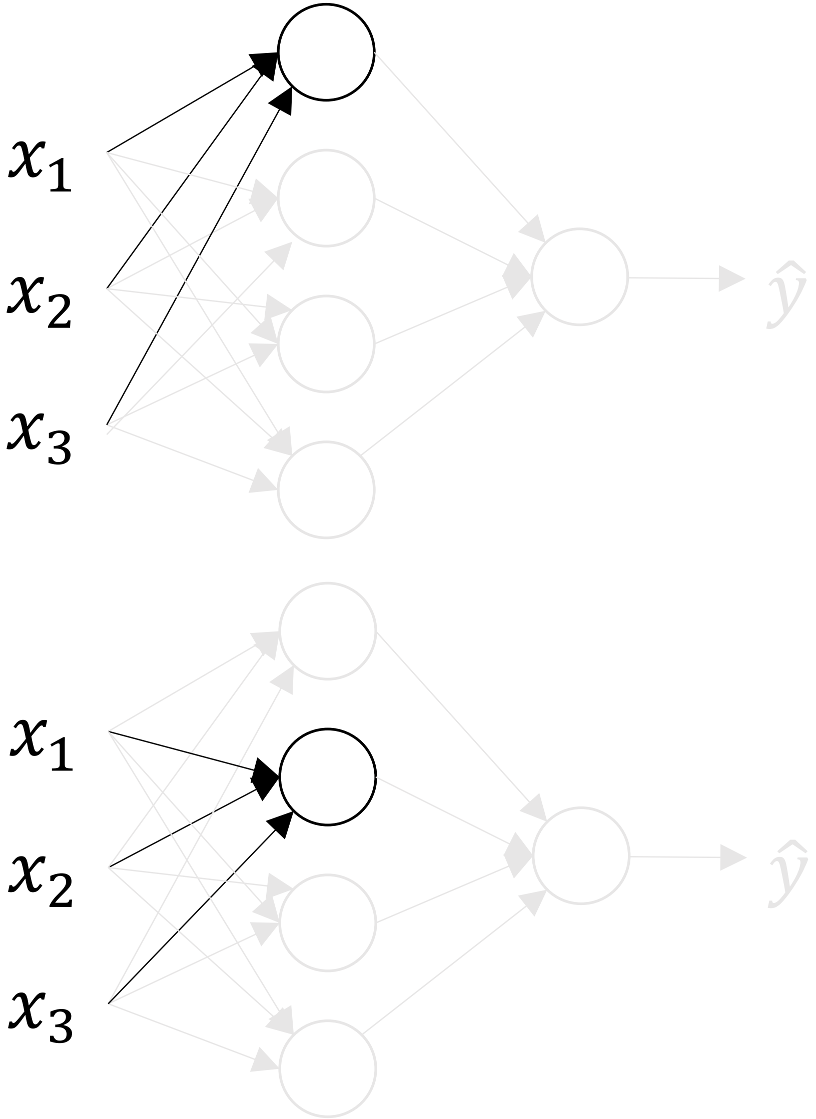


$$z = w^T x + b$$

$$a = \sigma(z)$$

Neural Network Representation

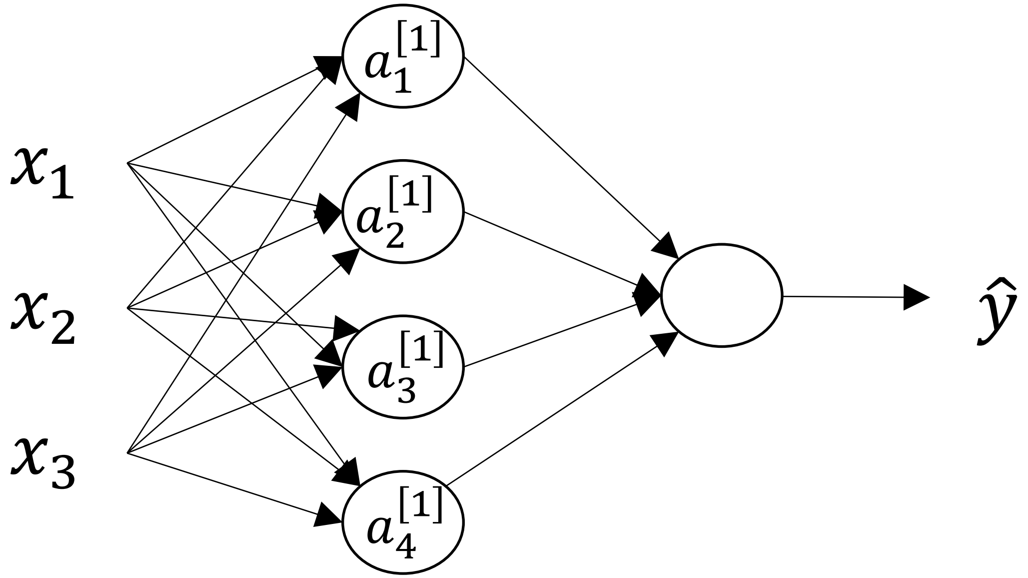




$$z = w^T x + b$$

$$a = \sigma(z)$$

Neural Network Representation



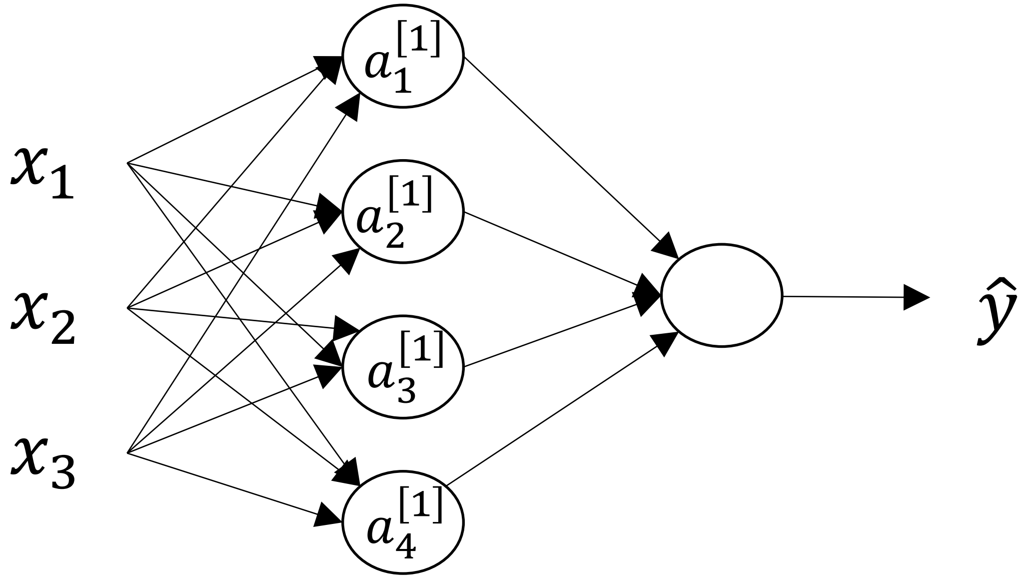
$$z_1^{[1]} = w_1^{[1]T}x + b_1^{[1]},\ a_1^{[1]} = \sigma(z_1^{[1]})$$

$$z_2^{[1]} = w_2^{[1]T}x + b_2^{[1]},\ a_2^{[1]} = \sigma(z_2^{[1]})$$

$$z_3^{[1]} = w_3^{[1]T}x + b_3^{[1]},\ a_3^{[1]} = \sigma(z_3^{[1]})$$

$$z_4^{[1]} = w_4^{[1]T}x + b_4^{[1]},\ a_4^{[1]} = \sigma(z_4^{[1]})$$

Neural Network Representation learning



Given input x:

$$z^{[1]} = W^{[1]}x + b^{[1]}$$

$$a^{[1]} = \sigma(z^{[1]})$$

$$z^{[2]} = W^{[2]}a^{[1]} + b^{[2]}$$

$$a^{[2]} = \sigma(z^{[2]})$$

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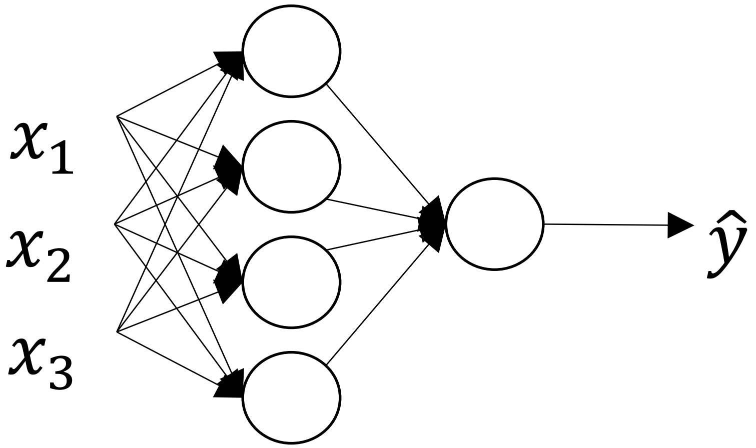
One hidden layer Neural Network

Vectorizing across multiple examples

Vectorizing across multiple examples



$$z^{[1]} = W^{[1]}x + b^{[1]}$$
$$a^{[1]} = \sigma(z^{[1]})$$
$$z^{[2]} = W^{[2]}a^{[1]} + b^{[2]}$$
$$a^{[2]} = \sigma(z^{[2]})$$

Vectorizing across multiple examples

```
for i = 1 to m:
```

$$z^{[1](i)} = W^{[1]}x^{(i)} + b^{[1]}$$

$$a^{[1](i)} = \sigma(z^{[1](i)})$$

$$z^{[2](i)} = W^{[2]}a^{[1](i)} + b^{[2]}$$

$$a^{[2](i)} = \sigma(z^{[2](i)})$$

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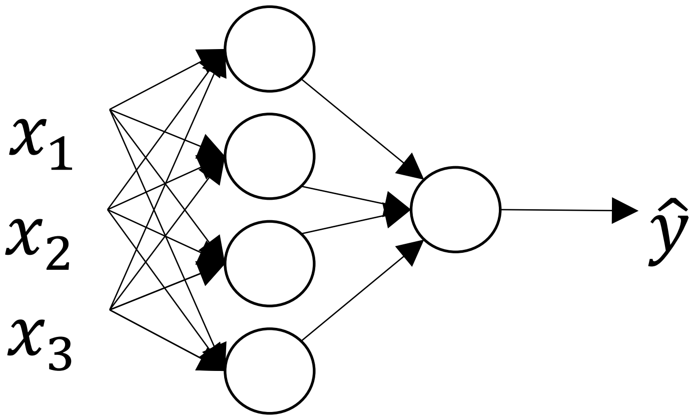
One hidden layer Neural Network

Explanation for vectorized implementation

Justification for vectorized implementation

Recap of vectorizing across multiple examples



$$X = \begin{bmatrix} | & | & & | \\ x^{(1)} & x^{(2)} & \cdots & x^{(m)} \\ | & | & & | \end{bmatrix}$$

$$A^{[1]} = \begin{bmatrix} | & | & & | \\ a^{[1](1)} & a^{[1](2)} & \cdots & a^{[1](m)} \\ | & | & & | \end{bmatrix}$$

```
for i = 1 to m
```

$$z^{[1](i)} = W^{[1]}x^{(i)} + b^{[1]}$$
$$a^{[1](i)} = \sigma(z^{[1](i)})$$
$$z^{[2](i)} = W^{[2]}a^{[1](i)} + b^{[2]}$$
$$a^{[2](i)} = \sigma(z^{[2](i)})$$

$$Z^{[1]} = W^{[1]}X + b^{[1]}$$
$$A^{[1]} = \sigma(Z^{[1]})$$
$$Z^{[2]} = W^{[2]}A^{[1]} + b^{[2]}$$
$$A^{[2]} = \sigma(Z^{[2]})$$

One hidden layer Neural Network

Activation functions

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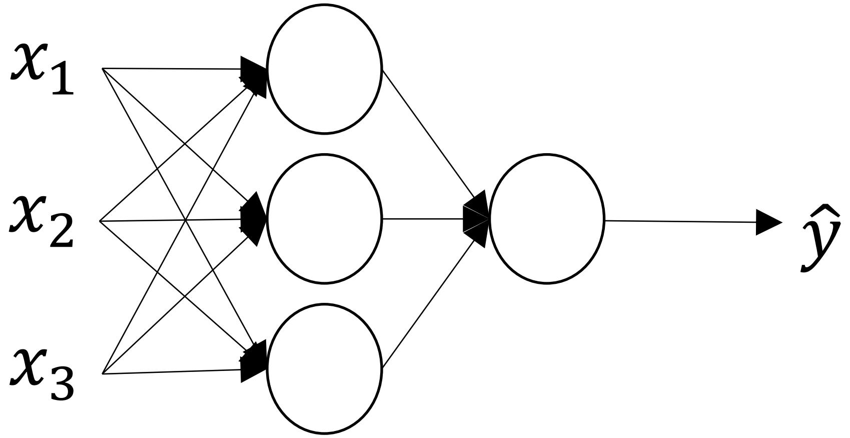
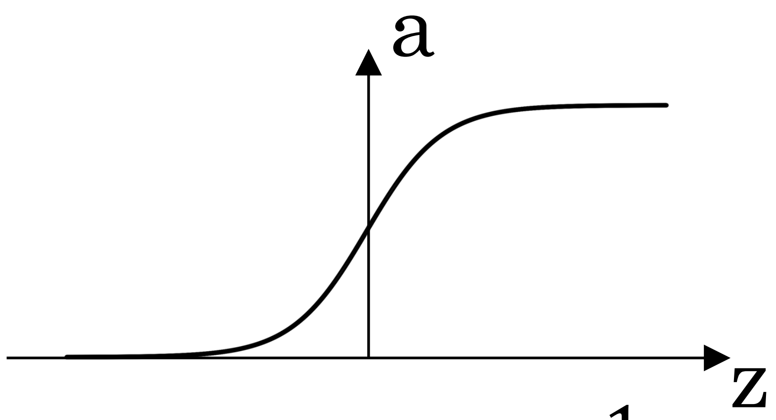
Activation functions



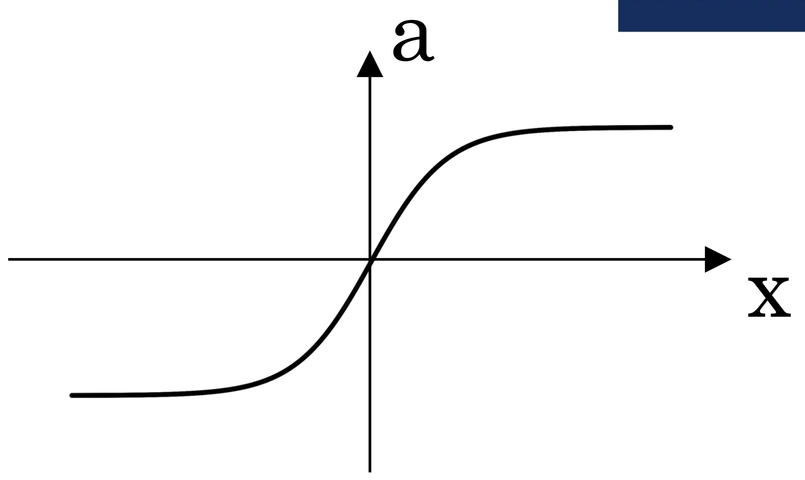
Given x:

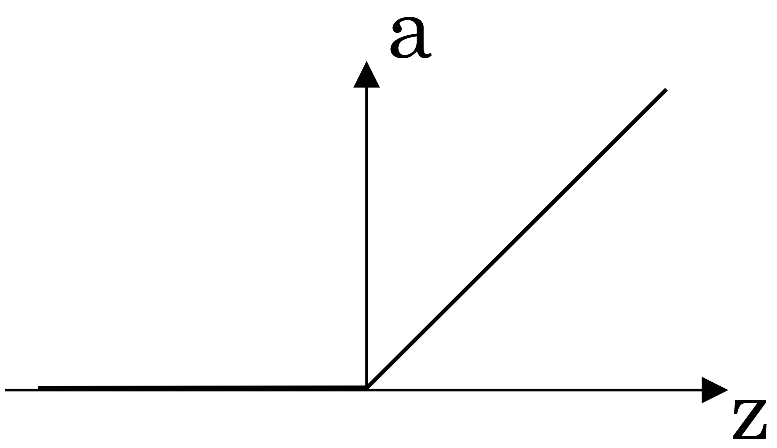
$$z^{[1]} = W^{[1]}x + b^{[1]}$$
$$a^{[1]} = \sigma(z^{[1]})$$
$$z^{[2]} = W^{[2]}a^{[1]} + b^{[2]}$$
$$a^{[2]} = \sigma(z^{[2]})$$

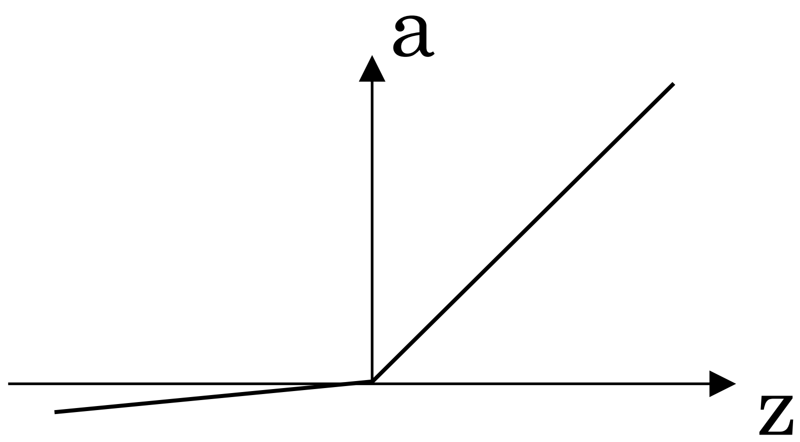
Pros and cons of activation functions



sigmoid: $a = \dfrac{1}{1 + e^{-z}}$







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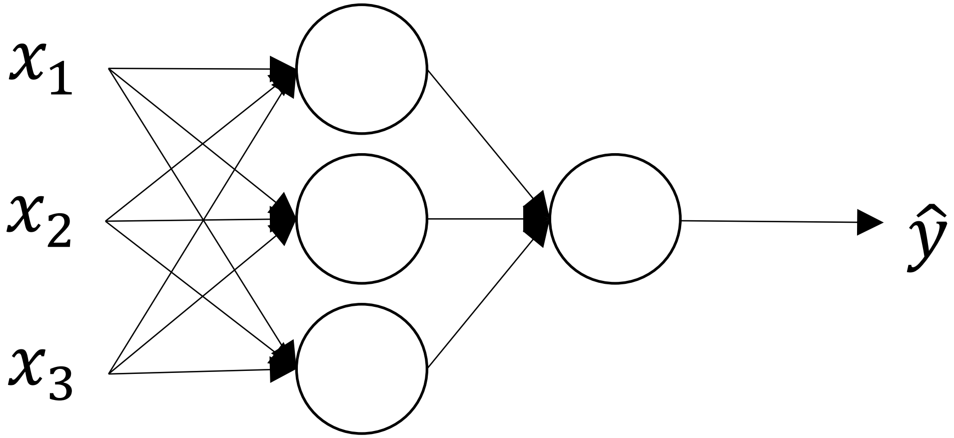
One hidden layer Neural Network

Why do you need non-linear activation functions?

Activation function



Given x:

$$z^{[1]} = W^{[1]}x + b^{[1]}$$

$$a^{[1]} = g^{[1]}(z^{[1]})$$

$$z^{[2]} = W^{[2]}a^{[1]} + b^{[2]}$$

$$a^{[2]} = g^{[2]}(z^{[2]})$$

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One hidden layer Neural Network

Gradient descent for neural networks

Gradient descent for neural networks

Formulas for computing derivatives

One hidden layer Neural Network

Backpropagation intuition

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Computing gradients

Logistic regression

$$
\begin{tikzcd}
x \arrow[dr] & & & \\
w \arrow[r] & \boxed{z = w^T x + b} \arrow[r] & \boxed{a = \sigma(z)} \arrow[r] & \boxed{\mathcal{L}(a, y)} \\
b \arrow[ur] & & &
\end{tikzcd}
$$

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Neural network gradients

$$
\begin{tikzcd}
x \arrow[dr] & & & b^{[2]} \arrow[d] & W^{[2]} \arrow[dl] & & \\
W^{[1]} \arrow[r] & \boxed{z^{[1]} = W^{[1]}x + b^{[1]}} \arrow[r] & \boxed{a^{[1]} = \sigma(z^{[1]})} \arrow[r] & \boxed{z^{[2]} = W^{[2]}x + b^{[2]}} \arrow[r] & \boxed{a^{[2]} = \sigma(z^{[2]})} \arrow[r] & \boxed{\mathcal{L}(a^{[2]}, \mathrm{y})} \\
b^{[1]} \arrow[ur] & & & & & &
\end{tikzcd}
$$

Summary of gradient descent

$$dz^{[2]} = a^{[2]} - y$$

$$dW^{[2]} = dz^{[2]} {a^{[1]}}^T$$

$$db^{[2]} = dz^{[2]}$$

$$dz^{[1]} = W^{[2]T} dz^{[2]} * g^{[1]\prime}(z^{[1]})$$

$$dW^{[1]} = dz^{[1]} x^T$$

$$db^{[1]} = dz^{[1]}$$

Summary of gradient descent

$$dz^{[2]} = a^{[2]} - y$$

$$dW^{[2]} = dz^{[2]} a^{[1]^T}$$

$$db^{[2]} = dz^{[2]}$$

$$dz^{[1]} = W^{[2]T} dz^{[2]} * g^{[1]\prime}(\mathrm{z}^{[1]})$$

$$dW^{[1]} = dz^{[1]} x^T$$

$$db^{[1]} = dz^{[1]}$$

$$dZ^{[2]} = A^{[2]} - Y$$

$$dW^{[2]} = \frac{1}{m} dZ^{[2]} A^{[1]^T}$$

$$db^{[2]} = \frac{1}{m} np.sum(dZ^{[2]}, axis = 1, keepdims = True)$$

$$dZ^{[1]} = W^{[2]T} dZ^{[2]} * g^{[1]\prime}(\mathrm{Z}^{[1]})$$

$$dW^{[1]} = \frac{1}{m} dZ^{[1]} X^T$$

$$db^{[1]} = \frac{1}{m} np.sum(dZ^{[1]}, axis = 1, keepdims = True)$$

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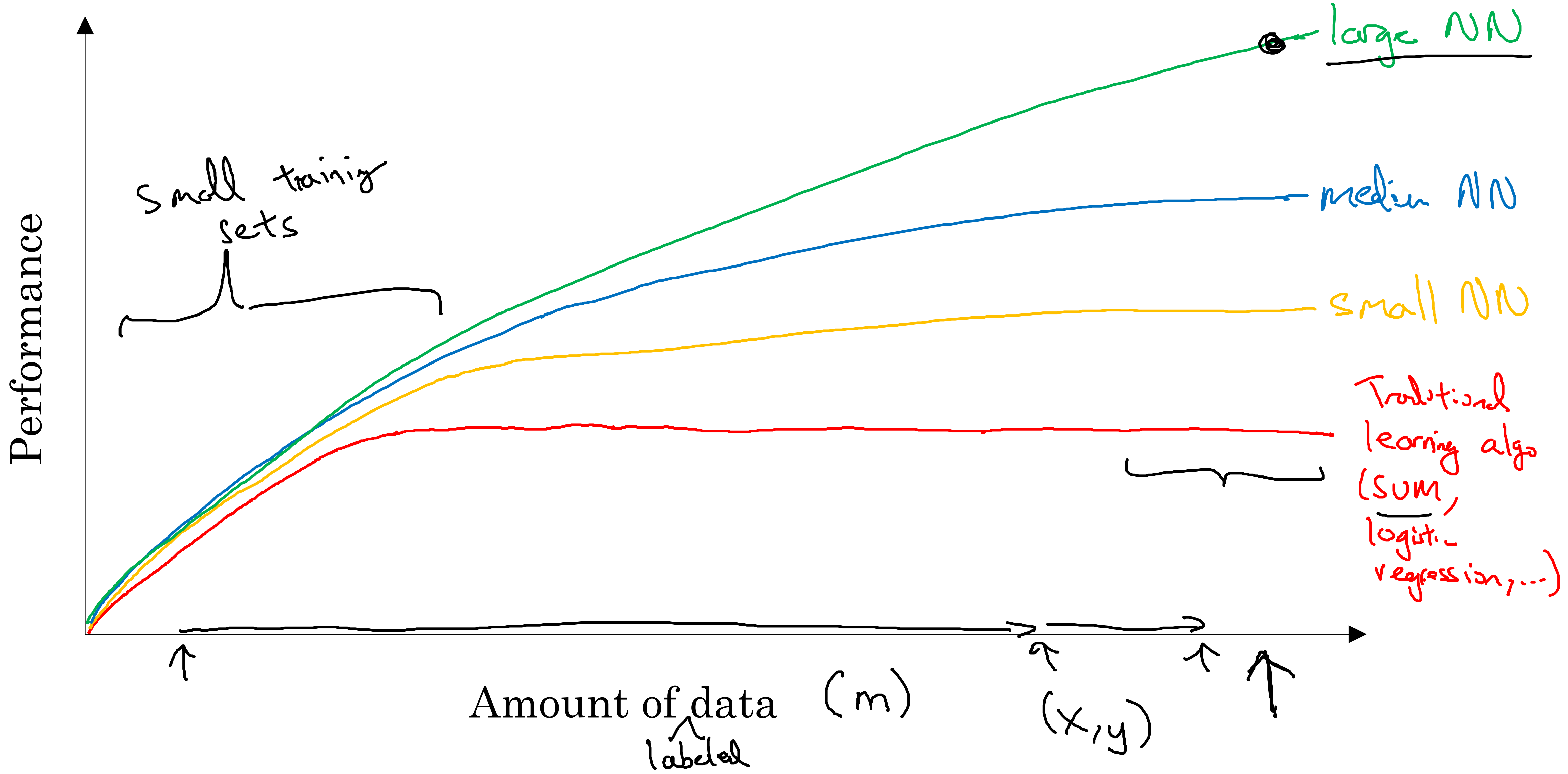
Introduction to Neural Networks

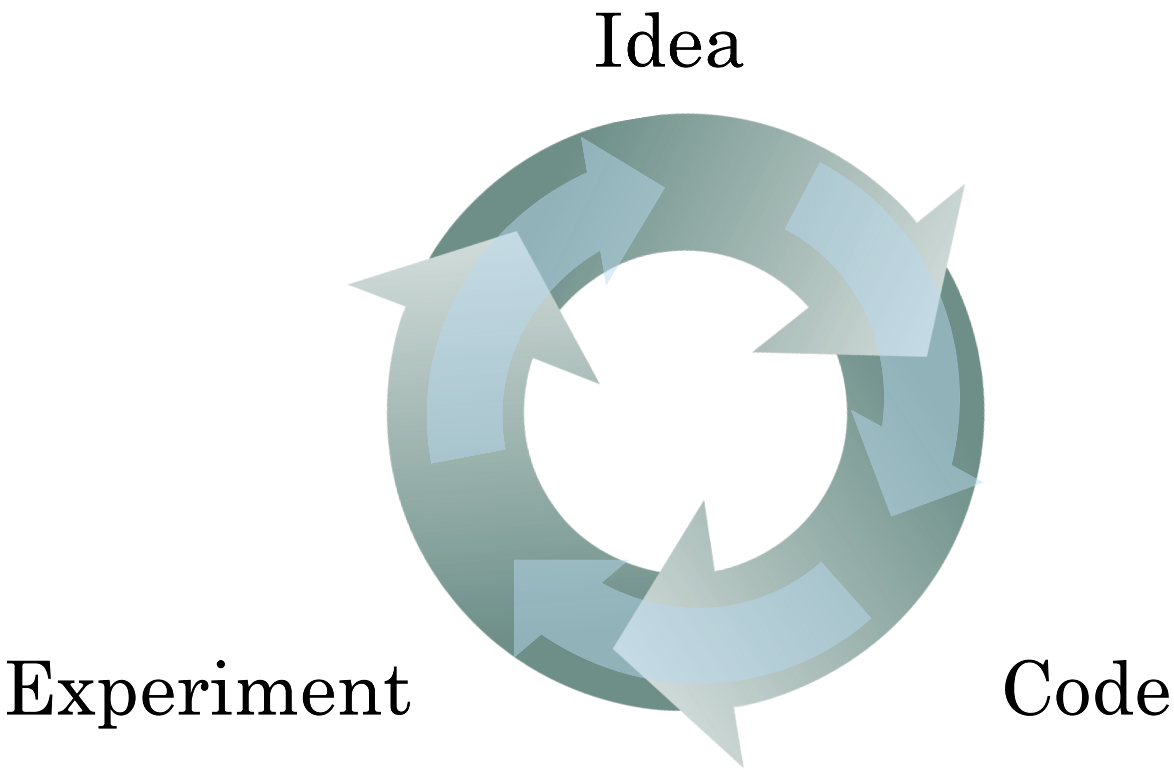
Why is Deep Learning taking off?

Scale drives deep learning progress



Scale drives deep learning progress

- Data
- Computation
- Algorithms



One hidden layer Neural Network

Random Initialization

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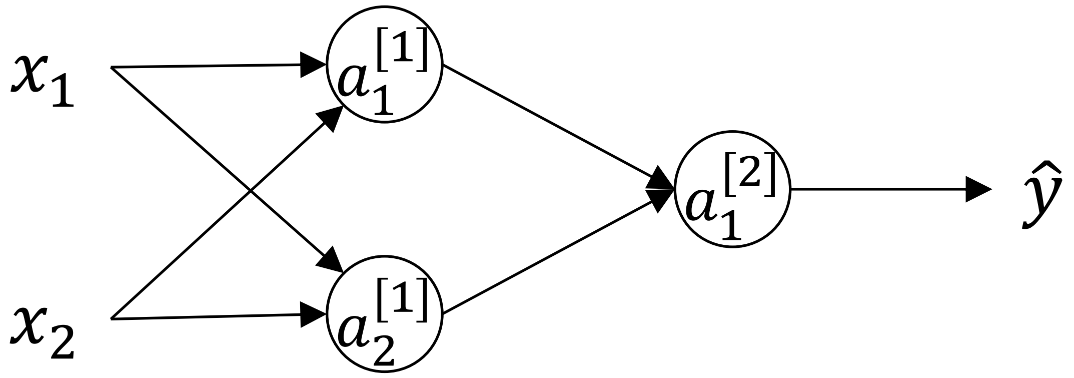
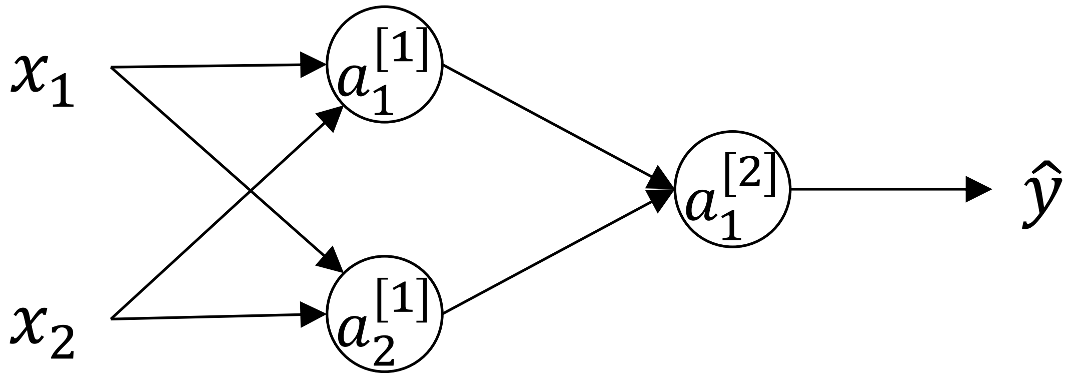
What happens if you initialize weights to zero?



Random initialization



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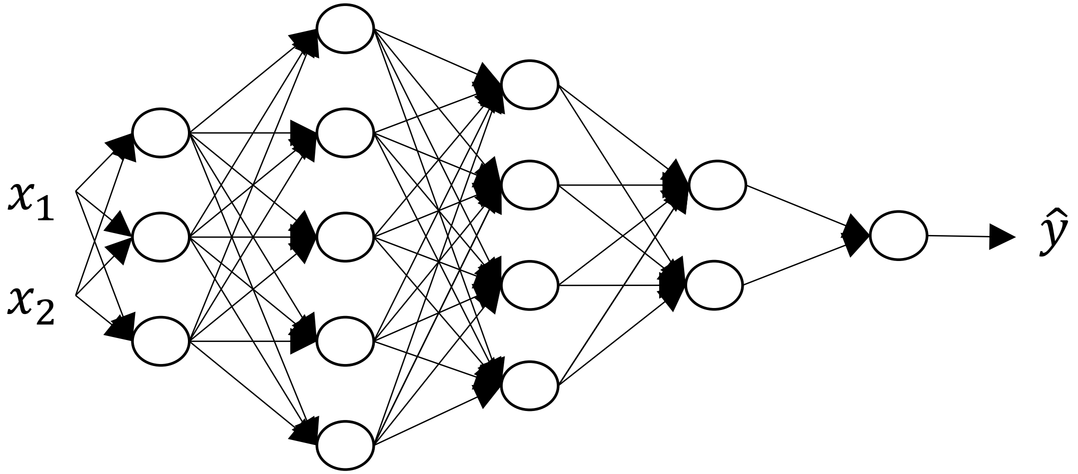
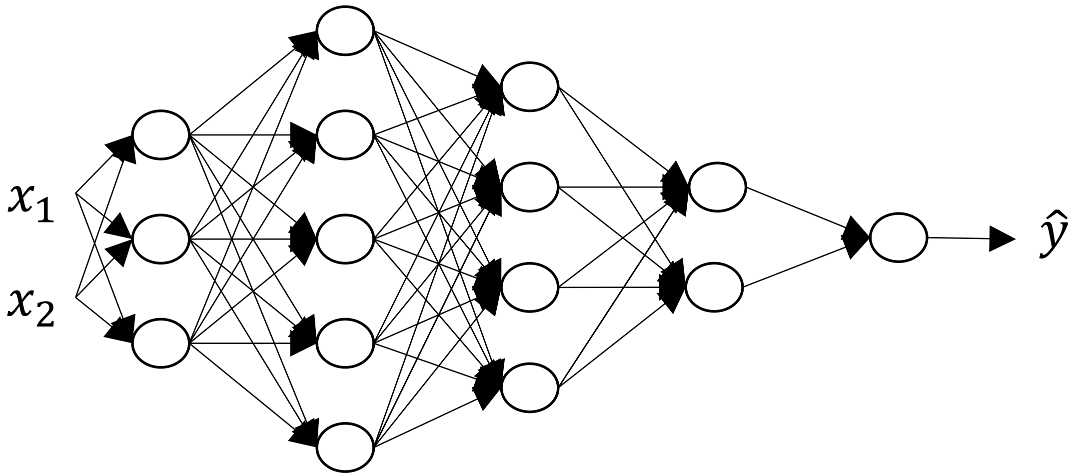
Deep Neural Networks

Getting your matrix dimensions right

Parameters $W^{[l]}$ and $b^{[l]}$



Vectorized implementation



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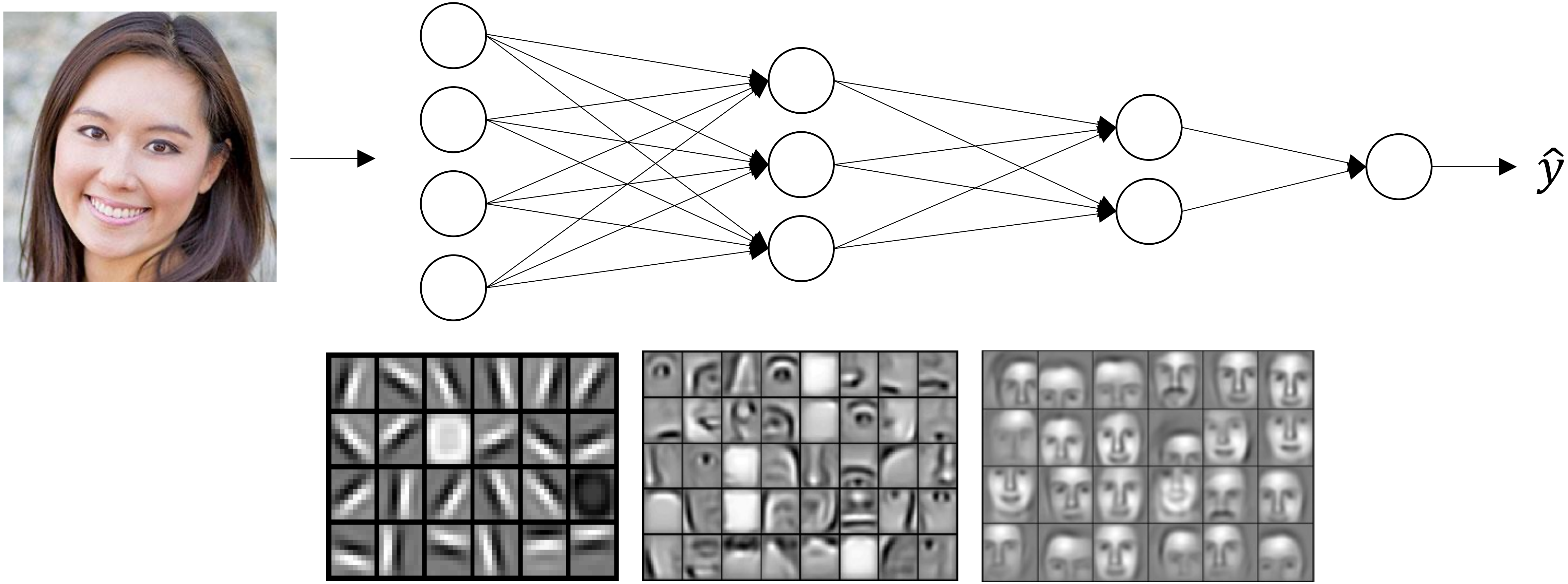
Deep Neural Networks

Why deep representations?

Intuition about deep representation



Circuit theory and deep learning

Informally: There are functions you can compute with a "small" L-layer deep neural network that shallower networks require exponentially more hidden units to compute.

Deep Neural Networks

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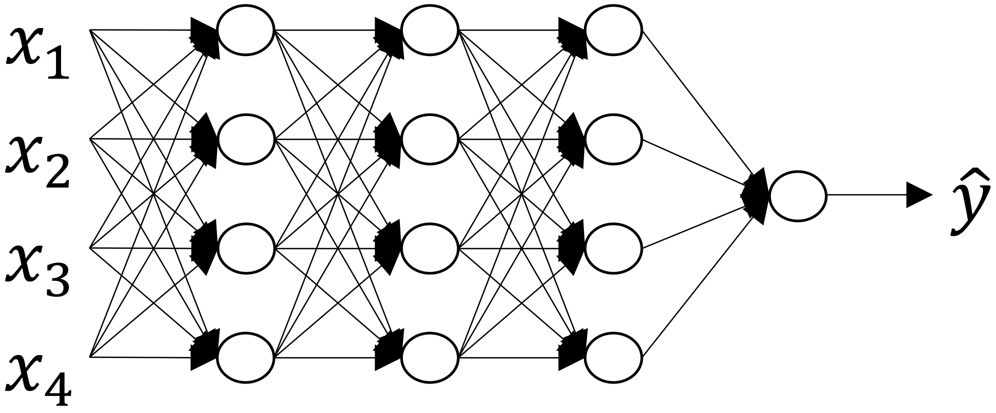
Building blocks of deep neural networks

Forward and backward functions



Forward and backward functions

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Deep Neural Networks

Forward and backward propagation

Forward propagation for layer *l*

Input $a^{[l-1]}$

Output $a^{[l]}$, cache $(z^{[l]})$

Backward propagation for layer *l*

Input $da^{[l]}$

Output $da^{[l-1]}, dW^{[l]}, db^{[l]}$

Summary