Intro to Neural Networks

Data Science Immersive

Henry Cham

FLATIRON SCHOOL

Quote:

AI is the new electricity. Just as electricity transformed almost everything 100 years ago, today I actually have a hard time thinking of an industry that I don’t think AI will transform in the next several years.

-Andrew Ng

Question:

What are some current use cases for neural networks?

Current use cases:

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

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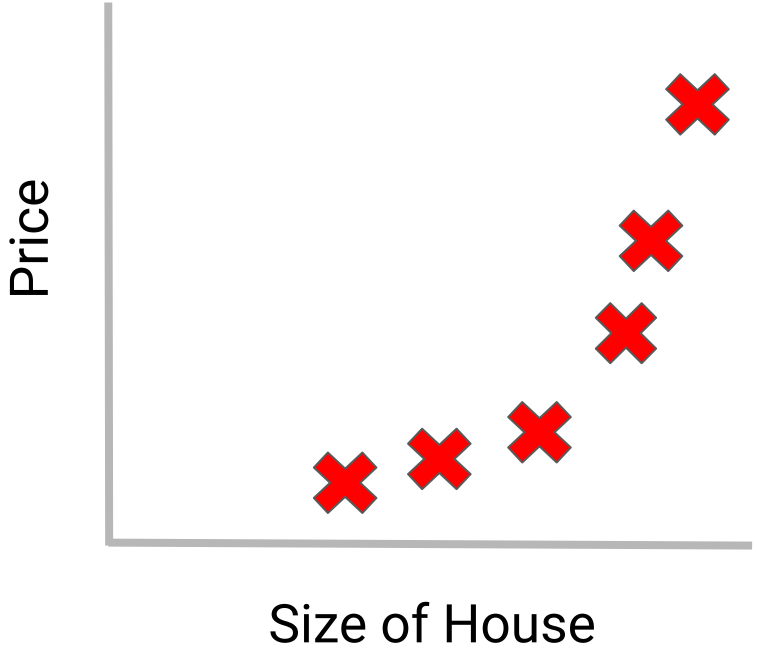
Aims:

- Examine the intuition of why neural networks can solve complex problems
- Explain the mathematics operations underlying how artificial neurons predict and learn

Why do neural networks work?

Predicting House Price



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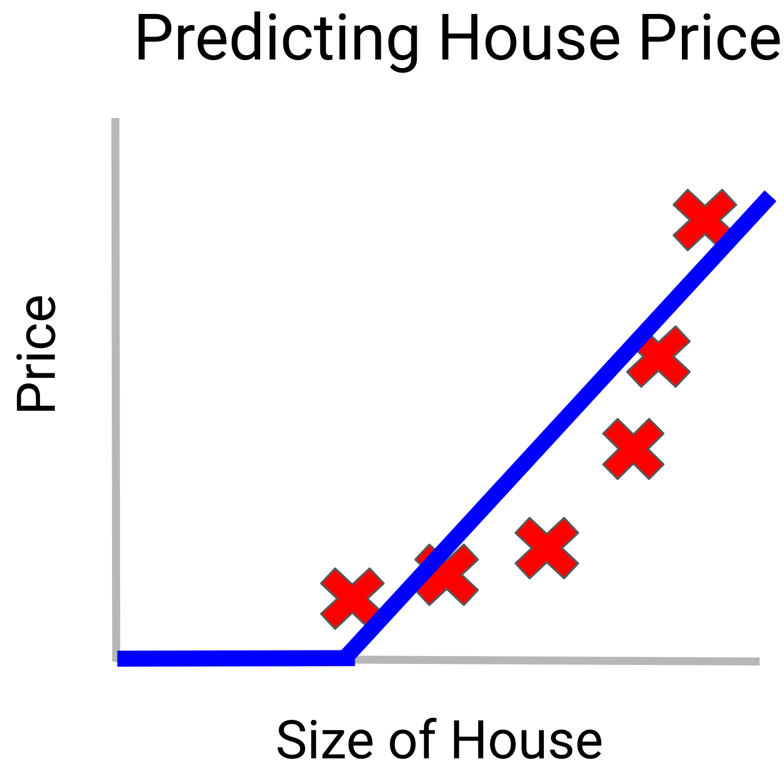

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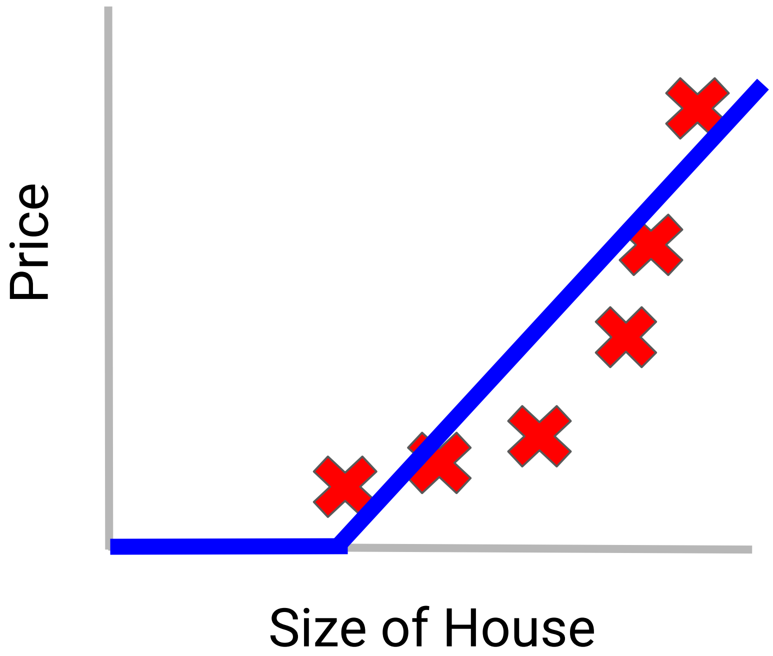
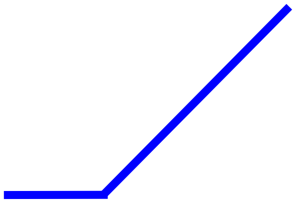
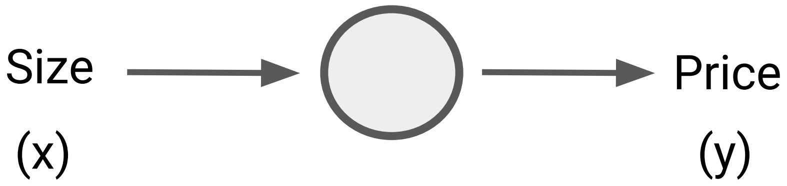


Rectified Linear (Relu)



Neuron



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Why do neural networks work?

Predicting House Price

size

# of bedrooms

zip code

wealth

(x)

price

(y)

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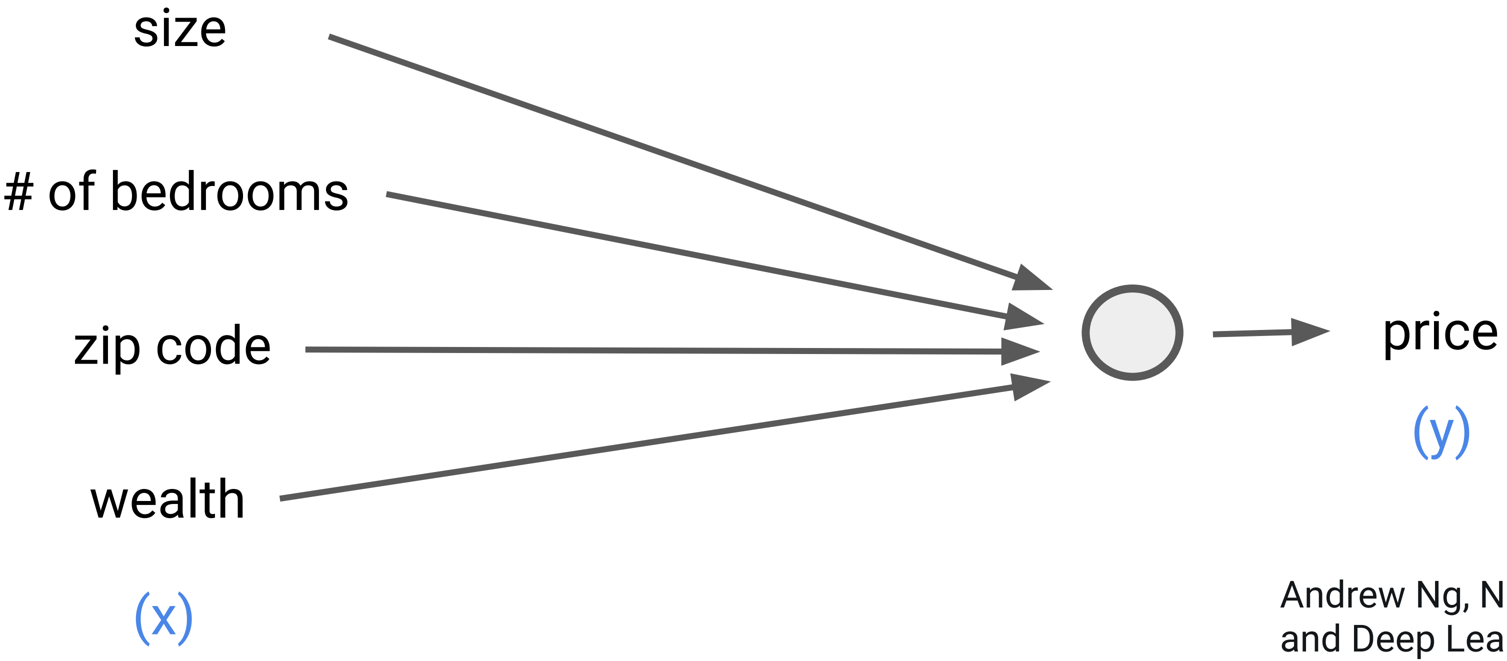
Why do neural networks work?

Predicting House Price



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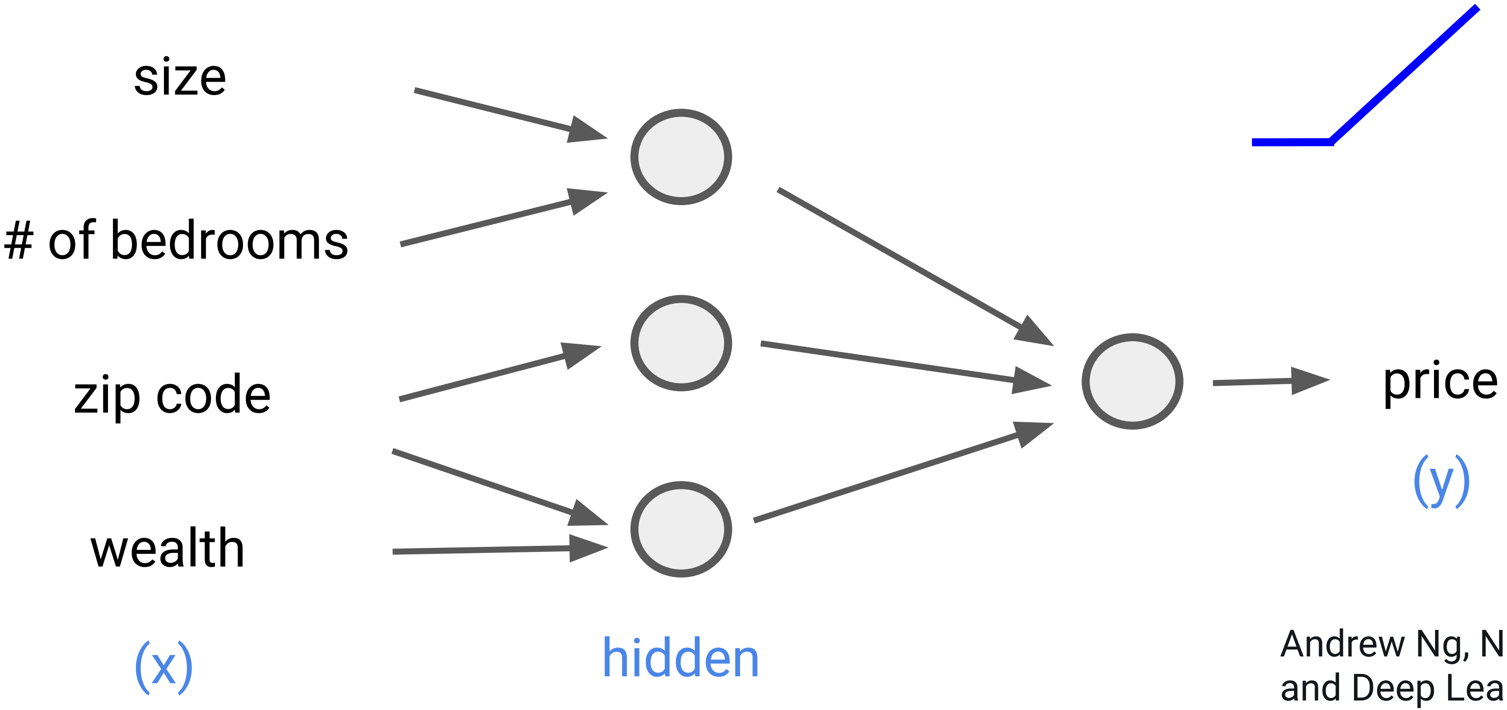

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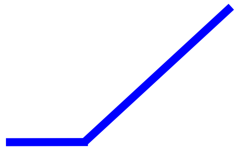
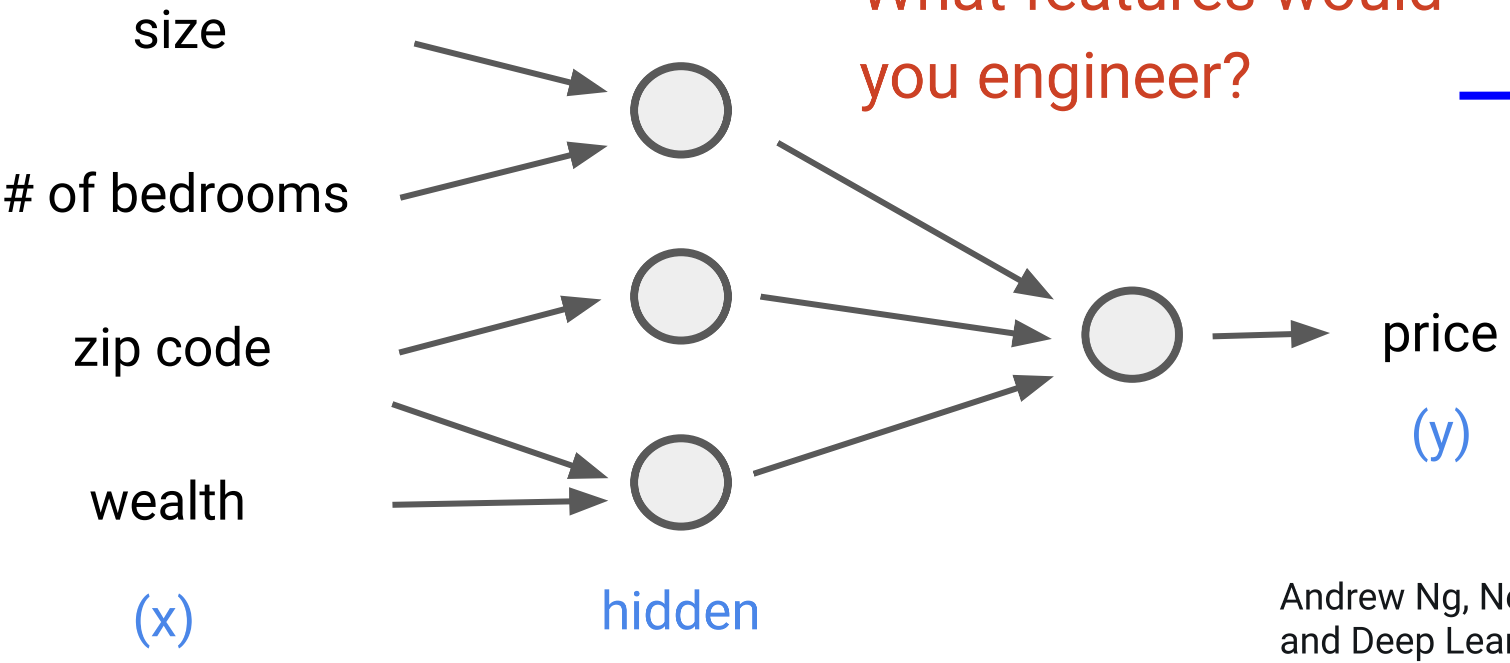


What features would you engineer?



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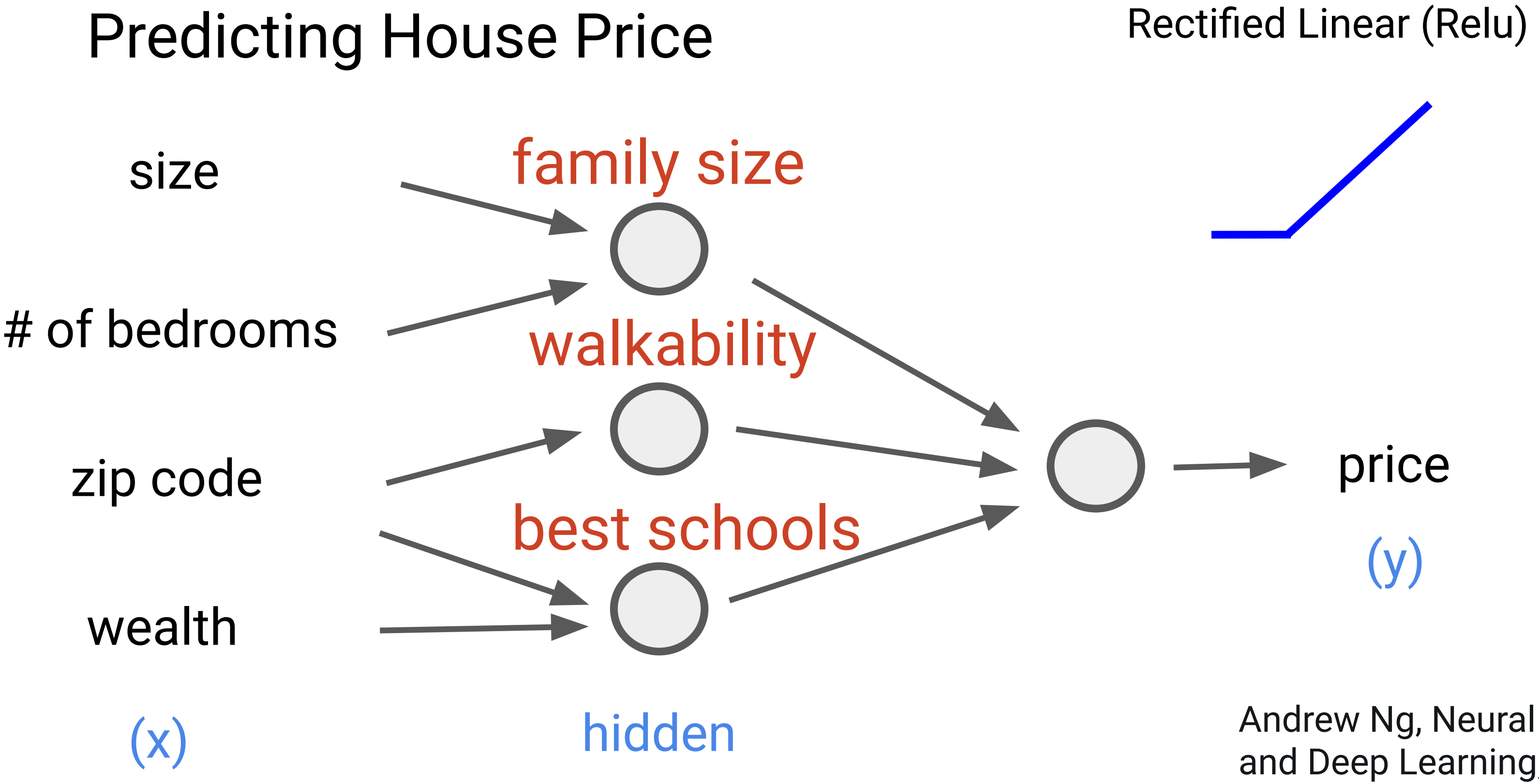

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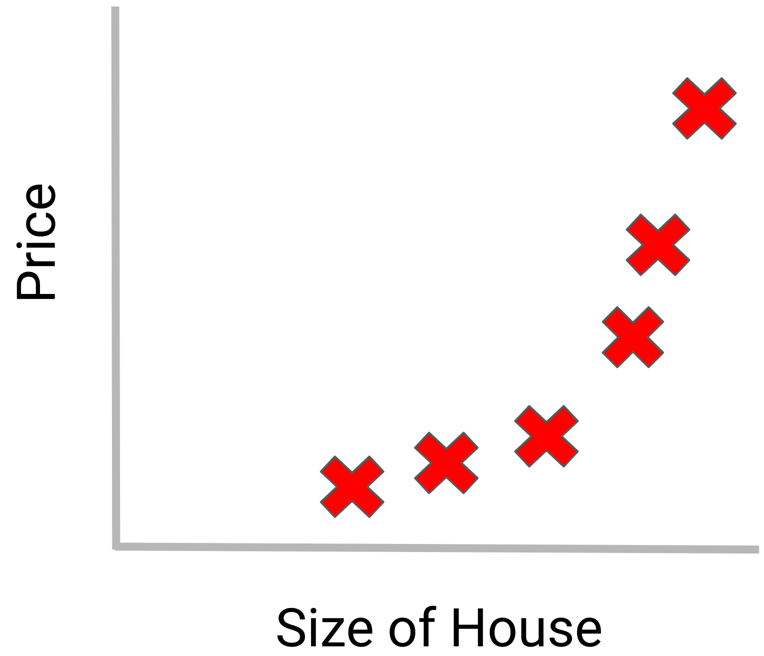

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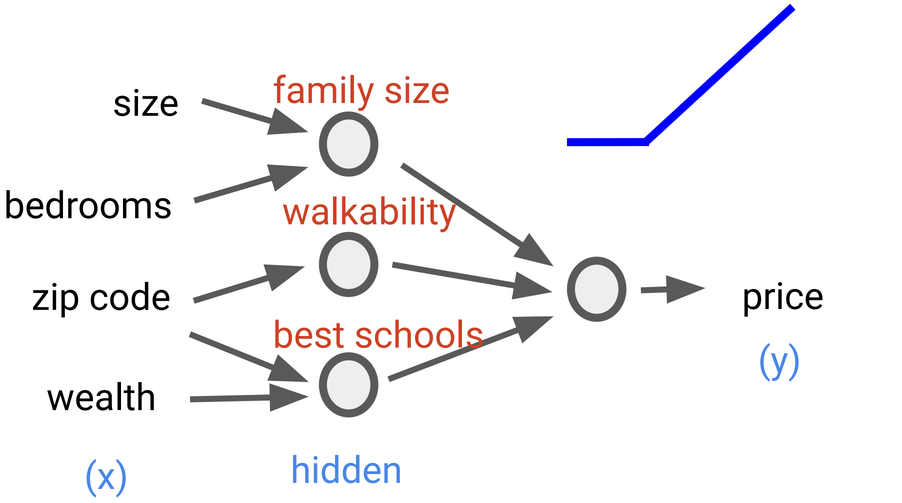

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Why do neural networks work?

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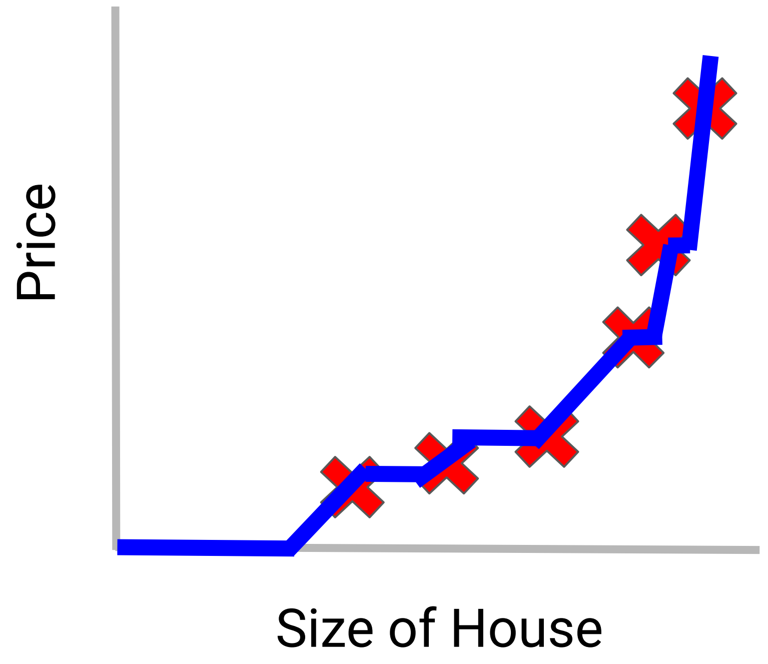

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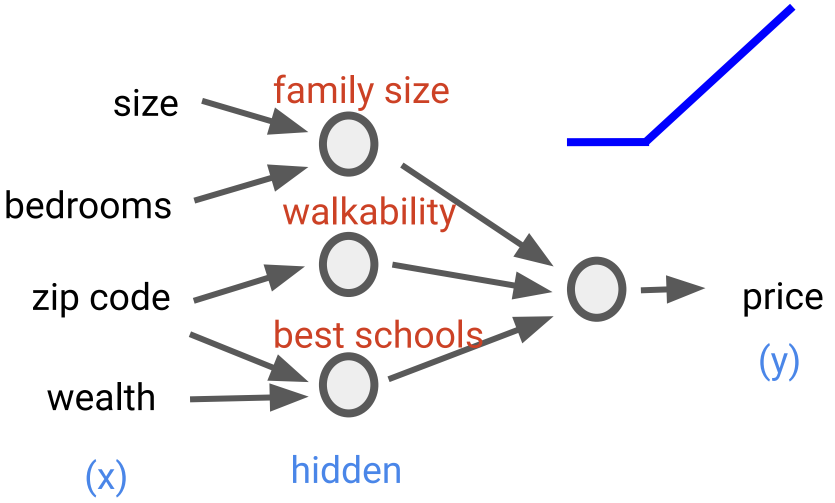

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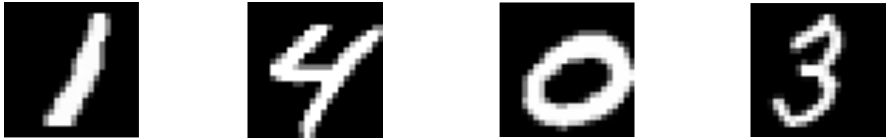
What do hidden layers capture?

MNIST

Input



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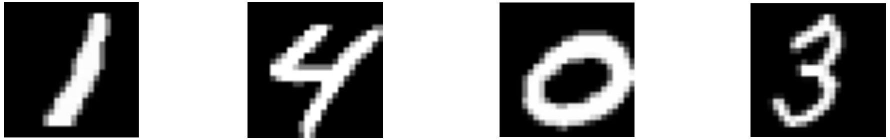
MNIST

Input



What do the hidden layers of a network train on MNIST data capture?

What do hidden layers capture?

MNIST

Input

Hidden Neuron

A

What do hidden layers capture?

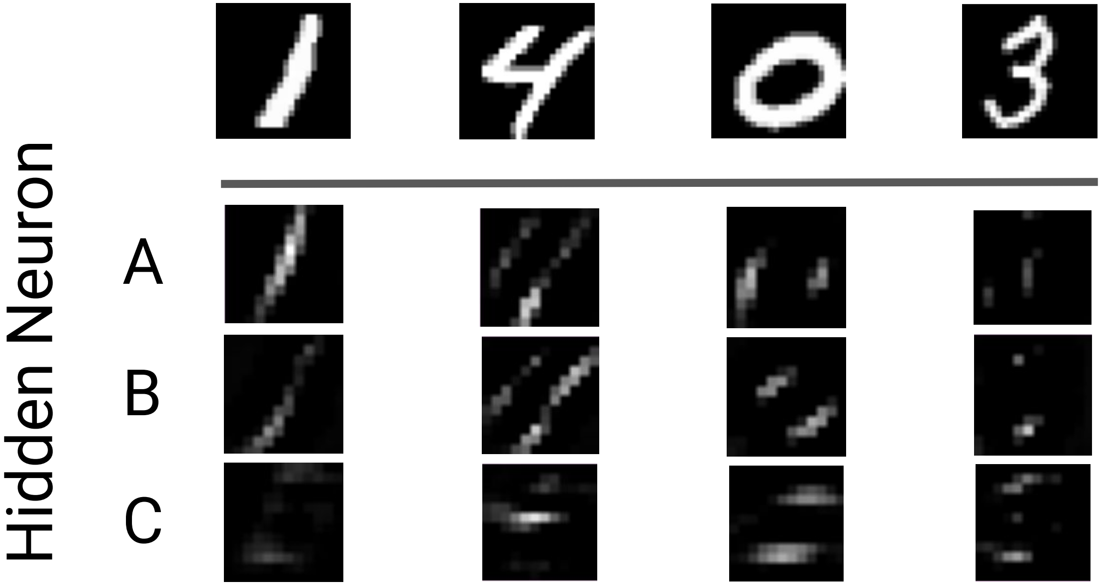
MNIST

Input

What do hidden layers capture?

MNIST

Input



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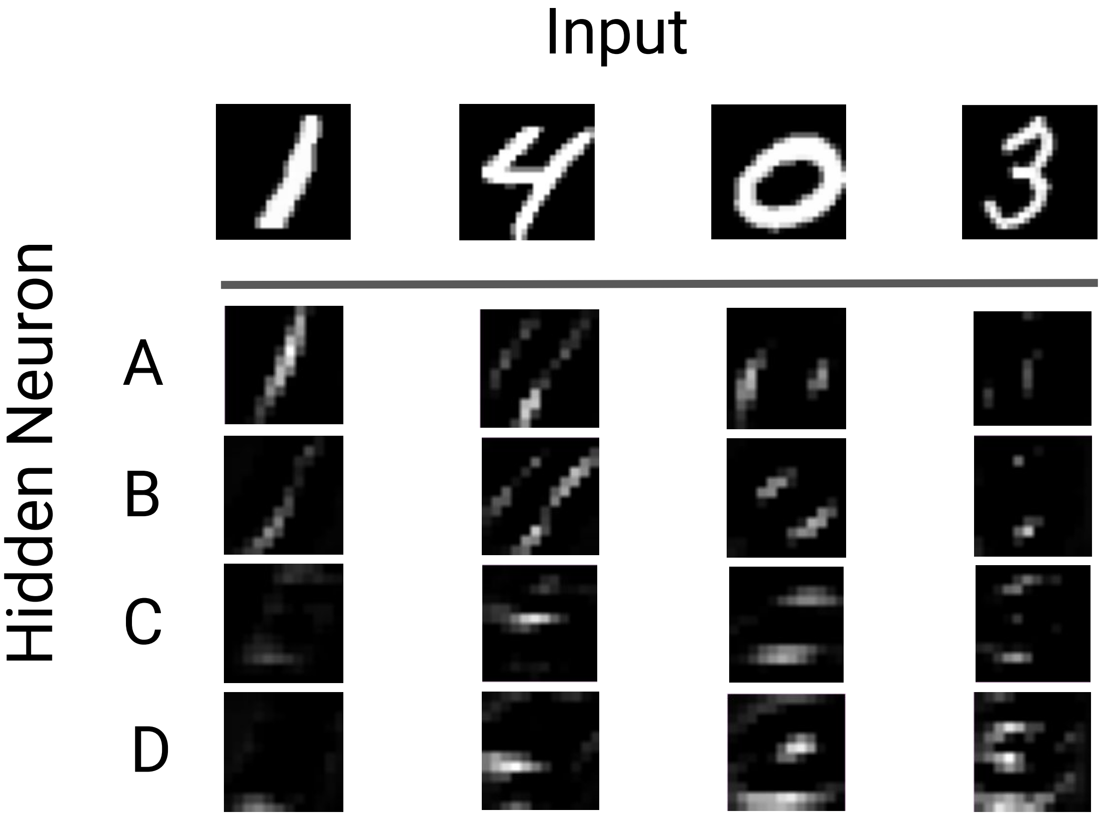
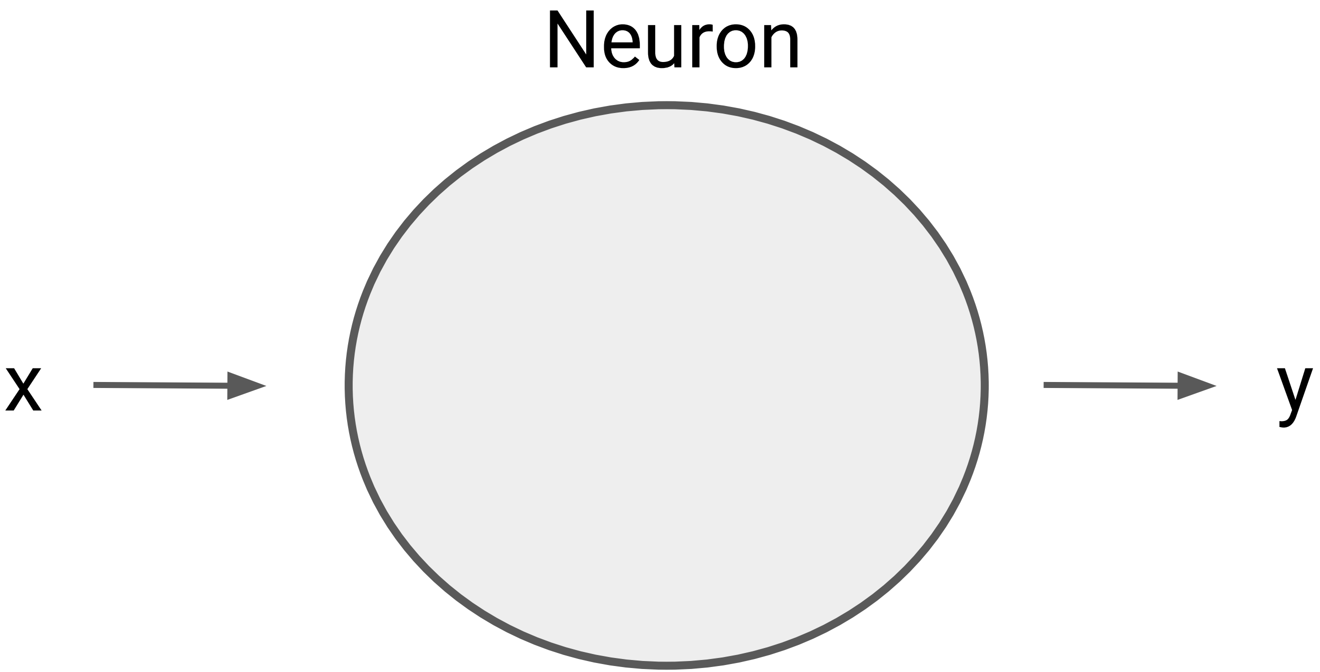
MNIST



Simple Neural Network



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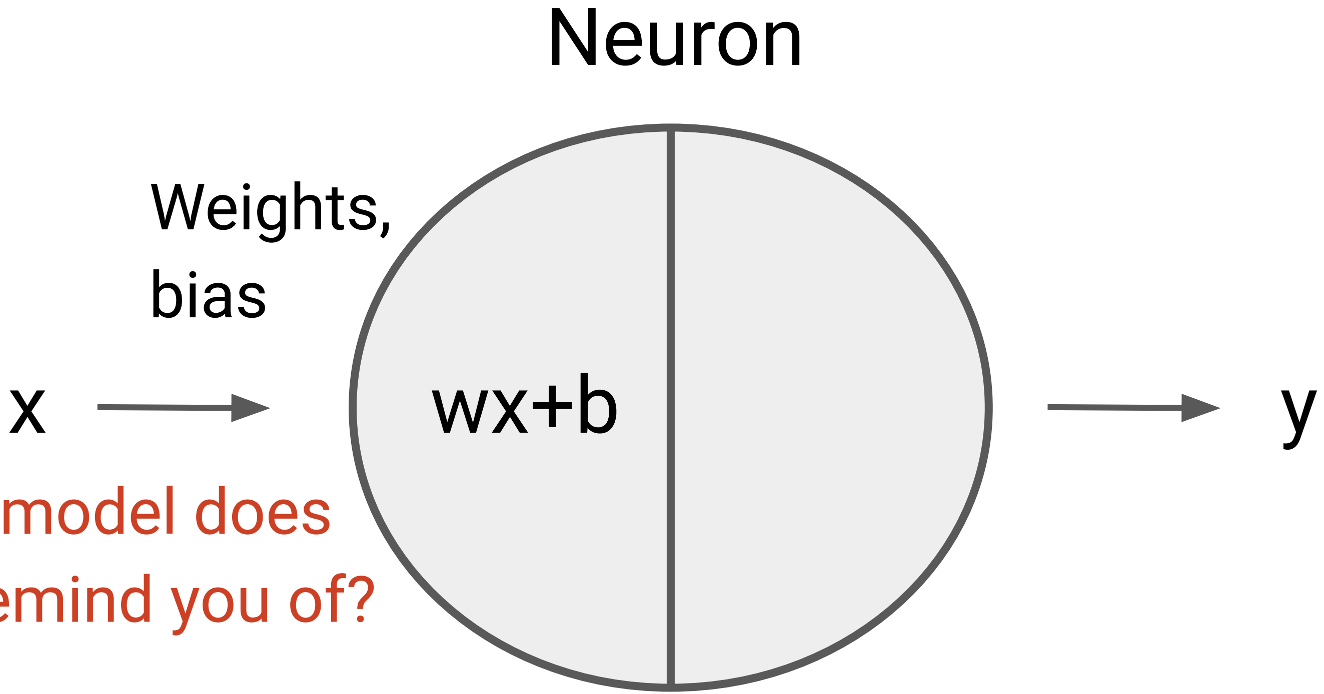

What model does this remind you of?

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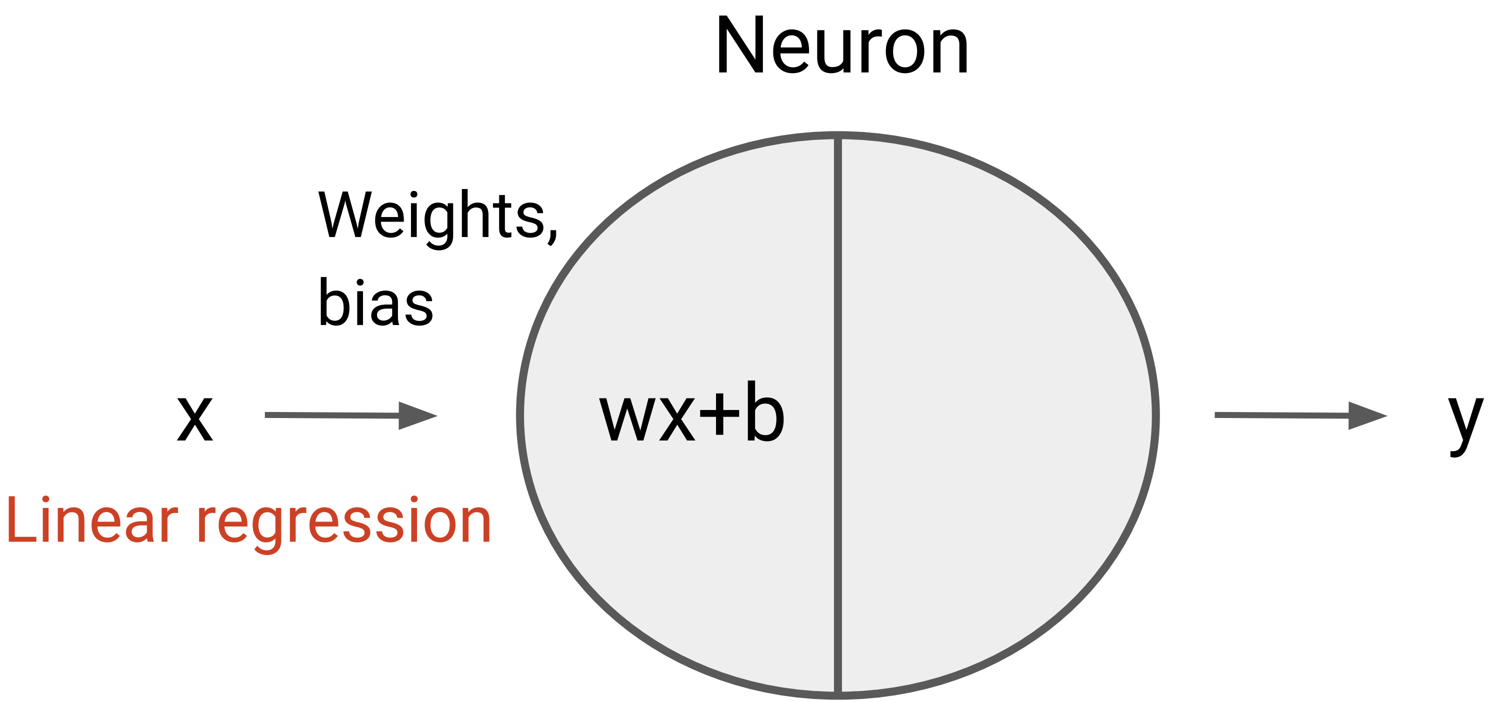
Simple Neural Network



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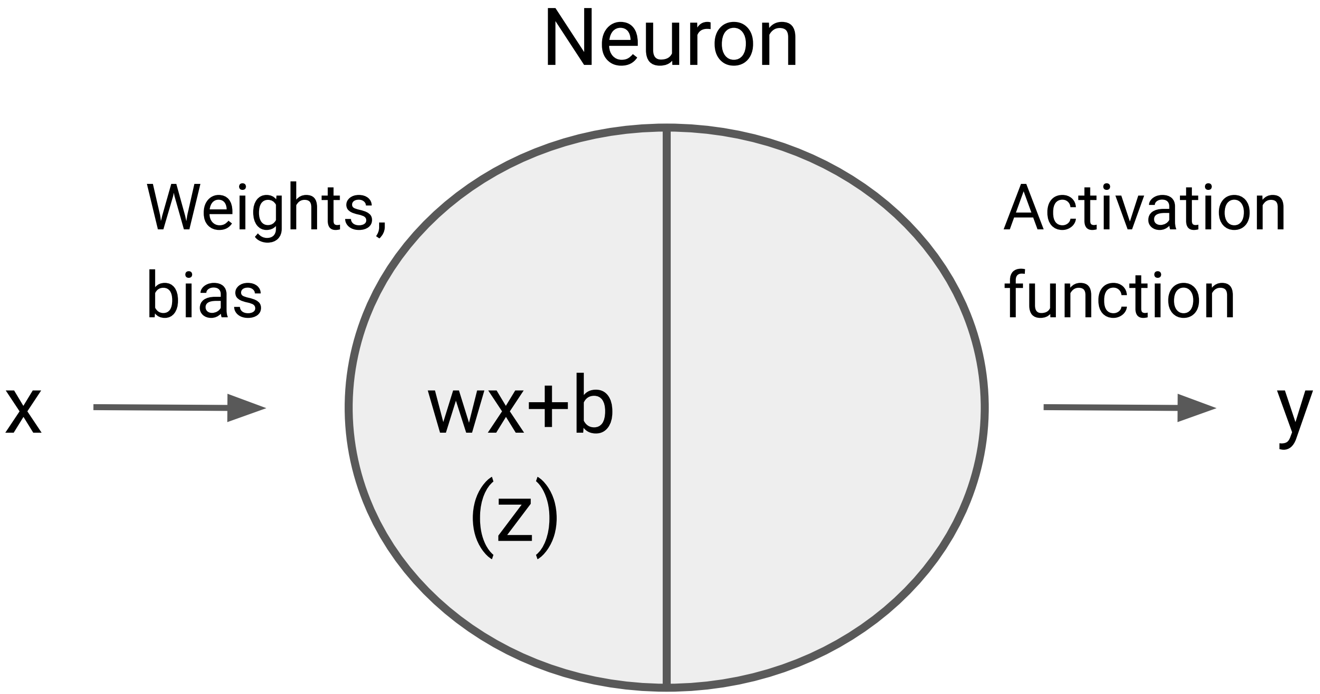
Simple Neural Network



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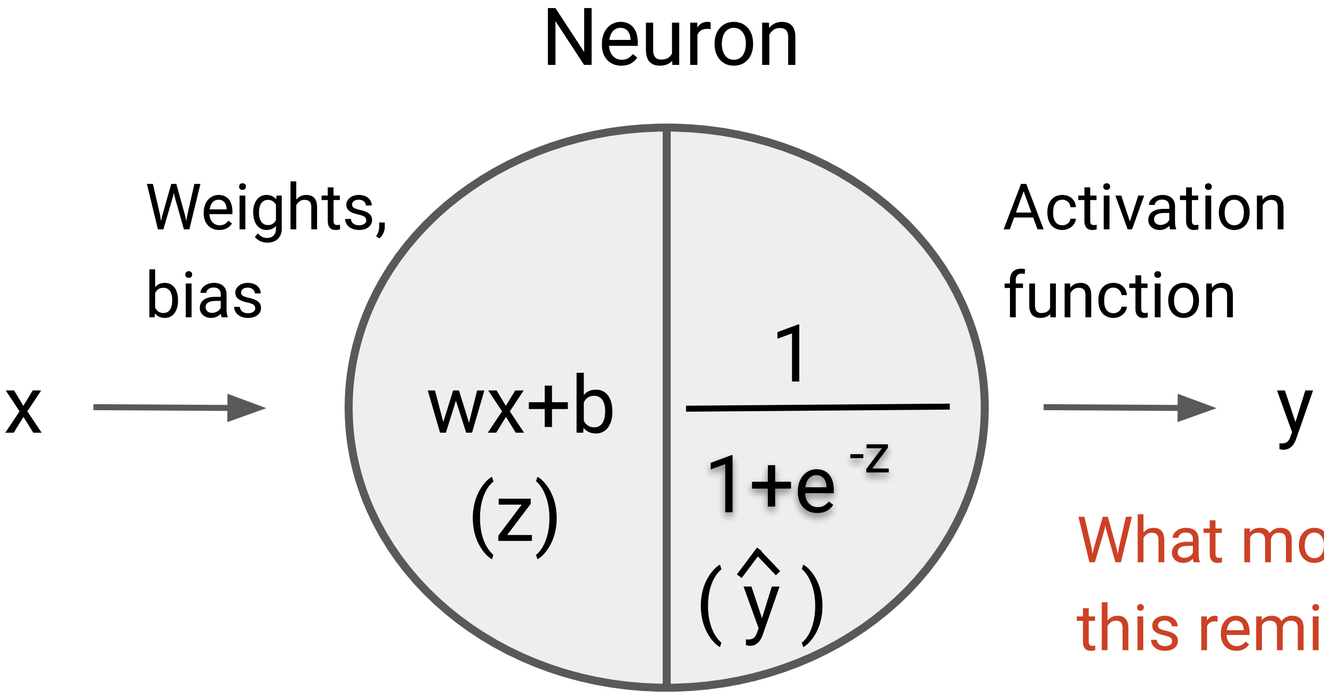

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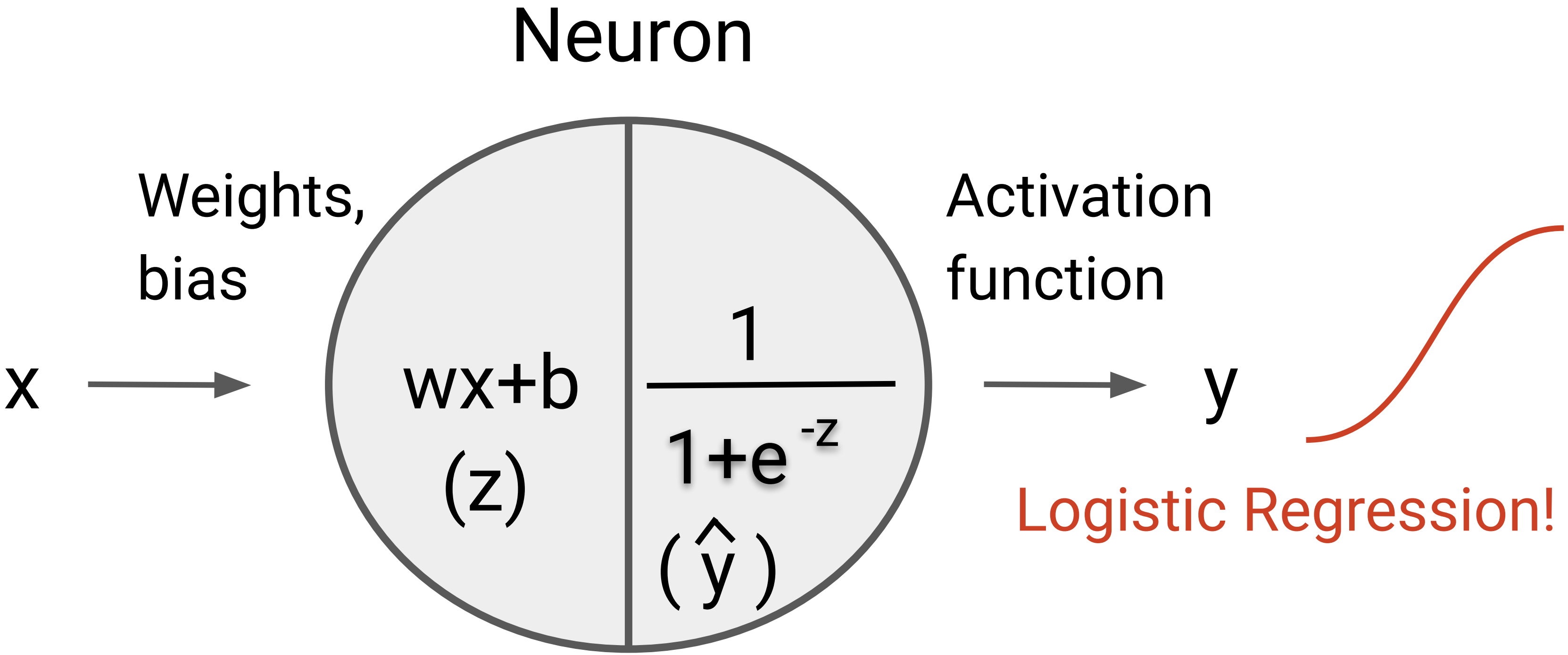

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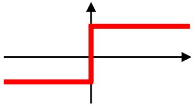
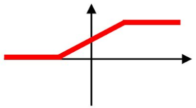
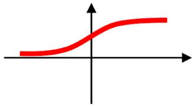
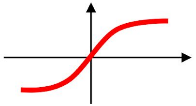
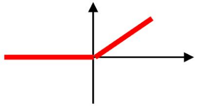
Neural Network Activation Functions

What are some good activation functions for neural networks?

Neural Network Activation Functions

Activation function	Equation	Example	1D Graph
Sign (Signum)	$\phi(z) = \begin{cases} -1, & z < 0, \\ 0, & z = 0, \\ 1, & z > 0, \end{cases}$	Perceptron variant	
Piece-wise linear	$\phi(z) = \begin{cases} 1, & z \geq \frac{1}{2}, \\ z + \frac{1}{2}, & -\frac{1}{2} < z < \frac{1}{2}, \\ 0, & z \leq -\frac{1}{2}, \end{cases}$	Support vector machine	
Logistic (sigmoid)	$\phi(z) = \frac{1}{1 + e^{-z}}$	Logistic regression, Multi-layer NN	
Hyperbolic tangent	$\phi(z) = \frac{e^{z} - e^{-z}}{e^{z} + e^{-z}}$	Multi-layer Neural Networks	
Rectifier, ReLU (Rectified Linear Unit)	$\phi(z) = max(0, z)$	Multi-layer Neural Networks	

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Neural Network Forward Pass

Simple logistic network to predict the quality of wine

alcohol	weight bias	activation	Good wine
x	$z=wx+b$	$\hat{y}=\dfrac{1}{1+e^{-z}}$	y

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x	$z=wx+b$	$\hat{y}=\dfrac{1}{1+e^{-z}}$	y
$x=.12$	$w=15$, $b=-.4$ random initial values	Find $\hat{y}$	

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x	$z=wx+b$	$\hat{y}=\frac{1}{1+e^{-z}}$	y
$x=.12$	$w=15, b=-.4$	$\hat{y}=.80$	
	random initial values		

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x	$z=wx+b$	$\hat{y}=\frac{1}{1+e^{-z}}$	y
$x=.12$	$w=15, b=-.4$ random initial values	$\hat{y}=.80$	If $y = 1$, what was the error in the predict?

Logistic error function

Predicted ($\hat{y}$)	Real (y)	error	Squared error
.01	1	.99	.980
.001	1	.999	.998

Logistic error function

Predicted ($\hat{y}$)	Real (y)	error	Squared error	Negative Log error
.01	1	.99	.980	4.6
.001	1	.99	.998	6.9

$$J = \begin{cases} -\ln(\hat{y}) & \text{if } y = 1 \\ -\ln(1 - \hat{y}) & \text{if } y = 0 \end{cases}$$

J is the logistic regression loss (error)

Neural Network Loss Minimization

Simple logistic network to predict the quality of wine

alcohol	weight bias	activation	Good wine	Loss
x	$z=wx+b$	$\hat{y}=\frac{1}{1+e^{-z}}$	y	J
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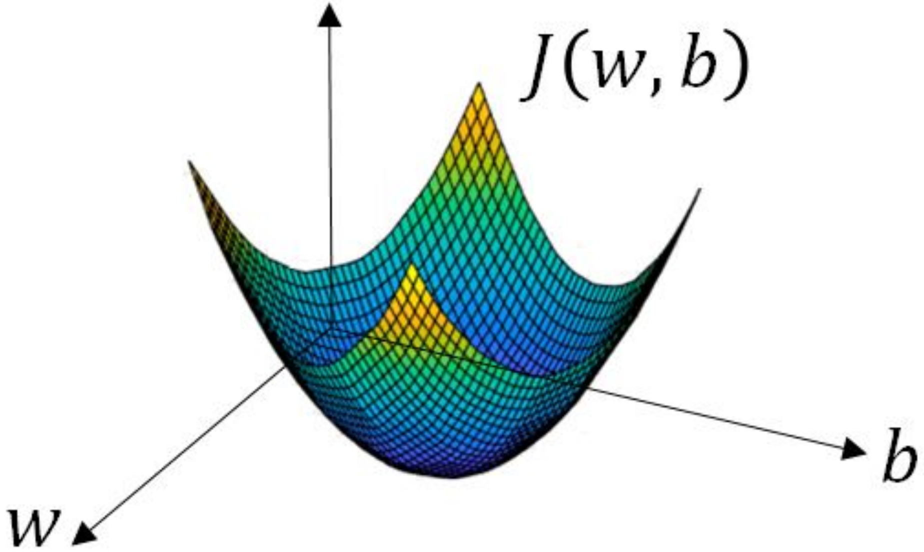
How should we change *w* and *b* to minimize the error?

Neural Network Gradient Descent

We can find the *w* and *b* that minimizes the error using gradient descent.



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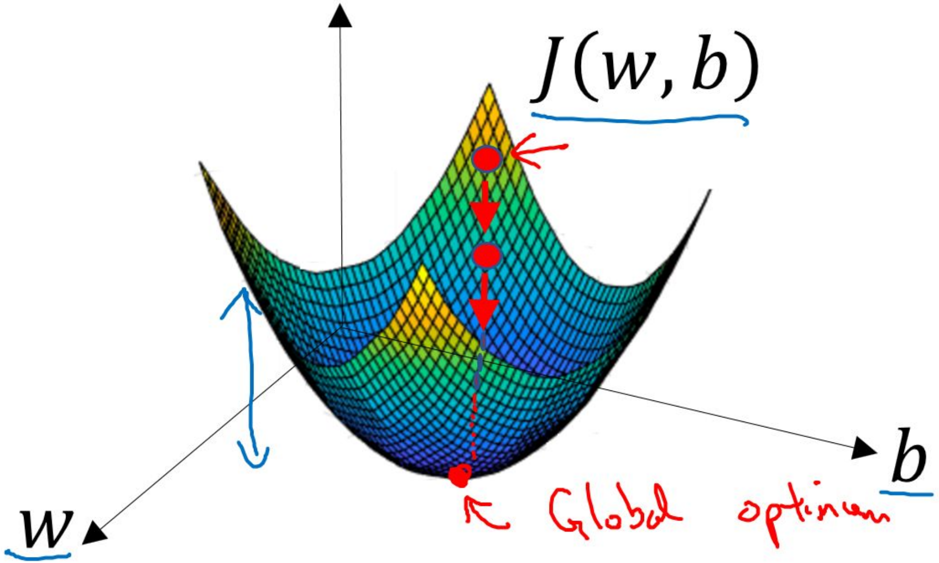

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Neural Network Gradient Descent

Simple logistic network to predict the quality of wine

alcohol	weight bias	activation	Good wine	Loss
x	$z = wx + b$	$\hat{y} = \frac{1}{1+e^{-z}}$	y	J
$x = .12$	$w = 15$, $b = -.4$	$\hat{y} = .80$	$y = 1$	$J = 1.6$

How do we calculate how changing *w* and *b* affects the error?

Neural Network Gradient Descent

Simple logistic network to predict the quality of wine

alcohol	weight bias	activation	Good wine	Loss
x	$z=wx+b$	$\hat{y}=\frac{1}{1+e^{-z}}$	y	J
$x=.12$	$w=15$, $b=-.4$	$\hat{y}=.80$	$y=1$	$J=1.6$

$$\frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

Neural Network Gradient Descent

Simple logistic network to predict the quality of wine

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$x=.12$	$w=15$, $b=-.4$	$\hat{y}=.80$	$y=1$	$J=1.6$

$$\frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}$$

$$\frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

Neural Network Gradient Descent

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$$\frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\hat{y}(1-\hat{y}) \qquad \frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

Neural Network Gradient Descent

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$$\frac{dJ}{dw}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}\frac{dz}{dw} \qquad \frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\hat{y}(1-\hat{y}) \qquad \frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

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$x=.12$	$w=15$, $b=-.4$	$\hat{y}=.80$	$y=1$	$J=1.6$

$$\frac{dJ}{dw}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}x \qquad \frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\hat{y}(1-\hat{y}) \qquad \frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

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$x=.12$	$w=15, b=-.4$	$\hat{y}=.80$	$y=1$	$J=1.6$

$$\frac{dJ}{db}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}\frac{dz}{db} \qquad \frac{dJ}{dw}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}x$$

$$\frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\hat{y}(1-\hat{y}) \qquad \frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

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$$\frac{dJ}{db}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}1 \qquad \frac{dJ}{dw}=\frac{dJ}{d\hat{y}}\frac{d\hat{y}}{dz}x \qquad \frac{dJ}{dz}=\frac{dJ}{d\hat{y}}\hat{y}(1-\hat{y}) \qquad \frac{dJ}{d\hat{y}}=-\frac{1}{\hat{y}}$$

Neural Network Gradient Descent

Simple logistic network to predict the quality of wine

alcohol	weight bias	activation	Good wine	Loss
x	$z=wx+b$	$\hat{y}=\frac{1}{1+e^{-z}}$	y	J
$x=.12$	$w=15,\ b=-.4$	$\hat{y}=.80$	$y=1$	$J=1.6$

$\frac{dJ}{db}=-.2$ $\frac{dJ}{dw}=-.024$ $\frac{dJ}{dz}=-.2$ $\frac{dJ}{d\hat{y}}=-1.25$

Neural Network Gradient Descent

old weight bias

$w=15, b=-.4$

gradients

$$\frac{dJ}{db}=-.2 \qquad \frac{dJ}{dw}=-.024$$

update rule

$$w := w - \alpha \frac{dJ}{dw} \qquad b := b - \alpha \frac{dJ}{db}$$

α is the learning rate

Neural Network Gradient Descent

old weight bias

$w=15,\ b=-.4$

gradients

$$\frac{dJ}{db} = -.2 \qquad \frac{dJ}{dw} = -.024$$

update rule

$$w := w - \alpha \frac{dJ}{dw} \qquad b := b - \alpha \frac{dJ}{db}$$

α is the learning rate

If $\alpha = .1$, what is the new *w* and *b*?

Neural Network Gradient Descent

old weight bias

$w=15, b=-.4$

gradients

$\frac{dJ}{db}=-.2 \quad \frac{dJ}{dw}=-.024$

update rule

$w:= w - \alpha \frac{dJ}{dw} \qquad b:= b - \alpha \frac{dJ}{db}$

α is the learning rate

new weight bias

$w=14.9976, b=-.38$

Summary

- Neural networks create advanced features to make predictions
- A forward pass of a neural network require weight, bias, and an activation function
- Neural networks minimizes the error in the prediction by using gradient descent to change the weights and biases