

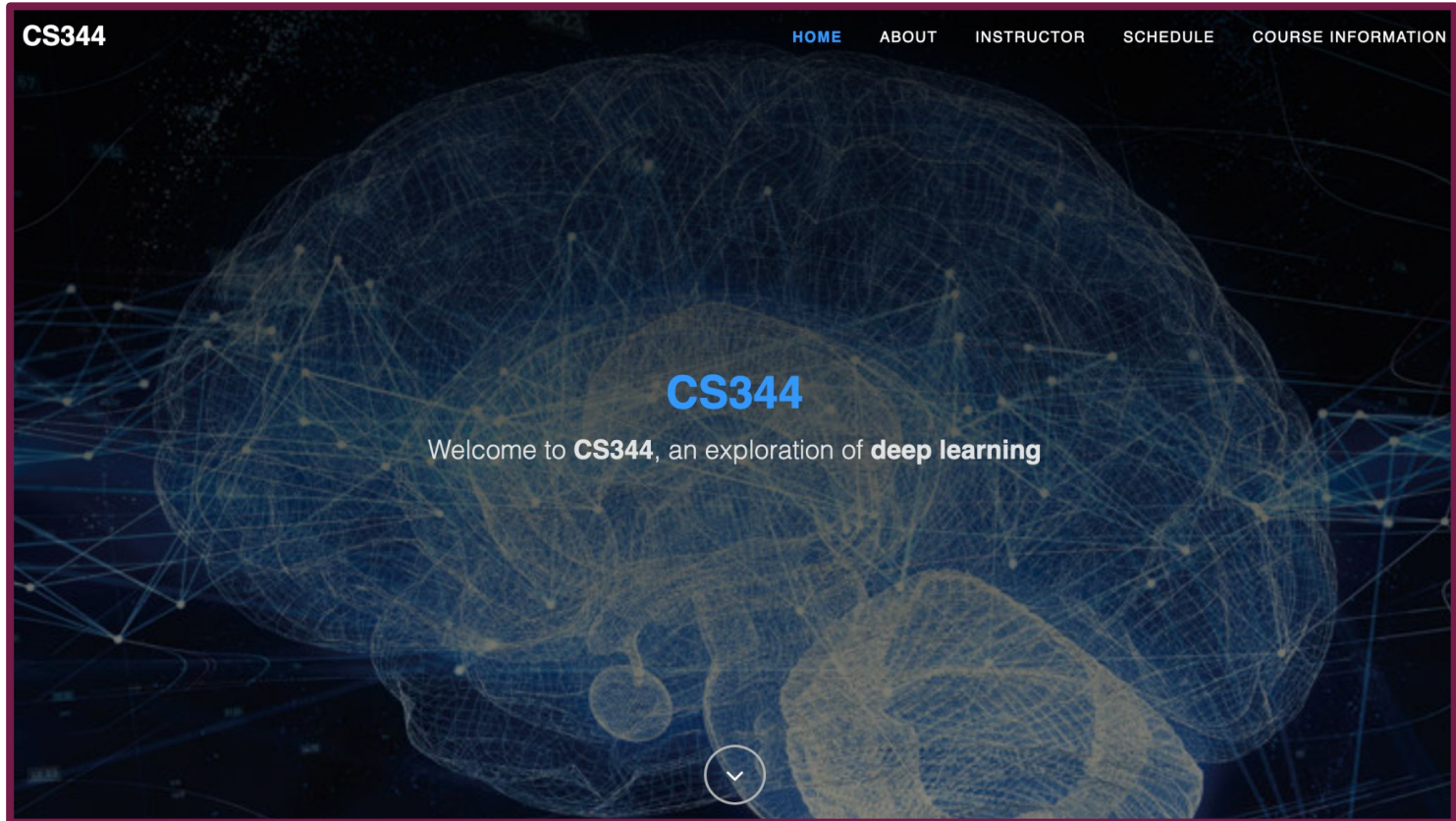
Machine Learning Fundamentals



CS344
Deep Learning



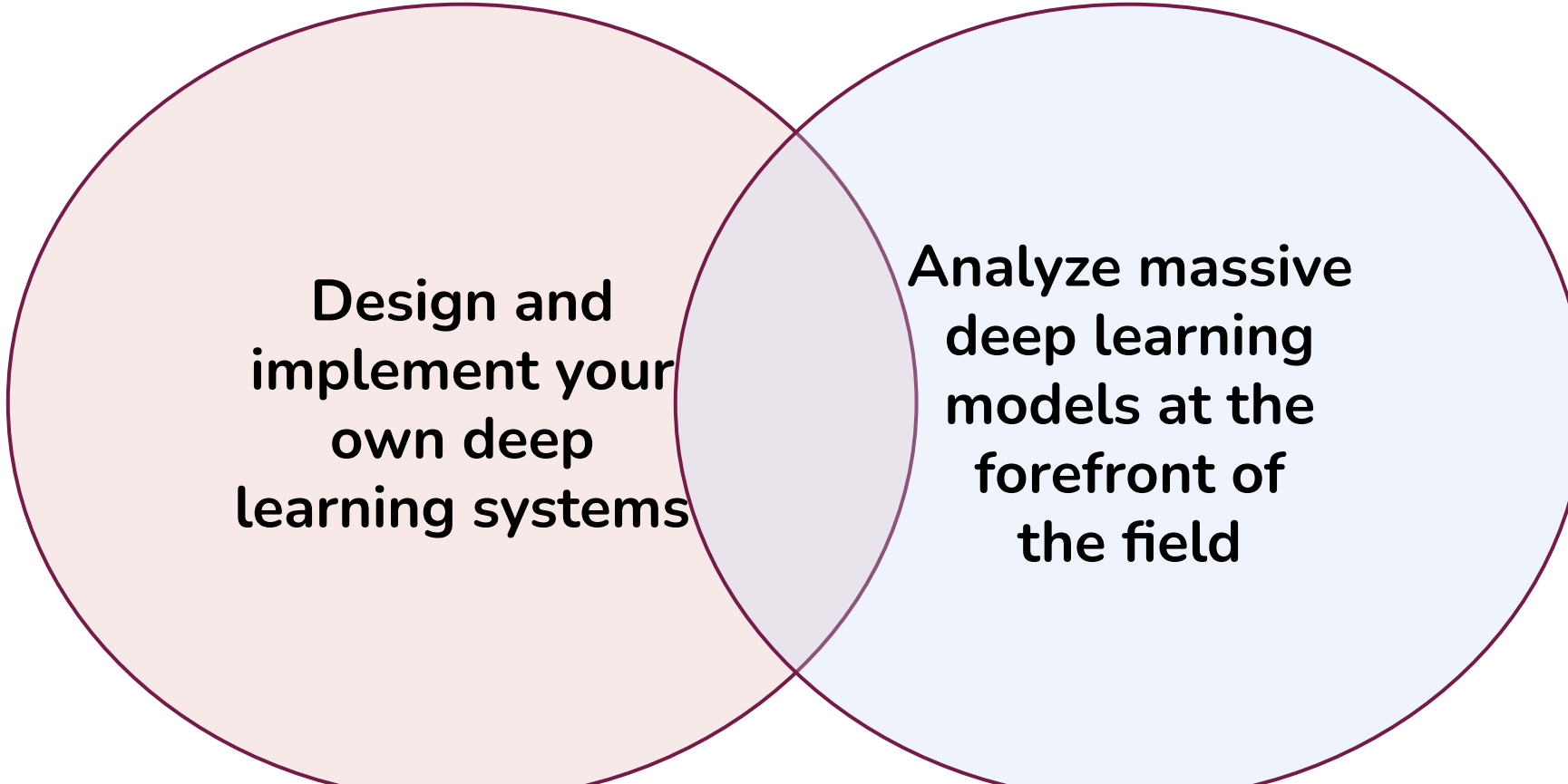
Course Information



Deep Learning

- ❖ Deep learning is a subfield of machine learning (ML)
- ❖ Deep learning is about how computers can learn from data
- ❖ Deep learning is inspired by neural connections in the brain
- ❖ Deep learning uses artificial neural networks (NNs)

CS 344



**Design and
implement your
own deep
learning systems**

**Analyze massive
deep learning
models at the
forefront of
the field**

Common Problems ML May Help Solve

BINARY CLASSIFICATION

Predicting 2 categorical outcomes

Email is spam or not

Someone has a disease or not

MULTICLASS CLASSIFICATION

Predicting >2 categorical outcomes

Song is pop, rap, or country

Flower is daisy, rose, sunflower, or tulip

REGRESSION

Predicting a continuous outcome

Stock price

Hours of sleep per night

Amazoogole and Applesoft are hiring!



Receive thousands of applications

Which few applicants should they contact for interviews?

Use deep learning to scan applications (résumé and cover letter) and extract relevant information



Data

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	Yes	Cat	2.8	No	Yes
Alba	2	Yes	Dog	3.7	No	Yes
Brian	0	No	Cat	0.3	Yes	No
Zuri	5	Yes	Fish	3.9	No	Yes
Sarahi	9	No	Dog	4.0	No	Yes
Tao	8	No	Cat	3.2	No	No
Sakura	1	Yes	Dog	2.5	No	Yes

Binary Classification

Data

Features

Label

Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
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Lavina	6	Yes	Cat	2.8	No	Yes
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Alba	2	Yes	Dog	3.7	No	Yes
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Brian	0	No	Cat	0.3	Yes	No
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Zuri	5	Yes	Fish	3.9	No	Yes
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Sarahi	9	No	Dog	4.0	No	Yes
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Tao	8	No	Cat	3.2	No	No
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Sakura	1	Yes	Dog	2.5	No	Yes
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Featurize (Encode)

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	Yes	Cat	2.8	No	Yes
Alba	2	Yes	Dog	3.7	No	Yes
Brian	0	No	Cat	0.3	Yes	No
Zuri	5	Yes	Fish	3.9	No	Yes
Sarahi	9	No	Dog	4.0	No	Yes
Tao	8	No	Cat	3.2	No	No
Sakura	1	Yes	Dog	2.5	No	Yes

Featurize (Encode)

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	Cat	2.8	No	Yes
Alba	2	1	Dog	3.7	No	Yes
Brian	0	0	Cat	0.3	Yes	No
Zuri	5	1	Fish	3.9	No	Yes
Sarahi	9	0	Dog	4.0	No	Yes
Tao	8	0	Cat	3.2	No	No
Sakura	1	1	Dog	2.5	No	Yes

Featurize (Encode)

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	No	Yes
Alba	2	1	0	3.7	No	Yes
Brian	0	0	1	0.3	Yes	No
Zuri	5	1	2	3.9	No	Yes
Sarahi	9	0	0	4.0	No	Yes
Tao	8	0	1	3.2	No	No
Sakura	1	1	0	2.5	No	Yes

Featurize (Encode)

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	Yes
Alba	2	1	0	3.7	0	Yes
Brian	0	0	1	0.3	1	No
Zuri	5	1	2	3.9	0	Yes
Sarahi	9	0	0	4.0	0	Yes
Tao	8	0	1	3.2	0	No
Sakura	1	1	0	2.5	0	Yes

Featurize (Encode)

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

One-Hot Encoding

	Years Experience	Has			GPA	Embezzled	Interview	
		Required Skills	Dog	Cat				Fish
Lavina	6	1	0	1	0	2.8	0	1
Alba	2	1	1	0	0	3.7	0	1
Brian	0	0	0	1	0	0.3	1	0
Zuri	5	1	0	0	1	3.9	0	1
Sarahi	9	0	1	0	0	4.0	0	1
Tao	8	0	0	1	0	3.2	0	0
Sakura	1	1	1	0	0	2.5	0	1

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

x

y

Avoid bugs: print shape!

$X.shape = (m, d)$

$y.shape = (m, 1)$

	X					y
m	6	1	1	2.8	0	1
	2	1	0	3.7	0	1
	0	0	1	0.3	1	0
	5	1	2	3.9	0	1
	9	0	0	4.0	0	1
	8	0	1	3.2	0	0
	1	1	0	2.5	0	1

Siiri $\begin{bmatrix} 2 & 0 & 2 & 1.6 & 1 \end{bmatrix}$ Interview?

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

$b = -9.3$ $w_1 = 1.1$ $w_2 = 15.5$ $w_3 = 0.0$ $w_4 = 0.02$ $w_5 = -31.8$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled Interview

Lavina 6 1 1 2.8 0 1

Alba 2 1 0 3.7 0 1

Brian 0 0 1 0.3 1 0

Zuri 5 1 2 3.9 0 1

Sarahi 9 0 0 4.0 0 1

Tao 8 0 1 3.2 0 0

Sakura 1 1 0 2.5 0 1

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years
Experience Required
Skills Favorite Pet
(Dog/Cat/Fish) GPA Embezzled

$$-9.3 + 6 * 1.1 + 1 * 15.5 + 1 * 0.0 + 2.8 * 0.02 + 0 * -31.8 = 12.9$$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

$$6 \quad 1 \quad 1 \quad 2.8 \quad 0 \quad = 12.9$$

$$-9.3 \quad + \quad 2 * 1.1 \quad + \quad 1 * 15.5 \quad + \quad 0 * 0.0 \quad + \quad 3.7 * 0.02 + 0 * -31.8 \quad = 8.5$$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

$$6 \quad 1 \quad 1 \quad 2.8 \quad 0 \quad = 12.9$$

$$2 \quad 1 \quad 0 \quad 3.7 \quad 0 \quad = 8.5$$

$$-9.3 \quad + \quad 0 * 1.1 \quad + \quad 0 * 15.5 \quad + \quad 1 * 0.0 \quad + \quad 0.3 * 0.02 + 1 * -31.8 \quad = -41$$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

$$6 \quad 1 \quad 1 \quad 2.8 \quad 0 \quad = 12.9$$

$$2 \quad 1 \quad 0 \quad 3.7 \quad 0 \quad = 8.5$$

$$0 \quad 0 \quad 1 \quad 0.3 \quad 1 \quad = -41$$

$$-9.3 \quad + \quad 5 * 1.1 \quad + \quad 1 * 15.5 \quad + \quad 2 * 0.0 \quad + \quad 3.9 * 0.02 + 0 * -31.8 \quad = 11.8$$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

$$6 \quad 1 \quad 1 \quad 2.8 \quad 0 \quad = 12.9$$

$$2 \quad 1 \quad 0 \quad 3.7 \quad 0 \quad = 8.5$$

$$0 \quad 0 \quad 1 \quad 0.3 \quad 1 \quad = -41$$

$$5 \quad 1 \quad 2 \quad 3.9 \quad 0 \quad = 11.8$$

$$-9.3 \quad + \quad 9 * 1.1 \quad + \quad 0 * 15.5 \quad + \quad 0 * 0.0 \quad + \quad 4.0 * 0.02 + 0 * -31.8 \quad = 0.7$$

$b = -9.3$ $w_1 = 1.1$ $w_2 = 15.5$ $w_3 = 0.0$ $w_4 = 0.02$ $w_5 = -31.8$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

6 1 1 2.8 0 = 12.9

2 1 0 3.7 0 = 8.5

0 0 1 0.3 1 = -41

5 1 2 3.9 0 = 11.8

9 0 0 4.0 0 = 0.7

$-9.3 + 8 * 1.1 + 0 * 15.5 + 1 * 0.0 + 3.2 * 0.02 + 0 * -31.8 = -0.4$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years Experience Required Skills Favorite Pet (Dog/Cat/Fish) GPA Embezzled

$$6 \quad 1 \quad 1 \quad 2.8 \quad 0 \quad = 12.9$$

$$2 \quad 1 \quad 0 \quad 3.7 \quad 0 \quad = 8.5$$

$$0 \quad 0 \quad 1 \quad 0.3 \quad 1 \quad = -41$$

$$5 \quad 1 \quad 2 \quad 3.9 \quad 0 \quad = 11.8$$

$$9 \quad 0 \quad 0 \quad 4.0 \quad 0 \quad = 0.7$$

$$8 \quad 0 \quad 1 \quad 3.2 \quad 0 \quad = -0.4$$

$$-9.3 \quad + \quad 1 * 1.1 \quad + \quad 1 * 15.5 \quad + \quad 0 * 0.0 \quad + \quad 2.5 * 0.02 + 0 * -31.8 \quad = 7.4$$

$b = -9.3$

$w_1 = 1.1$

$w_2 = 15.5$

$w_3 = 0.0$

$w_4 = 0.02$

$w_5 = -31.8$

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	
	6	1	1	2.8	0	= 12.9
	2	1	0	3.7	0	= 8.5
	0	0	1	0.3	1	= -41
	5	1	2	3.9	0	= 11.8
	9	0	0	4.0	0	= 0.7
	8	0	1	3.2	0	= -0.4
	1	1	0	2.5	0	= 7.4

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

Has
Years
Experience Required
Skills Favorite Pet
(Dog/Cat/Fish) GPA Embezzled

$$-9.3 + 2 * 1.1 + 0 * 15.5 + 2 * 0.0 + 1.6 * 0.02 + 1 * -31.8 = -39$$

$$b = -9.3 \quad w_1 = 1.1 \quad w_2 = 15.5 \quad w_3 = 0.0 \quad w_4 = 0.02 \quad w_5 = -31.8$$

$$w = (1.1, 15.5, 0.0, 0.02, -31.8)$$

$$x = (2, 0, 2, 1.6, 1)$$

$$w \cdot x + b$$

Siiri	2	0	2	1.6	1
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If $w \cdot x + b > 0$, predict label of 1 (interview)

If $w \cdot x + b \leq 0$, predict label of 0 (no interview)

Training Data and Testing Data

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

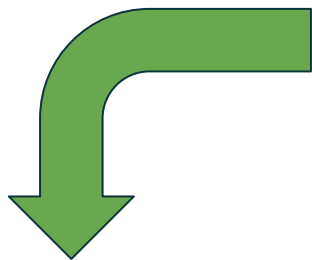
Training Data and Testing Data

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

X_{train} (rows 1-5) y_{train} (rows 1-5)

X_{test} (rows 6-7) y_{test} (rows 6-7)

Workflow



Featurize data

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

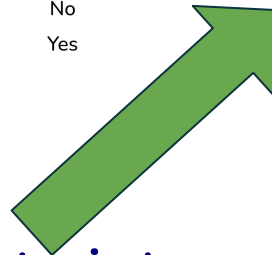


Load data

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	Yes	Cat	2.8	No	Yes
Alba	2	Yes	Dog	3.7	No	Yes
Brian	0	No	Cat	0.3	Yes	No
Zuri	5	Yes	Fish	3.9	No	Yes
Sarahi	9	No	Dog	4.0	No	Yes
Tao	8	No	Cat	3.2	No	No
Sakura	1	Yes	Dog	2.5	No	Yes

$$w = (1.1, 15.5, 0.0, 0.02, -31.8)$$

$$b = -9.3$$

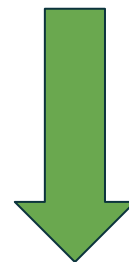


Split data into training and testing

	Years Experience	Has Required Skills	Favorite Pet (Dog/Cat/Fish)	GPA	Embezzled	Interview
Lavina	6	1	1	2.8	0	1
Alba	2	1	0	3.7	0	1
Brian	0	0	1	0.3	1	0
Zuri	5	1	2	3.9	0	1
Sarahi	9	0	0	4.0	0	1
Tao	8	0	1	3.2	0	0
Sakura	1	1	0	2.5	0	1

X_{train} (rows 1-5) and y_{train} (rows 1-5) are grouped together. X_{test} (rows 6-7) and y_{test} (rows 6-7) are grouped together.

Fit model on training data to learn parameters



Once all

parameters have been finalized, evaluate model's performance when making predictions on testing data

Accuracy: 81%