

Machine Learning Foundations - Part 2

- by **Nagaraju Budigam**

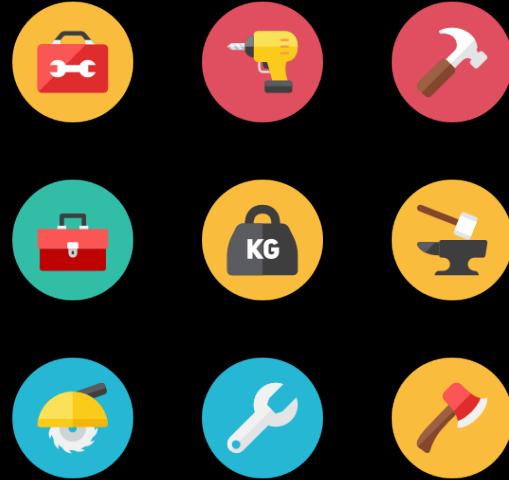
Learning Goals

- ❑ Model Training
- ❑ Model Testing
- ❑ Evaluation Metrics

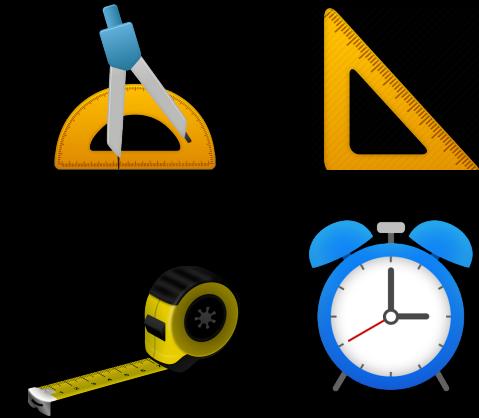
Model Building - Overview



Problem



Algorithms



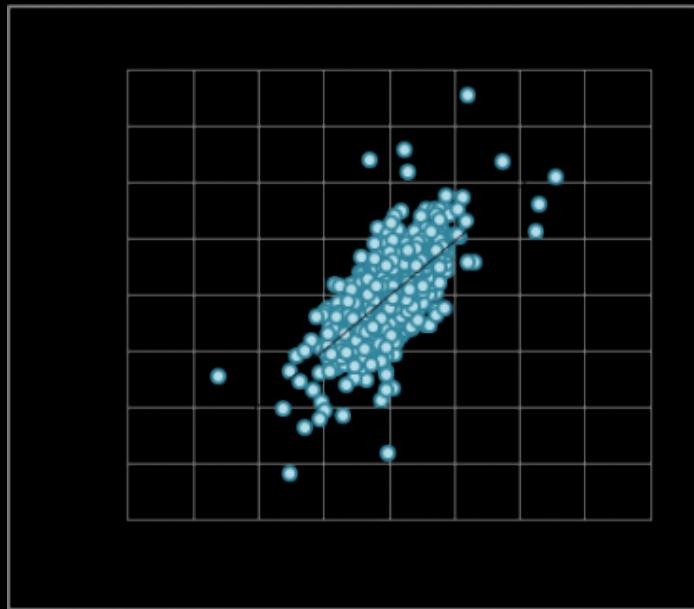
Evaluation Metrics

Supervised Learning – Types of Problems

Regression

vs

Classification

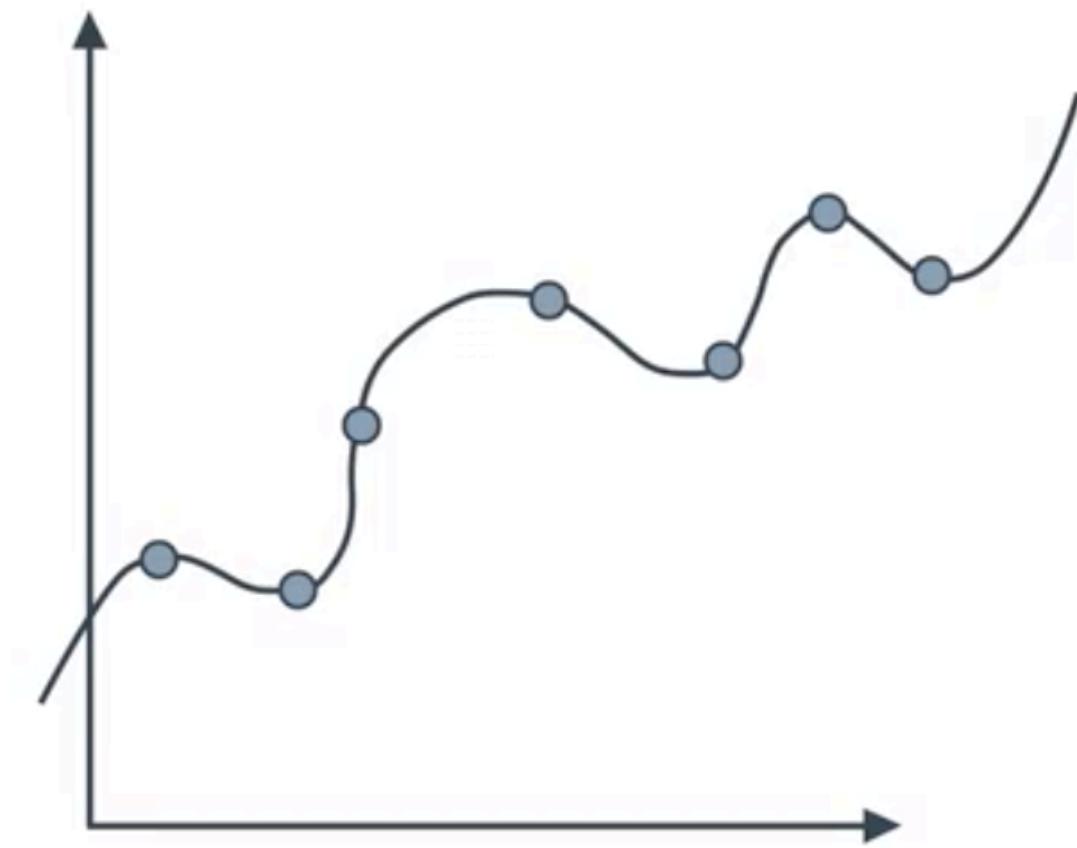
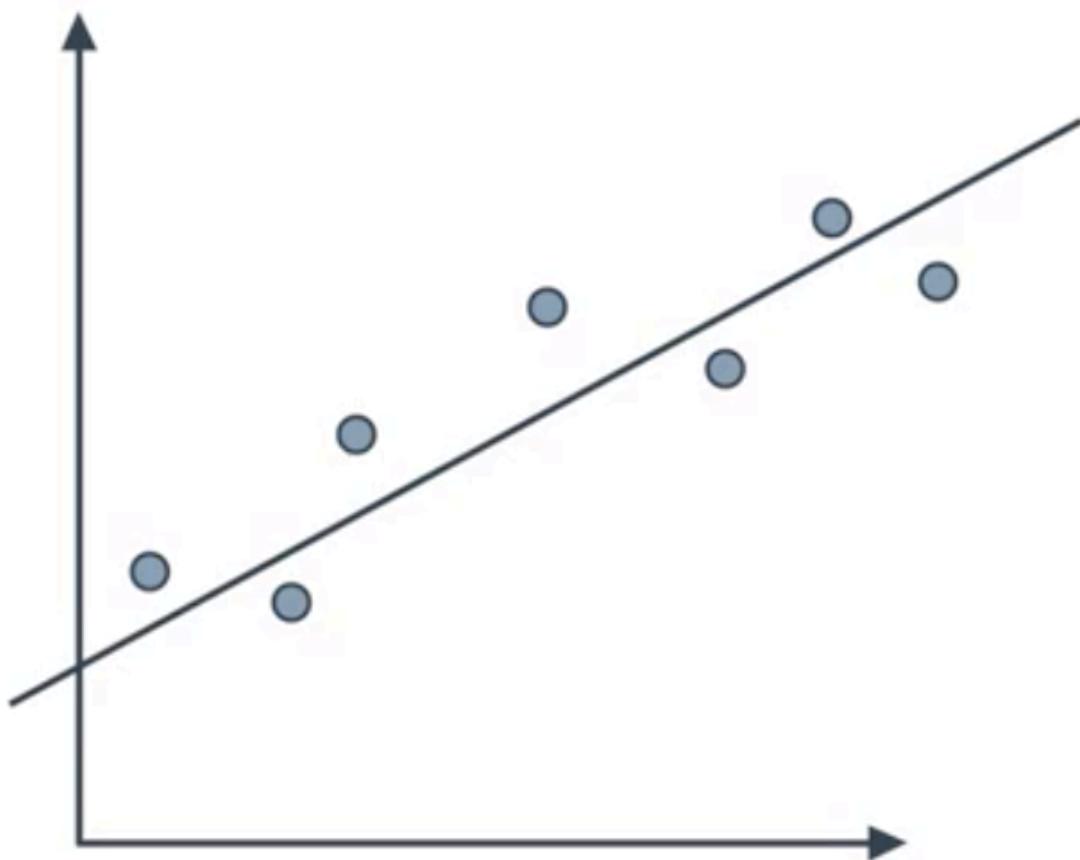


Model Testing



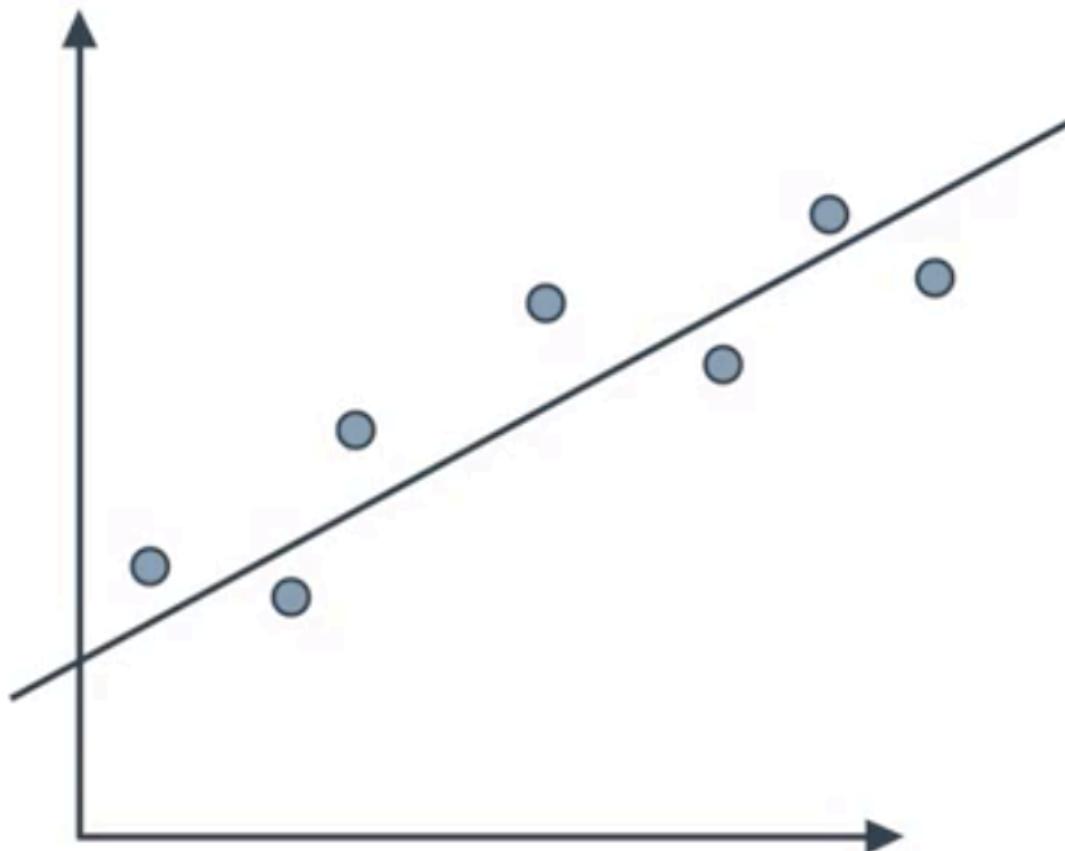
How well my model is doing?

WHICH MODEL IS BETTER?

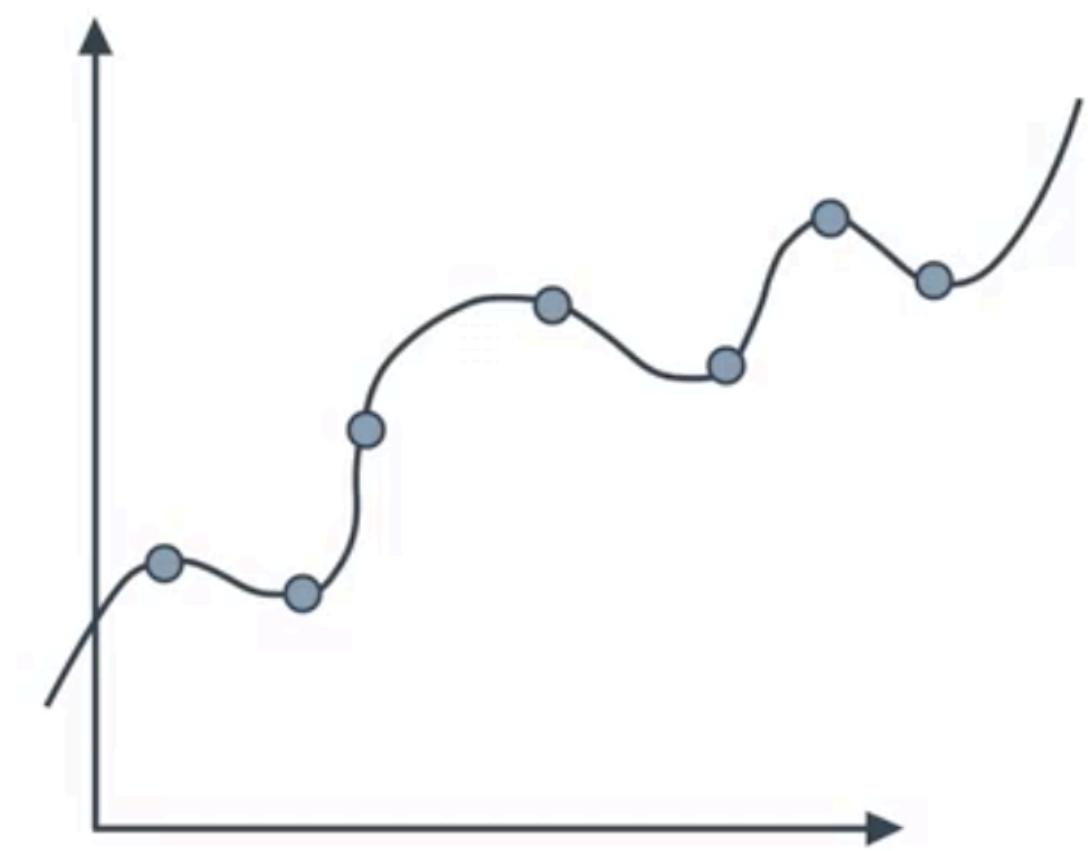


WHICH MODEL IS BETTER?

Does not fit the data

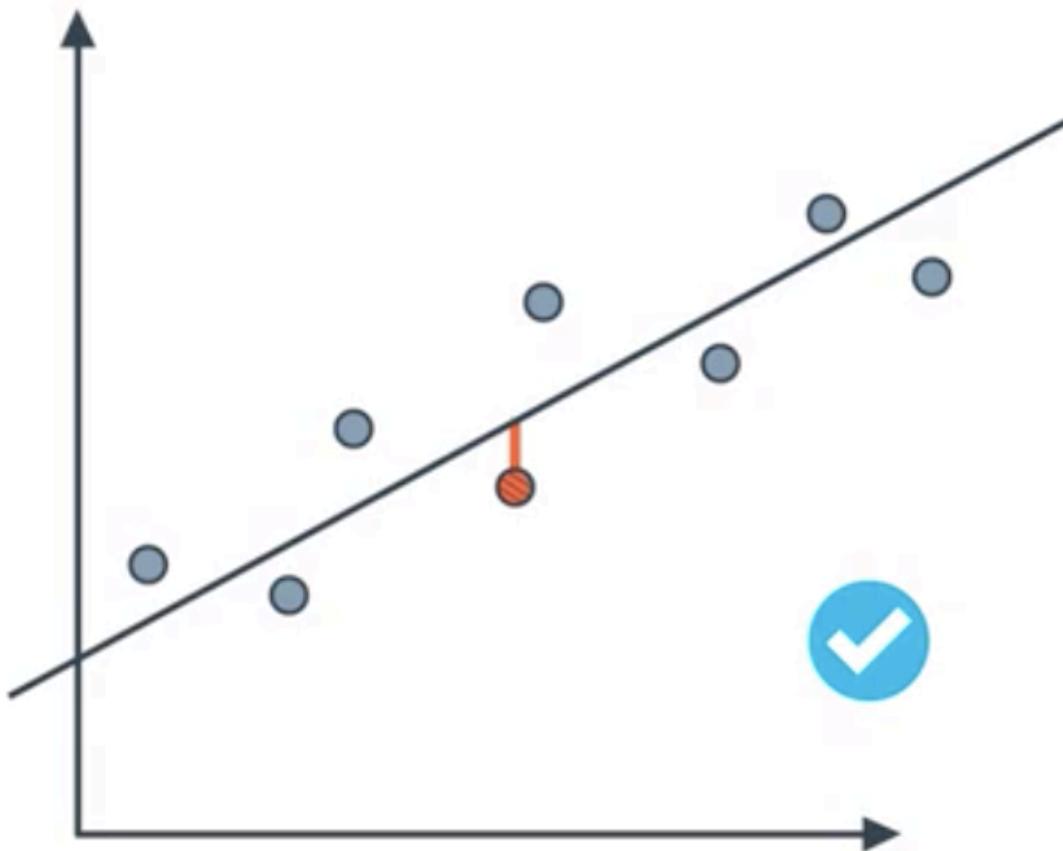


Fits the data



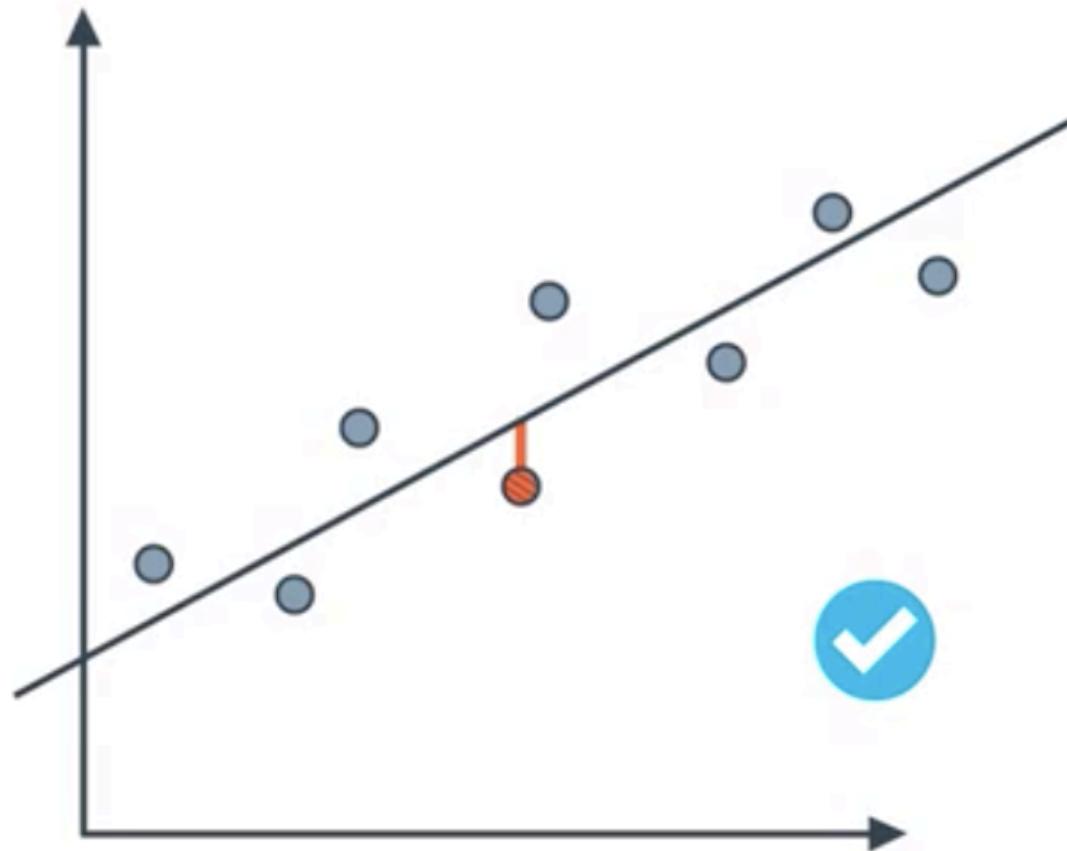
WHICH MODEL IS BETTER?

This model generalizes better



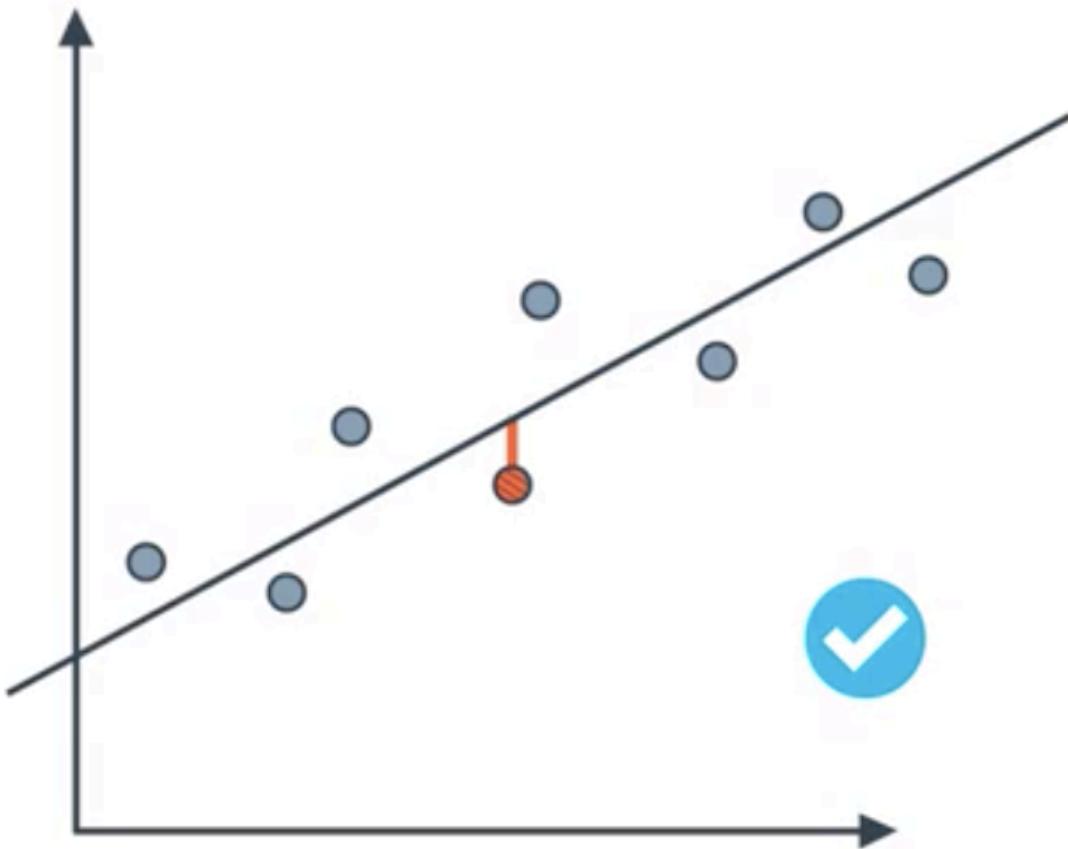
WHICH MODEL IS BETTER?

Overfitting

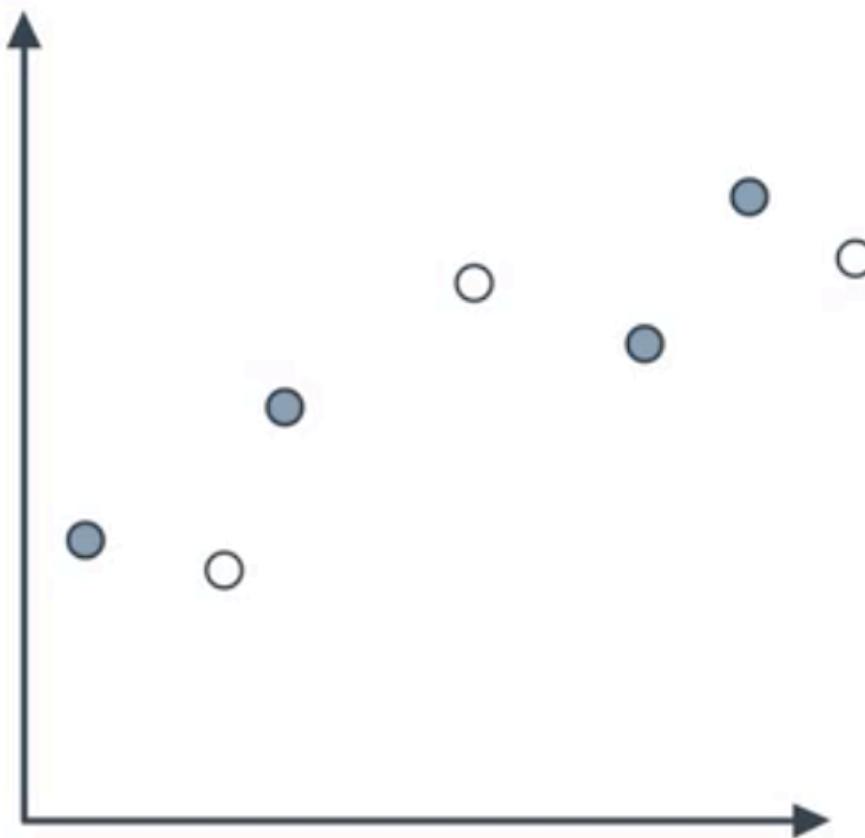


WHICH MODEL IS BETTER?

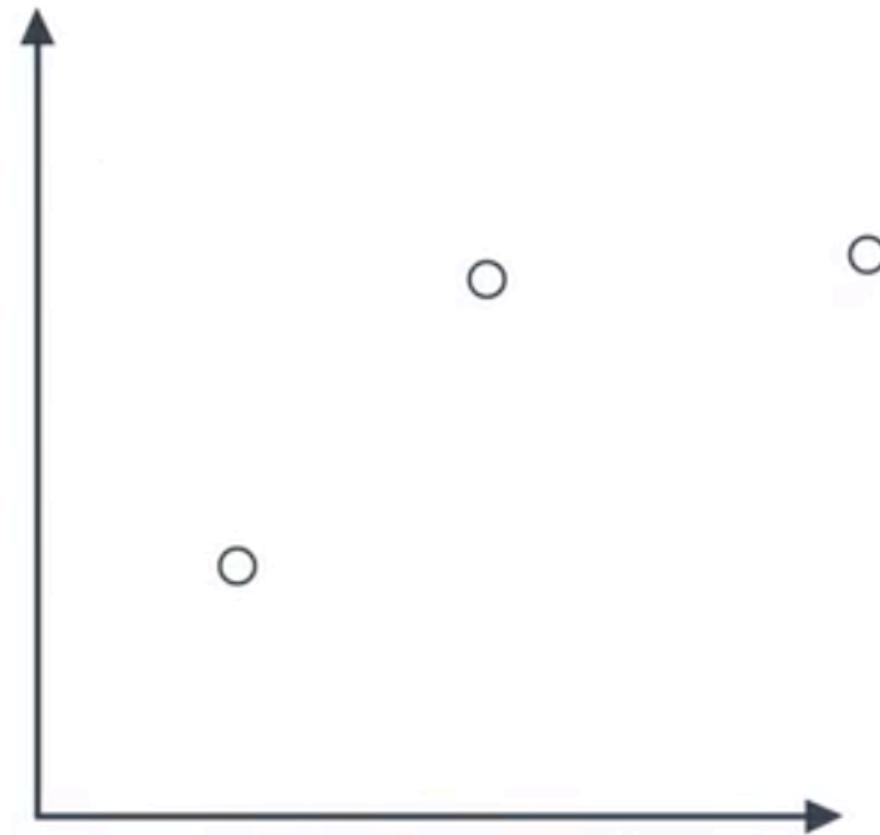
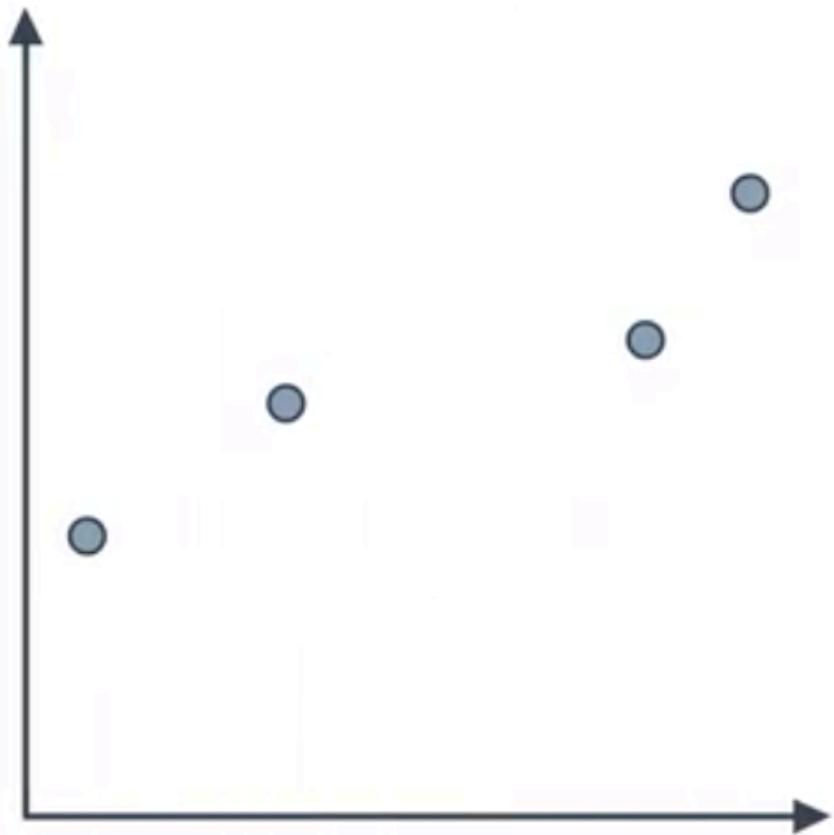
- HOW DO WE FIND A MODEL THAT GENERALIZES WELL?



TESTING

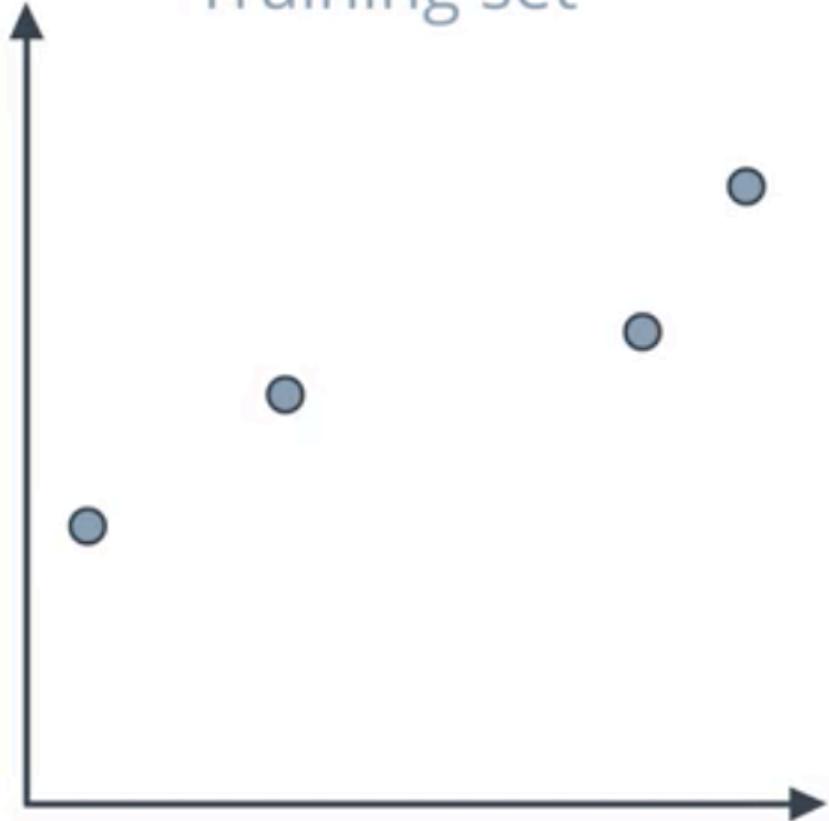


TESTING



TESTING

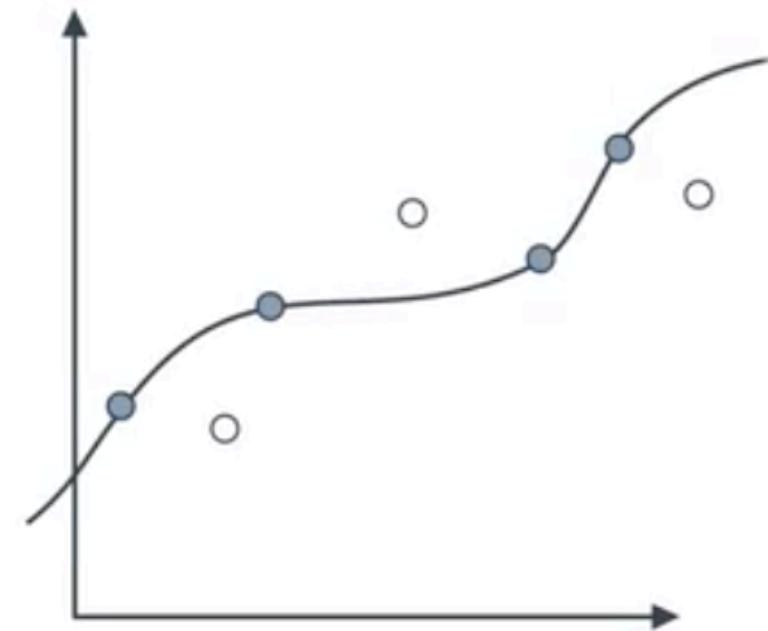
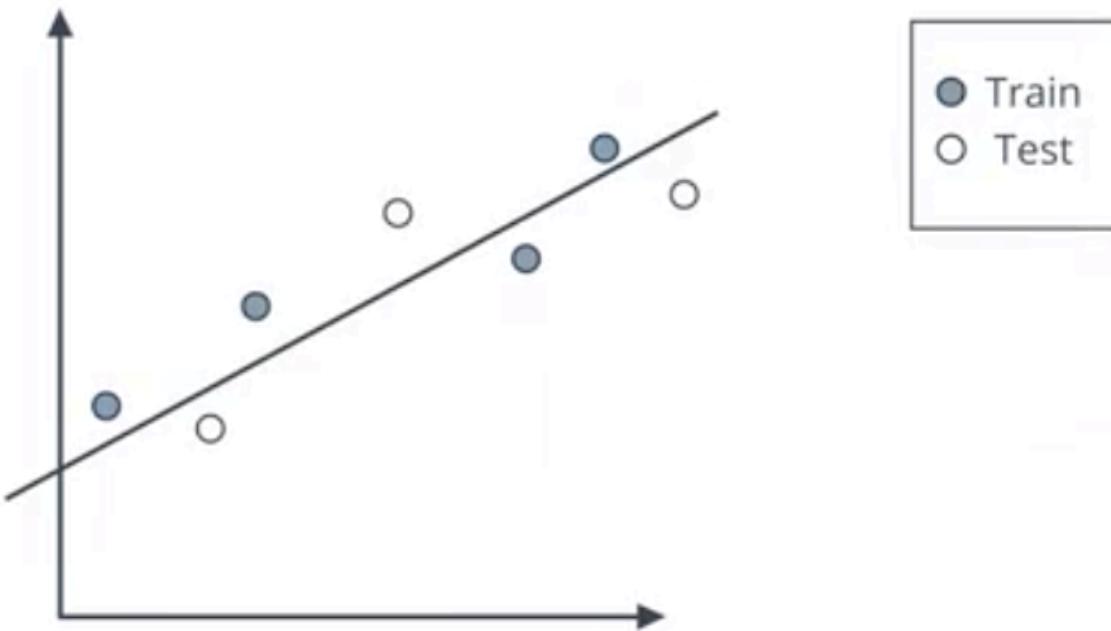
Training set



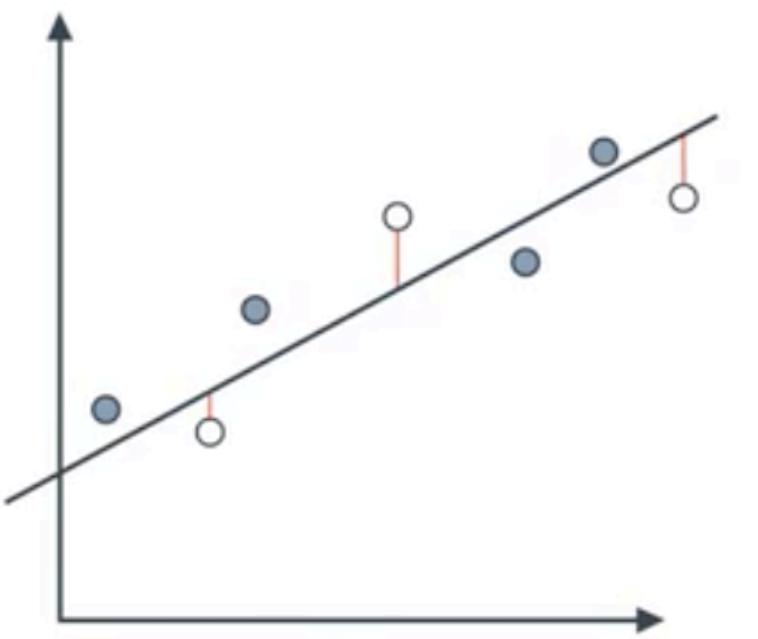
Testing set



TESTING



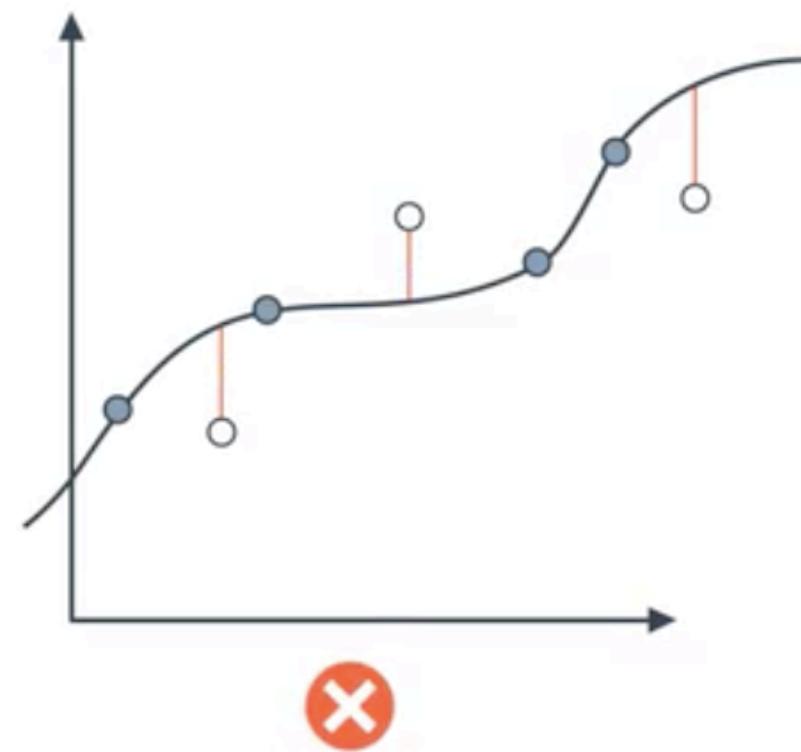
TESTING



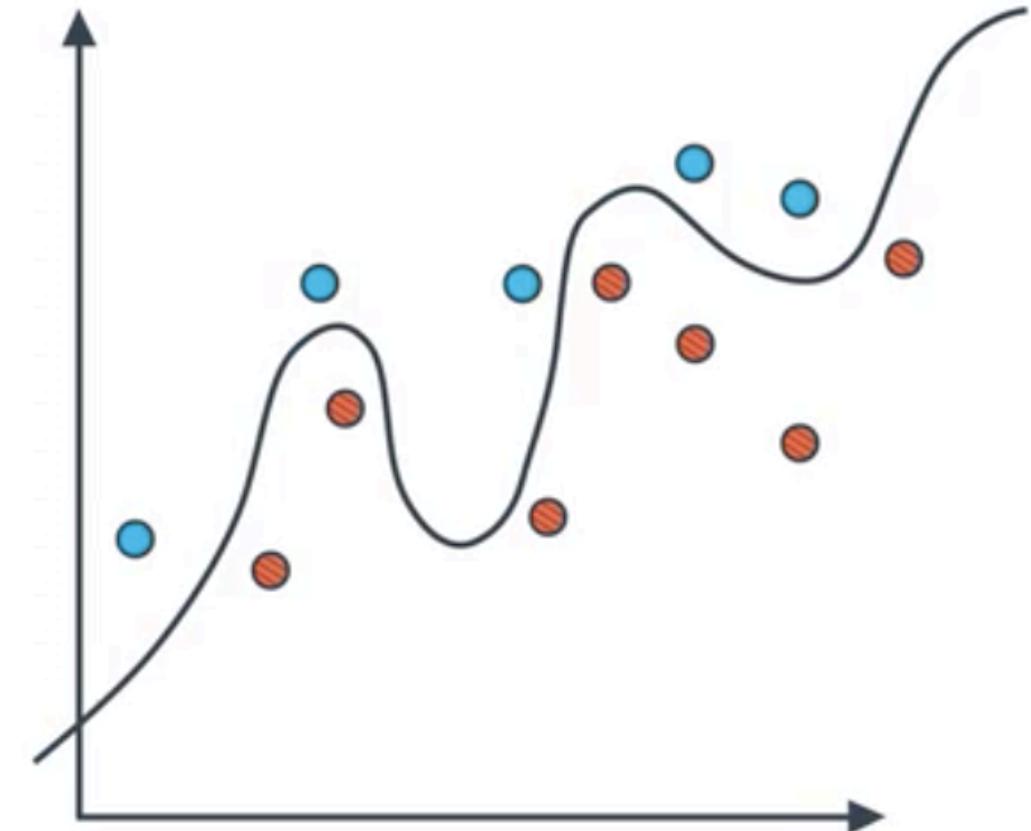
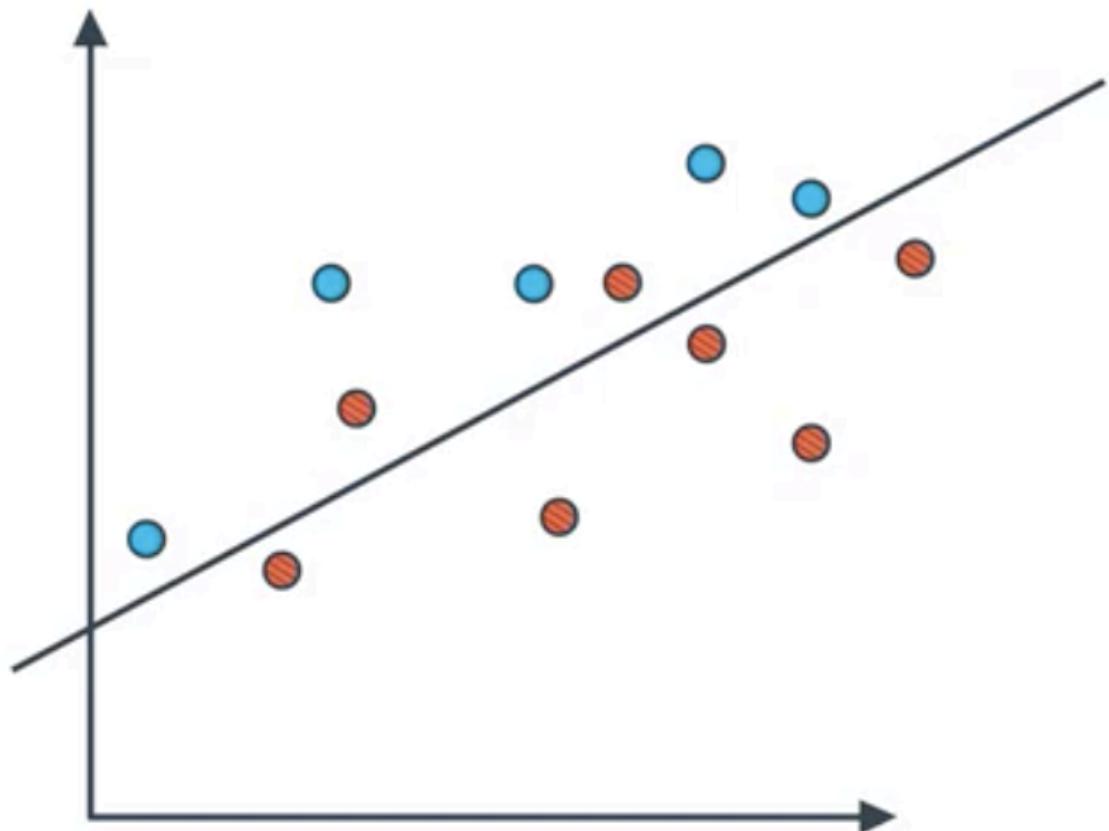
Train
Test



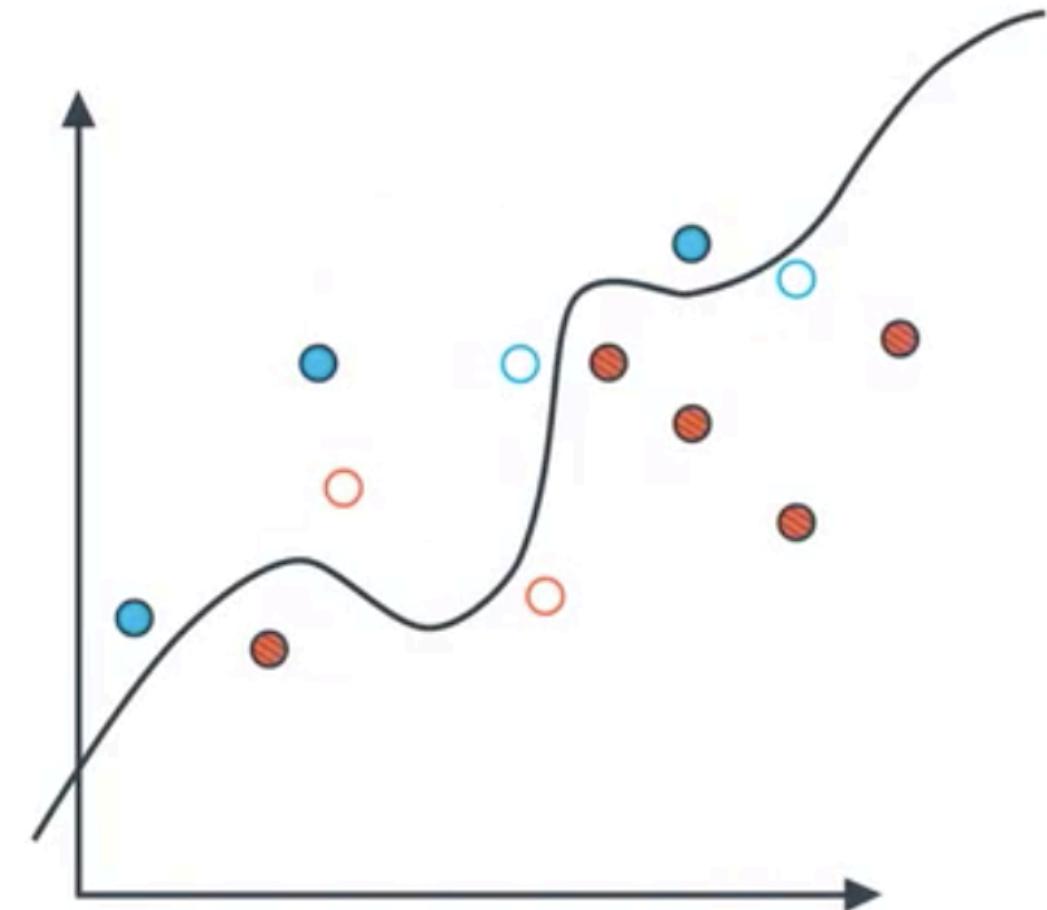
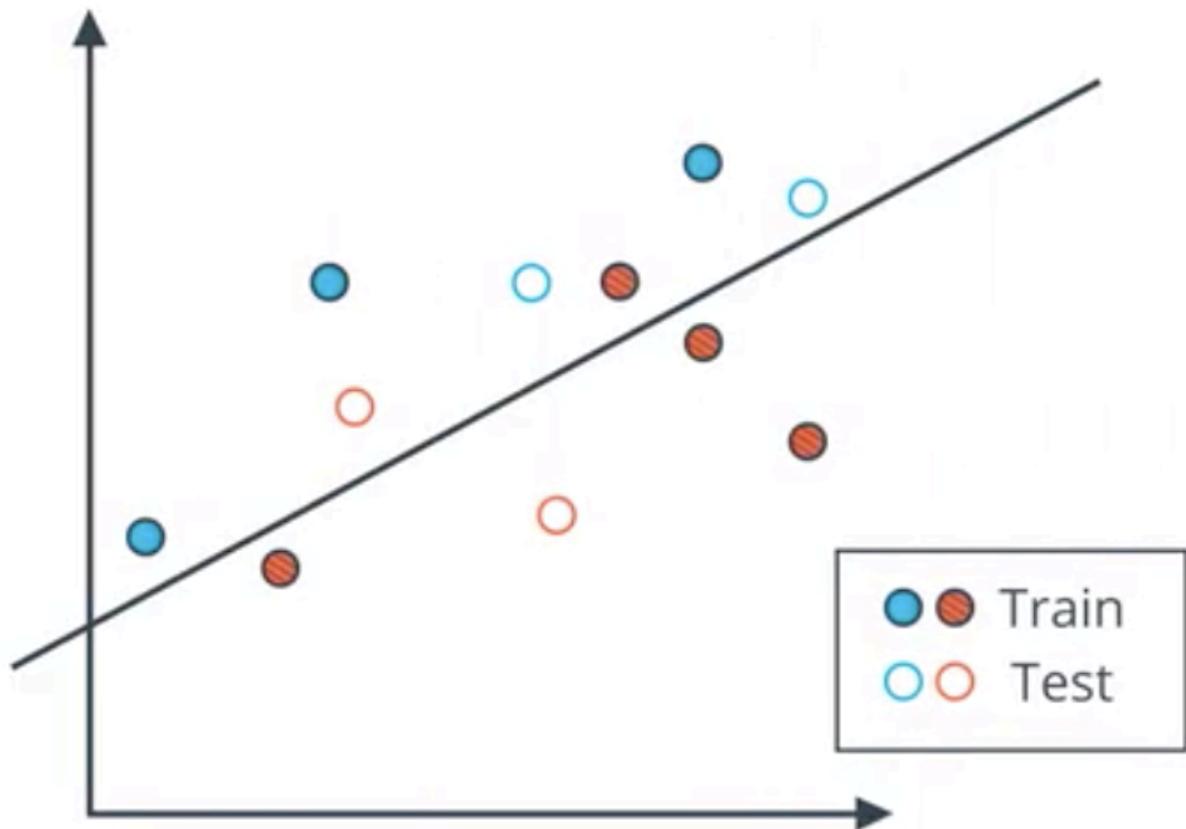
Errors are smaller



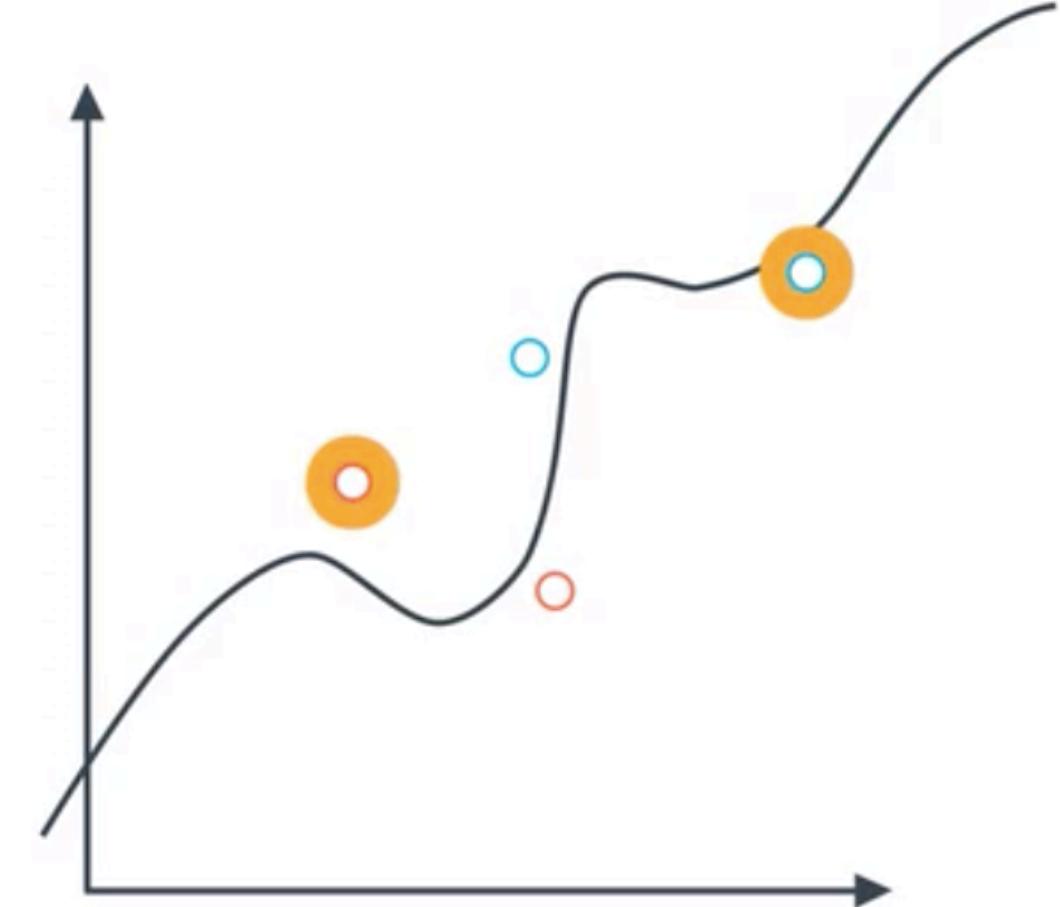
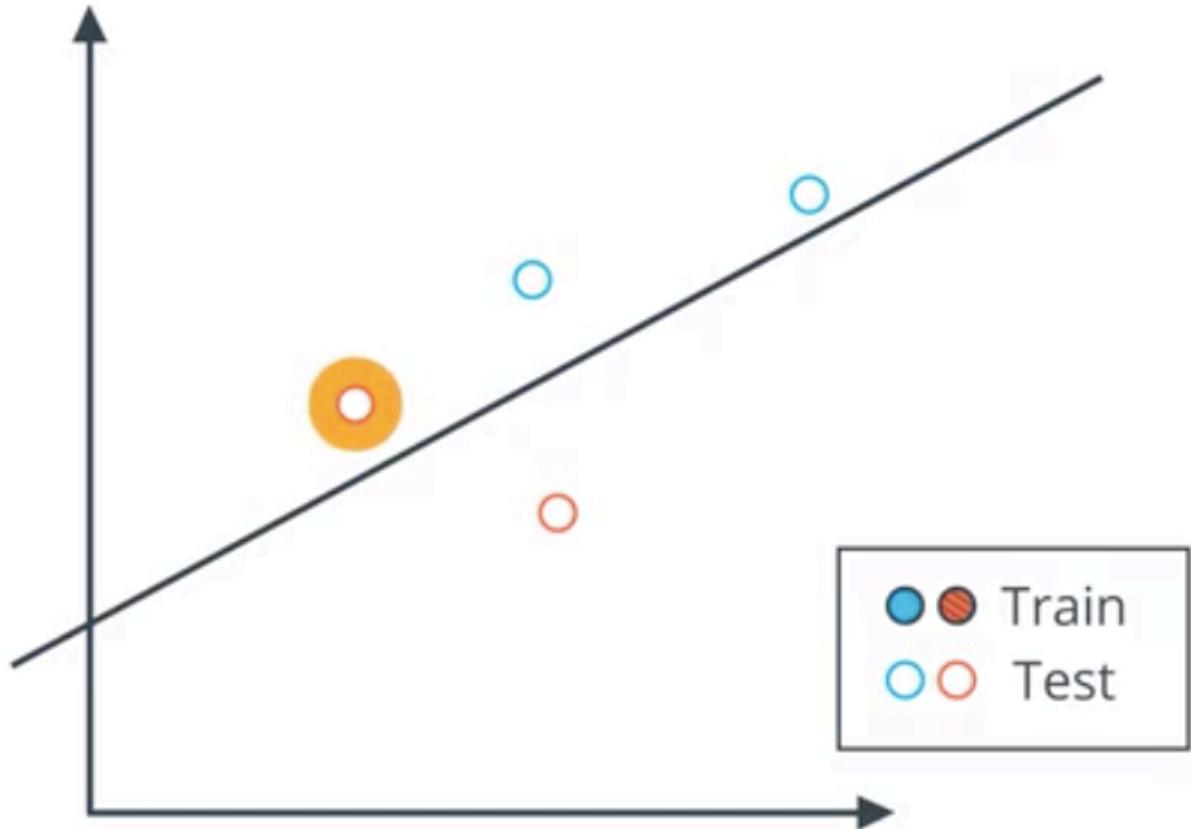
WHICH MODEL IS BETTER?



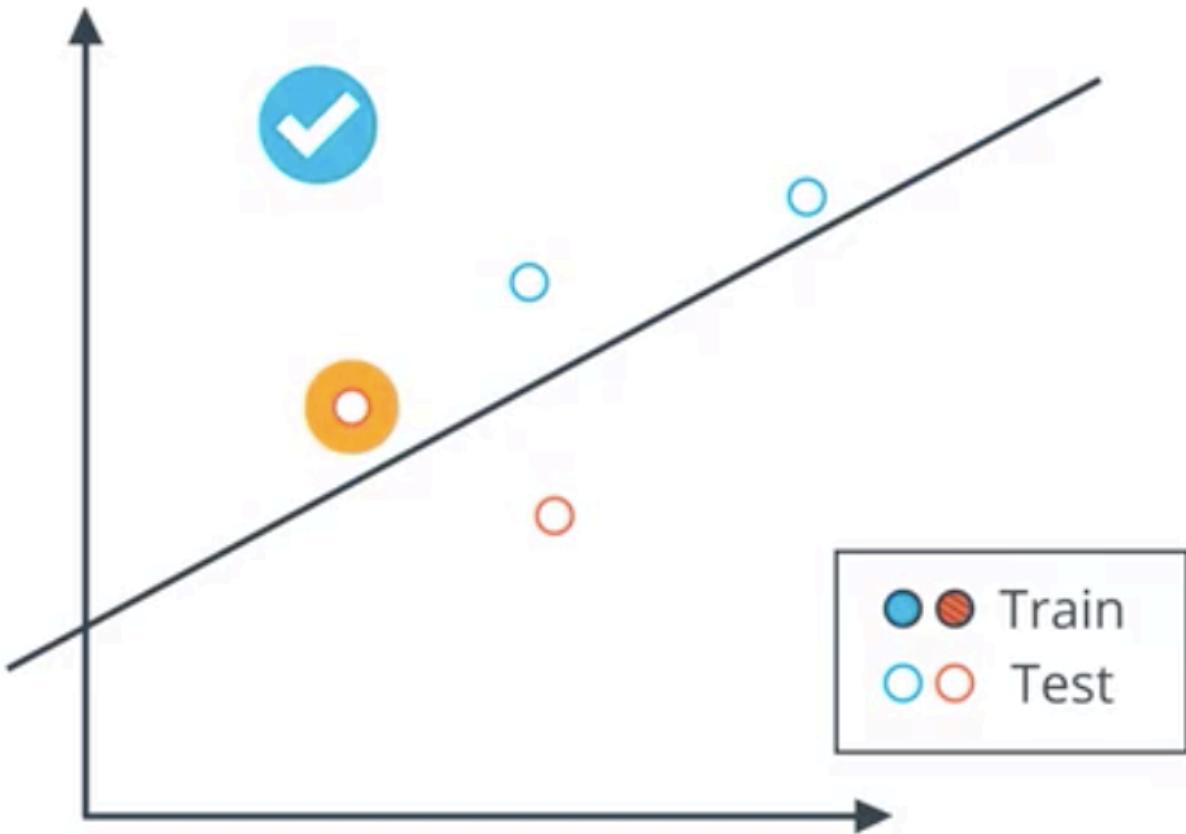
WHY TESTING?



WHY TESTING?



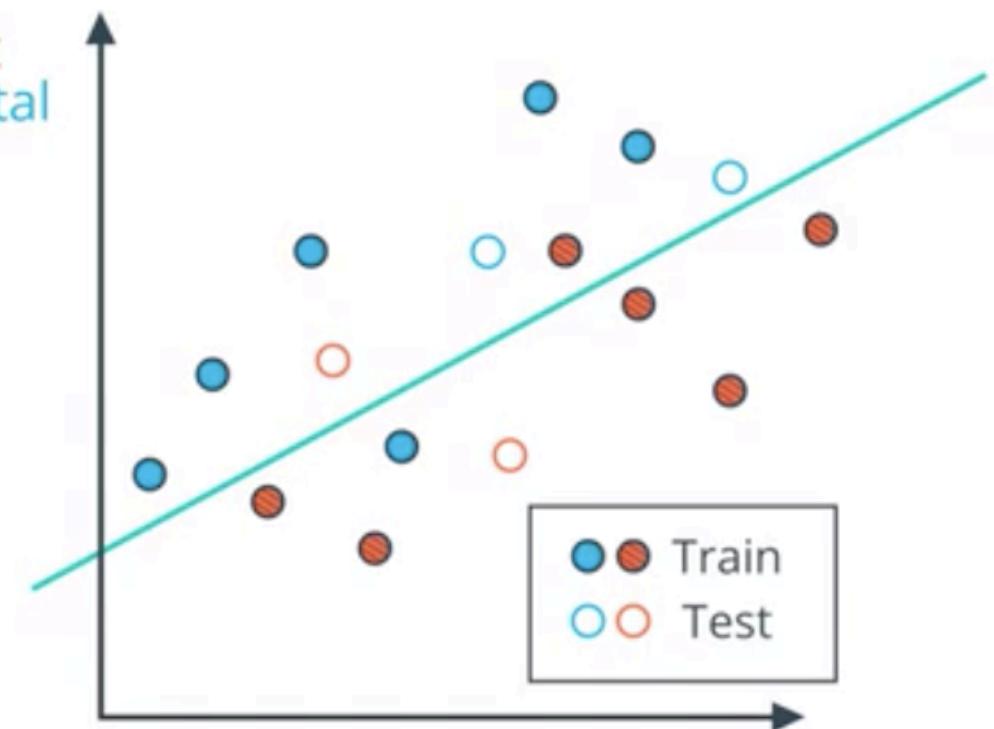
WHY TESTING?



TESTING IN SKLEARN

```
from sklearn.model_selection import train_test_split  
  
X_train, X_test, y_train, y_test =  
train_test_split(X,  
                 y,  
                 test_size = 0.25)
```

4 test
16 total



Evaluation Metrics

- ❖ Confusion Matrix
- ❖ Accuracy
- ❖ Precision
- ❖ Recall
- ❖ F1 Score
- ❖ F-beta Score
- ❖ ROC Curve
- ❖ Regression Metrics

- EVALUATION MATRIX

How well is my model doing?



MEDICAL MODEL



HEALTHY



SICK



SPAM CLASSIFIER MODEL



NOT SPAM



SPAM



MEDICAL MODEL

	Diagnosed Sick	Diagnosed Healthy
Sick	 True Positive	 False Negative
Healthy	 False Positive	 True Negative

- CONFUSION MATRIX



10,000 PATIENTS

PATIENTS	DIAGNOSIS	
	Diagnosed Sick	Diagnosed Healthy
Sick	1000 True Positives	200 False Negatives
Healthy	800 False Positives	8000 True Negatives



SPAM CLASSIFIER MODEL

	Sent to Spam Folder	Sent to Inbox
Spam		
Not Spam		



SPAM CLASSIFIER MODEL

	Sent to Spam Folder	Sent to Inbox
Spam	True Positive	False Negative
Not Spam	False Positive	True Negative

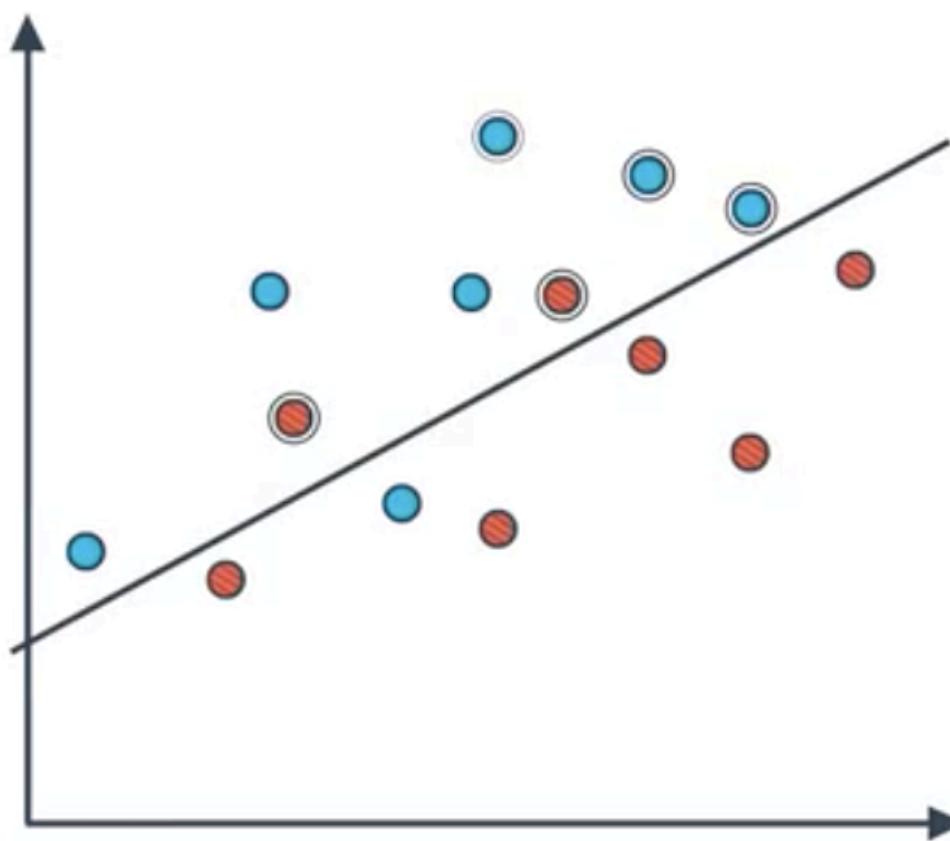
- CONFUSION MATRIX



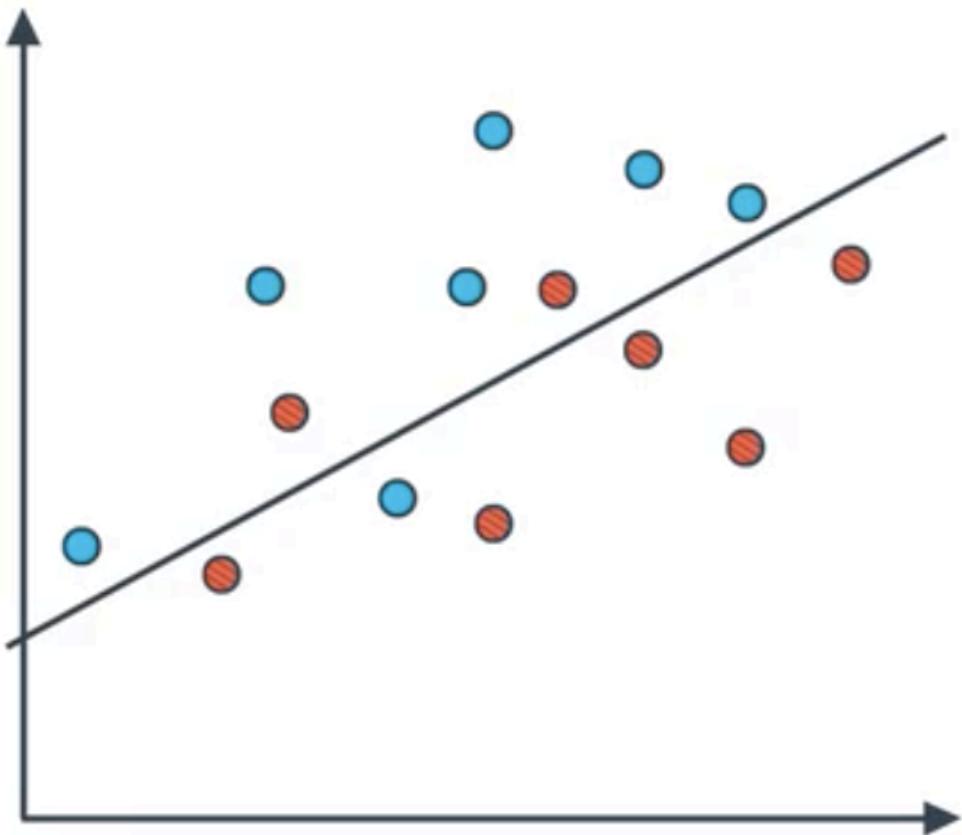
1000 EMAILS

		SPAM	
		Spam Folder	Inbox
EMAIL	Spam	100 True Positives	170 False Negatives
	Not Spam	30 False Positives	700 True Negatives

- CONFUSION MATRIX

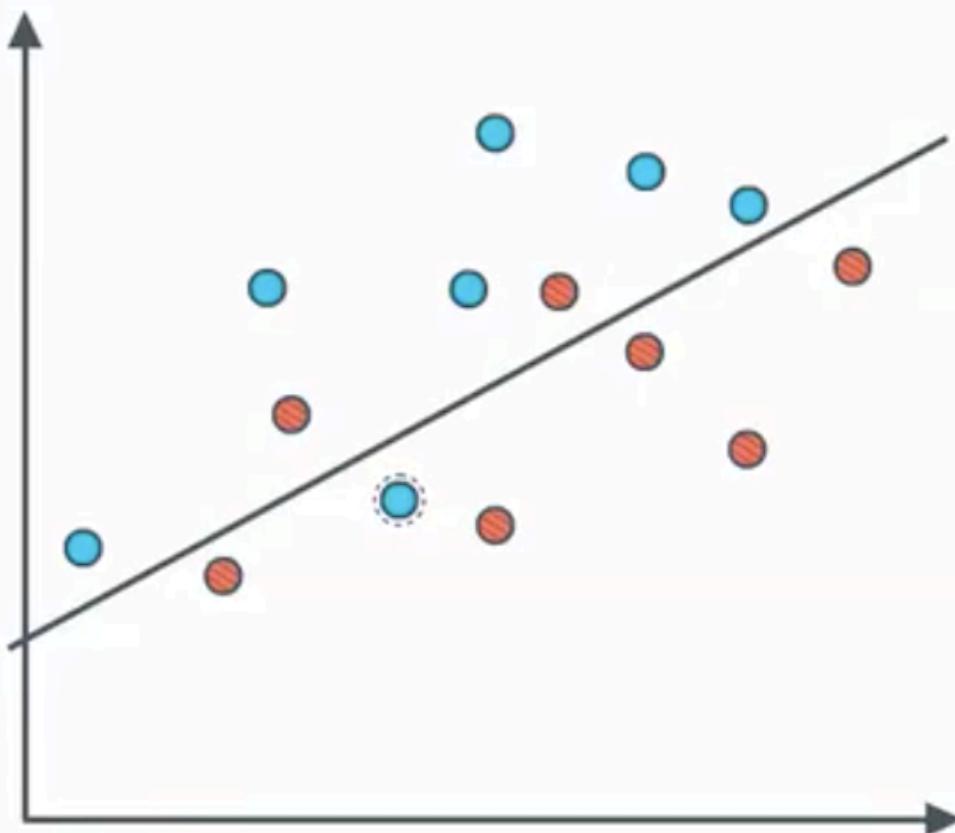


- CONFUSION MATRIX



	Guessed Positive	Guessed Negative
Positive	True Positives	False Negatives
Negative	False Positives	True Negatives

- CONFUSION MATRIX



	Guessed Positive	Guessed Negative
Positive	6 True Positives	1 False Negatives
Negative	2 False Positives	5 True Negatives



- ACCURACY

One of the ways to measure how good a model is.



- ACCURACY

Out of all the patients, how many did we classify correctly?

○ ACCURACY

Out of all the patients, how many did we classify correctly?

	Diagnosed sick	Diagnosed healthy
Sick	1,000	200
Healthy	800	8,000

$$\text{Accuracy} = \frac{1,000 + 8,000}{10,000} = 90\%$$

○ ACCURACY

Out of all the patients, how many did we classify correctly?

	Diagnosed sick	Diagnosed healthy
Sick	1,000	200
Healthy	800	8,000

$$\text{Accuracy} = \frac{1,000 + 8,000}{10,000} = 90\%$$

o ACCURACY

Out of all the patients, how many did we classify correctly?

	Diagnosed sick	Diagnosed healthy
Sick	1,000	200
Healthy	800	8,000

$$\text{Accuracy} = \frac{1,000 + 8,000}{10,000} = 90\%$$

```
from sklearn.metrics import accuracy_score  
accuracy_score (y_true, y_pred)
```

o ACCURACY

Out of all the emails, how many did we classify correctly?

	Spam folder	Inbox
Spam	100	170
Not spam	30	700

$$\text{Accuracy} = \frac{100 + 700}{1,000} = 80\%$$

○ ACCURACY

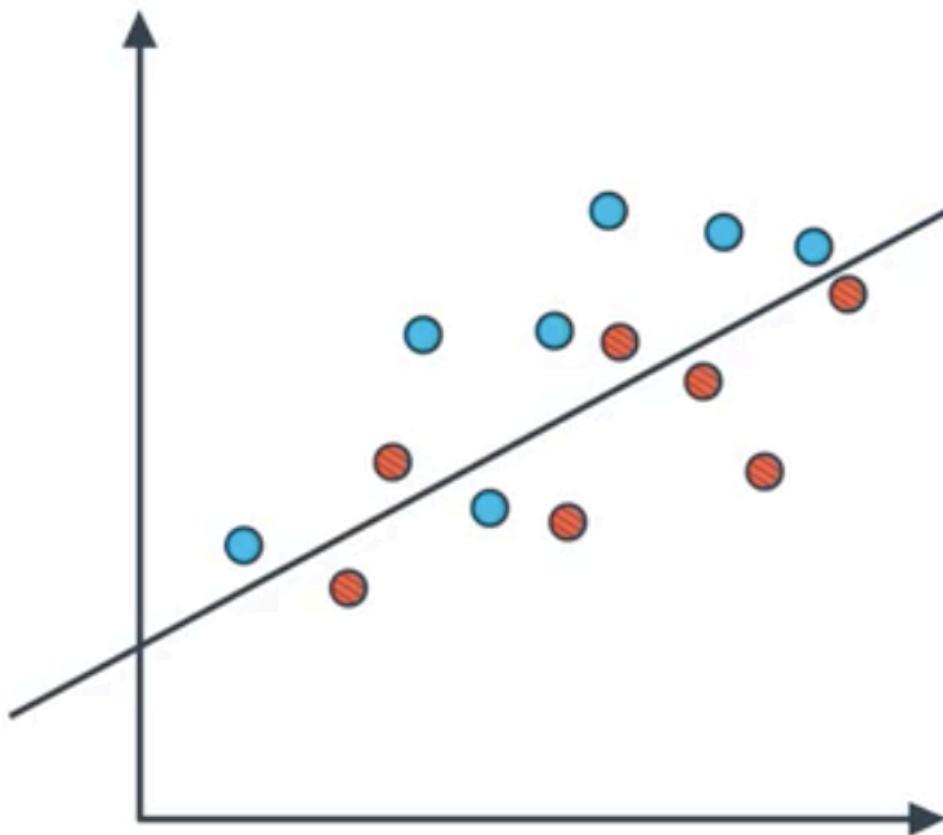
Out of all the emails, how many did we classify correctly?

	Spam folder	Inbox
Spam	100	170
Not spam	30	700

$$\text{Accuracy} = \frac{100 + 700}{1,000} = 80\%$$


- ACCURACY

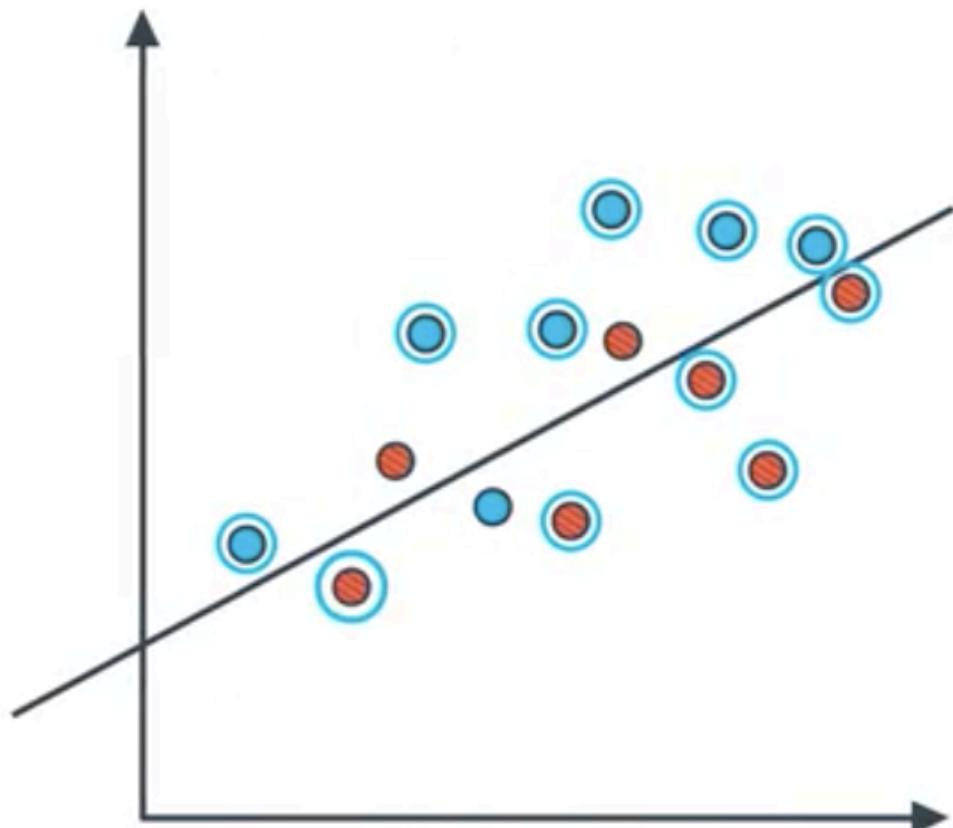
Out of all the data, how many points did we classify correctly?



- o ACCURACY

Out of all the data, how many points did we classify correctly?

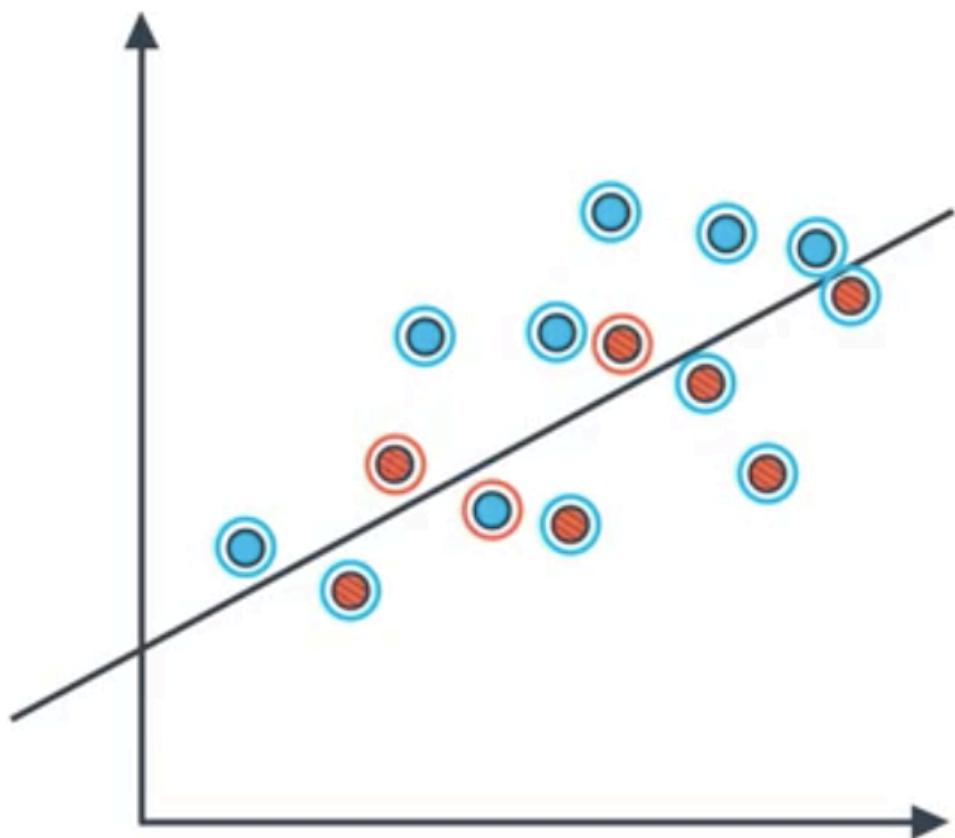
$$\text{Accuracy} = \frac{\text{Correctly classified points}}{\text{All points}}$$



o ACCURACY

Out of all the data, how many points did we classify correctly?

$$\text{Accuracy} = \frac{\text{Correctly classified points}}{\text{All points}}$$



$$= \frac{11}{11 + 3}$$

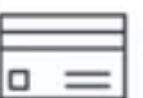
$$= \frac{11}{14}$$

$$= 78.57\%$$

- CREDIT CARD FRAUD



- CREDIT CARD FRAUD



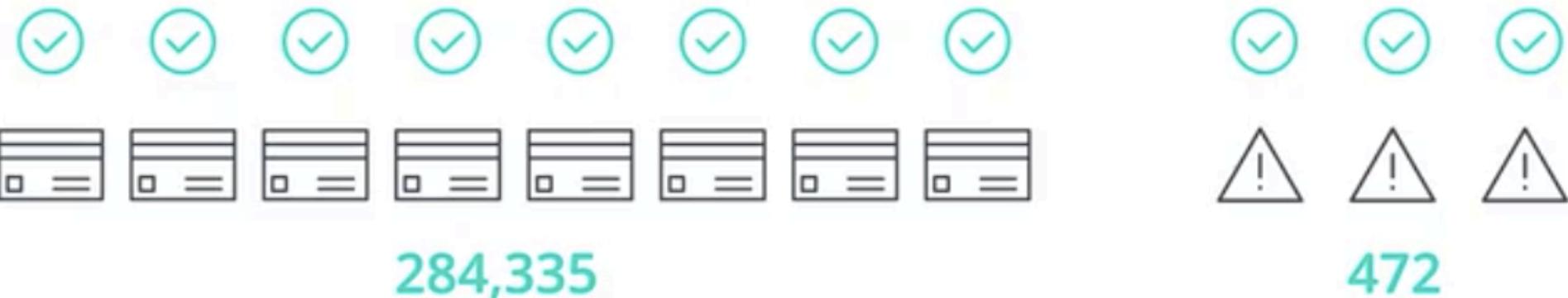
284,335



472



- CREDIT CARD FRAUD



MODEL: ALL TRANSACTIONS ARE GOOD.

$$\text{ACCURACY} = \frac{284,335}{284,887} = 99.83\%$$

- CREDIT CARD FRAUD



MODEL: ALL TRANSACTIONS ARE GOOD.

$$\text{ACCURACY} = \frac{284,335}{284,887} = 99.83\%$$

PROBLEM: I'M NOT CATCHING ANY OF THE BAD ONES.

- CREDIT CARD FRAUD



284,335



472

MODEL: ALL TRANSACTIONS ARE FRAUDULENT.

GREAT! NOW I'M CATCHING ALL OF THE FRAUDULENT TRANSACTIONS!

- CREDIT CARD FRAUD



MODEL: ALL TRANSACTIONS ARE FRAUDULENT.

GREAT! NOW I'M CATCHING ALL OF THE FRAUDULENT TRANSACTIONS!

PROBLEM: I'M ACCIDENTALLY CATCHING ALL OF THE GOOD ONES!

- QUIZ FALSE POSITIVES AND NEGATIVES

		DIAGNOSIS	
		Diagnosed Sick	Diagnosed Healthy
PATIENTS	Sick	 True Positive	 False Negative
	Healthy	 False Positive	 True Negative

- QUIZ FALSE POSITIVES AND NEGATIVES

		FOLDER	
		Sent to Spam Folder	Sent to Inbox
EMAIL	Spam	 True Positive	 False Negative
	Not Spam	 False Positive	 True Negative

- SOLUTION: FALSE POSITIVES AND NEGATIVES

		DIAGNOSIS	
		Diagnosed Sick	Diagnosed Healthy
PATIENTS	Sick		
	Healthy	 False Positive	

 False Negative

- SOLUTION: FALSE POSITIVES AND NEGATIVES

	FOLDER	
EMAIL	Sent to Spam Folder	Sent to Inbox
Spam		 False Negative
Not Spam	 False Positive	

- SOLUTION: FALSE POSITIVES AND NEGATIVES



Medical Model

FALSE POSITIVES OK

FALSE NEGATIVES NOT OK

OK IF NOT ALL ARE SICK
FIND ALL THE SICK PEOPLE



Spam Detector

FALSE POSITIVES NOT OK

FALSE NEGATIVES OK

DON'T NECESSARILY NEED
TO FIND ALL THE SPAM

- SOLUTION: FALSE POSITIVES AND NEGATIVES

PRECISION

RECALL

- SOLUTION: FALSE POSITIVES AND NEGATIVES



Medical Model

FALSE POSITIVES OK

FALSE NEGATIVES NOT OK

OK IF NOT ALL ARE SICK
FIND ALL THE SICK PEOPLE

HIGH RECALL



Spam Detector

FALSE POSITIVES NOT OK

FALSE NEGATIVES OK

DON'T NECESSARILY NEED
TO FIND ALL THE SPAM
BETTER BE SPAM

HIGH PRECISION

- PRECISION

		DIAGNOSIS	
		Diagnosed Sick	Diagnosed Healthy
PATIENTS	Sick	1000	200 
	Healthy	800	9000

- PRECISION

		DIAGNOSIS	
		Diagnosed Sick	Diagnosed Healthy
PATIENTS	Sick	1000	200 
	Healthy	800	9000

PRECISION: OUT OF THE PATIENTS WE DIAGNOSED WITH AN ILLNESS, HOW MANY DID WE CLASSIFY CORRECTLY?

$$\text{PRECISION} = \frac{1,000}{1,000 + 800} = 55.6\%$$

- PRECISION

FOLDER

EMAIL		Sent to Spam Folder	Sent to Inbox
Spam	100	170	
Not Spam	30 	700	

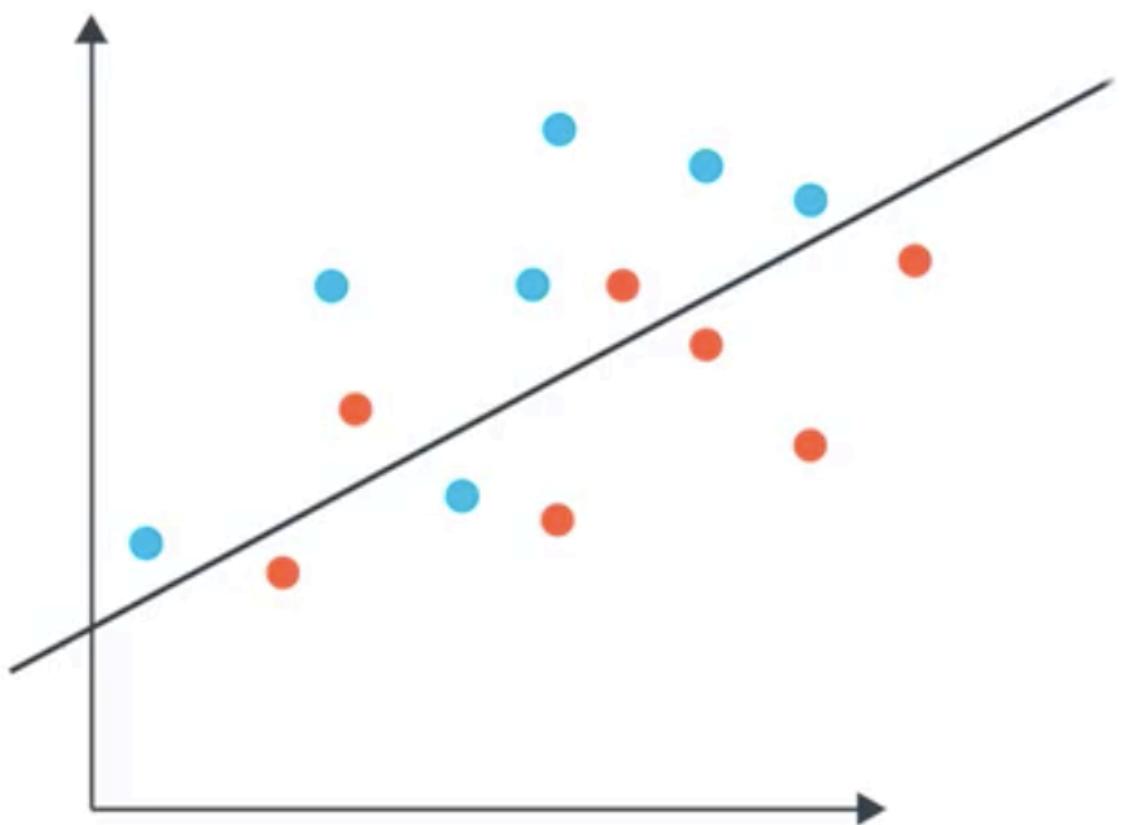
- PRECISION

EMAIL		FOLDER	
		Sent to Spam Folder	Sent to Inbox
Spam		100	170
Not Spam		30 	700

OUT OF ALL THE E-MAILS
SENT TO THE SPAM FOLDER,
HOW MANY WERE ACTUALLY SPAM?

$$\text{PRECISION} = \frac{100}{100 + 30} = 76.9\%$$

- PRECISION



OUT OF THE POINTS WE HAVE
PREDICTED TO BE POSITIVE,
HOW MANY ARE CORRECT?

- RECALL

DIAGNOSIS

PATIENTS	DIAGNOSIS	
	Diagnosed Sick	Diagnosed Healthy
Sick	1000	200 
Healthy	800	8000

- RECALL

DIAGNOSIS

PATIENTS	DIAGNOSIS	
	Diagnosed Sick	Diagnosed Healthy
Sick	1000	200 
Healthy	800	8000

OUT OF THE SICK PATIENTS,
HOW MANY DID WE CORRECTLY
DIAGNOSE AS SICK?

$$\text{RECALL} = \frac{1,000}{1,000 + 200} = 83.3\%$$

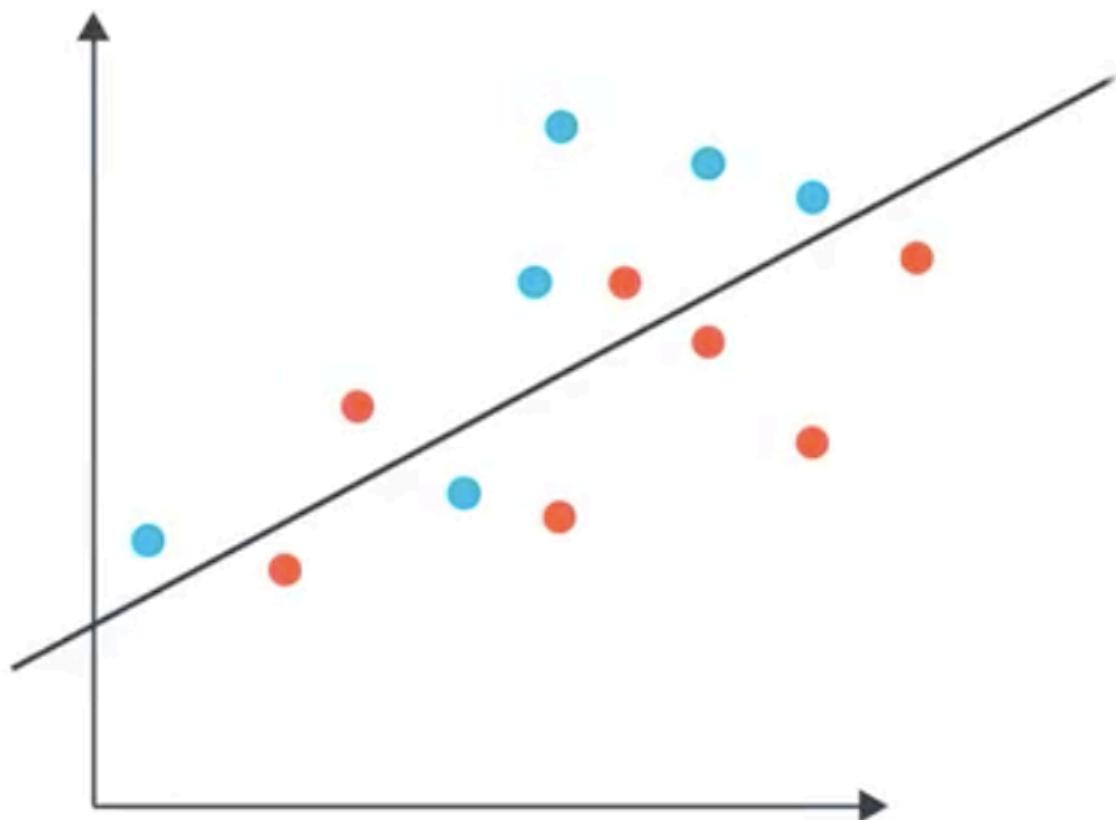
- RECALL

EMAIL		FOLDER	
		Sent to Spam Folder	Sent to Inbox
Spam	Sent to Spam Folder	100	170
	Not Sent to Spam Folder	30 	700

OUT OF ALL THE SPAM E-MAILS,
HOW MANY WERE CORRECTLY
SENT TO THE SPAM FOLDER?

$$\text{Recall} = \frac{100}{100 + 170} = 37\%$$

○ RECALL



OUT OF THE POINTS
LABELLED "POSITIVE,"
HOW MANY DID WE
CORRECTLY PREDICT?

- PRECISION AND RECALL



MEDICAL MODEL

PRECISION: 55.7%

RECALL: 83.3%



SPAM DETECTOR

PRECISION: 76.9%

RECALL: 37%

- PRECISION AND RECALL



MEDICAL MODEL

PRECISION: 55.7%

RECALL: 83.3%

ONE SCORE?



SPAM DETECTOR

PRECISION: 76.9%

RECALL: 37%

◦ F_1 SCORE



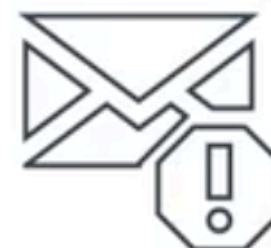
MEDICAL MODEL

PRECISION: 55.7%

RECALL: 83.3%

AVERAGE = 69.5%

ONE SCORE?



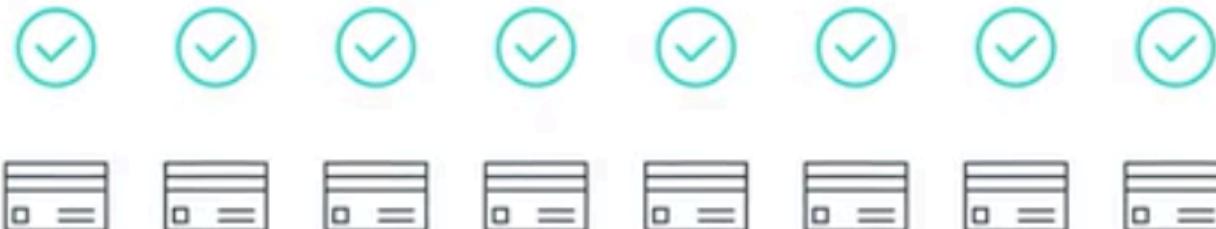
SPAM DETECTOR

PRECISION: 76.9%

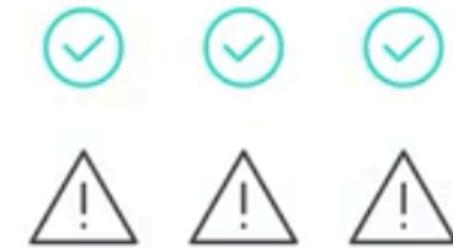
RECALL: 37%

AVERAGE = 56.95%

- CREDIT CARD FRAUD



284,335



472

MODEL: ALL TRANSACTIONS ARE GOOD.

PRECISION = 100%

AVERAGE = 50%

RECALL = 0%

◦ CREDIT CARD FRAUD



284,335

472

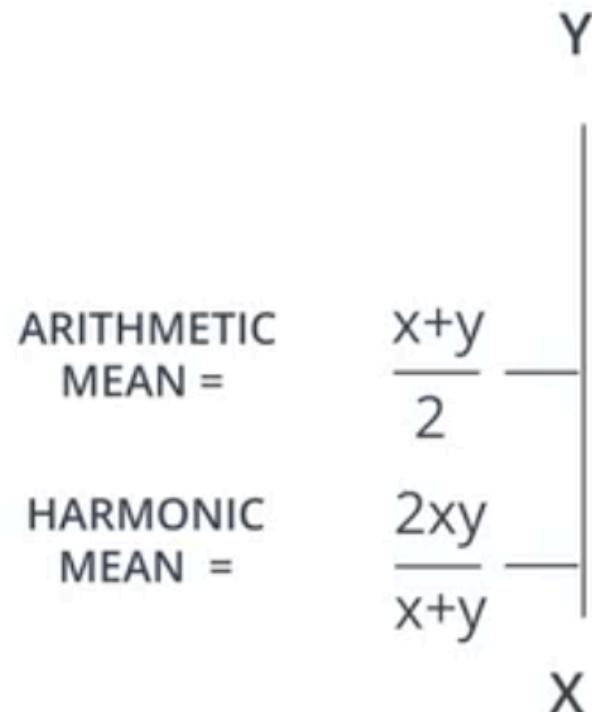
MODEL: ALL TRANSACTIONS ARE FRAUDULENT.

PRECISION = $472/284,807 = 0.16\%$

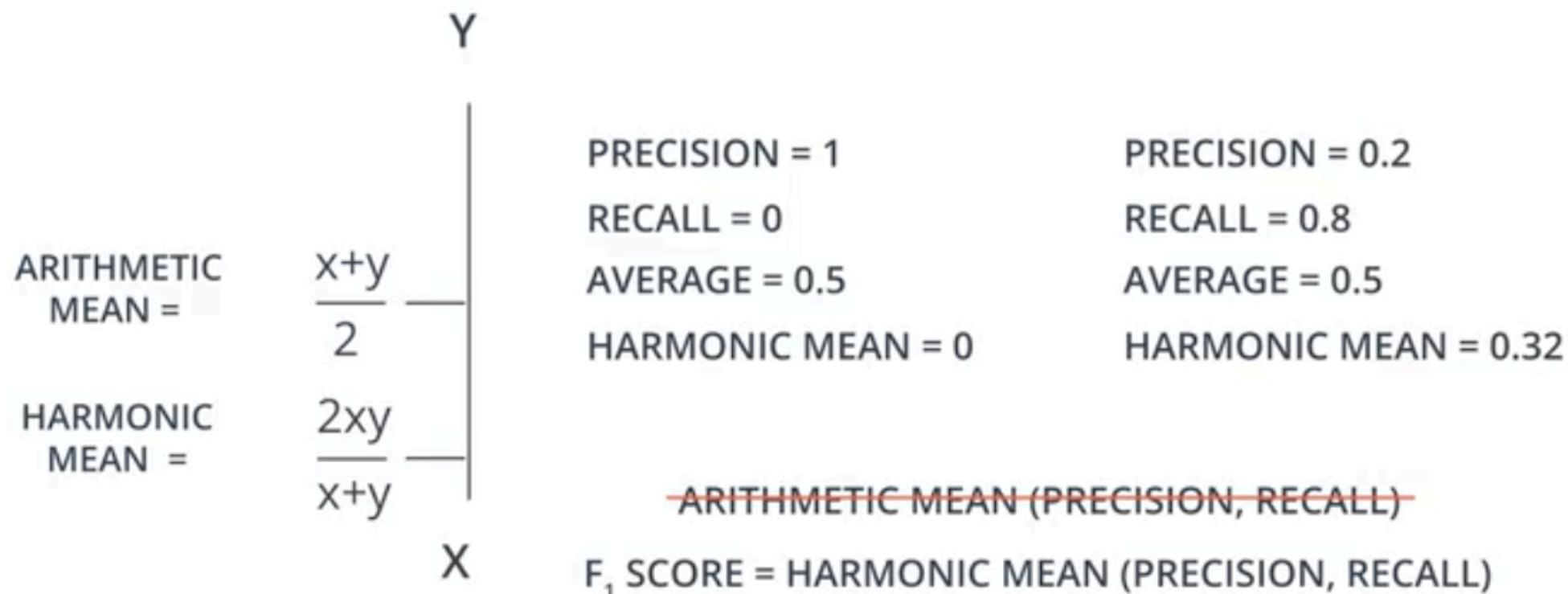
RECALL = $472/472 = 100\%$

AVERAGE = 50.08%

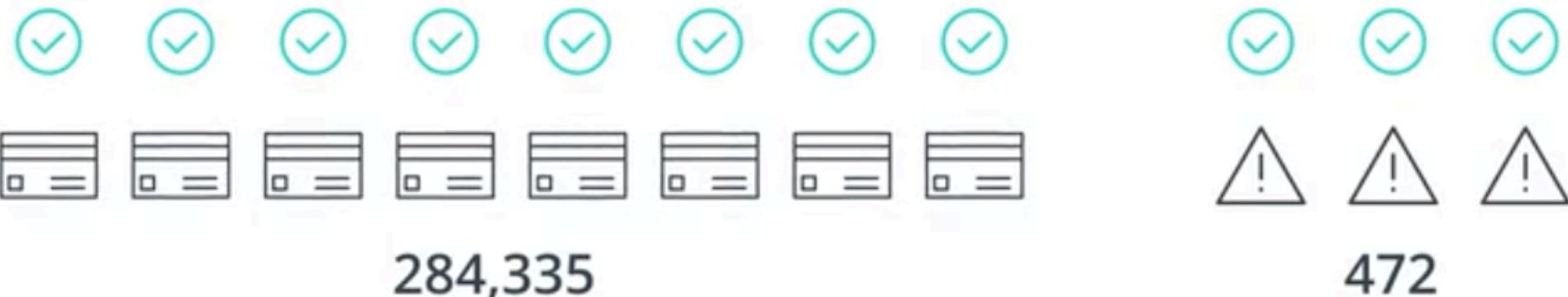
◦ HARMONIC MEAN



- HARMONIC MEAN



- CREDIT CARD FRAUD



MODEL: ALL TRANSACTIONS ARE GOOD.

PRECISION = 100%

F₁ SCORE = 0

RECALL = 0%

- QUIZ: F_{β} SCORE

$$F_1 \text{ SCORE} = 2 \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$



PRECISION

$F_{0.5}$ SCORE

F_1 SCORE

F_2 SCORE



RECALL

- QUIZ: F_{β} SCORE

$$F_1 \text{ SCORE} = 2 \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$

$$F_{\beta} \text{ SCORE} = (1+\beta^2) \beta^2 \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$



PRECISION

$F_{0.5}$ SCORE

F_1 SCORE

F_2 SCORE



RECALL

- QUIZ: F_{β} SCORE

- DETECTING MALFUNCTIONING PARTS ON A SPACESHIP
- SENDING PHONE NOTIFICATIONS ABOUT VIDEOS A USER MAY LIKE
- SENDING FREE SAMPLES IN THE MAIL TO POTENTIAL CLIENTS



PRECISION

$F_{0.5}$ SCORE

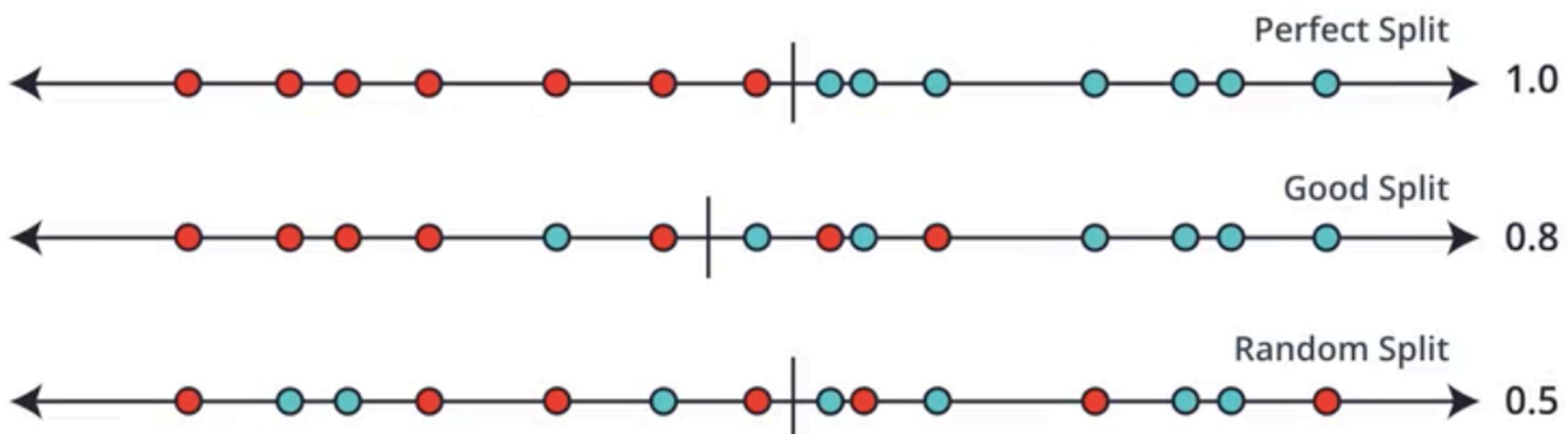
F_1 SCORE

F_2 SCORE



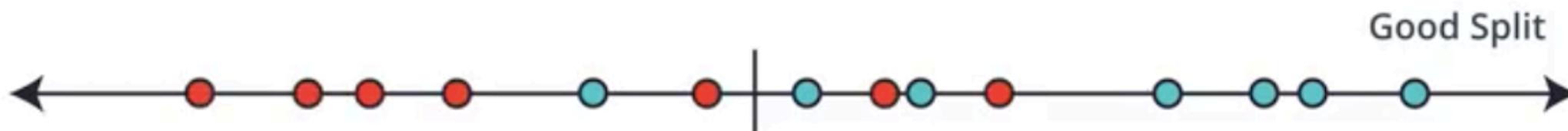
RECALL

- RECEIVER OPERATING CHARACTERISTIC



- ROC CURVE

$$\text{True Positive Rate} = \frac{\text{TRUE POSITIVES}}{\text{ALL POSITIVES}} = \frac{6}{7} = 0.857$$



- ROC CURVE

True Positive Rate =

$$\frac{\text{TRUE POSITIVES}}{\text{ALL POSITIVES}} = \frac{6}{7} = 0.857$$

False Positive Rate =

$$\frac{\text{FALSE POSITIVES}}{\text{ALL NEGATIVES}} = \frac{2}{7} = 0.286$$



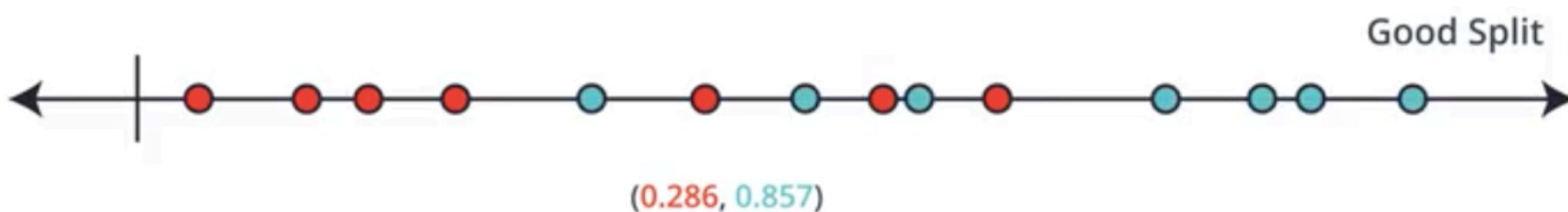
- ROC CURVE

True Positive Rate =

$$\frac{\text{TRUE POSITIVES}}{\text{ALL POSITIVES}} = \frac{7}{7} = 1$$

False Positive Rate =

$$\frac{\text{FALSE POSITIVES}}{\text{ALL NEGATIVES}} = \frac{7}{7} = 1$$



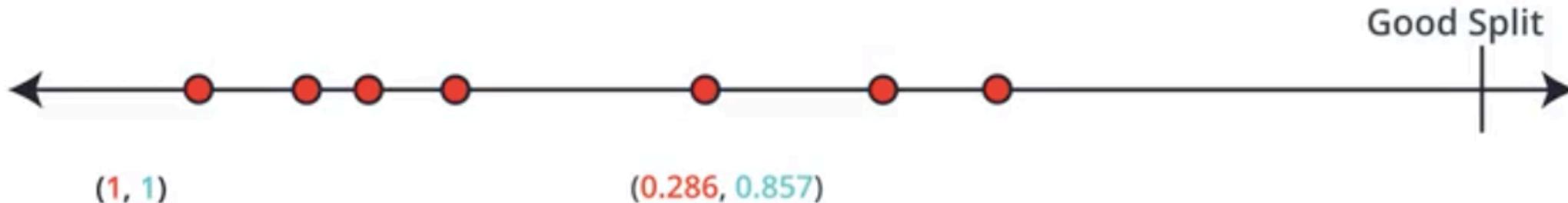
- ROC CURVE

True Positive Rate =

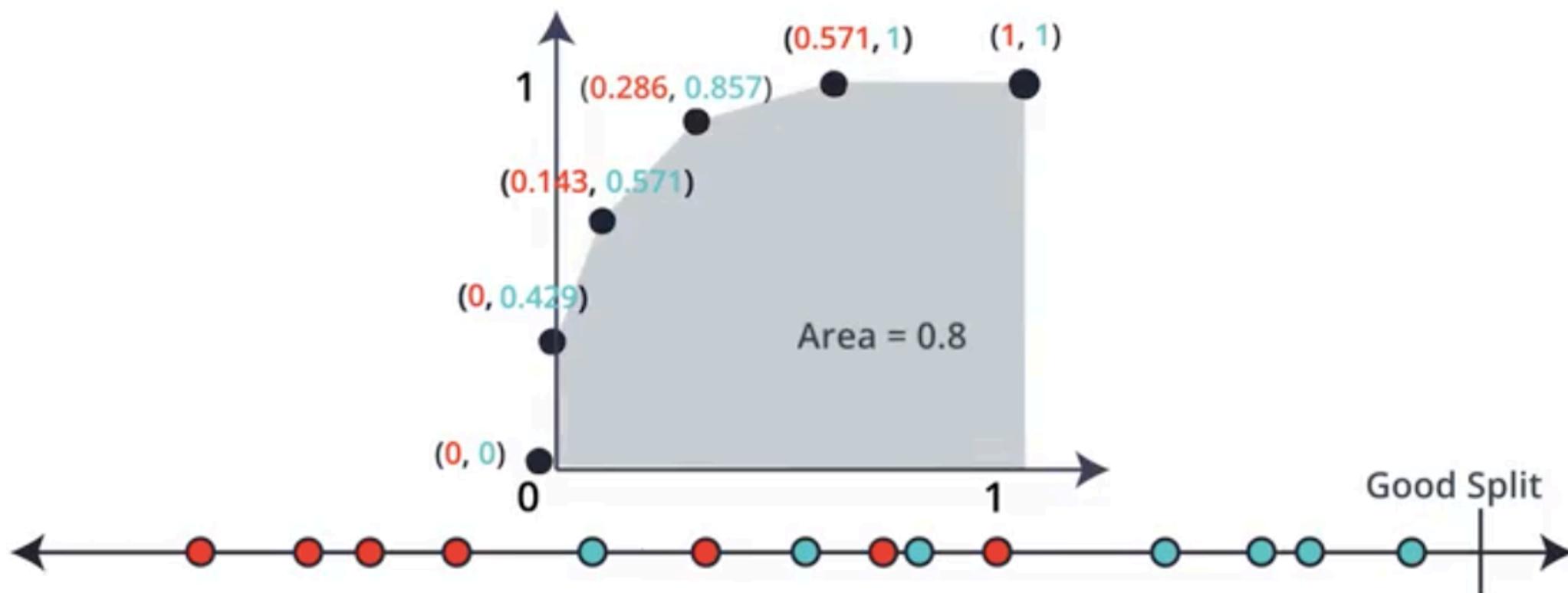
$$\frac{\text{TRUE POSITIVES}}{\text{ALL POSITIVES}} = \frac{0}{7} = 0$$

False Positive Rate =

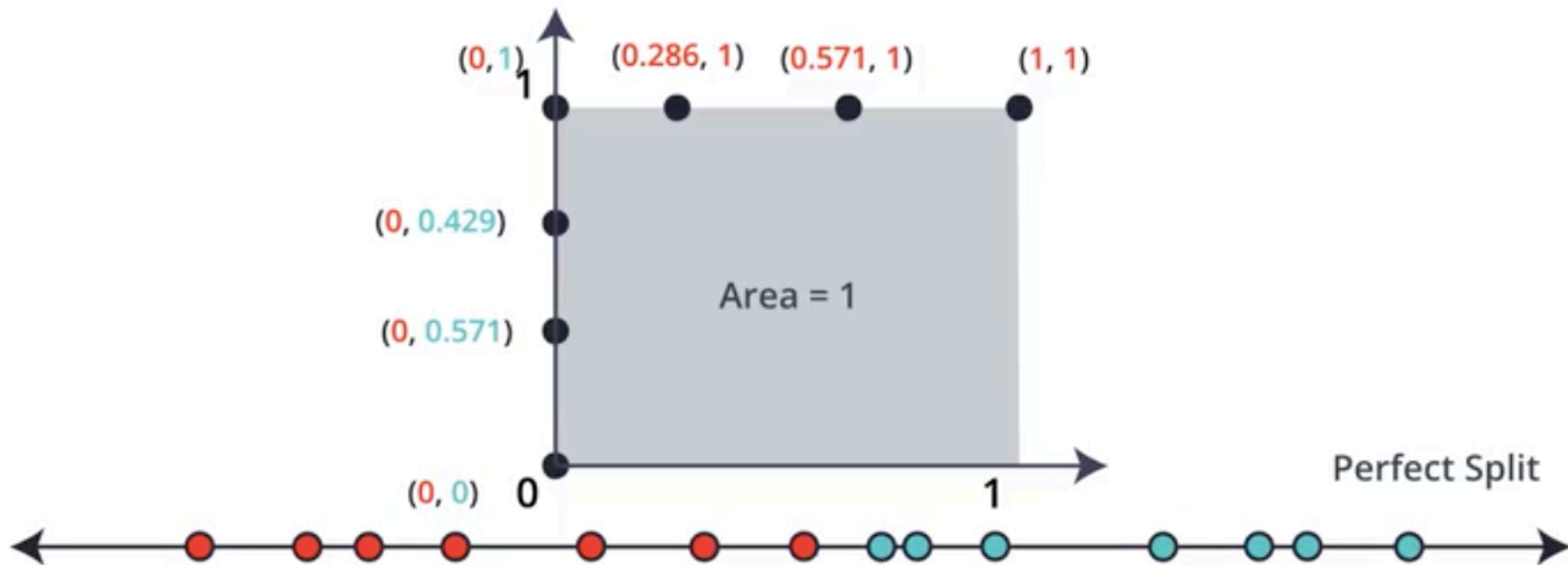
$$\frac{\text{FALSE POSITIVES}}{\text{ALL NEGATIVES}} = \frac{0}{7} = 0$$

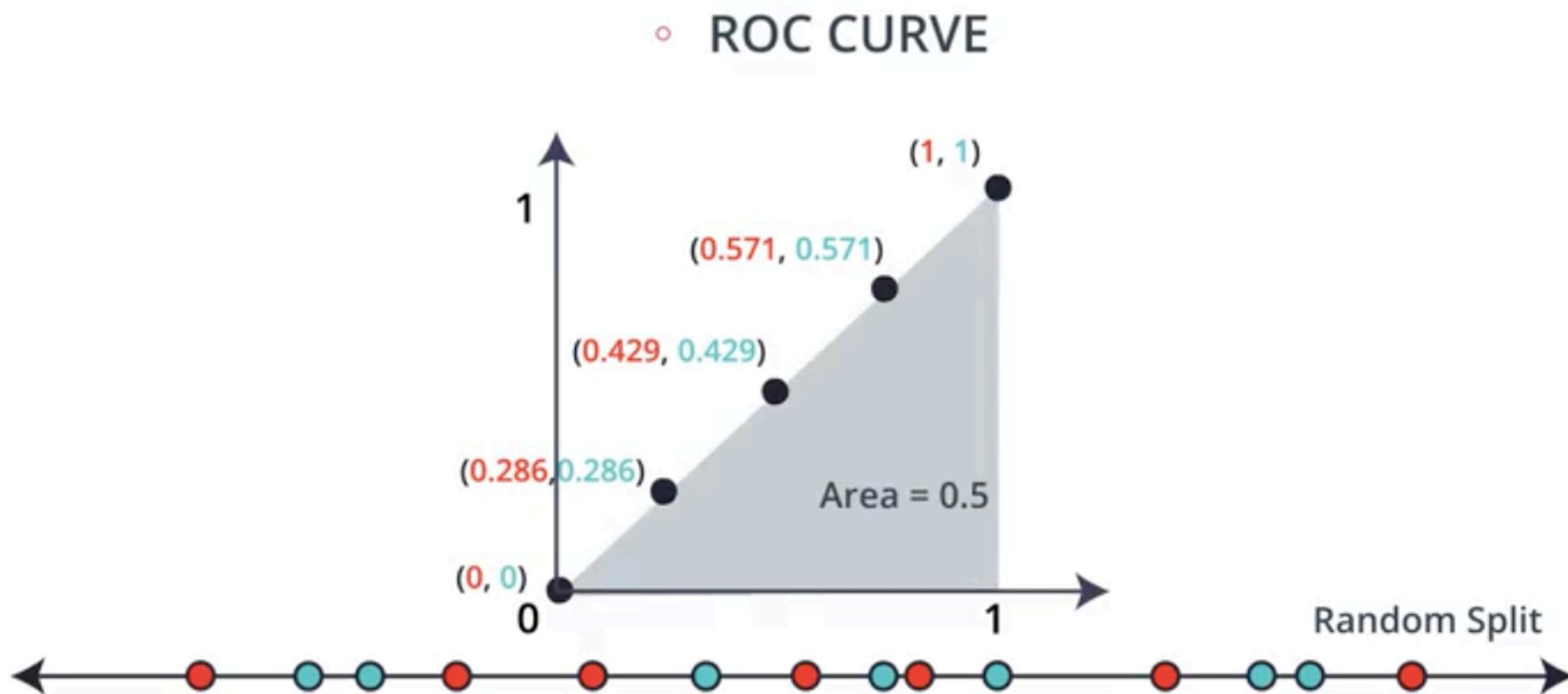


◦ ROC CURVE



ROC CURVE





- AREA UNDER A ROC CURVE



RANDOM SPLIT



GOOD SPLIT



PERFECT SPLIT

