

# INTRO TO CLASSIFICATION

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# OUR PROGRESS SO FAR

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## UNIT 1: RESEARCH DESIGN AND EXPLORATORY DATA ANALYSIS

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What is Data Science	Lesson 1
Research Design and Pandas	Lesson 2
Statistics Fundamentals I	Lesson 3
Statistics Fundamentals II	Lesson 4
Flexible Class Session	Lesson 5

## UNIT 2: FOUNDATIONS OF DATA MODELING

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Introduction to Regression	Lesson 6
Evaluating Model Fit	Lesson 7
› Introduction to Classification	Lesson 8
› Introduction to Logistic Regression	Lesson 9
› Communicating Logistic Regression Results	Lesson 10
› Flexible Class Session	Lesson 11

## UNIT 3: DATA SCIENCE IN THE REAL WORLD

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› Decision Trees and Random Forests	Lesson 12
› Natural Language Processing	Lesson 13
› Dimensionality Reduction	Lesson 14
› Time Series Data I	Lesson 15
› Time Series Data II	Lesson 16
› Database Technologies	Lesson 17
› Where to Go Next	Lesson 18
› Flexible Class Session	Lesson 19
› Final Project Presentations	Lesson 20

Today's Class



## LAST CLASS

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# WHAT DID WE LEARN?

- ✓ Define R-squares and residuals
- ✓ Define bias and error metrics for regression problems
- ✓ Understand cross validation
- ✓ Define regularization and grid search
- ✓ Evaluate model fit using Gradient Descent

You got all objectives?



Not all of them...

*Let's form groups of 1's and 2's ...*

## LAST CLASS

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# ANNOUNCEMENTS

- ❖ Unit Project 2 feedback & Final Project 1
- ❖ Moving to Rino Station starting next Thursday December 14<sup>th</sup>
- ❖ Parking is free on the streets behind the Rino Station building, and all of your key fobs should work now at Rino Station as well
- ❖ You will need to return your parking garage passes by Monday 12/11.

Will i ever get  
a parking  
pass?

Just need to play around with SKLearn a  
bunch. Have still been dedicating time  
playing around with pandas as much as  
possible since I think its foundational

Others?

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**QUIZ**

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# WHAT DO YOU KNOW ABOUT REGRESSION?

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## **QUIZ (25 min)**

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*The aim of this exercise is to predict the number of games that a Major-League Baseball team won that season, based on the teams statistics and other variables from that season.*

→ *Report the best performing model (Lowest MSE)*

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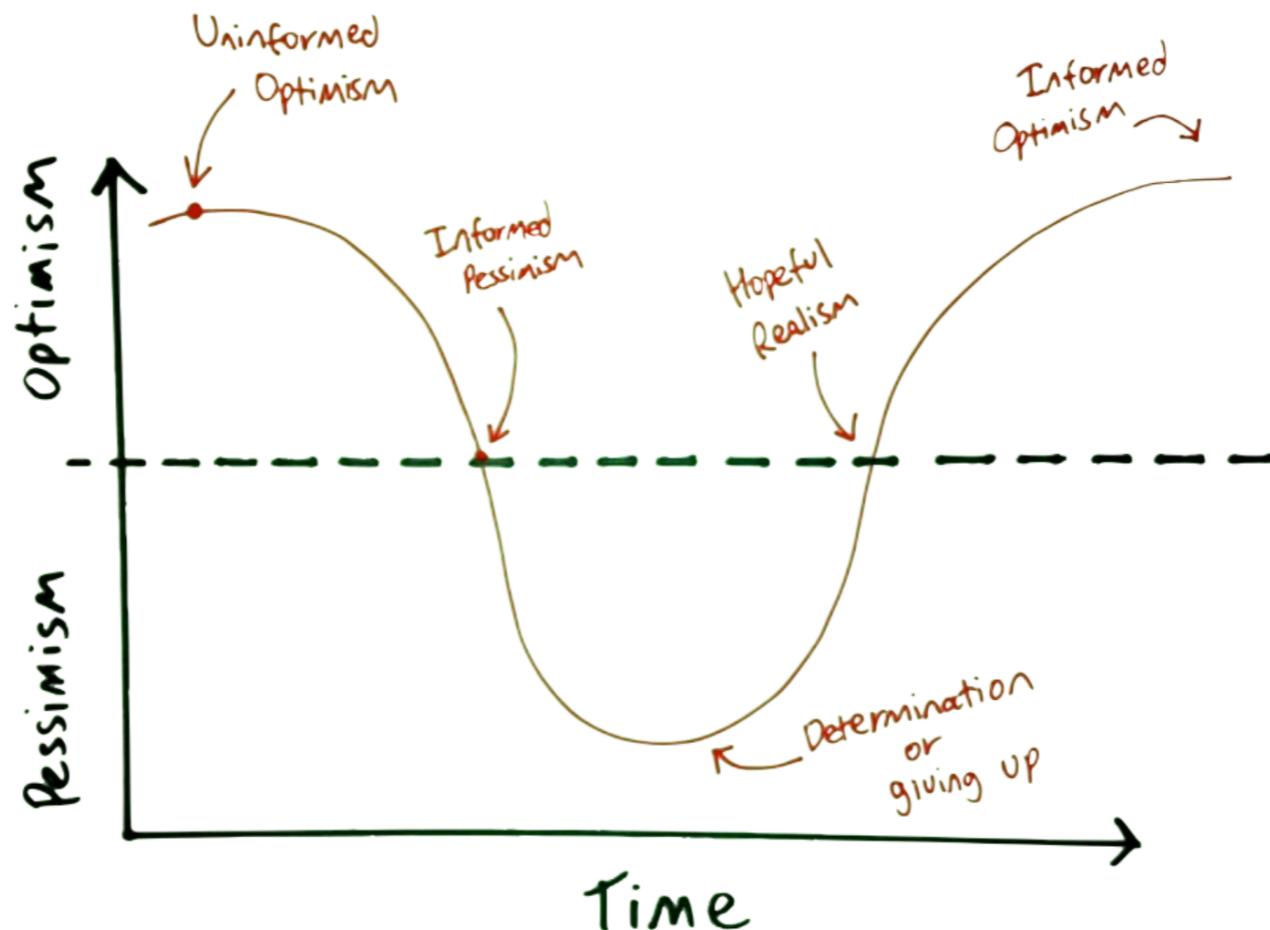
**REFRESH YOUR KNOWLEDGE**

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**BIG  
IMAGE**

## CLASS EXPECTATIONS

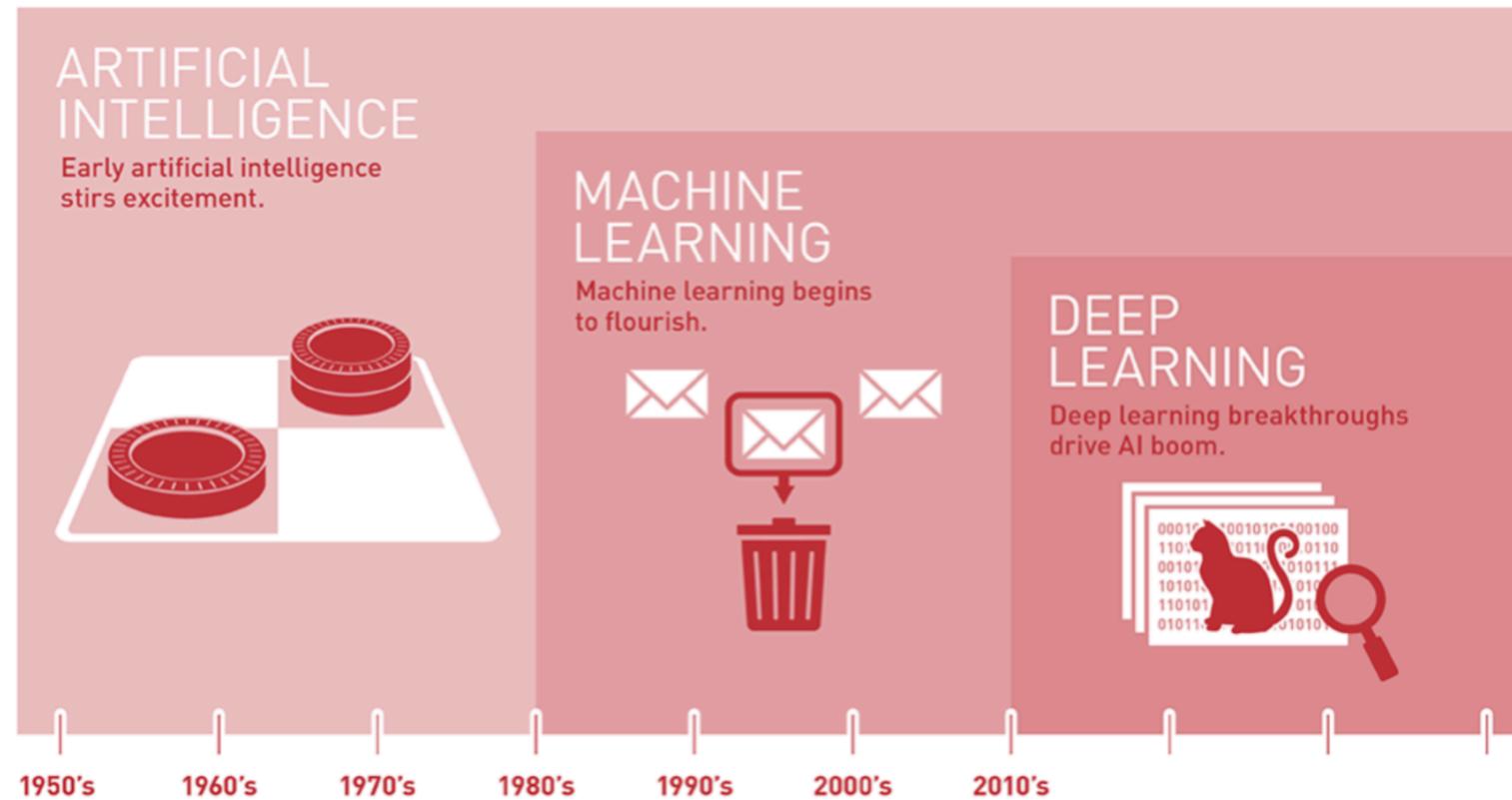
# Where Are You Now?



# WHAT IS MACHINE LEARNING

*[Machine Learning is the] field of study that gives computers the ability to learn without being explicitly programmed.*

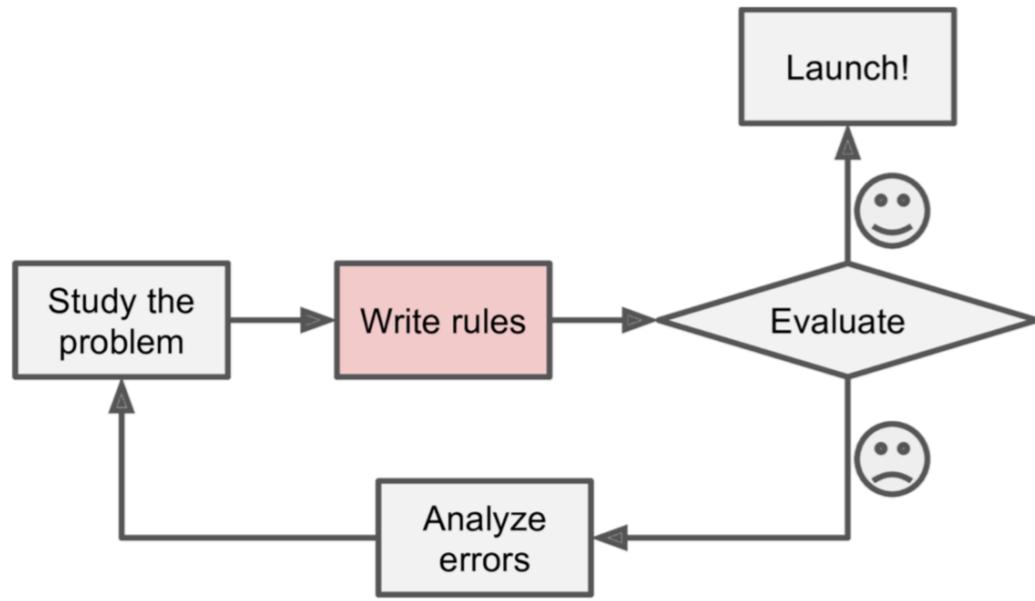
Arthur Samuel, 1959



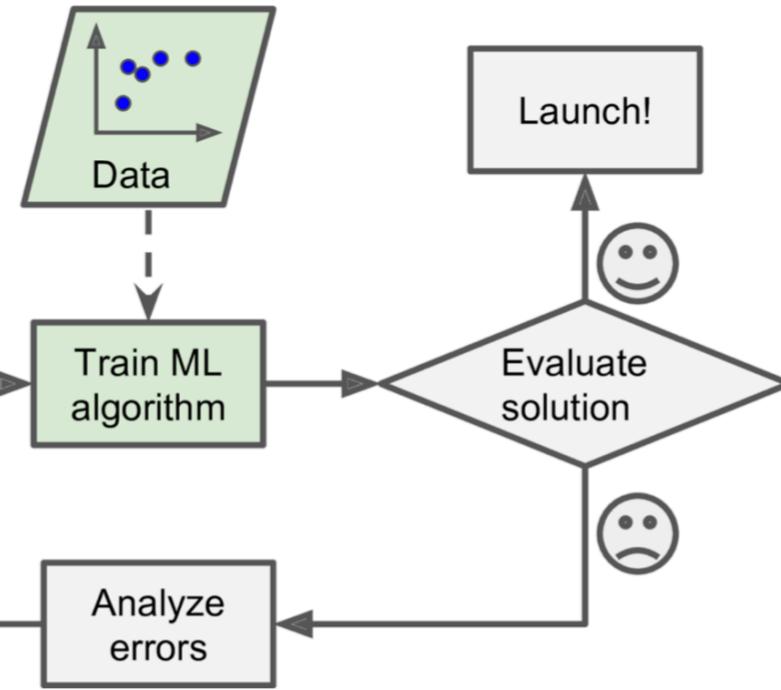
Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

**Machine Learning:** is the science (and art) of programming computers so they can *learn from data*.

# WHY TO USE MACHINE LEARNING?



*Traditional approach*



**Vs.**

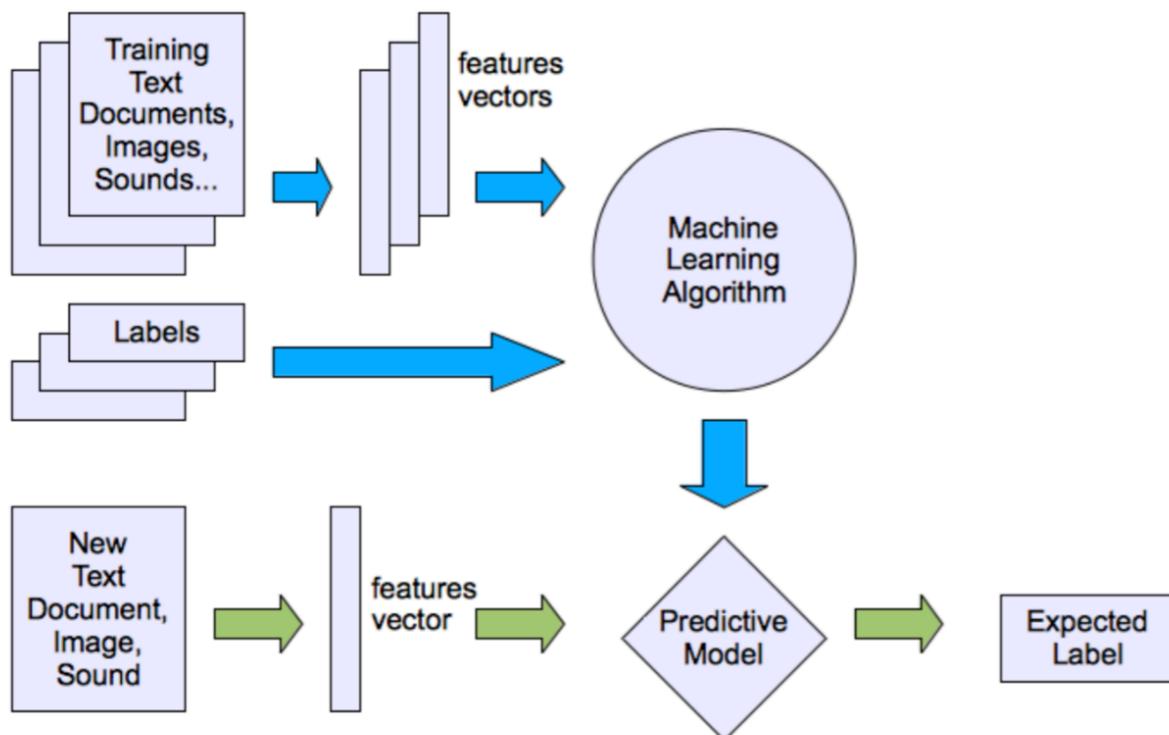
*Machine Learning approach*

**Did you know?**

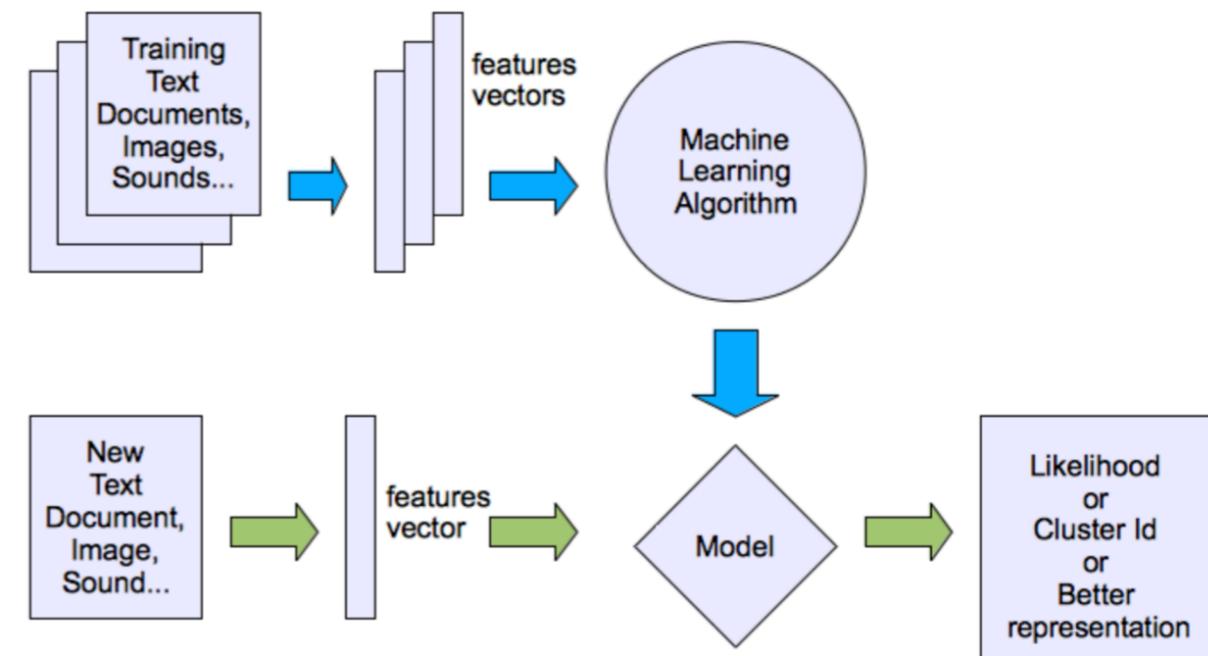
Machine learning algorithms are expected to replace 25% of the jobs across the world, in the next 10 years.

# TYPES OF MACHINE LEARNING

## Supervised



## Unsupervised



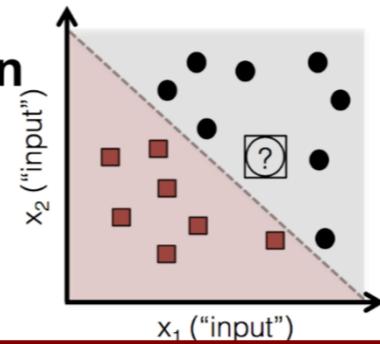
# TYPES OF MACHINE LEARNING

**Discrete**  
Countable Data

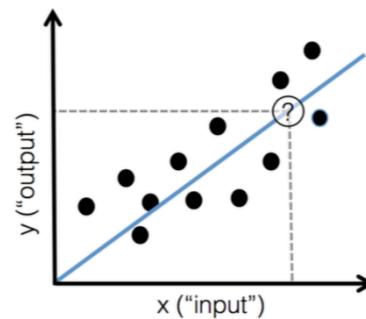
**Continuous**  
Infinite Data

**Supervised**  
Working with Labeled Data

**Classification**

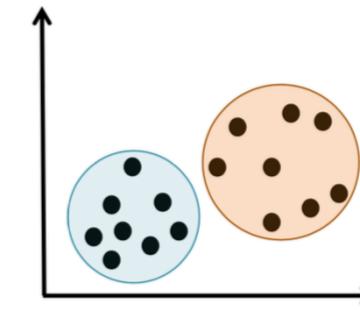


**Regression**

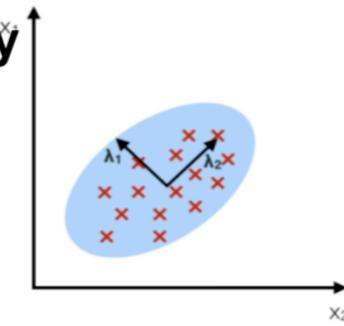


**Unsupervised**  
Working with Unlabeled Data

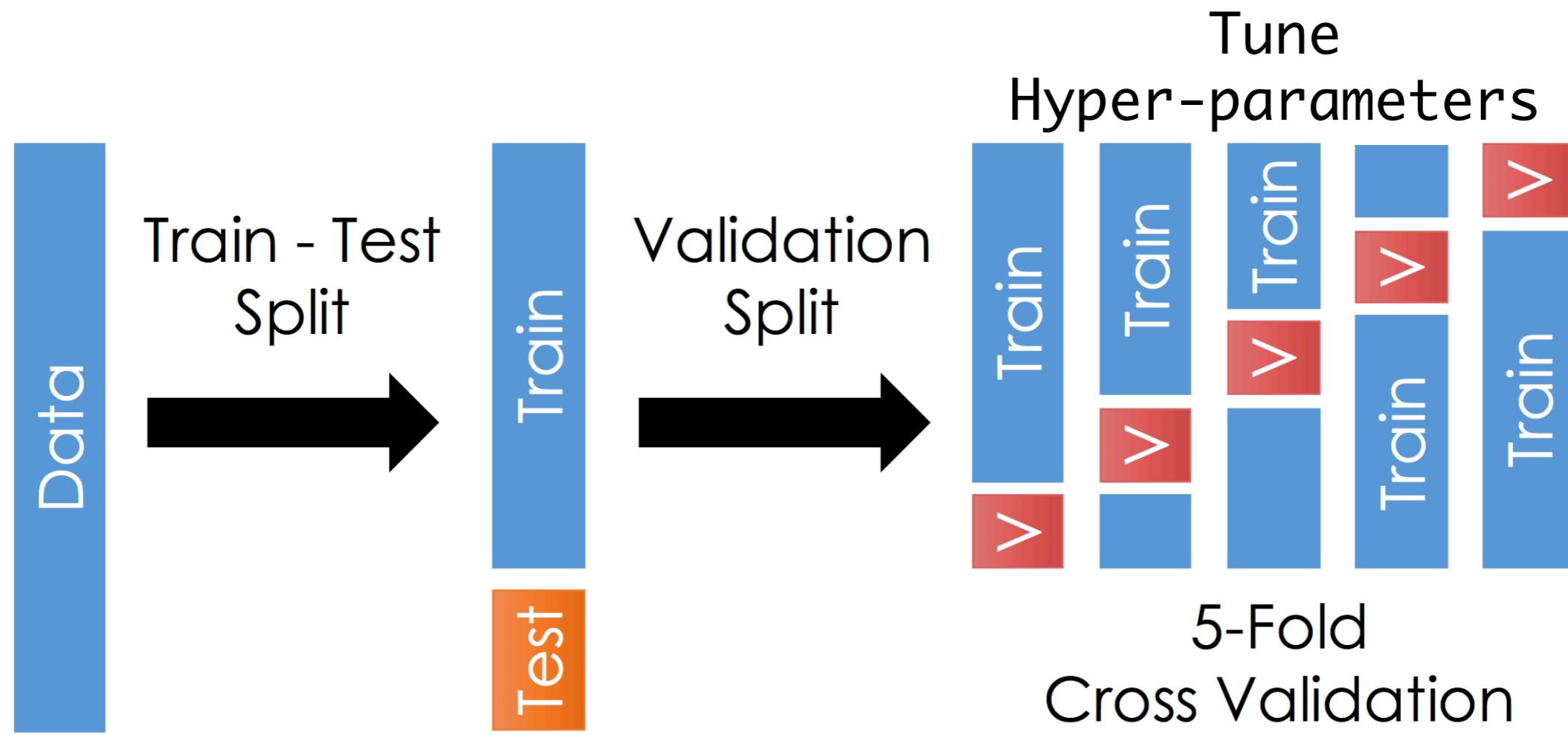
**Clustering**



**Dimensionality Reduction**



# TRAINING – VALIDATING - TESTING



## INTRO TO CLASSIFICATION

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# LEARNING OBJECTIVES

- Define class label and classification
- Build a K-Nearest Neighbors using the scikit-learn library
- Evaluate and tune model by using metrics such as classification accuracy/error

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**OPENING**

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# INTRO TO CLASSIFICATION

# INTRO TO CLASSIFICATION

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- So far, we've worked primarily with regression problems. We've focused on predicting a continuous set of values.
- In regression, 1 is greater than 0, and 100 is greater than 1.
- That means we've been able to use distance to measure how accurate our prediction is.
- However, for other problems, we need to predict binary responses.  
E.g.: A loan will default or it won't. An email is spam or isn't spam.

# ACTIVITY: KNOWLEDGE CHECK

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## ANSWER THE FOLLOWING QUESTIONS

1. What if we want to build a model to predict a set of values, like a photo color or the gender of a baby?
2. Can we use regression for binary values?
3. Do the same principles apply?

## DELIVERABLE

Answers to the above questions

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## INTRODUCTION

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# WHAT IS CLASSIFICATION?

# WHAT IS CLASSIFICATION?

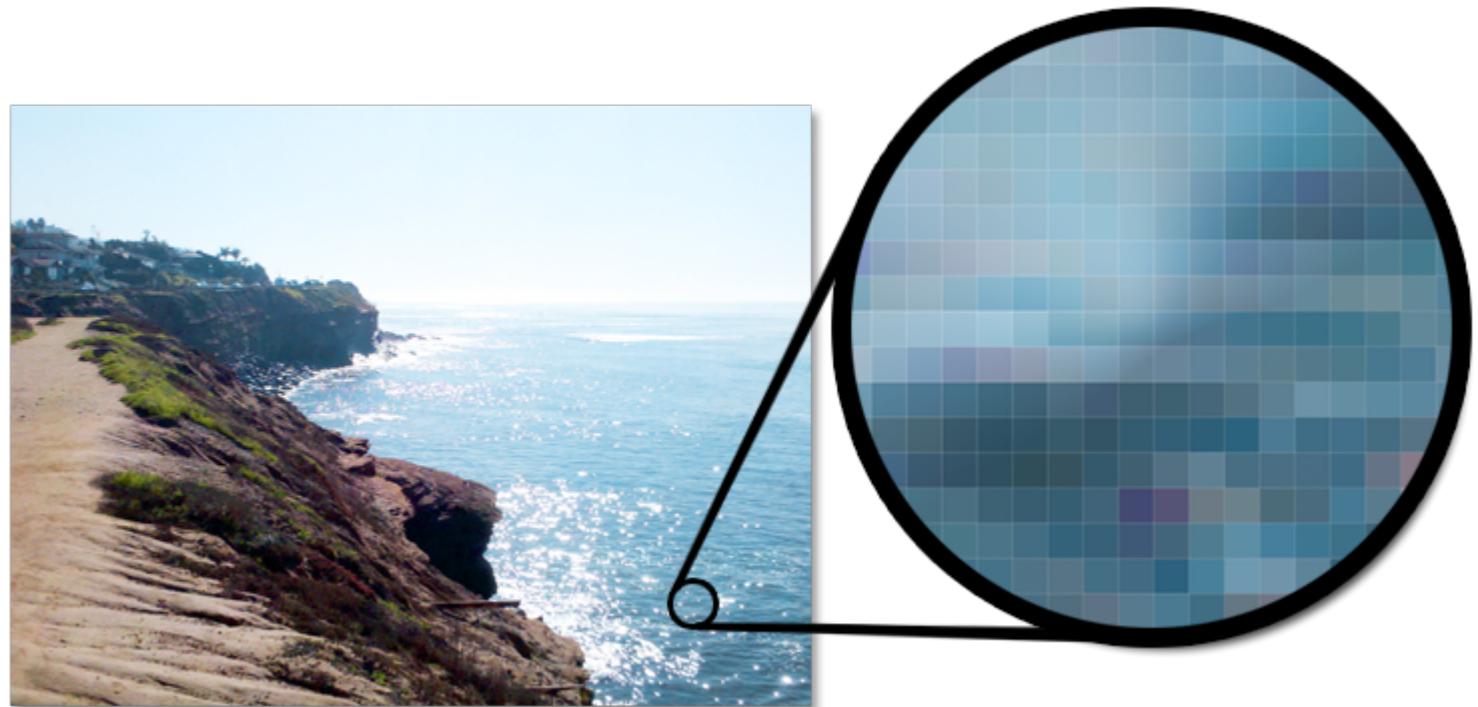
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- › **Classification** is a machine learning problem for solving a set value given the knowledge we have about that value.
- › Many classification problems are trying to predict *binary* values.
- › For example, we may be using patient data (medical history) to predict whether the patient is a smoker or not.

# WHAT IS CLASSIFICATION?

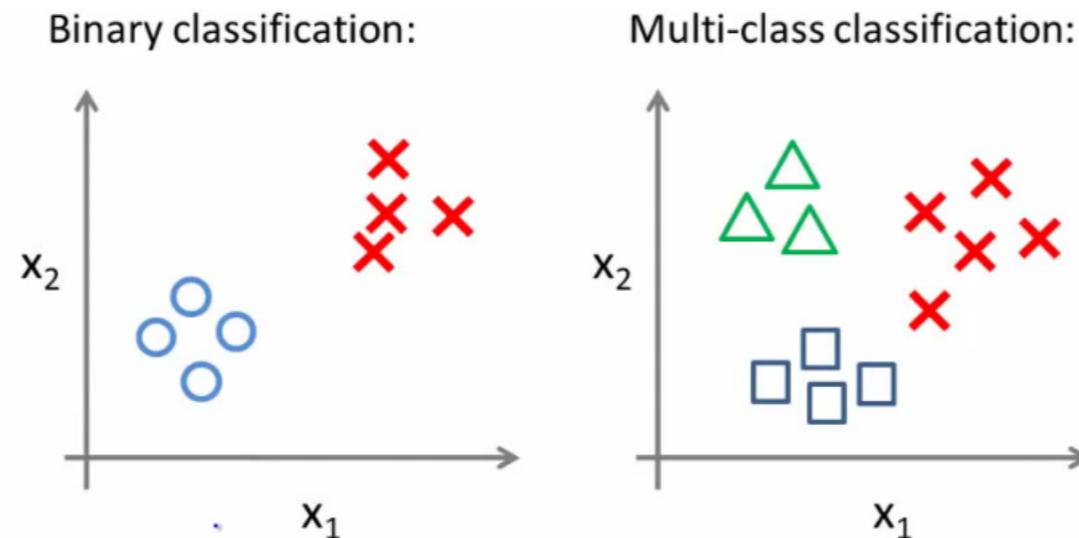
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- Some problems don't appear to be binary at first glance. However, you can boil down the response to a *boolean* (true/false) value.
- What if you are predicting whether an image pixel will be red or blue?
- We don't need to predict that a pixel is blue, just that it is not red.
- This is similar to the concept of dummy variables.



# WHAT IS CLASSIFICATION?

- › Binary classification is the simplest form of classification.
- › However, classification problems can have multiple *class labels*.
- › Instead of predicting whether the pixel is red or blue, you could predict whether the pixel is red, blue, or green.



# WHAT IS A CLASS LABEL?

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- A **class label** is a representation of what we are trying to predict: our *target*.
- Examples of class labels from before are:

Data Problem	Class Labels
Patient data problem	is smoker, is not smoker
pixel color	red, blue, green

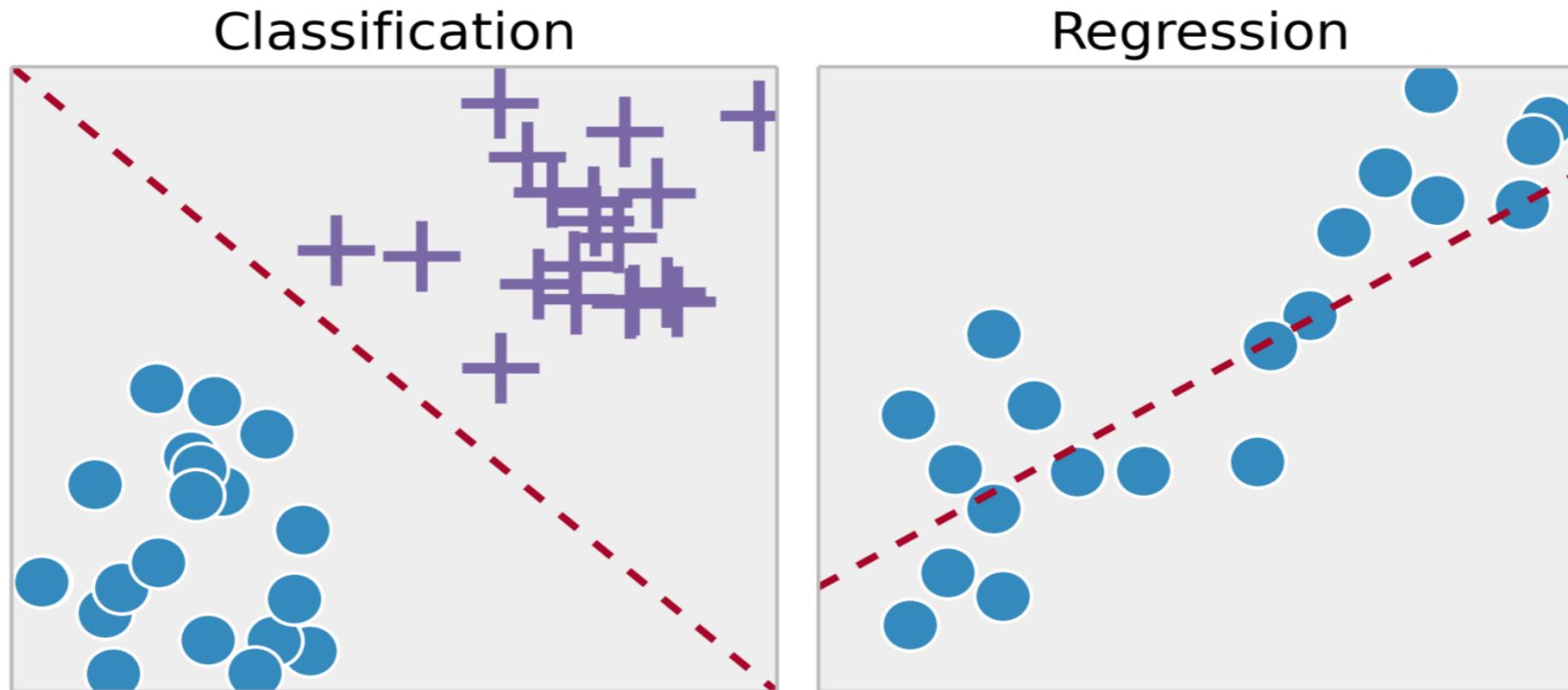
# DETERMINING REGRESSION OR CLASSIFICATION

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- One of the easiest ways to determine if a problem is regression or classification is to determine if our *target* variable can be ordered mathematically.
- For example, if predicting company revenue, \$100MM is greater than \$90MM. This is a *regression* problem because the target can be ordered.
- However, if predicting pixel color, red is not inherently greater than blue. Therefore, this is a *classification* problem.

# DETERMINING REGRESSION OR CLASSIFICATION

- Classification and regression differ in what you are trying to predict.



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## **GUIDED PRACTICE**

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# **REGRESSION OR CLASSIFICATION?**

# ACTIVITY: REGRESSION OR CLASSIFICATION?



## DIRECTIONS

Review the following situations and decide if each one is a regression problem, classification problem, or neither:

1. Using the total number of explosions in a movie, predict if the movie is by JJ Abrams or Michael Bay.
2. Determine how many tickets will be sold to a concert given who is performing, where, and the date and time.
3. Given the temperature over the last year by day, predict tomorrow's temperature outside.
4. Using data from four cell phone microphones, reduce the noisy sounds so the voice is crystal clear to the receiving phone.
5. With customer data, determine if a user will return or not in the next 7 days to an e-commerce website.

## DELIVERABLE

Answers to the above questions

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**INDEPENDENT PRACTICE**

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**BUILD A  
CLASSIFIER!**

# ACTIVITY: BUILD A CLASSIFIER!



## DIRECTIONS (20 minutes)

1. Re-explore the iris dataset and build a program that classifies each data point. Use if-else statements and some Pandas functions.
2. Measure the *accuracy* of your classifier using the math of “total correct” over “total samples”.
3. Your classifier should be able to:
  - a. Get one class label 100% correct (one type of iris is easily distinguishable from the other two).
  - b. Accurately predict the majority of the other two classes with some error (hint: make sure you *generalize*).

## DELIVERABLE

Classification program for the iris dataset

# ACTIVITY: BUILD A CLASSIFIER!

EXERCISE

## STARTER CODE

```
from sklearn import datasets, neighbors, metrics  
import pandas as pd
```

```
iris = datasets.load_iris()  
irisdf = pd.DataFrame(iris.data,  
columns=iris.feature_names)  
irisdf['target'] = iris.target  
cmap = {'0': 'r', '1': 'g', '2': 'b' }  
irisdf['ctarget'] = irisdf.target.apply(lambda x:  
cmap[str(x)])
```

# ACTIVITY: BUILD A CLASSIFIER!



## STARTER CODE

```
irisdf.plot('petal length (cm)', 'petal width (cm)',  
kind='scatter', c=irisdf.ctarget)  
print irisdf.plot('petal length (cm)', 'petal width (cm)',  
kind='scatter', c=irisdf.ctarget)  
print irisdf.describe()
```

# ACTIVITY: BUILD A CLASSIFIER!

## STARTER CODE

EXERCISE

```
# starter code
def my_classifier(row):
    if row['petal length (cm)'] < 2:
        return 0
    else:
        return 1

predictions = irisdf.apply(my_classifier, axis=1)
```

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# ACTIVITY: BUILD A CLASSIFIER!

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## DIRECTIONS

Answer the following questions.

1. How simple could the if-else classifier be while remaining *relatively* accurate?
2. How complicated could our if-else classifier be and remain *completely* accurate? How many if-else statements would you need, or nested if-else statements, in order to get the classifier 100% accurate? (The above uses a count of 2).
3. Which if-else classifier would work better against iris data that it hasn't seen? Why is that the case?

## DELIVERABLE

Answers to the above questions

## INTRO TO CLASSIFICATION

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# LEARNING OBJECTIVES

- ▶ ~~Define class label and classification~~
- ▶ Build a K-Nearest Neighbors using the scikit-learn library
- ▶ Evaluate and tune model by using metrics such as classification accuracy/error

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## INTRODUCTION

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# WHAT IS K NEAREST NEIGHBORS?

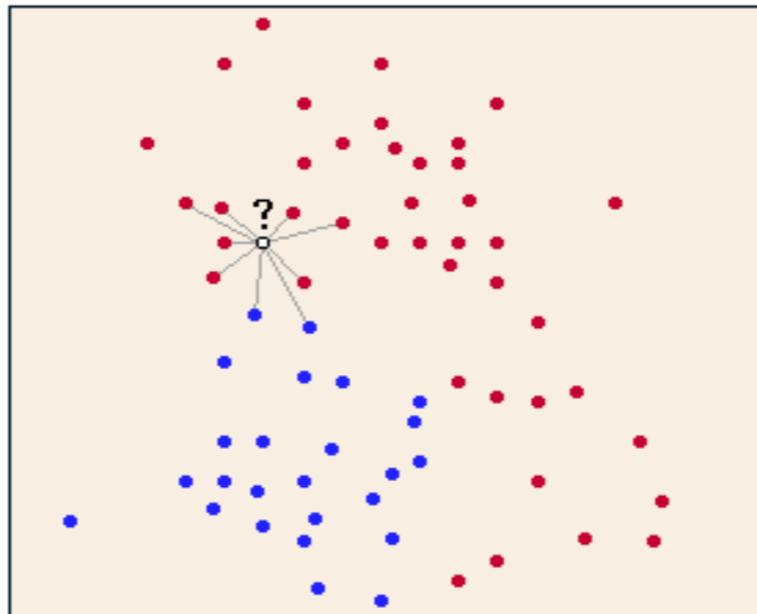
# WHAT IS K NEAREST NEIGHBORS?

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- **K Nearest Neighbors (KNN)** is a classification algorithm that makes a prediction based upon the closest data points.
- The KNN algorithm:
  - For a given point, calculate the distance to all other points.
  - Given those distances, pick the  $k$  closest points.
  - Calculate the probability of each class label given those points.
  - The original point is classified as the class label with the largest probability (“votes”).

# WHAT IS K NEAREST NEIGHBORS?

- KNN uses distance to predict a class label. This application of distance is used as a measure of similarity between classifications.
- We're using shared traits to identify the most likely class label.



# WHAT IS K NEAREST NEIGHBORS?

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- › Suppose we want to determine your favorite type of music. How might we determine this without directly asking you?
- › Generally, friends share similar traits and interests (e.g. music, sports teams, hobbies, etc). We could ask your five closest friends what their favorite type of music is and take the majority vote.
- › This is the idea behind KNN: we look for things similar to (or close to) our new observation and identify shared traits. We can use this information to make an educated guess about a trait of our new observation.

# ACTIVITY: KNOWLEDGE CHECK

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## ANSWER THE FOLLOWING QUESTIONS

1. In what other tasks do we use a heuristic similar to K Nearest Neighbors?

## DELIVERABLE

Answers to the above questions

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**DEMO**

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# KNN IN ACTION

## KNN IN ACTION

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- The following code demonstrates using KNN via sklearn.

```
from sklearn import datasets, neighbors, metrics
import pandas as pd

iris = datasets.load_iris()
# n_neighbors is our option in KNN. We'll tune this value to attempt
to improve our prediction.
knn = neighbors.KNeighborsClassifier(n_neighbors=5, weights=uniform)
knn.fit(iris.data[:,2:], iris.target)
print knn.predict(iris.data[:,2:])
print iris.target
print knn.score(iris.data[:,2:], iris.target) # returns mean accuracy
```

## WHAT HAPPENS IN TIES?

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- What happens if two classes get the same number of votes?
- This could happen in binary classification if we use an even number for  $k$ . This could also happen if there are multiple class labels.
- In sklearn, it will choose the class that it first saw in the *training set*.

## WHAT HAPPENS IN TIES?

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- We could implement a *weight*, taking into account the distance between the point and its neighbors.
- This can be done in sklearn by changing the `weights` parameter to “`distance`”.
- Try changing the `weights` parameter. How does this affect accuracy?

## WHAT HAPPENS IN HIGH DIMENSIONALITY?

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- Since KNN works with distance, higher dimensionality of data (i.e. more features) requires *significantly* more samples in order to have the same predictive power.
- Consider this: with more dimensions, all points slowly start averaging out to be equally distant. This causes significant issues for KNN.
- Keep the feature space limited and KNN will do well. Exclude extraneous features when using KNN.

## WHAT HAPPENS IN HIGH DIMENSIONALITY?

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- Consider two different examples: classifying users of a newspaper and users of a particular toothpaste.
- The features of the newspapers are very broad and there are many: sections, topics, types of stories, writers, online vs print, etc.
- However, the features of a toothpaste are more narrow: has fluoride, controls tartar, etc.
- For which problem would KNN work better?

## WHAT HAPPENS IN HIGH DIMENSIONALITY?

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- KNN would work better on classifying users of a particular toothpaste since the feature set is more narrow and distinct.

## INTRO TO CLASSIFICATION

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# LEARNING OBJECTIVES

- ▶ Define class label and classification
- ▶ Build a K Nearest Neighbors using the scikit-learn library
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## INTRODUCTION

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# CLASSIFICATION METRICS

# INTRODUCTION TO CLASSIFICATION METRICS

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- Metrics for regression do **not** apply to classification.
- We *could* measure the distance between the probability of a given class and an item being in that class. Guessing 0.6 for a 1 is a 0.4 error.
- But this overcomplicates our goal: understanding binary classification, whether something is black or white, right or wrong.
- To do this, we'll measure “correctness” or “incorrectness”.

# INTRODUCTION TO CLASSIFICATION METRICS

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- We'll use two primary metrics: *accuracy* and *misclassification rate*.
- **Accuracy** is the number of *correct* predictions out of all predictions in the sample. This is a value we want to *maximize*.
- **Misclassification rate** is the number of *incorrect* predictions out of all predictions in the sample. This is a value we want to *minimize*.
- These two metrics are directly opposite of each other.
- $1 - \text{misclassification rate} = \text{accuracy}$

# INTRODUCTION TO CLASSIFICATION METRICS

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- **WARNING:** You cannot use regression evaluation metrics for a classification problem, or vice versa. This is a common mistake.
- sklearn will not intuitively understand if you are doing regression or classification, so make sure to manually review your metrics.

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**INDEPENDENT PRACTICE**

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**SOLVING FOR K**

# ACTIVITY: SOLVING FOR K



## DIRECTIONS (35 minutes)

One of the primary challenges of KNN is solving for k - how many neighbors do we use?

The **smallest** k we can use is 1. However, using only one neighbor will probably perform poorly.

The largest k we can use is  $n-1$  (every other point in the data set). However, this would result in always choosing the largest class in the sample. This would also perform poorly.

Use the lesson 8 starter code and the iris data set to answer the following questions:

1. What is the accuracy for  $k=1$ ?
2. What is the accuracy for  $k=n-1$ ?
3. Using cross validation, what value of k optimizes model accuracy. Create a plot with  $k$  as the x-axis and *accuracy* as the y-axis (called a “fit chart”) to help find the answer.

## DELIVERABLE

Answers to the above questions

# ACTIVITY: SOLVING FOR K



## STARTER CODE

```
from sklearn import grid_search  
  
params = {'n_neighbors': }  
  
gs = grid_search.GridSearchCV(  
    estimator=,  
    param_grid=,  
    cv=,  
)  
gs.fit(iris.data, iris.target)  
gs.grid_scores_
```

# ACTIVITY: SOLVING FOR K

## DIRECTIONS

EXERCISE

### Bonus Questions:

1. By default, the KNN classifier in sklearn uses the *Minkowski metric* for distance.
  - a. What *type* of data does this metric work best for?
  - b. What *type* of data does this distance metric not work for?
  - c. You can read about distance metrics in [the sklearn documentation](#).

## DELIVERABLE

Answers to the above questions

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**CONCLUSION**

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**TOPIC REVIEW**

## REVIEW

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- What are class labels? What does it mean to classify?
- How is a classification problem different from a regression problem?  
How are they similar?
- How does the KNN algorithm work?
- What primary parameters are available for tuning a KNN estimator?
- How do you define: accuracy, misclassification?

# TIPS FOR KNN

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## Pros:

- Very easy to understand and implement.
- Does not assume any probability distributions on the input data.
- Can quickly respond to changes in input.

## Cons:

- Sensitive to localized data.
- Computation time.
- Dimensions: in the case of many dimensions, inputs can commonly be "close" to many data points.

## INTRO TO CLASSIFICATION

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# LEARNING OBJECTIVES

- ▶ Define class label and classification
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- ▶ Evaluate and tune model by using metrics such as classification accuracy/error

COURSE

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BEFORE NEXT  
CLASS

# OUR PROGRESS SO FAR

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Next Class

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## **BEFORE NEXT CLASS**

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## **DUE DATE**

- Start with Home Extra Lab
- Project: Unit Project 3 due Thursday Dec 14<sup>th</sup>
- Next Class: mid-class survey

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**LESSON**

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**Q & A**

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**LESSON**

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# **EXIT TICKET**

**DON'T FORGET TO FILL OUT YOUR EXIT TICKET**