Supervised learning

SUPERVISED LEARNING WITH SCIKIT-LEARN

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What is machine learning?

- The art and science of:
  - Giving computers the ability to learn to make decisions from data
  - without being explicitly programmed!
- Examples:
  - Learning to predict whether an email is spam or not
  - Clustering wikipedia entries into different categories
- Supervised learning: Uses labeled data
- Unsupervised learning: Uses unlabeled data

Unsupervised learning

- Uncovering hidden patterns from unlabeled data
- Example:
  - Grouping customers into distinct categories (Clustering)

Reinforcement learning

- Software agents interact with an environment
  - Learn how to optimize their behavior
  - Given a system of rewards and punishments
  - Draws inspiration from behavioral psychology
- Applications
  - Economics
  - Genetics
  - Game playing
- AlphaGo: First computer to defeat the world champion in Go

Supervised learning

- Predictor variables/features and a target variable
- Aim: Predict the target variable, given the predictor variables
  - Classification: Target variable consists of categories
  - Regression: Target variable is continuous

Predictor variables

	sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)
0	5.1	3.5	1.4	0.2
1	4.9	3.0	1.4	0.2
2	4.7	3.2	1.3	0.2
3	4.6	3.1	1.5	0.2
4	5.0	3.6	1.4	0.2

Target variable

species
setosa
setosa
setosa
setosa
setosa

Naming conventions

- Features = predictor variables = independent variables
- Target variable = dependent variable = response variable

Supervised learning

- Automate time-consuming or expensive manual tasks
  - Example: Doctor's diagnosis
- Make predictions about the future
  - Example: Will a customer click on an ad or not?
- Need labeled data
  - Historical data with labels
  - Experiments to get labeled data
  - Crowd-sourcing labeled data

Supervised learning in Python

- We will use scikit-learn/sklearn
    - Integrates well with the SciPy stack
- Other libraries
    - TensorFlow
    - keras

Let's practice!

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Exploratory data analysis

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The Iris dataset

Features:

- Petal length
- Petal width
- Sepal length
- Sepal width

Target variable: Species

- Versicolor
- Virginica
- Setosa

The Iris dataset in scikit-learn

```
from sklearn import datasets
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
plt.style.use('ggplot')
iris = datasets.load_iris()
type(iris)
```

```
sklearn.datasets.base.Bunch
```

```
print(iris.keys())
```

```
dict_keys(['data', 'target_names', 'DESCR', 'feature_names', 'target'])
```

The Iris dataset in scikit-learn

```
type(iris.data), type(iris.target)
```

```
(numpy.ndarray, numpy.ndarray)
```

```
iris.data.shape
```

```
(150, 4)
```

```
iris.target_names
```

```
array(['setosa', 'versicolor', 'virginica'], dtype='<U10')
```

Exploratory data analysis (EDA)

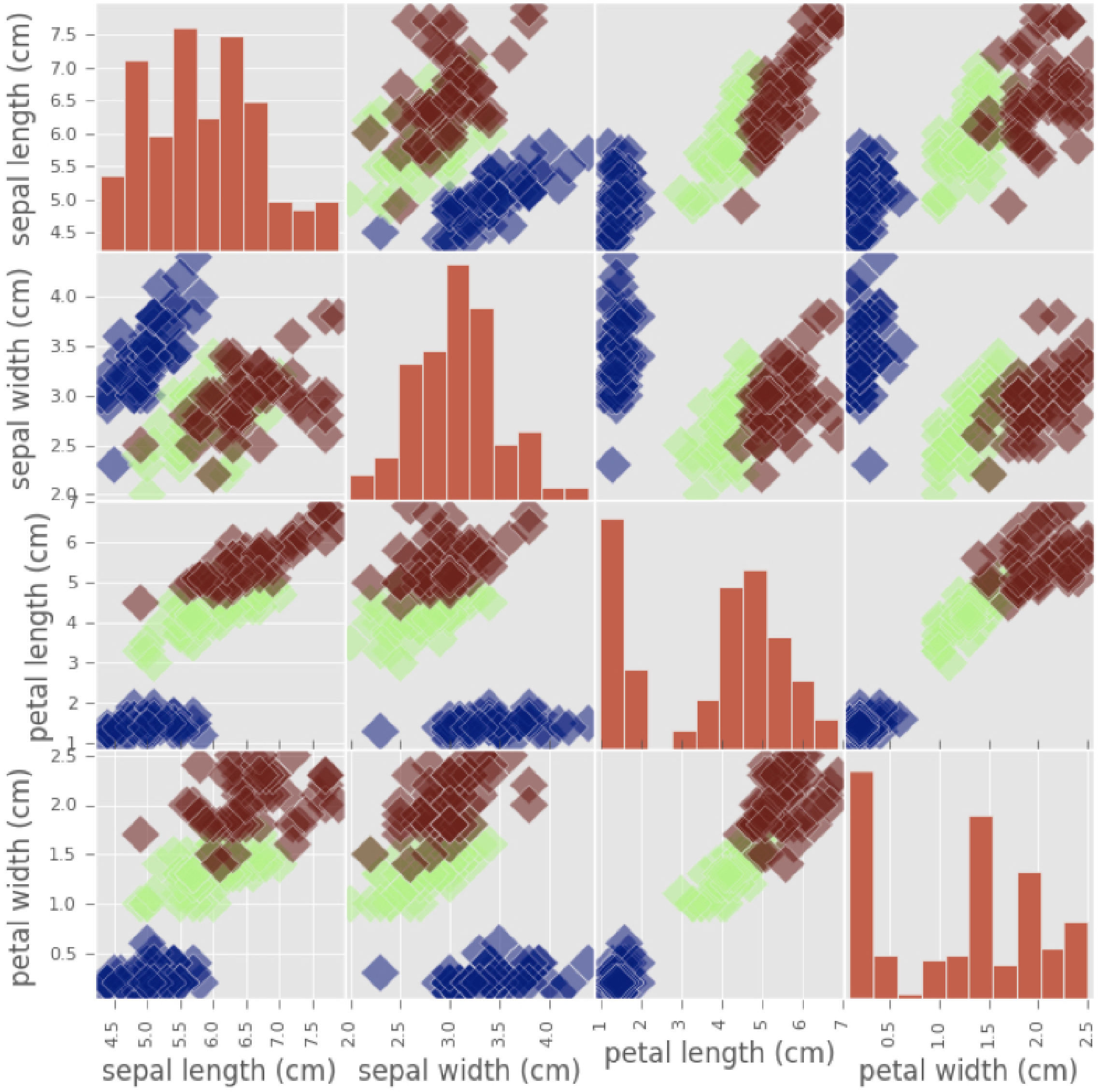
```
X = iris.data
y = iris.target
df = pd.DataFrame(X, columns=iris.feature_names)
print(df.head())
```

```
   sepal length (cm)  sepal width (cm)  petal length (cm)  petal width (cm)
0                5.1               3.5                1.4               0.2
1                4.9               3.0                1.4               0.2
2                4.7               3.2                1.3               0.2
3                4.6               3.1                1.5               0.2
4                5.0               3.6                1.4               0.2
```

Visual EDA

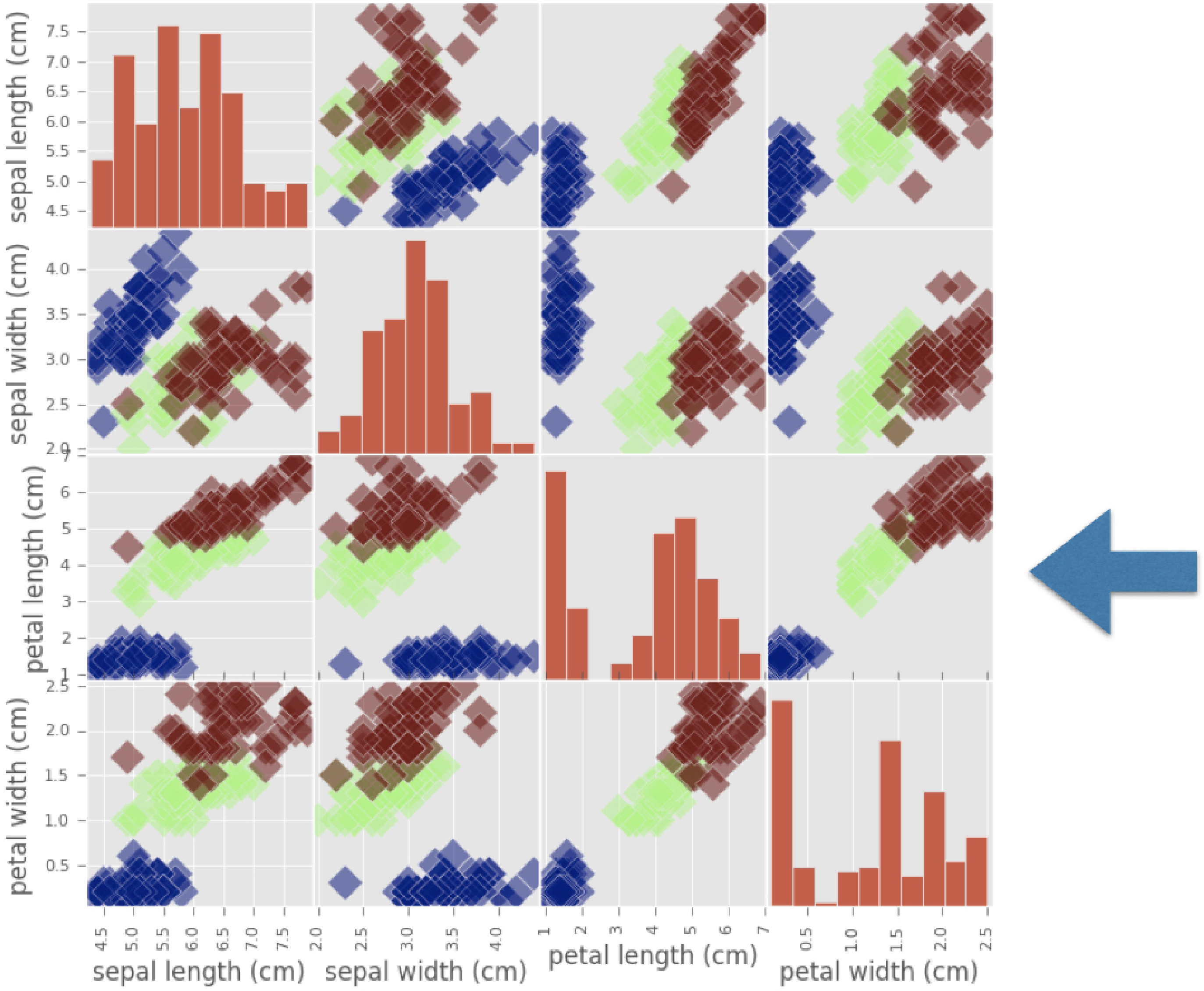
```
_ = pd.plotting.scatter_matrix(df, c = y, figsize = [8, 8],
                               s=150, marker = 'D')
```

Visual EDA



sepal length (cm)
sepal width (cm)
petal length (cm)
petal width (cm)

Visual EDA



sepal length (cm)
sepal width (cm)
petal length (cm)
petal width (cm)

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The classification challenge

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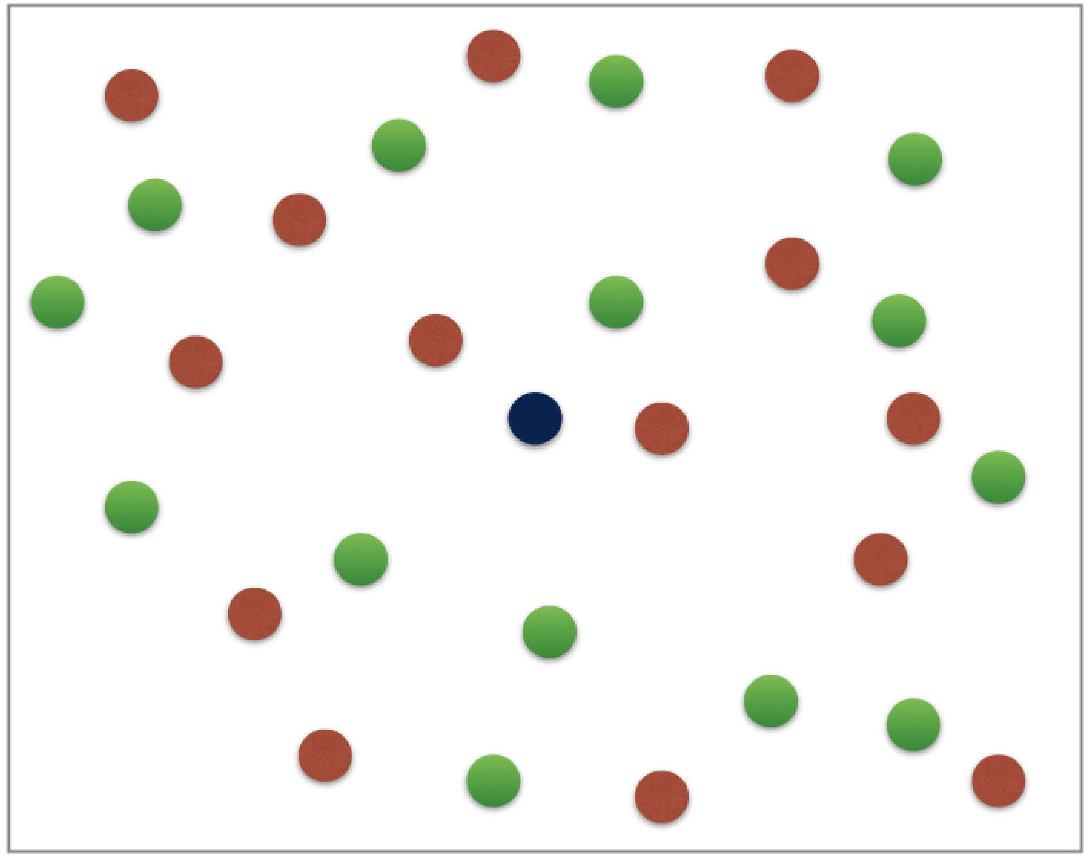
We have a set of labeled data and we want to build a classifier that takes unlabeled data as input and outputs a label.
So how do we construct this classifier?
We first need choose a type of classifier and it needs to learn from the already labeled data.
For this reason, we call the already labeled data the training data.
So let's build our first classifier!

k-Nearest Neighbors

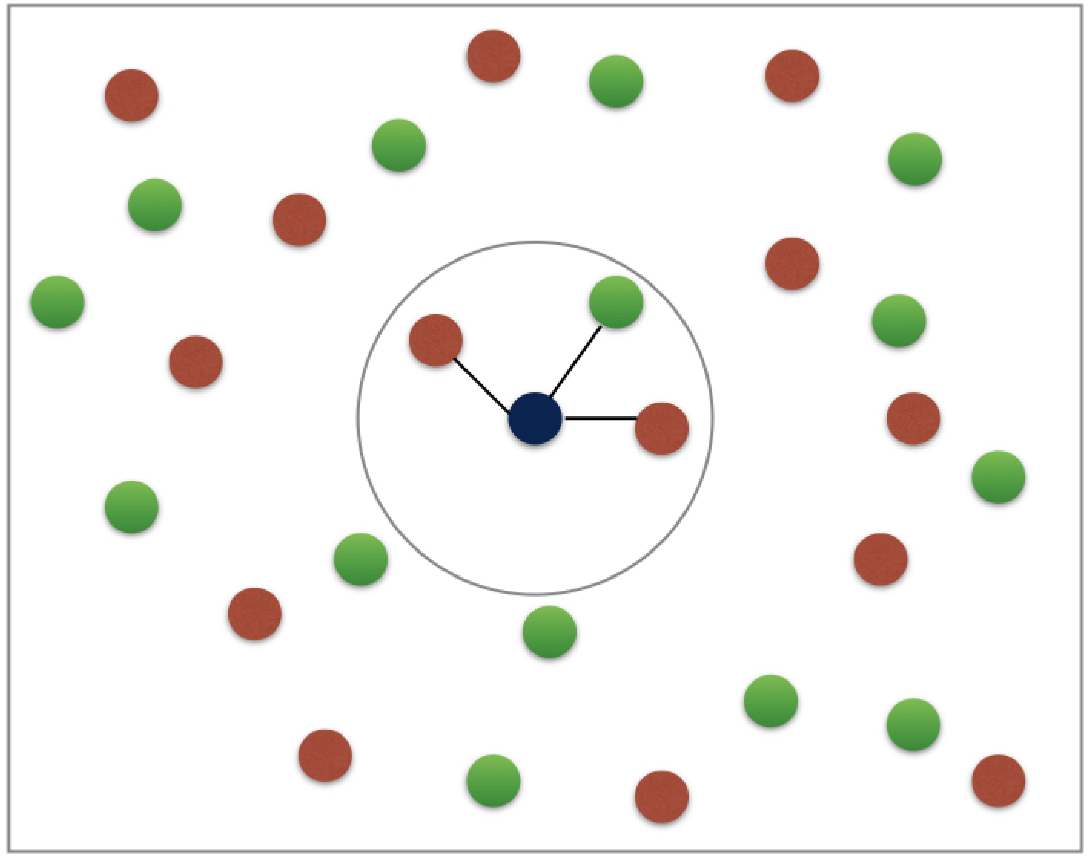
- Basic idea: Predict the label of a data point by
  - Looking at the 'k' closest labeled data points
  - Taking a majority vote

kjdfkldfjgkdfgjdfl;gksdgkfdjgdgkdsljgkfdlgnfjdkghfkj
gkfdkjghdfjkgdf
klgjdfkgjdf
fgjdflkg
kfgjdflk
kfgldfkg
kgjdflk
kdgkldf

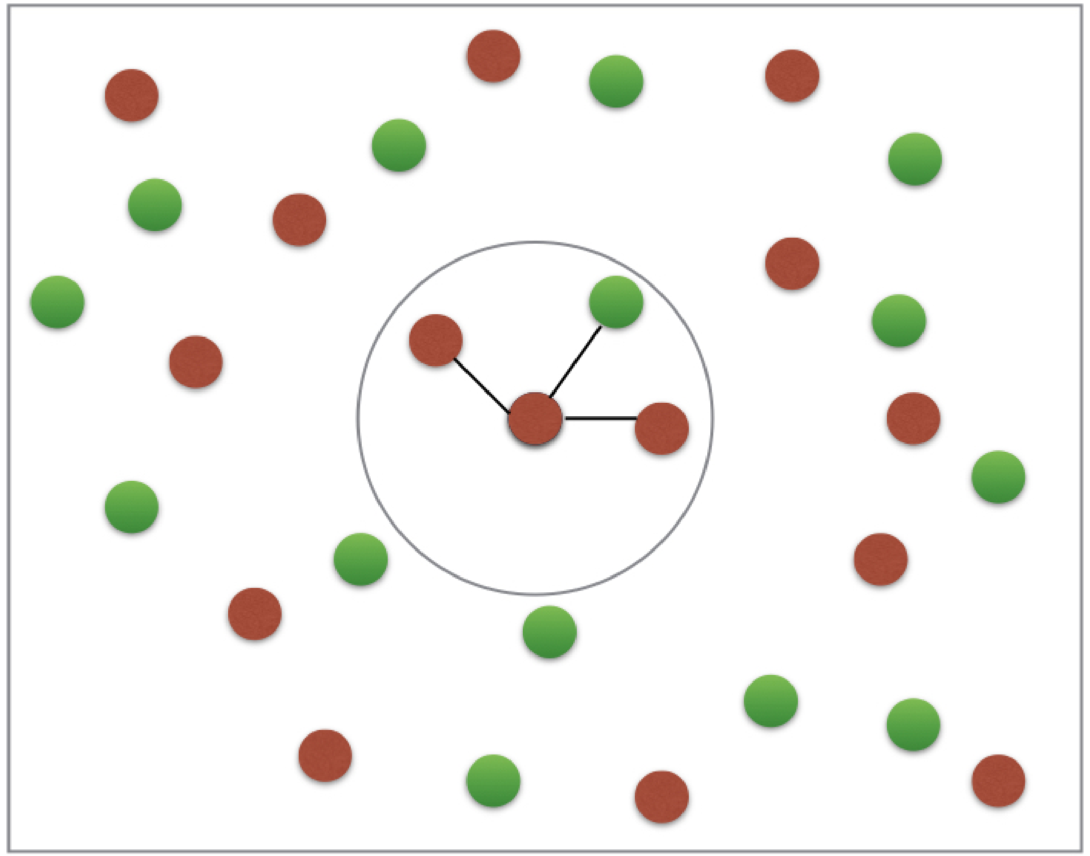
k-Nearest Neighbors



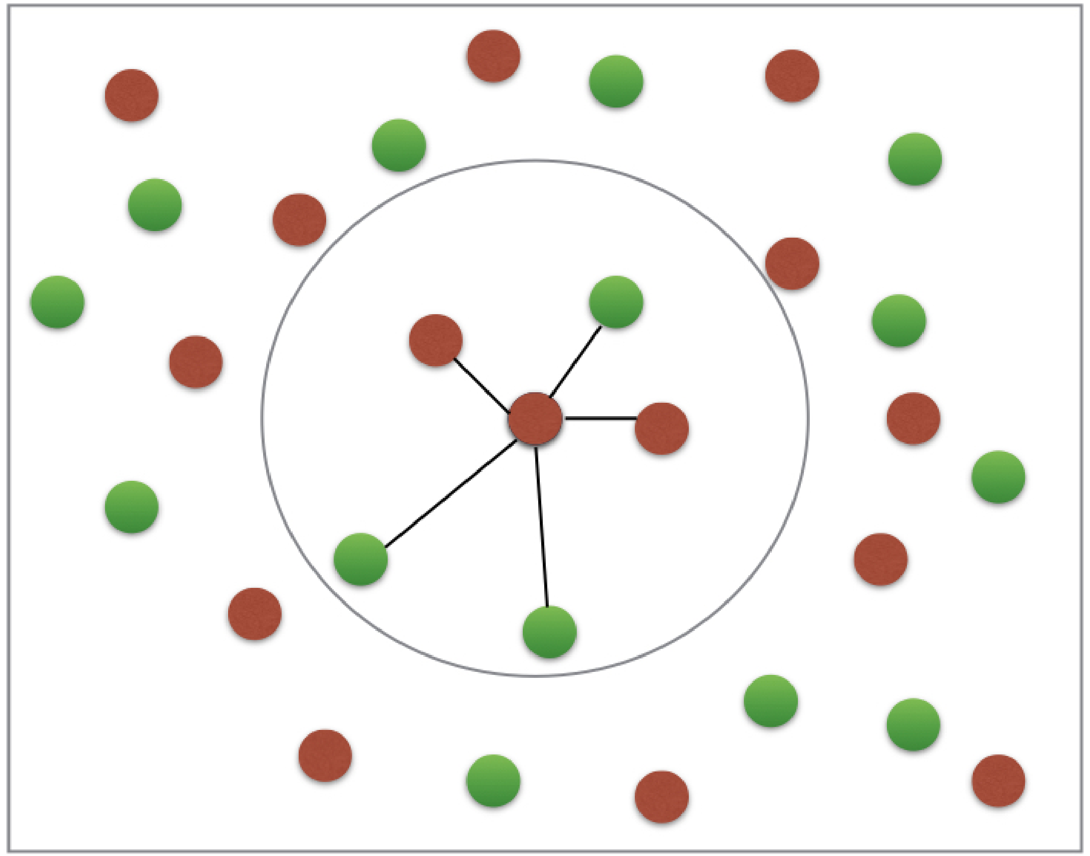
k-Nearest Neighbors



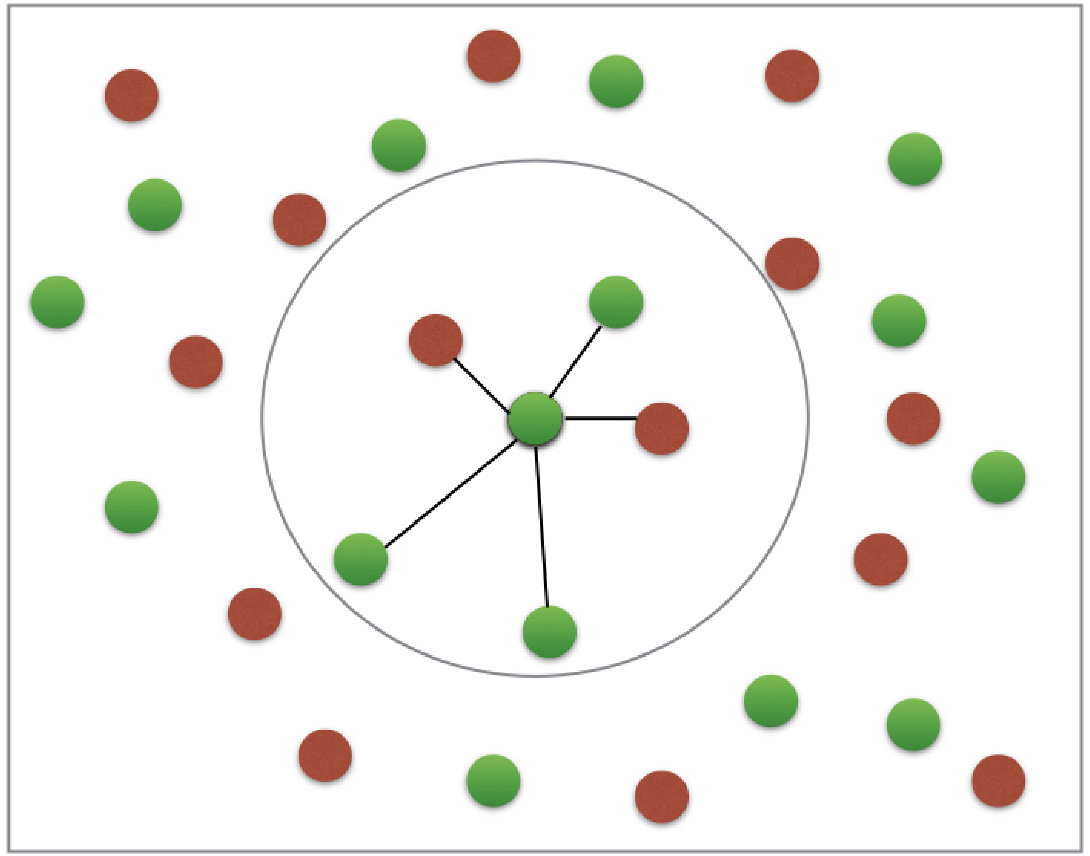
k-Nearest Neighbors



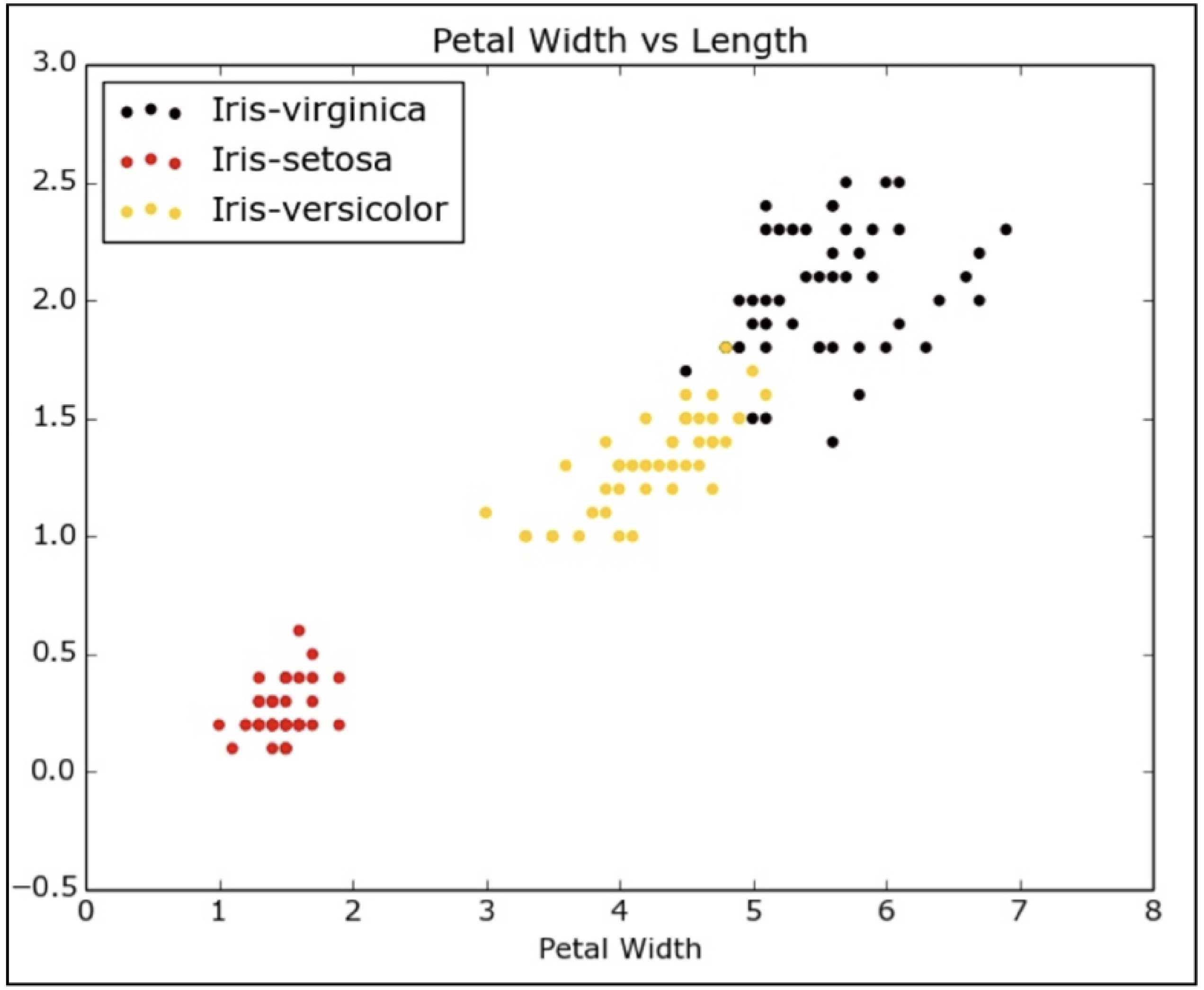
k-Nearest Neighbors



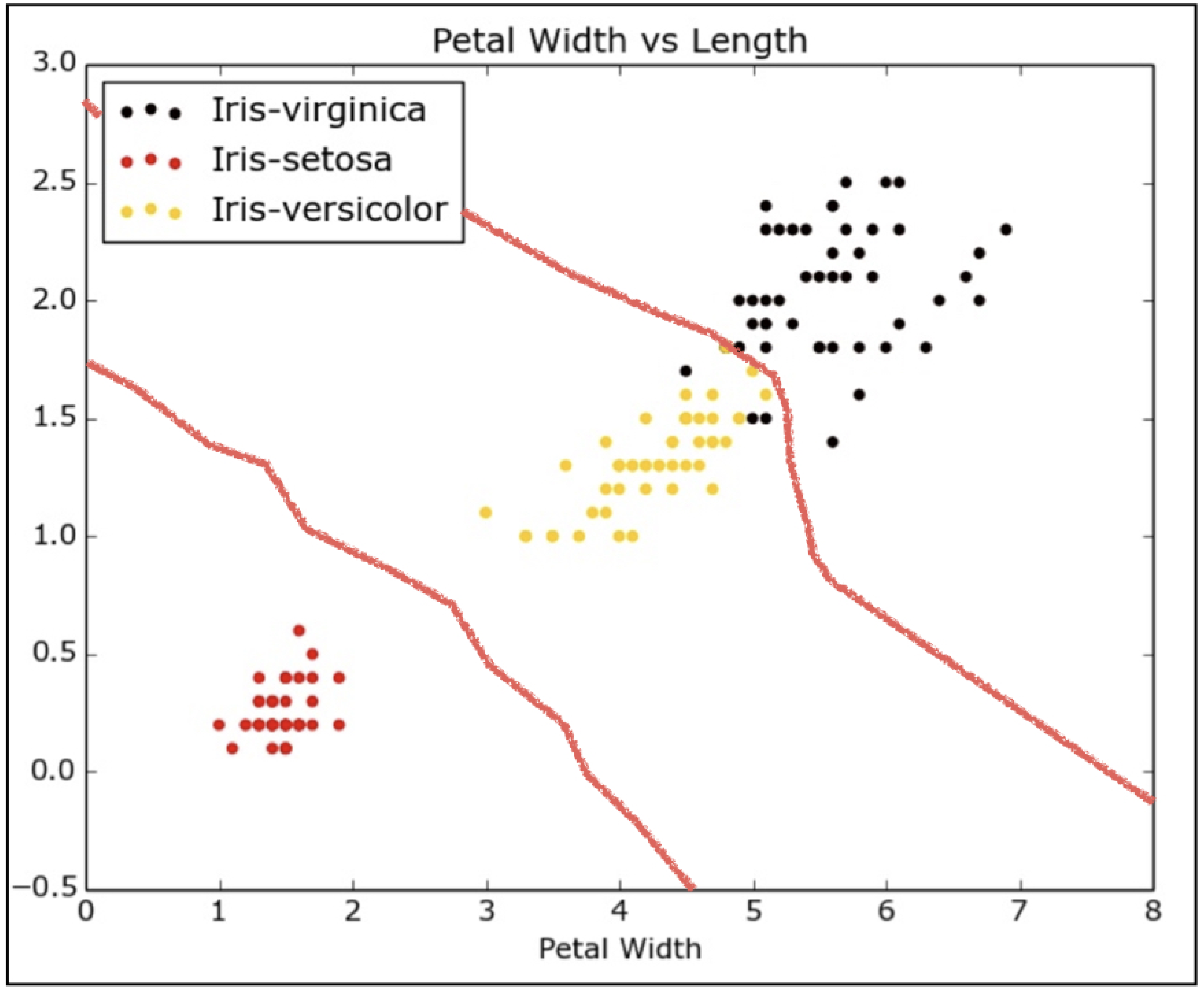
k-Nearest Neighbors



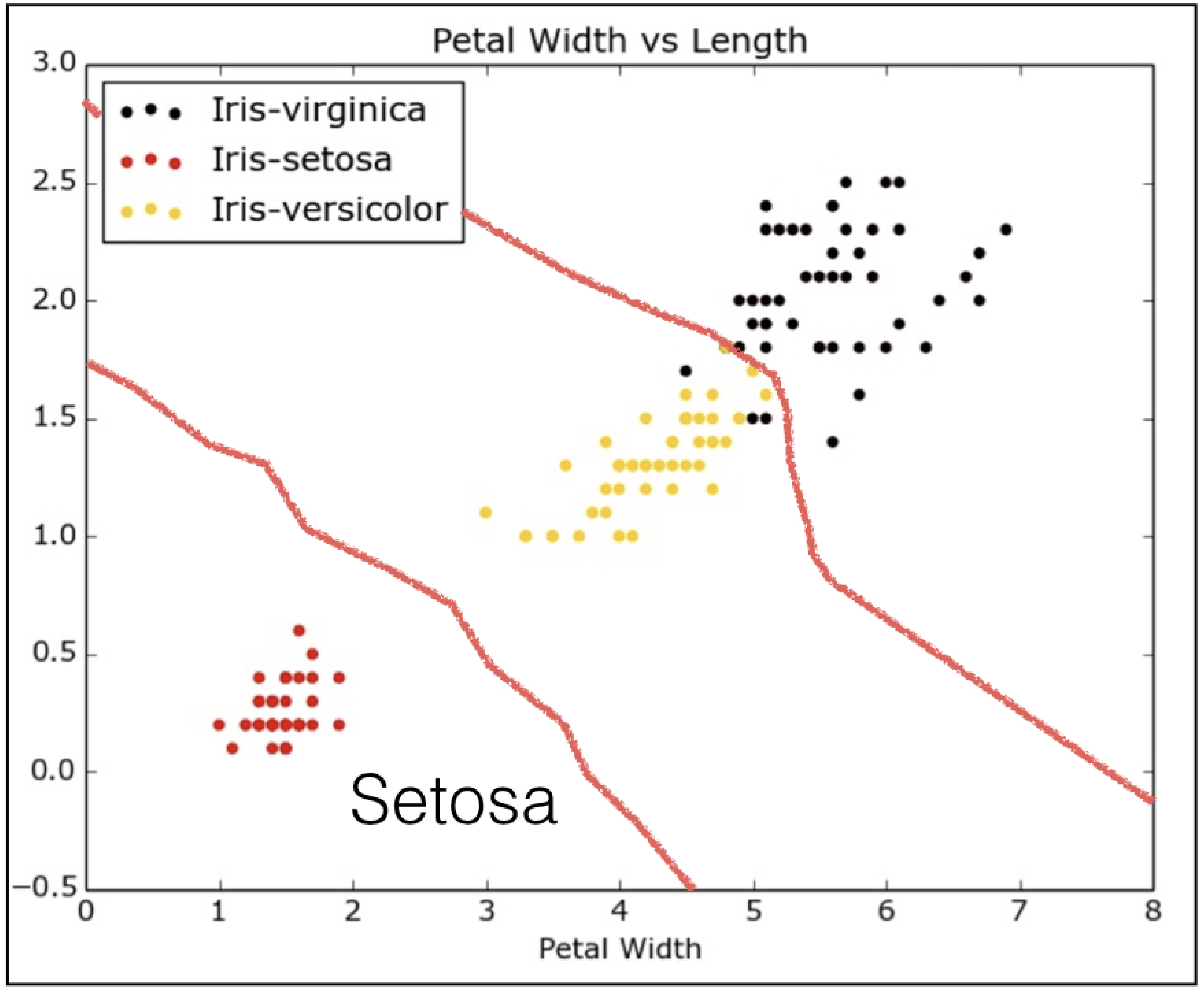
k-NN: Intuition



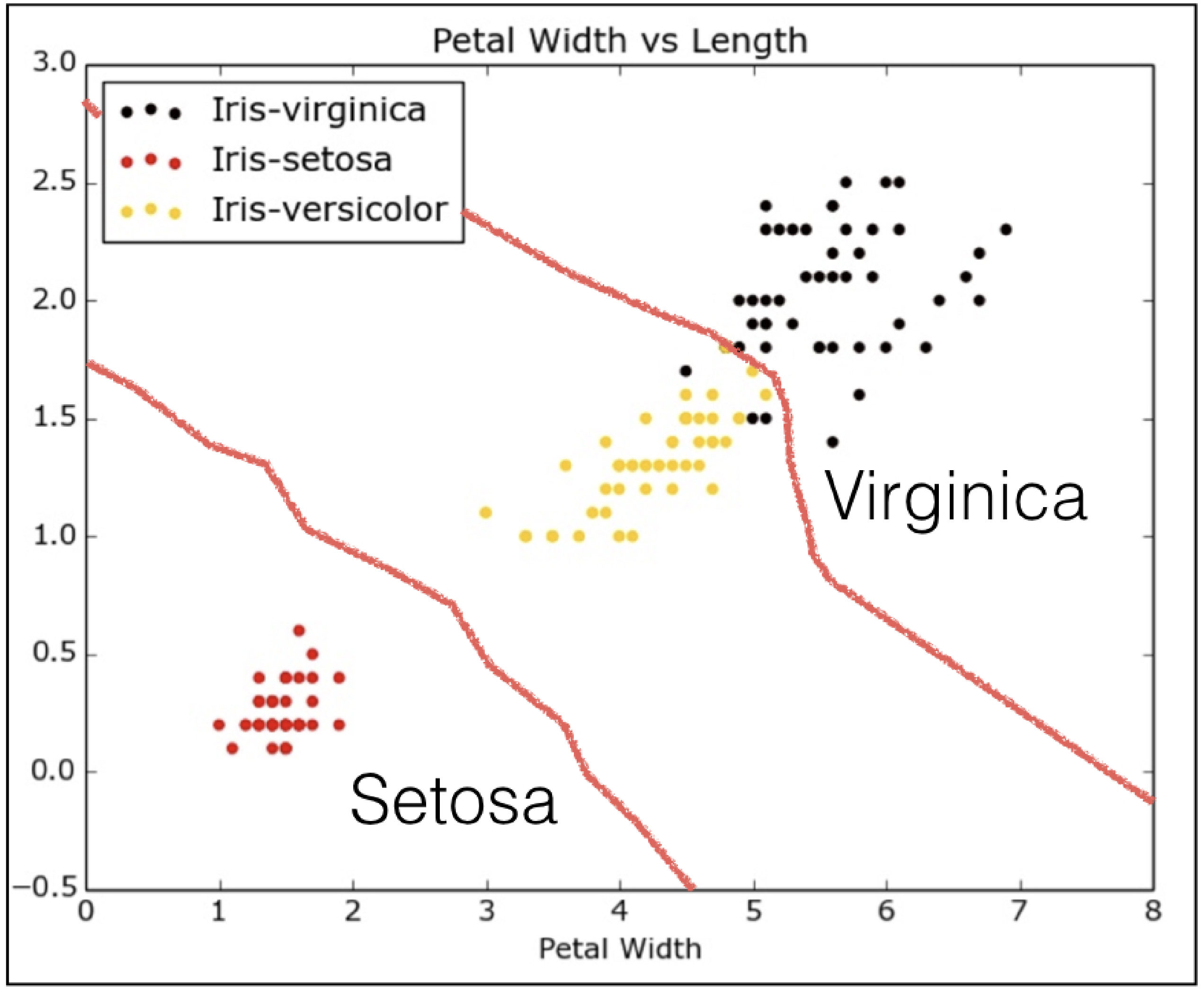
k-NN: Intuition



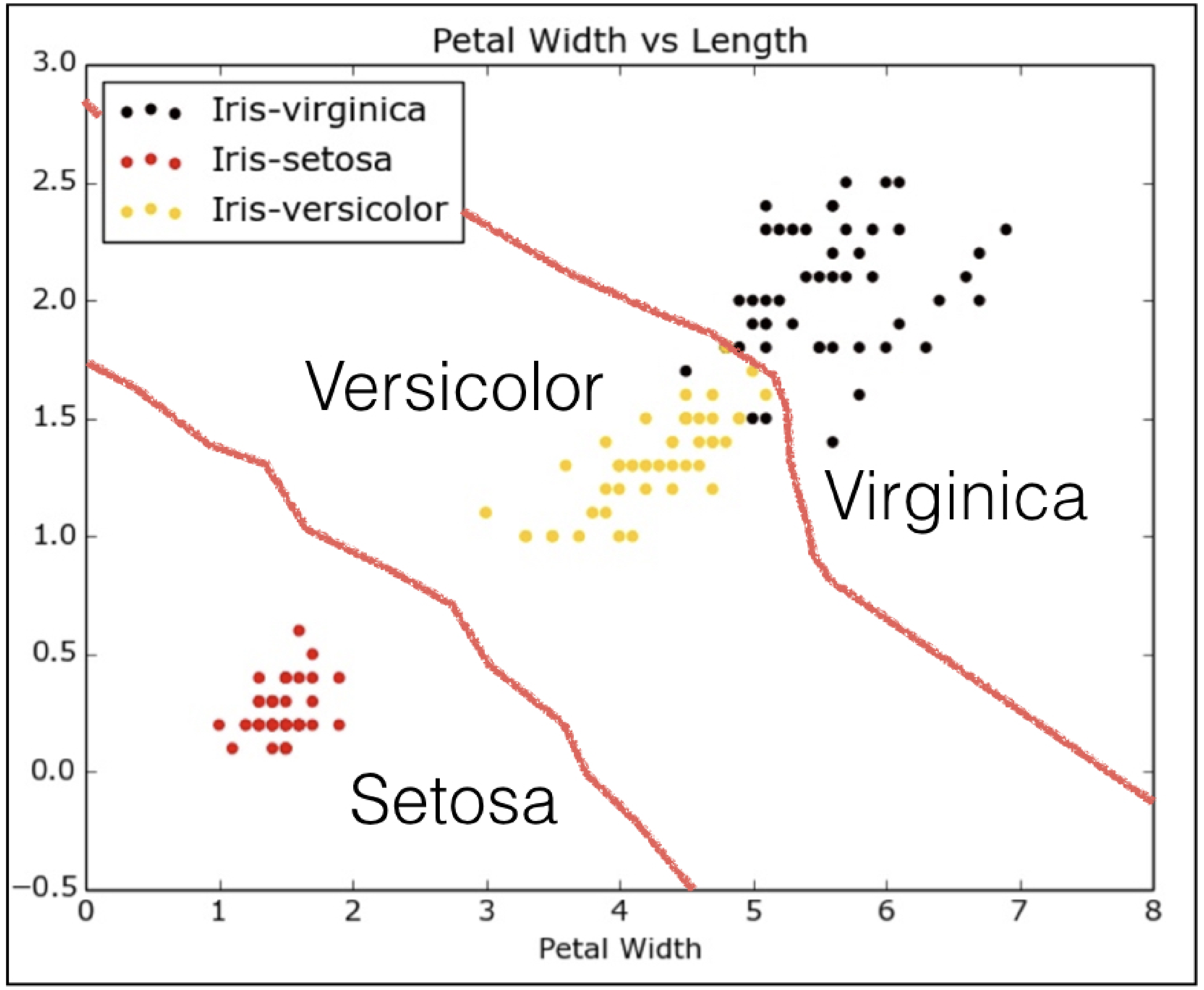
k-NN: Intuition



k-NN: Intuition



k-NN: Intuition



Scikit-learn fit and predict

- All machine learning models implemented as Python classes
  - They implement the algorithms for learning and predicting
  - Store the information learned from the data
- Training a model on the data = ‘fitting’ a model to the data
  - `.fit()` method
- To predict the labels of new data: `.predict()` method

Using scikit-learn to fit a classifier

```python
from sklearn.neighbors import KNeighborsClassifier
knn = KNeighborsClassifier(n_neighbors=6)
knn.fit(iris['data'], iris['target'])
```

```
KNeighborsClassifier(algorithm='auto', leaf_size=30,
    metric='minkowski',metric_params=None, n_jobs=1,
    n_neighbors=6, p=2,weights='uniform')
```

```python
iris['data'].shape
```

```
(150, 4)
```

```python
iris['target'].shape
```

```
(150,)
```

Predicting on unlabeled data

```
prediction = knn.predict(X_new)

X_new.shape
```

```
(3, 4)
```

```
print('Prediction: {}'.format(prediction))
```

```
Prediction: [1 1 0]
```

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Measuring model performance

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Measuring model performance

- In classification, accuracy is a commonly used metric
- Accuracy = Fraction of correct predictions
- Which data should be used to compute accuracy?
- How well will the model perform on new data?

Measuring model performance

- Could compute accuracy on data used to fit classifier
- NOT indicative of ability to generalize
- Split data into training and test set
- Fit/train the classifier on the training set
- Make predictions on test set
- Compare predictions with the known labels

Train/test split

```python
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test =
    train_test_split(X, y, test_size=0.3,
                     random_state=21, stratify=y)
knn = KNeighborsClassifier(n_neighbors=8)
knn.fit(X_train, y_train)
y_pred = knn.predict(X_test)
print(\"Test set predictions:\\n {}\".format(y_pred))
```

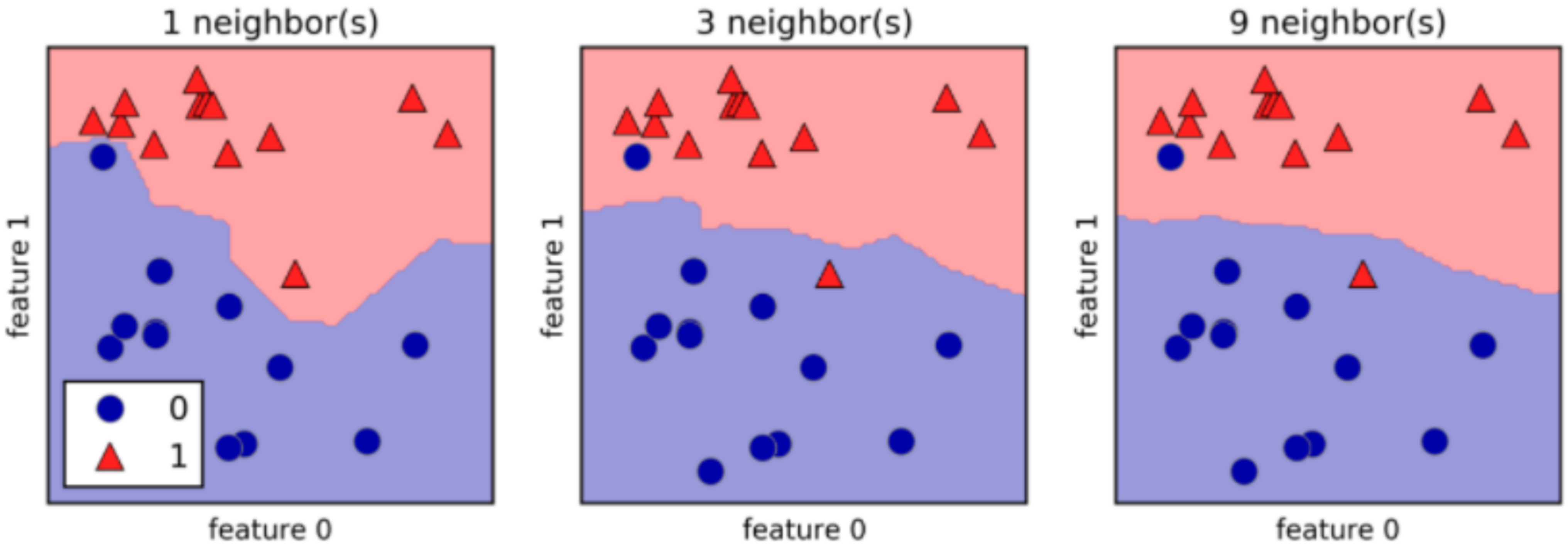
```
Test set predictions:
 [2 1 2 2 1 0 1 0 0 1 0 2 0 2 2 0 0 0 1 0 2 2 2 0 1 1 1 0 0
 1 2 2 0 0 2 2 1 1 2 1 1 0 2 1]
```

```python
knn.score(X_test, y_test)
```

```
0.9555555555555556
```

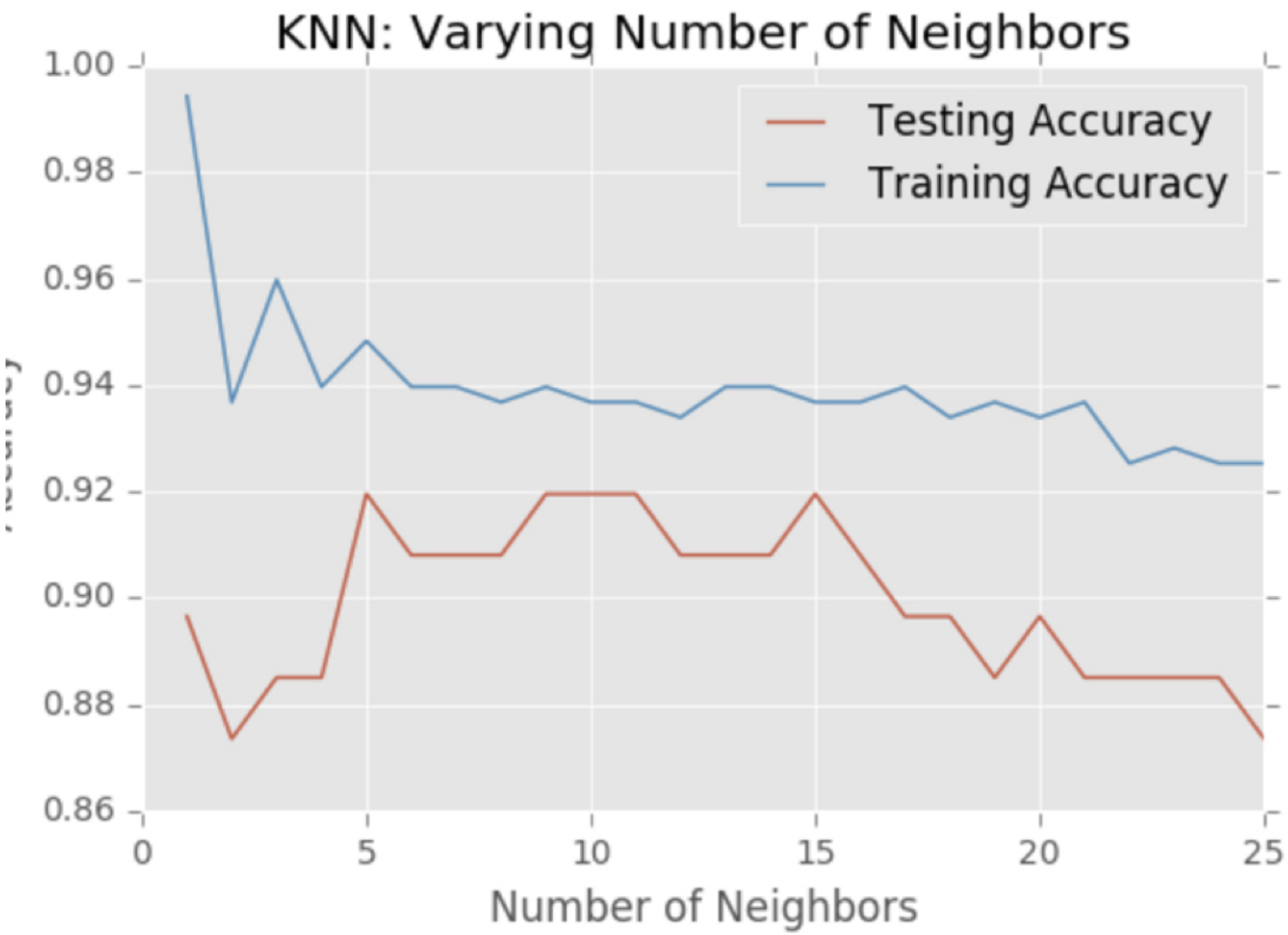
Model complexity

- Larger k = smoother decision boundary = less complex model
- Smaller k = more complex model = can lead to overfitting

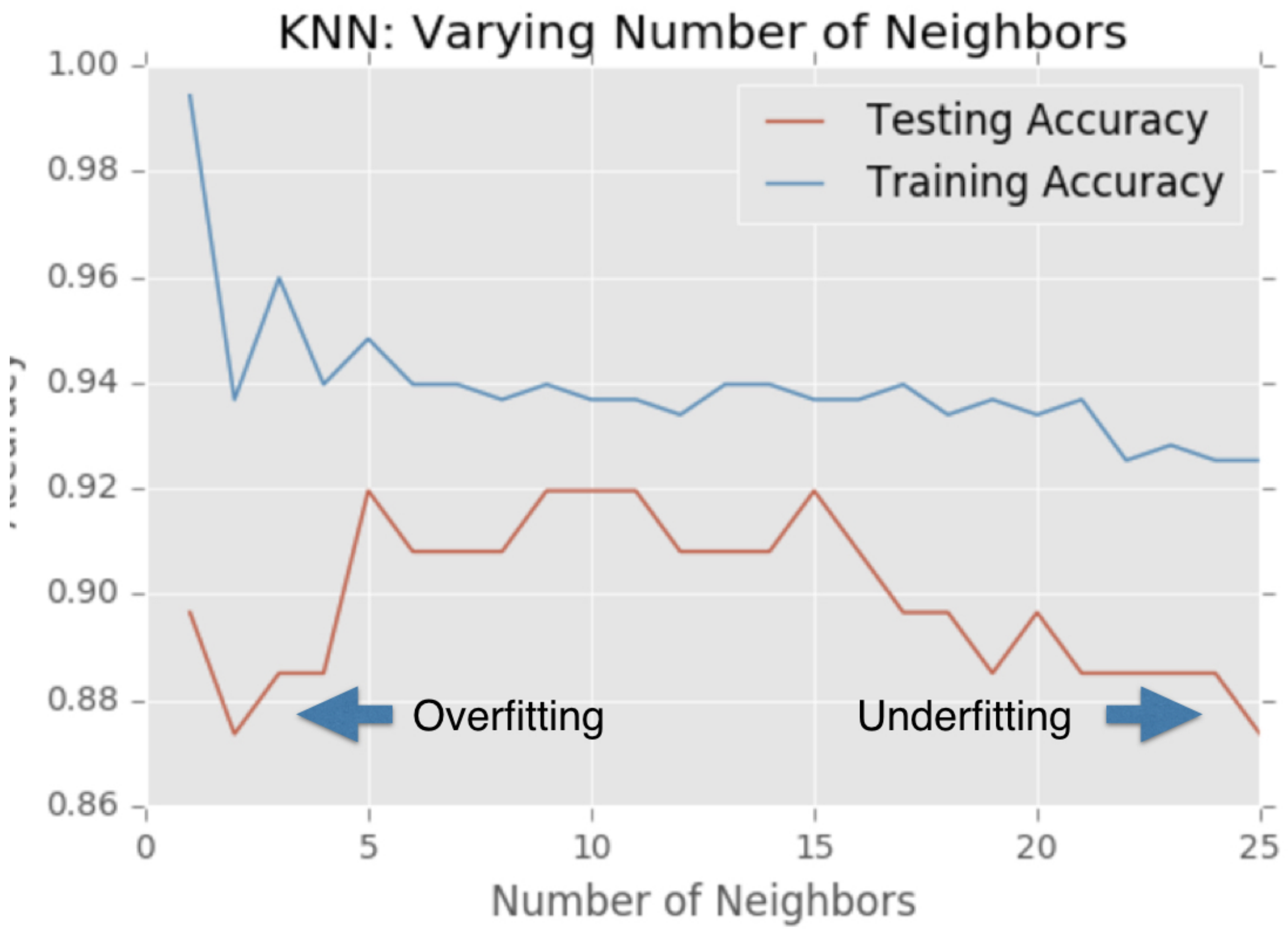


[1] Source: Andreas Müller & Sarah Guido, Introduction to Machine Learning with Python

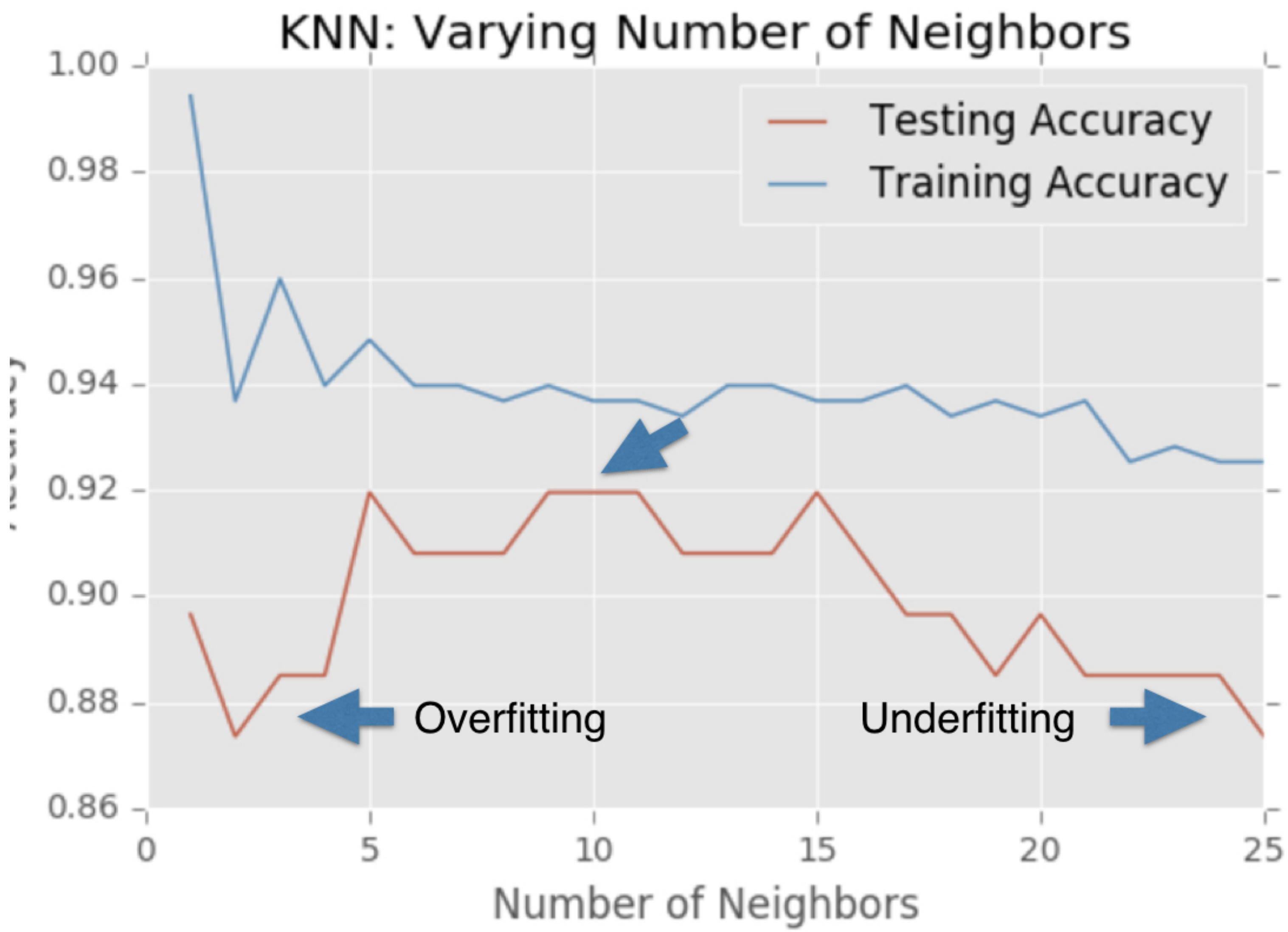
Model complexity and over/underfitting



Model complexity and over/underfitting



Model complexity and over/underfitting



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