Classification

Boston University CS 506 - Lance Galletti

Classification Tasks

- Predicting tumor cells as benign or malignant
- Classifying images
- Classifying credit card transactions as being legitimate or fraudulent
- Many more

Classification Techniques

- Instance-Based Classifiers
- Decision Trees
- Naive Bayes
- Support Vector Machines
- Neural Networks

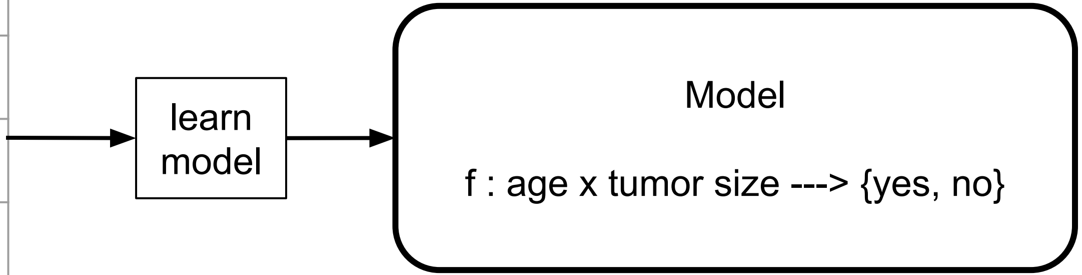
在需要对新实例进行分类时，算法会搜索训练集、寻找与新实例最相似的一个或多个训练实例，并基于这些相似实例的标签预测新实例的标签。

What is Classification?

- Given a **training set** where data is labeled with a special **attribute** called a **class** (a discrete value)
- We want to find a **model** describing how the **class** attribute varies as a function of the values of the other attributes
- Goal: use this model on unlabeled data to assign a class as accurately as possible

Example

age	Tumor size	malignant?
20	10	no
30	15	yes
40	20	no
50	25	yes



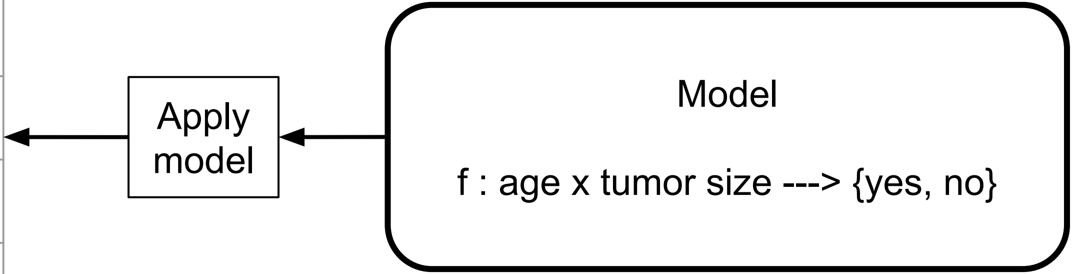
learn model

Model

f : age x tumor size ---> {yes, no}

Example

age	Tumor size	malignant?
25	5	?
35	10	?
45	25	?



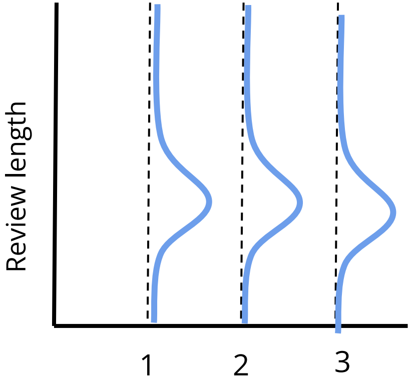
Apply model

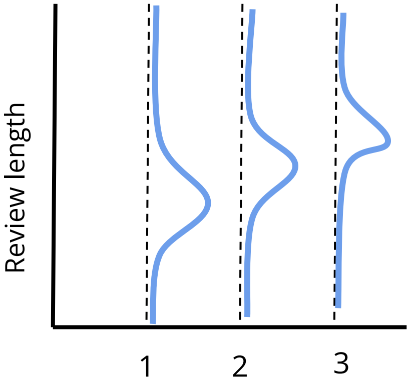
Model

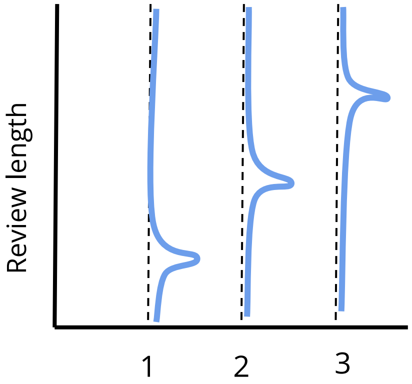
f : age x tumor size ---> {yes, no}

Modeling Philosophy

- What constitutes a good feature?

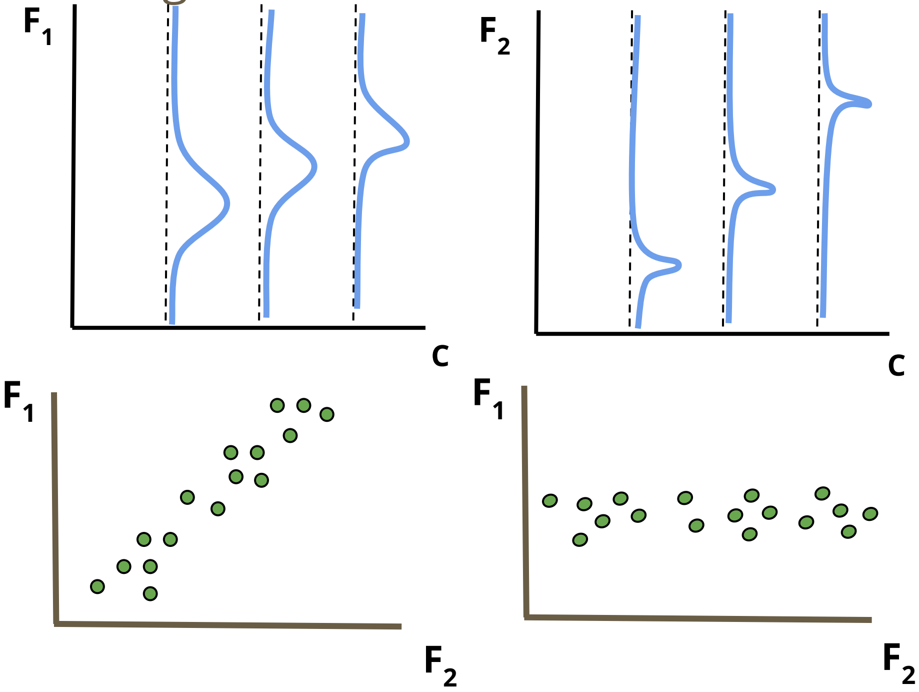






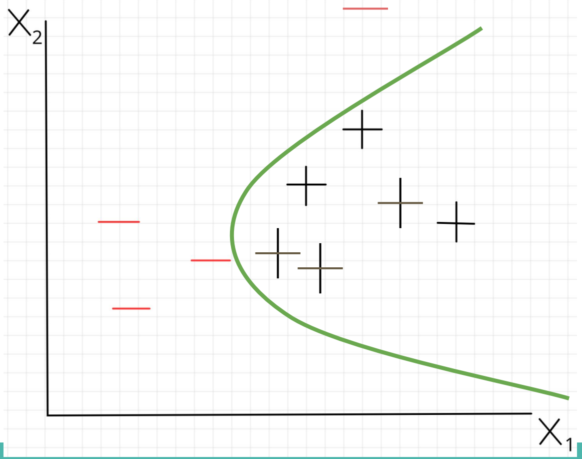
Modeling Philosophy

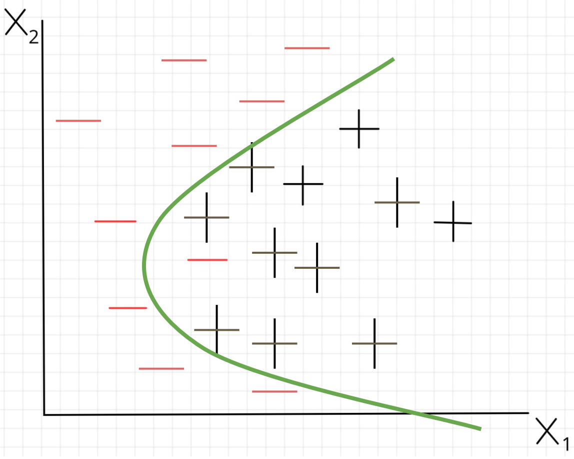
- What constitutes a good feature?
- What constitutes a good set of features?



Modeling Philosophy

- What constitutes a good feature?
- What constitutes a good set of features?
  - Change in $F_1, \dots, F_m$ means expect a change in Y
- Correlation vs causation
- Primary goal is to capture the general trend / relationship between class and features as simply as possible
  - Outliers
  - Noise





Modeling Philosophy

- What constitutes a good feature?
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  - Change in F_1, …, F_m means expect a change in Y
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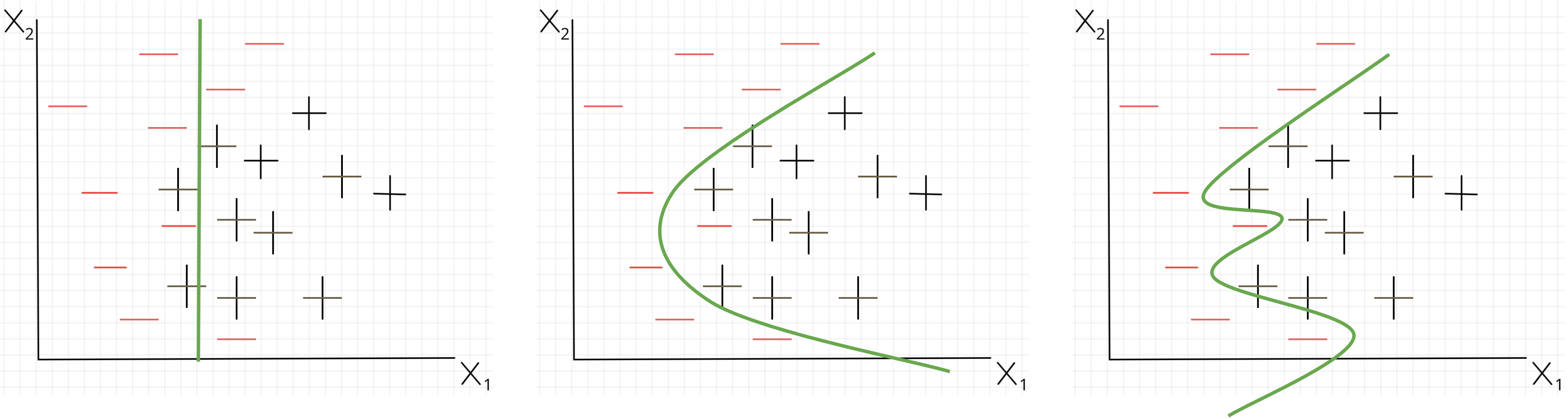
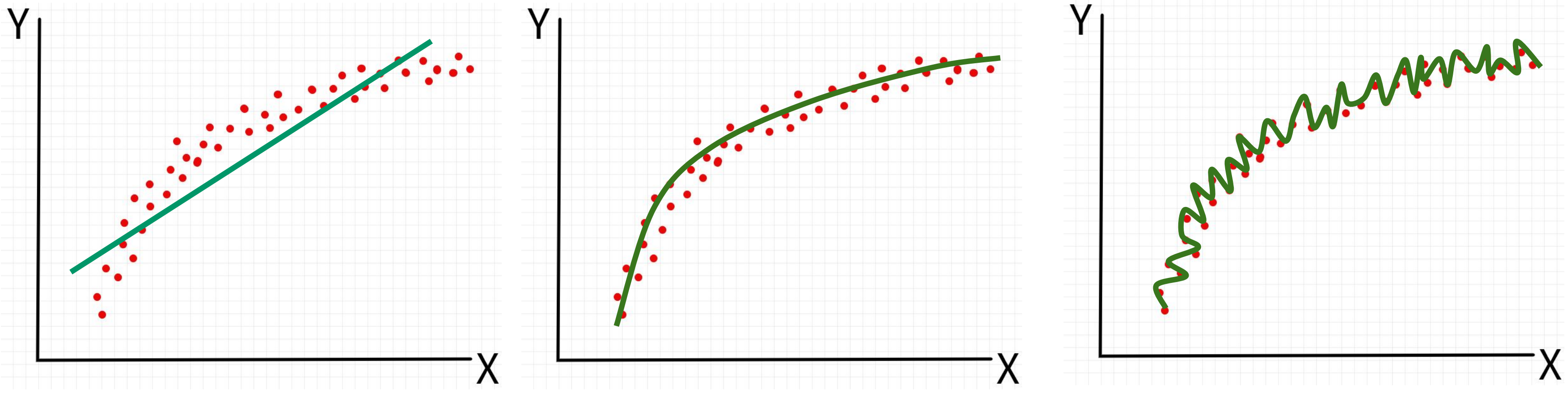
- Primary goal is to capture the general trend / relationship between class and features as simply as possible
  - Outliers
  - Noise
- Model performance / evaluations
  - Overfitting vs Underfitting
- All models are wrong but *some* are useful. What value does your model provide?

Underfitting VS Overfitting

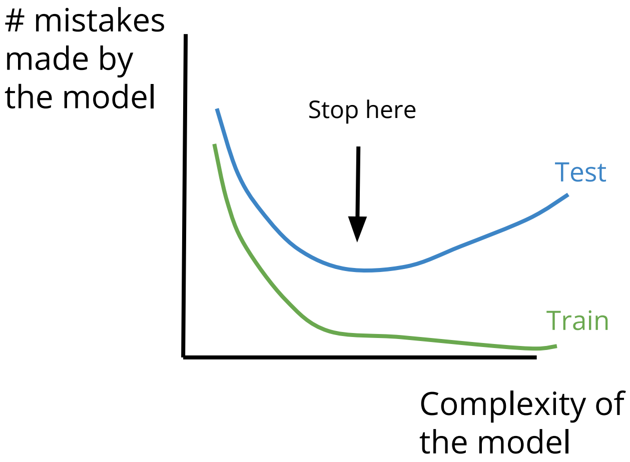


Underfitting VS Overfitting



Model Evaluation (simply)

- Evaluating a model on the data it was trained on is cheating - can just memorize.
- Distinction between data used for training and data left out used for testing / evaluation.



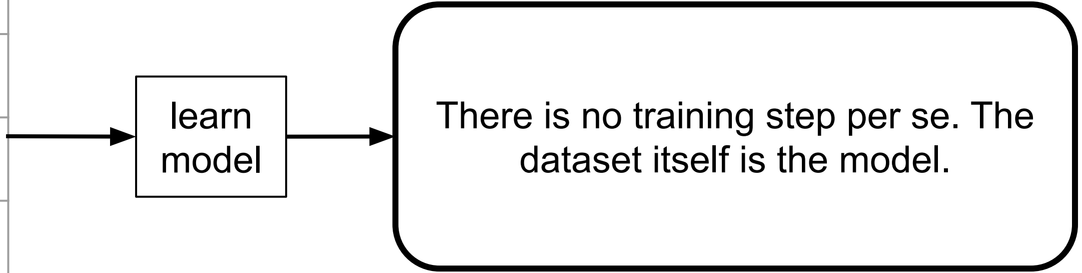
Worksheet Part 1

Instance-Based Classifiers

- Use the stored training records to predict the class label of unseen cases
- Rote-learners:
  - Perform classification only if the attributes of the unseen record exactly match a record in our training set

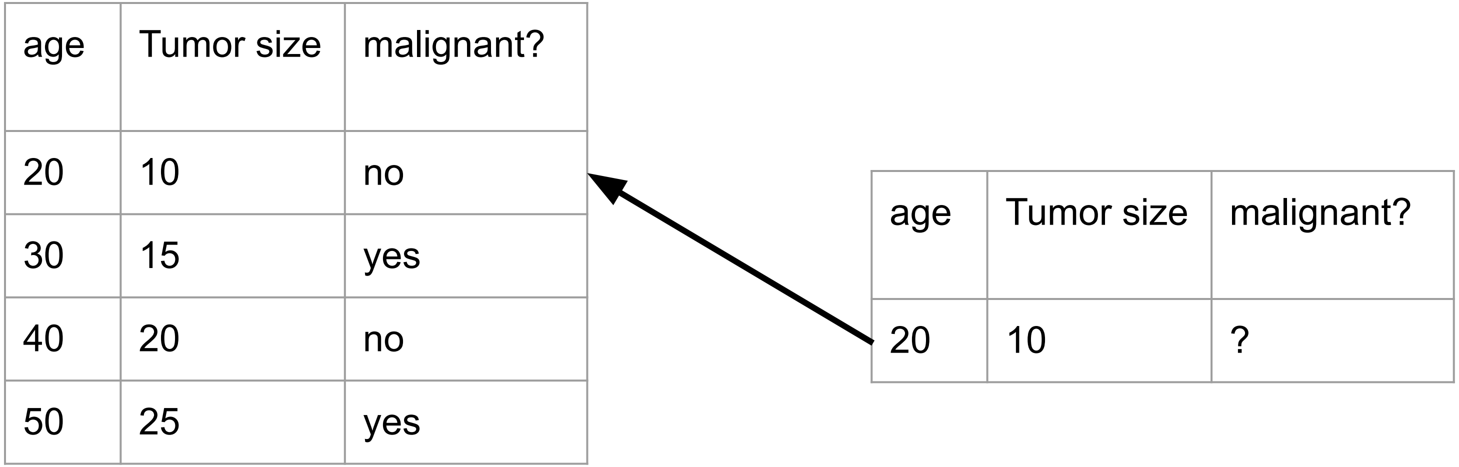
Instance-Based Classifiers: Training Step

age	Tumor size	malignant?
20	10	no
30	15	yes
40	20	no
50	25	yes



There is no training step per se. The dataset itself is the model.

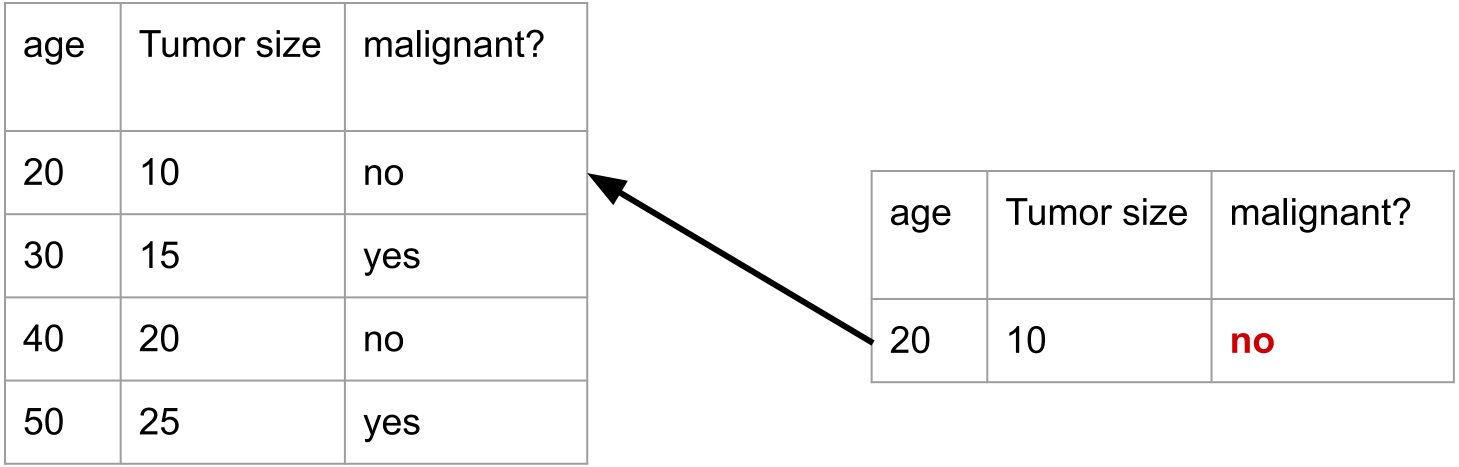
Instance-Based Classifiers: Applying the model



age	Tumor size	malignant?
20	10	no
30	15	yes
40	20	no
50	25	yes

age	Tumor size	malignant?
20	10	?

Instance-Based Classifiers: Applying the model



age	Tumor size	malignant?
20	10	no
30	15	yes
40	20	no
50	25	yes

age	Tumor size	malignant?
20	10	**no**

Instance-Based Classifiers

- Use the stored training records to predict the class label of unseen cases
- Rote-learners:
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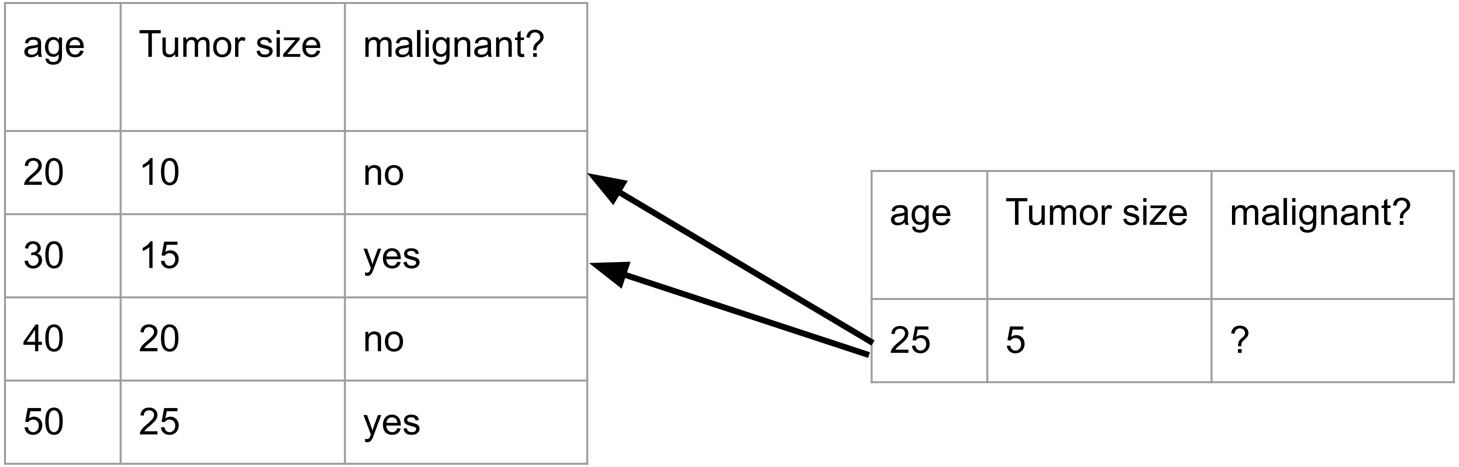
Instance-Based Classifiers



age	Tumor size	malignant?
20	10	no
30	15	yes
40	20	no
50	25	yes

age	Tumor size	malignant?
25	5	?

Nearest Neighbor Classifier

Use **SIMILAR** records to perform classification

K Nearest Neighbor Classifier

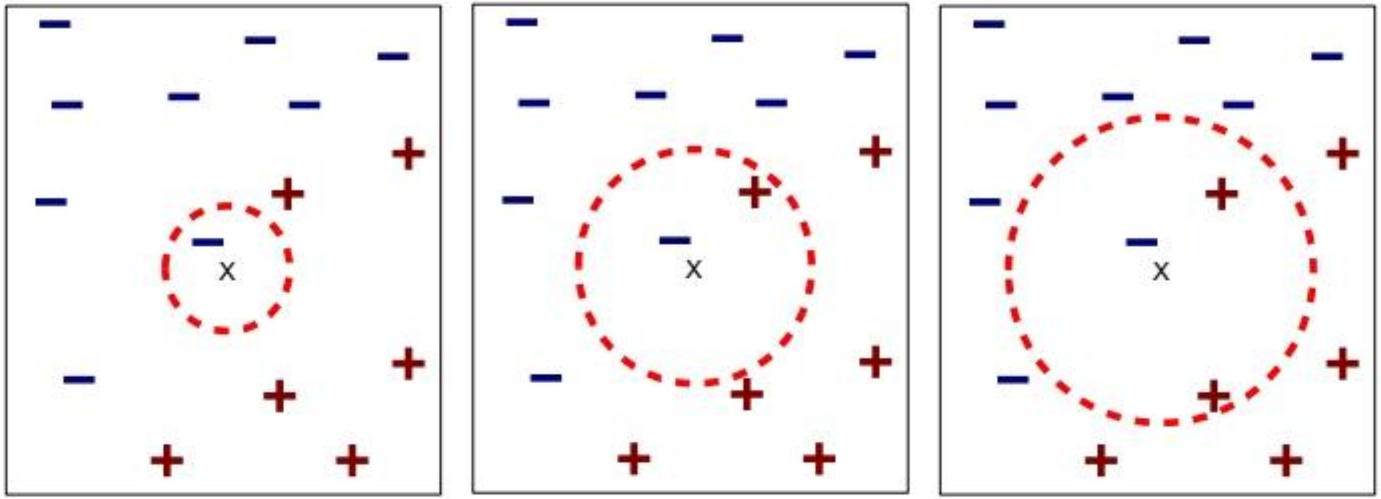
Requires:

- Training set
- Distance function
- Value for k

How to classify an unseen record:

1. Compute distance of unseen record to all training records
2. Identify the k nearest neighbors
3. Aggregate the labels of these k neighbors to predict the unseen record class (ex: majority rule)

K Nearest Neighbor Classifier



(a) 1-nearest neighbor (b) 2-nearest neighbor (c) 3-nearest neighbor

K Nearest Neighbor Classifier

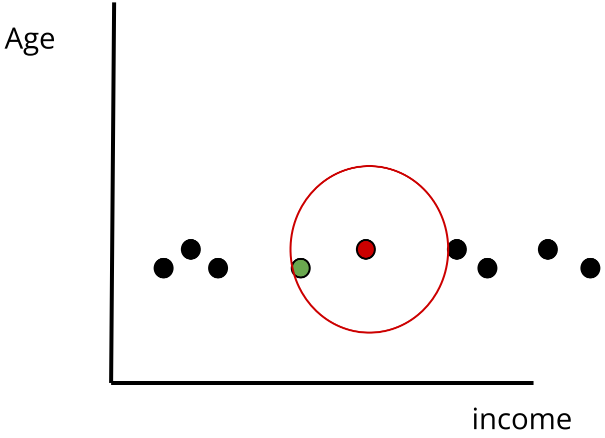
Aggregation methods:

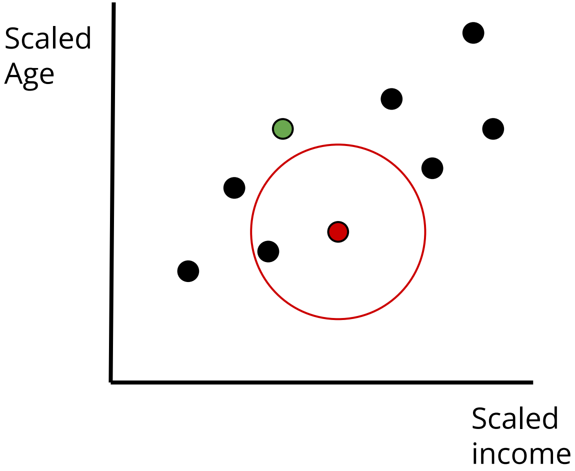
- Majority rule
- Weighted majority based on distance ($w = 1/d^2$)

Scaling issues:

- Attributes should be scaled to prevent distance measures from being dominated by one attribute. Example:
    - Age: 0 -> 100
    - Income: 10k -> 1million

Scaling Attributes



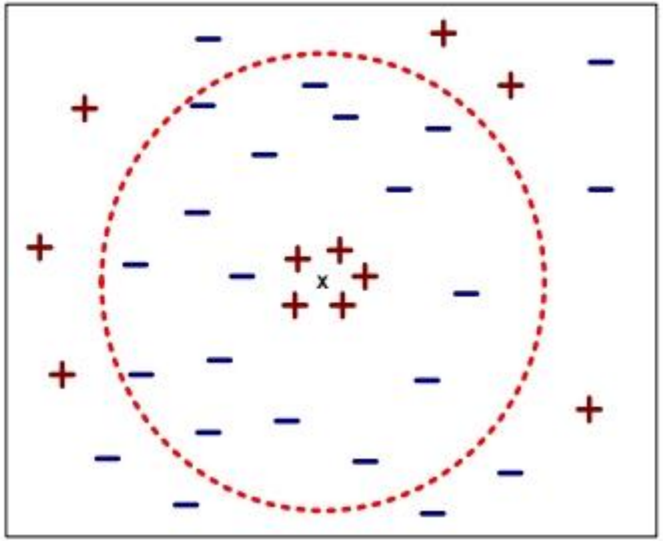


K Nearest Neighbor Classifier

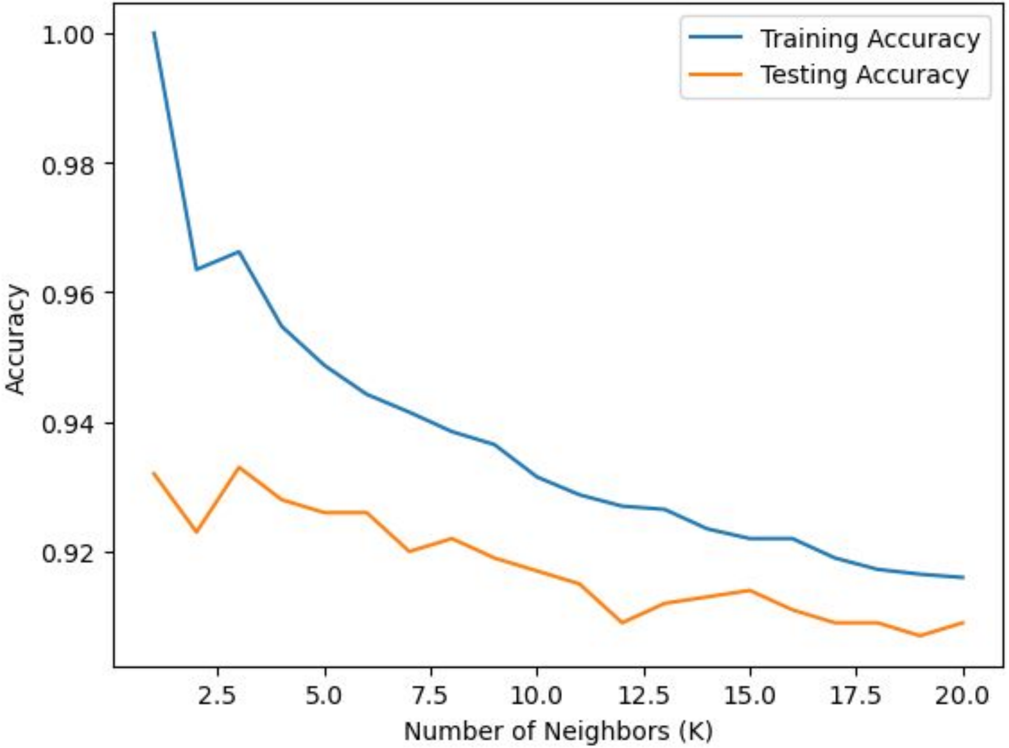
Choosing the value of k:

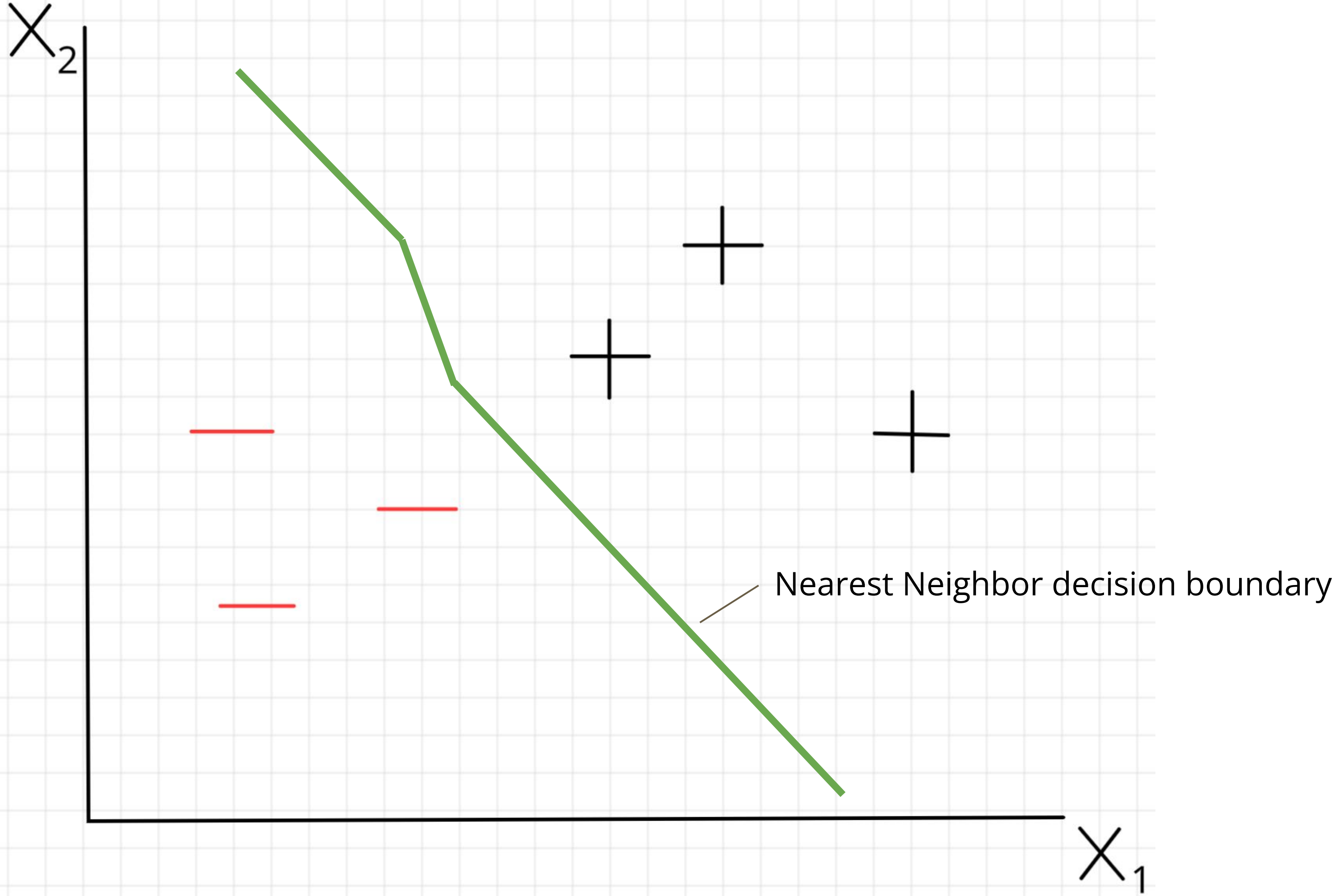
- If k is too small ->
  - sensitive to noise points + overfitting (doesn't generalize well)

- If k is too big ->
  - neighborhood may include points from other classes



How to choose k




X₂
X₁
Nearest Neighbor decision boundary

K Nearest Neighbor Classifier

Pros:

- Simple to understand why a given unseen record was given a particular class

Cons:

- Expensive to classify new points
- KNN can be problematic in high dimensions (curse of dimensionality)