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

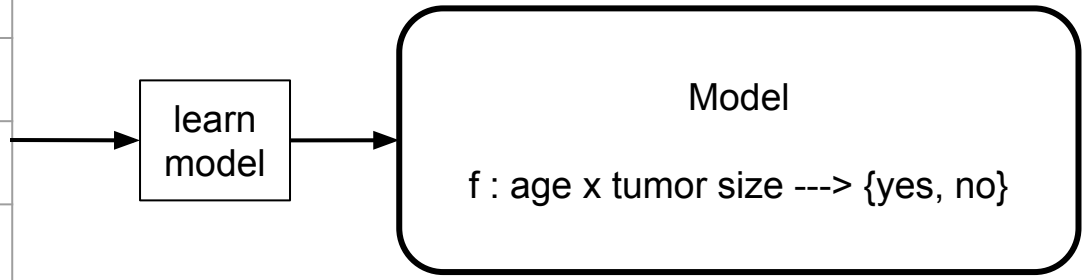
- Instance-Based Classifiers
- Decision Trees
- Naive Bayes
- Support Vector Machines
- Neural Networks

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

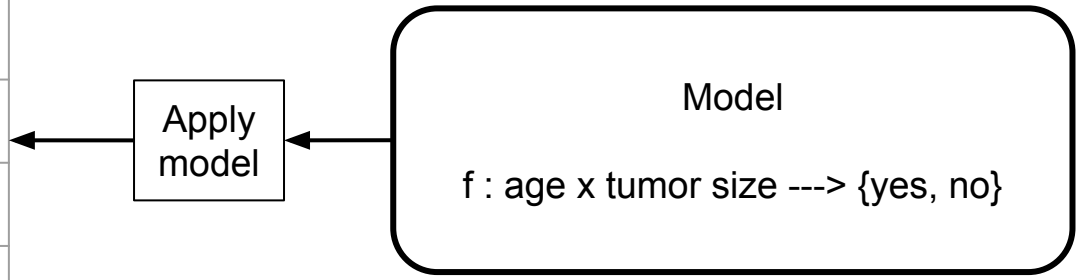
Example

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



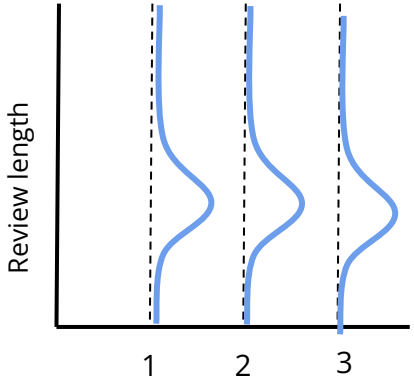
Example

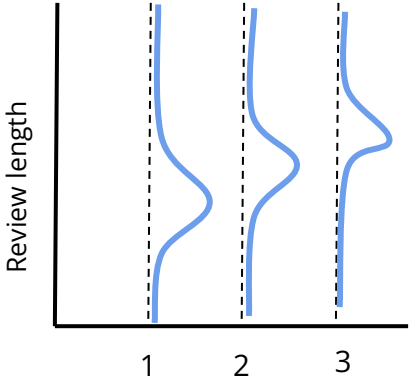
age	Tumor size	malignant?
25	5	?
35	10	?
45	25	?

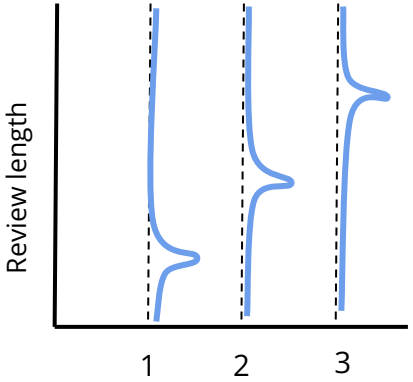


Modeling Philosophy

- What constitutes a good feature?







Modeling Philosophy

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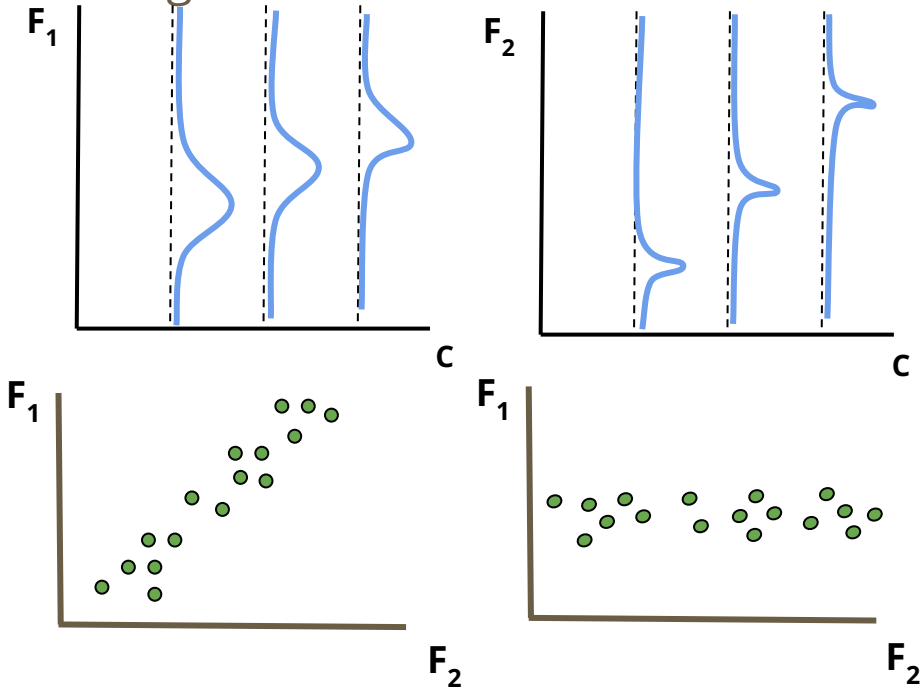
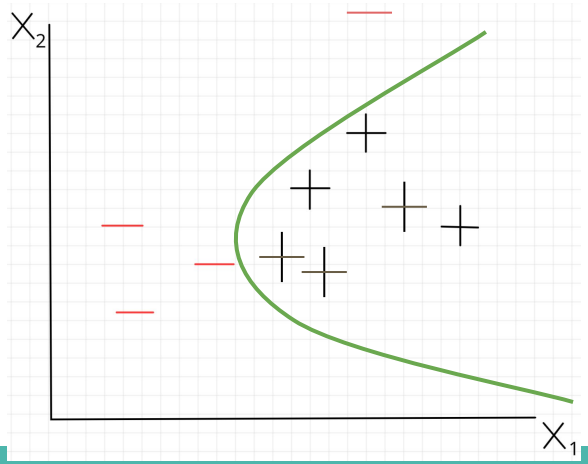
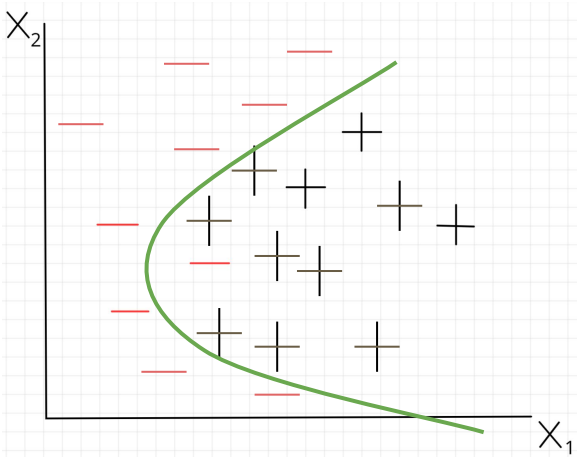
- What constitutes a good set of features?



Modeling Philosophy

- What constitutes a good feature?
- What constitutes a good set of features?
  - Change in F_1, ..., 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





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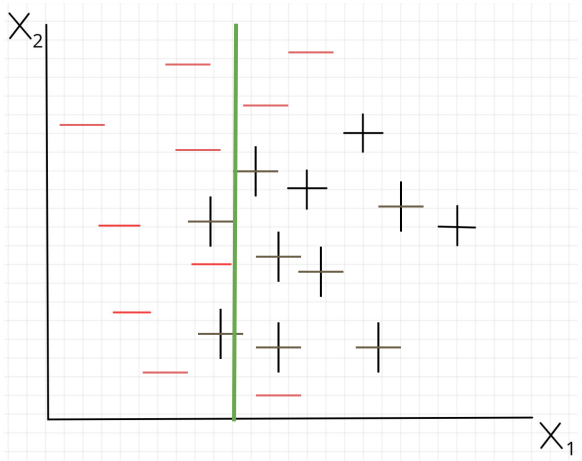
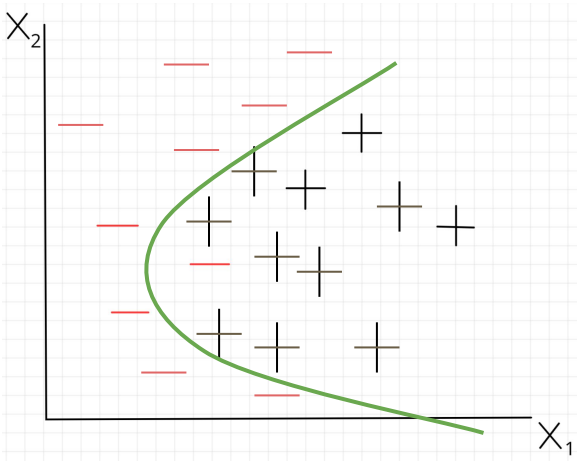
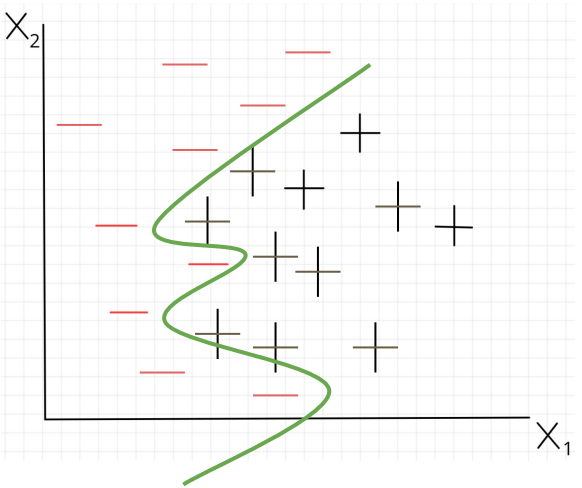
  - Noise
- Model performance / evaluations
  - Overfitting vs Underfitting
- All models are wrong but *some* are useful. What value does your model provide?

Underfitting VS Overfitting



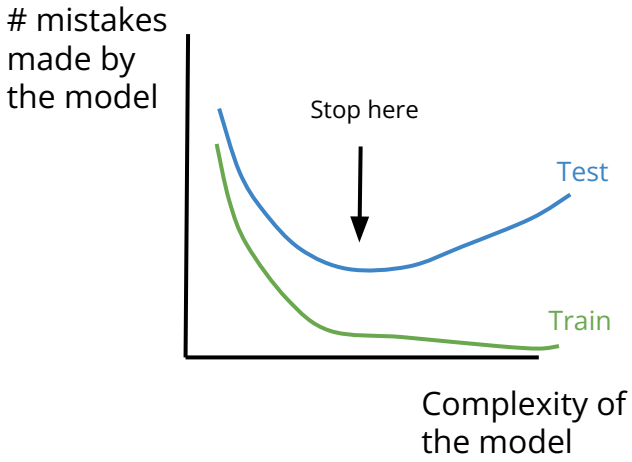




Underfitting VS Overfitting

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.



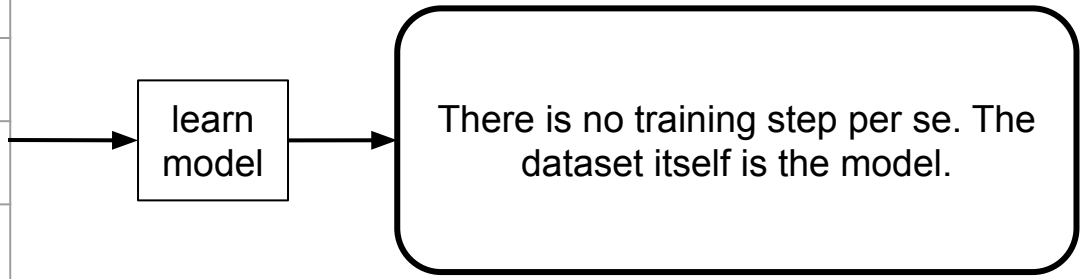
Worksheet Part 1

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



Instance-Based Classifiers: Applying the model

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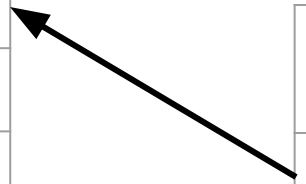

age	Tumor size	malignant?
20	10	?

Instance-Based Classifiers: Applying the model

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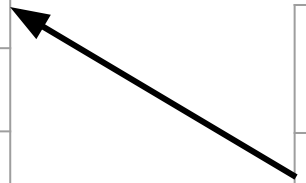

age	Tumor size	malignant?
20	10	**no**

Instance-Based Classifiers

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Instance-Based Classifiers

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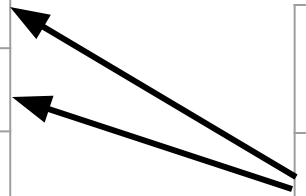


age	Tumor size	malignant?
25	5	?

Nearest Neighbor Classifier

Use **SIMILAR** records to perform classification

K Nearest Neighbor Classifier

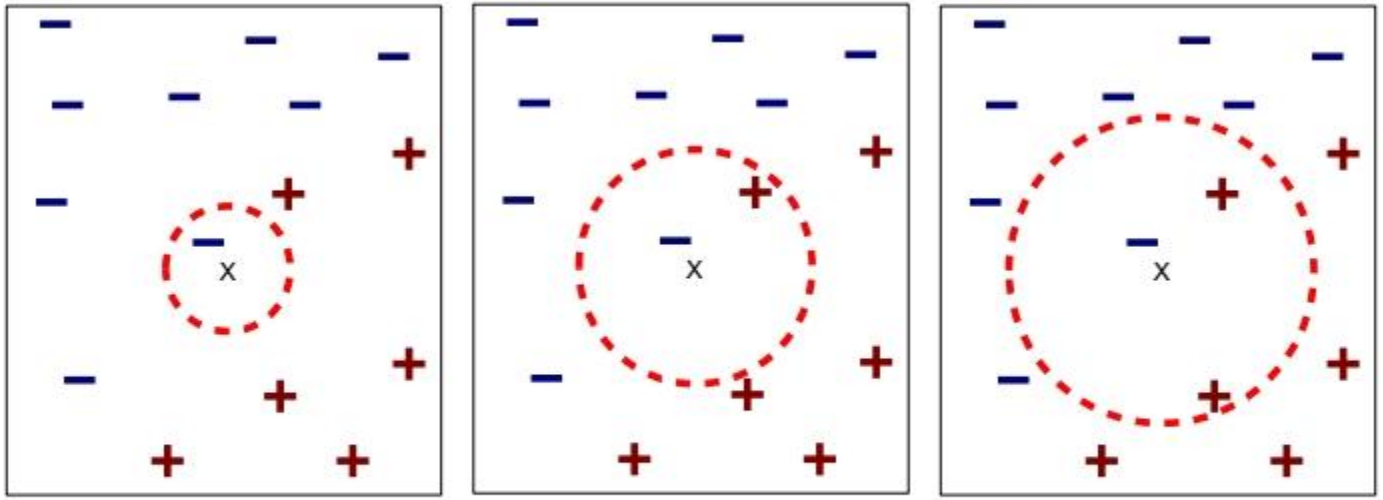
Requires:

- 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

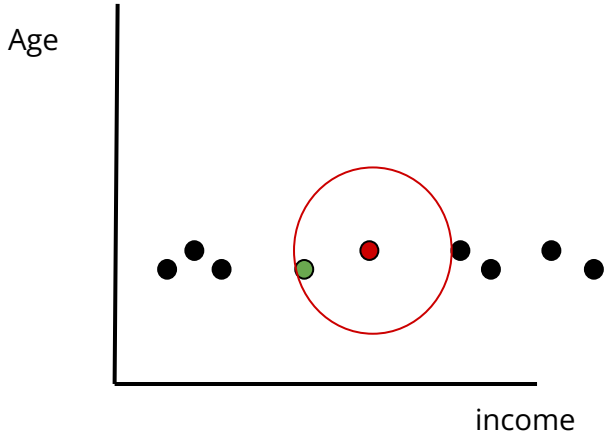
Aggregation methods:

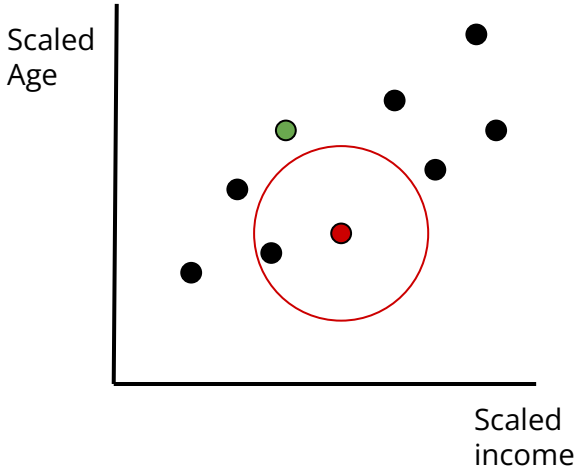
- Majority rule
- Weighted majority based on distance ($w = 1/d^2$)

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



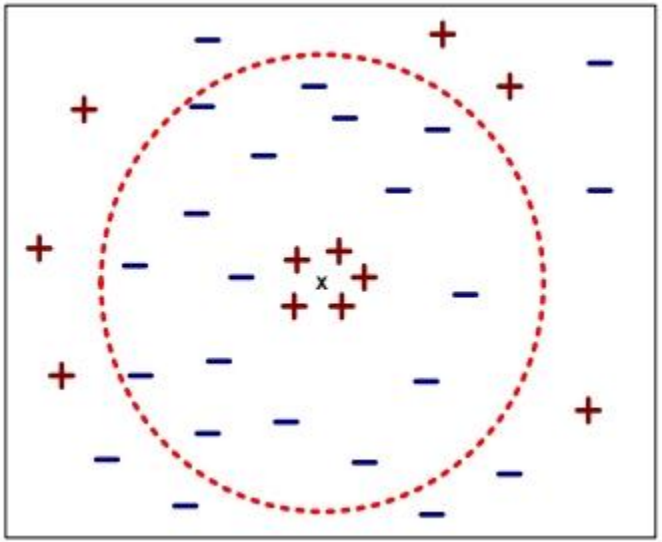


K Nearest Neighbor Classifier

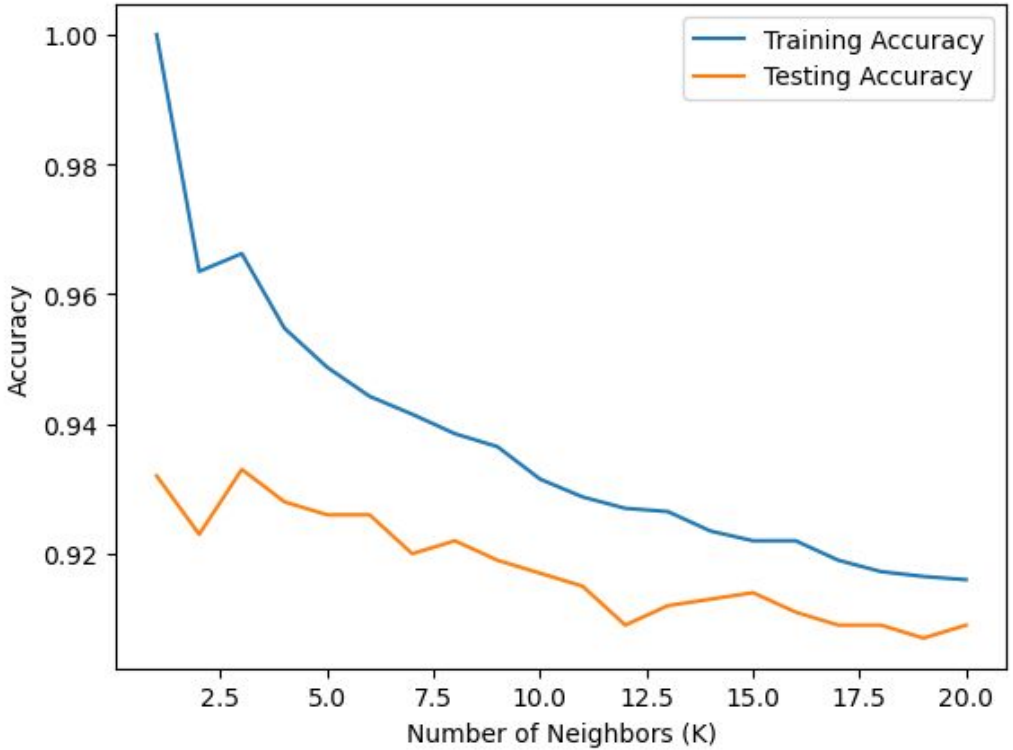
Choosing the value of k:

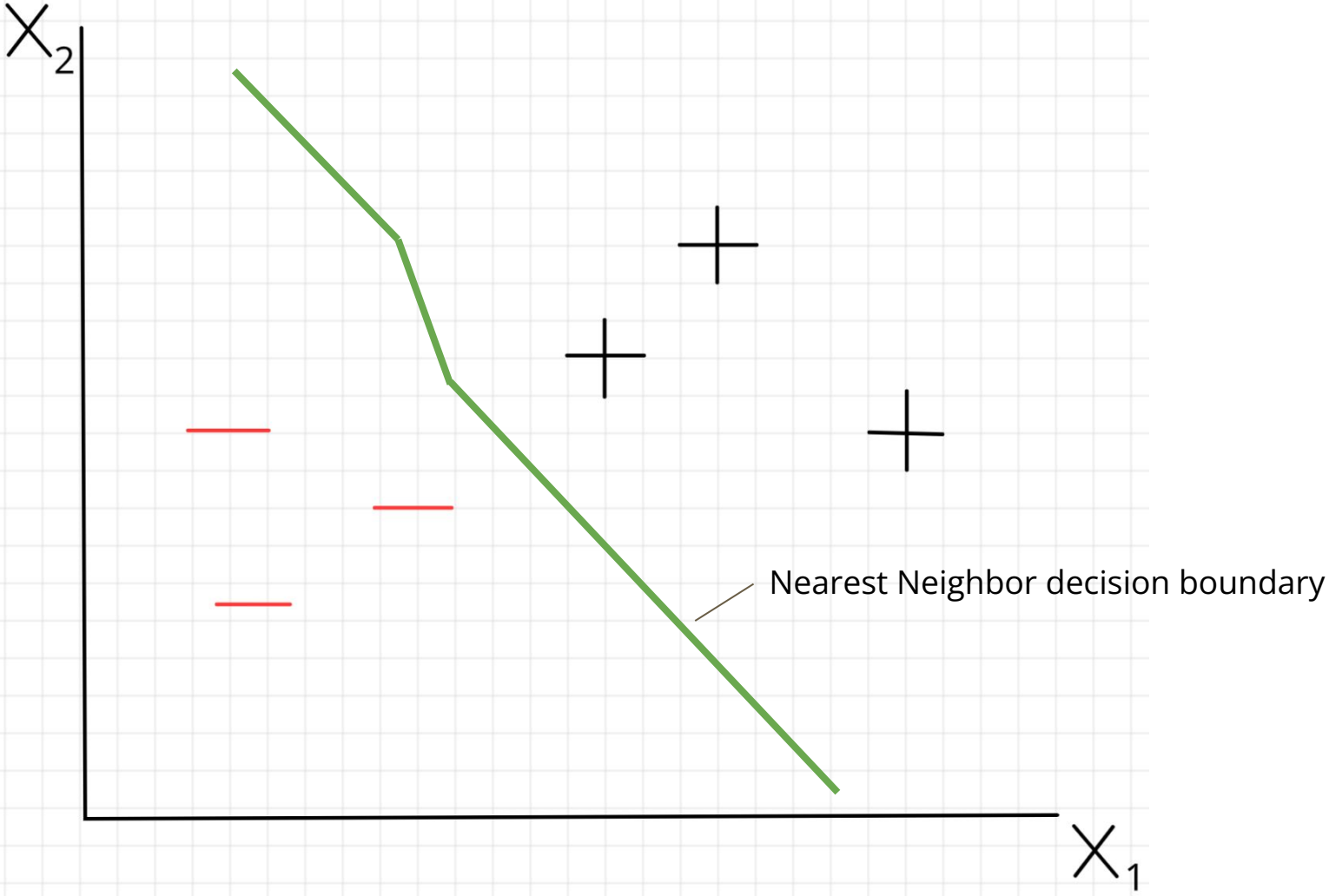
- If k is too small ->
  - sensitive to noise points + overfitting (doesn't generalize well)

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



How to choose k




X_2
X_1
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)