MAI4CAREU
Master programmes in Artificial Intelligence 4 Careers in Europe

Visual Computing Group

CYENS CENTRE OF EXCELLENCE

University of Cyprus – MSc Artificial Intelligence

MAI644 – COMPUTER VISION

Lecture 11: Visual Recognition – Image Classification

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Last time

- Visual Recognition Tasks
- Introduction to segmentation and clustering
- Agglomerative clustering
- K-means clustering
- Mean-shift clustering
- Efficient Graph-based image segmentation

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Today’s Agenda

- A simple Image Classification pipeline
  - Classification overview
- K-nearest neighbor algorithm
  - kNN: algorithm
  - kNN: analysis

[material based on Niebles-Krishna]

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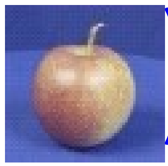
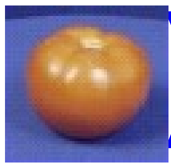
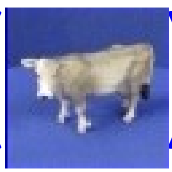
Visual recognition: a classification framework

- Apply a prediction function to a feature representation of the image to get the desired output:

f() = "apple"

f() = "tomato"

f() = "cow"

Dataset: ETH-80, by B. Leibe Slide credit: L. Lazebnik

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The machine learning framework

$$y = f(\mathbf{x})$$

output — prediction function — Image feature

- **Training:** given a *training set* of labeled examples $\{(\mathbf{x}_1,y_1), \ldots, (\mathbf{x}_N,y_N)\}$, estimate the prediction function f by minimizing the prediction error on the training set
- **Testing:** apply f to a never-before-seen *test example* $\mathbf{x}$ and output the predicted value $y = f(\mathbf{x})$

Slide credit: L. Lazebnik

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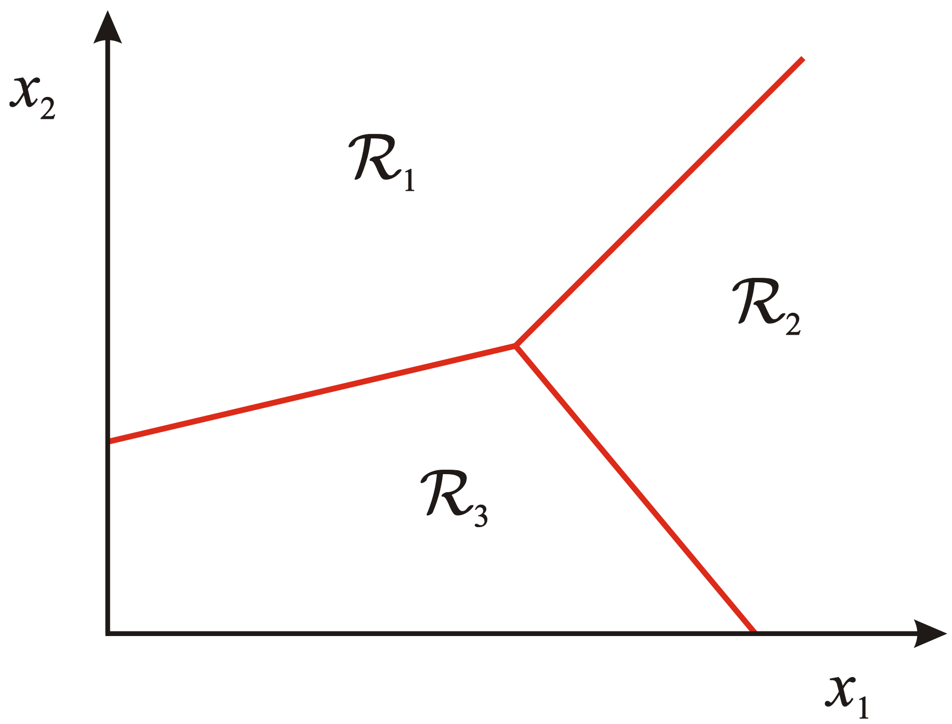
Classification

- Assign input feature vector to one of two or more classes
- Any decision rule divides input space into *decision regions* separated by *decision boundaries*



Slide credit: L. Lazebnik

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A simple pipeline - Training

Training Images

Image Features

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A simple pipeline - Training

Training Images

Image Features

Training Labels

Training

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A simple pipeline - Training

Training Images

Training Labels

Image Features → Training → Learned Classifier

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A simple pipeline - Testing

Training Images

Training Labels

Image Features → Training → Learned Classifier

Test Image

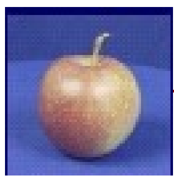

Image Features

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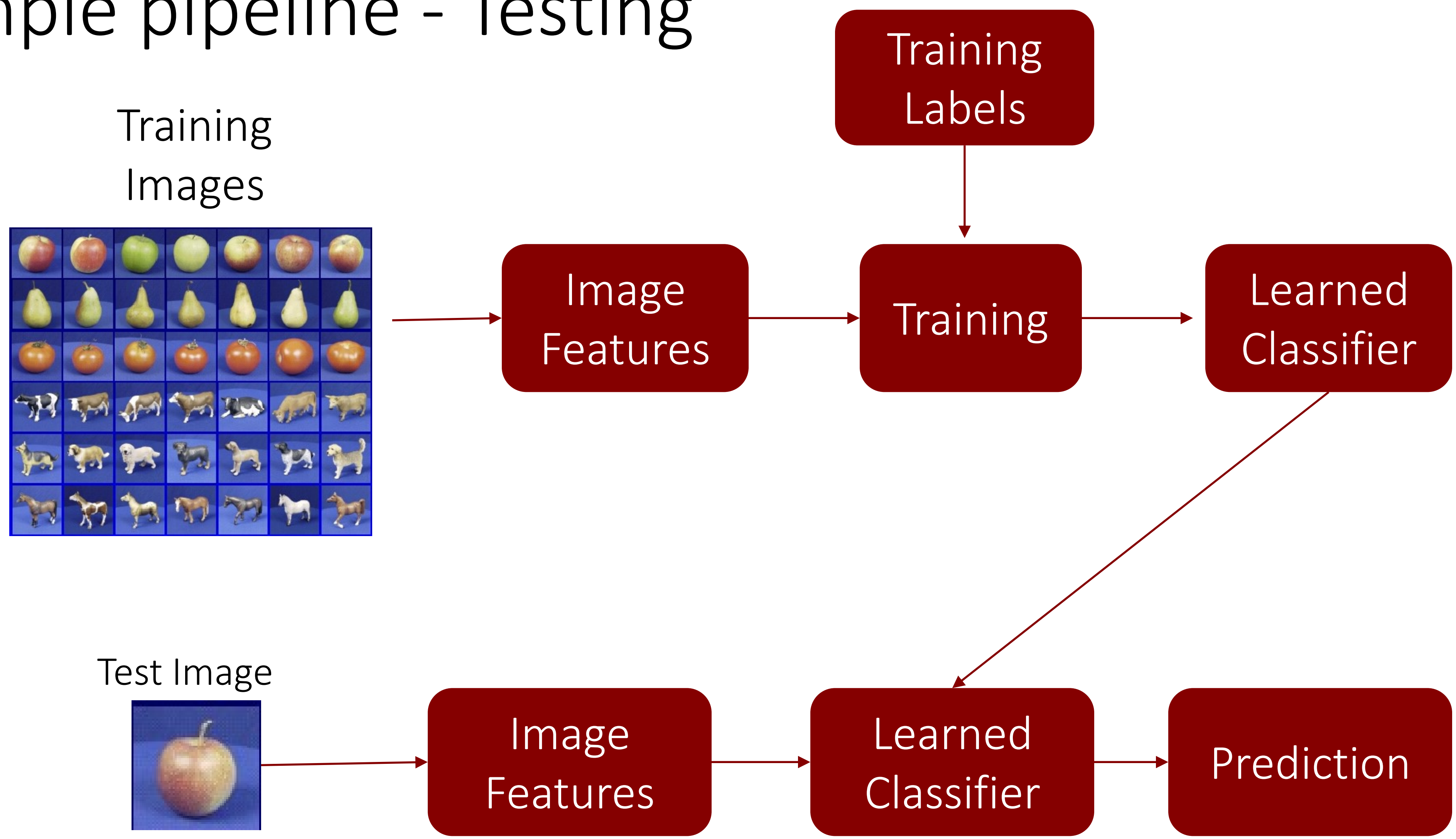
A simple pipeline - Testing



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Test Image

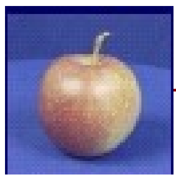

Image Features → Learned Classifier → Prediction

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Image Features

Input image

Many features to choose from

- Histogram of Color
- Histogram of Gradients
- SIFT
- Bag of words
- etc…

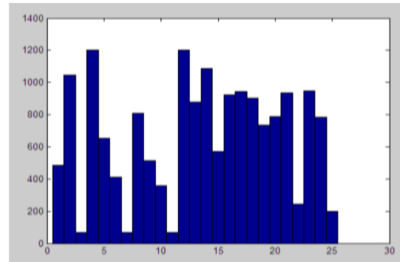

Image From ETH-80 dataset: Analyzing Appearance and Contour Based Methods for Object Categorization - by Leibe et al 2003

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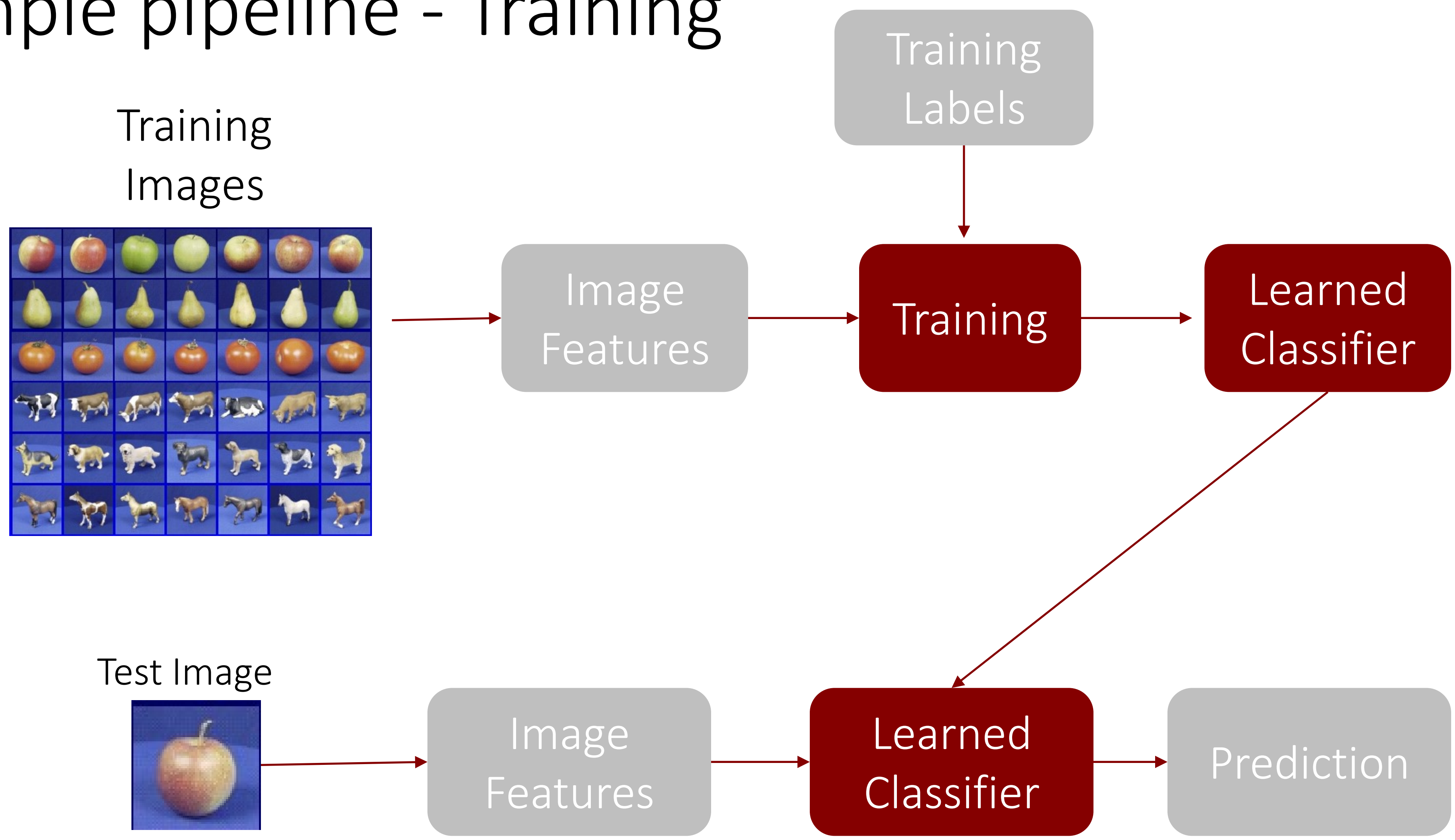
A simple pipeline - Training



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Many classifiers to choose from

- K-nearest neighbor
- SVM
- Neural networks
- Naïve Bayes
- Bayesian network
- Logistic regression
- Randomized Forests
- Boosted Decision Trees
- Restricted Boltzmann Machines
- Etc.

Which is the best one?

Slide credit: D. Hoiem

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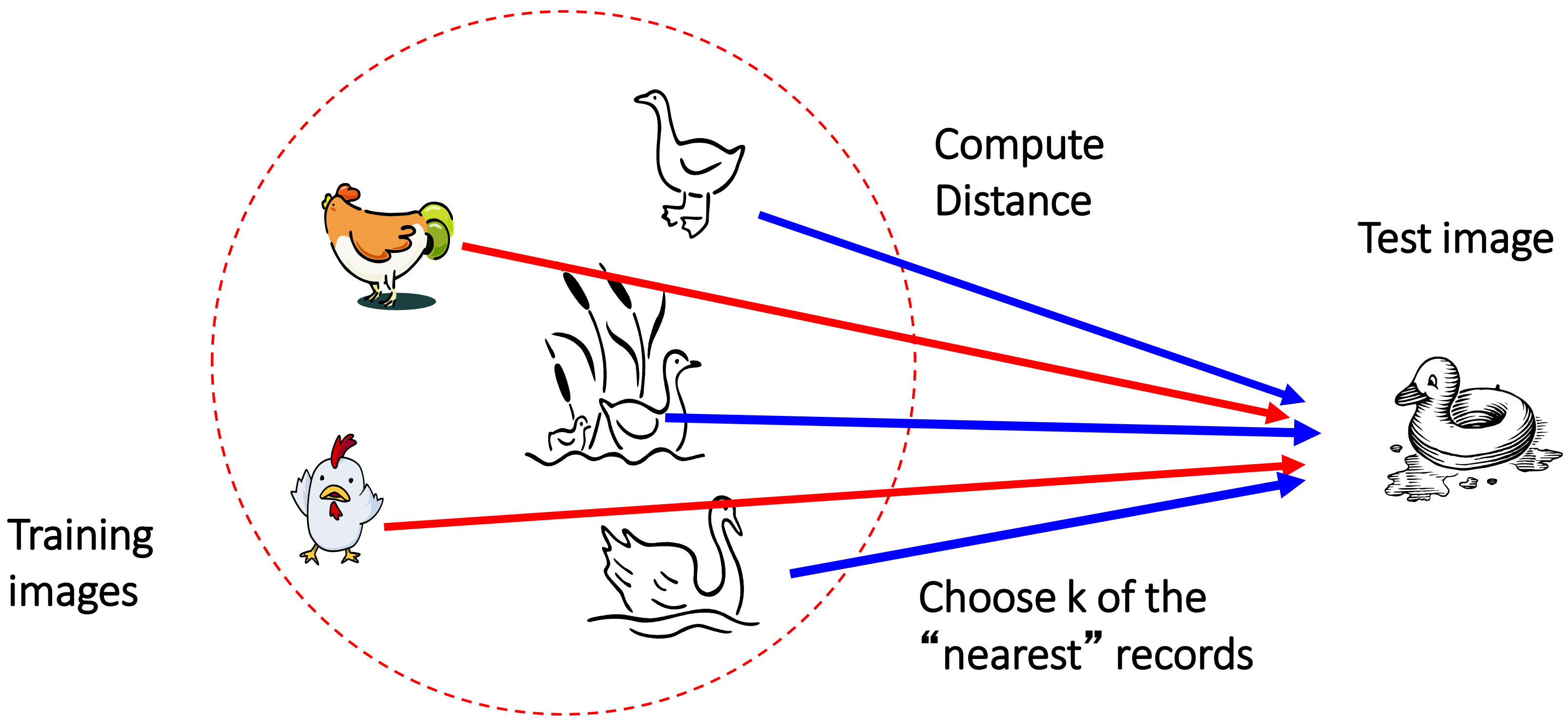
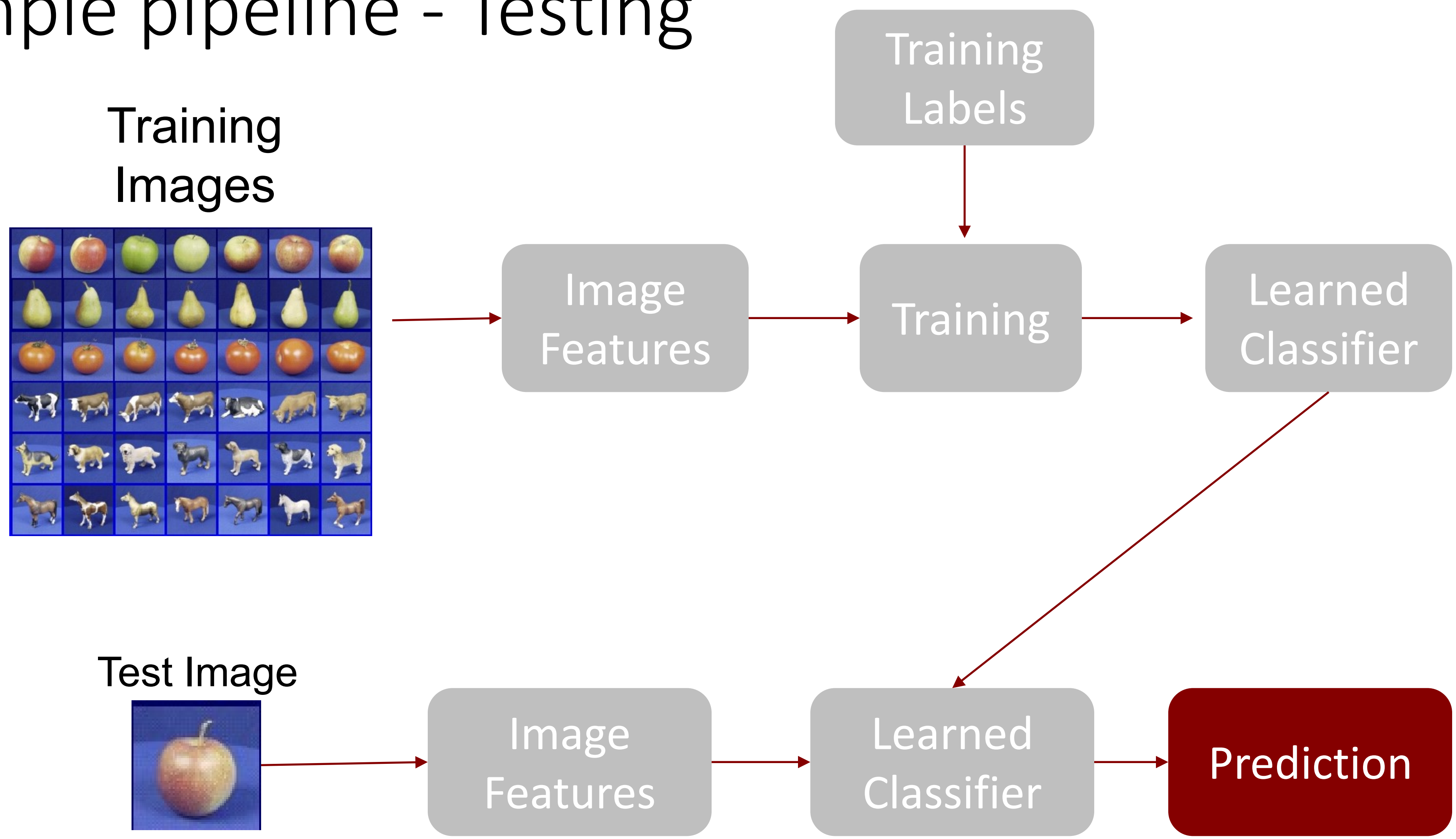
Classifiers: Nearest neighbor

Assign label of nearest training data point to each test data point



Source: N. Goyal

A simple pipeline - Testing



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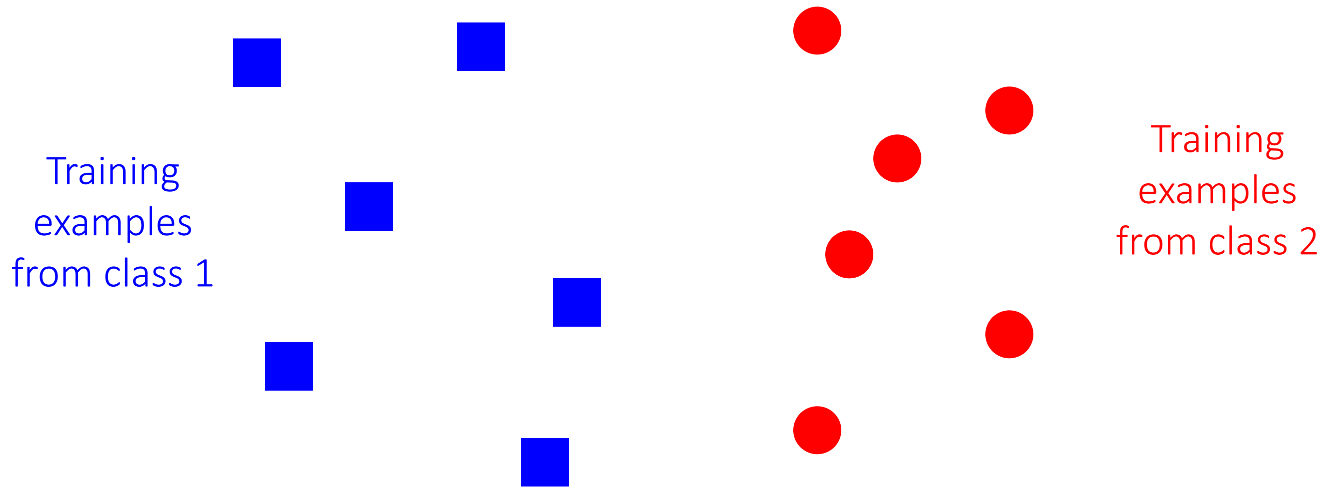
Classifiers: Nearest neighbor



Slide credit: L. Lazebnik

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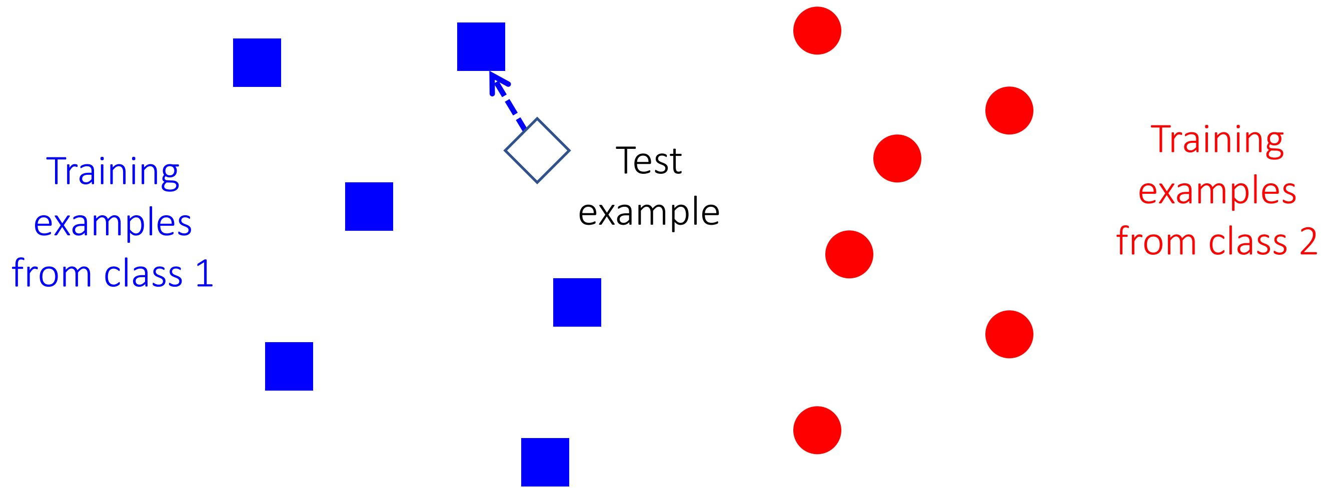

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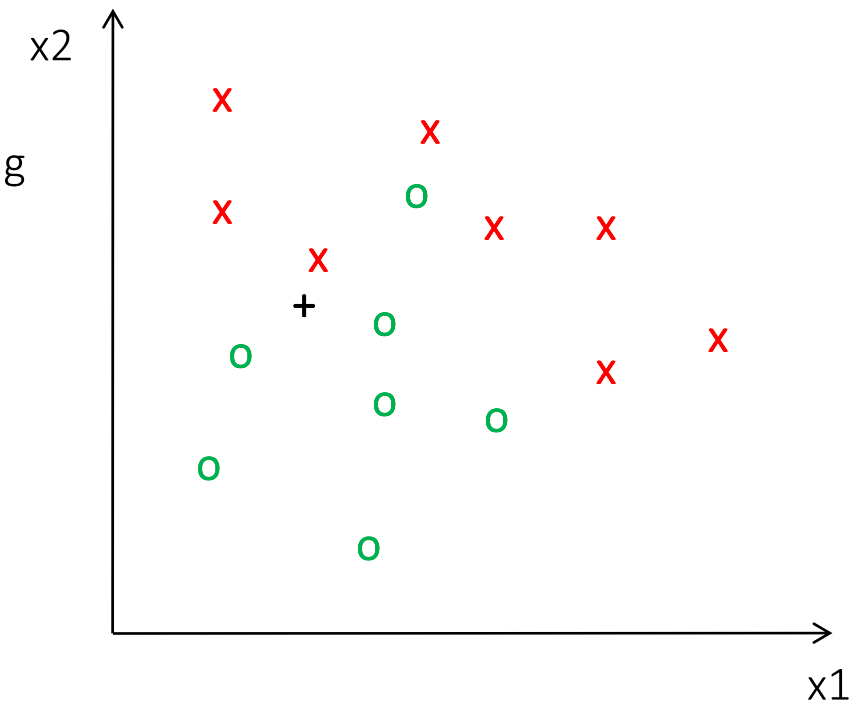
K-nearest neighbor

- Algorithm (training):

1. Store all training data points $\boldsymbol{x}_i$ with their corresponding category labels y_i

- Algorithm (testing):

1. We are given a new test point $\boldsymbol{x}$
2. Compute distance to all training data points
3. Select k training points closest to $\boldsymbol{x}$
4. Assign $\boldsymbol{x}$ to label y that is most common among the k nearest neighbors.

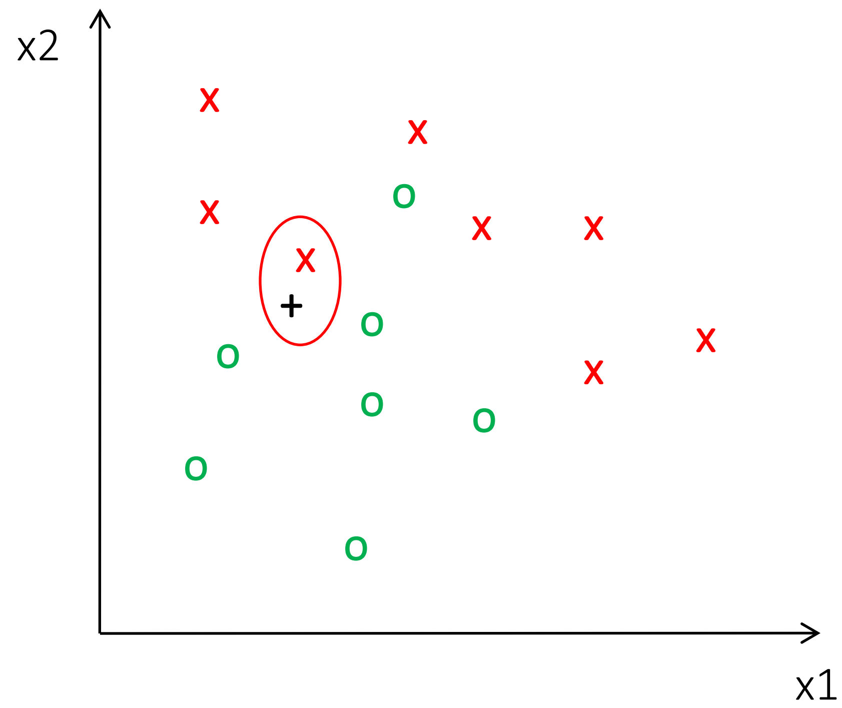


- Distance measurement: – Euclidean

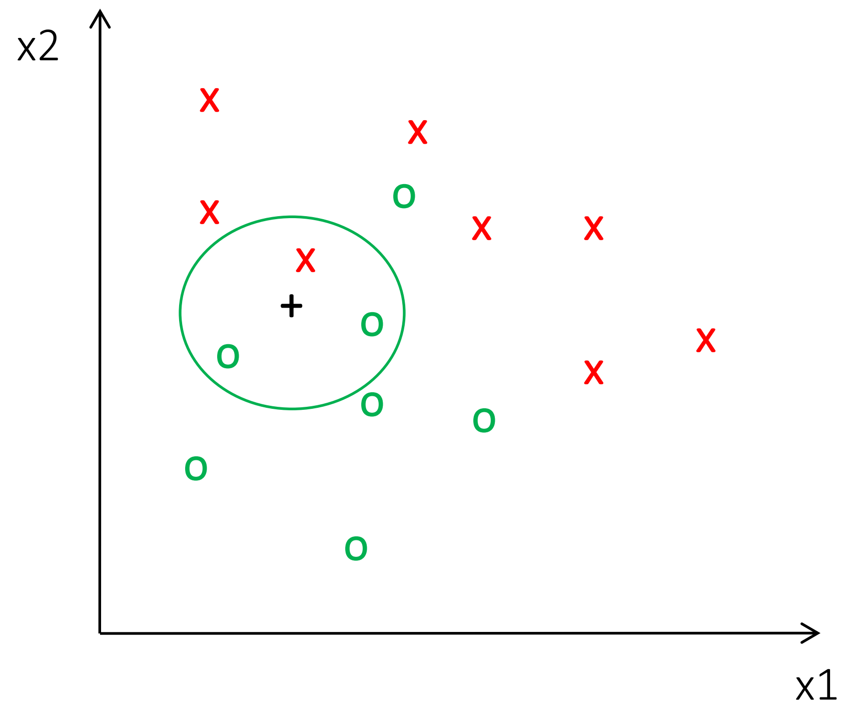
$$Dist(X^n, X^m) = \sqrt{\sum_{i=1}^{D} (X_i^n - X_i^m)^2}$$

Where X^n and X^m are the n-th and m-th data points

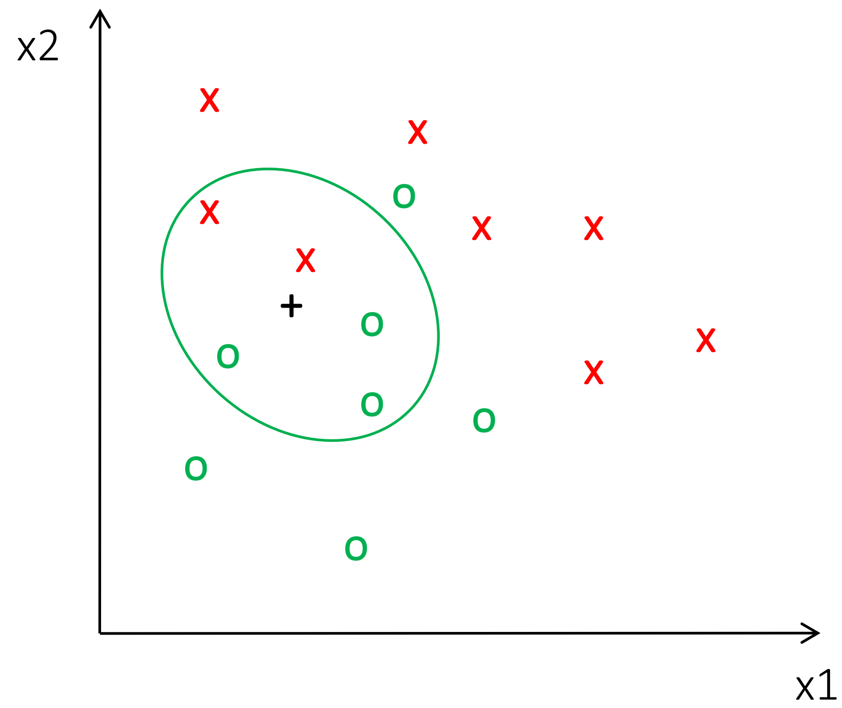
1-nearest neighbor



3-nearest neighbor



5-nearest neighbor



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K-NN: a very useful algorithm

- Simple, a good one to try first
- Very flexible decision boundaries

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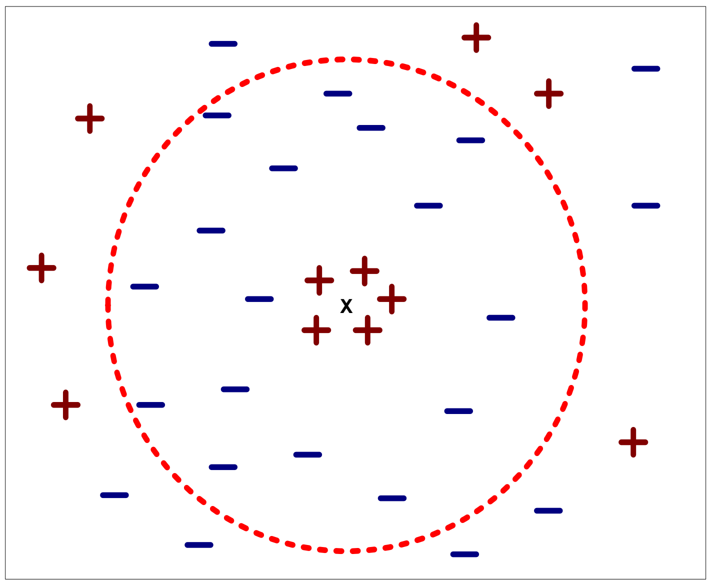
K-NN: issues to keep in mind

- Choosing the value of k:
  - If too small, sensitive to noise points
  - If too large, neighborhood may include points from other classes



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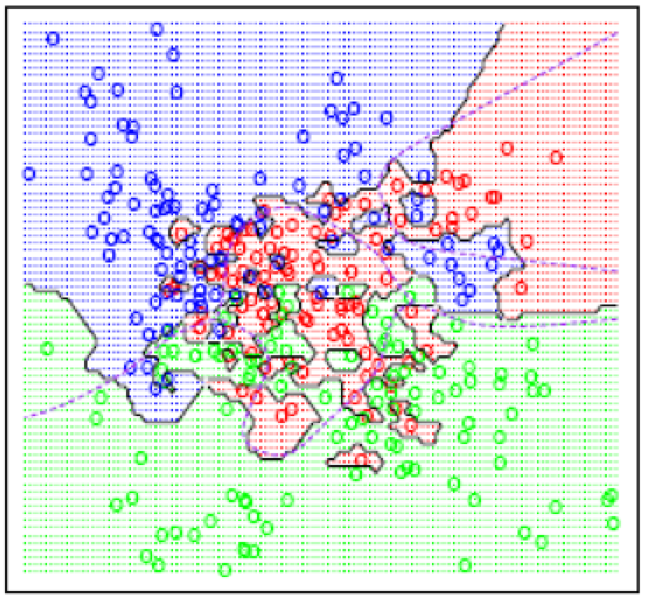
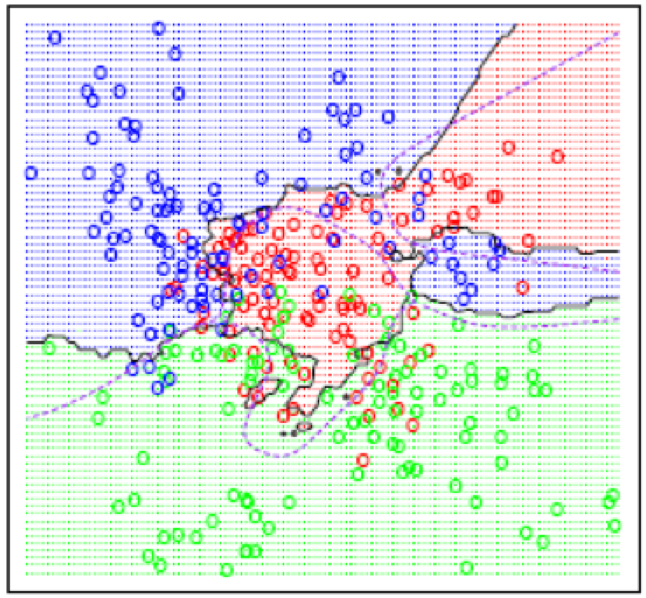
K=1



K=15



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K-NN: issues to keep in mind

- Choosing the value of k:
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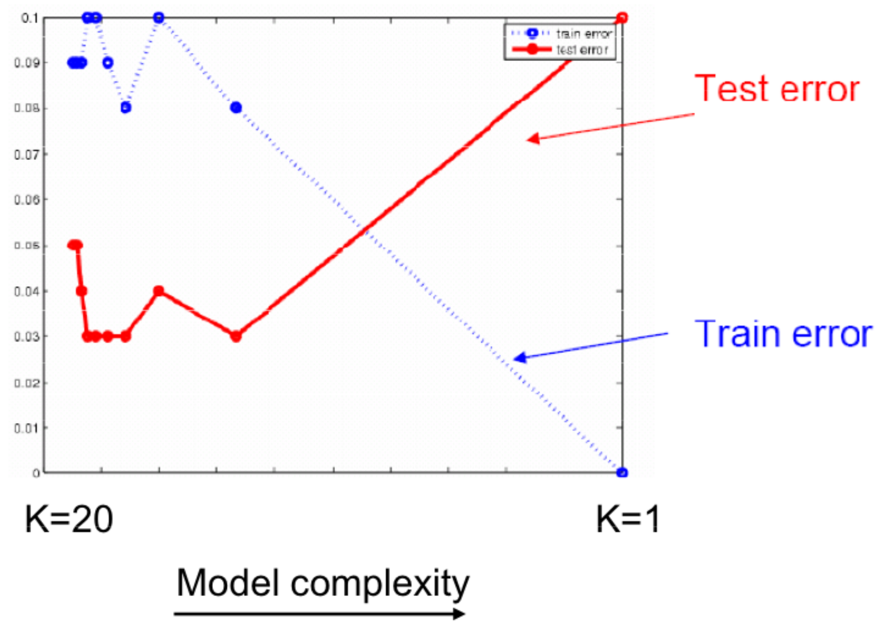
  - If too large, neighborhood may include points from other classes
  - Solution: cross validate!



Cross validation

- For each value of k in the nearest neighbors algorithm:
- Create multiple train/test splits
  - For each split:
    - Measure performance
- Average performance over all splits
- Select k with best average performance

K-NN: issues to keep in mind

- Choosing the value of k:
  - If too small, sensitive to noise points
  - If too large, neighborhood may include points from other classes
  - Solution: cross validate!

- Can produce counter-intuitive results (using Euclidean measure)

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Euclidean measure

1 1 1 1 1 1 1 1 1 1 1 1 0
0 1 1 1 1 1 1 1 1 1 1 1 1

d = 1.4142

VS

1 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 1

d = 1.4142

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K-NN: issues to keep in mind

- Choosing the value of k:
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  - If too large, neighborhood may include points from other classes
  - Solution: cross validate!
- Can produce counter-intuitive results (using Euclidean measure)
  - Solution: normalize the vectors to unit length

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- Curse of Dimensionality

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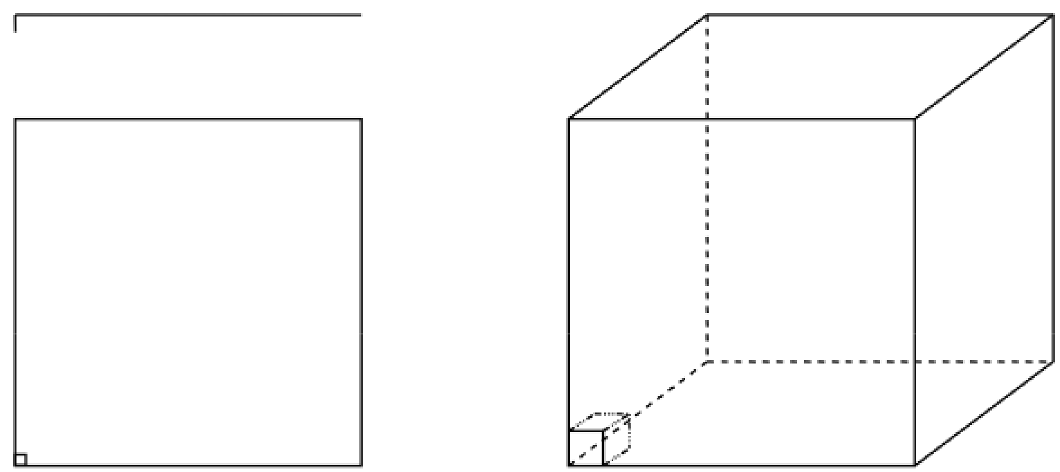
Curse of dimensionality

- Assume 5000 points uniformly distributed in the unit (hyper)cube and we want to apply 5-NN. Suppose our query point is at the origin.
  - In 1-dimension, we must go a distance of 5/5000=0.001 on average to capture 5 nearest neighbors.
  - In 2 dimensions, we must go $\sqrt{0.001}$ to get a square that contains 0.001 of the volume.
  - In d dimensions, we must go $(0.001)^{1/d}$



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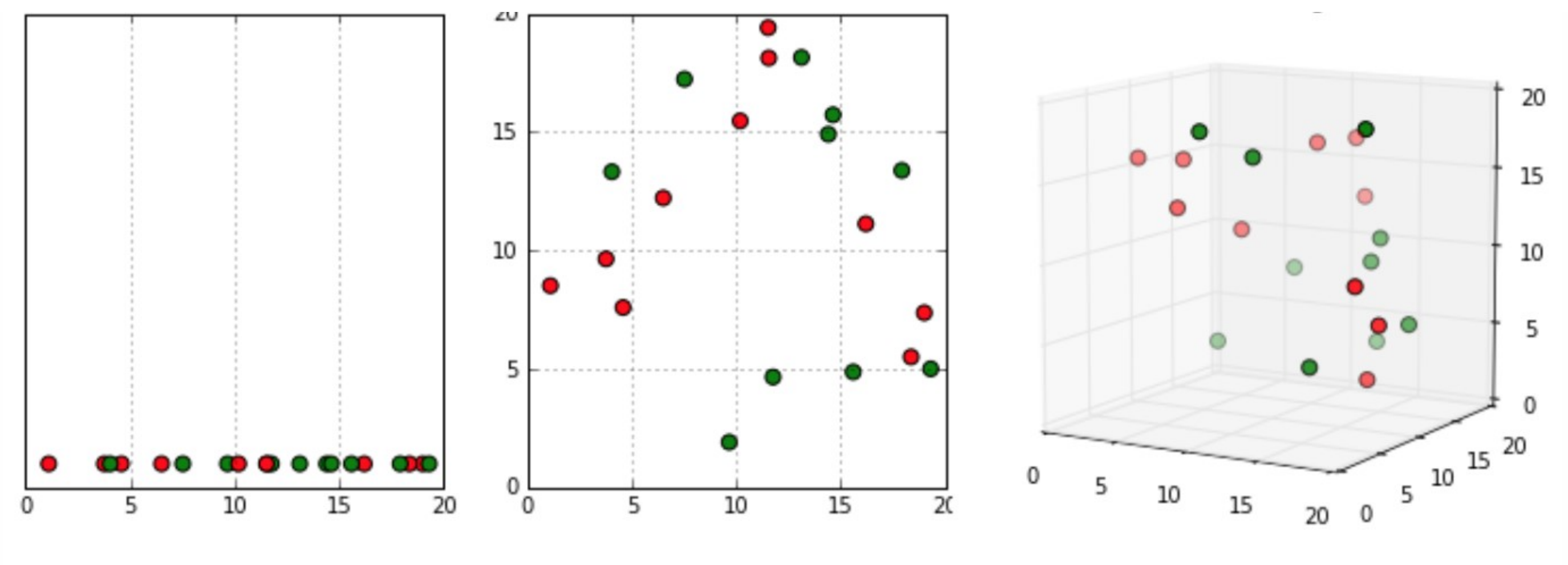

K-NN: issues to keep in mind

- Choosing the value of k:
  - If too small, sensitive to noise points
  - If too large, neighborhood may include points from other classes
  - Solution: cross validate!
- Can produce counter-intuitive results (using Euclidean measure)
  - Solution: normalize the vectors to unit length
- Curse of Dimensionality
  - Solution: no good one – need to get more data

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