# Instance-Based Learning

**CS478 – Machine Learning**
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**Reading: Mitchell Chapter 1 & Sections 8.1 - 8.2**

## Concept Learning

**Definition:**
Acquire an operational definition of a general category of objects given positive and negative training examples.

## Concept Learning Example

| correct (3) | color (2) | original (2) | presentation (3) | binder (2) | A+Homework |
|---|---|---|---|---|---|
| complete | yes | yes | clear | no | yes |
| complete | no | yes | clear | no | yes |
| partial | yes | no | unclear | no | no |
| complete | yes | yes | clear | yes | yes |

**Instance Space X:** Set of all possible objects described by attributes (often called features).

**Concept c:** Subset of objects from X (c is unknown).

**Target Function f:** Characteristic function indicating membership in c based on attributes (i.e. label)(f is unknown).

**Training Data S:** Set of instances labeled with target function.

## Concept Learning as Learning a Binary Function

- **Task:**
  - Learn (to imitate) a function f: X → {+1,-1}
- **Training Examples:**
  - Learning algorithm is given the correct value of the function for particular inputs → **training examples**
  - An **example** is a pair (*x*, *y*), where *x* is the input and *y=f(x)* is the output of the target function applied to *x*.
- **Goal:**
  - Find a function
    h: X → {+1,-1}
    that approximates
    f: X → {+1,-1}
    as well as possible.

## K-Nearest Neighbor (KNN)

- **Given: Training data** $(\vec{x}_1, y_1), \ldots, (\vec{x}_n, y_n)$
  - Attribute vectors: $\vec{x}_i \in X$
  - Label: $y_i \in \{-1, +1\}$
- **Parameter:**
  - Similarity function: $K : X \times X \longrightarrow \Re$
  - Number of nearest neighbors to consider: *k*
- **Prediction rule**
  - New example *x'*
  - K-nearest neighbors: *k* training examples with largest $K(\vec{x}_i, \vec{x}')$

$$h(\vec{x}') = \arg\max_{y \in Y} \left\{ \sum_{i \in knn(\vec{x}')} 1_{[y_i = y]} \right\}$$

## KNN Example

| | correct (3) | color (2) | original (2) | presentation (3) | binder (2) | A+Homework |
|---|---|---|---|---|---|---|
| 1 | complete | yes | yes | clear | no | yes / +1 |
| 2 | complete | no | yes | clear | no | yes / +1 |
| 3 | partial | yes | no | unclear | no | no / -1 |
| 4 | complete | yes | yes | clear | yes | yes / +1 |

- **How will new examples be classified?**
  - Similarity function?
  - Value of k?

$$h(\vec{x}') = \arg\max_{y \in Y} \left\{ \sum_{i \in knn(\vec{x}')} 1_{[y_i = y]} \right\}$$

## Weighted K-Nearest Neighbor

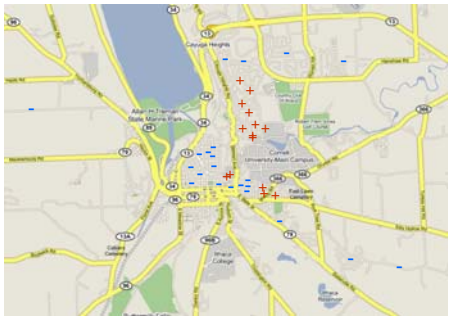
- **Given: Training data** $(\vec{x}_1, y_1), \ldots, (\vec{x}_n, y_n)$
  - Attribute vectors: $\vec{x}_i \in X$
  - Target attribute: $y_i \in \{-1, +1\}$
- **Parameter:**
  - Similarity function: $K : X \times X \longrightarrow \Re$
  - Number of nearest neighbors to consider: *k*
- **Prediction rule**
  - New example *x'*
  - K-nearest neighbors: *k* training examples with largest $K(\vec{x}_i, \vec{x}')$

$$h(\vec{x}') = \arg\max_{y \in Y} \left\{ \sum_{i \in knn(\vec{x}')} 1_{[y_i = y]} K(\vec{x}_i, \vec{x}') \right\}$$

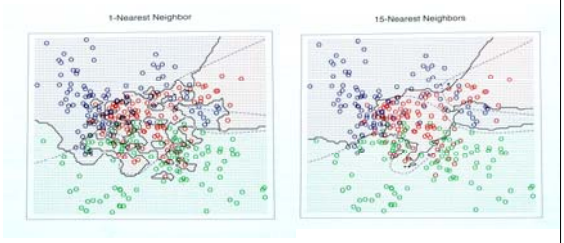
## Types of Attributes

- **Symbolic (nominal)**
  - *EyeColor {brown, blue, green}*
- **Boolean**
  - *anemic {TRUE,FALSE}*
- **Numeric**
  - Integer: *age* [0, 105]
  - Real: *length*
- **Structural**
  - Natural language sentence: parse tree
  - Protein: sequence of amino acids

## Example: Expensive Housing (>$200 / sqft)



## Example: Effect of k




*Hastie, Tibshirani, Friedman 2001*

## Supervised Learning (Concept Learning, Classification, Regression, etc.)

- **Task:**
  - Learn (to imitate) a function f: X → Y
- **Training Examples:**
  - Learning algorithm is given the correct value of the function for particular inputs → **training examples**
  - An **example** is a pair (*x*, *f*(*x*)), where *x* is the input and *f*(*x*) is the output of the function applied to *x*.
- **Goal:**
  - Find a function
    h: X → Y
    that approximates
    f: X → Y
    as well as possible.

## Weighted K-Nearest Neighbor for Regression

- **Given: Training data** $(\vec{x}_1, y_1), \ldots, (\vec{x}_n, y_n)$
  - Attribute vectors: $\vec{x}_i \in X$
  - Target attribute: $y_i \in \Re$
- **Parameter:**
  - Similarity function: $K : X \times X \longrightarrow \Re$
  - Number of nearest neighbors to consider: *k*
- **Prediction rule**
  - New example *x'*
  - K-nearest neighbors: *k* training examples with largest $K(\vec{x}_i, \vec{x}')$

$$h(\vec{x}') = \frac{\sum_{i \in knn(\vec{x}')} y_i K(\vec{x}_i, \vec{x}')}{\sum_{i \in knn(\vec{x}')} K(\vec{x}_i, \vec{x}')}$$

## Collaborative Filtering