Instance-Based Learning

CS4780 – 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

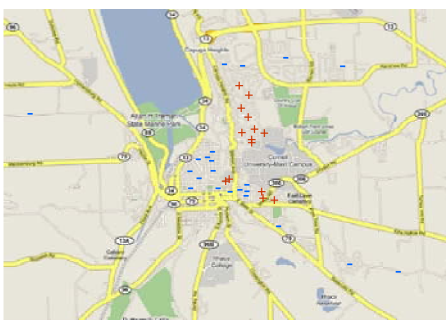
- **Given: Training data $(\vec{x}_1, y_1), \ldots, (\vec{x}_n, y_n)$**
  - Attribute vectors: $\vec{x}_i \in X$
  - Target attribute: $y_i \in \{-1, +1\}$
- **Parameter:**
  - Similarity function: $K : X \times X \longrightarrow \Re$
  - Number of nearest neighbors to consider: *k*
- **Prediction rule**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

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

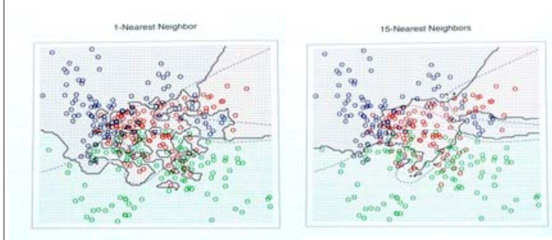
Types of Attributes

- **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