# Supervised Classification

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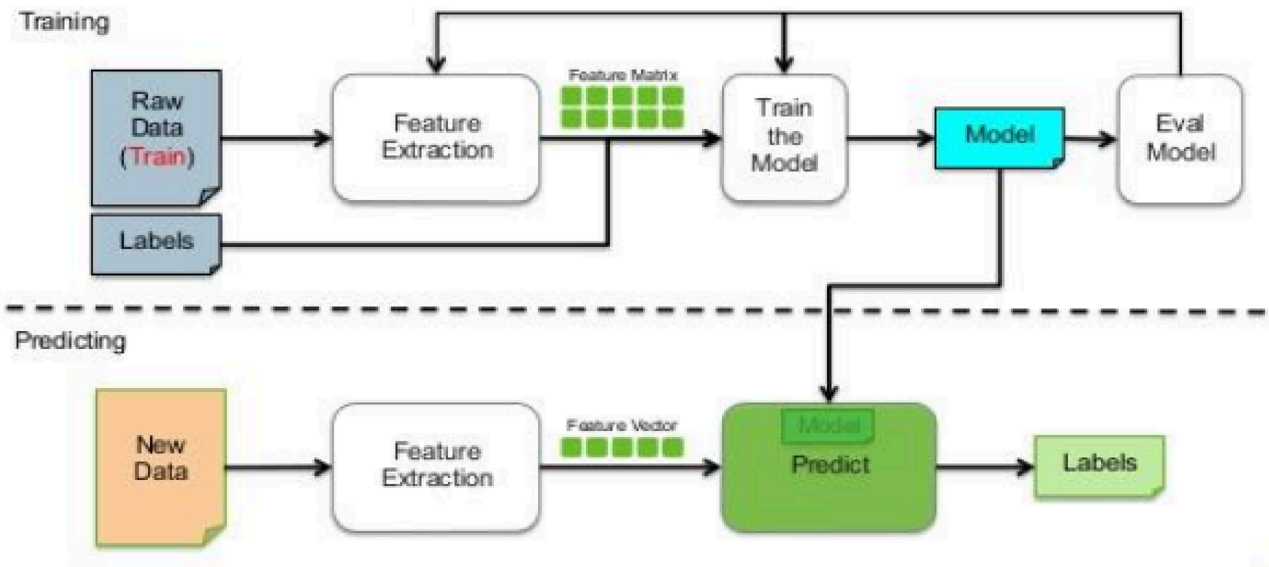
# Types of Machine Learning

# Supervised Learning Workflow







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# Instance Based Classifiers

- First Example of Supervised Classification
- Examples:
  - Rote-learner
    - Memorizes entire training data and performs classification only if attributes of record match one of the training examples exactly

– Nearest neighbor

- Uses k "closest" points (nearest neighbors) for performing classification

# Instance-Based Classifiers

C

B

Set of Stored Cases

- Store the training records
- Use training records to predict the class label of unseen cases

Atr1 ……… AtrN Class A

B

B

C

A

Unseen Case

Atr1 ……… AtrN

# Nearest Neighbor Classifiers

- Basic idea:
  - If it walks like a duck, quacks like a duck, then it’s probably a duck

Compute Distance

Test Record

Choose k of the “nearest” records

Training Records

# Nearest-Neighbor Classifiers

**Unknown record**

- Requires three things

– The set of stored records – Distance Metric to compute distance between records

– The value of *k*, the number of nearest neighbors to retrieve

- To classify an unknown record: – Compute distance to other training records

– Identify *k* nearest neighbors – Use class labels of nearest neighbors to determine the class label of unknown record (e.g., by taking majority vote)

# Definition of Nearest Neighbor

x x x

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

K-nearest neighbors of a record x are data points that have the k smallest distance to x

# Nearest Neighbor Classification

- Compute distance between two points:
  - Euclidean distance

$$d(p,q) = \sum_i (p_i - q_i)^2$$

$$d(p,q) = \sum_i abs(p_i - q_i)$$

- Determine the class from nearest neighbor list
  - take the majority vote of class labels among the k nearest neighbors
  - Weigh the vote according to distance

- weight factor, $w = 1/d^2$

# Example (NN Classifier)

| F1 | F2 | Class |
|---|---|---|
| 1 | 5 | 0 |
| 0 | 8 | 0 |
| 0 | 6 | 1 |
| 1 | 2 | 1 |

| | | |
|---|---|---|
| *1* | *3* | *?* |

| | | |
|---|---|---|
| 1 | 4 | ? |
| 0 | 3 | ? |
| 0 | 4 | ? |

**Training Data** **Test Data**

# Example (NN Classifier)

Step 1: Computer Distance from Test Sample 1 to Training Data Step 2:

| | | |
|---|---|---|
| 1 | \|1-1\|+\|3-5\| = 0 + 2 = 2 | 0 |
| 2 | \|1-0\|+\|3-8\| = 1 + 5 = 6 | 0 |
| 3 | \|1-0\|+\|3-6\| = 1 + 3 = 4 | 1 |
| 4 | \|1-1\|+\|3-2\| = 0 + 1 = 1 | 1 |

Step 3: Assign the Test Sample to Class with minimum Distance, Here is Class 1. So Test Sample 1 belongs to Class 1

# Example (NN Classifier)

Exercise: Calculate for

other 3 Test Samples

| | | |
|---|---|---|
| 1 | 0 | 1 |
| 2 | 0 | 0 |
| 3 | 1 | 1 |
| 4 | 1 | 0 or 1 |

## Nearest Neighbor Classification…

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

other classes

x

# Nearest Neighbor Classification…

- Scaling issues
  - Attributes may have to be scaled to prevent distance measures from being dominated by one of the attributes
  - Example:
    - height of a person may vary from 1.5m to 1.8m

- weight of a person may vary from 90lb to 300lb
- income of a person may vary from $10K to $1M

# Example (NN Classifier)

Normalize Data from 0 to 1

| F1 | F2 | Class |
|---|---|---|
| 1 | 0.5 | 0 |
| 0 | 1 | 0 |
| 0 | 0.667 | 1 |
| 1 | 0 | 1 |

| | | |
|---|---|---|
| *1* | *0.167* | *?* |
| *1* | *0.334* | *?* |
| *0* | *0.167* | *?* |
| *0* | *0.334* | *?* |

**Training Data Test Data**

# Example (NN Classifier)

After Normalization

| | | |
|---|---|---|
| 1 | 0 | 1 |
| 2 | 0 | 0 |

| | | |
|---|---|---|
| 3 | 1 | 1 |
| 4 | 1 | 1 |

# Confusion Matrix

- In the field of machine learning, a **confusion matrix** is a specific table layout that allows visualization of the performance of an algorithm

| | Predicted Negative | Predicted Positive |
|---|---|---|
| Actual Negative | True Negative | False Positive |
| Actual Positive | False Negative | True Positive |

## Confusion Matrix

- ***TN*** is the number of correct predictions that an instance is negative
- ***FP*** is the number of incorrect predictions that an instance is positive
- ***FN*** is the number of incorrect predictions that an instance is negative
- ***TP*** is the number of correct predictions that an instance is positive

## Confusion Matrix

- Confusion Matrix from the example of Lecture 2 (without Normalization)

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 0 | 0 |
| 3 | 1 | 1 |
| 4 | 1 | 0 |

| | | |
|---|---|---|
| Negative | TN = 1 | FP = 0 |
| Positive | FN = 1 | TP = 2 |

# Confusion Matrix

# Confusion Matrix

- Several standard terms have been defined for the 2 class matrix
- The *accuracy* (*AC*) is the proportion of the total number of predictions that were correct

$$Accuracy = \frac{TN + TP}{TN + FN + TP + FP}$$

- Accuracy = 3 / 4 = 75%

- The *recall* or *true positive rate* (*TPR*) is the proportion of positive cases that were correctly identified

$$TP \quad TPR \quad + \quad = \quad TP \quad FN$$

- The *false positive rate* (*FPR*) is the proportion of negatives cases that were incorrectly classified as positive

$$FP \quad FPR \quad + \quad = \quad FP \quad TN$$

- TPR or recall = 2 / 3 = 66.7%

- FPR = 0 / 1 = 0 %

# Confusion Matrix

- The *true negative rate* (*TNR*) is defined as the proportion of negatives cases that were classified correctly,

$$TNR = \frac{TN}{FP + TN}$$

- The *false negative rate* (*FNR*) is the proportion of positives cases that were incorrectly classified as negative

$$FNR = \frac{FN}{TP + FN}$$

- TNR = 1 / 1 = 100%
- FNR = 1 / 3 = 33.3%

$FN\ TP$

# Confusion Matrix

- *precision* (*P*) is the proportion of the predicted positive cases that were correct,

$$precision = \frac{tp}{tp + fp} \quad 100\%$$

- precision = 2/2 =

- F measure is harmonic mean of precision and recall

$$F_1 = 2 \cdot \frac{\mathrm{precision} \cdot \mathrm{recall}}{\mathrm{precision} + \mathrm{recall}}$$

- F1 = (2 * 1 * 0.667)/(1+0.667) = 0.8

## Exercise

| |
|---|
| |
| Neg |

| | |
|---|---|
| | 9760 |
| Positive | 140 |

# References


- Introduction to Data Mining by Tan, Steinbach, Kumar (Lecture Slides)
- http://robotics.stanford.edu/~ronnyk/glossary.html
- http://www.cs.tufts.edu/comp/135/Handouts/introduction lecture-12-handout.pdf


Questions!