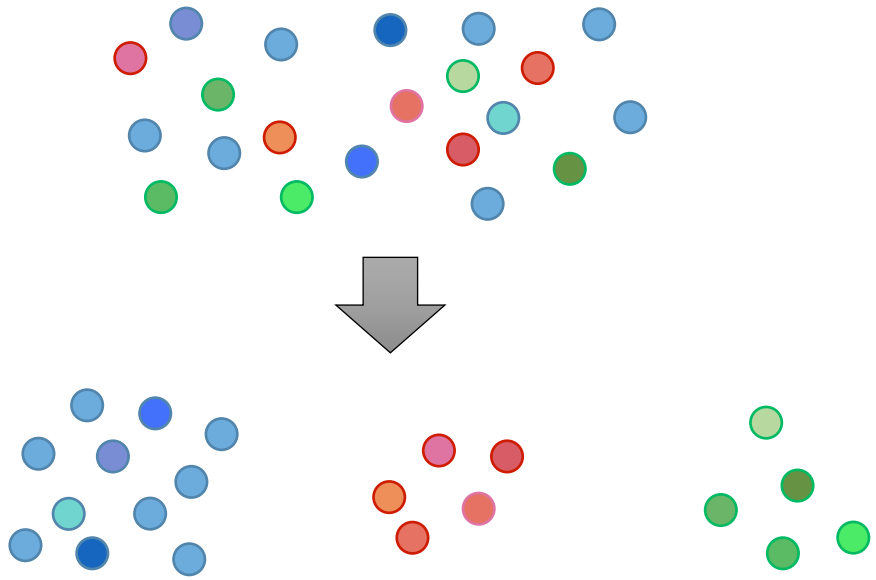
Introduction to Machine Learning

Topics

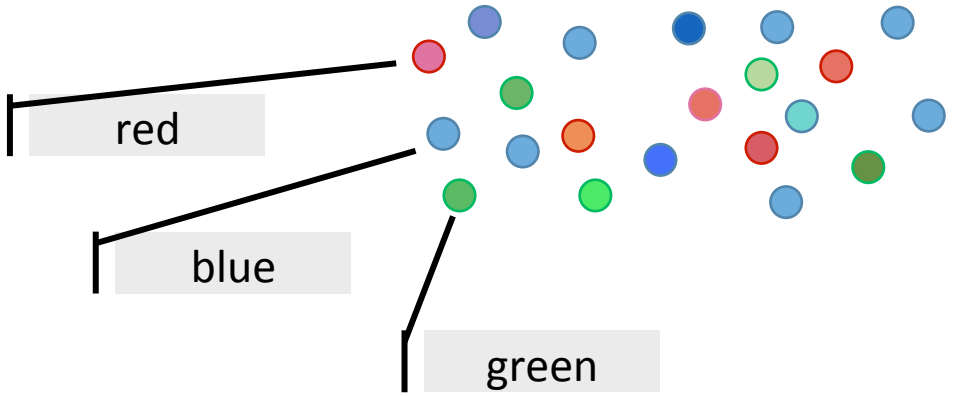
- Basic concepts and process
- Algorithms
- Example (WEKA)

Unsupervised Learning



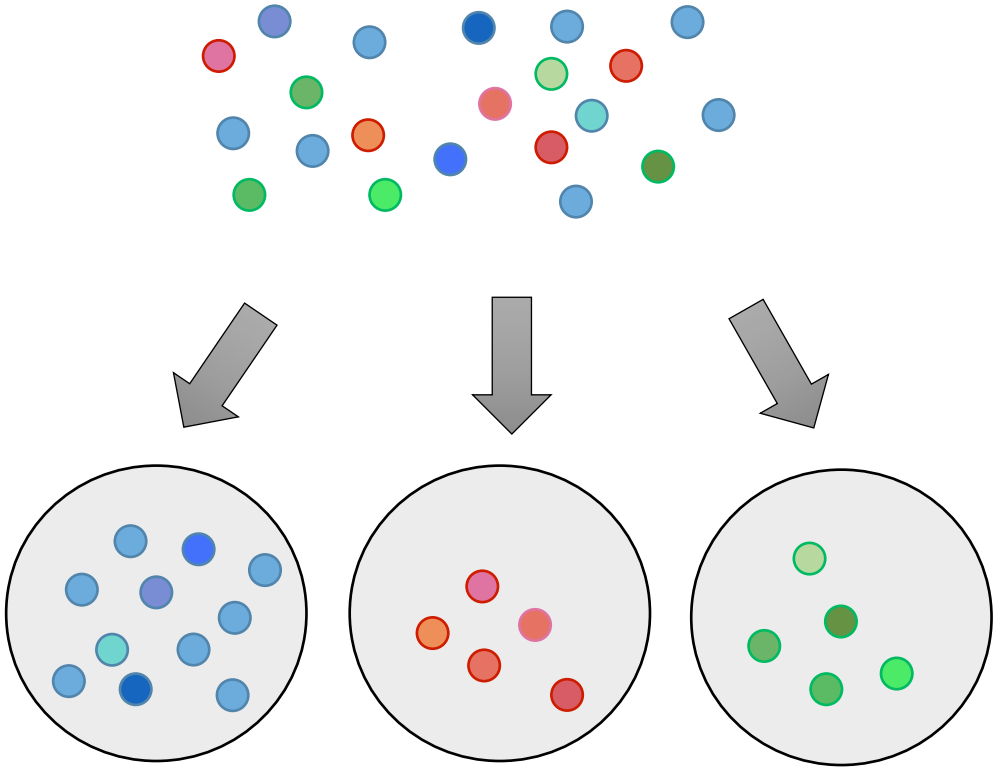
- Find patterns / clusters
- Evaluation: similarity value, classes to clusters, …

Supervised Learning



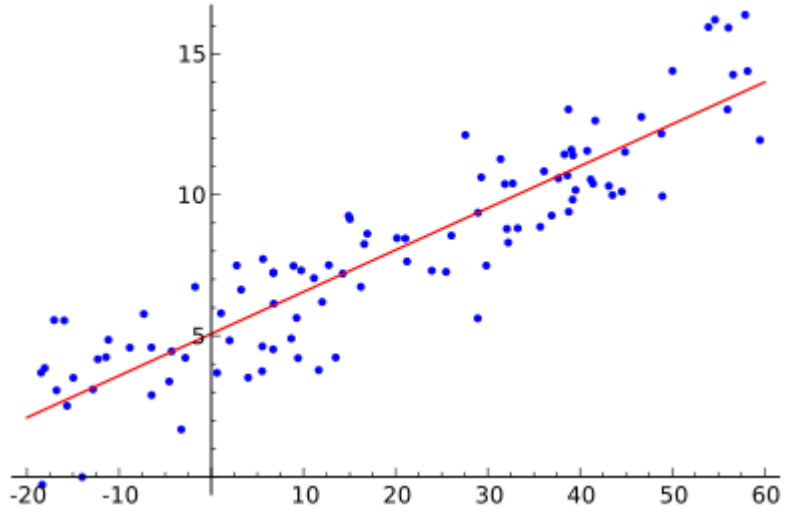
- Predict the correct label
- Evaluation: correctly classified instances, false positive rate, …

Classification



blue red green

Regression



no distinct categories, but a real value

Features / Attributes, Instances

Label /
Class attribute

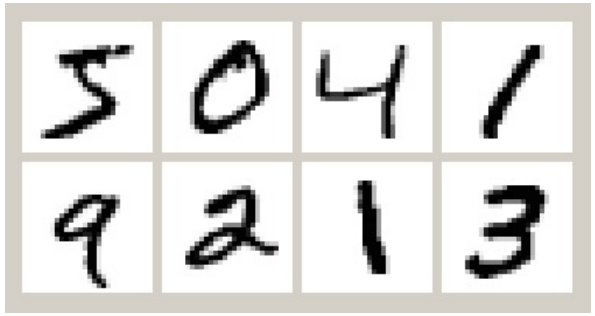
	R	G	B	Color
1	227	25	59	Red
2	17	184	56	Green
3	113	125	222	Blue
4	230	67	175	Red

Features /
Attributes

Instance

Training Set – Test Set

Dataset



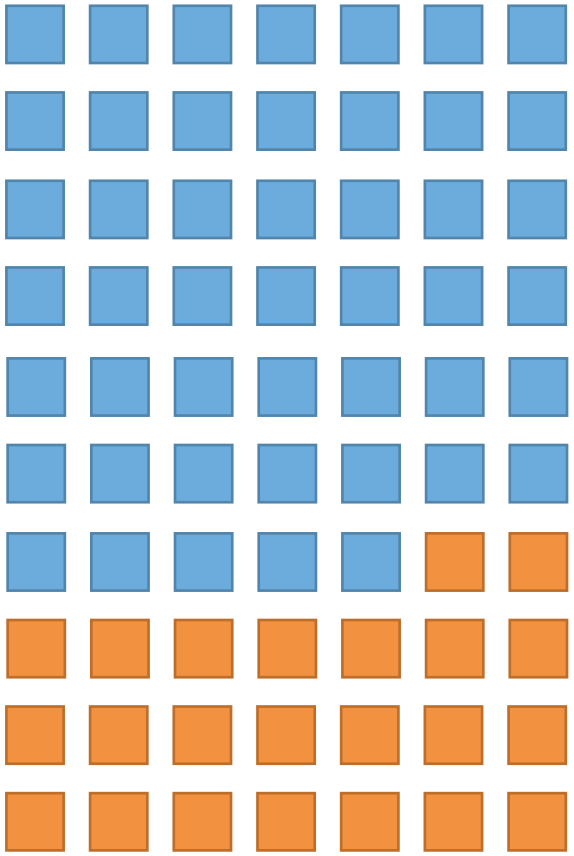
Labels

5	0	4	1
4	2	1	3

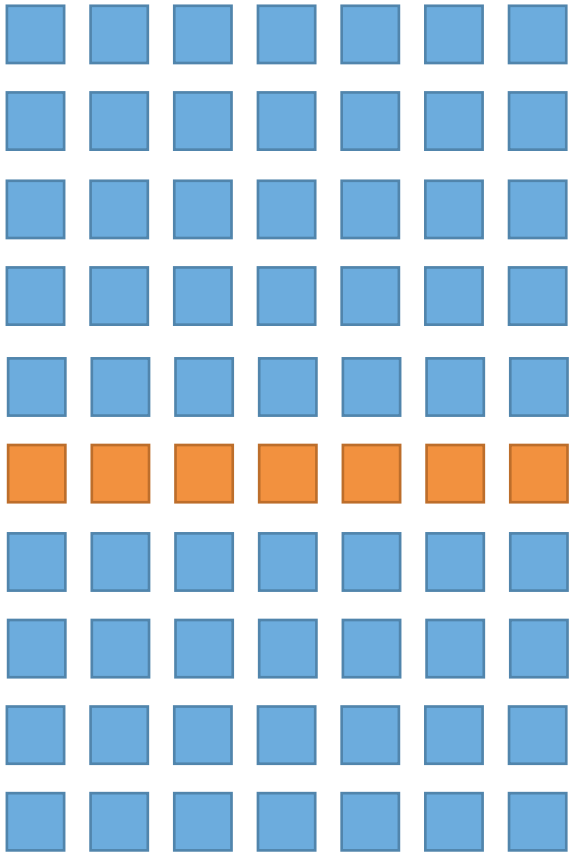
Training Set
Test Set

Validation Methods

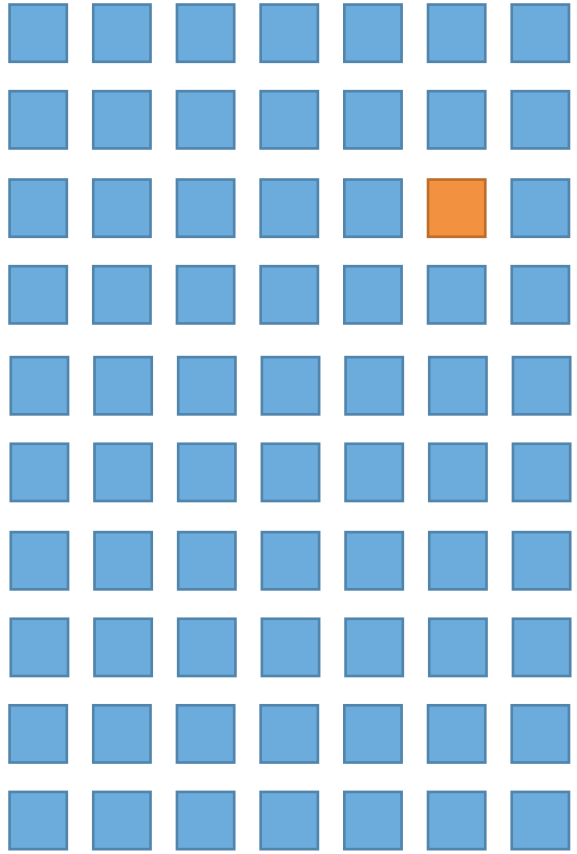
2/3 Training Set
1/3 Test Set



10-fold
Cross-validation



Leave-one-out
cross-validation



Validation Metrics

Confusion Matrix

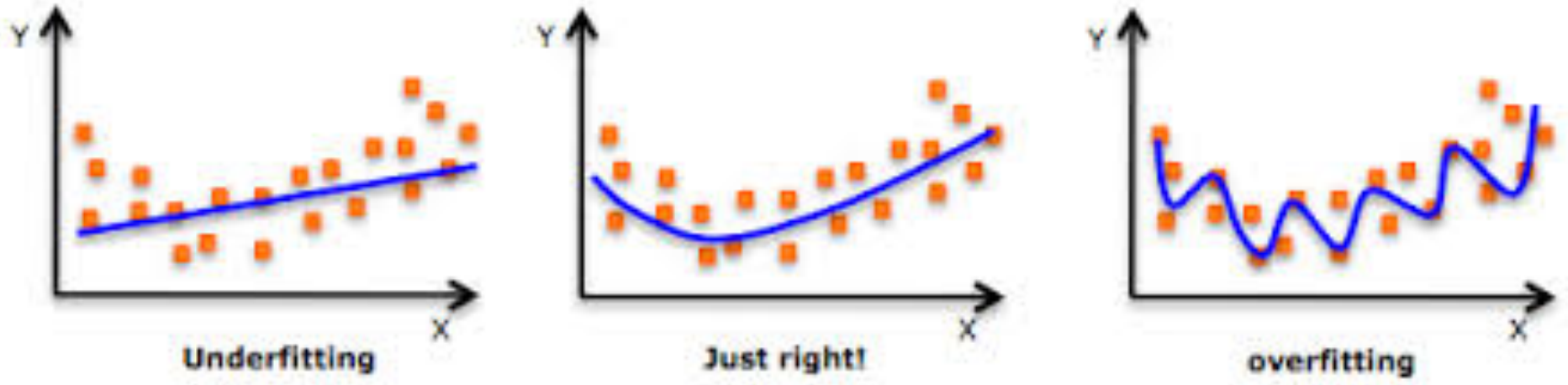
	Classifier outcome: Positive	Classifier outcome: Negative
Condition (label): Positive	**True positive**	**False negative**
Condition (label): Negative	**False positive**	**True negative**

Accuracy: (Σ True positive + Σ True negative) / total
Compare to: base accuracy = percentage share of most likely category

True positive rate = **Recall**: Σ True positive / Σ condition positive
True negative rate: Σ True negative / Σ condition negative
Precision: Σ True positive / Σ Classifier outcome positive

Source and more information: http://en.wikipedia.org/wiki/Confusion_matrix

Underfitting - Overfitting



Basic Process

1. Data collection
2. Feature calculation
3. Feature selection
4. Classification

Algorithms

- Naive Bayes
- Support Vector Machine
- Decision Trees

(There are many more: Neural networks, k-nearest neighbour, …)

Naïve Bayes

- Fast and high performance
- Based on Bayes Theorem
- Assumes independence of features

Example: e-mail classification into *spam* and *no spam.* Features: words

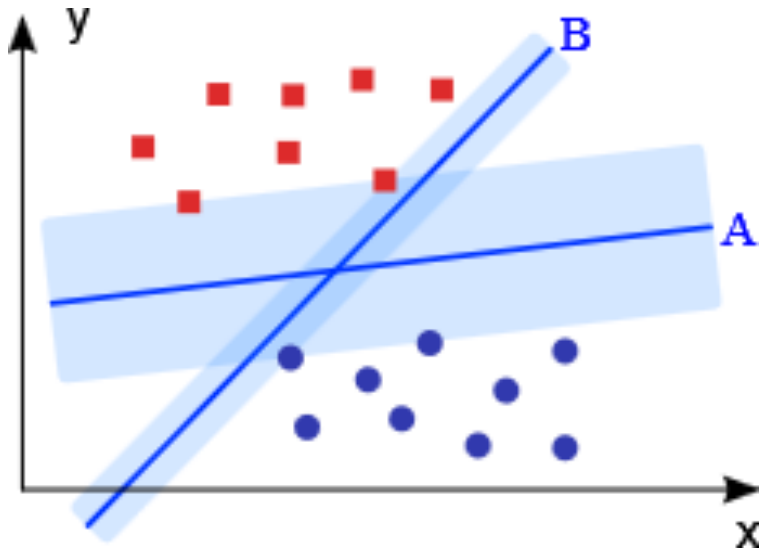
Bayes Theorem: $$P(Spam|W) = \frac{P(Spam \cap W)}{P(W)} = \frac{P(W|Spam)P(Spam)}{P(W)}$$

$$Q = \frac{P(Spam|W)}{P(\overline{Spam}|W)} = \frac{P(W|Spam)P(Spam)}{P(W)} \frac{P(W)}{P(W|\overline{Spam})P(\overline{Spam})} = \frac{P(W|Spam)P(Spam)}{P(W|\overline{Spam})P(\overline{Spam})}$$

Source: http://de.wikipedia.org/wiki/Bayes-Klassifikator

Support Vector Machine

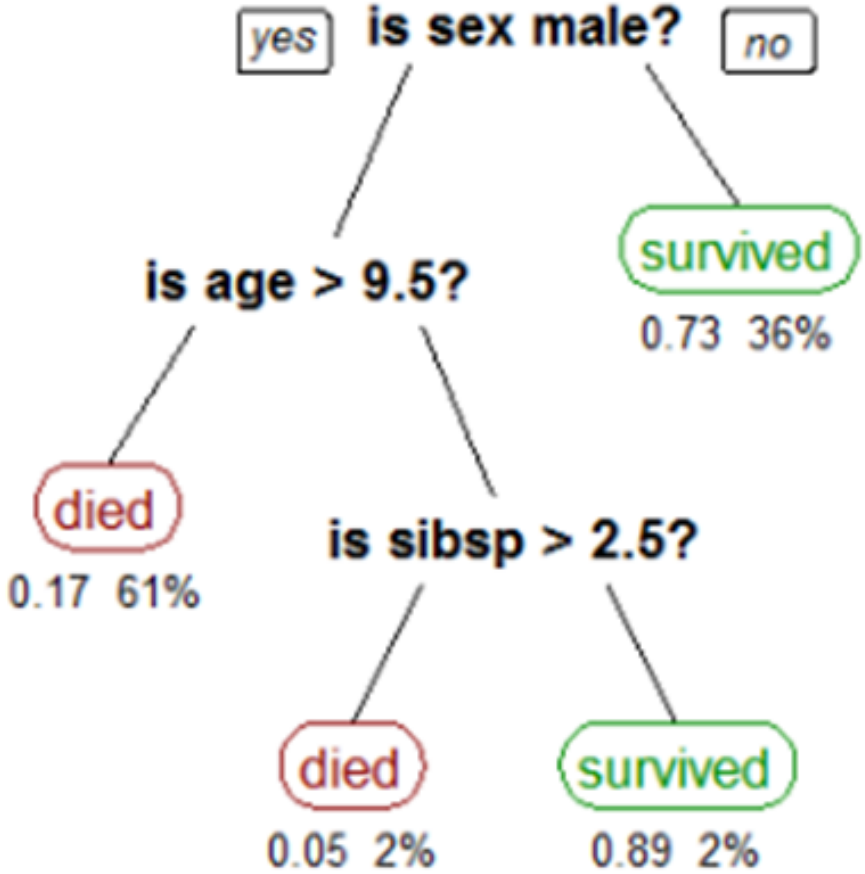
- Divides objects in classes by maintaining a maximally large margin between the objects → *Large Margin Classifier*
- can be used for classification and regression



Source: http://de.wikipedia.org/wiki/Support_Vector_Machine

Decision Tree

- Builds a tree to classify objects
- leaves = class labels
  branches = conjunctions of features that lead to those class labels
- can be used for classification and regression

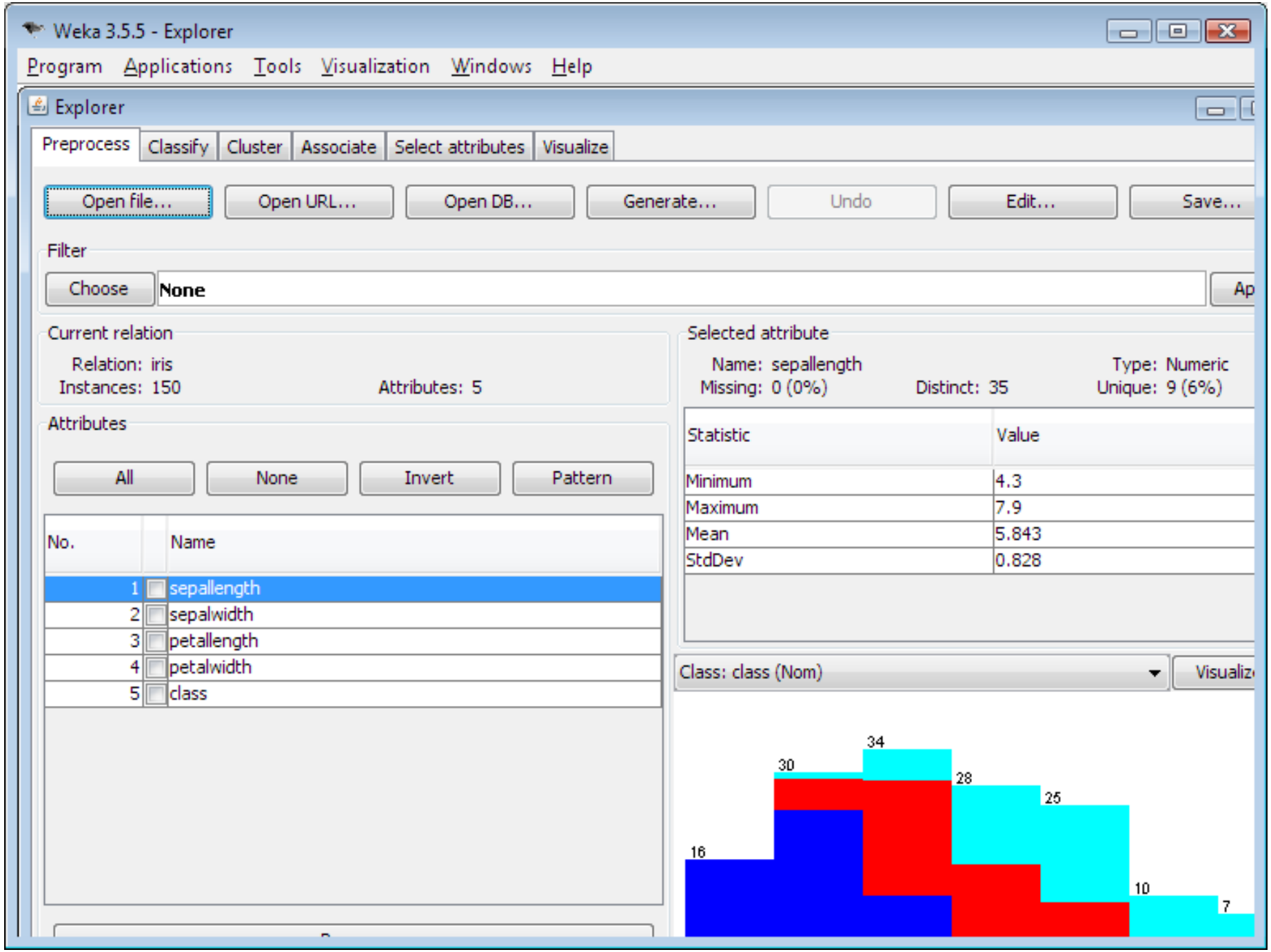


Source: http://en.wikipedia.org/wiki/Decision_tree_learning

WEKA

- Java machine learning framework
- Provides a Java library and a graphical user interface
- Implements many preprocessing algorithms (filters) and classifiers
- Filters: attribute selection, transforming and combining attributes, discretization, normalization, …
- Classifiers: Support Vector Machine (SMO), Decision Tree (J48), Naive Bayes, …

Source: http://www.cs.waikato.ac.nz/ml/weka/


Weka 3.5.5 - Explorer
Program Applications Tools Visualization Windows Help
Explorer
Preprocess Classify Cluster Associate Select attributes Visualize
Open file... Open URL... Open DB... Generate... Undo Edit... Save...
Filter
Choose None
Current relation
Relation: iris
Instances: 150 Attributes: 5
Attributes
All None Invert Pattern
No. Name
1 sepallength
2 sepalwidth
3 petallength
4 petalwidth
5 class
Selected attribute
Name: sepallength Type: Numeric
Missing: 0 (0%) Distinct: 35 Unique: 9 (6%)
Statistic Value
Minimum 4.3
Maximum 7.9
Mean 5.843
StdDev 0.828
Class: class (Nom)
34
30
28
25
16
10
7

Example Dataset: diabetes.arff

General Info:

- Number of Instances: 768
- Number of Attributes: 8 plus class
- Number of instances with label *tested_negative*: 500
- Number of instances with label *tested_positve*: 268

```
6,148,72,35,0,33.6,0.627,50,tested_positive
1,85,66,29,0,26.6,0.351,31,tested_negative
8,183,64,0,0,23.3,0.672,32,tested_positive
1,89,66,23,94,28.1,0.167,21,tested_negative
0,137,40,35,168,43.1,2.288,33,tested_positive
```

Attributes:

1. Number of times pregnant
2. Plasma glucose concentration a 2 hours in an oral glucose tolerance test
3. Diastolic blood pressure (mm Hg)
4. Triceps skin fold thickness (mm)
5. 2-Hour serum insulin (mu U/ml)
6. Body mass index (weight in kg/ (height in m)^2)
7. Diabetes pedigree function
8. Age (years)
9. Class variable (0 or 1)

This and more datasets here: http://storm.cis.fordham.edu/~gweiss/data-mining/datasets.html

Example Weka Code Part 1

```
//read data file
DataSource source = new DataSource("C:/Users/Manuela/SkyDrive/Work/Lectures/HASE/
diabetes.arff");
Instances data = source.getDataSet();

//set class variable
if (data.classIndex() == -1) {
    data.setClassIndex(data.attribute("class").index());
}

//Attribute selection
AttributeSelection filter = new AttributeSelection();
CfsSubsetEval eval = new CfsSubsetEval();
GreedyStepwise search = new GreedyStepwise();
search.setSearchBackwards(true);
filter.setEvaluator(eval);
filter.setSearch(search);
filter.setInputFormat(data);

// Attribute reduction
Instances filteredData = Filter.useFilter(data, filter);
```

Example Weka Code Part 2

```
for (int i = 0; i < 10; i++) {
    int seed = i + 1;
    Random rand = new Random(seed);
    Instances randData = new Instances(data);
    randData.randomize(rand);
    if (randData.classAttribute().isNominal())
        randData.stratify(10);

    Evaluation evalJ48 = new Evaluation(randData);
    for (int n = 0; n < 10; n++) {
        Instances train = randData.trainCV(10, n);
        Instances test = randData.testCV(10, n);

        J48 newTree = (J48) J48.makeCopy(tree);
        newTree.buildClassifier(train);
        evalJ48.evaluateModel(newTree, test);
    }
}
```

We do a **10 times** 10-fold cross-validation

Randomize the data

We do a 10 times **10-fold** cross-validation

Set training set and test set

build and evaluate the classifier

Interpretation of Results

Base accuracy: 65.1 %

Classifier	Features	Accuracy (%)
J48	All	74.49
J48	Selected	74.38
SMO	All	76.81
SMO	Selected	76.95
Naïve Bayes	All	75.76
Naïve Bayes	Selected	77.06

Selected Features:

- Plasma glucose concentration a 2 hours in an oral glucose tolerance test
- Body mass index
- Diabetes pedigree function (synthesis of family history concerning diabetes)
- Age

Interpretation of Results

Confusion Matrix: Naïve Bayes, selected features

	Classifier outcome: Positive	Classifier outcome: Negative
Condition (label): Positive	436.3	63.7
Condition (label): Negative	112.5	155.5

Summary

Basic concepts of Machine Learning

- **Classification**
- **Cross-Validation**
- **Confusion Matrix**
- **Test Set**
- **Overfitting**

Machine Learning algorithms

- **Naïve Bayes**
- **Decision Tree**
- **Support Vector Machine**

Example

```
J48 newTree = (J48) J48.makeCopy(tree);
newTree.buildClassifier(train);
evalJ48.evaluateModel(newTree, test);
```

Classifier	Features	Accuracy (%)
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Further Readings / Links to Machine Learning

- Weka Download: http://www.cs.waikato.ac.nz/ml/weka/downloading.html
- Weka Wiki: http://weka.wikispaces.com/
- Sample Datasets: http://storm.cis.fordham.edu/~gweiss/data-mining/datasets.html
- Book about Machine Learning and Weka: http://www.cs.waikato.ac.nz/ml/weka/book.html
- Book about Artificial Intelligence: http://aima.cs.berkeley.edu/

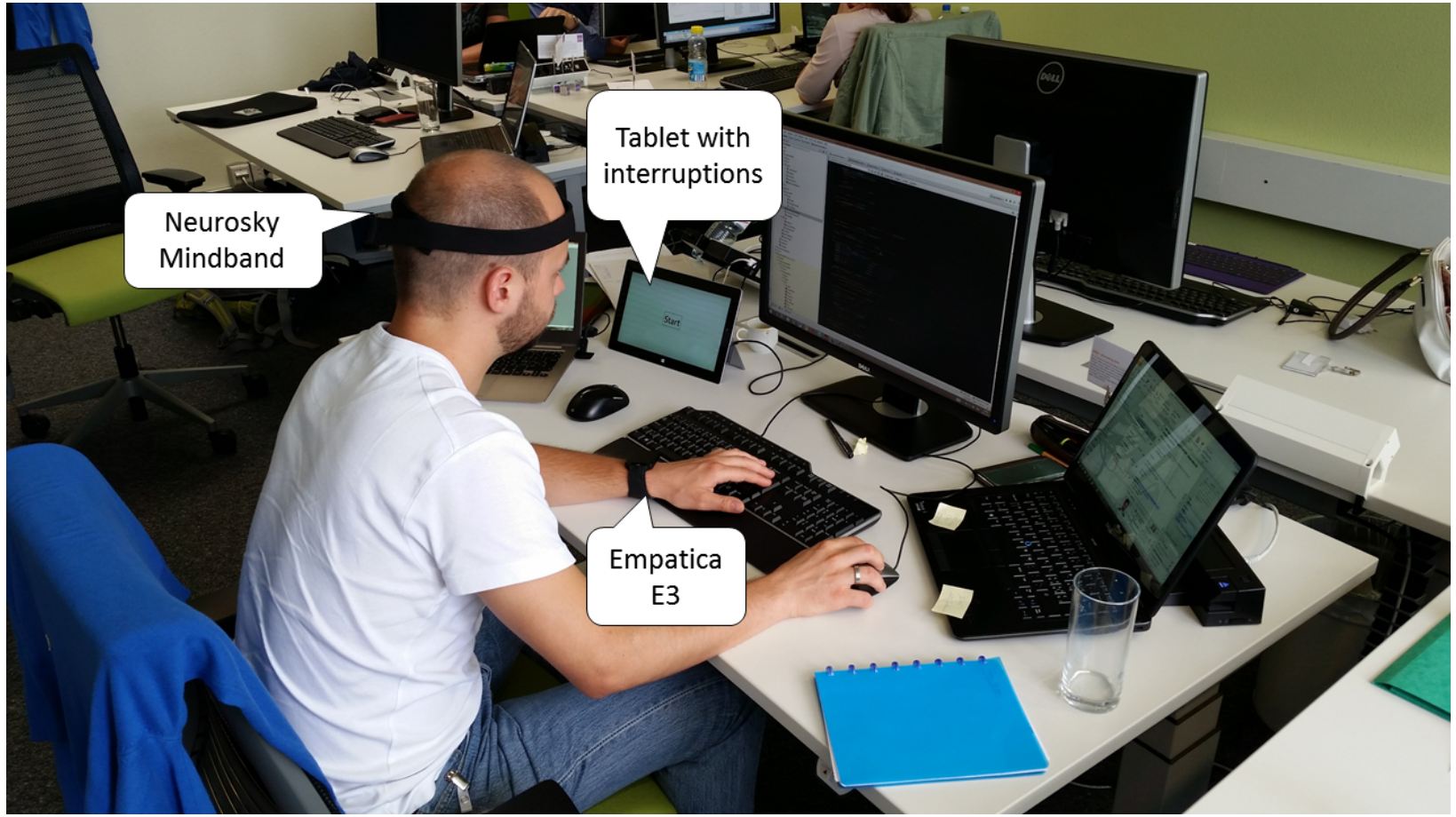
Interruption

Dataset

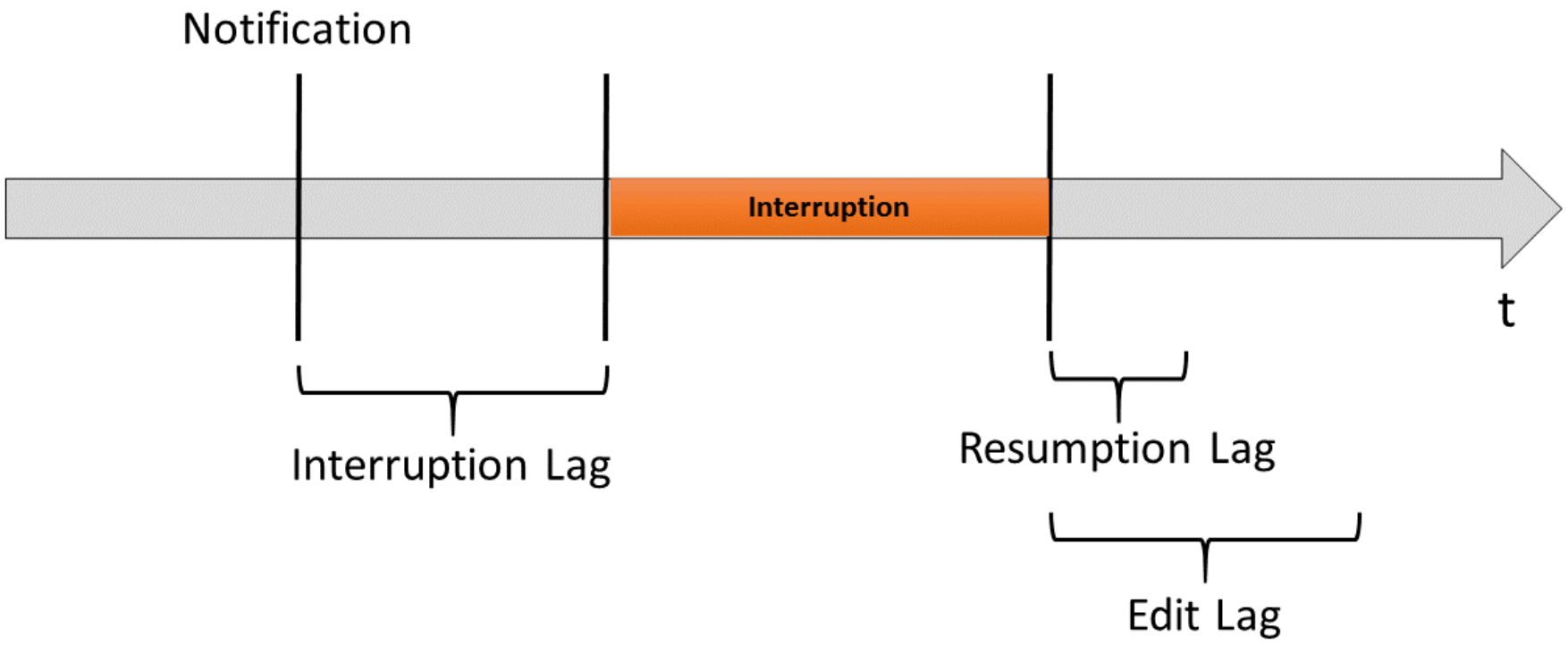
Interruption Dataset: Intro

- Study with 18 participants
- Lab study and field study
- Software developers wore psycho-physiological sensors
- Software developers were interrupted with short arithmetic tasks and a subjective rating of interruptibility, disturbance and mental load
  - Interruptibility and mental load at the time of the notification
  - Disturbance in general for the current interruption
- Our goal: predict interruptibility

Field Study Setting



Interruptions



Psycho-Physiological Sensors

Neurosky Mindband:

- 1-channel Electroencephalograph (EEG)
- Measures the electrical activity of the brain
- Raw wave, frequency bands, attention and meditation, eye blinks

Brainwave Type	Frequency Range [Hz]	Mental states and condition
Delta	0.1 – 3	Deep, dreamless sleep, non-REM sleep, unconsciousness
Theta	4 – 7	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8 – 12	Relaxed, but nod drowsy, tranquil, conscious
Low Beta	12 – 15	Relaxed yet focused, integrated
Midrange Beta	16 – 20	Thinking, aware of self & surroundings
High Beta	21 – 30	Alertness, agitation
Gamma	30 – 100	Motor functions, higher mental activity

Source: https://myndplay.com/webimages/mindsetmanual.pdf

Psycho-Physiological Sensors

Empatica E3:

- Photoplethysmography (PPG)
- Accelerometer
- Temperature
- Electro Dermal Activity (EDA):
  conductivity of the skin → Sweating activity

Soruce: https://www.empatica.com/products.php

Interruption Dataset

- Information and timestamps of interruptions (notification, start, end, etc.)
- Start and end times of the baselines and main study
- Raw data recorded by the sensors
- Calculated features using the sensors
  - for different time windows relative to the notification time
  - normalized with the baseline measure for each participant
  - Examples:
    - Attention mean
    - Alpha / Beta
    - BVP number of peaks per minute
    - Eye blinks per minute

Possible Research Questions

- Can we predict mental load / interruptibility in 2 / 3 / 5 states with psycho-physiological sensors?
- Can we predict mental load / interruptibility on a linear scale?
- Can we detect task switches with psycho-physiological sensors?
- Can we predict the interruption lag with psycho-physiological sensors?

Image Sources

Title Page: http://www.enterprisetech.com/2014/02/11/netflix-speeds-machine-learning-amazon-gpus/

Regression: http://www.digplanet.com/wiki/Linear_regression

Handwritten Letters: http://yann.lecun.com/exdb/mnist/

Overfitting: http://pingax.com/regularization-implementation-r/

Naïve Bayes Formulas: http://de.wikipedia.org/wiki/Bayes-Klassifikator

Support Vector Machine: http://de.wikipedia.org/wiki/Support_Vector_Machine

Decision Tree: http://en.wikipedia.org/wiki/Decision_tree_learning

Weka Logo: http://www.cs.waikato.ac.nz/ml/weka/

Weka Screenshot: http://commons.wikimedia.org/wiki/File:Weka-3.5.5.png

Mindband: http://www.amazon.de/home-of-attention-v1-6-NeuroSky-MindBand-Bundle/dp/B00AAVWBL0

Empatica: https://www.empatica.com/products.php