

# Multivariate Statistical Learning Using Random Forests

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# Outline

- ▶ Statistical Learning
- ▶ Examples of Statistical Learning
- ▶ The Nonparametric Bootstrap
- ▶ Trees
- ▶ Random Forests
- ▶ Making Sense out of a Forest
- ▶ Iris Data

# What is Statistical Learning?

- ▶ In artificial intelligence, machine learning involves some type of machine that modifies its behavior based on experience.
- ▶ In statistics, machine learning uses data to learn.
- ▶ Training data:  $(y, x)$ 's  
Two types: supervised and unsupervised learning

# Some Examples of Statistical Learning

- ▶ Predict whether a patient hospitalized due to a heart attack will have second heart attack.  
Based on demographic, diet and clinical measurements for that patient.
- ▶ Predict the price of a stock 6 months in the future.  
Based on company performance measures and economic data.
- ▶ Identify numbers in handwritten ZIP codes.  
Based on digitized image.

# Some Goals of the Statistical Analysis

- ▶ *Classification*: Group data based on predetermined classes, develop criteria for distinguishing between classes (Supervised Method)
- ▶ *Clustering*: Discover reasonable groupings within a dataset (Unsupervised Method)
- ▶ *Variable Selection*: Reduce the number variables required to perform a classification or clustering task, determine interrelationships between variables (can be Supervised or Unsupervised)

## Example: South African Heart Disease Data

- ▶ 462 observations on males in South Africa
- ▶ Variable of interest is congestive heart disease where a 1 indicates the person has the disease, 0 he does not
- ▶ Explanatory variables include measurements on blood pressure, tobacco use, bad cholesterol, adiposity (fat %), family history of disease (absent or present), type A personality, obesity, alcohol usage, and age
  
- ▶ Question: How could you find the best predictors of heart disease?

# Statistical Methods

- ▶ R
- ▶ Bootstrap
- ▶ Trees
- ▶ Random Forests

# The Nonparametric Bootstrap

- ▶ What does nonparametric mean?
- ▶ What is bootstrapping and what is it good for?
  - ▶ Resampling technique used to obtain properties of estimators (summary statistics) from data
  - ▶ Uses random sampling with replacement



# Trees

- ▶ What is a tree?
- ▶ Tree-based algorithms
- ▶ How to grow (and prune) a tree in R
- ▶ Example: South African Heart Disease Data

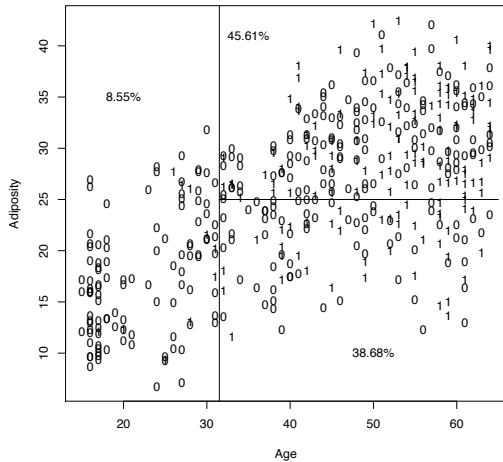


Figure 6.1: Splitting on age and adiposity



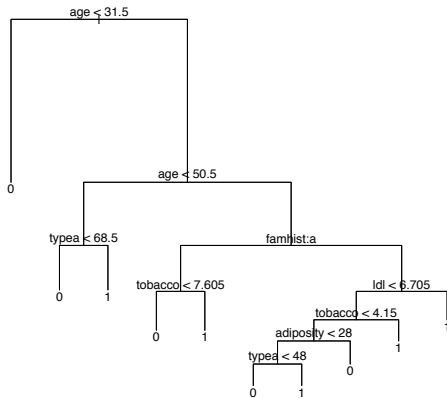
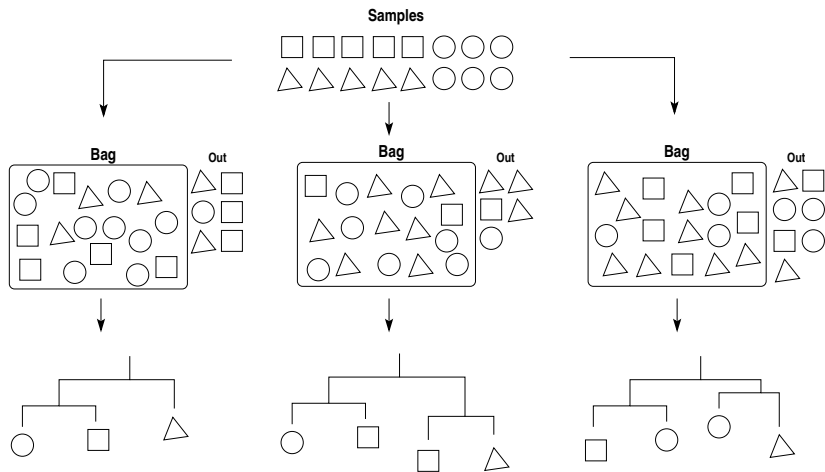


Figure 6.4: The tree, with unnecessary branches snipped

# Random Forests

- ▶ A Random Forest is composed as a set of trees.
- ▶ Each tree in a Random Forest is generated from a random subset of all the data. This subset is generated by bagging: **bootstrap aggregation** - sampling with replacement. Unsampld data in each set are called *out-of-bag*.
- ▶ Each node in each tree is determined from a random subset of all the variables.
- ▶ Instead of classifying new data by tree branching rules, Random Forest classifies by vote of its component trees.

# Random Forest Generation



# Supervised and Unsupervised Random Forests

A Random Forest can be supervised or unsupervised.

- ▶ Supervised:

- ▶ In a supervised Random Forest, groupings for the training data are input to the algorithm.
- ▶ Estimated classification error is computed using out-of-bag data.

## RF: Variable Importance

Random Forests can report which variables were most important during construction. Particular variables are considered more important if:

- ▶ The accuracy of prediction of a sample is diminished when that particular variable in the sample is replaced with random noise during error analysis.
- ▶ The nodes of the trees become more homogeneous when that particular variable is used.



# References for Trees (and more)

- ▶ Notes on Statistical Learning by John Marden