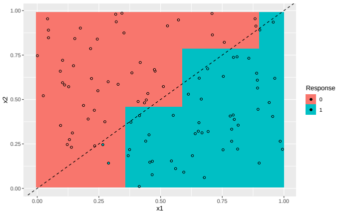
Introduction to Machine Learning

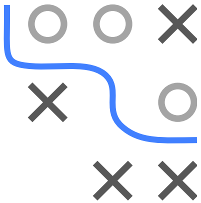
CART
Advantages & Disadvantages



Learning goals

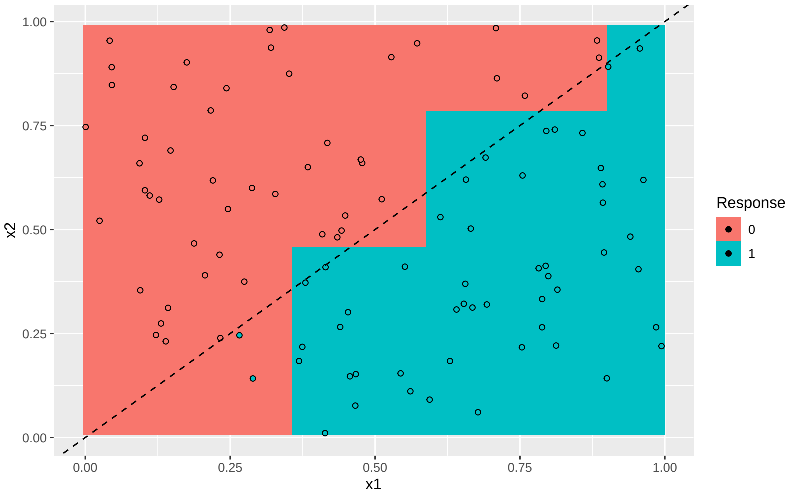
- Understand the advantages and disadvantages of CART
- Know when and where CART are applied

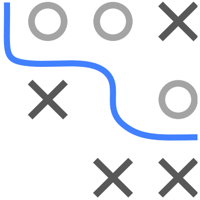
ADVANTAGES



- Fairly easy to understand, interpret and visualize.
- Not much preprocessing required:
  - Automatic handling of non-numerical features
  - Automatic handling of missing values via surrogate splits
  - No problems with outliers in features
  - Monotone transformations do not affect the model fit: scaling becomes irrelevant
- Interaction effects between features are easily possible
- Can model discontinuities and non-linearities
- Performs automatic feature selection
- Relatively fast, scales well with larger data
- Flexibility through the definition of custom split criteria or leaf-node prediction rules: clustering trees, semi-supervised trees, density estimation, etc.

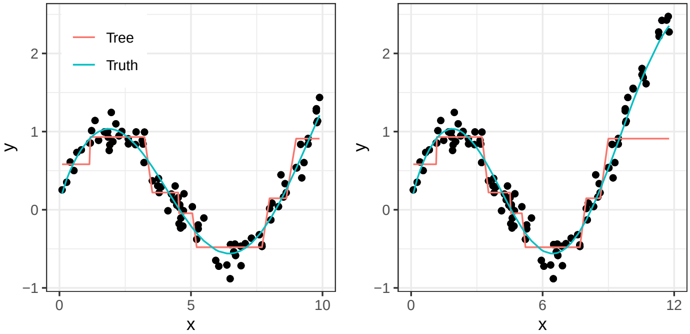
DISADVANTAGE: LINEAR DEPENDENCIES





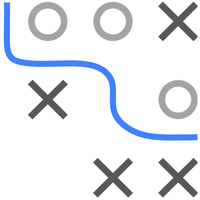
Linear dependencies must be modeled over several splits. Logistic regression would model this easily with fewer parameters.

DISADVANTAGES: SMOOTH FUNCTIONS AND EXTRAPOLATION



Prediction functions of trees are never smooth as they are always step functions and do not extrapolate well beyond the training observations.

DISADVANTAGE: INSTABILITY



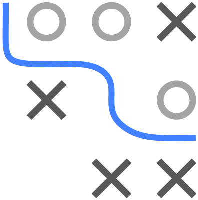
- High instability (variance) of the trees
- Small changes in the data may lead to very different splits/trees
- This leads to a) less trust in interpretability b) is a reason why the prediction error of trees is usually comparably high

Consider the Wisconsin Breast Cancer data set with 699 observations on 9 features and binary target (“benign” vs. “malignant”). We fit two trees: (A) with the full data set and (B) where we eliminated a single observation. Results in label flip for 17 observations of the training data:

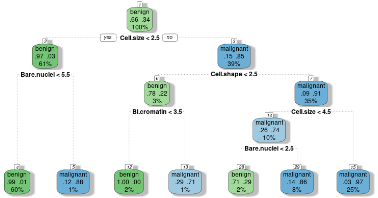
	benign	malignant
benign	445	6
malignant	11	236

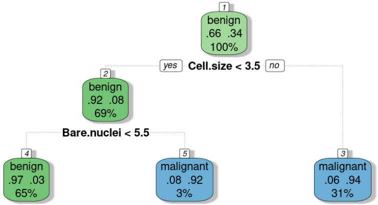
Rows: Predictions of (A), columns: Predictions of (B)

DISADVANTAGE: INSTABILITY



The resulting decision trees look very different:

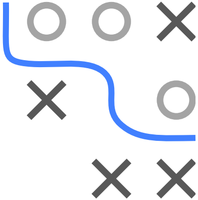




CART IN PRACTICE

- Compared to other learners CART has suboptimal predictive performance, mainly because of the problems previously shown.
- However, most disadvantages can be overcome when trained in ensembles: bagging or random forests.
- Furthermore, trees are attractive tools if an interpretable model is desired or legally required.

FURTHER TREE METHODOLOGIES



This lecture is mainly focused on Classification and Regression Trees (CART) ▸ Breiman et al. 1984

However, there are noteworthy other tree-based approaches as well:

- Automatic Interaction Detection (AID) ▸ Sonquist and Morgan 1964 and Chi-squared Automatic Interaction Detection (CHAID) ▸ Kass 1980: Creates all possible cross-tabulations for each categorical predictor until the best outcome is achieved and no further splitting can be performed
- C4.5 ▸ Quinlan 1993: Not limited to binary splitting
- Unbiased Recursive Partitioning ▸ Hothorn, Hornik, and Zeileis 2006: Improves the variable selection algorithm