Lecture 14: Handling overfitting in decision trees

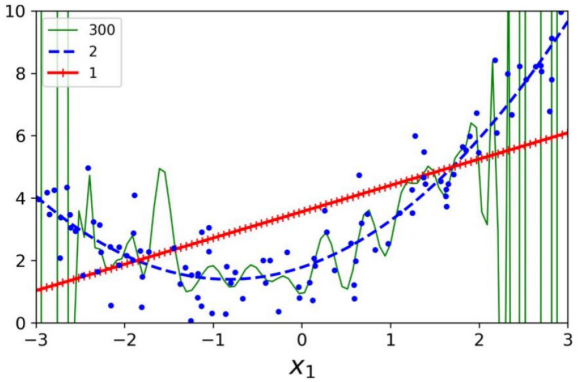
Madhavan Mukund

https://www.cmi.ac.in/~madhavan

Data Mining and Machine Learning
August–December 2020

Overfitting

- Overfitting: model too specific to training data, does not generalize well
- Regression — use regularization to penalize model complexity
- What about decision trees?
- Deep, complex trees ask too many questions
- Prefer shallow, simple trees

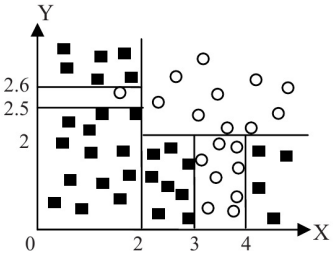


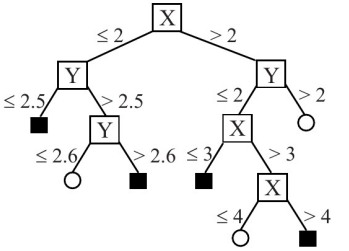
Tree pruning

- Remove leaves to improve generalization
- Top-down pruning
  - Fix a maximum depth when building the tree
  - How to decide the depth in advance?
- Bottom-up pruning
  - Build the full tree
  - Remove a leaf if the reduced tree generalizes better
  - How do we measure this?

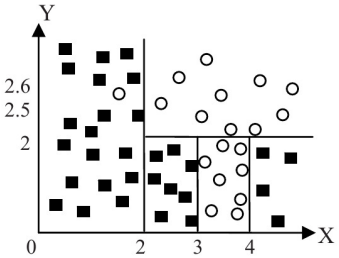
Tree pruning

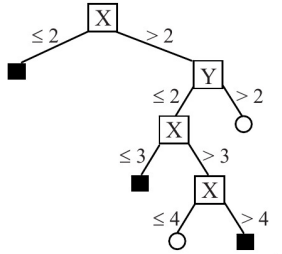
Overfitted tree





Pruned tree





Bottom up tree pruning

- Build the full tree, remove leaf if the reduced tree generalizes better
- How do we measure this?
- Check performance on a test set
- Use sampling theory [Quinlan]
- Given n coin tosses with h heads, estimate probability of heads as h/n
  - Estimate comes with a confidence interval: $h/n \pm \delta$
  - As n increases, δ reduces: 7 heads out of 10 vs 70 out of 100 vs 700 out of 1000
- Impure node, majority prediction, compute confidence interval
- Pruning leaves creates a larger impure sample one level above
- Does the confidence interval decrease (improve)?

Example: Predict party from voting pattern [Quinlan]

- Predict party affiliation of US legislators based on voting pattern
  - Read the tree from left to right
- After pruning, drastically simplified tree
- Quinlan's comment on his use of sampling theory for post-pruning

Now, this description does violence to statistical notions of sampling and confidence limits, so the reasoning should be taken with a large grain of salt. Like many heuristics with questionable underpinnings, however, the estimates it produces seem frequently to yield acceptable results.

```
physician fee freeze = n:
|   adoption of the budget resolution = y: democrat (151)
|   adoption of the budget resolution = u: democrat (1)
|   adoption of the budget resolution = n:
|   |   education spending = n: democrat (6)
|   |   education spending = y: democrat (9)
|   |   education spending = u: republican (1)
physician fee freeze = y:
|   synfuels corporation cutback = n: republican (97/3)
|   synfuels corporation cutback = u: republican (4)
|   synfuels corporation cutback = y:
|   |   duty free exports = y: democrat (2)
|   |   duty free exports = u: republican (1)
|   |   duty free exports = n:
|   |   |   education spending = n: democrat (5/2)
|   |   |   education spending = y: republican (13/2)
|   |   |   education spending = u: democrat (1)
physician fee freeze = u:
|   water project cost sharing = n: democrat (0)
|   water project cost sharing = y: democrat (4)
|   water project cost sharing = u:
|   |   mx missile = n: republican (0)
|   |   mx missile = y: democrat (3/1)
|   |   mx missile = u: republican (2)
```

Summary

- Small decision trees are less prone to overfitting
- In addition to interpretability, another motovition to prefer small trees
- Tree pruning
  - Top-down pruning: restrict depth in advance
  - Bottom-up pruning: remove leaves