ONLINE MASTERS IN **DATA SCIENCE**

DSC 255 - MACHINE LEARNING FUNDAMENTALS

DECISION TREE BASICS

SANJOY DASGUPTA, PROFESSOR

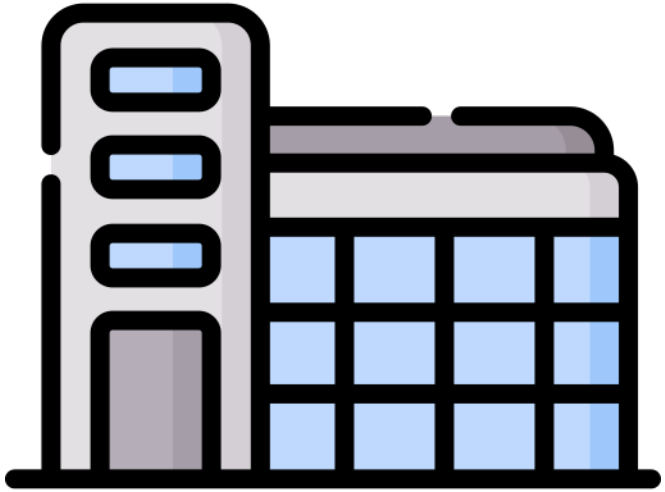
UC San Diego

COMPUTER SCIENCE & ENGINEERING

HALICIOĞLU DATA SCIENCE INSTITUTE

Decision Trees

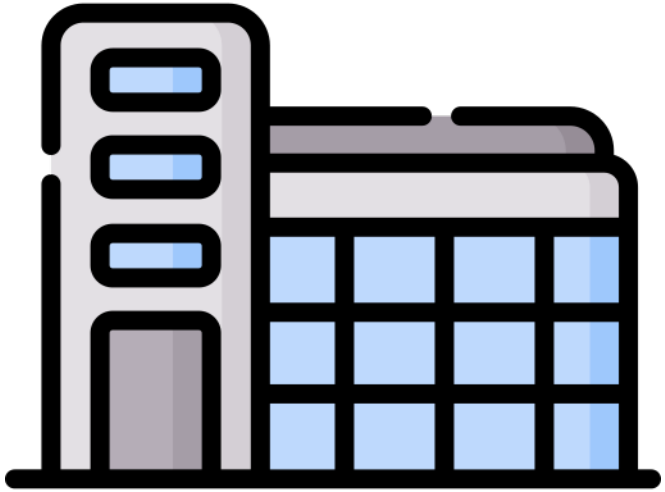
UCSD Medical Center (1970s): identify patients at risk of dying within 30 days after heart attack.



Decision Trees

UCSD Medical Center (1970s): identify patients at risk of dying within 30 days after heart attack.

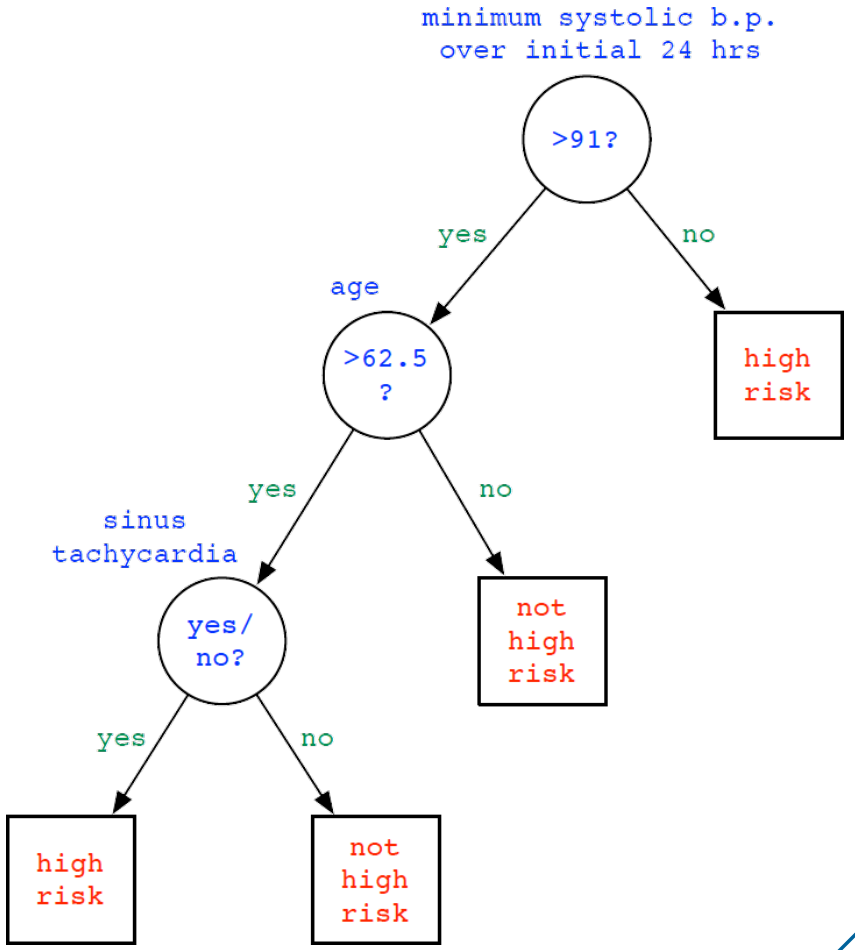
Data set:
215 patients.
37 (=20%) died.
19 features.



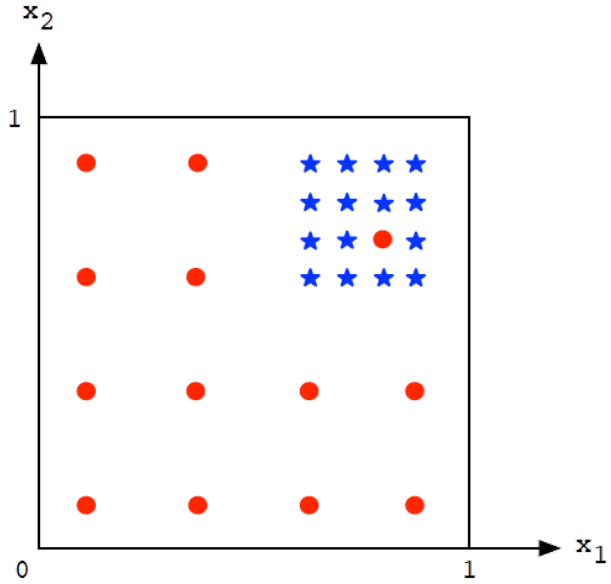
Decision Trees

UCSD Medical Center (1970s): identify patients at risk of dying within 30 days after heart attack.

Data set:
215 patients.
37 (=20%) died.
19 features.

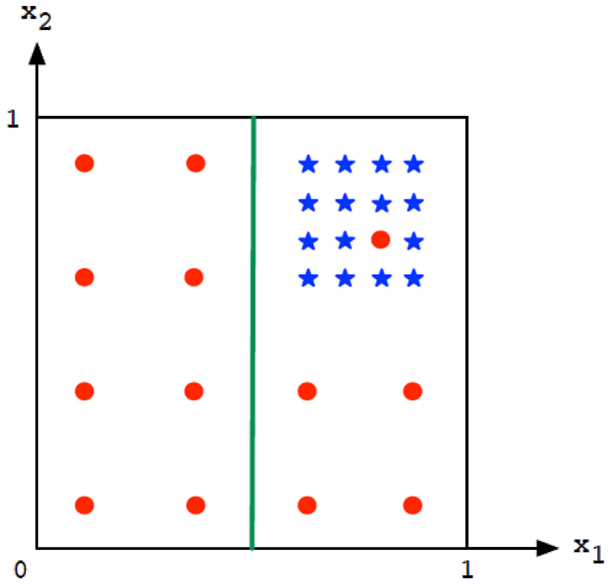


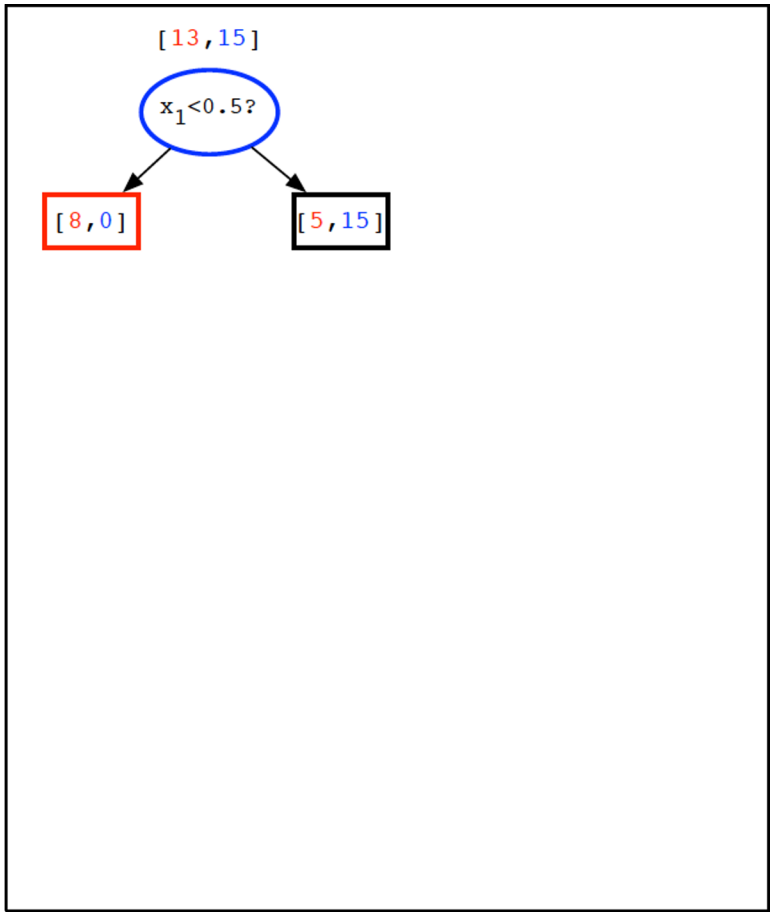
Example: Building a Decision Tree



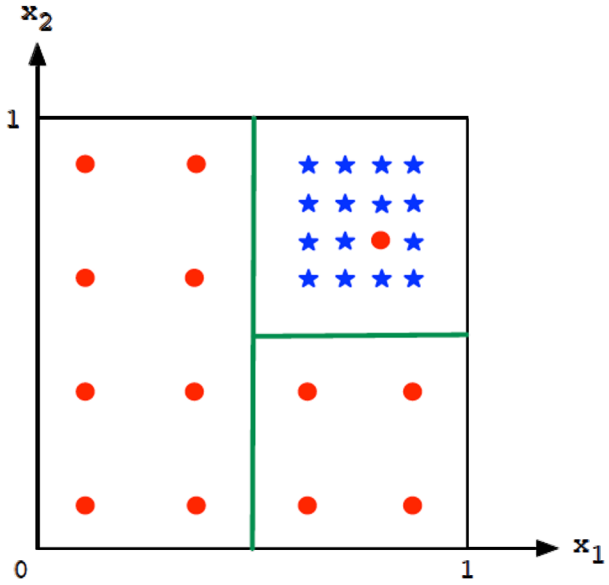
[13,15]

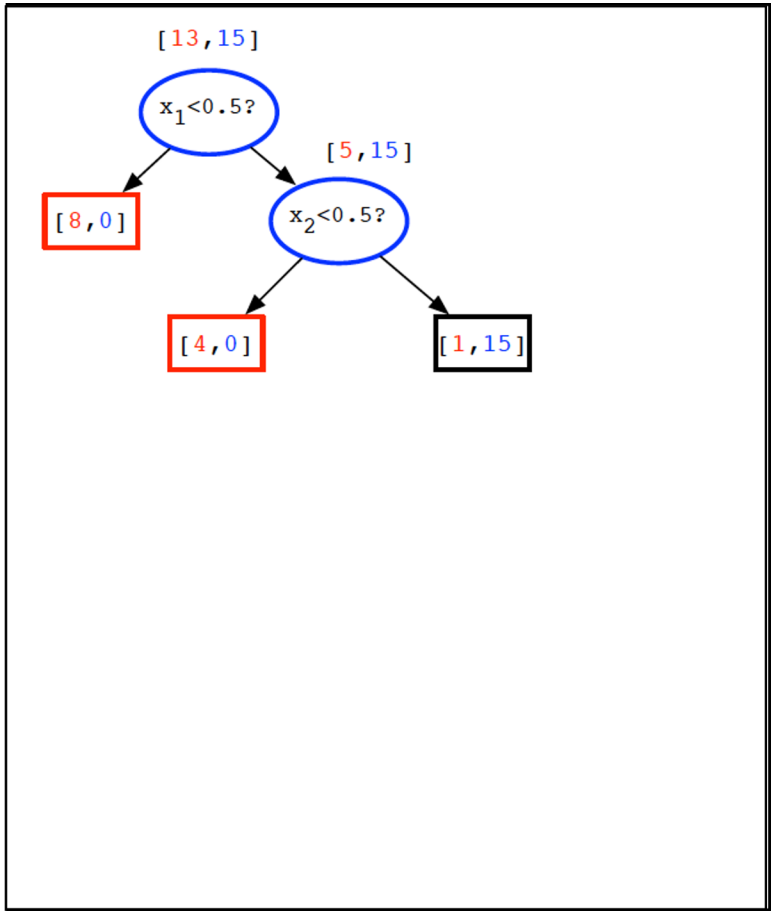
Example: Building a Decision Tree



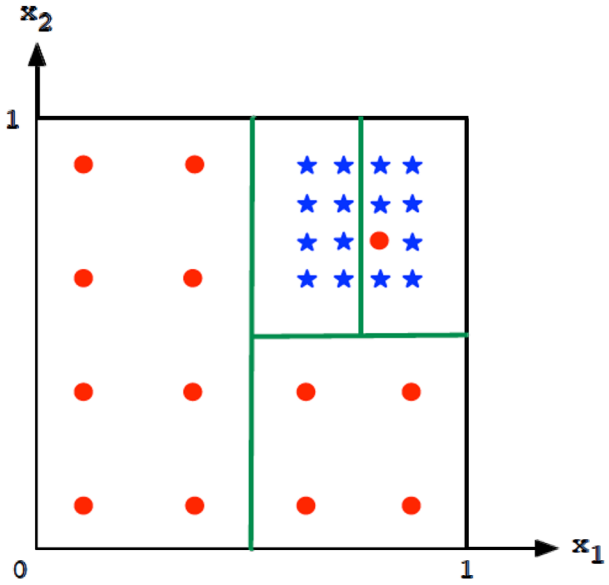


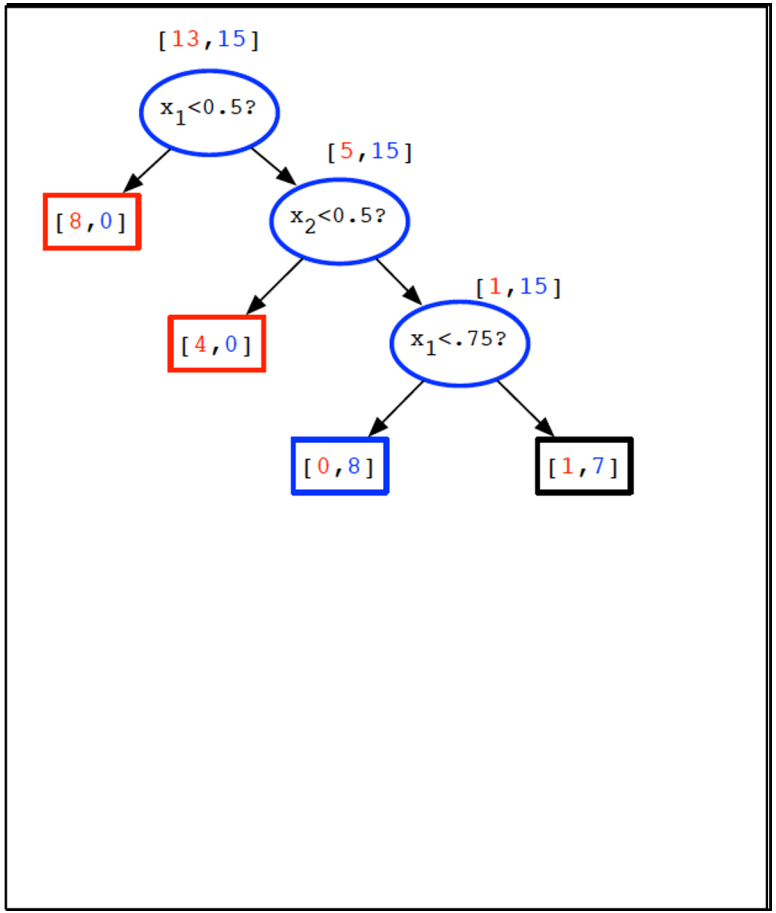
Example: Building a Decision Tree



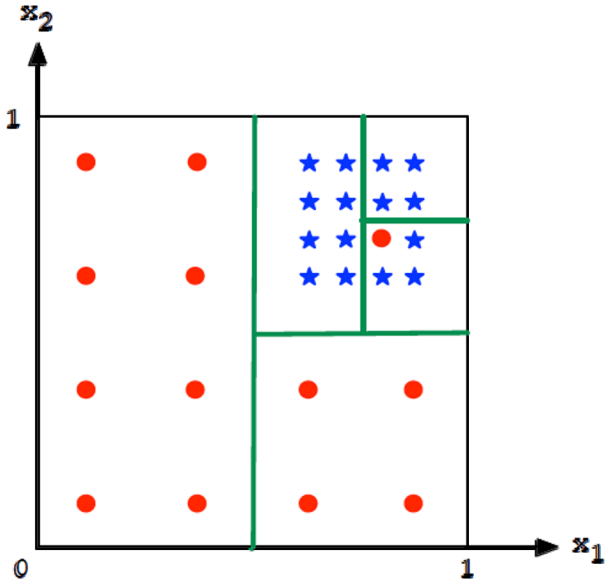


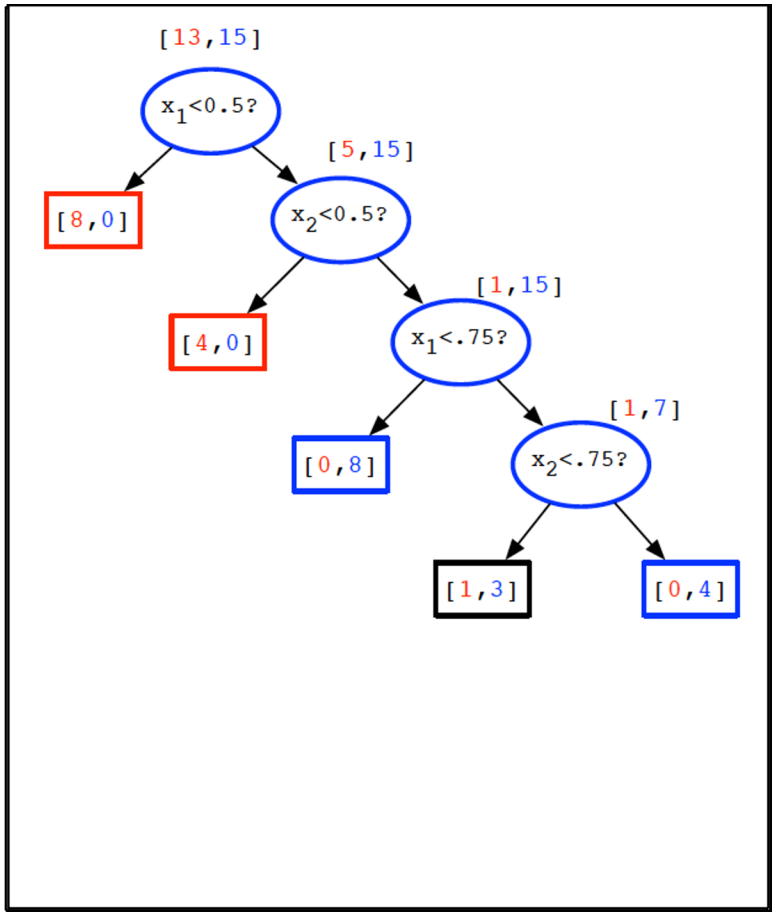
Example: Building a Decision Tree



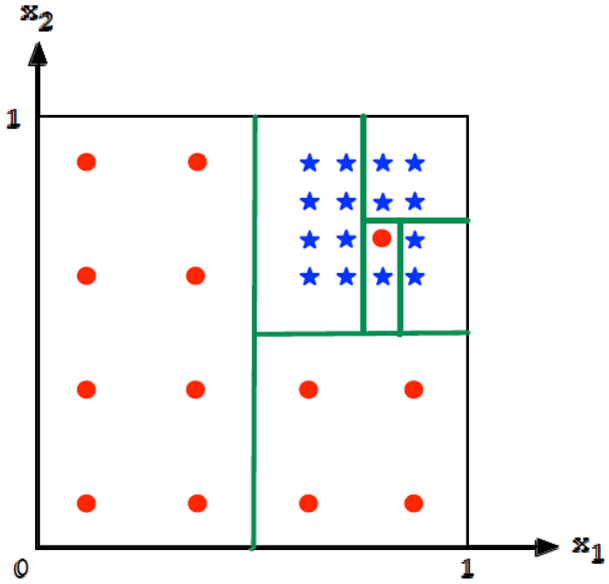


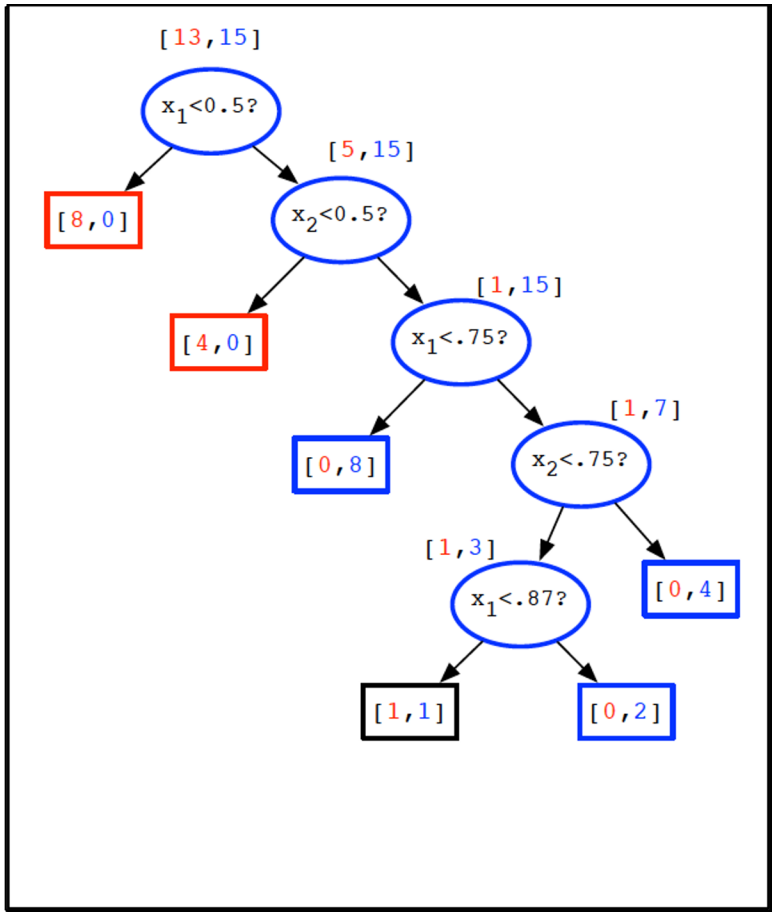
Example: Building a Decision Tree



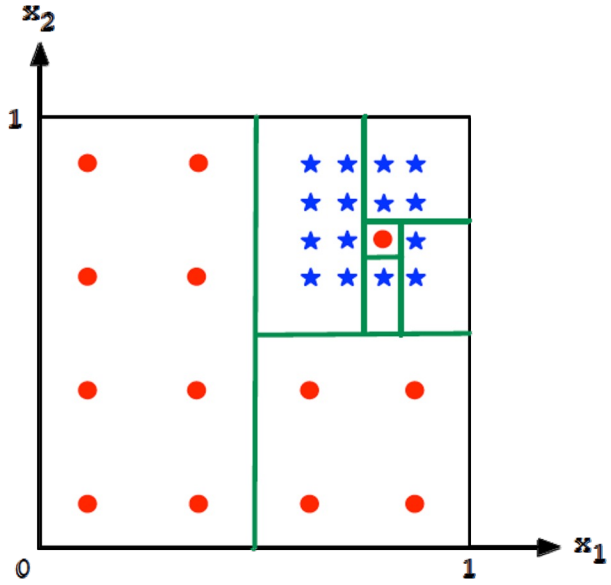


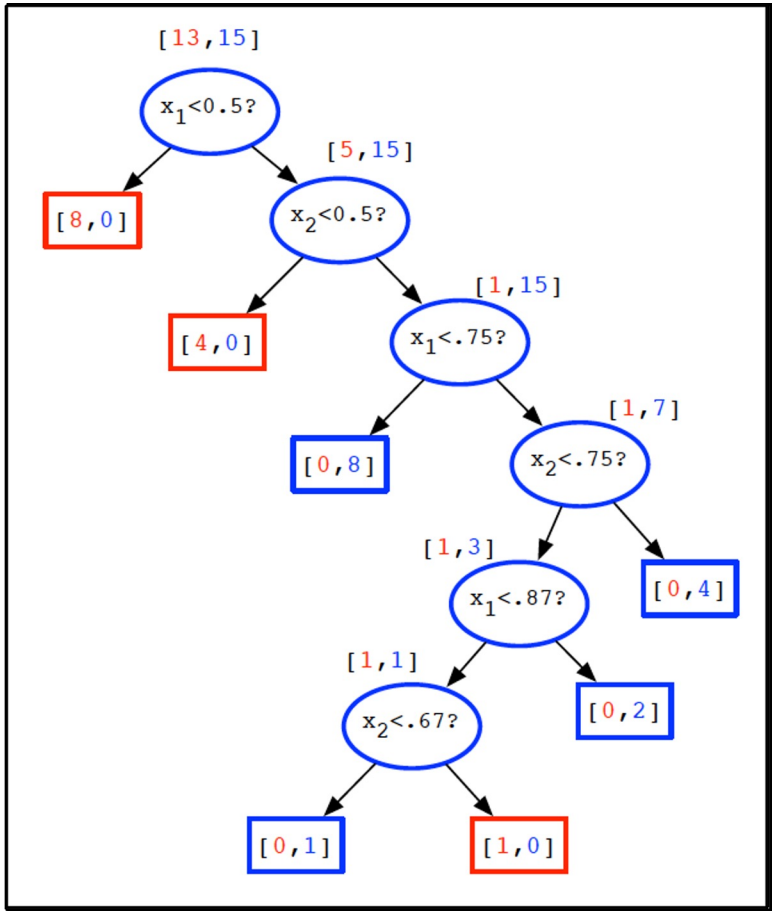
Example: Building a Decision Tree





Example: Building a Decision Tree





Building a Decision Tree

Greedy algorithm: build tree top-down.

- Start with a single node containing all data points
- Repeat:
  - ➢ Look at all current leaves and all possible splits
  - ➢ Choose the split that most decreases the uncertainty in prediction

We need a measure of **uncertainty in prediction.**

Uncertainty in Prediction

Say there are two labels:

$+$ label p fraction of the points
$-$ label $(1 - p)$ fraction of the points

What uncertainty score should we give to this?

Uncertainty in Prediction

Say there are two labels:

$+$ label p fraction of the points
$-$ label $(1-p)$ fraction of the points

What uncertainty score should we give to this?

1. Misclassification rate

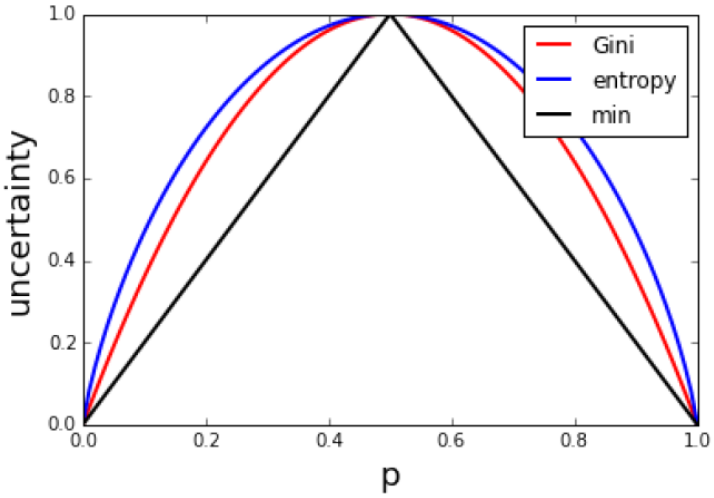
$$min\{p, 1-p\}$$

2. Gini index

$$2p(1-p)$$

3. Entropy

$$p \log \frac{1}{p} + (1-p) \log \frac{1}{1-p}$$



Uncertainty: K Class

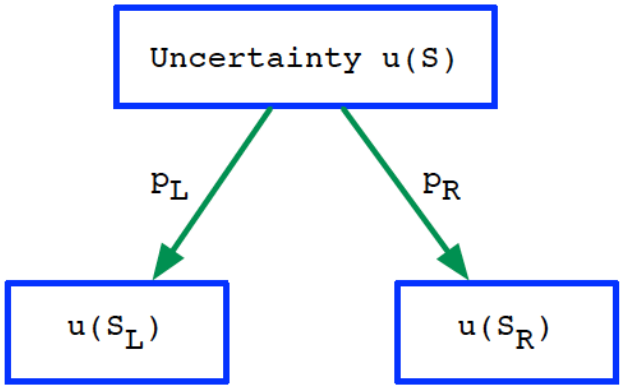
Suppose there are k classes, with probabilities $p_1, p_2, \ldots, p_k$.

	$k = 2$	General k
Misclassification rate	$\min\{p, 1-p\}$	$1 - \max_i p_i = 1 - \|p\|_\infty$
Gini Index	$2p(1-p)$	$\sum_{i \neq j} p_i p_j = 1 - \|p\|^2$
Entropy	$p \log\frac{1}{p} + (1-p)\log\frac{1}{1-p}$	$\sum_i p_i \log\frac{1}{p_i}$

Benefit of a Split

Let $u(S)$ be the uncertainty score for a set of labeled points S.

Consider a particular split:



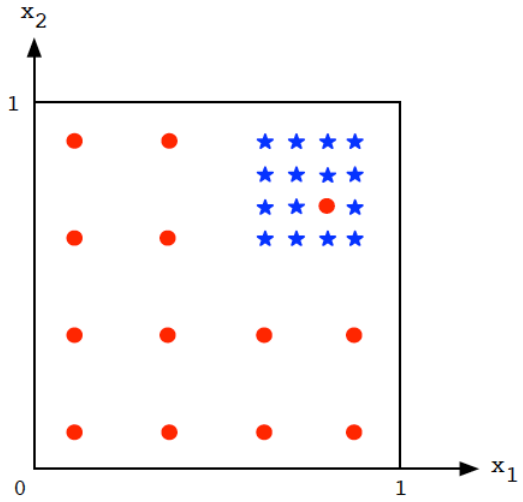
Of the points in S:

- p_L fraction go to S_L
- p_R fraction go to S_R

Benefit of split = reduction in uncertainty:

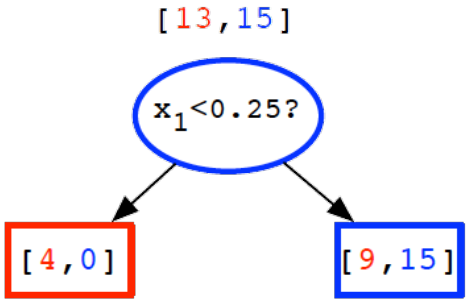
$$\left(u(S) - \underbrace{(p_L u(S_L) + p_R u(S_R))}_{\text{expected uncertainty after split}}\right) \times |S|$$

Benefit of a Split: Example

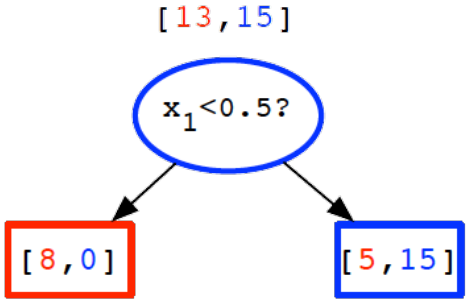


Initial Gini uncertainty:

$$2 \times \frac{13}{28} \times \frac{15}{28}$$



$$p_L u_L + p_R u_R = \frac{4}{28} \cdot 0 + \frac{24}{28} \cdot 2 \cdot \frac{9}{24} \cdot \frac{15}{24} = \frac{45}{112}$$



$$p_L u_L + p_R u_R = \frac{8}{28} \cdot 0 + \frac{20}{28} \cdot 2 \cdot \frac{5}{20} \cdot \frac{15}{20} = \frac{30}{112}$$

Building a Decision Tree: Summary

Greedy algorithm: build tree top-down.

- Start with a single node containing all data points
- Repeat:
  - ➢ Look at all current leaves and all possible splits
  - ➢ Choose the split that most decreases the uncertainty in prediction