

Prediction and Overfitting

CS4780/5780 – Machine Learning
Fall 2014

Thorsten Joachims
Cornell University

Reading: Mitchell Sections 3.6 – 3.7

Example: Text Classification

- Task: Learn rule that classifies Reuters Business News
 - Class +: “Corporate Acquisitions”
 - Class -: Other articles
 - 2000 training instances
- Representation:
 - Boolean attributes, indicating presence of a keyword in article
 - 9947 such keywords (more accurately, word “stems”)

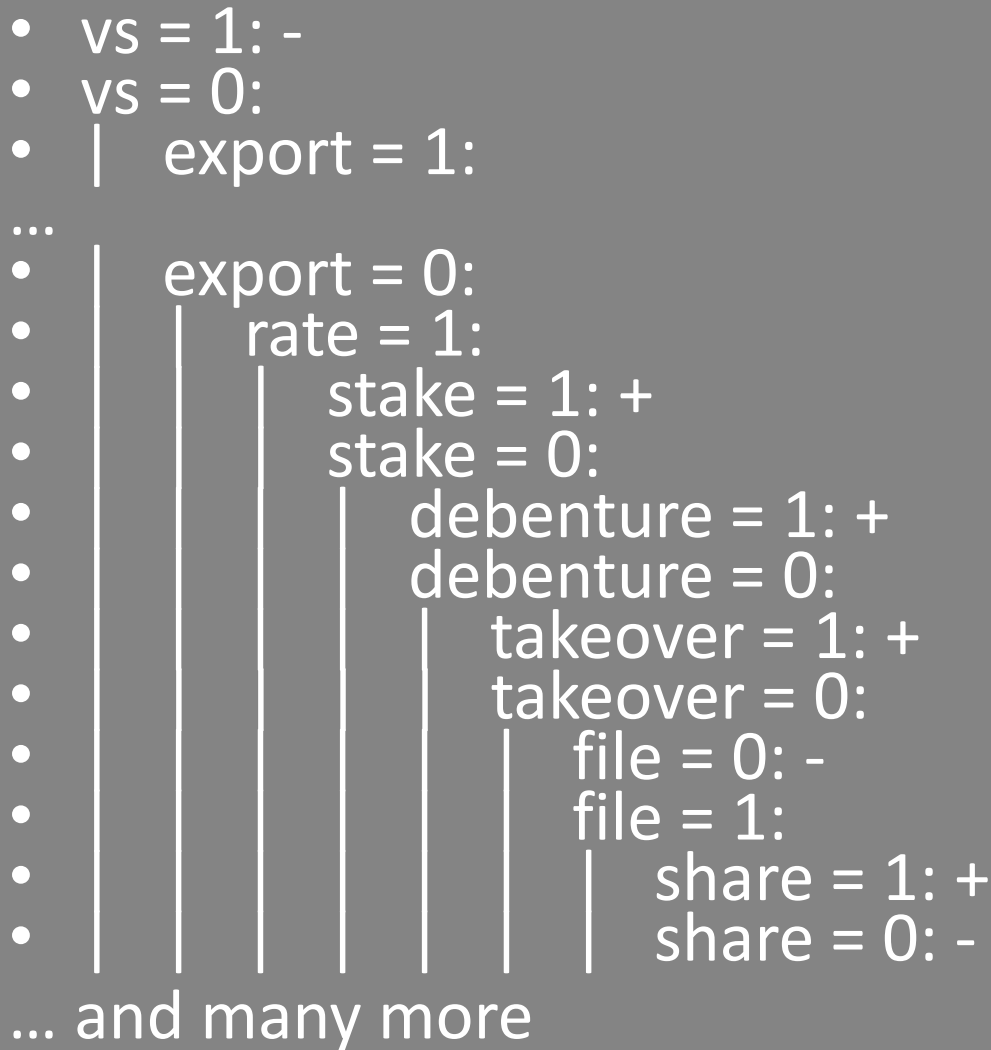
LAROCHE STARTS BID FOR NECO SHARES

Investor David F. La Roche of North Kingstown, R.I., said he is offering to purchase 170,000 common shares of NECO Enterprises Inc at 26 dlrs each. He said the successful completion of the offer, plus shares he already owns, would give him 50.5 pct of NECO's 962,016 common shares. La Roche said he may buy more, and possible all NECO shares. He said the offer and withdrawal rights will expire at 1630 EST/2130 gmt, March 30, 1987.

SALANT CORP 1ST QTR FEB 28 NET

Oper shr profit seven cts vs loss 12 cts.
Oper net profit 216,000 vs loss 401,000. Sales 21.4 mln vs 24.9 mln.
NOTE: Current year net excludes 142,000 dlr tax credit. Company operating in Chapter 11 bankruptcy.

Decision Tree for “Corporate Acq.”



Learned tree of ID3:

- has 299 nodes
- is consistent

Accuracy of learned tree:

- 11% error rate

Note: word stems expanded for improved readability.

Learning as Prediction

Definition: *A particular instance of a learning problem is described by a probability distribution $P(X, Y)$.*

Definition: *A sample $S = ((\vec{x}_1, y_1), \dots, (\vec{x}_n, y_n))$ is independently identically distributed (i.i.d.) according to $P(X, Y)$ if*

$$P(S = ((\vec{x}_1, y_1), \dots, (\vec{x}_n, y_n))) = \prod_{i=1}^n P(X = \vec{x}_i, Y = y_i)$$

Sample Error and Generalization Error

Definition: The error on sample S $Err_S(h)$ of a hypothesis h is $Err_S(h) = \frac{1}{n} \sum_{i=1}^n \Delta(h(\vec{x}_i), y_i)$.

Definition: $\Delta(a, b)$ is the 0/1-loss function

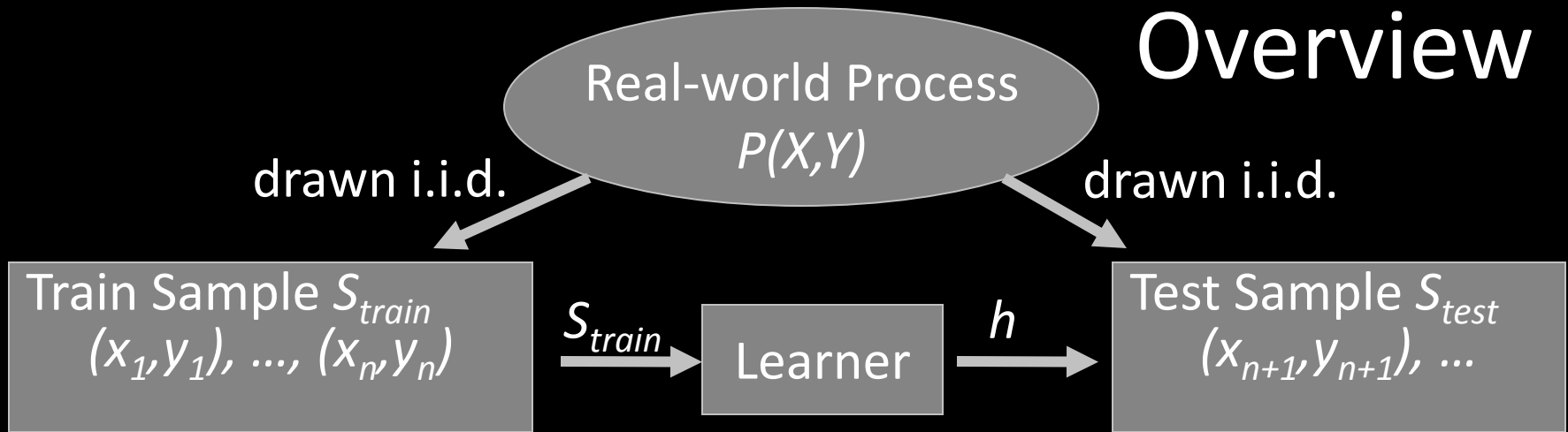
$$\Delta(a, b) = \begin{cases} 0 & \text{if } (a == b) \\ 1 & \text{else} \end{cases}$$

Definition: The prediction/generalization/true error $Err_P(h)$ of a hypothesis h for a learning task $P(X, Y)$ is

$$Err_P(h) = \sum_{\vec{x} \in X, y \in Y} \Delta(h(\vec{x}), y) P(X = \vec{x}, Y = y).$$

Learning as Prediction

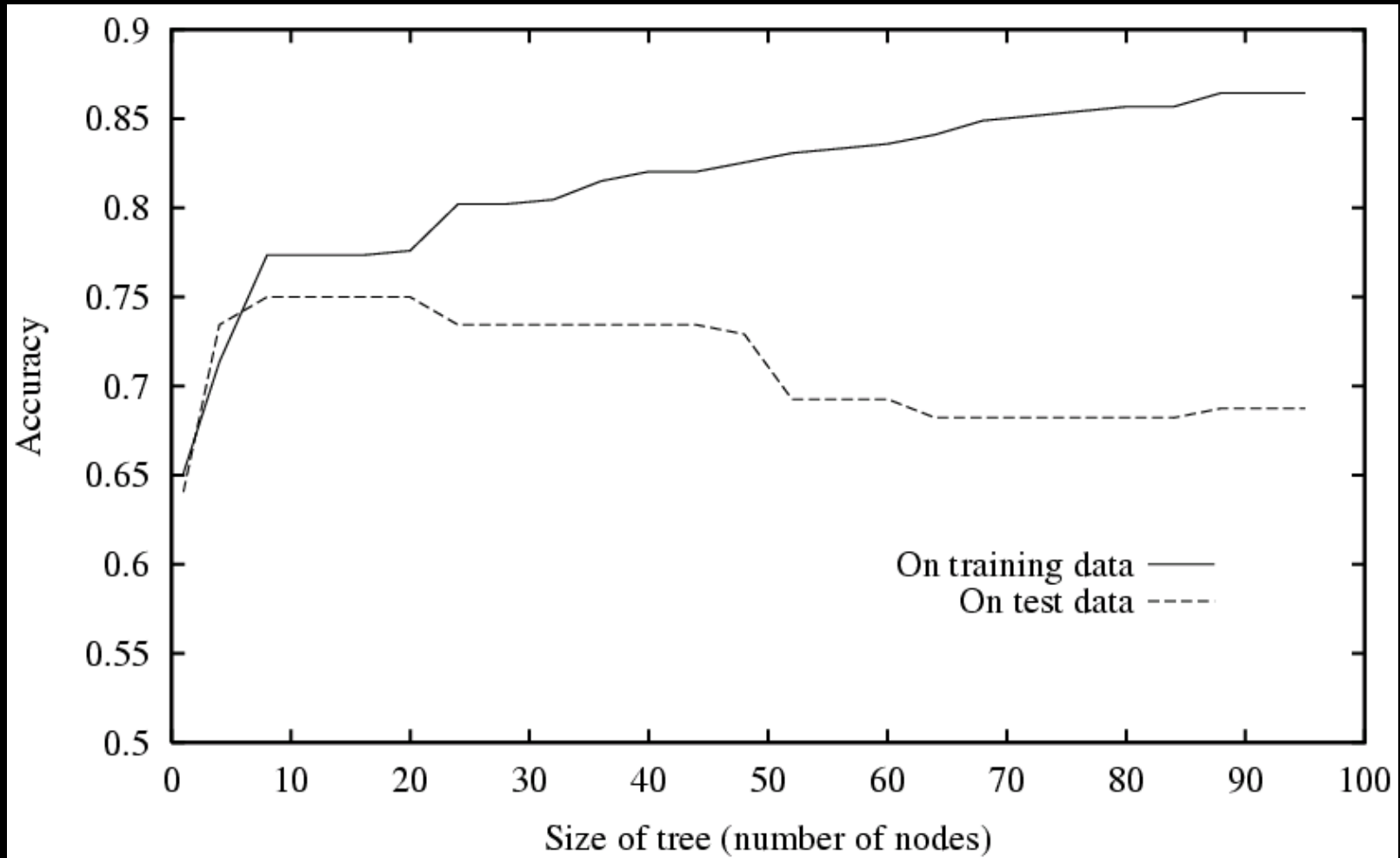
Overview



- Goal: Find h with small prediction error $Err_P(h)$ over $P(X,Y)$.
- Strategy: Find (any?) h with small error $Err_{S_{train}}(h)$ on training sample S_{train} .

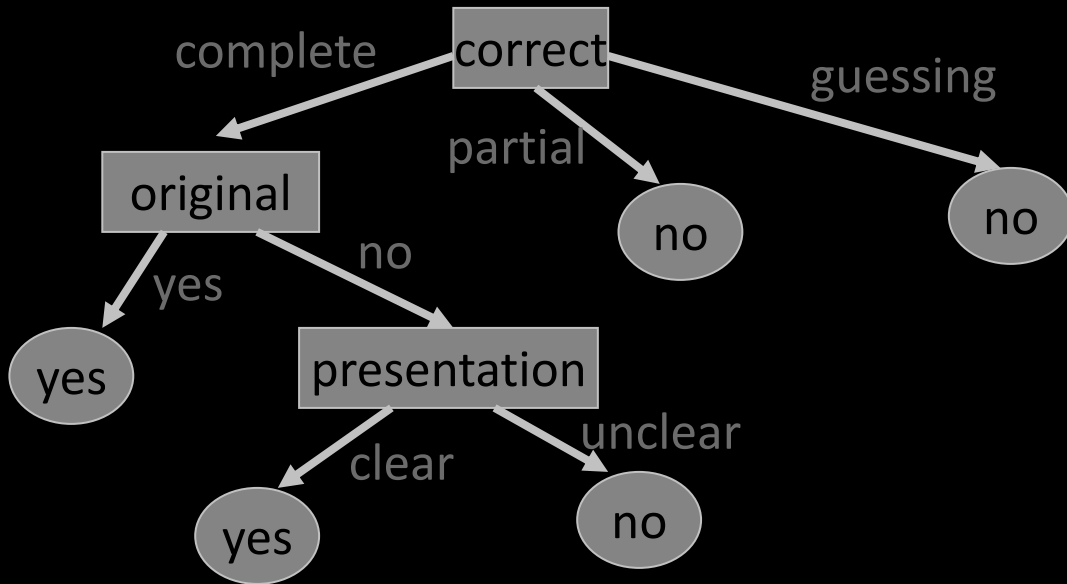
- Training Error: Error $Err_{S_{train}}(h)$ on training sample.
- Test Error: Error $Err_{S_{test}}(h)$ on test sample is an estimate of $Err_P(h)$.

Overfitting



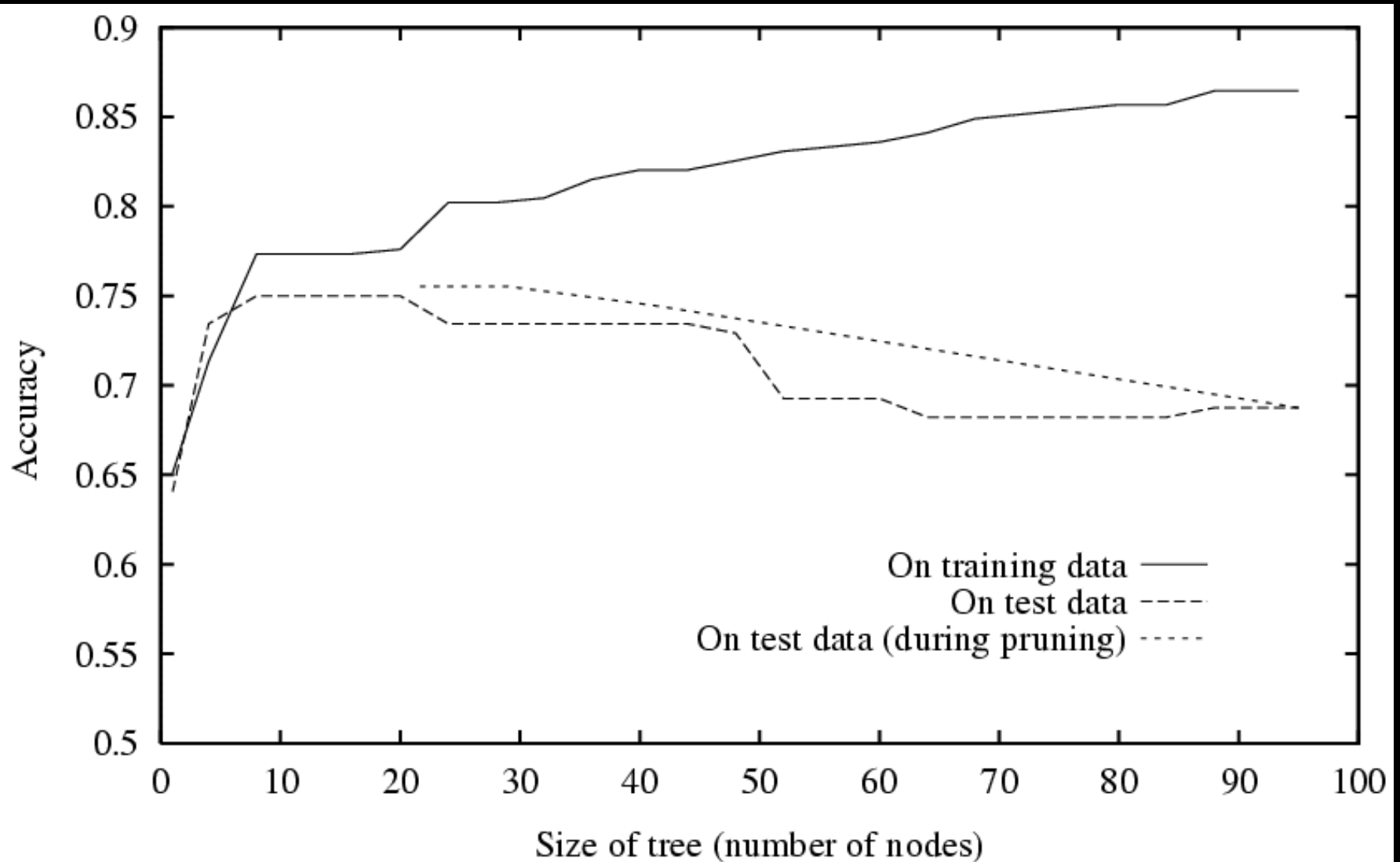
- Note: Accuracy = 1.0-Error

Decision Tree Example: revisited



C O P	A^+
$\vec{x}_1 = (c, y, c)$	$y_1 = +1$
$\vec{x}_2 = (c, n, u)$	$y_2 = -1$
$\vec{x}_3 = (c, y, u)$	$y_3 = +1$
$\vec{x}_4 = (c, n, c)$	$y_4 = +1$
$\vec{x}_5 = (p, y, c)$	$y_5 = -1$
$\vec{x}_6 = (g, y, c)$	$y_6 = -1$
$\vec{x}_7 = (c, y, c)$	$y_7 = +1$
$\vec{x}_8 = (c, y, u)$	$y_8 = +1$
$\vec{x}_9 = (p, y, c)$	$y_9 = -1$
$\vec{x}_{10} = (c, y, c)$	$y_{10} = +1$

Reduced-Error Pruning



Text Classification Example

“Corporate Acquisitions” Results

- Unpruned Tree (ID3 Algorithm):
 - Size: 437 nodes Training Error: 0.0% Test Error: 11.0%
- Early Stopping Tree (ID3 Algorithm):
 - Size: 299 nodes Training Error: 2.6% Test Error: 9.8%
- Reduced-Error Pruning (C4.5 Algorithm):
 - Size: 167 nodes Training Error: 4.0% Test Error: 10.8%
- Rule Post-Pruning (C4.5 Algorithm):
 - Size: 164 tests Training Error: 3.1% Test Error: 10.3%
 - Examples of rules
 - IF vs = 1 THEN - [99.4%]
 - IF vs = 0 & export = 0 & takeover = 1 THEN + [93.6%]