Answers Intermediate Exam Machine Learning

Duration of the exam: 2 hours

October 25, 2007

You are allowed to use a calculator for this exam. It will be graded as follows: You start with 1 point, and for each of the nine subquestions you can get 1 point. Partial points may be awarded for partially correct answers. Good luck!

1. For each of the following learning problems, please indicate whether it is a prediction, regression or classification problem. (An explanation is not required.)

   (a) A search engine tries to determine whether a website is about sports based on the number of times the website contains the following words/phrases: 'sports', 'football', 'tennis', 'hockey', 'elections', 'human rights' and 'party'.

   (b) A farmer has used different amounts of fertilizer on different parts of his land. He has recorded the average height of his corn for each part. Now he wants to learn how the average height of his corn depends on the amount of fertilizer that he uses.

   (c) Each spring a biologist counts the number of offspring in the same lion population. Based on her counts of the previous years she wants to estimate the number of offspring in the coming year.

   Answers:

   (a) classification
   (b) regression
   (c) prediction

2. Suppose we run the List-Then-Eliminate algorithm on the data in Table 1 with the hypothesis space $\mathcal{H}$ that contains the four decision trees in Figure 1.

   (a) Which trees are left in the version space after running the algorithm?

   (b) How would the algorithm classify a new feature vector with $A =$ False, $B =$ True, $C =$ True?

   (c) How would the algorithm classify a new feature vector with $A =$ False, $B =$ True, $C =$ False?

   (d) Come up with a new hypothesis that is consistent with the data in Table 1, but is not contained in $\mathcal{H}$. Your hypothesis needs to be semantically different from all members of $\mathcal{H}$.

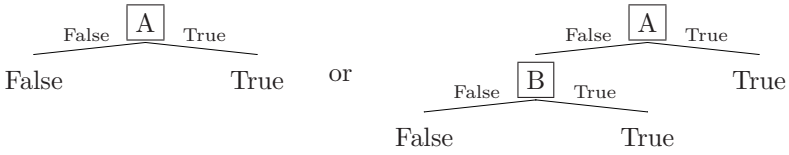
   Answers:

   (a) Left in the version space: (a) and (c).

(b) True

(c) Cannot classify

(d) Many different answers are possible. For example,



Using Mitchell's notation, these hypotheses might equivalently be described using a list of constraints with disjunctions:

$$\langle \text{True}, ?, ? \rangle \quad \text{or} \quad \langle \text{True}, ?, ? \rangle \vee \langle \text{False}, \text{True}, ? \rangle,$$

and I would probably write:

$$h(\mathbf{x}) = \begin{cases} \text{True} & \text{if } A = \text{True}, \\ \text{False} & \text{otherwise}, \end{cases} \quad \text{or} \quad h(\mathbf{x}) = \begin{cases} \text{True} & \text{if } A = \text{True or } B = \text{True}, \\ \text{False} & \text{otherwise}. \end{cases}$$

All of these answers are equivalent.

3. Suppose we first run the ID3 algorithm and then perform reduced-error pruning.

   (a) How does reduced-error pruning change the preference bias of our algorithm (compared to running ID3 without pruning)?

   (b) The decision to prune a node of the tree is based on the accuracy of the resulting tree on a validation set. What would go wrong if we used the train set instead of this validation set?
   Hint: See Figure 2, which is also in Mitchell.

Answers:

(a) The algorithm will prefer even smaller trees, which are not necessarily consistent with all the training data.

(b) No pruning at all would occur, because removing nodes would decrease performance on the train set.
To see this, see Figure 2 or consider the following argument: ID3 stops adding nodes as soon as it has found a tree that is consistent with all training data. Hence removing any node from this tree will result in a tree that is not consistent with all the training data. Thus any pruning will lower the accuracy on the training data.
The purpose of pruning is to prevent overfitting. Hence when no pruning occurs, our algorithm is likely to overfit the training data.

Grading notes:

- The preferred answer is that no pruning would occur.
- The observation that it is likely that overfitting will occur is also acceptable, but only if it is correctly motivated and the word 'overfitting' is mentioned.

- The following answer is not correct: The tree will achieve high accuracy on the train set and **as a consequence** overfitting or worse generalisation performance will occur. This is not correct, because high accuracy on the train set does not imply bad generalisation performance and is even desirable in general (unless we have to search a very large hypothesis space to achieve it, which would cause overfitting).

Table 1: Boolean-valued data

	x		y
A	B	C	
True	False	True	True
False	False	True	False
True	False	False	True

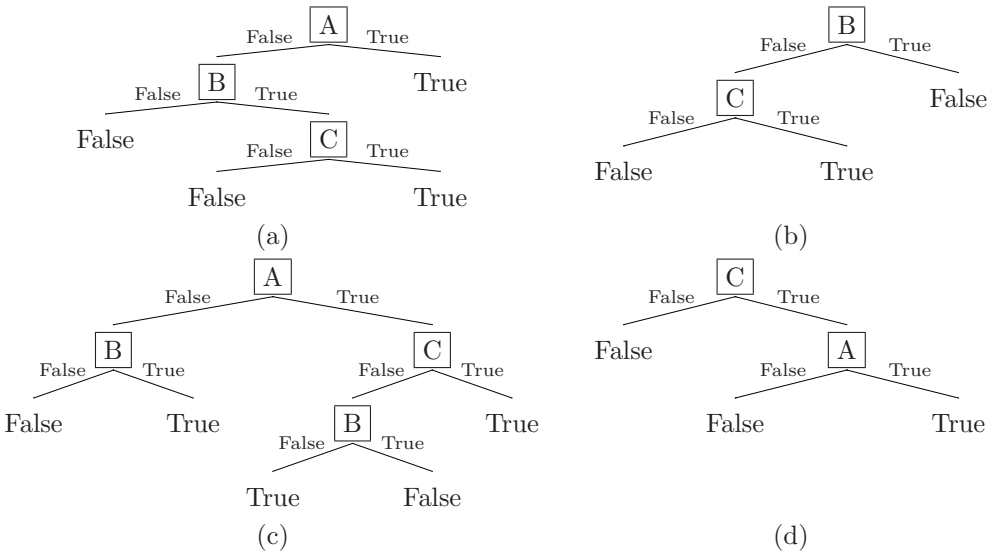


Figure 1: Four decision trees

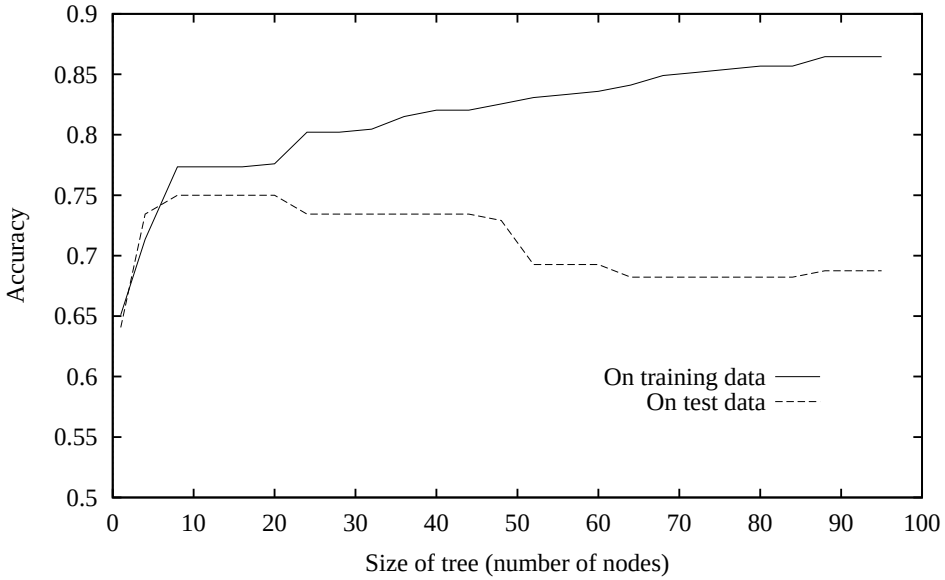


Figure 2: Accuracy of the decision tree learned by ID3 as the algorithm adds more nodes