Foundations of Artificial Intelligence

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Exercise Sheet 4

Due: Tuesday, June 21, 2011

Exercise 4.1 (CSPs)

The $SEND + MORE = MONEY$ problem consists in finding distinct digits for the letters D, E, M, N, O, R, S, Y such that S and M are different from zero, i.e. no leading zeros, and the equation

$$SEND + MORE = MONEY$$

is satisfied.

(a) Explain in a nutshell, why it would be good to formulate the problem as a *constraint satisfaction problem*?

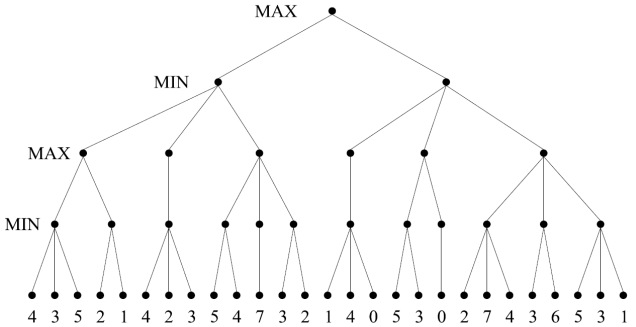
(b) Formulate the problem as a *constraint satisfaction problem*, i.e. what are the variables, what constraints do we have, etc.

(c) Find a solution using *forward checking* and *arc consistency*. Give the search tree.
(Hint: consider the letters in the following order: O, M, Y, E, N, D, R, S.)

Exercise 4.2 (Minimax algorithm)

(a) Perform the minimax algorithm in the tree in Figure 1 using $\alpha\beta$-pruning. Traverse the tree from left to right. Annotate the nodes with their alpha and beta values.

(b) Can the nodes be ordered in such a way that $\alpha\beta$-pruning can cut off more branches? If so, give the order. Otherwise, argue why not.

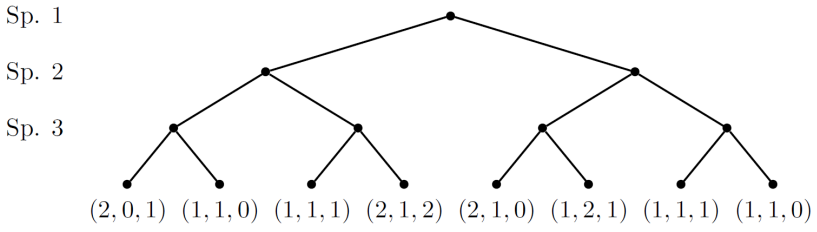


Exercise 4.3 (Generalization of the Minimax algorithm)

Consider the problem of search in a three-player game (you may assume that no alliances are allowed) without the zero-sum condition. The players are called 1, 2, and 3. Unlike in the case of two-player zero-sum games, the evaluation function now returns a triple (x_1, x_2, x_3) such that x_i is the value the node has for player i.

(a) Complete the game tree given below by annotating all interior nodes and the root node with the backed-up value triples.

(b) Assume that the value triple $(1, 1, 1)$ at the third leaf nodes from the left is replaced by $(0, 1, 2)$. Which problem arises now when you try to back up value triples? Suggest how to modify the back-up procedure to obtain a "robust" result at the root node.



Exercise 4.4 (Joint Probability Distribution)

Given the joint probability distribution table

	A	$\neg A$
B	0.4	0.2
$\neg B$	0.1	0.3

where cell A,B specifies the probability for $P(A \wedge B)$[1] $= 0.4$, calculate the following probabilities:

(a) $P(A)$, $P(B)$, $P(\neg A)$, and $P(\neg B)$

(b) $P(A \vee B)$ and $P((A \vee B) \wedge \neg(A \wedge B))$

(c) $P(A|B)$ and $P(B|A)$

The exercise sheets may and should be handed in and be worked on in groups of three (3) students. Please fill the cover sheet[2] and attach it to your solution.

[1] shorthand for $P(X_1 = A \text{ and } X_2 = B)$

[2] `http://ais.informatik.uni-freiburg.de/teaching/ss11/ki/cover-sheet.pdf`