Artificial Intelligence - Midterm Examination Solutions

Winter 2010

1. [15 points] **Small questions**

   (a) Can iterative deepening be used in game tree search? If yes, explain how, and what would be its advantages/disadvantages. If no, explain why not. (3 sentences)

   Answer: Yes, it can be used instead of searching to a fixed depth. One could search to depth 1, use the heuristic on the resulting boards and pick the best move based on this; then, if there is still time, search to depth 2 and use the heuristic at this depth, re-pick the best move, etc. The advantage is that you can continue searching as long as you have time. The disadvantage is that work gets duplicated - the top of the tree gets expanded and searched multiple times.

   (b) True or false: Alpha-beta pruning with a heuristic evaluation function yields an optimal playing strategy against an optimal opponent

   Answer: False. If you use a heuristic, the solution depends on how good the heuristic is.

   (c) True or false: Monte Carlo tree search yields an optimal playing strategy against an optimal opponent

   False: The quality depends on how many trajectories you generated, on how good the policy for generating these trajectories is.

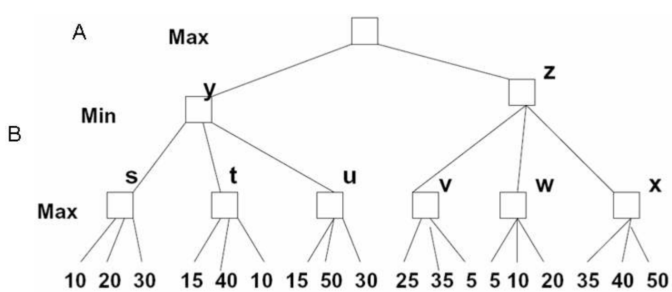
   (d) Suppose you do simulated annealing and lower the temperature parameter very quickly. Will you find the optimal solution? Explain why or why not.

   Answer: False: lowering the temperature eliminates randomness; if this is done too quickly, the algorithm can get trapped in local optima.

   (e) Consider the following two bit strings: 01100000 and 10110111. Suppose that the fitness function is given by the number of bits that are 1. What should the crossover point be, in order to get in the next generation an individual with the highest possible fitness? Show the result of the crossover.

   Answer: If you cut between bits 2 and 3 or between bits 3 and 4, you will get an individual with 6 bits of 1 in the next generation.

2. [10 points] **Game tree search** Consider the game tree below.



(a) Use minimax to determine the best strategy for both players, and give the actions that would be chosen and their values.

Answer: The values for the nodes are as follows: $s = 30$, $t = 40$, $u = 50$, $y = 30$, $v = 35$, $w = 20$, $x = 50$, $z = 20$. The top node value is 30. The best move for Max is to go to y, and the best follow-up for Min is to move to s.

(b) How would you re-order the nodes in order to get maximal pruning when using the alpha-beta algorithm? Feel free to use the figure to show the re-ordering

Answer: At Max nodes, nodes should be ordered from highest to lowest, and at Min nodes, from lowest to highest. This will ensure maximum pruning.

3. [30 points] **Problem formulation**

At the Olympic games, the organizers have to transport all the athletes from the hotel to the opening ceremony. To make things organized, they want to issue for each athlete a ticket with a given shuttle number. They use shuttles which can each carry 10 athletes. A shuttle cannot leave until it is full (we assume the number of athletes is a multiple of 10). Each athlete has to be assigned to exactly one shuttle. Athletes have a strong preference to travel with their team mates; so if an athlete travels with k athletes who are not from their own team, a cost of k is incurred. Costs incurred for all athletes are cumulated. So, for example, in a shuttle with 7 athletes from team A and 3 athletes from team B, the cost incurred for the shuttle would be $7 * 3 + 3 * 7$.

(a) Formulate this as a search problem, specifying precisely all required components.

Answer: This is a constrained optimization problem. There are several ways to formulate the problem, but for example, you can use variables X_{ij} where i is the index of the athlete and j is the index of the shuttle. The value of X_{ij} is 1 if athlete i has been assigned to shuttle j and 0 otherwise (so the domain is $\{0, 1\}$. The constraints become:

- Each athlete has to be assigned to exactly one shuttle: $\sum_j X_{ij} = 1$
- Each shuttle holds exactly 10 athletes: $\sum_i X_{ij} = 10$

The cost for the shuttle is computed as described above.

(b) Explain what search method you would use to solve this problem, and why. Describe how your search method would be implemented for this problem.

Answer: Again, several answers are possible, but one example is simulated annealing, where each assignment of athletes is a state, and moves swap two athletes. Temperature should be decreased over time.

(c) Suppose that instead of optimizing this cost function, the organizers just want to make sure that no shuttle has more than 3 teams inside. How does this change the type of search problem, and what search methods would you be using now?

Answer: This is now a constraint satisfaction problem, not optimization, and could be solved, e.g. by depth-first search with backtracking.

4. [10 points] **Propositional Logic**

   Alice, Bob, Camilla and Dan are making plans for spring break. They go to the travel agency, but there are only 2 tickets left. Alice will only go if Bob goes too. Dan will only go if Camilla goes too. Bob has found out that he has to work on the AI project, so he cannot go.

   (a) Using 4 literals, write the propositional logic formulas corresponding to this text

   Answer: Let A, B, C and D denote that Alice, Bob, Camilla and Dan will go, respectively. The statement that there are exactly two tickets gets translated as:

$$(A \wedge B \wedge \neg C \wedge \neg D) \vee (A \wedge \neg B \wedge C \wedge \neg D) \vee (A \wedge \neg B \wedge \neg C \wedge D) \vee (\neg A \wedge B \wedge C \wedge \neg D) \vee (\neg A \wedge B \wedge \neg C \wedge D) \vee (\neg A \wedge \neg B \wedge C \wedge D)$$

   (2) Alice will go only if Bob goes: $A \rightarrow B$, which can be re-written as $\neg A \vee B$
   (3) Dan goes only if Camilla goes: $D \rightarrow C$, which can be re-written as $\neg D \vee C$
   (4) Bob cannot go: $\neg B$

   (b) Find (through a formal proof) who will go on vacation.

   Answer: By resolution between (2) and (4), we have $\neg A$, so we know $\neg A \wedge \neg B$. By forward search from (1), based on this statement, we obtain $C \wedge D$.

5. [15 points] **First-order Logic**

   Consider the following sentences. For each of them, explain if it can be written out in first-order logic. If your answer is yes, give the corresponding logical statement. If the answer is no, explain the difficulty.

   (a) All the existing kinds of birds can fly

$$\forall x Bird(x) \rightarrow Fly(x)$$

   (b) Some existing kinds of birds can fly

$$\exists x Bird(x) \wedge Fly(x)$$

   (c) At least two existing kinds of birds can fly

$$\exists x \exists y \neg(x = y) \wedge Bird(x) \wedge Bird(y) \wedge Fly(x) \wedge Fly(y)$$

   (d) Most existing kinds of birds can fly

   This cannot be said din first-order logic, because "most" implies some form of counting, which is not supported in FOL.

   (e) All existing kinds of birds can fly, except two.

$$\exists x \exists y Bird(x) \wedge Bird(y) \wedge \neg(x = y) \wedge \neg Fly(x) \neg Fly(y) \wedge (\forall z Bird(z) \wedge \neg(y = z) \wedge \neg(x = z) \rightarrow Fly(z))$$