ECS 170 - Intro to Artificial Intelligence – Suggested Solutions
Mid-term Examination (100 points)
Open textbook and open notes only
Show your work clearly
Winter 2003

Problem 1. (15 points) Consider the so-called Cryptarithmetic problem shown below.

```
   S A V E
 + M O R E
  ---------
  M O N E Y
```

The problem is to figure out the digits (0 thru 9) that should be assigned to these letters so that the indicated arithmetic operation is valid.
Your job is to formulate this as a search problem. Clearly indicate a definition of state, initial state, goal state, operators and define a suitable path cost. Estimate the size of the search tree and draw a small segment of the search tree just to show that you understood the procedure.

Suggested Solution.
Each state represents a partial assignment of numbers to letters.

Cryptarithmetic Problem

```
   S A V E
  + M O R E
  ---------
  M O N E Y
```

Each state represents a partial assignment of numbers to letters.

```
            {no assignments}
           /   |        |     \
          /    |        |      \
         /     |        |       \
        /      |        |        \
      {S=1} {A=1 {V=1}     {E=1}
      /  |   \
     /   |    \
    /    |     \
 {S=1,  {S=1,   ...
 A=2}   A=3}
```

Goal State: A leaf at which the assignment is consistent and is a solution to the puzzle.

Problem 2. (20 points) The following search tree is given. Your job is to find the maximum number located at one of the leaf nodes of the tree. You are asked to compare a newly discovered heuristic search with the Best First search by actually finding the maximum number using both methods on the given search tree. For each of the methods, your answer should show the list of nodes waiting to be expanded after each step. In each case, what is the answer produced by your search method? What is the correct answer?

First I will describe the new method and next I will help you by re-stating the Best First method, described in your textbook.

New method: Follow the path that looks like it's improving the fastest. Keep going as long as the path is improving.

Best First method: Continue working from the "best node on the active list so far" as long as its successors are still improving.

```
                              New          BEST
                              Method        FIRST
           0                   0           (0)
        /     \                            (4 2)
      4          2
    /  \       / | \
   7    5     1   9   6
   |    / \   |   |   / \
  8    10  3  |  12 34 17
              |
              |
             50
```

Solution:

```
                              New          BEST
                              Method        FIRST
           0                     0         (0)
        /     \                            (4 2)
      4          2               4         (7 5 2)
    /  \       / | \                       (8 5 2)
   7     5    1   9   6          7         (8 10 2)
   |    / \   |   |   / \                  (8 10 9 6)
  8  10  3    |  12 34 17          8       (8 10 12 6)
   (New)      |.   BF                      (8 10 12 34 17)
              |.
              50 (optimal)
```

Node 8 (marked New) follows fastest improving path. Is efficient.
Node 34 (marked BF) pursues best nodes, but will not find path that looks bad at first
Obtained a better solution.

Problem 3. (25 points) For each of the following statements below, indicate whether the statement is true or false, and give a brief but precise justification for your answer. Correct answers *with correct justifications* will carry 3 points. No points will be awarded for answers without correct justifications.

Example Question: The time and memory requirements of IDA* can be improved by using A* algorithm to do search in individual iterations.

Model Answer: False. Because A* in the worst case can take as much memory as breadth-first, and thus using A* in the individual iterations will make IDA* require exponential memory (instead of linear memory).

A). Breadth-first search is complete if the state space has infinite depth but finite branching factor.

Solution TRUE. It won't return if there is no goal, butcompleteness does not require this – nor can any algorithm guarantee it.

B). Assume that a king can move one square in any of the 8 directions in a chess board. Manhattan distance is then an admissible heuristic for the problem of moving the king from square A to Square B.

Solution . FALSE. For a single diagonal move the Manhattan Distance is 2.

C.) For a uniform tree of depth 10 and branching factor b, iterative deepening dept-first search will search at most 5 times more nodes than depth-first search, whatever be the value of b.

D.) A* search does b^(d/2) node expansions when searching a unifrom tree of branching factor *b* and depth *d*, using a perfect heuristic.

E.) Consider a uniform search tree of depth d and branching factor b, where there are many goal nodes, all of which are uniformly distributed at the leaf level d. Assuming that memory consumption is not a problem, we are better off using breadth-first search than depth-first search in this scenario.

F.) A* search with heuristic h = 0 will always have to search the entire tree before finding the optimal solution.

G.) Suppose A* search uses an evaluation function f(n) = (1-w) g(n) + w h(n). For any value of w between 0 and 1 (inclusive), A* will terminate and return optimal solution.

H.) If h1 and h2 are two admissible heuristics, and h3 is defined as h3(n) = max {h1(n) , h2(n)} , then A* search with h3 is guaranteed to return an optimal solution while expanding as many or fewer nodes than either h1 or h2.

4. (20 points) Consider the game tree shown elsewhere on this questi0on paper in which the static scores are from the first player's point of view.

(a) Suppose the first player is the maximizing player. What move should be chosen? Justify your answer by showing all work.

(b) What nodes would not need to be examined using the alpha-beta pruning procedure.

5. (20 points) Given the following facts, prove that "Some who are intelligent cannot read."

a. Whoever can read is literate
b. Dolphins are not literate
c. Some dolphins are intelligent

Use the symbols R for Read, L for Literate, D for dolphins and I for intelligent.
Show clearly all the work.

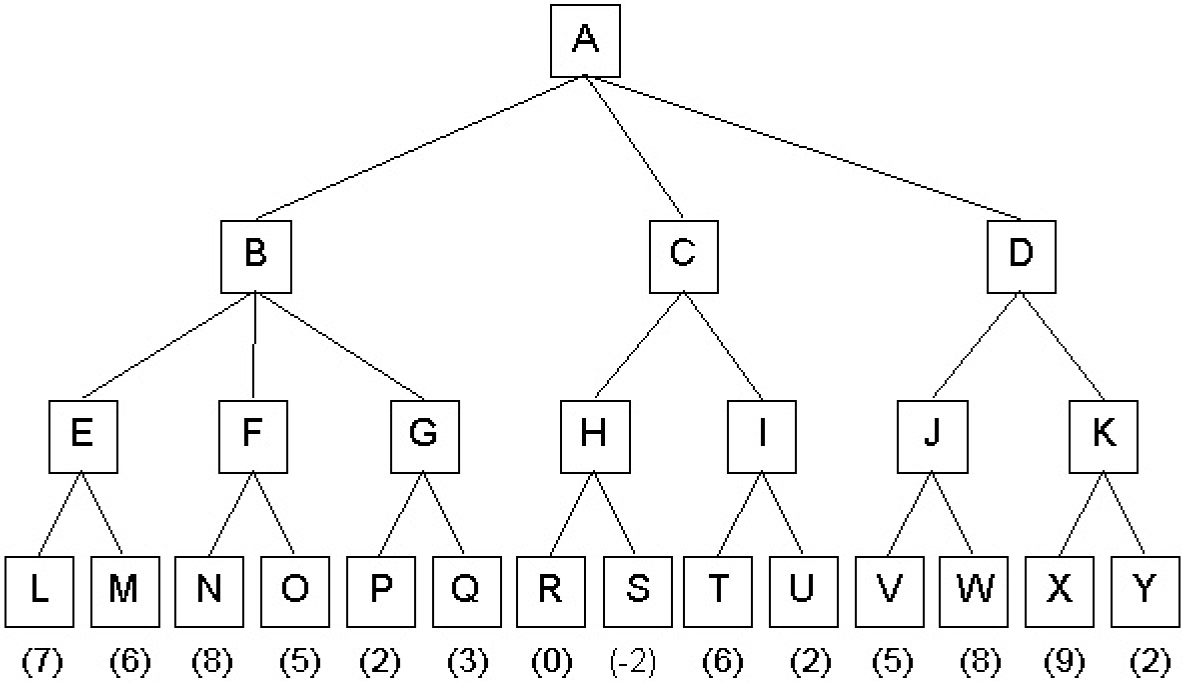
Suggested Solution
The three facts are
(for all x) [R(x) → L(x)]
(for all x) [D(x) → ~L(x)]
(there exists x) [D(x) ^ L(x)]

The goal is

(there exists x) [I(x) ^ ~R(x)]

Add negated goal to axioms
(for all x) [R(x) → L(x)]
(for all x) [D(x) → ~L(x)]
(there exists x) [D(x) ^ L(x)]
~(there exists x) [I(x) ^ ~R(x)]

Put in clausal form



1. ~R(x) V L(x)
2. ~D(y) V ~L(y)
3. D(F), F is a Skolmenizing constant
4. I(F)
5. ~I(z) V R (z)

Develop a Resolution tree

5 and 4 → 6. R(F)

6. and 1 → 7. L(F)
7. and 2 → 8. ~D(F)
8. and 3 → Null