CS 4700: Foundations of Artificial Intelligence
Homework 1
Due: Tuesday, February 28, 2017 8:40am
(Clarification added to Question 3 on 2/19)
(Typo fixed in Question 5d on 2/22)

1. In the first lecture I gave you a few minutes to think about how one might define "intelligence". I'm asking you to do so again as part of this homework:

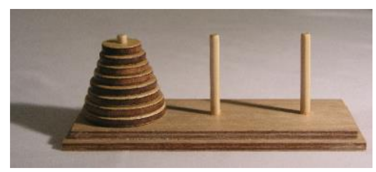
    Define, in your own words, "intelligence".

    You may consult dictionaries, encyclopedias, textbooks, or whatever other sources you like. However, your definition must be in your own words, to capture your own thinking about what elements of intelligence are most salient. It must not be merely a copy of an existing definition that you found somewhere, no matter how compelling you might find it.

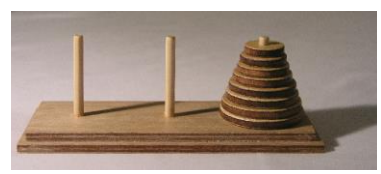
    Note there is no right or wrong answer here. The goal is to have you consider how one might crisply capture in words what intelligence is.

    Please submit your answer to this question online, at https://docs.google.com/forms/d/e/1FAIpQLSeImTaTPtvT1TeqTpXtMAHL9c-NO4XKUtnDNb9wzlNcdJp9pw/viewform.

2. In the Tower of Hanoi problem you have three pegs, and sitting on one of the pegs are n discs going from the smallest on the top in increasing diameter to the largest at the bottom. The image to the right shows an example for n=8.



    The problem is to move discs one-by-one until all n discs are transferred from the peg on one side to the peg on the other. In other words, the discs on the left peg in the first should be moved to the peg on the right, as in the second image to the right. Once again the discs must go from the smallest at the top to the largest at the bottom .



    There is one additional constraint you must abide by when you solve this puzzle: You must *never* place a larger disc on top of a smaller disc.

    a. Formulate this problem as a state space search.
        - What are the states?
          (Don't just show a picture, come up with a notation for states that a computer might use.)
        - What are the initial and goal states?
        - What are the operators?
        - What is the branching factor?
    b. Draw the search space for the case of n=2.
    c. Annotate the nodes with the numbers 1, 2, 3, … in the order in which they'd be visited by a depth-first search (making sure to check for cycles).

d. Number the nodes with capital letters A, B, C, … in the order in which they'd be visited by a breadth-first search (making sure to check for cycles).
e. Number the nodes with lower case letters a, b, c, … in the order in which they'd be visited by iterative deepening search (making sure to check for cycles).

3. You have two jugs. One holds 10 liters of water when completely full, the other holds 6 liters when completely full. You have an unlimited source of water to fill either or both jugs, and you may do so as often as you like, but there are no markings on the jugs, so if you fill a jug the only way to know how much water you've put in is if you fill it to the top. In addition, you have amazing accuracy in pouring water from one jug to another and never lose a drop. When you do choose to pour water from one jug to another you must keep pouring until either the receiving jug is full or the source jug is emptied of water. You can also always choose to fully empty either jug. Can you get 8 liters of water in the larger jug?
   a. Formulate this problem as a state space search.
      - What are the states?
      - What are the initial and goal states?
      - What are the operators?
      - What is the branching factor?
   b. Draw the search space for this problem.
   c. Draw a path from the initial state to the goal state.

4. Consider a problem where you start with the three-tuple (0,0,0) and at each step you can take one of the three values and increase it or decrease it by 1. Your goal is to reach the point (a,b,c) for some integer values a, b, and c.
   a. What is the branching factor of the search space for this problem?
   b. How many distinct states are there that are k steps from the initial state? (Your answer should be a function of the depth k.)
   c. For a given state s = (x,y,z), consider using A* search with h(x,y,z) = |x-a|+|y-b|+|z-c|. Is h admissible? Please explain.
   d. Imagine a variant of this problem where if you are at state (x,y,z) and x is odd you can only change its value by 1 if both y and z are themselves also odd. Is h admissible? Explain.
   e. Imagine a different variant of this problem where if x is odd you not only can increase or decrease its value by 1, you can also choose to increase or decrease its value by 3. Is h admissible? Explain.
   f. Imagine another variant of this problem in which the coordinates for each state and the goal are non-negative. Give a heuristic evaluation function f(x,y,z) for which hillclimbing will always find an optimal solution.

5. If h(s) is an admissible heuristic:
   a. Is $h_1(s) = 2h(s)$ an admissible heuristic?
   b. Is $h_2(s) = \frac{h(s)}{2}$ an admissible heuristic?
   c. Is $h_3(s) = -h(s)$ an admissible heuristic?
   d. Under what conditions is A* search guaranteed to find an optimal solution if it is guided by the evaluation function $f(s) = a \times g(s) + b \times h(s)$?

   Please explain your answers.