CMSC 421 Homework 1

Due Date: Tuesday, September 16, at the start of class

1. An agent is placed in an environment containing two slot machines, each of which costs \$1 to play. The expected payoffs are p and q and the agent can play each machine as many times as it likes. Describe, in qualitative terms, how a rational agent should behave in each of the following cases:
   (a) $p = \$2$ and $q = 50¢$.
   (b) $p = \$2$ and q is unknown.
   (c) $p = 99¢$ and q is unknown.
   (d) p and q are unknown.

2. For each of the following agents, develop a PEAS description of the task environment and characterize the environment along the four dimensions given in lecture:
   (a) Microsoft Office Assistant (aka the paper clip)
   (b) PDA/Internet Travel Assistant
   (c) Search and secure robot
   (d) Algebra tutor
   (e) Robot soccer player

3. Give the initial state, goal test, successor function, and cost function for each of the following. Choose a formulation that is precise enough to be implemented.
   (a) (Traveling Salesperson Problem) You have n cities, and a roadmap describing highways between the cities and you want to plan a tour for the salesman that visits each of the cities exactly once.
   (b) A 3-foot-tall monkey is in a room where some bananas are suspended from the 8-foot ceiling. He would like to get the bananas. The room contains two stackable, movable, climbable 3-foot high crates.
   (c) In cryptarithmetic problems, letters stand for digits and the aim is to find a substitution of digits for letters such that the resulting sum is arithmetically correct. Each letter must stand for a different digit. Here is an example of such a problem:

FORTY	Solution:	29786
+ TEN		+ 850
+ TEN		+ 850
———-		———
SIXTY		31486

   That is: F=2, O=9, R=7, T=8, Y=6, E=5, N=0, S=3, I=1, X=4

   Make your answer general enough to be applicable to any cryptarithmetic problem.
   (d) You have three jugs measuring 12 gallons, 8 gallons, and 3 gallons, and a water faucet. You need to measure out exactly one gallon.

4. Consider a state space where the start state is number 1, and the successor function for state n returns two states labelled $2n$ and $2n + 1$.

(a) Draw the portion of the state space for states 1 to 15.

(b) Suppose that the goal state is 13. List the order in which nodes will be visited for breadth-first search, depth-limited search with depth limit 3, and iterative deepening search.

(c) Can you apply best-first search to this problem? What would be a good heuristic? List the order in which nodes are visited in searching for the goal of 13 using your heuristic.

(d) Would bidirectional search be appropriate for this problem? If so, describe how it would work. What is the branching factor in each direction of the bidirectional search? Does this suggest a reformulation of the problem that would allow you to solve the problem of getting from state 1 to a given goal state with almost no search at all?

5. Come up with heuristics for the following problems. Explain whether they are admissible, and whether the state spaces contain local maxima with your heuristic:

   (a) The general case of the chain problem (i.e., with an arbitrary goal state) from Exercise 3.15. Operators are opening a link and closing a link.

   (b) Algebraic equation solving (e.g., "solve x**2 y**3 = 3 - xy for x").

6. Consider the problem of constructing crossword puzzles: fitting words into a grid of intersecting horizontal and vertical squares. Assume that a list of words (i.e., a dictionary) is provided, and that the task is to fill in the squares using any subset of this list. Go through a complete goal and problem formulation for this domain, and choose a search strategy to solve it. Specify the heuristic function, if you think one is needed.

7. Consider a simplified version of the 8-queens problem with 4 queens that we are trying to place on a 4x4 chess board so that none can capture any other (that is, only one-queen can be on any row, column, or diagonal of the array). Suppose we try to solve this puzzle using the following problem space: The start node is labeled by an empty 4x4 array; the successor function creates new 4x4 arrays containing one additional legal placement of a queen anywhere in the array and the goal predicate is satisfied if and only if there are four queens in the array (legally positioned).

   (a) Invent an admissible heuristic function for this problem based on the number of queen placements remaining to achieve the goal. (Note that all goal nodes are precisely four steps from the start node)

   (b) Use your heuristic function in an A* search to a goal node. Draw the search tree consisting of all 4x4 arrays produced by the search and label each array by its value of g and $\hat{h}$. (Note that symmentry considerations mean we have to generate only three successors of the start node.)

8. A* does not terminate until a goal node is selected for expansion. However, a path to a goal node might be reached long before that node is selected for expansion. Why not terminate as soon as a goal node has been found? Illustrate your answer with an example.