University of St. Thomas, Saint Paul, Minnesota
Computer and Information Sciences Department

CISC440: Artificial Intelligence and Robotics

Quiz 2: Solving Problem by Search

Instruction:

1. Work with you team member and solve the quiz.
2. You both can submit one solution.
3. Please write names of both team members.

Names: ___SOLUTION_______________

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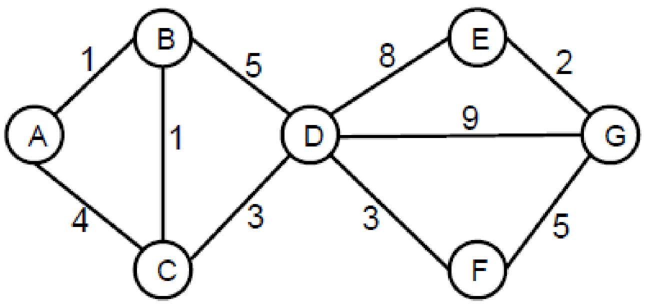
Total points: 30

Question 1: Search



Node	h_1	h_2
A	9.5	10
B	9	12
C	8	10
D	7	8
E	1.5	1
F	4	4.5
G	0	0

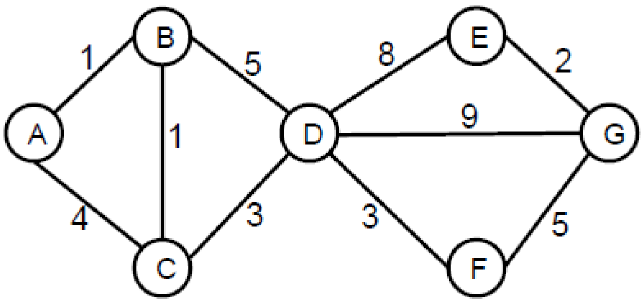
Consider the state space graph shown above. **A is the start state and G is the goal state.** The costs for each edge are shown on the graph. Each edge can be traversed in both directions. Note that the **heuristic h_1 is consistent but the heuristic h_2 is not consistent.**

(a) (10 points) Possible paths returned.

For each of the following graph search strategies (*do not answer for tree search*), mark which, if any, of the listed paths it could return. Note that for some search strategies the specific path returned might depend on tie-breaking behavior. In any such cases, make sure to mark *all* paths that could be returned under some tie-breaking scheme.

Search Algorithm	**A-B-D-G**	**A-C-D-G**	**A-B-C-D-F-G**
Depth first search	x	x	X
Breadth first search	x	X	
Uniform cost search			X
A* search with heuristic h_1			X
A* search with heuristic h_2			X

The return paths depend on tie-breaking behaviors, so any possible path must be marked. DFS can return any path. BFS will return all the shallowest paths, i.e. A-B-D-G and A-C-D-G. A-B-C-D-F-G is the optimal path for this problem, so that UCS and A* using consistent heuristic h1 will return that path. Although, h2 is not consistent, it will also return this path.



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(b) Heuristic function properties

Suppose you are completing the new heuristic function h_3 shown below. All the values are fixed except $h_3(B)$.

Node	A	B	C	D	E	F	G
h_3	10	?	9	7	1.5	4.5	0

For each of the following conditions, write the set of values that are possible for $h_3(B)$. For example, to denote all non-negative numbers, write $[0, \infty]$, to denote the empty set, write $\emptyset$, and so on.

(i) (3 points) What values of $h_3(B)$ make h_3 admissible?

To make h3 admissible, h3(B) must be less than or equal to the actual optimal cost from B to goal G, which is the cost of path B-C-D-F-G, i.e. 12. The answer is 0 <= h3(B) >= 12

(ii) (3 points) What values of $h_3(B)$ make h_3 consistent?

All the other nodes except node B satisfy the consistency conditions. The consistency conditions that do involve the state B are:

h(A) <= c(A;B) + h(B)	h(B) <= c(B;A) + h(A)
h(C) <= c(C;B) + h(B)	h(B) <= c(B;C) + h(C)
h(D) <= c(D;B) + h(B)	h(B) <= c(B;D) + h(D)

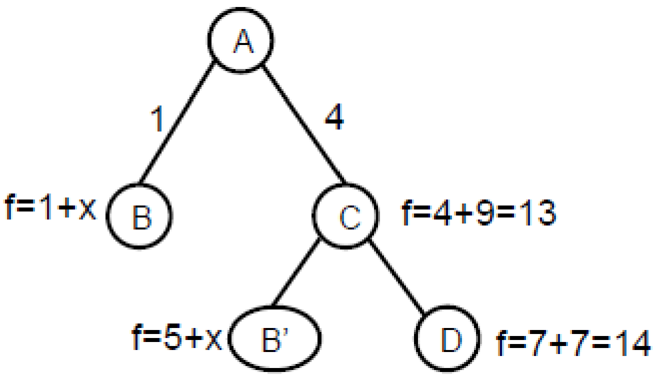
Filling in the numbers shows this results in the condition: 9 <= h3(B) >= 10

(iii) (4 points) What values of $h_3(B)$ **will cause A* graph search to expand node A, then node C, then node B, then node D in order?**

The A* search tree using heuristic h3 is on the right. In order to make A* graph search expand node A, then node C, then node B, suppose h3(B) = x, we need

$1 + x > 13$
$5 + x < 14$ (expand B') or $1 + x < 14$ (expand B)

so we can get 12 < h3(B) < 13



Question 2: Search Formulation:

Consider the problem of controlling n pacmen simultaneously. Several pacmen can be in the same square at the same time, and at each time step, each pacman moves by at most one unit vertically or horizontally (in other words, a pacman can stop, and also several pacmen can move simultaneously). The goal of the game is to have all the pacmen be at the same square in the minimum number of time steps. In this question, use the following notation: let M denote the number of squares in the maze that are not walls (i.e. the number of squares where pacmen can go); n the number of pacmen; and pi = (xi; yi) : i = 1 : : : n, the position of pacman i. Assume that the maze is connected.

1. **(2.5 points) What are the actions?**

   Stop and the 4 directions

2. **(2.5 points) What is the state space of this problem?**

   n-Tuples, where each entry is in {1, . . . , M}.

3. **(2.5 points) What is the size of the state space (not a bound, the exact size)?**

   M^n

4. **(2.5 points) Give the tightest upper bound on the branching factor of this problem.**

   5^n (Each pacman has five actions: Stop and the 4 directions).

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