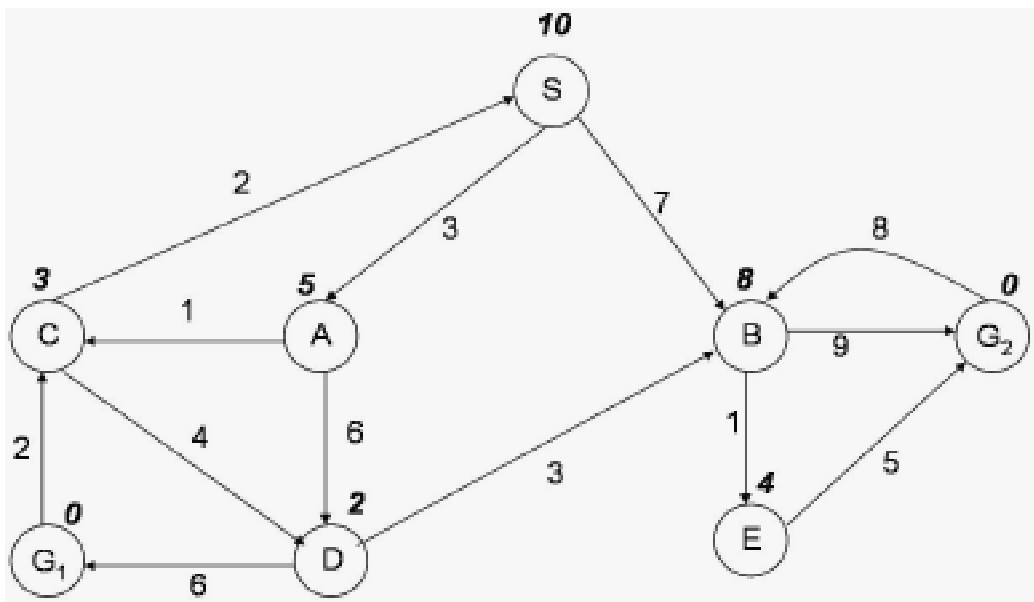
COMP 472: Artificial Intelligence
State Space Search
Solutions

Question 1 Consider the state space below. Assume that S is the initial state and G_1 and G_2 are the goal states. The possible actions between states are indicated by arrows. The number labelling each arc is the actual cost of the action. For example, the cost of going from S to A is 3. The number in bold italic near each state is the value of the heuristic function h at that state. For example, the value of h at state C is 3. When all else is equal, expand states in alphabetical order.



For the following search strategies, show the states visited, along with the open and closed lists at each step (where it applies).

(a) Breadth-first search

Step	Visited State	Closed List	Open List
1			S
2	S	S	A, B
3	A	S, A	B, C, D
4	B	S, A, B	C, D, E, G2
5	C	S, A, B, C	D, E, G2
6	D	S, A, B, C, D	E, G2, G1
7	E	S, A, B, C, D, E	G2, G1
8	G2	S, A, B, C, D, E, G2	G1

(b) Depth-first search

Step	Visited State	Closed List	Open List
1			S
2	S	S	A, B
3	A	S, A	C, D, B
4	C	S, A, C	D, B
5	D	S, A, C, D	G1, B
6	G1	S, A, C, D, G1	B

(c) Iterative deepening depth-first search *Note: The depth of each state in the open list is indicated in parenthesis.*

Depth 1:

Step	Visited State	Closed List	Open List
1			S(1)
2	S	S	

Depth 2:

Step	Visited State	Closed List	Open List
1			S(1)
2	S	S	A(2), B(2)
3	A	S, A	B(2)
4	B	S, A, B	

Depth 3:

Step	Visited State	Closed List	Open List
1			S(1)
2	S	S	A(2), B(2)
3	A	S, A	C(3), D(3), B(2)
4	C	S, A, C	D(3), B(2)
5	D	S, A, C, D	B(2)
6	B	S, A, C, D, B	E(3), G2(3)
7	E	S, A, C, D, B, E	G2(3)
8	G2	S, A, C, D, B, E, G2	

(d) Uniform cost search

Step	Visited State	Closed List	Open List
1			S(0)
2	S	S	A(3), B(7)
3	A	S, A	C(4), B(7), D(9)
4	C	S, A, C	B(7), D(8); lower cost to D replaces previous cost
5	B	S, A, C, B	D(8), E(8), G2(16)
6	D	S, A, C, B, D	E(8), G1(14), G2(16)
7	E	S, A, C, B, D, E	G2(13), G1(14); G2(13) replaces G2(16)
8	G2	S, A, C, B, D, E, G2	

(e) General Hill climbing *Note: Hill climbing does not use open and closed lists, instead the first neighboring state with a better heuristic than the current state is visited.*

Step	Visited State	Evaluations
1	S	A(5) $<$ S(10)
2	A	C(3) $<$ A(5)
3	C	D(2) $<$ C(3)
4	D	B(8) $\not<$ D(2); G1(0) $<$ D(2)
5	G1	

(f) Best-first search

Step	Visited State	Closed List	Open List
1			S(10)
2	S	S	A(5), B(8)
3	A	S, A	D(2), C(3), B(8)
4	D	S, A, D	G1(0), C(3), B(8)
5	G1	S, A, D, G1	C(3), B(8)

(g) Algorithm A

Step	Visited State	Closed List	Open List
1			S(10)
2	S	S	A(3+5=8), B(7+8=15)
3	A	S, A	C(3+1+3=7), D(3+6+2=11), B(15)
4	C	S, A, C	D(3+1+4+2=10), B(15)
5	D	S, A, C, D	G1(3+1+4+6+0=14), B(15)
6	G1	S, A, C, D, G1	

Question 2 Consider the classical game of Tetris. The objective of the game is to move and rotate each falling block so as to create an entire row of block pieces without any gap. If such a row is created, then that row disappears, and all rows on top of it fall down.

For example, in the figure above, a 1x4 block is falling from the top. The player can move this block left and right and rotate it by 90 degree to have it upright. As the figure shows, the player has at least 5 choices to position the block. Out of these 5 choices, position 5 is preferable, because then the 4 bottom rows would be complete. These rows would then disappear; all rows above would fall down, leaving more space on top to place the next random block to fall. The game ends when too many blocks are stacked up (no new complete rows can be created) and no more blocks can be placed on the board.

(a) Formulate a simple heuristic to determine how to place a falling (random) block on an existing board.

A possible heuristic is to count the number of complete rows created (that will be deleted). In that case, h(option2) = 0 and h(option4) = 0.

Another heuristic is to count the number of "touching sides" i.e. how many sides of the falling block will be in contact with the Tetris pile. In that case,
h(option2) = 5 (2 edges on the left + the bottom + 2 edges on the right)
h(option4) = 8 (4 edges on the left + the bottom + 3 edges on the right)

There are plenty of other possible heuristics.

(b) Now apply your heuristic to evaluate option 2 and option 4 of the figure above.