**HW2 Solution**

**2a - breadth first**

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| **1** | S | | S | A C D | A C D |
| **2** | A C D | S | A | B G1 | B G1 |
| **3** | C D B G1 | S A | C | B D F J | F J |
| **4** | D B G1 F J | S A C | D | E | E |
| **5** | B G1 F J E | S A C D | B | G1 | |
| **6** | G1 F J E | S A C D B | G1 | | |

**2b - depth first**

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| **1** | S | | S | A C D | A C D |
| **2** | A C D | S | A | B G1 | B G1 |
| **3** | B G1 C D | S A | B | G1 | |
| **4** | G1 C D | S A B | G1 | | |

**2c - iterative deepening**

note: no need to use closed for iterative deepening since the depth limit will handle loops

k=0

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| **1** | S | | S | none at k=0 | |

k=1

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| **1** | S | | S | A C D | A C D |
| **2** | A C D | S | A | none at k=1 | |
| **3** | C D | S A | C | none at k=1 | |
| **4** | D | S A C | D | none at k=1 | |

k=2

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| 1 | S | | S | A C D | A C D |
| 2 | A C D | S | A | B G1 | B G1 |
| 3 | B G1 C D | S A | B | none at k=2 | |
| 4 | G1 C D | S A B | G1 | | |

**2d - uniform cost (i.e, using f=g)**

note: you should keep track of parents for all searches, since they are needed to produce the solution path, but we'll only do so for Uniform Cost due to the clutter

| step | open | closed | x | children | rem |
|---|---|---|---|---|---|
| 1 | $S_0$ | | $S_0$ | $A^S_4$ $C^S_3$ $D^S_1$ | $A^S_4$ $C^S_3$ $D^S_1$ |
| 2 | $D^S_1$ $C^S_3$ $A^S_4$ | $S_0$ | $D^S_1$ | $E^D_4$ | $E^D_4$ |
| 3 | $C^S_3$ $A^S_4$ $E^D_4$ | $S_0$ $D^S_1$ | $C^S_3$ | $B^C_5$ $D^C_5$ $F^C_5$ $J^C_7$ | $B^C_5$ $F^C_5$ $J^C_7$ |
| 4 | $A^S_4$ $E^D_4$ $B^C_5$ $F^C_5$ $J^C_7$ | $S_0$ $D^S_1$ $C^S_3$ | $A^S_4$ | $B^A_7$ $G1^A_{12}$ | $G1^A_{12}$ |
| 5 | $E^D_4$ $B^C_5$ $F^C_5$ $J^C_7$ $G1^A_{12}$ | $S_0$ $D^S_1$ $C^S_3$ $A^S_4$ | $E^D_4$ | $F^E_7$ $G2^E_{10}$ | $G2^E_{10}$ |
| 6 | $B^C_5$ $F^C_5$ $J^C_7$ $G1^A_{12}$ $G2^E_{10}$ | $S_0$ $D^S_1$ $C^S_3$ $A^S_4$ $E^D_4$ | $B^C_5$ | $G1^B_9$ | $G1^B_9$ |
| 7 | $F^C_5$ $J^C_7$ $G1^B_9$ $G2^E_{10}$ | $S_0$ $D^S_1$ $C^S_3$ $A^S_4$ $E^D_4$ $B^C_5$ | $F^C_5$ | $G2^F_9$ | $G2^F_9$ |
| 8 | $J^C_7$ $G1^B_9$ $G2^F_9$ | $S_0$ $D^S_1$ $C^S_3$ $A^S_4$ $E^D_4$ $B^C_5$ $F^C_5$ | $J^C_7$ | $F^J_{12}$ $G1^J_{10}$ | |
| 9 | $G1^B_9$ $G2^F_9$ | $S_0$ $D^S_1$ $C^S_3$ $A^S_4$ $E^D_4$ $B^C_5$ $F^C_5$ $J^C_7$ | $G1^B_9$ | | |

**2e - best-first (using f=h)**

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| 1 | $S_9$ | | $S_9$ | $A_6$ $C_2$ $D_5$ | $A_6$ $C_2$ $D_5$ |
| 2 | $C_2$ $D_5$ $A_6$ | $S_9$ | $C_2$ | $B_2$ $D_5$ $F_3$ $J_1$ | $B_2$ $F_3$ $J_1$ |
| 3 | $J_1$ $B_2$ $F_3$ $D_5$ $A_6$ | $S_9$ $C_2$ | $J_1$ | $F_3$ $G1_0$ | $G1_0$ |
| 4 | $G1_0$ $B_2$ $F_3$ $D_5$ $A_6$ | $S_9$ $C_2$ $J_1$ | $G1_0$ | | |

**2f - best-first (using f=g+h)**

| step | open | closed | x | children | rem |
|---|---|---|---|---|---|
| 1 | $S_9$ | | $S_9$ | $A_{4+6}$ $C_{3+2}$ $D_{1+5}$ | $A_{10}$ $C_5$ $D_6$ |
| 2 | $C_5$ $D_6$ $A_{10}$ | $S_9$ | $C_5$ | $B_{5+2}$ $D_{5+5}$ $F_{5+3}$ $J_{7+1}$ | $B_7$ $F_8$ $J_8$ |

| step | open | closed | x | children | rem |
|---|---|---|---|---|---|
| 3 | $D_6$ $B_7$ $F_8$ $J_8$ $A_{10}$ | $S_9$ $C_5$ | $D_6$ | $E_{4+5}$ | $E_9$ |
| 4 | $B_7$ $F_8$ $J_8$ $E_9$ $A_{10}$ | $S_9$ $C_5$ $D_6$ | $B_7$ | $G1_{9+0}$ | $G1_9$ |
| 5 | $F_8$ $J_8$ $E_9$ $G1_9$ $A_{10}$ | $S_9$ $C_5$ $D_6$ $B_7$ | $F_8$ | $G2_{9+0}$ | $G2_9$ |
| 6 | $J_8$ $E_9$ $G1_9$ $G2_9$ $A_{10}$ | $S_9$ $C_5$ $D_6$ $B_7$ $F_8$ | $J_8$ | $F_{12+3}$ $G1_{10+0}$ | |
| 7 | $E_9$ $G1_9$ $G2_9$ $A_{10}$ | $S_9$ $C_5$ $D_6$ $B_7$ $F_8$ $J_8$ | $E_9$ | $F_{7+3}$ $G2_{10+0}$ | |
| 8 | $G1_9$ $G2_9$ $A_{10}$ | $S_9$ $C_5$ $D_6$ $B_7$ $F_8$ $J_8$ $E_9$ | $G1_9$ | | |

### 2g - beam search (with beam width=2 and f=h)

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| 1 | $S_9$ | | $S_9$ | $A_6$ $C_2$ $D_5$ | $A_6$ $C_2$ $D_5$ |
| 2 | $C_2$ $D_5$ ~~$A_6$~~ | $S_9$ | $C_2$ | $B_2$ $D_5$ $F_3$ $J_1$ | $B_2$ $F_3$ $J_1$ |
| 3 | $J_1$ $B_2$ ~~$F_3$~~ ~~$D_5$~~ | $S_9$ $C_2$ | $J_1$ | $F_3$ $G1_0$ | $F_3$ $G1_0$ |
| 4 | $G1_0$ $B_2$ ~~$F_3$~~ | $S_9$ $C_2$ $J_1$ | $G1_0$ | | |

### 2h - hill climbing (using the h function only)

| step | open | closed | x | children | rem children |
|---|---|---|---|---|---|
| 1 | $S_9$ | | $S_9$ | $A_6$ $C_2$ $D_5$ | $A_6$ $C_2$ $D_5$ |
| 2 | $C_2$ ~~$D_5$~~ ~~$A_6$~~ | $S_9$ | $C_2$ | $B_2$ $D_5$ $F_3$ $J_1$ | $B_2$ $D_5$ $F_3$ $J_1$ |
| 3 | $J_1$ ~~$B_2$~~ ~~$F_3$~~ ~~$D_5$~~ | $S_9$ $C_2$ | $J_1$ | $F_3$ $G1_0$ | $F_3$ $G1_0$ |
| 4 | $G1_0$ ~~$F_3$~~ | $S_9$ $C_2$ $J_1$ | $G1_0$ | | |

### 2i - admissibility

This h function is admissible. For all nodes n, h(n) <= h*(n), where h*(n) is the actual cost to reach the goal from node n.

| Node | h | h* |
|---|---|---|
| **S** | 9 | 9 |
| **A** | 6 | 7 |
| **B** | 2 | 4 |
| **C** | 2 | 6 |
| **D** | 5 | 9 |

| Node | h | h* |
|---|---|---|
| **E** | 5 | 6 |
| **F** | 3 | 4 |
| **J** | 1 | 3 |

**3a**

The temperature is 100
The score at node **C** is -2
The score at node **J** is -1

Since the score of **J** is greater than the score of **C**, simulated annealing would accept **J** with a probability of 1.

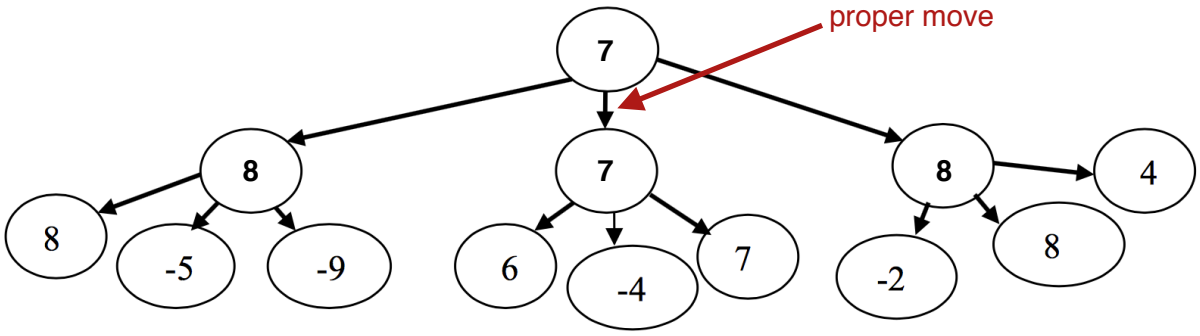
**3b**

The temperature is 100
The score at node **C** is -2
The score at node **F** is -3

Since the score of **F** is **not** greater than the score of **C**, simulated annealing would accept **F** with the probability of:

$e^{(\text{score(F)} - \text{score(C)}) / \text{temperature}} = e^{(-3 - -2) / 100} = e^{-1 / 100} = 0.99$

**4a**




**4b**

The leaf node with SBE=4 need not be computed. The parent of that leaf is a maximizer and would therefore not select any value less than 8. The root of the tree is a minimizer and would therefore not select any value greater than 7. Since the right subtree has a minimum value of 8

(and no value less than 8 would ever be selected for that subtree), there is no need to compute any more values in that subtree after the 8 is encountered.