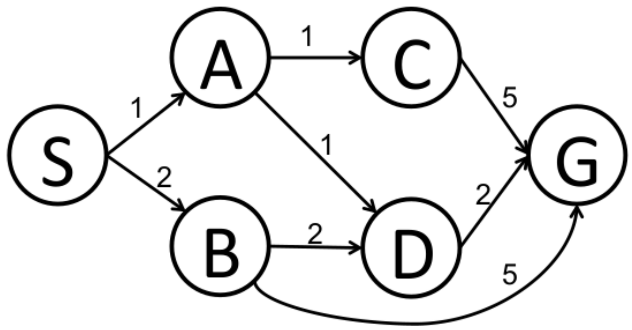
1 Search

Consider the graph below, where S is the start-state and G is the (only) goal-state. Using a priority queue, perform search using the following methods. Not all lines may be needed. Start the search from S.



1. **Breadth First Graph Search.**

Step	Priority Queue	Expand
1	(S,1)	S
2	(S-A,2), (S-B,2)	A
3	(S-A-C,3), (S-A-D,3), (S-B,2)	B
4	(S-A-C,3), (S-A-D,3), (S-B-D,3), (S-B-G,3)	C
5	(S-A-C-G,4), (S-A-D,3), (S-B-D,3), (S-B-G,3)	D
6	(S-A-C-G,4), (S-A-D-G,4), (S-B-D,3), (S-B-G,3)	G
7	(S-B-G,3)	

2. **Depth First Graph Search.**

Step	Priority Queue	Expand
1	(S,1)	S
2	(S-A,2), (S-B,2)	A
3	(S-A-C,3), (S-A-D,3), (S-B,2)	C
4	(S-A-C-G,4), (S-A-D,3), (S-B,2)	G
5	(S-A-C-G,4)	

3. **Uniform Cost Graph Search.**

Step	Priority Queue	Expand
1	(S,0)	S
2	(S-A,1), (S-B,2)	A
3	(S-A-C,2), (S-A-D,2), (S-B,2)	C
4	(S-A-C-G,7), (S-A-D,2), (S-B,2)	D
5	(S-A-C-G,7), (S-A-D-G,4), (S-B,2)	B
6	(S-A-C-G,7), (S-A-D-G,4), (S-B-D,4), (S-B-G,9)	G
7	(S-A-D-G,4)	

4. **A* Search.** Use the heuristic $h(S) = 0$, $h(A) = 2$, $h(B) = 5$, $h(C) = 4$, $h(D) = 2$, and $h(G) = 0$.

Step	**Priority Queue**	**Expand**
1	(S,0)	S
2	(S-A,3), (S-B,7)	A
3	(S-A-C,6), (S-A-D,4), (S-B,7)	D
4	(S-A-C,6), (S-A-D-G,4), (S-B,7)	G
5	(S-A-D-G,4)	

(a) Is this heuristic admissible? Why or why not?

No. $h(B) = 5 > h*(B) = 4$.

(b) Is this heuristic consistent? Why or why not?

No. $h(B) - h(D) = 3 > 2$.

2 Constraint Satisfaction

After years of struggling through mazes, Pacman has finally made peace with the ghosts (Blinky, Pinky, Inky, and Clyde), and invited them to live with him and Ms. Pacman. The move has forced Pacman to change the rooming assignments in his house, which has 6 rooms. He has decided to figure out the new assignments with a CSP in which the variables are Pacman **(P)**, Ms. Pacman **(M)**, Blinky **(B)**, Pinky **(K)**, Inky **(I)**, and Clyde **(C)**, the values are which room they will stay in, from 1-6, and the constraints are:

i) No two agents can stay in the same room

ii) **P** $>$ 3	vi) **B** is even
iii) **K** is less than **P**	vii) **I** is not 1 or 6
iv) **M** is either 5 or 6	viii) $|$**I**-**C**$|$ = 1
v) **P** $>$ **M**	ix) $|$**P**-**B**$|$ = 2

1. (3pts) On the grid below, cross out the values from each domain that are eliminated by enforcing unary constraints.

P				4	5	6
B		2		4		6
C	1	2	3	4	5	6
K	1	2	3	4	5	6
I		2	3	4	5	
M					5	6

2. (7pts) On the grid below, now cross out the values from each domain that are eliminated by running arc consistency. List each arc that leads to a value being eliminated, and specify which arcs are then added back in.

P						6
B				4		
C	1	2	3			
K	1	2	3			
I		2	3			
M					5	

- Remove 4 and 5 from P because of constraint v). Thus P=6.
- Remove 6 from B, C, K and M because of constraint i). Thus M=5.

- Remove 5 from C, K and I because of constraint i).
- Remove 2 from B because of constraint ix). Thus B=4.
- Remove 4 from C, I and K because of constraint i).

3. (2pts) According to the Minimum Remaining Value (MRV) heuristic, which variable should be assigned to first? Explain your answer.

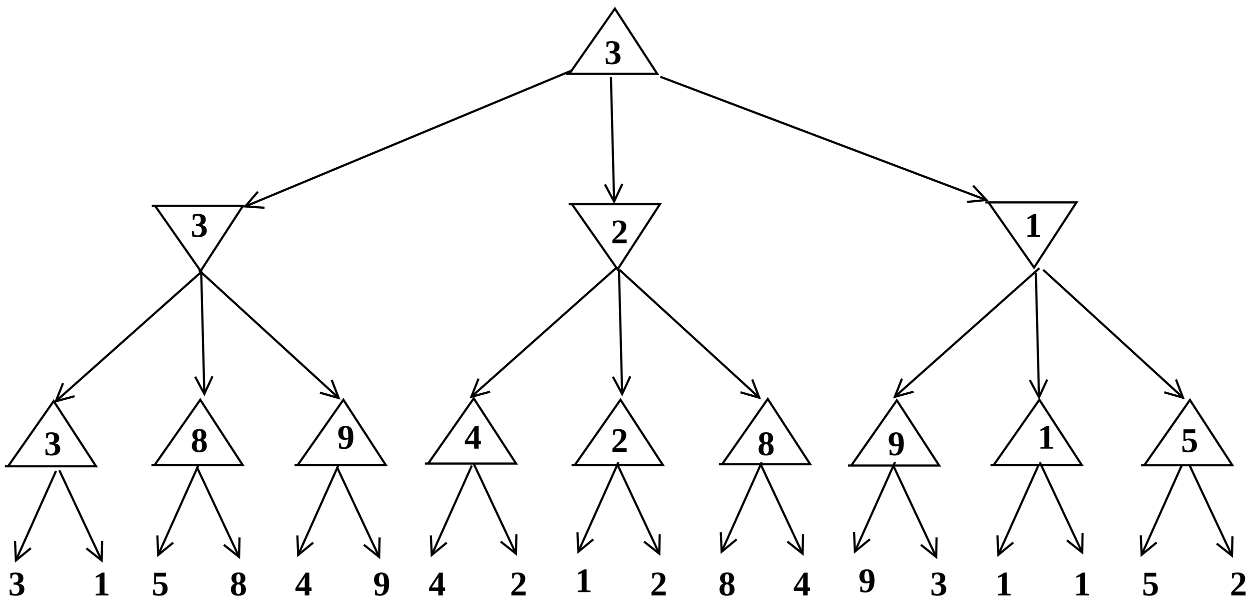
   Answer: I has 2 values left, while C and K have 3. Therefore choose I.

4. (3pts) According to the Least Constraining Value (LCR) heuristic, which value of the variable identified above (MRV) should be chosen first? Explain your answer.

   Answer: According to constraint vii), I=3 leaves only C=2, while I=2 leaves both C=1 and C=3. Therefore choose I=2.

3 Games

Alice and Clarence play a minimax game depicted by the game tree below. Alice takes one move (a max move), Clarence takes the second move (a min move) and Alice takes a third move (another max) and then the game ends. Alice's score is shown in the leaves.



1. Fill in the minimax values at each node in the graph (just write them in the triangles).

2. Circle the nodes that would have been pruned by alpha-beta pruning. Assume nodes are evaluated in a left-to-right order.

   It's okay to ignore the tiny leaves and just prunes triangles. In this case, you should have circled the $8 \to 8$, 4 and $5 \to 5$, 2 nodes at the bottom.

3. Suppose Clarence is a random agent instead of an adversary. However, he does not select uniformly among options. He chooses action one with probability 1/2, action two with probability 1/4 and action three with probability 1/4. What are the new values for the three Clarence nodes and what is the expected game value at the root of the tree?

   From left to right, they are 5:75, 4:5 and 6. The value at the root is 6.

4 Probability

There has been an outbreak of mumps at the U. You feel fine, but you're worried that you might already be infected and therefore won't be healthy enough to take your AI final. You first think about the following two factors:

- You think you have immunity from the mumps ($+i$) due to being vaccinated recently, but the vaccine is not completely effective, so you might not be immune ($-i$).
- Your roommate didn't feel well yesterday, and though you aren't sure yet, you suspect your roommate might have the mumps ($+r$).

Denote these random variables by I and R. Let the random variable M take the value $+m$ if you have the mumps, and $-m$ if you do not. You write down the following probability distributions to describe your chances of being sick:

I	$P(I)$
$+i$	0.8
$-i$	0.2

R	$P(R)$
$+r$	0.4
$-r$	0.6

I	R	M	$P(M\|I,R)$
$+i$	$+r$	$+m$	0
$+i$	$+r$	$-m$	1
$+i$	$-r$	$+m$	0
$+i$	$-r$	$-m$	1
$-i$	$+r$	$+m$	0.7
$-i$	$+r$	$-m$	0.3
$-i$	$-r$	$+m$	0.2
$-i$	$-r$	$-m$	0.8

1. Fill in the following table with the joint distribution $P(I, M, R)$.

I	R	M	$P(I,M,R)$
$+i$	$+r$	$+m$	0
$+i$	$+r$	$-m$	0.32
$+i$	$-r$	$+m$	0
$+i$	$-r$	$-m$	0.48
$-i$	$+r$	$+m$	0.056
$-i$	$+r$	$-m$	0.024
$-i$	$-r$	$+m$	0.024
$-i$	$-r$	$-m$	0.096

2. What is the marginal probability $P(+m)$ that you have the mumps?

$$\begin{aligned} P(+m) &= \sum_{i,r} P(i,r,+m) \\ &= P(+i,+r,+m) + P(+i,-r,+m) + P(-i,+r,+m) + P(-i,-r,+m) \\ &= 0 + 0 + 0.056 + 0.024 = 0.08 \end{aligned}$$

3. Assuming you do have the mumps, you're concerned that your roommate may have the disease as well. What is the probability $P(+r|+m)$ that your roommate has the mumps given that you have the mumps? Note that you still don't know whether or not you have immunity.

$$P(+r|+m) = \frac{P(+r,+m)}{P(+m)} = \frac{\sum_i P(i,+r,+m)}{P(+m)} = \frac{0 + 0.056}{0.080} = \frac{7}{10}$$

4. What is the probability distribution $P(R|-m,-i)$?

$$\begin{aligned} P(R|-m,-i) &= \alpha P(R,-m,-i) \\ &= \alpha \begin{bmatrix} P(+r,-m,-i) \\ P(-r,-m,-i) \end{bmatrix} \\ &= \alpha \begin{bmatrix} 0.024 \\ 0.096 \end{bmatrix} \\ &= \frac{1}{0.120} \begin{bmatrix} 0.024 \\ 0.096 \end{bmatrix} \\ &= \begin{bmatrix} 0.2 \\ 0.8 \end{bmatrix} \end{aligned}$$