CAP 6635 Artificial Intelligence (2023 Spring)

Final (21+2 pts)

8:00PM – 10:30 PM (May 03, Eastern Time)

Solutions must be submitted, through Canvas, by 10:30PM (unless an extension is announced otherwise).

Open book (open notes). By individual efforts. Copy and paste answers from external sources are strictly prohibited (0 grade). [If two homework submissions are found to be similar to each other, both submissions will receive 0 grade]

All solutions must be submitted through Canvas. No email submission is accepted. We can only grade the version submitted to the Canvas (students are responsible to verify that corrections files are submitted to the system).

DO NOT POST QUESTIONS ONLINE!

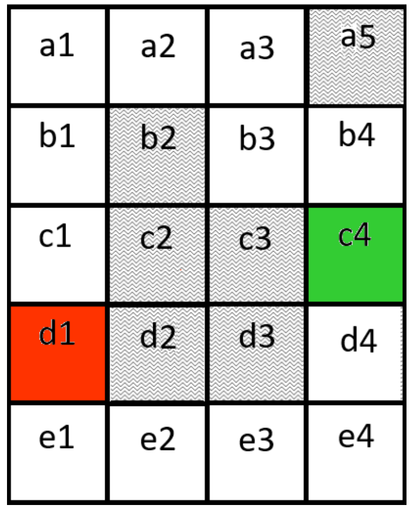

Figure 1

Question 1 [3 pts]: Figure 1 shows a robot navigation field, where the red square (d1) is the robot, and green square (c4) is the goal. The shade squares (such as b2, c2, etc.) are obstacles. The robot is not allowed to move in diagonal line. Nodes are coded using an alphabet letter followed by a digit (such as a1, b1, b2 etc.). When two sibling nodes are inserted into fringe (queue), use deque order to favor node with a lower alphabet and a lower digit. For example, if d1 and e2 are sibling nodes, d1 will be dequeued first (because "d" has a lower alphabetic order than "e"). If a1 and a2 are sibling nodes, a1 will be dequeued first (because "1" has a lower digit than "2"). Node expanded/visited does not need to be revisited.

- Use Best First Search to find path from d1 to c4 (Using Manhattan distance as the heuristic function)
  - Report nodes in the fringe (including their f(N) values) in the orders they are included in the fringe. **[0.5 pt]**
  - Report the order of the nodes being expanded. **[0.5 pt]**
  - Report the final path from d1 to c4. **[0.5 pt]**
- Use A* to find path from d1 to c4 (Using Manhattan distance as the heuristic function).
  - Report nodes in the fringe (including their f(N) values) in the orders they are included in the fringe. **[0.5 pt]**
  - Report the order of the nodes being expanded. **[0.5 pt]**
  - Report the final path from d1 to c4. **[0.5 pt]**

Best First Search

Fringe: f(N)=h(N)	**Node visited/expanded**

A* Search

Fringe: f(N)=h(N)+g(N)	Node visited/expanded

Question 2 [3 pts]: Figure 2 shows a Bayesian network. Assume x ⊥ y denotes that x are independent of y, and x ⊥ y | z denotes that x and y are conditionally independent, given z. Complete Table 1, and use √ to mark correct answers. **[1 pt]**

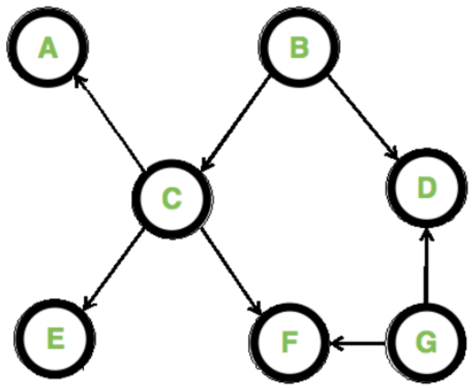

Figure 2

Table 1 (must use √ to mark correct answers)

Relationship	True	False
A⊥B		
A⊥B | C		
A⊥D		
C⊥D |B		
E⊥D | B		
E⊥F | C		
A⊥F | C		
C⊥G		
A⊥E| C		
C⊥D|B		

Question 3 [4 pts]: Table 2 shows joint probability distributions between three random variables A, B, and C, and their observed values (each has binary values 1 or 0).

Table 2

A	B	C	P(A, B, C)
0	0	0	0.2
0	0	1	0.05
0	1	0	0.2
0	1	1	0.05
1	0	0	0.1
1	0	1	0.15
1	1	0	0.1
1	1	1	0.15

(1) Calculate probability value P(A=1, B=1), using only variables shown in Table 2. **[1 pt]**
(2) Calculate probability value P(A=1 | B = 1), using only variables shown in Table 2. **[2 pts]**
(3) Are B and C independent or not? Explain your answer? **[1 pt]**

Question 4 [4 pts]: Figure 3.a shows a 3x4 robot navigation field. The shade squares are obstacles, and the three cells [2,4], [3,2] and [3,3] are terminal states, and the values showing are the reward of the terminal states (each cell is also a state). The reward for each of the rest states (except the obstacles and terminal states) is -0.05. To train a robot to navigate in the field, a stochastic transition model shown in Figure 3.b is used. At any location, say [1,1], if the robot cannot move in a certain direction (e.g., there is wall or obstacle), it will remain in the same position. For example, when the robot is at [1,1], it cannot move to the left because of the wall. The discount γ=0.9, and the initial utility values of each state are 0.

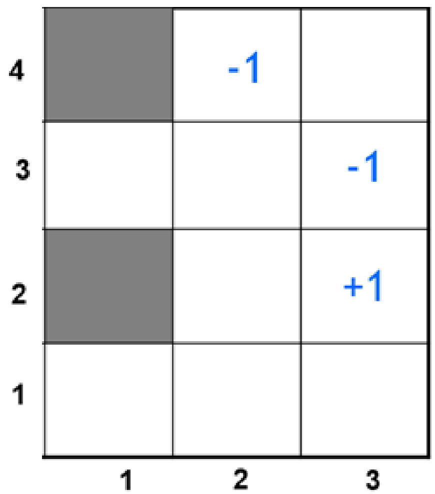

Figure 3.a

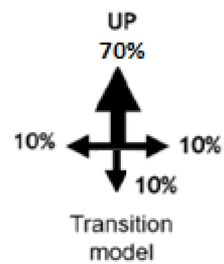

Figure 3.b

(1) Use value iteration algorithm to find utility values for cells [2,2] and [2,3], respectively after the FIRST iteration (exclude terminal states and obstacles). Solutions must show calculations (no need to calculate values for other cells) **[2 pts]**

(2) Why the reward for the non-terminal states (except the obstacles) are set as a small negative value (such as -0.05)? **[1 pt]**

(3) If the reward for each of the rest states (except obstacles and terminal nodes) is -2, how would robot behave during the learning process, comparing to the reward -0.05, and explain why **[1 pt]**

Question 5 [7+2 pts]: A house installed an automatic water-saving sprinkler which monitors weather (r: rain or not) to turn the sprinkler on or off (s: on or off). This forms a Bayesian network shown in Figure 4 with three random variables:
r: 1/0 denoting raining (r=1) or not (r=0).
s: 1/0 denoting sprinkler is on (s=1) or off (s=0).
w: 1/0 denoting lawn is wet (w=1) or dry (w=0).
In the past, the house owner has observed following probability values:

P(r=1)=0.1	The probability of raining is 0.1
P(s=1|r=0)=0.8	The probability of sprinkler is on given there is NO rain is 0.8
P(s=1|r=1)=0.3	The probability of sprinkler is on given there is raining is 0.3
P(w=1|r=1,s=1)=0.9	The probability of lawn being wet given rain and sprinkler is on
P(w=1|r=1,s=0)=0.8	The probability of lawn being wet given rain and sprinkler is off
P(w=1|r=0,s=1)=0.6	The probability of lawn being wet given No rain and sprinkler is on
P(w=1|r=0,s=0)=0.1	The probability of lawn being wet given No rain and sprinkler is off

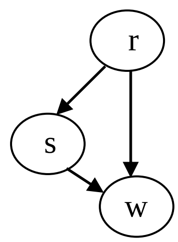

Figure 4: A Bayesian network with three random variables

Based on the above descriptions, please answer following questions (show your solutions/calculations)

1. Write formula calculating joint probability value of the network P(r,s,w) [1 pt] (just write the formula, no need to show calculation)
2. Calculate joint probability of raining and the sprinkler is on: P(r=1, s=1) [2 pts]
3. Calculate joint probability of raining and the lawn is wet: P(r=1, w=1) [2 pts]
4. Calculate joint probability of No rain and the lawn is wet: P(r=0, w=1) [2 pts]
5. Calculate probability of raining, given the lawn is wet: P(r=1| w=1) [Extra credit: 2 pts]