Name:
Student ID:

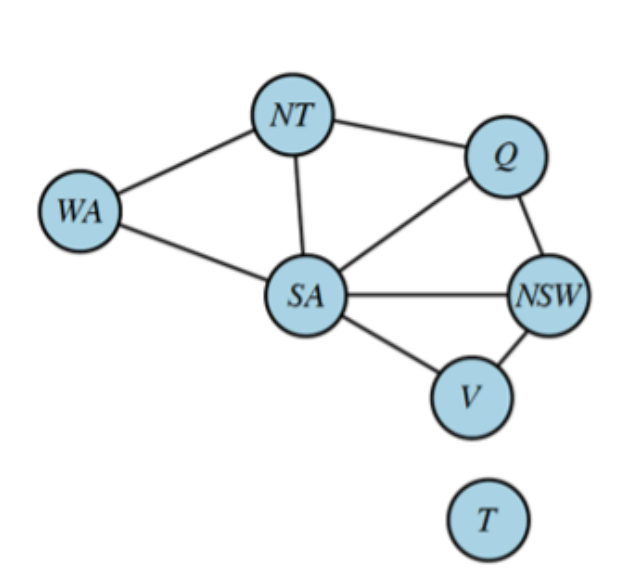
CS3263 Mid-Term Exam S2AY2324 Solutions

Instructions:
Answer all the questions in the answer areas provided.

Question #: 1

[1 mark]

In the task of coloring the map of Australia with three distinct colors {Red, Blue, Green} to ensure adjacent states have different colors, assigning NT=Red and NSW=Red is a consistent choice.



Answer:

✓A. True
B. False

Question #: 2

[1 mark]

At temperature T =0, simulated annealing behaves exactly like (greedy or steepest ascent) hill-climbing search.

Answer:

A. True
✓B. False

Note: The following reasons are acceptable for the answer:

In general, at T = 0, simulated annealing behaves like a “first choice” hill climbing – it will still choose uphill (or downhill) but suboptimal moves, as the successors are randomly generated in SA.

For the SA implementation provided in Lecture Notes (RN Figure 4.4), T = 0 is a terminating condition, at which the Boltzman distribution is undefined.

Question #: 3

[1 mark]

For any two integers M <N, conducting a Monte Carlo Tree Search with N rollouts consistently yields better results (i.e., more optimal decisions) compared to M rollouts.

Answer:

A. True
✓B. False

Note: As the number of rollouts → ∞, MCTS would yield the optimal decision (or best move). For finite numbers of rollouts, however, due to the stochastic (probabilistic) nature of the roll outs, MCTS may not always yield a better result for a larger number of rollouts.

Question #: 4

[1 mark]

Passing the clarity test in decision analysis refers to the confirmation that all the relevant factors in the decision situation are captured in the appropriate components of a decision model.

Answer:

A. True
✓B. False

Question #: 5

[10 marks]

Consider the following propositions, each representing a unique event or condition within a magical garden:

A: Apple tree blooms.
B: Butterfly visits.
C: Caterpillar emerges.
D: Dew falls.
E: Elf sings.
F: Flowers open.
G: Garden glows.
H: Honey is made.

The Knowledge Base (KB) includes the following facts and rules:

1. If a Butterfly visits and a Caterpillar emerges, then an Apple tree blooms.
2. If an Elf sings and Flowers open, then an Apple tree blooms.
3. If Dew falls, then a Butterfly visits.
4. If Flowers open and Honey is made, then a Butterfly visits.
5. If an Elf sings, then a Caterpillar emerges.
6. If Honey is made, then Dew falls.
7. If the Garden glows, then Flowers open.
8. If a Caterpillar emerges, then the Garden glows.
9. Fact: An Elf sings (Observed)

a) Is the proposition: “Apple trees bloom” entailed by the knowledge base?
Answer: Yes or No __1__

b) If the answer in Part a) is YES, what is the sequence of the rules (separated by commas, e.g., 1, 2, 3, 4, ...,) checked or fired using backward chaining, starting with rule 2, to determine “Apple trees bloom” is entailed by the knowledge base. You can assume the facts are checked (and asserted) in the same way as the rules. If the answer in Part a) is NO, write NIL in the answer.
Answer: __2__

c) If the answer in Part a) is YES, what is the sequence of the rules (separated by commas, e.g., 1, 2, 3, 4, ...,) checked or fired using forward chaining to determine “Apple trees bloom” is entailed by the knowledge base. You can assume the facts are checked (and asserted) in the same way as the rules. If the answer in Part a) is NO, write NIL in the answer.
Answer:__3__

d) Which of the following are models of the knowledge base (choose all that apply)?

i. A possible world or model where {A, C, E, F, G} are TRUE and {B, D, H} are FALSE.
ii. A possible world or model where {A} is FALSE and {B, C, D, E, F, G, H} are TRUE
iii. A possible world where {A, B, C, D, E, F, G, H} are TRUE
iv. A possible world where {A, B, C, D, E, F, G, H} are FALSE

Answer: __4__

e) Is the proposition "Butterfly visits" entailed by the knowledge base?
Answer: Yes or No __5__

Answers:

1. Choice of: Yes | No - Correct Answer:Yes
2. Choice of: 2, 5, 4, 6, 3, 1 | 2, 9, 7, 8, 5, 2 | 2, 9, 5, 8, 7, 2 | NIL - Correct Answer:2, 9, 7, 8, 5, 2
3. Choice of: 9, 2, 7, 8, 5, 2 | 9, 5, 8, 7, 2 | 2, 9, 4, 6, 3, 5, 1 | NIL - Correct Answer:9, 5, 8, 7, 2
4. Choice of: Only i | Only ii | i and ii | i and iii | ii and iv - Correct Answer:i and iii
5. Choice of: YES | NO - Correct Answer:NO

Question #: 6

[10 marks]

a) Consider a constraint satisfaction problem (CSP) with variables X, Y with domains {1, 2, 3, 4, 5, 6} for X and {1, 3, 7 } for Y , and constraints X <Y and X +Y >9. List the values that will remain in the domain of X and the domain of Y after enforcing arc consistency for the arc X → Y

Answer: Resulting domain for X : {__1__}; resulting domain for Y: {__2__}

b) Consider a CSP with three variables: X, Y, and Z. Each of the three variables can take on one of two values: either 1 or 2. There are three constraints on the variable assignments:

- $X \neq Y$
- $Y \neq Z$
- $X \neq Z$

Which value(s) for each variable would be eliminated by enforcing arc-consistency? Write "NIL" if no value is removed for a variable.
Answer: Values eliminated for A: {__3__}, B: {__4__}, C: {__5__}

c) Consider a CSP with three variables: X, Y, and Z. Each of the three variables can take on one of two values: either 1 or 2. There are four constraints on the variable assignments, where each constraint indicates two values that a pair of variables CANNOT take on simultaneously, that is , if one variable is assigned its specified value the second variable CANNOT be assigned its specified value and vice-versa:

- $(X, Y) != (1, 2)$ (read: if $X = 1$ then $Y \neq 2$ AND if $Y = 2$, then $X \neq 1$)
- $(X, Z) != (1, 1)$
- $(Y, Z) != (1, 2)$
- $(Y, Z) != (2, 2)$

Assume an alphabetic variable order (X before Y before Z) and numeric value order (1 before 2).
i) What is the first satisfying assignment found for the CSP?
Answer: X = __6__, Y = __7__, Z = __8__

ii) What is the order of assignments made using backtracking search with chronological order? Answer in the following format: e.g., X =1, Y =1, Z =1, ..., etc.
Answer: __9__

iii) What is the order of assignments made using backtracking search AND forward checking? Answer in the following format: e.g., X =1, Y =1, Z =1, ..., etc.
Answer: __10__

Answers:

1. 3, 4, 5, 6
2. 1, 3, 7
3. NIL
4. NIL
5. NIL
6. Choice of: 1 | 2 - Correct Answer:2
7. Choice of: 1 | 2 - Correct Answer:1
8. Choice of: 1 | 2 - Correct Answer:1
9. Note: Acceptable solutions:

   In general, the following variable-value assignment pairs are checked in chronological backtracking:
   X = 1, Y = 1, Z = 1, Z= 2, Y = 2, Z = 1, Z= 2, X = 2, Y = 1, Z = 1

   For the Backtrack-Search algorithm provided in Lecture Notes (RN Figure 6.5), some of the variable-value pairs that violate the constraints are not explicitly recorded as “assignments” in the implementation:
   X = 1, Y = 1, X = 2, Y = 1, Z = 1

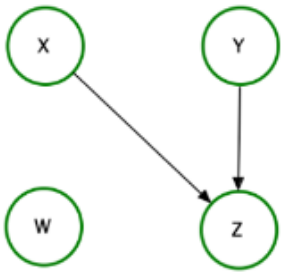
10. X = 1, Y = 1, X = 2, Y = 1, Z = 1

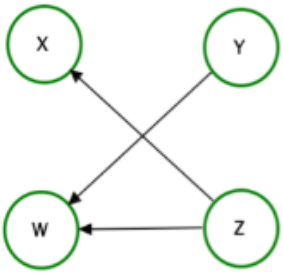
Question #: 7

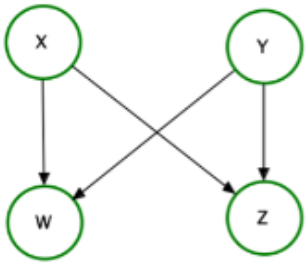
[10 marks]
a) Which of the following expressions is/are true for any distribution over four random variables X,Y, Z, and W? (Choose all that apply)
I. P(X, Y |Z, W) = P(X|Z, W)P(Y|X, Z,W)
II. P(X, Y|Z, W) =P(X, Y)P(Z, W)P(Z, W|X, Y).
III. If P(X, Y | Z) =P(X | Z)P(Y | Z) then X is independent of Y given Z
IV. If P(X, Y, Z) =P(X)P(Z)P(Y) then X is independent of Y given Z.

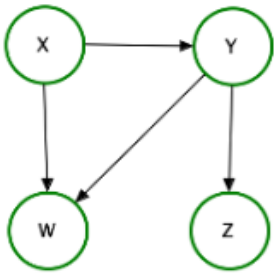
Answer: 1

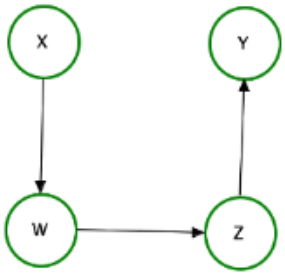
For the following Bayesian networks that involve variables W, X, Y, Z, match the network structure such that: The resulting structure is able to represent the specified distribution or all distributions that satisfy the stated independence and non- independence constraints (on the network structure). If no such Bayesian network is possible, answer "NIL".

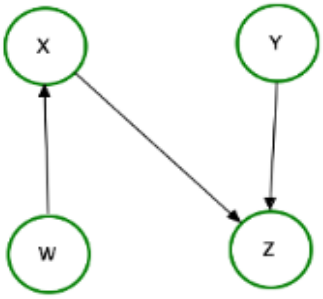
BN_1: 

BN_2: 

BN_3: 

BN_4: 

BN_5: 

BN_6: 

b) Constraints:

- $X \perp Y$
- $Y \perp Z$
- $X \perp W \mid \{Z\}$
- $not\ [X \perp Y] \mid \{W\}$ (read: X is not conditionally independent of Y given {W})

Answer: 2

c) Constraints:

- $X \perp W \mid \{Y\}$
- $Z \perp W \mid \{Y\}$

Answer: 3

d) Constraints:

- $X \perp Y$
- $Z \perp W \mid \{X, Y\}$
- $not\ [\ Z \perp W\ ] \mid \{X\}$
- $not\ [\ Z \perp W\ ] \mid \{Y\}$

Answer: 4

e) Distribution:

$$P(X)P(W|X) = P(W)P(X|Y)$$

Answer: 5

Answers:

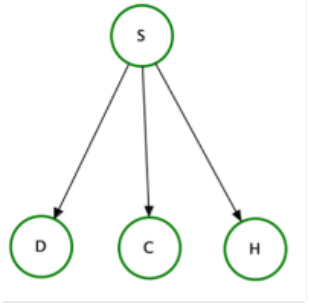
1. Correct Answer: I and III
2. Correct Answer: BN_2
3. Correct Answer: BN_1
4. Correct Answer: BN_3
5. Correct Answer: BN_1

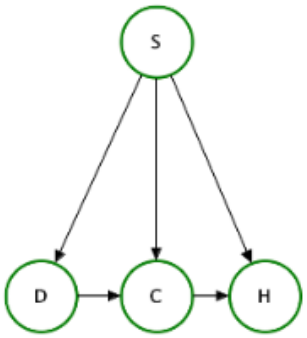
Question #: 8

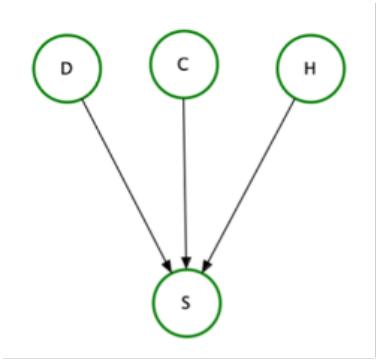
[10 marks]

Persy the Mars rover is trying to determine what counts as a successful outing of sample collecting (S) on Mars. There are many factors that may affect the sample collecting. Despite the challenges, an outing can sometimes be considered successful even when no samples are collected (e.g., Persy may encounter new terrains or new artifacts on the outing). To model this situation, Persy decides to create a naive Bayes model with S as the Boolean class variable and three features: whether there was a dust storm (D), how many samples were collected (C) with values {none, few, many}, and whether there was a high temperature on the surface (H).

a) Which of the following diagrams denotes the naïve Bayes model of the situation?

A. 

B. 

C. 

Answer: Diagram __1__

b) What is a correct symbolic expression for the following probabilities based on the naïve Bayes network shown above:

I. $P(D,C,H|S) = P(D|S)P(C|S)P(H|S)$

II. $P(D) = \sum_{c,h} P(D|c,h)P(c,h)$

III. $P(S|\ D,\ C,\ H) = P(S|D)P(S|C)P(S|H)$

IV. $P(S) = \sum_{d}[P(S \mid d)P(d)]\sum_{c}[P(S \mid c)P(c)]\sum_{h}[P(S \mid h)P(h)]$

Answer: __2__

The following probabilities for Persy's sample collecting mission are estimated as follows:

$P(S = false) = 0.9$
$P(H = true \mid S = false) = 0.5, P(H = true \mid S = true) = 0.2$
$P(D = True \mid S = false) = 0.4, P(D = true \mid S = true) = 0.1$
$P(C = many \mid S = true) = 0.3, P(C = few \mid S = true) = 0.4, P(C = many \mid S = false) = 0.1, P(C = few \mid S = false) = 0.2$

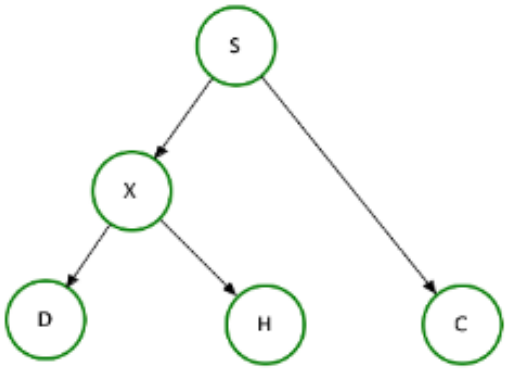
c) What is the probability of the sample collecting being successful, given that there was a dust storm, no sample was collected, and the surface temperature was high?

Answer: __3__

d) What is the probability of the sample collecting being successful, given that there was no dust storm, many sample were collected, and the surface temperature was not high?

Answer: __4__

e) The naïve Bayes model impose strong conditional independence assumptions among the variables. Assume that we now know that there is a true distribution for the Sample Collecting situation on Mars, taking into consideration a latent or unknown variable X. The true distribution is depicted in the Bayesian network below. Determine whether the naïve Bayes model as defined in part (a) is guaranteed to be able to represent the true conditional probability P(S | D, C, H) as defined in the true distribution.



Answer: Yes or No __5__

Answers:

1. Correct Answer: A.
2. Correct Answer: I
3. ~0.005
4. ~0.444
5. Correct Answer: No

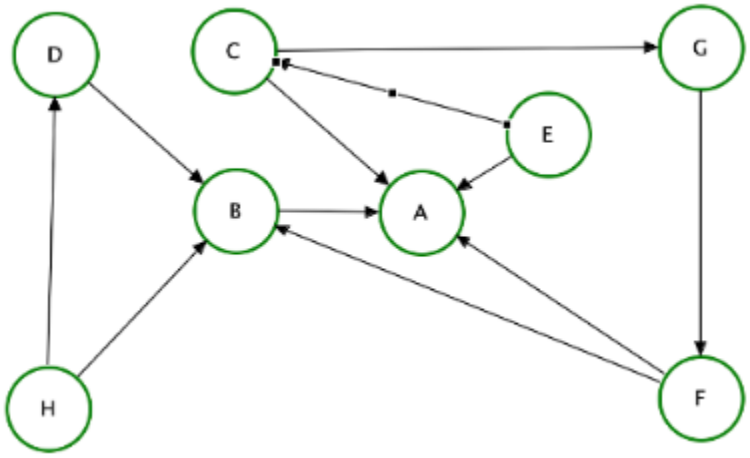
Question #: 9

[6 marks]

Consider the following causal Bayesian network that represent a Magical Garden scenario, with the following binary variables:
A: Apple tree blooms.
B: Butterfly visits.
C: Caterpillar emerges.
D: Dew falls.
E: Elf sings.
F: Flowers open.
G: Garden glows.
H: Honey is made.

that correspond to the following propositions:

1. If a Butterfly visits and a Caterpillar emerges, then an Apple tree blooms.
2. If an Elf sings and Flowers open, then an Apple tree blooms.
3. If Dew falls, then a Butterfly visits.
4. If Flowers open and Honey is made, then a Butterfly visits.
5. If an Elf sings, then a Caterpillar emerges.
6. If Honey is made, then Dew falls.
7. If the Garden glows, then Flowers open.
8. If a Caterpillar emerges, then the Garden glows.



a) What is the Markov Blanket of “Butterfly visits”? Answer in terms of the variable symbols in alphabetical order; put in NIL if there is no applicable variable:

Answer: {__1__}

b) The following minimum set of variables satisfies the backdoor criterion from of Butterfly visits to Apple tree blooms; put in NIL if there is no applicable variable:

Answer: {__2__}

c) Our belief that Apple tree blooms is different if we hear an “Elf sings” from that if we actually make (command) an “Elf sings”.

Answer: True or False __3__

d) The following minimum set of variables satisfies the backdoor criterion from Elf sings to Apple tree blooms; put in NIL if there is no applicable variable:

Answer: {__4__}

e) The following set of variables does NOT satisfy the backdoor criterion from Apple Tree blooms to Garden glows:

Answer: __5__

f) We do not have to worry about how Apple Tree blooms would affect Garden glows, if we observe whether Caterpillar emerges and Flower opens.

Answer: True or False __6__

Answers:

1. A, C, D, E, F, H
2. F
3. Correct Answer: False
4. NIL
5. Correct Answer: {B, E, F}
6. Correct Answer: True