CS601 Introduction to AI

Assignment-1

Note: Your solution for this assignment should have two parts---a pdf document and code files.

- Have a **single** pdf document that shows your solution for different questions (show either numerical values if the question asks for it, and/or theoretical justification as required). Include in this pdf, the code you wrote for the solution for the respective question (if coding is required).
- Upload your real code files that you used to solve the particular question. Make sure your code is neatly organized per question, runs correctly, and has comments that highlight the part you implemented.
- Combine your solution pdf and code files in a single zip folder and upload it on the eLearn assignment folder
- Solution should be typeset using a professional software (word, keynote, latex etc). Figures should also be made using software such as power point. **No handwritten solutions are allowed and will not be graded.**

Question-1 [10 points]

You are given the information like this:

There are three bus services (131, 166, 146) outside the SCIS building that Marry travels between SMU and her home. The bus service 131 operates more frequently than 166, and the bus service 166 is more frequent than 146. The frequency ratio among the three buses is 5:3:2.

The bus service 131 is a single deck bus in 9 out of the 10 trips during the daytime, and it is always a single deck bus during the evening time. The bus service 166 rarely uses a single deck bus and the single deck bus only operates in 1 out of the 5 trips during the evening time. The bus service 146 uses the equal number of single and double deck buses during the daytime and evening time. In other words, it always alternates between single and double deck buses during operation.

There are four bus companies managing these three bus services: SGS Transit (or SGS), SMT Bus (or SMT), Tower Tinggi (or TT), Cepatlah Bus (or CB). The bus service 131 is operated by SGS and SMT, where SGS bus operates in 2 out of 5 trips. The bus service 166 is operated by all the four companies, where SMT bus operates in 40% of the trips, and the remaining trips are equally shared by other three companies. The bus service 146 is operated by both TT and CB, where TT only uses single deck bus and CB only uses double deck bus.

The daytime regime is between 6am to 6pm (12 hours), and the evening time regime is between 6pm to 12am (6 hours).

Answer the followings:

(a) Draw a Bayesian Network to capture the information and derive probability tables for all the variables in the network. State clearly which conditional independences hold when designing the network.

(b) It is evening. Mary waits for a bus to return home. What is the probability that it is a single deck SMT bus?

(c) It is daytime. A single deck bus arrives at the stop. What is the probability that the bus is operated by SMT?

(d) The bus service 166 arrives. Mary wants to take the bus returning home. What is the probability that it is a double deck bus?

PS: You can either (i) write a python program **(copy and paste the code snippets in your solution pdf for easy reference)** and show the answers, or (ii) simply calculate the answers. In either case, show your program or steps clearly.

Question-2 [10 points]

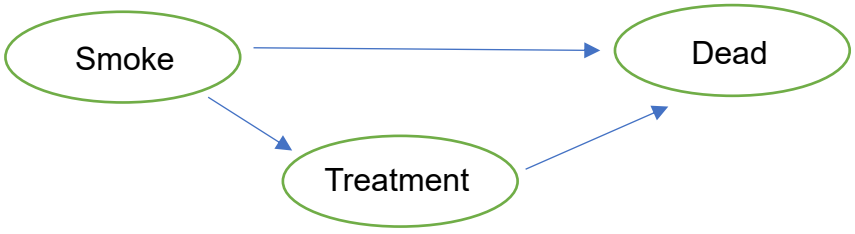
You are given the hospital records (see the sample data file) with three columns or variables ("smoke", "treatment", "dead") taking the binary values. The value of 0 indicates absence (e.g., no smoking habit; not under treatment; alive) and the value of 1 indicates presence (e.g., smoke; under treatment; die). Write a python program **(copy and paste the code snippets in your solution pdf for easy reference)** and compute the "treatment effect" (TE) from the sample data file that contains the records of one million persons. TE is defined as:

TE = Probability of being alive for the treated population – Probability of being alive for the untreated population.

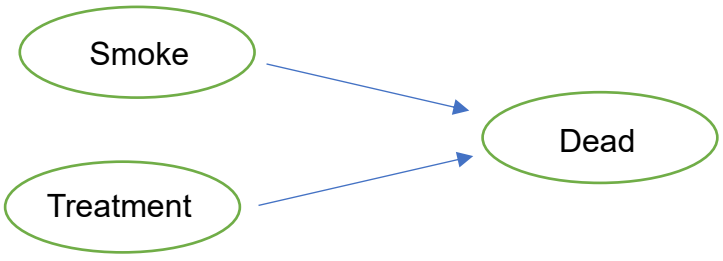
In other words, the population is first divided into two groups ("treatment" = 1 and "treatment" = 0). Then, TE is calculated as the difference in probabilities of being alive between the treated and untreated population.

(a) Calculate TE based on the chain rule by using the random variables "treatment" and "dead" only. Justify on whether the TE value makes sense.

(b) Bob is a data scientist, and he uses the data-driven approach to derive the Bayesian Network below to specify the relationship between the three random variables. Calculate TE based on Bob's Bayesian Network.



(c) Alan is a hospital doctor. He uses his "medical sense" to suggest the Bayesian Network below. Calculate TE based on Alan's Bayesian Network.



(d) What is the fundamental difference between Bob and Alan's Bayesian Networks in terms of conditional independence? Comment on whether Bob or Alan's Bayesian Network is more accurate in calculating treatment effect.

Question-3 [10 marks]

Let's experiment the 8-puzzle problem using the following heuristic:

- **X-distance**: count the number of titles out of row, then the count number of tiles out of column. Add these two values together.

(a) You are given the following pairs of initial and goal states. Run your programs **(copy and paste the code snippets in your solution pdf for easy reference)** with three different heuristics (X-distance, Hamming distance, Manhattan distance) and **show how many times are required to reopen a node in the explored list** (i.e., the last step of A* algorithm in page 34 of PPT) for reaching the goal state from the initial state for each of the heuristics.
PS: The eight puzzle programs for Hamming and Manhattan distances are given.

8	7	1
6		2
5	4	3

Initial State

Goal state

1	2	3
4	5	6
7	8	

Case-1

X-distance = 6+7

7	2	4
5		6
8	3	1

Goal state

	1	2
3	4	5
6	7	8

Case-2

X-distance = 5+8

Initial State

7	2	4
5		6
8	3	1

Initial State

Goal state

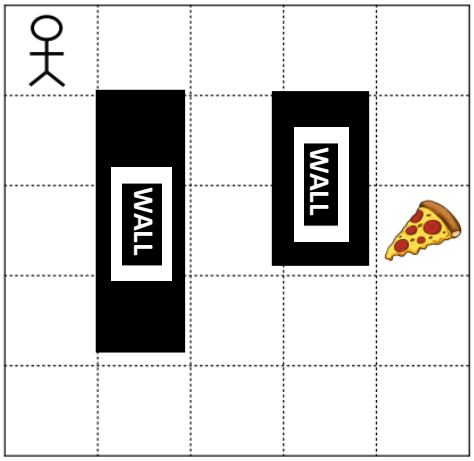
1	6	7
2	5	8
3	4	

Case-3

X-distance = 5+8

(b) Compare the X-distance with the Hamming and Manhattan distances learnt in the lecture. Which heuristic is better? Explain your answer.

Question-4 [10 marks]



The agent moves in the grid world one step at a time. There are four actions of movement: *East*, *West*, *South*, *North*. If reaching a grid with the pizza, the agent wins a reward of **+1**. Otherwise, a reward of **-1** is obtained. During movement, if hitting the wall or the border of the grid world, the agent remains in the original grid.

Using the following notations for answering:
S: current state, **A**: action; **S'**: next state; **R**: reward
***V*(S)**: state value for S; **Q(S, A)**: action value for S
***P*(S, A, S')**: transition probability from S to S' by taking action A

(a) If an agent always starts movement from the top left corner and the game finishes when the agent eats pizza, how many states are there in the grid world?

(b) If the environment is *not dynamic* (i.e., the agent will reach the desired grid after taking an action to move), write an **action value function** to express the Markov Decision Problem.

(c) Assume the environment is *dynamic* as following: The probability of reaching the desired grid after taking an action is 0.9. There is a probability of 0.05 reaching the grid on the left or right of the current grid (in the direction of movement), respectively.

Apply **Value Iteration algorithm** and fill in the state values in the *appropriate entries* of the tables below. Assume that discount factor = 1.

Before the start of value iteration:
***Assuming all states are initialized to 0**

0		**0**		**0**
0		**0**		**0**
0		**0**		**0**
0		**0**		**0**
0		**0**		**0**

After 1st iteration of value iteration:

-1		**-1**		
-1		**-1**		
-1		**-1**		
-1		**-1**		
-1		**-1**		

After 2nd iteration of value iteration:

(d) Assume the agent can start from any grid. At any time, there will only be one pizza in the grid world. When the pizza is eaten and disappeared, the next pizza will appear in another grid. The goal of the agent is to eat as many pizzas as possible with the minimum number of movements. How many states are there in the grid world? Explain your answer.

(e) Based on Question (d), assuming an agent *can jump to any grid* (i.e., no need to move in stepwise manner) to eat pizza. The environment is *dynamic* (i.e., an agent may be landed in a grid different from the desired grid to jump to). The goal is to eat as many pizzas as possible with minimum number of jumps. However, the grid having the pizza is hidden from the agent. In other words, the agent needs to first jump to a grid before knowing whether the pizza is on the grid.

Can Bellman Equation still be applied to solve this Markov Decision Process problem? Explain your answer briefly. If your answer is yes, how many entries should there be for the action value table, Q(S,A)?