FINAL EXAMINATION

Course: CS420 – Artificial Intelligence	
Time: 100 minutes	Term: I – Academic year: 2020-2021
Lecturer(s): Nguyễn Ngọc Thảo	
Student name:	Student ID:

(Notes: Neither books nor laptops, phones allowed)

There are NINE questions in total.

These are arranged into THREE sections in SEVEN pages (excluding this page)

Scores (for grader only)

Q1.		Q6.	
Q2.		Q7.	
Q3.		Q8.	
Q4.		Q9.	
Q5.			

Important notes for students

- For TRUE/FALSE questions, an answer without explanation gets zero point.
- For questions that ask you to check all possible choices, a wrong choice gives you minus points; however, the total points must not be smaller than zero.

PART I – PROBLEM SOLVING BY SEARCH (2.5pt)

Question 1. (0.5pt) *Heuristic admissibility and consistency*. For each of the following statements, identify whether it is TRUE or FALSE. Justify your answer in 1-2 sentences.

a) If two search heuristics, $h_1(s)$ and $h_2(s)$, have the same average value, the heuristic $h_3(s) = \max(h_1(s), h_2(s))$ could help A* achieve better efficiency than h_1 or h_2 does. (0.25pt)

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b) If $h_1(s)$ is a consistent heuristic and $h_2(s)$ is an admissible heuristic, then $\min(h_1(s), h_2(s))$ must be consistent. (0.25pt)

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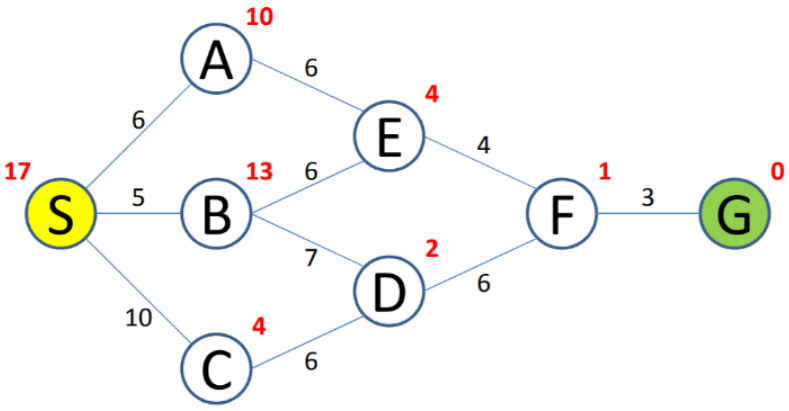
Question 2. (1pt) *A* algorithm*.

a) Consider the graph shown aside. Numbers on the edges are path costs, while those next to the states are heuristic values. Find the shortest path from S to G by A*. Ties are broken in alphabetical order. (0.5pt)



List of expanded states in the exact order: .....

Path returned: .....

b) A* graph search returns an optimal path when a consistent heuristic is used. How do you modify the algorithm so that A* graph search still preserves its optimality even with an admissible, yet inconsistent, heuristic? (0.5pt)

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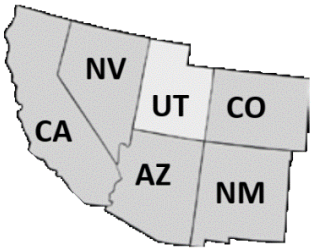
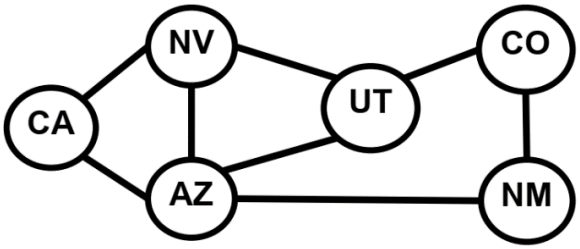
Question 3. (1pt) *Constraint Satisfaction Problem.* You are a map-coloring robot assigned to color this Southwest USA map. Adjacent regions must be colored a different color (R=Red, B=Blue, G=Green). The constraint graph is shown below.





Note that the following questions are mutually independent.

a) Cross out all values that would be eliminated by *Forward Checking*, after variable **AZ** has just been assigned value R as shown. (0.25pt)

CA	NV	AZ	UT	CO	NM
R G B	R G B	**R**	R G B	R G B	R G B

b) **CA** and **AZ** have been assigned values, but no constraint propagation has been done. Cross out all values that would be eliminated by *Arc Consistency AC-3*. (0.25pt)

CA	NV	AZ	UT	CO	NM
B	R G B	**R**	R G B	R G B	R G B

c) Consider the assignment below, where. **NV** is assigned and constraint propagation has been done. Circle all unassigned variables that might be selected by the *Minimum-Remaining-Values (MRV) Heuristic*. (0.25pt)

CA	NV	AZ	UT	CO	NM
R B	**G**	R B	R B	R G B	R G B

d) Consider the assignment below. **NV** is assigned and constraint propagation has been done. Circle all unassigned variables that might be selected by the *Degree Heuristic*. (0.25pt)

CA	NV	AZ	UT	CO	NM
R B	**G**	R B	R B	R G B	R G B

Part II – KNOWLEDGE REPRESENTATION (4.5pts)

Question 4. (1.5pts) Consider a universe where the objects are people and the following predicates.

- sat(X) --- X is satisfied with life
- doc(X) --- X is a doctor
- psy(X) --- X is a psychiatrist
- child(X, Y) --- X is a child of Y
- Bob --- an individual person (constant)

a) Express the following statements in FOL using the given predicates and objects. (0.5pt)

No.	English sentences	FOL clauses
1	A person is satisfied with life if all his/her children are doctors.	
2	All of Bob's children are psychiatrists	
3	Psychiatrists are doctors.	
4	Bob is satisfied with life.	

b) Convert your expressions to a set of clauses in CNF. (0.5pt)

c) From a KB that includes the first three sentences in a), Prove via **resolution** that "*Bob is satisfied with life"*. Show all the resolutions and the substitutions. (0.5pt)

Question 5. (1.5pts) The Horned and Magical Unicorn. If the unicorn is mythical, then it is immortal. If it is not mythical, then it is a mortal mammal. If the unicorn is either immortal or a mammal, then it is horned. The unicorn is magical if it is horned.

a) Represent the given text in Propositional Logic, using the following propositional variables only. It is worth nothing that "immortal" = "not mortal". (0.5pt)

Y = unicorn is mYthical R = unicorn is moRtal M = unicorn is a maMmal

H = unicorn is Horned G = unicorn is magical

1)

2)

3)

4)

5) (Original conclusion)

b) Convert the propositional statements above into CNF. (0.5pt)

c) Prove via **resolution** that "*The unicorn is both horned and magical*.". You do not have to enumerate all new clauses. For each new clause, state the pair of clauses being resolved. (0.5pt)

Question 6. (1.5pts) As part of a comprehensive study of the role of the course CS420 on students' happiness, we have been collecting important data from graduating students. In an entirely optional survey that all students are required to complete, we ask the following highly objective questions:

- Do you party frequently [Party: Yes/No]?
- Are you wicked smart [Smart: Yes/No]?
- Are you creative [Creative: Yes/No]? (Please only answer Yes or No)
- Did you do well on all your homework assignments? [HW: Yes/No]
- Do you use a Mac? [Mac: Yes/No]
- Did your CS420 project succeed? [Project: Yes/No]
- Did you succeed in your most important class (which is CS420)? [Success: Yes/No]
- Are you currently Happy? [Happy: Yes/No]

After consulting a psychologist, we obtained the following complete set of conditional relationships:

- HW depends only on Party and Smart
- Mac depends only on Smart and Creative
- Project depends only on Smart and Creative
- Success depends only on HW and Project
- Happy depends only on Party, Mac, and Success

a) Draw the Bayesian network for the given problem. (0.5pt)

b) Write down the expression for the joint probability distribution as a product of conditional probabilities in the Bayesian network. (0.25pt)

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c) How many independent parameters are required for each conditional probability table? (0.5pt)

CPT	**Number of independent parameters**

d) Assume there were no conditional independence between the variables, how many independent parameters would be required then? Explain your answer. (0.25pt)

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Question 7. (bonus 0.5pt for Part II only) Translate the below English sentences to FOL sentences.

a) There are at least two apples. .....

b) There is at most one apple. .....

Part III – MACHINE LEARNING (3pts)

Question 8. (1.5pts) Last year, five randomly selected students took a math aptitude test before they began their statistics course. In the table below, the $\mathbf{x_i}$ column shows scores on the aptitude test, while the $\mathbf{y_i}$ column shows statistics grades. The last two columns show deviations scores on each test. The last two rows show sums and mean scores that will be used for the regression analysis.

Student	x_i	y_i	$(x_i - \bar{x})$	$(y_i - \bar{y})$
1	95	85	17	8
2	85	95	7	18
3	80	70	2	-7
4	70	65	-8	-12
5	60	70	-18	-7
Sum	390	385		
Mean	78	77		

For each of the following questions, you should give an arithmetic expression in terms of numbers and then a numerical answer.

a) Fit a simple linear regression model to the given data and present the best fitting line. (0.5pt)

b) What is the estimate of the error variance? (0.5pt)

c) If a student made a 20 on the aptitude test, what grade would we expect her to make in statistics? (0.25pt)

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d) Justify whether we should use the obtained model to make the above prediction. (0.25pt)

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Question 9. (1.5pts) NASA wants to be able to discriminate between Martians (M) and Humans (H) based on the following characteristics: Green ∈ {N, Y}, Legs ∈ {2, 3}, Height ∈ {S, T}, Smelly ∈ {N, Y}. Our available training data is as follows.

No.	Species	Green	Legs	Height	Smelly
1	M	N	3	S	Y
2	M	Y	2	T	N
3	M	Y	3	T	N
4	M	N	2	S	Y
5	M	Y	3	T	N
6	H	N	2	T	Y
7	H	N	2	S	N
8	H	N	2	T	N
9	H	Y	2	S	N
10	H	N	2	T	Y

a) Build a classification model from the given training data using **the ID3 algorithm**. Present all calculations and draw the final decision tree. (1pt)

	Draw your final tree here

b) Is the above tree optimal (i.e., does it get zero training error with minimal depth)? If it is optimal, simply write YES. Otherwise, draw the optimal tree as well. (0.5pt)

THE END