THE UNIVERSITY OF HONG KONG

FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE

Final Examination

COMP3270 Artificial Intelligence

23 December 2019, 9:30 am - 11:30 am

This is an open book examination. All answers must be your own.
Write your university number on the first page.

Only approved calculators as announced by the Examinations Secretary can be used in this examination. It is candidates' responsibility to ensure their calculator operates satisfactorily, and candidates must record the brand and model of the calculator after the University Number in their answer script.

Answer ALL questions.
Write your answer into a single Microsoft Word file.
You may, if necessary, insert scanned handwritten answers into your Word file.
Submit your Word file (or PDF) to OLEX before the deadline.

Question	Max. Mark	Your Mark (examiner use only)
1	9	
2	4	
3	10	
4	8	
5	9	
6	10	
Total	50	

1: Search (Blind + Informed)

You are trying to recover a password to an encrypted file, by using search. You know that the password is up to nine letters long and contains only the letters A, B, C, and D. You formulate the search problem as follows.

- The initial state is the empty string.
- The successor function is to append one letter (A, B, C, or D) to the string. Assume that successors are added to the frontier in alphabetical order. States representing passwords with 9 letters do not have any successors.
- The goal test is to verify a candidate password using the decryption software.
- There are six correct passwords: AAACCC, ABBCC, BABAB, BCABACB, CBAC, and CBACB.

1.1 (2 marks): From the six correct passwords below, select the one that will be returned by DFS-TSA and write down the exact number of explored nodes.

- ○ AAACCC
- ○ ABBCC
- ○ BABAB
- ○ BCABACB
- ○ CBAC
- ○ CBACB

1.2 (2 marks): From the six correct passwords below, select the one that will be returned by BFS-TSA and write down the exact number of explored nodes.

- ○ AAACCC
- ○ ABBCC
- ○ BABAB
- ○ BCABACB
- ○ CBAC
- ○ CBACB

1.3 (2 marks): You suspect that some letters are more likely to occur in the password than others. You model this by setting cost(A) = 1, cost(B) = 2, cost(C) = 3, cost(D) = 4. From the six correct passwords below, select the one that will be returned by uniform cost search using these costs.

- ○ AAACCC
- ○ ABBCC
- ○ BABAB
- ○ BCABACB
- ○ CBAC
- ○ CBACB

1.4 (3 marks): Now suppose that all letters have cost = 1, and that there is a single correct password, chosen uniformly at random from the state space. Candidate passwords can be checked using the decryption software, but the correct password is unknown. Which of the following statements is correct?

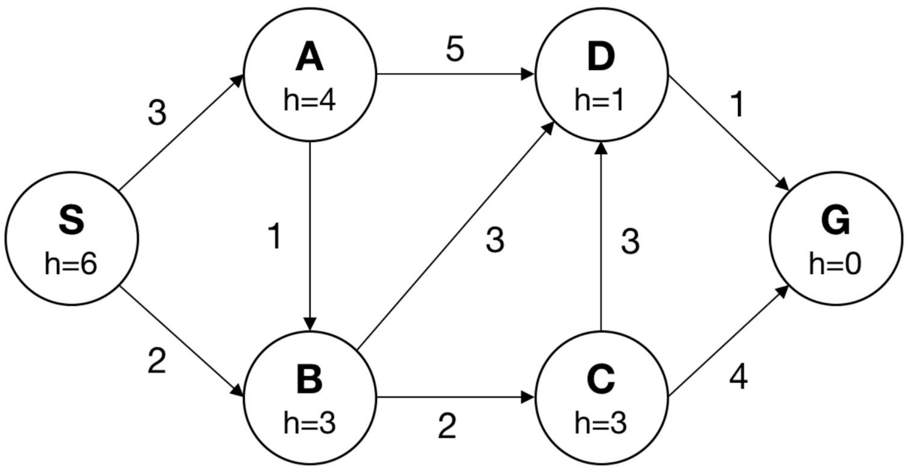
- ○ Given any heuristic, A*-TSA will, on average, expand fewer states than DFS-TSA
- ○ Given any heuristic, A*-TSA will, on average, expand fewer states than BFS-TSA
- ○ There exists a heuristic, for which A*-TSA will, on average, expand fewer states than DFS-TSA
- ○ Given any heuristic, A*-TSA will, on average, expand the same number of states as DFS-TSA
- ○ Given any heuristic, A*-TSA will, on average, expand more states than DFS-TSA
- ○ There exists a heuristic, for which A*-TSA will, on average, expand more states than DFS-TSA

2: Search (Informed)

2.1 (1 mark): If $h_1(s)$ is a consistent heuristic, and $h_2(s)$ is an admissible heuristic, then the minimum of the two must be consistent.

- ○ Yes
- ○ No

2.2: Consider the following graph where S is the start state and G is the goal state.



2.2.1 (1.5 marks): Is the heuristic in the above graph admissible? If not, provide a minimal set of edges whose costs must be changed along with their new costs in order to make the heuristic admissible.

- ○ Yes
- ○ No

2.2.2 (1.5 marks): Is the heuristic in the above graph consistent? If not, provide a minimal set of edges whose costs must be changed along with their new costs in order to make the heuristic consistent.

- ○ Yes
- ○ No

3. Search (Constraint Satisfaction Problems)

We have five aircrafts: A, B, C, D, and E and two runways (RW): RW1 and RW2. We would like to schedule a time slot and runway for each aircraft to either land or take off. We have four time slots: {1, 2, 3, 4} for each runway, during which we can schedule a landing or take off of a plane. We must find an assignment that meets the following constraints:

- No two aircrafts can reserve the same time slot for the same runway
- Plane D must land at time slot 3 or after
- Plane D must land before plane C takes off
- Plane A must land at time slot 2 or before
- Plane B must land in time slot 1

3.1 (3 marks): Complete the formulation of this problem as a CSP in terms of variables, domains, and constraints (both unary and binary). Constraints should be expressed implicitly using mathematical or logical notation rather than with words.

Variables: A, B, C, D, E for each plane.

3.2: For the following subparts, we add the following two constraints:

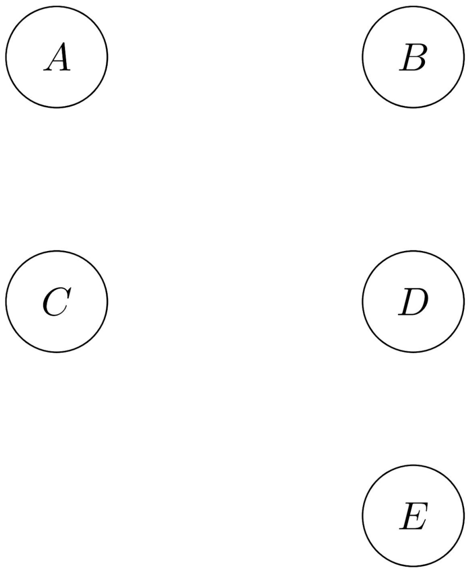
- Planes A, B, and C can only use RW1
- Planes D and E can only use RW2

3.2.1 (2 marks): With the addition of the two constraints above, we completely reformulate the CSP. You are given the variables and domains of the new formulation. Complete the constraint graph for this problem given the original constraints and the two added ones.

Variables: A, B, C, D, E for each plane

Domains: $\{1, 2, 3, 4\}$

Constraint Graph:



3.2.2 (2 marks): What are the domains of the variables after enforcing arc-consistency?

3.2.3 (3 marks): Arc-consistency can be rather expensive to enforce, and we believe that we can obtain faster solutions using only forward-checking on our variable assignments. Using the Minimum Remaining Values heuristic, perform backtracking search on the graph, breaking ties by picking lower values and characters first. List the (variable, assignment) pairs in the order they occur (including the assignments that are reverted upon reaching a dead end). Enforce unary constraints before starting the search.

4. Markov Decision Process

In this MDP, the available actions at state A, B, C are LEFT, RIGHT, UP, and DOWN unless there is a wall in that direction. The only action at state D is the EXIT ACTION that gives the agent a reward of x. The reward for non-exit actions is always 1.

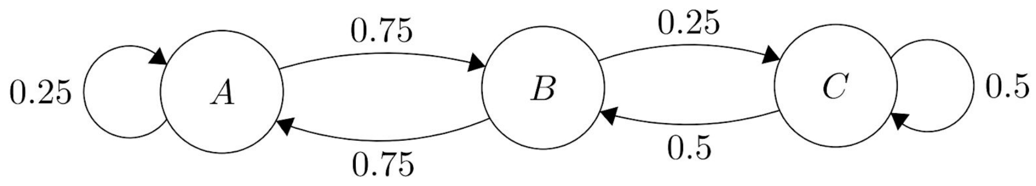
A	B
D	C

4.1 (4 marks): Let all actions be deterministic and assume that $\gamma = 0.75$. Express V*(A), V*(B), V*(C), V*(D) in terms of x.

4.2 (4 marks): Let any non-exit action be successful with probability = 0.5. Otherwise, the agent stays in the same state with reward = 0. The EXIT ACTION from the state D is still deterministic and will always succeed. Assume that $\gamma = 0.5$.
For which value of x does Q*(A, DOWN) = Q*(A, RIGHT)? Justify/show your work.

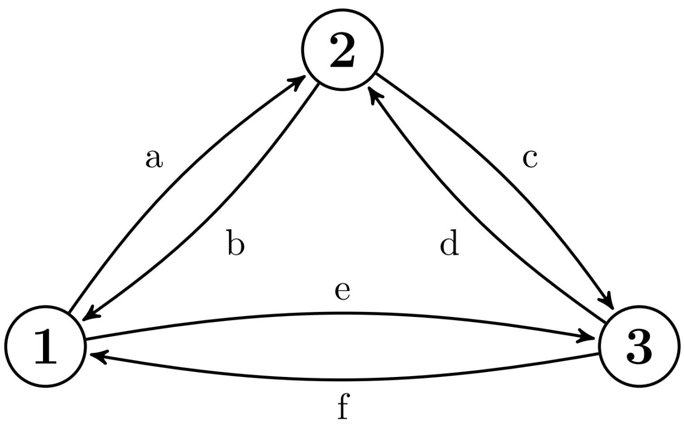
5. Markov Model

5.1 (3 marks): Consider a Markov chain with 3 states and transition probabilities as shown below.



Compute the stationary distribution. That is, compute $P_\infty(A)$, $P_\infty(B)$, $P_\infty(C)$.

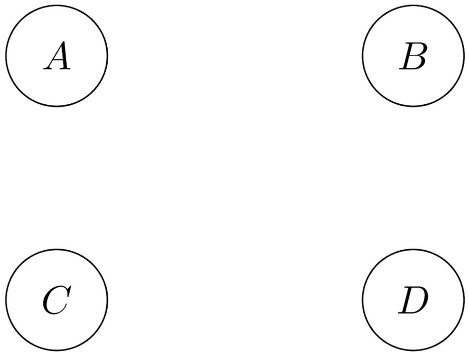
5.2 (6 marks): Consider a Markov chain for Y specified by the following transition diagram



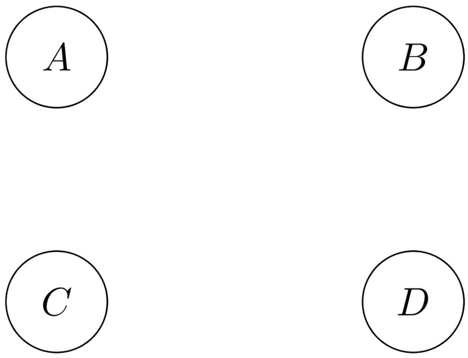
Given that $Y_0 = 1$, find $P(Y_1 = 3)$, $P(Y_2 = 3)$, $P(Y_3 = 3)$.

6. Bayesian Network

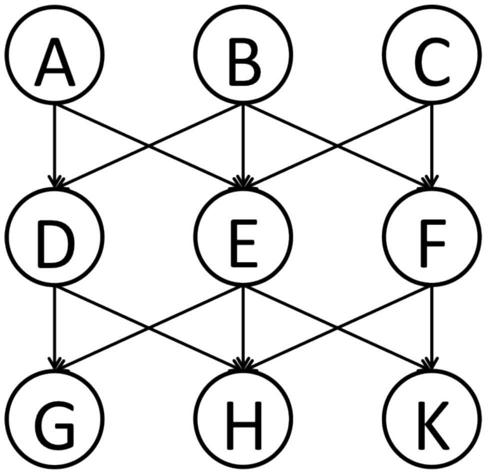
6.1 (3 marks): You are given a Bayes Net with the four nodes below. The "number of rows" in a Bayes Net is the total number of rows in all CPTs (including the two-row tables for variables with no incoming edges). Assume all variables are binary. Draw three edges such that the Bayes Net is valid, and the number of rows in the Bayes Net is smaller than the number of rows in the full joint table for all four variables.



6.2 (3 marks): Draw three edges such that the Bayes Net is valid, and the number of rows in the Bayes Net is larger than the full joint table.



6.3 (4 marks): Based only on the structure of the Bayes Net given below, indicate whether the following conditional independence assertions are guaranteed to be true, guaranteed to be false, or cannot be determined by the structure alone.



1	$A \perp\!\!\!\perp C$	Guaranteed false	Cannot be determined	Guaranteed true
2	$A \perp\!\!\!\perp C \mid E$	Guaranteed false	Cannot be determined	Guaranteed true
3	$A \perp\!\!\!\perp C \mid G$	Guaranteed false	Cannot be determined	Guaranteed true
4	$A \perp\!\!\!\perp K$	Guaranteed false	Cannot be determined	Guaranteed true
5	$A \perp\!\!\!\perp G \mid D, E, F$	Guaranteed false	Cannot be determined	Guaranteed true
6	$A \perp\!\!\!\perp B \mid D, E, F$	Guaranteed false	Cannot be determined	Guaranteed true
7	$A \perp\!\!\!\perp C \mid D, F, K$	Guaranteed false	Cannot be determined	Guaranteed true
8	$A \perp\!\!\!\perp G \mid D$	Guaranteed false	Cannot be determined	Guaranteed true

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