Written examination
TIN172/DIT410, Artificial Intelligence

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(I will visit some time around 15:30 to answer questions)

19 August 2014, 14:00–18:00

This examination consists of eight basic questions (numbered 1–8) and three advanced (numbered A–C). There are no points awarded for the questions, but you can either give a correct answer, or fail.

Grading

The number of questions (basic plus advanced) that you need to answer correctly in order to get a certain grade is shown in the following table:

Basic questions	Advanced questions	Final grade
≥ 5	—	3/G
≥ 6	≥ 1	4/VG
≥ 7	≥ 2	5

Accessories

- Paper and pencil.
- Crayons, paper glue, scissors.
- One A4 cheat sheet with any information you want on it.
- No books or calculators.

Notes

- Answer directly on the question page,
  but you can also use empty papers if you run out of space.
- ***Write readable, and explain your answers!***

1 Complexity dimensions of poker

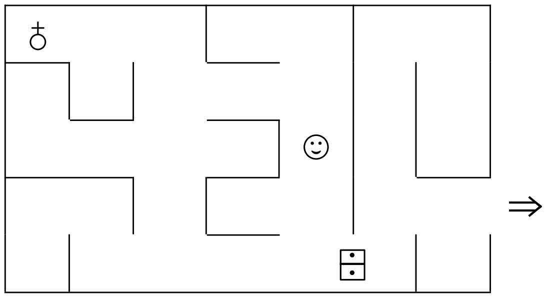
Assume that you want to write a program that can play the card game of poker against other players. Classify this program according to the complexity dimensions below. (Note that you could select more than one value). Also explain why you chose that/those value(s).

Dimension	Possible values	Value(s)	Explanation
Modularity	(F)lat (M)odular (H)ierarchical		
Representation	(S)tates (F)eatures (I)ndividuals +relations		
Planning horizon	(S)tatic (F)inite (I)ndefinite (∞)Infinite		
Observability	(F)ull (P)artial		
Dynamics	(D)eterministic (S)tochastic		
Number of agents	(S)ingle (M)ultiple		

2 Escaping a maze

You (☺) are trapped in a maze and needs to escape from it. Unfortunately there is a locked door (⍠) between you and the exit (⇒), and you have to take the key (♁) before you can unlock the door.

You are not facing any special direction and can move one step in any direction at any time step, as long as there is no wall in the way. Alternatively you can pick up the key (if you are in the right location), or you can unlock the door (if you have the key and are in the right location). Neither the key nor the door can move around on their own. Your goal is to find a plan for escaping the maze using as few moves as possible. Assume that the grid has size $M \times N$.

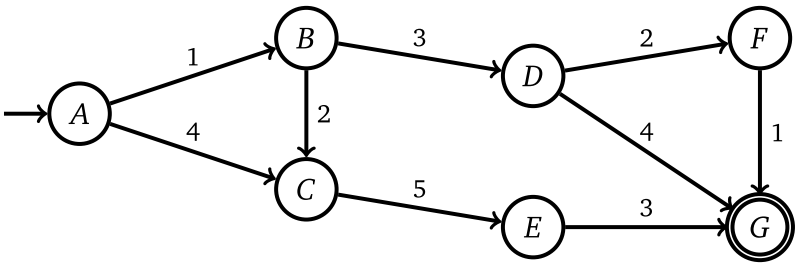


Give a suitable representation of the states in this searching problem.

What is the size of the state space?

3 Cost-based search

The following is a representation of a search problem, where A is the start node and G is the goal. There is also a heuristics h which is defined in the table. Note that $h(B)$ is unknown.



n	$h(n)$
A	5
B	?
C	4
D	3
E	3
F	1
G	0

What values of $h(B)$ make h admissible?

For each of the following search strategies, mark which of the listed paths it could return.

Assume that the heuristics h is admissible. Note that for some search strategies, the returned path might depend on tie-breaking. In these cases, make sure to mark *all* paths that could be returned.

Search algorithm	$A-C-E-G$	$A-B-C-E-G$	$A-B-D-G$	$A-B-D-F-G$
Depth-first				
Breadth-first				
$A*$ with heuristic h				

Write your answers directly on the exam, but you can also use extra papers if you run out of space.
Write readable, and don't forget to explain your answers!

4 Cryptoarithmetic puzzle

A cryptarithmetic puzzle is a mathematical game where the digits of some numbers are represented by letters (or symbols). Each letter represents a unique digit. The goal is to find the digits such that a given mathematical equation is verified.

Formulate the following puzzle as a CSP:

$$\begin{array}{ccccc} & & O & D & D \\ + & & O & D & D \\ \hline & E & V & E & N \end{array}$$

5 Knowledge base

$a \leftarrow b \wedge c.$	$a \leftarrow g.$	$a \leftarrow c \wedge k.$	$b \leftarrow g \wedge j.$	$b \leftarrow k.$
$b \leftarrow j \wedge a.$	$c \leftarrow f.$	$d \leftarrow m \wedge j.$	$d \leftarrow p \wedge a.$	$f \leftarrow m.$
$g \leftarrow f \wedge p.$	$k \leftarrow j.$	$k \leftarrow b \wedge p.$	$m.$	$p.$

Give a *nontrivial* model of the knowledge base above.

(A *trivial* interpretation or model is where all atoms are true or all atoms are false).

Give a *nontrivial* interpretation that is not a model of the knowledge base.

Give all atoms that are logical consequences of the knowledge base.

Give all atoms that are *not* logical consequences of the knowledge base.

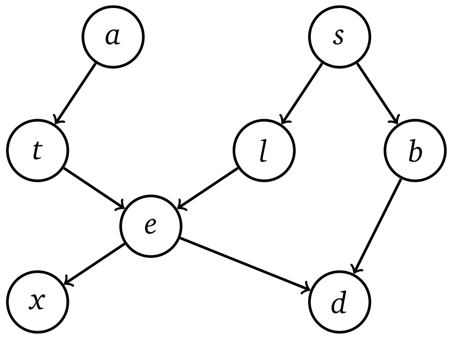
6 Rolling the dice

Assume that you roll two fair 6-sided dice.

What is the probability that one of them turns up six (⚅), given that their sum is 8?

What is the probability that one of them turns up six (⚅), given that they show different values?

7 Belief network



Mark which of the following independence assumptions that are true in the belief network above.

Assumption	**true / false**
a and t are independent	
a and s are independent	
l and b are conditionally independent given s	
s and d are conditionally independent given e	
s and x are conditionally independent given e	

8 A medical conundrum

(*Note:* the figures below are not really accurate, as they are liberally adapted from different studies.)

Many patients arriving at an emergency room, suffer from chest pain. This may indicate acute coronary syndrome (ACS). Patients suffering from ACS that go untreated may die with probability 2% in the next few days. Successful diagnosis results lowers the short-term mortality rate to 0.2%. Consequently, a prompt diagnosis is essential.

Approximately 50% of patients presenting with chest pain turn out to suffer from ACS (either acute myocardial infraction or unstable angina pectoris). Approximately 10% suffer from lung cancer.

Of ACS sufferers in general, 2⁄3 are smokers and 1⁄3 non-smokers. Only 1⁄4 of non-ACS sufferers are smokers. In addition, 90% of lung cancer patients are smokers. Only 1⁄4 of non-cancer patients are smokers.

Assumption 1 A patient may suffer from none, either or both conditions!

Assumption 2 When the smoking history of the patient is known, the development of cancer or ACS are independent.

One can perform an ECG to test for ACS. An ECG test has *sensitivity* of 66.67% (i.e., it correctly detects 2⁄3 of all patients that suffer from ACS), and a *specificity* of 75% (i.e., 1⁄4 of patients that do not have ACS, still test positive).

An X-ray can diagnose lung cancer with a sensitivity of 90% and a specificity of 90%.

Assumption 3 Repeated applications of a test produce the same result for the same patient, i.e. that randomness is only due to patient variability.

Assumption 4 The existence of lung cancer does not affect the probability that the ECG will be positive. Conversely, the existence of ACS does not affect the probability that the X-ray will be positive.

For the problem questions, please see next page.

A medical conundrum, the questions

What does the description on the previous page imply about the dependencies between the patient condition, smoking and test results? Assume the following events (i.e., variables that can be either true or false):

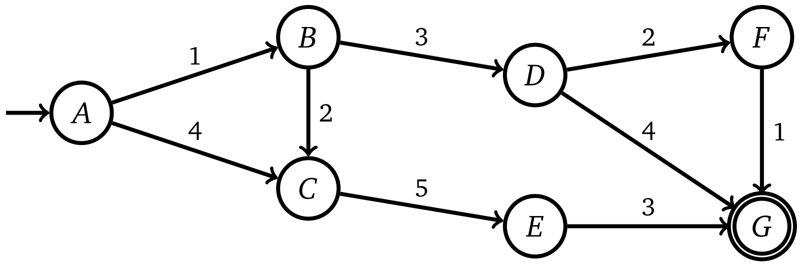
A: ACS C: Lung cancer S: Smoking E: Positive ECG result X: Positive X-ray result

Draw a belief network for the problem.

What is the probability that the patient suffers from ACS if the patient is a smoker?

A [Advanced] Cost-based search, continued

The search graph and heuristics from question 3 is repeated here.



n	$h(n)$
A	5
B	?
C	4
D	3
E	3
F	1
G	0

Recall that a heuristics is *monotone*, or *consistent*, if the difference in the heuristic values for any two nodes is always less than or equal to the actual cost of the lowest-cost path between the nodes. Or in mathematical notation: for any two nodes n and n', $|h(n) - h(n')| \leq \textit{lowest-cost}(n, n')$.

What values of $h(B)$ make h monotone/consistent?

What values of $h(B)$ will cause $A*$ search to expand node A, then node C, then node B in order?

What values of $h(B)$ will cause $A*$ to return a sub-optimal path?

B [Advanced] Optimal policy for driving

Imagine that you are driving a car from town A to town C, passing through town B. For each part of the trip, you have the choice of either taking the highway, or the country road. The travel time depends on whether the roads are congested or not. They are shown in the table below. For simplicity, assume that whenever that the state of congestion is global, i.e. that the roads are congested everywhere or nowhere and that your utility is the negative travel time, i.e. that you want to minimise expected travel time. Initially, you know that the probability of congestion is p_c. However, as soon as you have completed the first part of the trip ($A \to B$) you will know whether or not there is congestion.

Route	Highway		Country	
	No congestion	Congestion	No congestion	Congestion
$A \to B$	30 mins	60 mins	50 mins	55 mins
$B \to C$	40 mins	60 mins	45 mins	55 mins

What is the complete optimal policy for the case when $p_c = 0.75$?
Make a diagram to illustrate your calculations.

C [Advanced] A medical conundrum, continued

This is a continuation of question 8

Now consider the case where you have the choice between tests to perform. First, you observe S, whether or not the patient is a smoker. Then, you select a test to make: $d_1 \in \{X\text{-}ray, ECG\}$. Finally, you decide whether or not to treat for ASC: $d_2 \in \{treat, not\ treat\}$. An untreated ASC patient may die with probability 2%, while a treated one with probability 0.2%. Treating a non-ASC patient results in death with probability 0.1%.

Draw a decision diagram, where

- S is an observed random boolean variable, taking values in {*true, false*}.
- A and C are hidden boolean variables, taking values in {*true, false*}.
- d_1 and d_2 are choice variables, taking values in {*X-ray, ECG*} and {*treat, not treat*}, respectively.
- r_1 is a boolean result variable, corresponding to a positive (*true*) or a negative (*false*) test result.
- r_2 is a boolean result variable, corresponding to the patient living (*true*) or dying (*false*).

Let d_1= *X-ray*, and assume the patient suffers from ACS, i.e. A = *true*. How is the posterior distributed?