THE UNIVERSITY OF WARWICK

LEVEL 5 Open Book Assessment [2 hours]

Department of Computer Science

CS2550 Artificial Intelligence

Instructions
1. Read all instructions carefully – and read through the entire paper at least once before you start writing.
2. There are **5** questions. You should **attempt 4 questions**. You should not submit answers to more than the required number of questions.
3. All questions will carry the same number of marks unless otherwise stated.
4. You should handwrite your answers either with paper and pen or using an electronic device with a stylus (unless you have special arrangements for exams which allow the use of a computer). Start each question on a new page and clearly mark each page with the page number, your student id and the question number. Handwritten notes must be scanned or photographed and all individual solutions should (if you possibly can) be collated into a single PDF with pages in the correct order. You must upload two files to the AEP: your PDF of solutions and a completed cover sheet. You must click **FINISH ASSESSMENT** to complete the submission process. After you have done so you will not be able to upload anything further.
5. Please ensure that all your handwritten answers are written legibly, preferably in dark blue or black ink. If you use a pencil ensure that it is not too faint to be captured by a scan or photograph.
6. Please check the legibility of your final submission before uploading. It is your responsibility to ensure that your work can be read.
7. You are allowed to access module materials, notes, resources, references and the internet during the assessment.
8. You should not try to communicate with any other candidate during the assessment period or seek assistance from anyone else in completing your answers. The Computer Science Department expects the conduct of all students taking this assessment to conform to the stated requirements. Measures will be in operation to check for possible misconduct. These will include the use of similarity detection tools and the right to require live interviews with selected students following the assessment.

9. By starting this assessment you are declaring yourself fit to undertake it. You are expected to make a reasonable attempt at the assessment by answering the questions in the paper.

Please note that:

– You must have completed and uploaded your assessment before the 24 hour assessment window closes.

– You have an additional 45 minutes beyond the stated duration of this assessment to allow for downloading and uploading the assessment, your files and technical delays.

– For further details you should refer to the AEP documentation.

Use the AEP to seek advice immediately if during the assessment period:

- you cannot access the online assessment;
- you believe you have been given access to the wrong online assessment;

Please note that technical support is only available between 9AM and 5PM (BST).

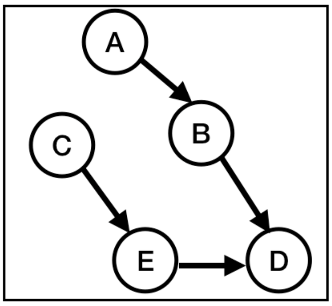
Invigilator support will be also be available (via the AEP) between 9AM and 5PM (BST).

Notify Dcs.exams@warwick.ac.uk as soon as possible if you cannot complete your assessment because:

- you lose your internet connection;
- your device fails;
- you become unwell and are unable to continue;
- you are affected by circumstances beyond your control (e.g. fire alarm).

Please note that this is for notification purposes, it is not a help line.

Your assessment starts below.



1. (a) Consider the bayesian belief network above.

    i. If we know B and D, what type of reasoning must be used to infer the probability E? Explain why this type of reasoning is appropiate. [2]

    ii. What type of reasoning would allow us to infer A from D? [1]

   (b) A scientist is trying to predict if there will be a meteor shower in the next year. The chance of a meteor shower in a given year is 10%. They have two different independent methods of prediction. One is based off of recent data from the nearby observatory (OB), the other from a neural network based on historical data (NN). In the past, the observatory has correctly predicated 82% of meteor showers, but has a false positive rate of 12%. The neural network has correctly predicated 88% of meteor showers, but has a false positive rate of 15%.

    i. Which method returning a positive is a better indicator that there will be a meteor shower? Justify your answer mathematically, including values for $P(shower|OB)$ and $P(shower|NN)$. [6]

    ii. The observatory data predicts there will be a shower, and the neural net predicts that there won't be. Should the scientist expect a meteor shower? Again, justify your answer mathematically. [4]

   (c) The probability of snow is 0.3. If there has been snow, the probability of an icy road is 0.7. If there has not been snow, the probability of an icy road is 0.4. On an icy road, the probability of a traffic accident is 0.6. On a non-icy road, the probability of a traffic accident is 0.5.

    i. Draw the inference diagram that represents this relationship. [2]

    ii. If you observe a traffic accident, what is the probability that there has been snow? [6]

   (d) Explain, with an example based on the table below, what marginalization is and how it relates to joint probability distributions. [4]

	Asthma		¬ Asthma	
	Smoker	¬ Smoker	Smoker	¬ Smoker
Dog Allergy	0.1	0.05	0.02	0.01
¬ Dog Allergy	0.2	0.25	0.015	0.35

2. (a) Martin Butcher's newest book, *Winter Talks*, is highly anticipated, but the release date is currently unknown. The biggest sign of a potential release date is a post from Butcher on their blog. They post infrequently, and the probability of a post in the next year is 0.3. If they post, the probability of the book releasing in the same year is 0.5, otherwise the probability of the book coming out in the same year is 0.1. Your friend is a huge cynic and believes the book will not come in the next year, and offers you a bet. If the book comes out in the next year, they will pay you £150, otherwise you must pay them £50.

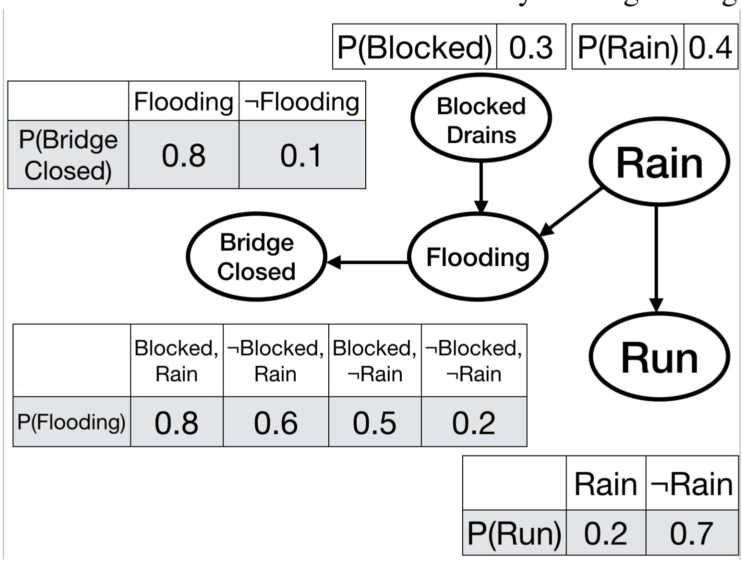
   i. Draw the decision tree for this problem. [4]

   ii. Solve the decision tree to determine whether you should take their bet or not. [6]

   iii. Represent the problem using an influence diagram. [3]

   iv. The above probabilities assume that Martin is at home for a month. When Martin is not at home, their chance of posting is 0.1. Assuming that Martin has a probability of 0.4 to be at home for a month, extend the influence diagram to incorporate this additional information. [3]

(b) Consider the inference diagram below, which describes the probability of a bridge on your way to work being closed. The bridge most often closes when it floods. If the local area's drains are blocked, or if it rains, the chances of flooding are much higher. You also know the rain affects the likelihood of your neighbour going for a run.



P(Blocked)	0.3

P(Rain)	0.4

	Flooding	¬Flooding
P(Bridge Closed)	0.8	0.1

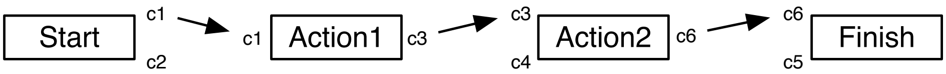
	Blocked, Rain	¬Blocked, Rain	Blocked, ¬Rain	¬Blocked, ¬Rain
P(Flooding)	0.8	0.6	0.5	0.2

	Rain	¬Rain
P(Run)	0.2	0.7

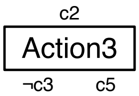
   i. List the five factors that can be used to describe these probability distributions. [3]

   ii. Given that the bridge is closed, and your neighbour went for a run, use variable elimination to find the probability that the drains are blocked. [6]

3. (a) Suppose that a partial order planner is operating and has created the partial plan shown below.



i. How would the planner incorporate $Action3$, defined by the schema below, to the plan? [3]



ii. Describe how a clobbering conflict might occur when incorporating $Action3$, stating any causal links that are threatened and how to resolve any threats. [3]

(b) Suppose there is a sensing action, $Action4$, which determines whether $c4$ is true or false. Explain how a conditional planning algorithm would incorporate $Action4$ into the partial plan in part (a) above. [3]

(c) Explain what is meant by action monitoring and plan monitoring. Considering the plan in part (a) above, after incorporating $Action3$, what is the result of action monitoring and plan monitoring assuming that $Action1$ has been executed and $Action2$ has been selected for execution. [3]

(d) What should a planner do if action monitoring or plan monitoring indicate failure? [1]

(e) Suppose you have the following rule-base:
$\{r_1 : a \wedge b \rightarrow c, r_2 : a \wedge b \rightarrow e, r_3 : a \wedge b \wedge c \wedge d \rightarrow y, r_4 : b \rightarrow d, r_5 : a \wedge c \rightarrow f\}$

i. What is the conflict set (without performing conflict resolution) if the knowledge base is $\{a_0, b_0\}$, where x_t indicates that x was added at time t? [2]

ii. Suppose that rule r_1 was fired giving the knowledge base $\{a_0, b_0, c_1\}$. Using specificity and refractoriness for conflict resolution, what is the conflict set? [2]

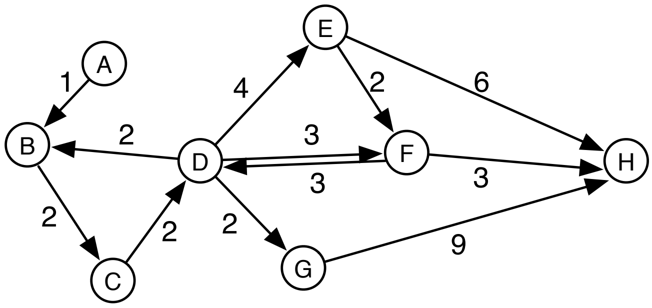
iii. If recency is also used for conflict resolution, which rule is selected? [1]

(f) Explain the two strategies for using an assumption based framework, and how they may work together. [3]

(g) Consider the following rule-base, and assume initially we only know $\{A\}$:
$A \rightarrow E$
$B \rightarrow C \wedge D$
$C \wedge E \rightarrow Z$
$E \rightarrow F \wedge B$
$F \rightarrow G$
Demonstrate how the forward-chaining approach operates, if we are interested in deriving Z, stating which rules are fired and the state of the knowledge base at each point of the reasoning process. [4]

4. (a) Consider the state space shown below, in which the arcs represent the legal successors of a node, and the labels indicate the action cost. The start state is A and the goal state is H. Suppose that you are given a heuristic, h, as defined below.

Node	A	B	C	D	E	F	G	H
$h(n)$	10	9	8	6	6	2	1	0



For the each of the following graph search methods, (i) give the state of the frontier and closed set at each step of the search, (ii) list any paths that are pruned, and (iii) state the route found, its cost, and the number of paths expanded. You should apply multiple-path pruning as appropriate.

i. Lowest-cost-first graph search. [5]

ii. Greedy best-first graph search. [5]

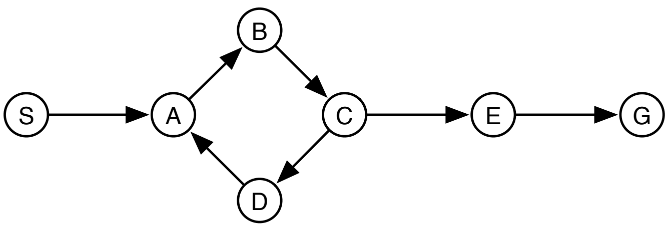
iii. A* graph search. [5]

(b) Explain how you would use dynamic programming to solve the search problem given above in (a), and show how to determine the distance table. [4]

(c) Suppose that you have a set of heuristics $h_1, \ldots, h_n$. Which of the following overall heuristics is best and why, and which of them are admissible assuming that each h_i is admissible?

$H_1 = \frac{\sum_{i=1}^{n}\{h_1,\ldots,h_n\}}{n}$, $H_2 = max\{h_1, \ldots, h_n\}$, $H_3 = \sum_{i=1}^{n}\{h_1, \ldots, h_n\}$ [2]

(d) Consider the state space shown below, in which S and G are the start and goal states respectively, and arcs represent the legal actions. Suppose you are performing a depth-first search. Explain how cycle checking works for this problem, stating what paths (if any) are pruned and their depth. What is the time overhead of cycle checking for such a search?



[4]

5. (a) In the context of reinforcement learning (RL), what is the difference between on-policy and off-policy learning? [1]

(b) If a RL learner always chooses the action with the maximum Q-value it can get stuck in a non-optimal policy. Suggest two ways to force the learner to explore. [2]

(c) Suppose a Q-learner, with learning rate $\alpha = 0.1$ and discount factor $\gamma = 0.95$, receives the following sequence of state-action-rewards. Initially all Q-values are zero.

$$s_1, right, 5, s_2, left, 8, s_1, pause, 10, s_1, right, 6, s_3$$

Show what Q values are assigned due to this sequence of experiences. [6]

(d) Consider a Q-learning agent, in a world containing states $\{Green, Blue\}$ and actions $\{Buy, Sell\}$. Suppose the Q-values are currently, at time t, as follows.

state	action	Q-value
$Green$	Buy	10
$Green$	$Sell$	12
$Blue$	Buy	18
$Blue$	$Sell$	3

Assume learning rate $\alpha = 0.1$, discount $\gamma = 0.95$ and that the agent is using softmax action selection with $\tau = 0.9$.

i. If at time t the agent was in state $Green$, performed action Buy, received reward 13 and ended in state $Green$, how is the table of Q-values updated for time $t+1$? [2]

ii. What is the probability of choosing action $Sell$ in state $Green$ at time $t+1$? [4]

(e) Suppose that you have a CSP containing variables $\{A, B, C, D\}$ each with domain $\{1, 2, 3, 4\}$, such that the following constraints hold.
$\{A \neq B, A = C, B \neq 3, B \neq C, C < 3, C < D\}$

i. Draw the constraint graph for this problem. [1]

ii. Draw the domain consistent constraint graph. [2]

iii. Apply the Arc Consistency Algorithm to this graph, stating the arc and relation considered at each step and which, if any, values are removed from which domains. Show the resulting arc-consistent constraint graph. [5]

iv. Show the constraint graph(s) that result from performing domain splitting on C in the constraint graph resulting from (e)(iii) above. [2]