Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Faculty of Engineering, Mathematics and Science

School of Computer Science & Statistics

Integrated Computer Science Programme — Trinity Term 2018
B.A. (Mod.) Computer Science & Business
B.A. (Mod.) Computer Science & Language
Year 3 Annual Examinations

Artificial Intelligence I

Mon, 14 May 2018 — SPORTS CENTRE — 14:00 – 16:00

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Instructions to Candidates:

Attempt *two* questions. All questions carry equal marks. Each question is scored out of a total of 50 marks.

You may not start this examination until you are instructed to do so by the Invigilator.

Exam paper is not to be removed from the venue.

Materials permitted for this examination:

Non-programmable calculators are permitted for this examination — please indicate the make and model of your calculator on each answer book used.

1. Recall that a goal node connected by arc to Node can be searched by calling `frontierSearch([Node])`, with the following Prolog clauses.

```
frontierSearch([Node|_]) :- goal(Node).
frontierSearch([Node|Rest]) :-
        findall(Next, arc(Node,Next), Children),
        add2frontier(Children, Rest, NewFrontier),
        frontierSearch(NewFrontier).
```

(a) Define `add2frontier(Children, Rest, NewFrontier)` so that `frontierSearch([Node])` searches **depth**-first for a goal connected to Node by arc.

```
frontierSearch( [ [] | _ ], _ ).
frontierSearch( [CurrentNode | RestOfFrontier], KB) :-
        findall( NextNode, arc(CurrentNode, NextNode), Children),
        append( Children, RestOfFrontier, NewFrontier),
        frontierSearch( NewFrontier,KB).
```

[5 marks]

(b) Define `add2frontier(Children, Rest, NewFrontier)` so that `frontierSearch([Node])` searches **breadth**-first for a goal connected to Node by arc.

```
frontierSearch( [ [] | _ ], _).
frontierSearch( [CurrentNode | RestOfFrontier], KB) :-
        findall( NextNode, arc(CurrentNode, NextNode), Children),
        append( RestOfFrontier, Children, NewFrontier),
        frontierSearch( NewFrontier, KB).
```

[5 marks]

(c) What modifications to `add2frontier(Children, Rest, NewFrontier)` are required for **A-star**?

[10 marks]

(d) What does it mean for A-star to be **admissible**?

Returns the minimum cost solution whenever a solution exists.

[5 marks]

1) Underestimate: All heuristics are less than the actual cost.

2) Termination: for some E > 0, every arc costs >= E.

3) Finite branching: {n' | arc(n,n')}, n' is finite.

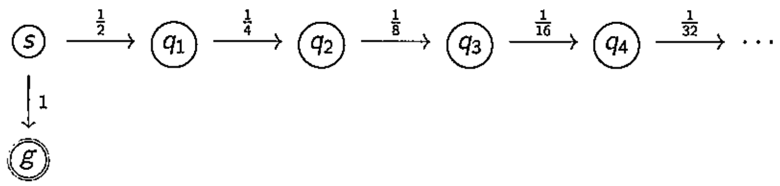
(e) Give three conditions sufficient for A-star to be admissible. Do these conditions guarantee that A-star will terminate? Justify your answer.

[10 marks]

(f) True or false: breadth-first is admissible. Justify your answer.

[5 marks]

(g) Suppose we were to apply A-star to the graph shown below



with arcs (s, g), (s, q_1) and (q_n, q_{n+1}) costing 1, $\frac{1}{2}$ and $\frac{1}{2^{n+1}}$ respectively

$$\begin{aligned} \text{cost}(s, g) &= 1 \\ \text{cost}(s, q_1) &= \frac{1}{2} \\ \text{cost}(q_n, q_{n+1}) &= \frac{1}{2^{n+1}} \quad \text{for } n \geq 1 \end{aligned}$$

and heuristics $h(s) = 1$, $h(g) = h(q_n) = 0$. Assuming g is the only goal node, is A-star admissible under this set-up? Justify your answer.

[5 marks]

(h) Suppose we were to change the cost of an arc (q_n, q_{n+1}) to $\frac{1}{n+2}$

$$\text{cost}(q_n, q_{n+1}) = \frac{1}{n+2} \quad \text{for } n \geq 1.$$

Would A-star be admissible if all other details of the set-up in part (g) were preserved. Justify your answer.

[5 marks]

2. Let $\langle S, A, p, r, \gamma \rangle$ be a *Markov decision process.*

   (a) What is a **policy**? Supposing S consists of three states, and A of two actions, how many possible policies are there?

   [5 marks]

   (b) What is a γ-**optimal policy** and how is it computed from the γ-**discounted value of** a pair (s, a) of a state $s \in S$ and action $a \in A$? How are γ-discounted values computed by value iteration $q_0, q_1, q_2, q_3 \ldots$? Compute $q_2(s_3, a_2)$ for

$$
\begin{aligned}
S &= \{s_1, s_2, s_3\} \\
A &= \{a_1, a_2\} \\
\gamma &= .1
\end{aligned}
$$

   and probabilities and immediate rewards given by Table a_1 and Table a_2 as follows: the entry of Table a_i at row s, column s' is the pair $p(s, a_i, s'),\ r(s, a_i, s')$.

a_1	s_1	s_2	s_3
s_1	.5, 3	.3, 0	.2, −2
s_2	.3, 0	.5, 1	.2, 2
s_3	0, 0	0, 0	1, 1

Table a_1

a_2	s_1	s_2	s_3
s_1	.2, 4	.2, 2	.6, −3
s_2	.1, 1	0, 0	.9, −2
s_3	0, 0	0, 0	1, 0

Table a_2

   [25 marks]

   (c) How can we learn γ-discounted values when we do not know the probabilities p and immediate rewards r?

   [10 marks]

   (d) What is the **exploration-exploitation** tradeoff in (c), and how can we adjust the notion of a policy (discussed in part (a)) to accommodate the trade-off?

   [10 marks]

3. (a) (i) What is a **definite clause**?

[5 marks]

(ii) What is a **Horn clause**?

[5 marks]

(iii) True or false: every set of definite clauses is satisfiable. Justify your answer.

[5 marks]

(iv) Outline an efficient algorithm to determine whether a set of Horn clauses is satisfiable.

[10 marks]

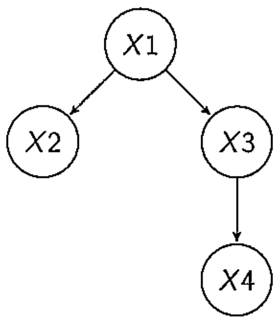
(b) True or false: a set KB of clauses is satisfiable if and only if the atom `false` is a logical consequence of KB. Justify your answer, stating what it means for a clause to be a logical consequence of KB.

[10 marks]

(c) Given the Bayes net and probabilities below for the Boolean variables $X1, X2, X3, X4$ (with negations $\overline{X1}, \overline{X2}, \overline{X3}, \overline{X4}$), calculate the probabilities in (i), (ii) and (iii).

$P(X1) = 0.3$

$P(X2|X1) = 0.7$
$P(X2|\overline{X1}) = 0.5$



$P(X3|X1) = 0.2$
$P(X3|\overline{X1}) = 0.6$

$P(X4|X3) = 0.6$
$P(X4|\overline{X3}) = 0.6$

(i) $P(X1|X2)$

[5 marks]

(ii) $P(X3|X2)$

[5 marks]

(iii) $P(X3|X4)$

[5 marks]