UNIVERSITY OF LONDON

BSc EXAMINATION 2024

For Internal Students of
Royal Holloway

DO NOT TURN OVER UNTIL TOLD TO BEGIN

CS2910: Symbolic Artificial Intelligence
CS2910R: Symbolic Artificial Intelligence – for
FIRSTSIT/RESIT CANDIDATES

Time Allowed: **TWO hours**

Please answer **ALL** questions

Calculators are not permitted

1. This question is about best-first search.

   (a) Briefly discuss the idea of the evaluation function in best-first search and explain how it affects the selection of which node to explore next. [5 marks]

   (b) Define equations based on a heuristic function for (i) greedy search and (ii) A* search. Briefly explain all functions you use. [5 marks]

   (c) In both graphs of Fig. 1, `A` denotes the initial state, `D` denotes the goal and a number next to an edge denotes the cost of moving from a node to another.

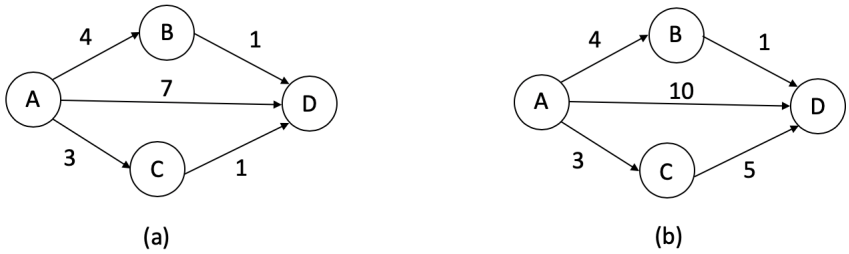
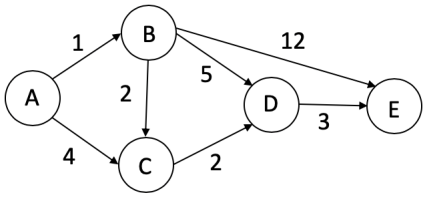


Figure 1: Two state-space graphs to search.

   Compare the solutions' cost found when applying the greedy search algorithm on the graphs to explain why greedy search is not optimal. [8 marks]

   (d) In the context of the A* algorithm explain what an admissible heuristic function is. [6 marks]

   (e) In order to apply A* search on the graph of Fig. 2, using `A` as the initial state and `E` as the goal, we need an admissible heuristic function. Is the function specified by the table below admissible? Justify your answer. [3 marks]



State	H
A	7
B	6
C	2
D	1
E	0

Figure 2: State-space graph and heuristic values for that graph.

2. This question is about logical learning and the role of knowledge in it.

   (a) Using a generic logical schema, briefly explain the aim of *inductive learning*. [5 marks]

   (b) Specialise the inductive learning schema you used in part 2(a) to define logically the decision tree shown in Fig. 3. This tree shows how an AI program should advise a user whether to go hiking. [5 marks]

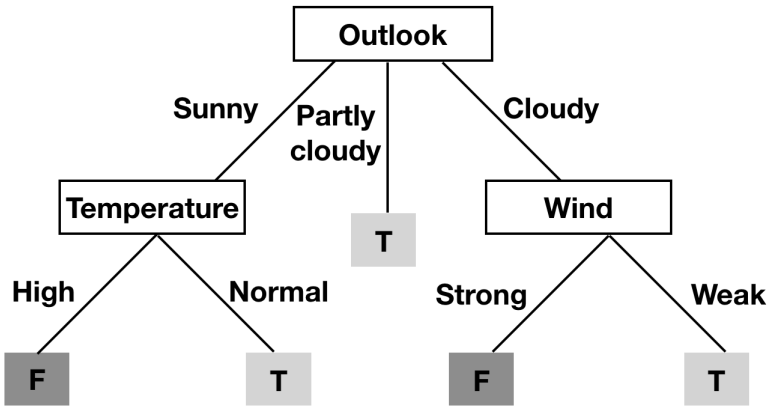


Figure 3: Decision tree for `GoHiking`. `T` and `F` stand for true and false respectively.

   (c) Briefly explain the *entailment constraint* for *knowledge learning* and state how you would change it to support *knowledge-based inductive learning*. [5 marks]

3. This question is about the mechanisms supporting logical inference and their formulation. Upper case letters denote variables, while lower case letters denote constants or function symbols.

   (a) Briefly explain when a substitution θ unifies two atomic sentences p and q; [2 marks]

   (b) Find the most general unifiers of the following terms, if they exist:

      i. `admires(molly, X)` and `admires(beatrice, lilly).` [2 marks]

      ii. `f(g(Y), h(c,d))` and `f(X, h(W, d)).` [3 marks]

   (c) Given the modus ponens rule below

$$\frac{\alpha,\ \alpha \rightarrow \beta}{\beta}$$

   write it in clausal form in order to explain how the basic resolution inference rule works for first order logic. [6 marks]

   (d) Explain how we would apply resolution to prove the goal connected(a, X) using the following KB.

```
edge(a, b).
edge(a, c).
edge(a, f(a)).

connected(a, X) ← edge(a, X).
```

   [8 marks]

   (e) Formally define what we mean when we say that an inference procedure i (like resolution), deriving a specific sentence α from a knowledge base KB, is sound and complete. Briefly explain any formal symbols that you use in your definitions. [8 marks]

4. This question is about AI planning.

   (a) Define the planning problem. [6 marks]

   (b) Briefly explain what are the conditions that define the classical planning problem. Is the observability of the environment relevant for the classical planning problem? Justify your answer. [8 marks]

   (c) Consider the state space of Vacuum World in Fig. 4 where a cleaning robot transitions between states by moving left (L), right (R) or sucking dirt (S).

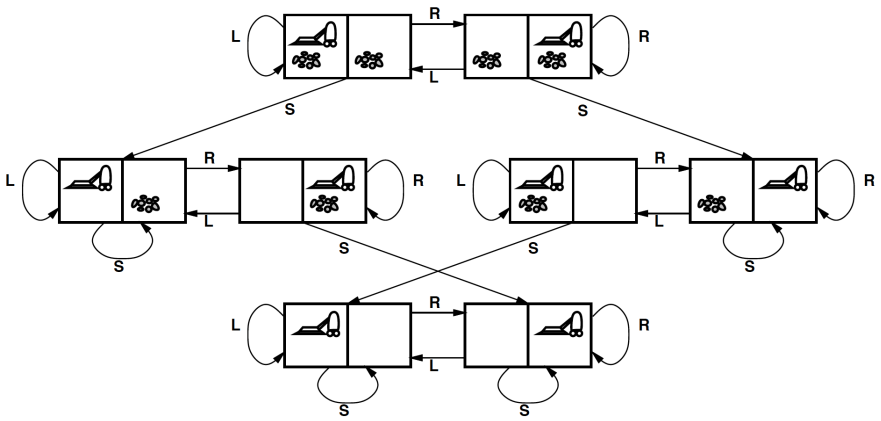


Figure 4: Vacuum World State Space

Formulate this problem as a classical planning problem with PDDL-like action schemas, stating any assumptions you make in your formulation. Exemplify your answer by showing how your formulation may generate a concrete plan between two states in the diagram of Fig. 4. [15 marks]

END