UNIVERSITY OF LONDON

BSc EXAMINATION 2018

For Internal Students of
Royal Holloway

DO NOT TURN OVER UNTIL TOLD TO BEGIN

CS2910: Artificial Intelligence

Time Allowed: **TWO hours**

Answer ALL questions
Calculators are NOT permitted

1. This question is about formulating search problems and informed search.

   (a) Explain briefly the key four properties of an environment for problems solved by classical search. [8 marks]

   (b) Formulate as a search problem the graph in Fig. 1, showing a map of locations used by a robot to go from a location to another. Use $At(n)$ to represent that the robot is at a location n, $goto(m)$ as the only action that gets the robot from where it is to a node m, and $cost(n, a, m)$ as the step cost function that gives the cost of taking action $goto(m)$ from node n. [8 marks]
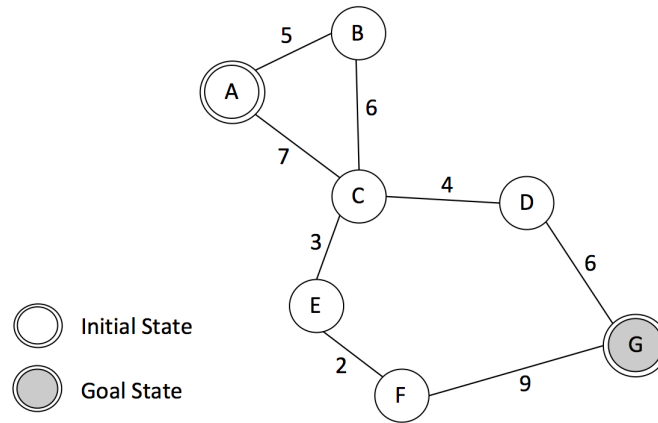

Figure 1: A map of locations and the actual distances between them.

   (c) Table 1 shows the straight line distance function $h_{SLD}(n)$ of a node n to the goal G for the graph shown in Fig. 1.

Node n	A	B	C	D	E	F	G
$h_{SLD}(n)$	16	15	9	5	10	9	0

Table 1: The straight line distance to G.

   i. Provide the evaluation function that A^* uses as the cost estimate to reach the goal. Your answer should define the function and show how its components link to what you know about the problem so far. [9 marks]

   ii. With the aid of a diagram, show how A^* applies the evaluation function to expand the nodes from the initial state and indicate which node is selected at each step until the goal is reached. [10 marks]

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2. This question is about logical models, entailment and inference procedures.

(a) Explain what we mean by a knowledge base KB specified in some logic to *entail* a sentence α in that logic. Use a formal definition to define entailment in terms of truth in the worlds in which the KB is true. Use a diagram to support your explanation. [10 marks]

(b) Entailment is implemented by writing programs for *inference procedures*.

   i. How do we express that an inference procedure i derives a statement α from a knowledge base KB? [2 marks]

   ii. What do we mean by *soundness* of an inference procedure? [2 marks]

   iii. What do we mean by *completeness* of an inference procedure? [2 marks]

   iv. How do we know that a KB is true in the world? Focus only on the meaning and truth of percept sentences. [4 marks]

(c) Explain what we mean when we say that first-order logic is *monotonic*. You may formulate your answer by showing how first-order entailment is used to model previous conclusions α when a set of sentences in a KB are extended with new information X. Re-express the formulation to meet the requirements of *default reasoning* in this context (you may assume the existence of a suitable *non-monotonic* entailment). [5 marks]

3. This question is about mechanisms of logical inference and using default reasoning to handle exceptions. Upper case letters denote constants, while lower case letters denote variables or function symbols.

(a) Explain why it is impractical to reduce first-order theories to propositional ones and, as a result, first-order inference methods to those in propositional logic. You may prefer to formulate your answer by explaining what happens when we are dealing with a set of sentences S that has p predicates of arity k and n constants. You should also explain what happens if the predicates in S contain function symbols. [5 marks]

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

   i. `gives(x, y, James)` and `gives(John, Money, f(y))`. [2 marks]

   ii. `gives(x, x, f(f(A)))` and `gives(y, f(z), f(y))`. [3 marks]

(c) Normal logic programs use negation-by-failure to provide a simple and practical formalism for expressing defaults and exceptions, and other forms of non-monotonic reasoning. Formulate the following sentences as normal logic programs:

   i. Typically (by default) birds fly. [3 marks]

   ii. Except that ostriches, which are birds, typically do not fly. [6 marks]

   iii. Except that magic ostriches can fly (in general). [6 marks]

4. 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 4(a) to define logically the decision tree shown in Fig. 2. This tree shows how an AI program should advise a user whether to play tennis. [5 marks]
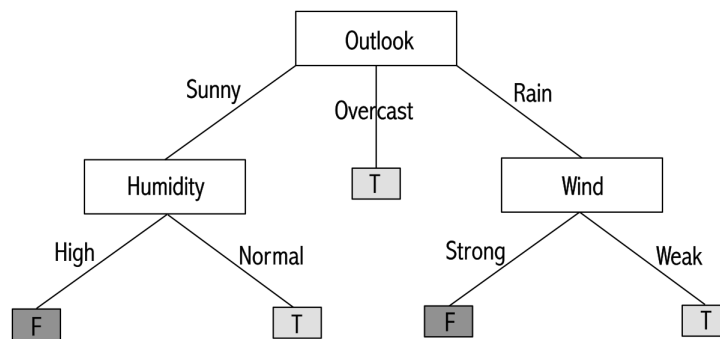

Figure 2: Decision tree for `PlayTennis`. T and F stand for true and false respectively.

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

        [5 marks]

END