UNIVERSITY OF LONDON

BSc EXAMINATION 2023

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

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

   (a) A mail delivery robot uses the map of Fig. 1 to distribute mail to rooms $r01, ..., r06$. The robot is currently in room $r01$ and has only one envelop left to deliver in room $r06$. Explain how you could formulate this situation as a search problem. Assume that the robot uses $At(n)$ as the predicate to represent its current location n, $moveto(m)$ as the action it takes to move from its current location to a reachable node m, and $cost(n, a, m)$ as the step cost function that gives the cost of taking action $moveto(m)$ from node n.   [8 marks]
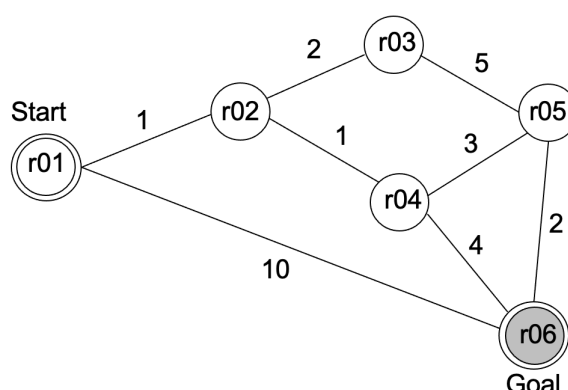

Figure 1: A map of rooms and the actual distances between them.

   (b) Table 1 shows heuristic function $h(n)$ of a node n to the goal $r06$ for the graph shown in Fig. 1.

Node n	r01	r02	r03	r04	r05	r06
$h(n)$	5	3	4	2	6	0

Table 1: Heuristic function for reaching room $r06$ (the goal).

   With the aid of a diagram, use your formulation and any additional equations to show how A^* uses $h(n)$ to expand the nodes from the initial state, indicating which node is selected at each step to reach the goal.   [10 marks]

   (c) Is $h(n)$, as shown in Table 1, admissible? Justify your answer.   [6 marks]

2. This question is about knowledge-based agents, logical models, entailment and inference procedures.

   (a) Informally explain what we mean by an agent knowledge base KB specified in some logic to entail a sentence α in that logic. Which symbol do we use to write that KB entails α? [2 marks]

   (b) Formally define entailment in terms of truth in the worlds in which the KB is true. Use a diagram to link entailment with the real world. [8 marks]

   (c) Entailment is implemented in knowledge-based agents by writing programs for *inference procedures*. How do we express that an inference procedure i derives a statement α from a knowledge base KB? [2 marks]

   (d) What do we mean by *soundness* of an inference procedure i? [2 marks]

   (e) What do we mean by *completeness* of an inference procedure i? [2 marks]

   (f) How do we know that the KB of an agent is true in the world? Discuss only the meaning and truth of the percept sentences that the agent receives from the environment. [4 marks]

NEXT PAGE

3. This question is about unification, knowledge representation and forward reasoning computation.

   (a) For each pair of atomic sentences, give the most general unifier if it exists. Here P, Q, $Coetaneous$, and $Adores$ are predicate symbols, F, G, $Twin$, and $Sister$ are function symbols, x, y and z are variables, while A and $John$ are constants.

   - i. $P(x, F(z))$, $P(A, y)$. [1 marks]
   - ii. $Q(F(A), G(y))$, $Q(x, x)$. [1 marks]
   - iii. $Coetaneous(Twin(y), y)$, $Coetaneous(Twin(x), John)$. [1 marks]
   - iv. $Adores(Sister(y), y)$, $Adores(x, x)$. [1 marks]

   (b) Represent the following as first-order definite clauses:

   - i. Academics, administrators, and managers are professsionals. [3 marks]
   - ii. A mentee is an academic who has an academic mentor. [3 marks]
   - iii. Max is an academic. [2 marks]
   - iv. Max is Albert's mentor. [2 marks]
   - v. Mentee and mentor are inverse relations. [6 marks]

   (c) Use forward reasoning on the definite clauses you specified in 3(b) to show that Max and Albert are professionals. Justify your answer. [10 marks]

NEXT PAGE

4. This question is about inductive learning using decision trees.

   (a) Why is learning essential as a

      i. system construction method; [2 marks]
      ii. mechanism for aiding decisions; [2 marks]
      iii. capability for partially unknown environments. [2 marks]

   (b) We wish to learn if a customer will wait at a restaurant from the data of Fig 2. Read examples like X_1 as: Alt(ernative) restaurants nearby is *T*(rue), a Bar in the restaurant is *F*(alse), it is Fri(day) is *F*(alse), customer is Hun(gry) is *T*(rue), other Pat(rons) is *Some*, $Price$ is *$$$*, $Rain$(ing) outside is *F*(alse), customer has Res(ervation) is *T*(rue), the restaurant $Type$ is *French*, the Est(imated) waiting is *0-10* min. The customer *WillWait* is *T*(rue).

Example	Attributes										Target
	Alt	Bar	Fri	Hun	Pat	Price	Rain	Res	Type	Est	WillWait
X_1	T	F	F	T	Some	$$$	F	T	French	0–10	T
X_2	T	F	F	T	Full	$	F	F	Thai	30–60	F
X_3	F	T	F	F	Some	$	F	F	Burger	0–10	T

...

Figure 2: Data table for *WillWait*.

Which major machine learning category (supervised, unsupervised, or reinforcement) does this problem fall under? Justify your answer. [4 marks]
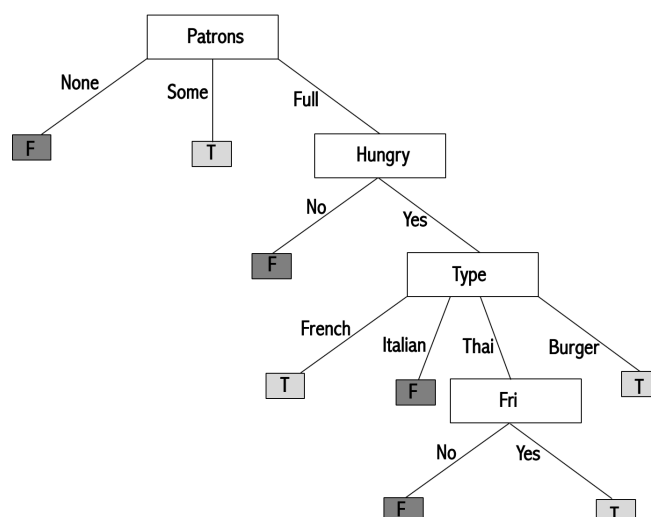

Figure 3: Learned Decision Tree for *WillWait*.

(c) Define logically the decision tree of Fig. 3 learned from the data of Fig 2.

[12 marks]

(d) What does learning of this kind allow knowledge-based agents to become? Briefly justify your answer. [4 marks]

END