# UNIVERSITY OF LONDON

## BSc EXAMINATION 2019

For Internal Students of
Royal Holloway

# DO NOT TURN OVER UNTIL TOLD TO BEGIN

## CS2910: Introduction to Artificial Intelligence

Time Allowed: **TWO hours**

Answer ALL questions

Calculators are NOT permitted

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1. This question is about adversarial search.

   (a) What is adversarial search? [4 marks]

   (b) Consider the game tree of Fig. 1.

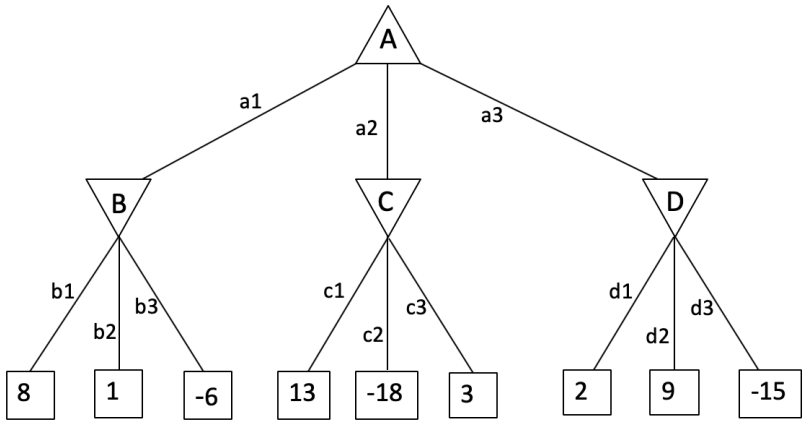


Figure 1: A two-ply game tree. $\triangle$ denote MAX nodes, while $\triangledown$ denote MIN nodes.

Redraw the above tree showing the values of non-leaf nodes after you apply the MINIMAX algorithm. Using these MINIMAX values, explain the solution of the search. [10 marks]

(c) Can you obtain any optimization if you apply $\alpha$-$\beta$ pruning to the same tree? If you can, redraw the tree to depict the $\alpha$-$\beta$ values for each of the non-leaf nodes as well as any branches that will be pruned. [5 marks]



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2. This question is about knowledge-based agents and decision tree learning.

   (a) Often in AI we develop agents as independent processes encapsulating their own state and pursuing their own goals in the environments in which they are situated. In this context briefly explain what you understand by knowledge-based agents. [4 marks]

   (b) Based on Mitchell's definition, explain when a computer program like a knowledge-based agent is said to learn. [6 marks]

   (c) A knowledge-based agent uses a logical formulation of decision trees to learn hypotheses that classify examples from its training set with the aim of generalising them to new ones and use them to take decisions. Provide a logical schema that the agent will need to use for this purpose and briefly explain its components. [4 marks]

   (d) Specialise the logical schema you gave in part 2(c) to define logically the decision tree shown in Fig. 2. This tree shows how an agent should advise a user on whether to give a loan to a client. [5 marks]

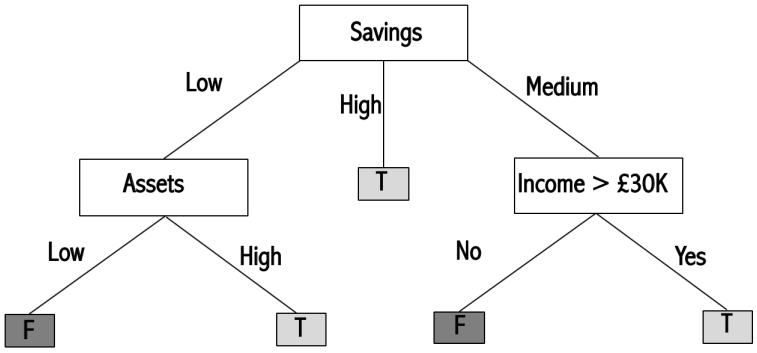


Figure 2: Decision tree for `GiveLoan`. `T` and `F` stand for true and false respectively.

   (e) Briefly explain why learning is important when building knowledge-based agents. [4 marks]



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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 $\theta$ unifies two atomic sentences p and q; [2 marks]

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

      i. `likes(john, X)` and `likes(george, bob)`. [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 likes(john, X) using the following KB.

   knows(john, jane).
   knows(john, bob).
   knows(john, motherOf(john)).

   likes(john, X) $\leftarrow$ knows(john, X).

   [8 marks]

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



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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. 3 where a cleaning robot transitions between states by moving left (L), right (R) or sucking dirt (S).

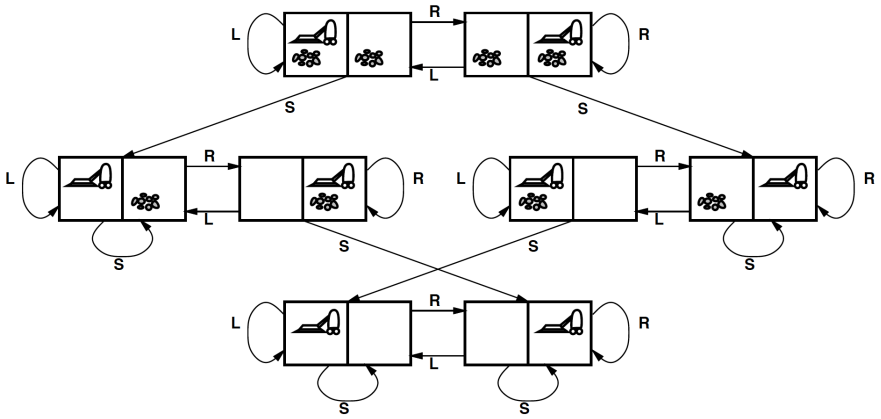


Figure 3: Vacuum World State Space

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. 3. [15 marks]

**END**



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