ROYAL HOLLOWAY, UNIVERSITY OF LONDON
BSc EXAMINATION 2021

CS2910: Introduction to Artificial Intelligence

Time allowed: **TWO hours**

Please answer **ALL** questions

- Handwrite your answers on paper, and write your candidate number and the module number at the top of each page. Photograph/scan the pages and keep the original paper versions, as they may be required by the examiners.
- For each question you attempt, please clearly state the question number.
- Please DO NOT include your name or Student ID anywhere on your work.
- **Academic Misconduct:** We will check all assignments for academic misconduct. Suspected offences will be dealt with under the College's formal Academic Misconduct procedures. Please remember:
  - The work submitted is expected to be your own work and only your work. You may not ask for help from any source, or copy anyone else's work.
  - You must not give help to anyone else, including sending them any parts of the questions or copies of your solutions.
  - You must not discuss the questions or solutions with anyone else.
- **Submitting your work:**
  - Your document must be submitted through Moodle using the submission link in the module Moodle page. If possible please convert your document into a PDF document to make the submission process quicker and easier.
  - Emailed submissions will not be accepted.
  - **You must complete your exam upload within 1 hour of the exam finish time.**

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

   (a) A mail delivery robot uses the map shown in Fig. 1 to distribute mail to rooms $r01, ..., r07$. The robot is currently in room $r01$ and has only one envelop left to deliver in room $r07$. 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 that 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]

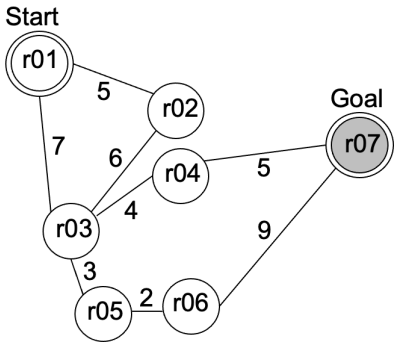

Figure 1: A map of rooms and the actual distances between them.

   (b) Table 1 shows the straight line distance function $h_{SLD}(n)$ of a node n to the goal $r07$ for the graph shown in Fig. 1.

Node n	r01	r02	r03	r04	r05	r06	r07
$h_{SLD}(n)$	16	15	9	5	10	9	0

Table 1: The straight line distance to room $r07$ (the goal).

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

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

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

   (a) Following logic programming conventions for variables, predicates and function symbols, give the most general unifier for each pair of atomic sentences, if it exists.

   i. $older(brotherOf(Y), Y)$, $older(brotherOf(X), john)$. [1 marks]
   ii. $in(a, f(f(X)), s(3))$, $in(Y, Z, s(Y))$. [1 marks]
   iii. $in(a, f(f(X)), 7)$, $in(W, Z, 5)$. [1 marks]
   iv. $ignores(friendOf(Y), Y)$, $ignores(X, X)$. [1 marks]

   (b) Represent the following statements as definite clauses:

   i. Dogs, cats, and parrots are pets. [3 marks]
   ii. An offspring of a dog is a dog. [3 marks]
   iii. Sparky is a dog. [2 marks]
   iv. Sparky is Juno's parent. [2 marks]
   v. Offspring and parent are inverse relations. [6 marks]

   (c) Use forward reasoning on the definite clauses you specified in 2(b) to show that Sparky and Juno are pets. Justify your answer. [8 marks]

3. This question is about using resolution and backward reasoning in normal logic programs with negation by failure (NBF). Upper case letters denote constants, while lower case letters denote variables.

   (a) Rewrite the modus ponens rule below

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

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

   (b) How would you apply resolution to prove the goal $respects(John, x)$ using the knowledge base below?

   $admires(John, Jane).$
   $admires(John, Bob).$
   $admires(John, motherOf(Jane)).$

   $respects(John, x) \leftarrow admires(John, x).$

   [9 marks]

   (c) Consider the logic program $\mathcal{P}$:

   $takes\_bribes(x) \leftarrow civil\_servant(x),\ not\ \ honest(x).$
   $honest(x) \leftarrow tax\_inspector(x),\ not\ \ rich(x).$
   $tax\_inspector(x) \leftarrow civil\_servant(x).$

   $tax\_inspector(John).$
   $civil\_servant(Mike).$
   $rich(Mike).$

   Use backward reasoning on the rules of $\mathcal{P}$ to determine who takes bribes. Justify your answer by showing step-by-step how your conclusions were reached using unification and the use of NBF (not). [10 marks]

4. This question is about temporal reasoning in the situation calculus. In this context consider the following fluents, predicates and actions about the Wumpus World:

   - $at(Sq)$ – a fluent meaning that the agent is at square Sq.
   - $heading(Dir)$ – a fluent meaning that the agent is facing in direction Dir.
   - $wumpus(Sq)$ – a fluent meaning that the Wumpus is in square Sq.
   - $empty(Sq)$ – a fluent meaning that the square Sq is empty.
   - $next(Sq1, Dir, Sq2)$ – a predicate meaning that square $Sq2$ is adjacent to square $Sq1$ in direction Dir.
   - $newdir(Dir1, X, Dir2)$ a predicate meaning that $Dir2$ is the new direction the agent will face if it is facing in direction $Dir1$ and turns $X \in \{left, right\}$.
   - $turn(X)$ – is the action of turning X where $X \in \{left, right\}$.
   - $shoot$ – is the action of shooting once forward.

   In the following we assume that the action $shoot$ only has an effect in directly adjacent squares.

   (a) Formalise as a logic program a precondition and an effect axiom for the Wumpus World that best describes the action $turn(X)$. Take into account that if the agent is heading in direction $Dir1$ and the result of turning X is $Dir2$, then the agent is heading in direction $Dir2$ in the situation following after turning X. [8 marks]

   (b) Formalise as a logic program a precondition and an effect axiom that best describe the $shoot$ action in the Wumpus World. Take into account that if the agent is at square $Sq1$ and heading in direction Dir, and the next square in direction Dir containing the Wumpus is $Sq2$, then the result of shooting in the direction of $Sq2$ kills the Wumpus and empties that square. [8 marks]

   (c) Formalise as a logic program a frame axiom that best describes the $shoot$ action in the Wumpus World. You only need to do this for the $wumpus/1$ fluent. Take into account that if the agent is at square $Sq1$ and heading in direction Dir, and the next square in direction Dir is $Sq2$, and the Wumpus is in square $Sq3$, and square $Sq2$ doesn't equal $Sq3$, then the Wumpus is still in square $Sq3$ after shooting. [7 marks]

END