UNIVERSITY OF BRISTOL

November 2023

FACULTY OF ENGINEERING

Third Year Examination for the Degrees of
Bachelor of Science and Master of Engineering

COMS30013 ***SAMPLE ANSWERS 1***
ARTIFICIAL INTELLIGENCE
Units Examined – COMS30013 & COMS30072

Section I (Multiple Choice): Answer all 15 (out of 15 possible) questions
There are 15 questions in Section I for which ALL of your answers will count
For each question, select exactly one correct option
(Please note that an MCQ tick sheet will be provided in the January exam)
Your 15 answers are all worth up to 1 mark each
There are a maximum of 15 marks available in Section I

Section II (Long Answers): Answer only 2 (out of 3 possible) questions
There are 3 questions in Section II for which only your best TWO answers will count
(Please note that an answer booklet will be provided in the January exam)
Clearly indicate which question, part, and sub-part you are answering
If you answer more than two questions, only your best two answers will count
Your 2 best two answers are both worth up to 15 marks each
There are a maximum of 30 marks available in Section II

The maximum possible mark on this exam is 45

The maximum time allowed on this exam is 2 hours

Calculators must have the Faculty of Engineering Seal of Approval.

Do not turn over until told to start the exam.

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Part I – Answer all 15 questions. Each question is worth 1 Mark.

1. Which one of the following is a well-formed Prolog term?

   A. `_r(_a)`
   B. `R(a,B)`
   C. `r_(a_)` << Answer
   D. `R'`

2. What is the standard logical interpretation of the Prolog operator ";"?

   A. OR << Answer
   B. XOR
   C. IF
   D. AND

3. Which one of the following is a unifier of the Prolog terms `p(W,f(W,X))` and `p(Y,f(a,Z))`?

   A. { `W/a` }
   B. { `W/Y , Y/a, Z/X` }
   C. { `W/a, Y/a, X/V, Z/V` } << Answer
   D. { }

4. If (x,y) are the coordinates of an agent in a modified GridWorld where agents can move one square at a time up, down, left, right OR diagonally, which one of the following is an admissible heuristic for the length of the shortest path back to the origin (0,0)?

   A. (x*x) + (y*y)
   B. x+y
   C. x*y
   D. x << Answer

5. Which one of the following statements is FALSE?

   A. A* will never return a worse solution than breadth-first search
   B. breadth-first search will never visit more nodes than A* << Answer
   C. breadth-first search will never return a worse solution than depth-first search
   D. depth-first search may visit fewer nodes than A*

6. During the execution of a simulated annealing algorithm, the temperature:

   A. increases with time
   B. decreases with time << Answer
   C. increases with fitness
   D. decreases with fitness

7. What is an “allele”?

   A. A value taken by a gene << Answer
   B. A loci
   C. A chromosome
   D. A genotype

8. Which of the following examples are major evolutionary transitions?

   A. Unicellular to Multi-cellular Creatures
   B. Asexual to Sexual Creatures
   C. Solitary Individuals to Social Colonies
   D. All of the above << Answer

9. The fitness score assigned to individual I in generation G of a GA's execution is X before fitness sharing is applied but becomes Y afterwards. If Y<X what can we infer?

   A. Other individuals in G are similar to I
   B. I is suboptimal
   C. Fitness sharing must have reduced the fitness score of other individuals in G
   D. Both A and C << Answer

10. Which of the following operations in a genetic algorithm always introduce stochasticity:

   A. Mutation and Selection
   B. Crossover and Selection
   C. Crossover and Mutation << Answer
   D. Mutation and Elitism

11. Proactive agents anticipate changes in the environment.

   A. TRUE
   B. FALSE << Answer

12. Consider a smart home as an agent. The smart home agent is programmed to switch off the lights in a room when the room's occupants leave the room. The behaviour that the smart agent exhibits is an example of a reactive behaviour.

    A. TRUE << Answer
    B. FALSE

13. In a norm lifecycle, which of these is a non-terminal state?

    A. Violated
    B. Satisfied
    C. Expired
    D. Conditional << Answer

14. Which of these statements about the environment and environmental properties is FALSE?

    A. The environment in a chess game is deterministic
    B. For a card game in which each player draws one card in each round and the player drawing the highest card is declared the winner of the round, the environment is episodic
    C. The environment through which a space probe travels is dynamic
    D. None of the above (i.e. A, B and C are all true statements) << Answer

15. The government's Christmas guidance for university students includes the following statement: "Universities should move learning online by 9 December so students can continue their education while also having the option to return home to study from there."
    Provide a normative representation (norm type, subject, object, antecedent, consequent) for the above-mentioned Christmas guidance statement.

    A. Authorization(Government, University, CurrentDate > 9 Dec 2020, Move-Learning-Online)
    B. Commitment(University, Student, True, Move-Learning-Online)
    C. Commitment(Student, University, CurrentDate > 9 Dec 2020, Move-Learning-Online)
    D. Commitment(University, Student, CurrentDate > 9 Dec 2020, Move-Learning-Online) << Answer

END OF PART I

Part II – Answer TWO of the three questions. Each is worth 15 Marks.

II.1 Logic Programming

You are given the following Prolog program, which aims to characterise the parity of natural numbers represented in Peano notation - where successive integers are denoted by the terms `0`, `s(0)`, `s(s(0))`, `s(s(s(0)))`, ….

The program consists of one fact (stating that the number zero is even) and two rules (one stating the double-successor of any even number is also even; and another stating that a number is odd is it is not even) :

```
even(0).
even(s(s(N))) :- even(N).
odd(N) :- \+ even(N).
```

a) Draw an SLD tree for the query `?-odd(s(0)).` This query asks Prolog to verify that the number one is odd. You should assume the default Prolog search strategy and the standard "cut-fail" definition of negation as failure. Clearly state whether the query succeeds or fails.

[3 marks]

The query succeeds, as shown by the following SLD (note that there is no computed answer as the query has no variables – and so Prolog just returns "true", which is the expected answer):

```
?- odd(s(0)).
|
?- \+ even(s(0)).
|
+--------------------------.
|                          |
?- even(s(0)), !, fail.    []
|                          true
#
```

b) Translate the above program into a well-formed formula First-Order Logic (FOL) in which each Prolog symbol is replaced by its closest classical counterpart (make sure your formula is correctly quantified and parenthesised, if necessary).

[3 marks]

```
even(s(0)) ^ ∀N(even(s(s(N))) ← even(N)) ^ ∀N(odd(N) ←¬even(N))
```

c) By reasoning about the structure of the possible SLD trees that result when the predicate `odd/1` is called with ground and variable arguments, respectively, highlight any potential pitfalls that users should be aware of when calling this predicate.

[8 marks]

```
CASE 1 – the argument is a ground term, t

  EITHER t is an even Peano number and the query fails as follows

    ?- odd(t).
    |
    ?- \+ even(t).
    |
    +------------X-------------.
    |                          |
    ?- even(t), !, fail.       []
    |
    :
    |
    ?- !, fail.
    |
    ?- fail.
    |
    #
```

[2 marks]

```
  OR t is not an even Peano number and the query succeeds as follows

    ?- odd(t).
    |
    ?- \+ even(t).
    |
    +--------------------------.
    |                          |
    ?- even(t), !, fail.       []
    |
    :
    |
    #
```

[2 marks]

```
CASE 2 – the argument is a variable and the query fails as follows:

    ?- odd(N).
    |
    ?- \+ even(N).
    |
    +-------X-----------------------------.
    |                                     |
    ?- even(N), !, fail.                  []
    |
    +-------X--------.
N/0 |                | N/s(s(N1))
    |                |
    ?- !, fail.      ?- even(N1), !, fail.
    |                |
    ?- fail.         :
    |                :
    #
```

[2 marks]

CONCLUSION – While the proposed definition of odd/1 works as expected if its argument is a ground Peano number, there two potential pitfalls that users should be aware of (as they are could be considered counter-intuitive): firstly it succeeds for ground terms that are not numbers (e.g. "odd(bogus)" succeeds); and secondly, it fails if its argument is a variable (e.g. "odd(X)" fails).

[2 marks]

d) Write down an alternative definition of `odd/1` whose behaviour is always intuitively correct (irrespective of whether its argument is an input or an output).

[1 mark]

```
?- odd(s(X)) :- even(X).
```

II.2 Genetic Algorithms

Gary is interested in evolving images using a genetic algorithm. Each image is a 50-by-50 grid of coloured pixels. Each genotype is a one-dimensional array of N alleles that each explicitly specify one Red-Green-Blue colour component of one pixel. The colour of one pixel is defined by three consecutive alleles on the genotype, specifying the red, green, and blue components of the pixel's colour, respectively. Each allele can take a floating point value in the legal range [0,1]. The first three alleles in the genotype define the colour of the top-left pixel, the next three alleles define the colour of the pixel immediately to the right of this first pixel. The final triple of alleles defines the colour of the bottom-right pixel in the image.

a) If each allele can take one of 2^16 different values between 0 and 1, how many different images does the search space contain?

[1 mark]

Answer: (2^16)^(50x50x3) = (2^16)^7500 = 65536^7500

b) Gary implements mutation in the following way. Each allele in the genotype of a new offspring image has independent probability m of being mutated. When an allele is mutated, the parental value is perturbed by adding a value drawn uniformly at random from the range [-0.1, +0.1]. If the new, perturbed value is outside the legal range of [0,1] it is truncated to the nearest legal value.

When Gary runs his genetic algorithm, he is interested to see that images with bright bold colours tend to be evolved. Explain how his mutation operator may be contributing to this result.

[4 marks]

Up to 4 marks from: There is a mutation bias in the system [1]. When an RGB component gets close to 1 (or 0) there are more ways for it to be mutated to the value 1 (or 0) than any other value [1], because any mutated value outside the legal range is truncated to this extreme value [1]. Once an allele has the value 0 or 1, its mutation rate is effectively halved since half of the perturbations it could experience will be truncated back to the original value [1]. Extreme RGB values will manifest as bold or bright colours such as red (1,0,0) or yellow (1,1,0) [1]. This mutation bias means we can expect to see bold bright colours over-represented in the population even if all solutions had equal fitness [1].

c) Gary is thinking of implementing sexual recombination. He wants to combine two high fitness parental images to create an offspring. He has considered one-point crossover at a randomly selected position on the genotype, but he isn't convinced that this will be a good choice. Define a simple crossover operator that will take two parental genotypes and create a single offspring genotype. The offspring genotype should comprise a rectangular section of one parent replacing the equivalent part of the image provided by the second parent.

[4 marks]

One possible scheme:

```
offspring = copy(parent2)
pick four random values in the range [0,50): x1, y1, x2, y2
for x in range x1,x2:
  for y in range y1,y2:
    offspring[(50*3*y)+x*3] = parent2[(50*3*y)+x*3]
```

Lose a mark for not picking a random rectangle
Lose a mark for messing up the loop
Lose a mark for not over-writing one parent with values from the other
Lose a mark for forgetting the "*3"

d) Gary is a little disappointed with the results generated by his genetic algorithm. The images in the population tend to be quite similar and it takes a long time to discover interesting images. Gary has been told by Sue that his "direct genotype-phenotype mapping might be too simplistic", but he has not come across this idea before. Help Gary to understand the concept of a genotype-phenotype mapping and explain how a less direct mapping could allow evolution to generate more diverse images more quickly.

[6 marks]

A genotype-phenotype mapping refers to the process of building a phenotype (image) from a genotype (string of floats) [1]. The current mapping is "direct" because every element of the image is explicitly represented as a separate unique allele in the genotype [1]. An alternative is for the genotype to define a recipe with which to build an image [1], e.g., a set of rules to follow, or image processing operators to apply, or a Biomorphs-like system [1]. Whereas a single mutation in the current scheme can only generate a very small change in the image (a change to one RGB component of a single pixel) [1], a small change to a genotype can lead to a big change in the associated image when the genotype-phenotype mapping is less direct [1].

II.3 Multi-Agent Systems

Consider a case in which two students (Grace and Judy) live together in a rented house. They need to agree on which Internet service to sign up for from their local cable company (Example Media Co.). Grace will sign the contract with the cable company and pay for the service but she would like to also sign a side contract with Judy in which Judy agrees to pay her share.

a) List and describe the social norms needed to characterize the interactions in this setting. Use the commitment-based notation to define the identified norms.

[6 marks]

Sample Answer. (Numbers in square bracket indicate marks awarded)

The interactions between Grace, Judy, and Example Media Co. can be captured via two commitment norms:

1) A Commitment between Grace and Example Media Co.: [1]
Grace is committed to Example Media Co. that if Example Media Co. provides Internet service to Grace and Judy's house, Grace will pay for the service for the Internet service. [1]

`C1 = C (Grace, ExampleMedia, InternetService, PaymentForInternet)` [1]

2) A Commitment between Grace and Judy: [1]
Judy is committed to Grace that if Grace makes payment for the Internet service to Example Media Co., Judy will pay Grace her share. [1]

`C2 = C (Judy, Grace, PaymentForInternet, PayShare)` [1]

b) Describe a scenario in which one of these norms is violated. State the relevant event sequence using the notation from your answer to part (a) above. Who is accountable for this norm violation?

[3 marks]

Sample Answer. (Numbers in square bracket indicate marks awarded)

(Recall from the commitment lifecycle, recall that a commitment transitions to a violated state if the antecedent holds but the consequent does not hold.)

C1 will be violated in the case when Example Media Co. provides Internet service to Grace and Judy's house but Grace does not pay the monthly rent as per the contract. [1]

Events leading to violation: `InternetService, ¬PaymentForInternet` [1]

Grace is accountable for this norm violation. [1]

Or

C2 will be violated in the case when Grace pays the monthly rent as per the contract but Judy does not pay Grace her share. [1]

Events leading to violation: `PaymentForInternet, ¬PayShare` [1]

Judy is accountable for this norm violation. [1]

Note: Although not required here, question (b) could also be approached using *commitment operations*. A sample answer using commitment operations to describe violation of C1 is given below.

Note: You *need not use commitment operations, unless the question explicitly requires it*. A question will carry more marks if it requires to use commitment operations.

Sample answer using commitment operations. (Numbers in square bracket indicate marks awarded)

C1 will be violated in the case when Example Media Co. provides Internet service to Grace and Judy's house *but* Grace does not pay the monthly rent as per the contract. [1]

<u>Event sequence *and commitment operations*</u>

```
1. Example Media Co. provides Internet service, i.e., antecedent
   InternetService is True.
      a. DECLARE (ExampleMedia, Grace, InternetService)
      b. InternetService ∧ C(Grace, ExampleMedia, InternetService,
         Payment) => C(Grace, ExampleMedia, T, PaymentForInternet)
      c. C1 transitions to a detached state
2. Grace does not make the payment by the due date
      a. ¬PaymentForInternet
      b. C1 transitions to a violated state
```

Grace is accountable for commitment C1's violation. [1]

c) Grace and Judy graduate. Grace (who signed the contract with the cable company) leaves the city. Judy finds a job in the same city and continues to stay in the same rented house. Judy takes over the contract with Example Media Co. from Grace. Olivia and Alice join Judy as her new house mates. Olivia and Alice sign side contracts with Judy to pay their shares of the cost for the Internet service.

Refine the initial normative specification and produce the new normative specification for the new setting. You should describe the required commitment changes and then use (some of) the ASSIGN, CANCEL, CREATE, DECLARE, DELEGATE and RELEASE commitment operations to define the required refinement process.

[6 marks]

Hint: The new normative specification can be captured by three commitments: (1) between Judy and Example Media Co., (2) between Judy and Olivia, and (3) between Judy and Alice.

Sample Answer. (Numbers in square bracket indicate marks awarded)

To arrive at the new specification, Grace needs to delegate her commitment C1 toward Example Media Co. to Judy [1]. She also needs to release Judy from her previous commitment C2 on paying her share of the Internet service payment [1]. Additionally, new commitments to pay their share of the cost need to be created between Judy and Olivia and Judy and Alice [1].

Operations.

Grace performs the DELEGATE operation to delegate her commitment C1 toward Example Media Co. to Judy.

```
DELEGATE(Grace, ExampleMediaCo, Judy, InternetService,
PaymentForInternet)
```
[1]

Grace performs the RELEASE operation to release Judy from her commitment on paying share.

```
RELEASE(Judy, Grace, PaymentForInternet, PayShare)
```
[1]

Olivia and Alice perform the CREATE operation to create a commitment toward Judy that when Judy makes payment for the Internet service, they will each pay Judy their share.

```
CREATE(Olivia, Judy, PaymentForInternet, PayShare)
CREATE(Alice, Judy, PaymentForInternet, PayShare)
```
[1]

END OF EXAM