Module Code
COM00020I

BSc, BEng, MEng and MMath Degree Examinations 2020–21

Department Computer Science

Title Intelligent Systems 1

Time Allowed 24 Hours (NOTE: Late papers will not be marked)

Time Recommended TWO hours

Word Limit Where applicable, word limits are indicated within individual questions.

Allocation of Marks:

There are **five** questions. Each question is worth **20 marks**.

Instructions:

Answer **all** questions.

Submit your answers to the Department's Teaching Portal as a single PDF file.

If a question is unclear, answer the question as best you can, and note the assumptions you have made to allow you to proceed.

Do not use colour: use black-on-white only, unless otherwise instructed.

Start each top-level question on a new page.

A Note on Academic Integrity

We are treating this online examination as a time-limited open assessment, and you are therefore permitted to refer to written and online materials to aid you in your answers.

However, you must ensure that the work you submit is entirely your own, and for the whole time the assessment is live you must not:

- communicate with departmental staff on the topic of the assessment
- communicate with other students on the topic of this assessment
- seek assistance with the assignment from the academic and/or disability support services, such as the Writing and Language Skills Centre, Maths Skills Centre and/or Disability Services. (The only exception to this will be for those students who have been recommended an exam support worker in a Student Support Plan. If this applies to you, you are advised to contact Disability Services as soon as possible to discuss the necessary arrangements.)
- seek advice or contribution from any third party, including proofreaders, online fora, friends, or family members.

We expect, and trust, that all our students will seek to maintain the integrity of the assessment, and of their award, through ensuring that these instructions are strictly followed. Failure to adhere to these requirements will be considered a breach of the Academic Misconduct regulations, where the offences of plagiarism, breach/cheating, collusion and commissioning are relevant: see AM1.2.1 *(Note this supercedes Section 7.3 of the Guide to Assessment)*.

1 (20 marks) Consider the graph shown in fig. 1

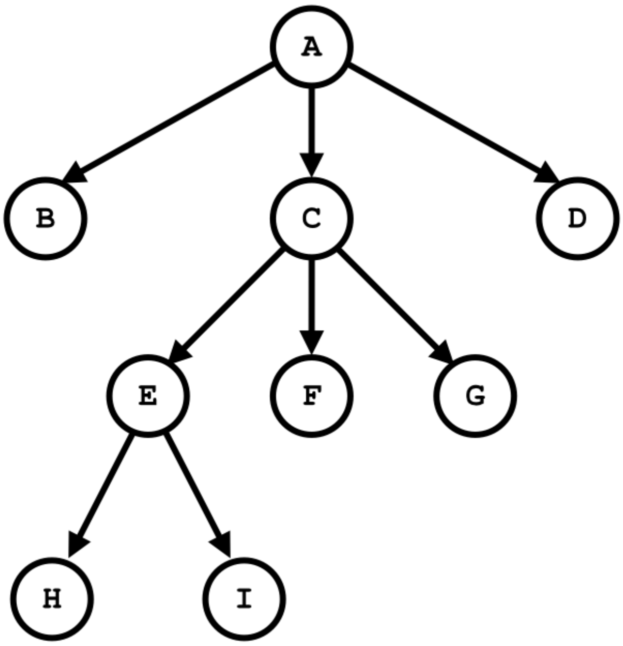

Figure 1: Graph for question 1.

(i) [16 marks] Write down the full list of visited nodes (in order) when searching the graph in fig. 1 using the following algorithms. Where the algorithm does not define the order explicitly, the nodes should be visited in alphabetical order.

(a) [4 marks] Breadth-first search

(b) [4 marks] Depth-first search

(c) [4 marks] Depth-limited depth-first search with limit 2 (N.B. the root node is at depth 0)

(d) [4 marks] Iterative-deepening depth-first search

(ii) [4 marks] Suppose you are using depth-first search, and have just visited node C. Give the data structure that represents the fringe, along with the ordered contents of that data structure. Clearly state to where you add new nodes, and from where you remove nodes.

2 (20 marks) Consider the following puzzle, depicted in fig. 2, commonly referred to as the *Towers of Hanoi*:

> The generic *Towers of Hanoi* puzzle consists of n poles, P_1 to P_n, and m disks with sizes D_1 to D_m, and disks can be moved between poles. The object of the puzzle is to move all disks from the left-most pole to the right-most pole in as few moves as possible. For any two disks D_i and D_{i+1}, $D_i > D_{i+1}$ for all D. As such, D_1 is the largest disk, and D_m is the smallest. All m disks start on the left-most pole P_1, and must all be moved to the right-most pole P_n. No disk may be placed on top of a smaller disk at any time. Only one disk (the top-most) may be removed from a pole at any time, and must be placed back on a pole before any other disk is removed.

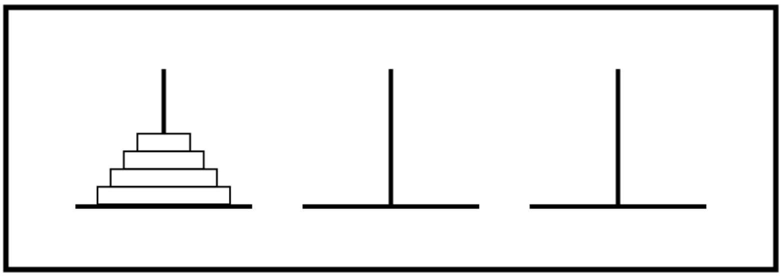

Figure 2: Diagram showing the starting state for the 3-pole, 4-disk variant of the Towers of Hanoi problem.

(i) [10 marks] Define a problem representation for the generic n-pole, m-disk variant of the puzzle. Recall that a problem representation consists of a state representation, initial state, goal test, successor function, and path cost.

(ii) [2 marks] Which uninformed search algorithm is best for this problem? Why?

(iii) [3 marks] Suppose I decide to use A* search for this problem, define an admissible heuristic function that directly references some part of the problem representation (i.e. you cannot just specify $h(n) = 0$). Note that this does not need to be a **good** heuristic, just needs to be an *admissible* heuristic for the problem.

(iv) [5 marks] Show that your heuristic function is admissible.

3 (20 marks) This question is about local search algorithms

(i) [12 marks] Consider the following equation, $f(x)$:

$$f(x) = x^2 + 4$$

In order to minimise $f(x)$, you decide to apply the *gradient descent* algorithm with starting value $x = 0.1$. Calculate the next **three** values of x from the gradient descent algorithm if you use a learning rate of $\eta = 0.05$.

(ii) [4 marks] What problem might you encounter if you increased the learning rate η? Briefly explain your answer.

(iii) [4 marks] If I decide to re-run the above gradient descent algorithm multiple times with different initial x values, should I expect to see a different final value of x each time? Briefly explain your answer.

4 (20 marks)

(i) [12 marks] Consider the following logical sentence, L:

$$(a \Leftrightarrow b) \wedge (c \Leftrightarrow \neg a)$$

(a) [4 marks] Rewrite L into conjunctive normal form (CNF).

(b) [8 marks] Show that L is satisfiable by applying the DPLL algorithm. Show your working.

(ii) [3 marks] Suppose I am using the DPLL algorithm to solve a (different) SAT problem, and it fails to find a satisfiable model. Should I try using WalkSAT instead? Give a reason for your answer.

(iii) [5 marks] Briefly, and in your own words, describe the relationship between SAT solving and local search. Word limit: 50 words.

5 (20 marks) Consider the following scenario, S:

> I have a rule that no cats are allowed to walk on any tables. My dining-room table has paw prints on it, all of which are from a cat. The only way paw prints can get on a table is by a pet walking on it. All of my pets leave paw prints when they walk. Of all my pets, I only have one cat and she is called Pixel.

(i) [10 marks] Represent S in first-order logic.

(ii) [10 marks] Consider the following statement, P:

> Pixel has broken my rule.

Using your representation of S, apply *backward chaining* to infer the truth about P. Make sure you show the inference tree and final substitutions.

End of examination paper