A36326

Calculators may be used in this examination provided they are not capable of being used to store alphabetical information other than hexadecimal numbers

UNIVERSITY OF BIRMINGHAM

School of Computer Science

Third Year Undergraduate

06-35310

LH Evolutionary Computation

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions.

Question 1

As a manager of a courier services company, you are planning to build new depots to cover an area with seven towns, denoted as A, B, C, D, E, F, and G. Each depot covers a specific set of towns, and its construction cost is also estimated:

- Depot 1: Covers A, B, C; costs $£5m$
- Depot 2: Covers B, D; costs $£3m$
- Depot 3: Covers C, E, F; costs $£4m$
- Depot 4: Covers D, E, G; costs $£6m$
- Depot 5: Covers A, F, G; costs $£2m$

Your objective is to build a set of depots to serve all the seven towns while minimising the total construction costs. Due to the high demand in town C, it must be served by at least two depots to ensure timely deliveries even if one depot is temporarily unavailable.

(a) Discuss how you formulate the problem as a constrained set cover problem.

[11 marks]

(b) Describe how to design a Genetic Algorithm (GA) to find an optimal solution (not necessarily the global optimum) to this problem. In your answer, explain your choices for the representation scheme, genetic operators (crossover and mutation), selection scheme, and constraint-handling method, and justify these choices.

[8 marks]

(c) Based on your design, provide a simplified example of one generation of your GA. Start with a population of four random individuals (solutions) (e.g., Individual 1: Depots 1 and 3, Individual 2: Depots 2 and 4, etc.). Then, select two individuals and demonstrate how your crossover and mutation operators would work to produce offspring for the next generation.

[7 marks]

(d) Discuss the advantages and disadvantages of using a GA in comparison with Simulated Annealing for solving this kind of constrained set cover problem.

[7 marks]

Question 2

As a manager of a courier services company, you are planning efficient routes for two vehicles to deliver packages from one depot to five customers, denoted as A, B, C, D and E. Each vehicle can carry packages for all customers (i.e., no capacity constraint) but must return back to the depot after delivery. Your goal is to minimise the total distance travelled by the two vehicles while ensuring that all customers are served. You decide to use Simulated Annealing (SA) to find an optimal solution (not necessarily the global optimum) to this problem. Answer the following question.

(a) Read the pseudocode in Table 1, and explain what is the main intuition behind Simulated Annealing. Based on the intuition, write down the function $P(e, e_{new}, T)$.

[8 marks]

$x := x_0$; $e := f(x)$ // x_0: initial solution; $f(x)$: objective function
$x_{best} := x$; // Initial "best" solution
$k := 0$
while $(k < k_{max})$
    $T := temperature(t_0)$ // Temperature calculation.
    $x_{new} := neighbour(x)$ // Pick some neighbour.
    $e_{new} := f(x_{new})$ // Compute its objective function value.
    if $P(e, e_{new}, T) > R(0, 1)$ then // Should we move to it?
        $x := x_{new}$; $e := e_{new}$ // Yes, change state.
    if $e_{new} < e_{best}$ then // Is this a new best?
        $x_{best} := x_{new}$; $e_{best} := e_{new}$ // Save as 'best found'.
    $k := k + 1$
Output x_{best}

Table 1: Pseudocode of Simulated Annealing algorithm for minimisation.

(b) Describe how to represent a possible solution of the routes for the two vehicles? Provide an example.

[9 marks]

(c) Describe how to generate immediate neighbour solutions? Provide an example.

[5 marks]

(d) Explain the role of temperature in the SA algorithm and how to design the temperature calculation function $temperature(t_0)$.

[6 marks]

(e) The company now needs to consider the maximum capacity of each vehicle. Discuss how you need to adapt your SA design to handle these additional constraints.

[6 marks]

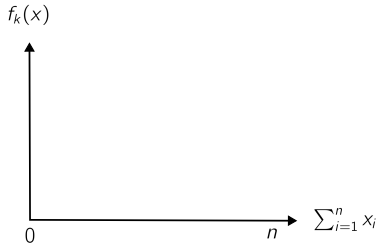
Question 3

(a) For any constant $k \in \mathbb{N}$, the fitness function f_k over the set of bitstrings of length n is defined by

$$f_k(x) := \begin{cases} n - \sum_{i=1}^{n} x_i & \text{if } n - k \leq \sum_{i=1}^{n} x_i < n, \text{ and} \\ \sum_{i=1}^{n} x_i & \text{otherwise.} \end{cases}$$

Here, x_i denotes the i-th bit in bitstring x and $\sum_{i=1}^{n} x_i$ is the number of 1-bits in x.

Complete the figure below by drawing a graph of the fitness $f_k(x)$ against the number of 1-bits in x. Assume that $k = 5$ and $n = 100$.



[6 marks]

(b) Explain why the function f_k may be difficult to optimise for evolutionary algorithms. When parameter k increases, does the function become easier or harder to optimise? Justify your answer.

[8 marks]

(c) Briefly state the artificial fitness levels method from runtime analysis.

[6 marks]

(d) What is the expected runtime of the (1+1) EA on f_k? You can assume that the parameter k is a constant, $k \geq 2$. Show your proof.

[13 marks]

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Do not complete the attendance slip, fill in the front of the answer book or turn over the question paper until you are told to do so

Important Reminders

- Coats/outwear should be placed in the designated area.
- Unauthorised materials (e.g. notes or Tippex) must be placed in the designated area.
- Check that you do not have any unauthorised materials with you (e.g. in your pockets, pencil case).
- Mobile phones and smart watches **must** be switched off and placed in the designated area or under your desk. They must not be left on your person or in your pockets.
- You are not permitted to use a mobile phone as a clock. If you have difficulty seeing a clock, please alert an Invigilator.
- You are not permitted to have writing on your hand, arm or other body part.
- Check that you do not have writing on your hand, arm or other body part – if you do, you must inform an Invigilator immediately
- Alert an Invigilator immediately if you find any unauthorised item upon you during the examination.

Any students found with non-permitted items upon their person during the examination, or who fail to comply with Examination rules may be subject to Student Conduct procedures.