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

Evolutionary Computation

Main Summer Examinations 2024

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions. Each question will be marked out of 20. The paper will be marked out of 60, which will be rescaled to a mark out of 100.

Question 1

We are going to invest $\pounds 10,000$ in three non-dividend paying stocks, S_i, $i = 1, 2, 3$ for a one year period. Our analysis shows that these three stocks will generate r_1, r_2 and r_3 returns, respectively. For example, if you invest $\pounds 1$ in S_1, you will get $\pounds r_1$ as return. We also estimate that the risk, i.e., the probability of losing your investment for each stock is p_1, p_2 and p_3. As a rational investor, our task is to invest our $\pounds 10,000$ in these three stocks, with an aim to minimise the chance of losing money, while expecting our total return will be no less than $\pounds 500$.

(a) Formulate the task as a constrained optimisation problem. Our decision variables are x_i , i = 1, 2, 3, denoting the pounds invested in S_i.

[5 marks]

(b) Answer the following question on the design an evolutionary algorithm for solving the constrained optimisation problem:

(i) Describe a suitable chromosome representation of an individual. Justify your answer.

[5 marks]

(ii) Design evolutionary operators based on your chromosome representation. Use example to illustrate how they work.

[5 marks]

(iii) Describe a constraint handling technique you would use. Discuss the pros and cons of the method.

[5 marks]

Question 2

(a) State the definition of Pareto dominance in multi-objective optimisation. Give two objective vectors $\mathbf{x} \in \mathbb{R}^3$ and $\mathbf{y} \in \mathbb{R}^3$ such that $\mathbf{x}$ Pareto dominates $\mathbf{y}$.

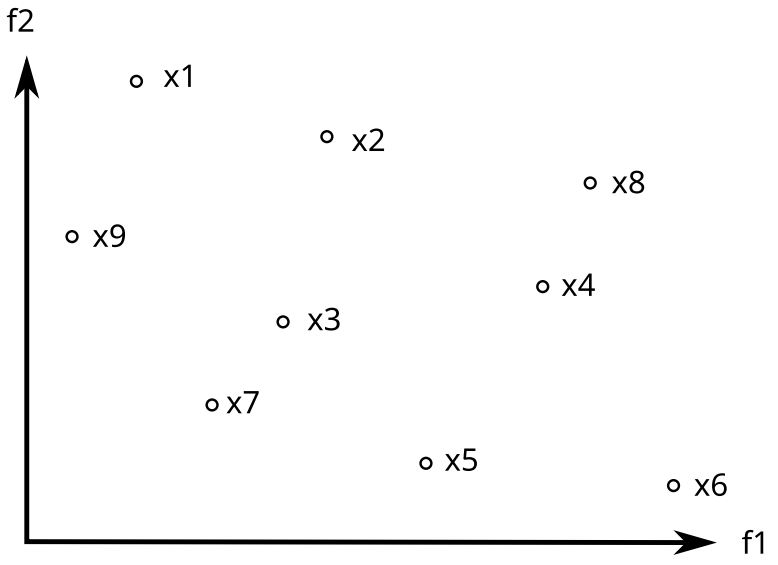
[6 marks]

(b) The figure below shows the values of 9 search points according to objective function f_1 and objective function f_2.

(i) Assume that both objective f_1 and objective f_2 should be maximised. Which of the nine solutions are non-dominated?

(ii) Assume that objective f_1 should be maximised, but objective f_2 should be minimised. Which of the nine solutions are non-dominated?

(iii) Assume that both objectives should be minimised. Which of the nine solutions are non-dominated?



[6 marks]

(c) Suppose "crowding distance" was removed from NSGA-II. What effect would you expect to see on the set of solutions returned by the algorithm?

[8 marks]

Question 3

(a) State the No Free Lunch theorem and explain briefly what the theorem means.

[4 marks]

(b) How realistic are the assumptions of the No Free Lunch theorem for real-world optimisation problems? Justify your answer.

[4 marks]

(c) What is the difference between convergence and time-complexity in the context of evolutionary algorithms?

[4 marks]

(d) Suppose the (1+1) EA is initialised with the current search point at the all-zeroes bitstring. Also, assume that the fitness of the all-zeroes bitstring is n, the fitness of the all-ones bitstring is $n + 1$, and the fitness of all other search points is less than n. What is the expected optimisation time of the (1+1) EA?

[8 marks]

End of Paper

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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.