A31669 *No calculator permitted in this examination*

UNIVERSITY OF BIRMINGHAM

School of Computer Science

Third Year - BSc Artificial Intelligence and Computer Science
Third Year - BEng Computer Systems Engineering
Third Year - MEng Computer Systems Engineering
Third Year - BSc Computer Science
Third Year - MSci Computer Science
Third Year - MEng Computer Science/Software Engineering
Fourth Year - MSci Mathematics + Computer Science
Third Year - BEng Computer Systems Engineering w Business Management
Fourth Year - BSc Computer Science w Study Abroad
Fourth Year - BSc Mathematics + Computer Science w Industrial Year
Fourth Year - BSc Computer Science w Industrial Year
MEng Comp Science/Software Engineering w Industrial Year
Third Year - MSci Computer Science w Industrial Year
Third Year - BEng Computer Systems Engineering w Industrial Year
Third Year - MEng Computer Systems Engineering w Industrial Year

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Nature-Inspired Search and Optimisation

Main Summer Examinations 2018

Time allowed: 01:30

[Answer ALL Questions]

Each question will be marked out of 24. Up to 20 marks will be awarded for content, with up to 4 additional marks for the quality, coherence, and clarity of your answer. The examination will be marked out of 72, which will be rescaled to a mark out of 100.

Answer ALL questions (3 in total). Each question will be marked out of 24. Up to 20 marks will be awarded for content, with up to 4 additional marks for the quality, coherence, and clarity of your answer. The examination will be marked out of 72, which will be rescaled to a mark out of 100.

1. (a) State the pseudo-code of a genetic algorithm.

[8 marks]

(b) What is the difference between a local and a global mutation operator? State one reason why global mutation is often preferred over local mutation. What is the probability that the global mutation operator flips exactly one bit, assuming mutation rate p_m and chromosome length n?

[6 marks]

(c) Consider two bitstrings x and z, each of of length n, as shown in the figure below. I.e., the bit-strings differ in the first $a + b$ positions, and they are equal in the last $c + d$ positions. Assume that bitstring y is obtained by applying the uniform crossover operator on the result of applying the global mutation operator with mutation rate p_m to bitstrings x and bitstring y separately, i.e.,

$$y = \texttt{crossover}(\texttt{mutation}(x), \texttt{mutation}(z))$$

What is the expected number of 1-bits in bitstring y?

	a	b	c	d
x	00...000	11...111	00...000	11...111
z	11...111	00...000	00...000	11...111

[6 marks]

2. (a) What is meant by step-size in continuous optimisation? Why is it important to adapt the step-size in continuous optimisation?

[8 marks]

(b) What is the advantage of using the normal distribution for mutation in continuous optimisation, rather than the uniform distribution?

[6 marks]

(c) Explain each line in the following pseudo-code.

Algorithm 1 CMA-ES

1: Initialise $m \in \mathbb{R}^n$, and $C = I$
2: Set $\sigma = 1$, learning rate $c_{cov} \approx 2/n^2$
3: **while** not terminate **do**
4: **for** $i = 1$ to λ **do**
5: $x_i = m + \sigma y_i \quad y_i \sim \mathcal{N}_i(0, C)$
6: **end for**
7: $m \leftarrow m + \sigma y_w$ where $y_w = \sum_{i=1}^{\mu} w_i y_{i:\lambda}$
8: $C \leftarrow (1 - c_{cov})C + c_{cov}\mu_W y_w y_w^{\mathsf{T}}$ where $\mu_w = \frac{1}{\sum_{i=1}^{\mu} w_i^2} \geq 1$
9: **end while**

[6 marks]

3. (a) What is the difference between single-objective and multi-objective optimisation? Give an example of a multi-objective optimisation problem. State the name of one multi-objective evolutionary algorithm (MOEA).

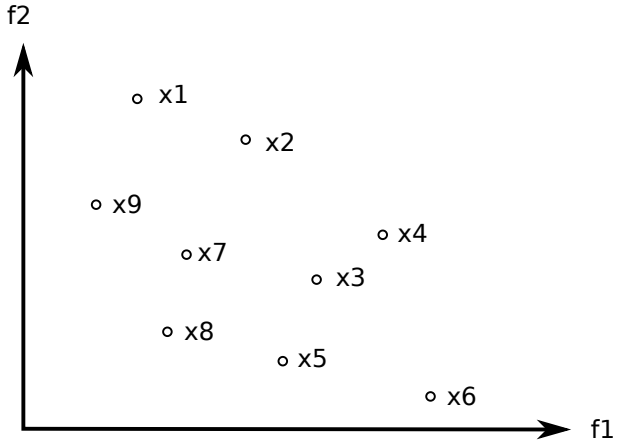
[8 marks]

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

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



[6 marks]

(c) Non-dominated sorting is one of the main steps in NSGA-II.

(i) What is the time-complexity of this operation, assuming M objectives and N search points?

(ii) Apply non-dominated sorting of the population from the figure in question 3 (b), assuming that both objectives should be maximised.

[6 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

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- 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.

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