Department of Engineering/Informatics, King's College London
Nature-Inspired Learning Algorithms (7CCSMBIM)
Assignment 2

This coursework is assessed. A type-written report needs to be submitted online through KEATS by the deadline specified on the module's KEATS webpage.

In the following questions, $s_1s_2s_3s_4s_5s_6s_7$ denotes the first 7- digits of your student ID. Please write down your **student ID**. Show the steps in your calculations when you answer the questions (As an example, you may refer to the solutions of tutorial questions).

Q1. Explain how *tournament selection* works in the selection process of the *binary genetic algorithm* with an example.

[5 Marks]

Q2. The binary genetic algorithm with $N_{keep} = 0$ and $\mu = 0.1$ is employed to minimise the function $f(x, y) = xy$. The representation of chromosome is $[x, y]$ where $10 \leq x \leq (10 + s_1 + s_2 + s_3)$ and $-5 \leq y \leq (-5 + s_4 + s_5 + s_6)$. Each decision variable is represented by a 4-bit binary string. The initial population is given in Table 1.

Chromosome
10001100
01101011
01111010
01010100

Table 1: Initial population in Q2.

a. Obtain the probability table for cost weighting selection.

[25 Marks]

b. Considering a random number generator that a sequence of random numbers {0.7, 0.2, 0.8, 0.6, 0.9, 0.2, 0.1} (the left most number is generated first) is generated, which two chromosomes will be selected as parents to undergo crossover?

[5 Marks]

c. Based on the selected parents in Q2.b, obtain the offspring when double-point crossover is employed where the first crossover point is after the 3$^{\text{rd}}$ and the second crossover point is before the 7$^{\text{th}}$ bit of the chromosome.

[5 Marks]

d. How many bits in the population will be mutated if elitism is **NOT** implemented?

[5 Marks]

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Q3. The *binary genetic algorithm* is used to maximise the function $f(x,y) = (x-y)^2$ subject to a constraint that $x \geq 10y$.

a. Formulate as minimisation problem and determine the penalised cost function.

[10 Marks]

b. Considering that $5 \leq x \leq 5 + (s_1 + s_2 + s_3)$ and $-10 \leq y \leq 10 + (s_4 + s_5)(s_6 + s_7)$, determine the number of bits for each variable such that a precision of 2 decimal places is achieved. Determine the representation of chromosome and the total number of bits of it.

[10 Marks]

Q4. $(1+1)$-ES and $(1,1)$-ES are employed to minimise the function $f(x_1, x_2) = x_1 - x_2$. The mutation process is given as below:

$$\text{Offspring: } x_j^{'}(t) = x_j(t) + \sigma_j(t) N_j, j = 1, 2,$$

$$\text{Strategy parameter: } \sigma_j^{'}(t) = 0.5\left(1 + \frac{s_1 + s_2}{s_1 + s_2 + s_3}\right)\sigma_j(t), j = 1, 2,$$

where t denotes the generation number, $N_j = j(3-j)$ for all t. Assuming $x_1(t) = 2$, $x_2(t) = -1$, $\sigma_1(t) = 0.1$ and $\sigma_2(t) = 0.3$ at the t^{th} generation, determine the population and strategy parameter at the next generation for both $(1+1)$-ES and $(1,1)$-ES.

[20 Marks]

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Q5. A graph of 5 nodes is shown in Figure 1. The information of the edge distance (d_{ij}) and pheromone concentration ($\tau_{ij}(t)$) at the t^{th} generation is given along each edge in the format of "$d_{ij}, \tau_{ij}(t)$". The *Simple Ant Colony Optimisation* with 2 ants is employed to find the shortest path from source node 1 to destination node 5. Each node is allowed to be visited once.

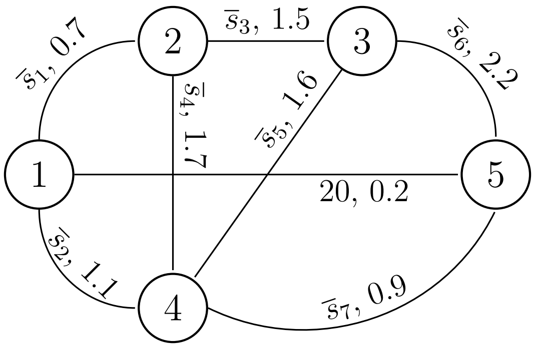

Figure 1: A graph of 5 nodes. $\bar{s}_i = s_i + 1$ for all i.

a. Determine the cost $f(x^k(t))$ of two ants: $x^1\{1, 2, 4, 5\}$ and $x^2\{1, 4, 2, 3, 5\}$.

[5 Marks]

b. Based on Q5 a, determine the pheromone concentrations $\tau_{24}(t+1)$ and $\tau_{45}(t+1)$ where the pheromone concentrations are evaporated according to $\tau_{ij}(t) \leftarrow 0.5\left(1 + \frac{s_1+s_2}{s_1+s_2+s_3}\right)\tau_{ij}(t)$

and are updated according to $\tau_{ij}(t+1) = \tau_{ij}(t) + \sum_{k=1}^{2} \Delta\tau_{ij}^k(t)$,

$$\Delta\tau_{ij}^k(t) = \begin{cases} \frac{1}{f(x^k(t))} & \text{if edge } (i,j) \text{ occurs in path } x^k(t), \\ 0 & \text{otherwise.} \end{cases}$$

[10 Marks]

Marking: The learning outcomes of this assignment are that students understand the fundamental concepts and working principle of various biologically inspired methods and are able to apply them to solve numerical questions. The assessment will look into the knowledge and understanding on the topics. When answering the questions, show/explain/describe clearly the steps and concepts with reference to the equations/theory/algorithms (stated in the lecture slides).

Purposes of Assignment: The purpose of this assignment is to recall and reinforce the algorithms learnt from lectures and apply them on some numerical problems. After doing this assignment, students should get better ideas how each algorithm work.

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