Exam Evolutionary Computing
23. 10. 2015

NOTES:

1. YOUR NAME MUST BE WRITTEN ON EACH SHEET IN CAPITALS.
2. Answer the questions in English.
3. Points to be collected: 90, free gift: 10 points, maximum total: 100 points.
4. Grade: total number of points divided by 10.
5. This is a closed book exam (no materials are allowed).

QUESTIONS

1. **(Total = 32pt)** We are to solve a graph 3-coloring problem with evolutionary computing. That is, we have a graph $G = (N, E)$ with $n = |N|$ nodes and $m = |E|$ edges and three colors $\{r, w, b\}$. We define a coloring as an assignment of colors to all nodes. Then the task is to find a coloring such that no neighboring nodes have the same color.

   (a) (2pt) What kind of problem is this, an FOP, a COP, or a CSP?

   We decide to represent a coloring by a vector $x = \langle x_1, \ldots, x_n \rangle \in \{r, w, b\}^n$, where the k-th position belongs to node $k \in N$ and x_k is the color of k. Constraints are denoted as $\{c_1, \ldots, c_m\}$. For each edge $e = (k, l) \in E$ there is a unique constraint c_i such that $c_i(x) = \mathit{true}$ if and only if $x_k \neq x_l$. Furthermore, we use the notation C^k for the set of constraints involving variable x_k (that is, involving the node k). Now we can define two different fitness functions as follows:

   $f_1(x) = \sum_{i=1}^{m} A(x, c_i)$ where

   $$A(x, c_i) = \begin{cases} 1 & \text{if } c_i(x) = \mathit{false} \text{ (i.e., } x \text{ violates } c_i) \\ 0 & \text{otherwise} \end{cases}$$

   and

   $f_2(x) = \sum_{j=1}^{n} B(x, C^j)$ where

   $$B(x, C^j) = \begin{cases} 1 & \text{if } x \text{ violates at least one } c \in C^j \\ 0 & \text{otherwise} \end{cases}$$

   (b) (5pt) What does the fitness function f_1 measure in terms of the (colored) graph?

   (c) (5pt) What does the fitness function f_2 measure in terms of the (colored) graph?

   (d) (6pt) Which of these fitness functions is preferable if we want to use a heuristic mutation operator that 'fixes' some errors in a chromosome it is applied to? Give arguments why do you prefer this f.

Using the above representation and either fitness functions specify a suitable EA[1] by

(e) **(2pt)** an appropriate crossover operator,

(f) **(2pt)** an appropriate mutation operator,

(g) **(2pt)** an appropriate selection mechanism,

(h) **(2pt)** an initialization method,

(i) **(2pt)** a stop condition,

(j) **(4pt)** a heuristic mutation operator that tries to 'fix' some errors in a chromosome it is applied to.

2. **(Total = 13pt)**

   (a) **(3 pt)** Give the definition of Order1 crossover. Do not forget to specify the kind of genotypes (i.e., representation) to which it is applicable.

   (b) **(3 pt)** Describe three problems for which this representation and Order1 crossover could be applied.

   (c) **(7 pt)** Show how Order1 crossover works by drawing two parents with at least 9 genes and the child(ren) you obtain by applying Order1 crossover to them.

3. **(Total = 5pt)**

   (a) **(2 pt)** What is the takeover time τ^* of a selection mechanism?

   (b) **(3 pt)** Assume that you use a (μ, λ) Evolution Strategy. How can you calculate the takeover time in general? What is the approximate value of τ^* for μ=15 and λ=100?

4. **(Total = 5pt)** Consider two schemes to perform self-adaptation of the mutation step-sizes. Scheme A is defined by equations 1 and 2.

$$\sigma' = \sigma \cdot e^{\tau \cdot N(0,1)} \tag{1}$$
$$x_i' = x_i + \sigma \cdot N_i(0,1) \tag{2}$$

   Scheme B is defined by equations 3 and 4.

$$\sigma' = \sigma \cdot e^{\tau \cdot N(0,1)} \tag{3}$$
$$x_i' = x_i + \sigma' \cdot N_i(0,1) \tag{4}$$

   Which of these schemes is better? Why?

5. **(Total = 15pt)**

   (a) **(1 pt)** What kind of problems is particle swarm optimisation (PSO) typically applied to?

[1] The EA does not have to be "smart" (efficient). But the operators should be such that a solution can be found.

(b) **(4 pt)** Give the technical summary tableau of a PSO. *Hint: there are 5 items and starting from the second correct answer you can receive a point per good answer.*

Suppose that we are minimising the function $f(x) = x_1 + x_2 - x_3$ where x_i is between [0,1]. The current population has a size of three with the following values:

	$\langle \bar{x_1}, \bar{v_1}, \bar{b_1} \rangle$	$\langle \bar{x_2}, \bar{v_2}, \bar{b_2} \rangle$	$\langle \bar{x_3}, \bar{v_3}, \bar{b_3} \rangle$
$\langle x_{i1}, v_{i1}, b_{i1} \rangle$	⟨ 0.68, -0.10, 0.60 ⟩	⟨ 0.32, 0.67, 0.33 ⟩	⟨ 0.20, -0.6, 0.20 ⟩
$\langle x_{i2}, v_{i2}, b_{i2} \rangle$	⟨ 0.89, 0.35, 0.70 ⟩	⟨ 0.68, -0.38, 0.70 ⟩	⟨ 0.45, 0.3, 0.40 ⟩
$\langle x_{i2}, v_{i2}, b_{i3} \rangle$	⟨ 0.04, 0.30, 0.12 ⟩	⟨ 0.32, -0.18, 0.13 ⟩	⟨ 0.15, 0.2, 0.50 ⟩

(c) **(5 pt)** How do you calculate the new velocity vector for individual 1 ($\bar{v_1'}$)? Calculate this vector with the values that you have. Leave the variables whose values you do not know uninstantiated (i.e., use them as variables).

(d) **(5 pt)** Suppose the new velocity vector for individual 1 looks like $\langle v'_{11}, v'_{12}, v'_{13} \rangle$ = ⟨ -0.08, -0.29, 0.06 ⟩. What does the first individual of the next generation look like?

6. **(Total = 15pt)**

   (a) **(6 pt)** Name three properties that make fitness functions in evolutionary robotics different from those in regular EAs for optimization. Explain the differences.

   (b) **(3 pt)** What is on-line evolution in evolutionary robotics?

   (c) **(6 pt)** What is the difference between encapsulated and distributed on-line evolution? For each approach, name at least one advantage and disadvantage.

7. **(Total = 5pt)** Consider the following statement:

   'The No Free Lunch Theorem implies that it is useless to compare different evolutionary algorithms.'

   Is this statement correct or not? Give arguments.