Exam Evolutionary Computing
15.12.2008

NOTES:

1. Your name must be written on each sheet in CAPITALS.
2. You can answer the questions in English or in Dutch.
3. Points to be collected: 90, free gift: 10 points, maximum total: 100 points.
4. Grade: total number of points divided by 10.

QUESTIONS

1. 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.
   (2p) What kind of problem is this, an FOP, a COP, or a CSP?

2. 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

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

   (a) **(5p)** What does the fitness function f_1 measure in terms of the (colored) graph?

   (b) **(5p)** What does the fitness function f_2 measure in terms of the (colored) graph?

   (c) **(6p)** Which of these fitness functions is preferable if we want to use a heuristic mutation operator that 'fixes' some errors in a given chromosomes? Give arguments why.

3. Using the above representation and either fitness functions specify an EA suitable[1] for solving the above problem. In particular, give

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

(a) **(2p)** an appropriate crossover operator,

(b) **(2p)** an appropriate mutation operator,

(c) **(2p)** an appropriate selection mechanism,

(d) **(2p)** an initialization method,

(e) **(2p)** a stop condition,

(f) **(4p)** an heuristic mutation operator that tries to 'fix' some errors in a given chromosome.

4. Fitness sharing is a method to adjust the fitness of an individual prior to selection, depending on other individuals in its neighborhood.

   (a) **(2p)** In what direction is will this adjustment act? Will it increase or decrease the fitness?

   (b) **(2p)** How does this adjustment depend on the number of neighbors? More neighbors more change or more neighbors less change?

   (c) **(2p)** How does this adjustment depend on the distance of neighbors? Does a closer neighbor imply more change or less change than a distant neighbor?

   (d) **(6p)** Provide the standard formula that specifies the adjusted fitness $F'(i)$ of an individual i.

5. **(6p)** Consider two schemes to perform self-adaptation of the mutation step-sizes. Scheme A is defined by equations 1 and 2.

$$\sigma' = \sigma \cdot e^{\tau \cdot N(0,1)} \quad (1)$$

$$x_i' = x_i + \sigma \cdot N_i(0,1) \quad (2)$$

   Scheme B is defined by equations 3 and 4.

$$\sigma' = \sigma \cdot e^{\tau \cdot N(0,1)} \quad (3)$$

$$x_i' = x_i + \sigma' \cdot N_i(0,1) \quad (4)$$

   Which of these schemes is better. Why?

6. **(12p)** There are three major options for getting problem instances for experimentation with EAs. Name these options and their (dis)advantages.

7. **(24p)** Make a schematic comparison of the four main EA dialects GA, ES, EP, and GP. (Hint: Compare them along a number of features, e.g., Typical problems, Typical repesentation, Role of recombination, Role of mutation, Parent selection, Survivor selection, Self-adaptation, ect.)

8. **(4p)** Consider the following statement:

   > Evolution Strategies do not suffer from bloat, because they are self-adapting the mutation stepsize.

   Is this statement correct or not? Give arguments.