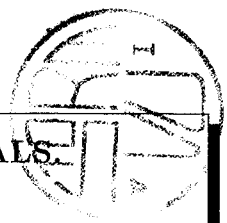
Vrije Universiteit Amsterdam
Exam Evolutionary Computing
23.12.2002



Note 1 Your name must be written on each sheet in CAPITALS.

Note 2 You can answer the questions in English or in Dutch.

Points to be collected: 57.

Your grade: points collected divided by 5.7 and rounded up to the first decimal.

1. We are to solve a so-called 3-satisfiability problem (3-SAT) with evolutionary computing. The short definition of a 3-SAT problem is as follows. We are given a propositional formula in a specific form and we need to decide if it is satisfiable, that is whether there is a truth assignment of its variables that makes the formula true.

   In details: We have n logical variables $p_1, p_2, \ldots, p_n$ (that can be true or false) and a formula given as a conjuntion of clauses, where each clause is a disjuntion of 3 literals. For example, if we have 4 variables, a formula can be $(p_1 \vee \neg p_4 \vee \neg p_2) \wedge (p_3 \vee p_2 \vee \neg p_1) \wedge (p_2 \vee \neg p_1 \vee p_4)$. A truth assignment is the assignment of a truth value (true/false or 1/0) to each variable, e.g., $p_1 = 0, p_2 = 0, p_3 = 0, p_4 = 1$. Any given truth assignment determines the truth value of the formula, in our example the above assignment makes all three clauses true, therefore the whole conjunction is also true. The 3-SAT problem amounts to searching the space of the 2^n possible truth assignments for an assignment that makes each clause and thereby the whole formula true.

   Your task is to specify an EA suitable[1] for solving this problem. In particular, give

   (a) **(4p)** a representation, that is, the syntax of the chromosomes (genotypes) and a mapping between chromosomes and truth assignments (phenotypes),

   (b) **(4p)** a fitness function,

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

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

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

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

   (g) **(2p)** a stop condition.

   (h) **(4p)** Furthermore, discuss whether we can claim that the formula is satisfiable, repectively not satisfiable, based on running our EA. (Hint: distinguish EA runs terminating with a good truth assignment and those that do not.)

2. (a) **(6p)** Name 3 features in which Evolution Strategies and Genetic Algorithms differ.

   (b) **(4p)** Assume you have to solve a continuous parameter optimization problem, i.e., to minimize $f : \mathbb{R}^n \rightarrow \mathbb{R}$. What is your preferred EA to solve it, an ES or GA? Give arguments.

[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.

3. **(6p)** Explain what the No Free Lunch Theorem is.

4. (a) **(2p)** Explain what order-based representation is.
   (b) **(2p)** Sketch a problem that can be well treated by order-based representation.
   (c) **(4p)** Give the description of an order-based crossover operator.
   (d) **(2p)** Give the description of an order-based mutation operator.

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. **(3p)** Consider the following statement:

   'An EA can not work without recombination (or crossover).'

   Is this statement correct or not? Give arguments.