Exam Evolutionary Computing
17.12.2009

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 working on an Artificial Life project that involves a population of active agents or individuals in a virtual (simulated) arena that contains green blocks and red blocks, spread over the space randomly. Our task is to develop a good controller for the agents, that is, a piece of program code that enables the agents to survive and to perform a specific task. To survive, the agents need to "eat" green blocks and their task is to "collect" red blocks.

   Formally, we are to evolve a controller that 1) takes inputs from the agents' sensors (producing information on the given environment including other agents and the internal state of the given agent) and 2) produces appropriate actions the given agent can perform. In other words, we are looking for a good controller function $cf : I \longrightarrow A$, where I is the space of all possible sensory input vectors and A is the space of all possible actions. NB. Actions may have their own parameters, for instance a **MOVE(d,s)** action, where d is the direction and s is the speed. Hence, the output descriptor may be a vector, similarly to the input descriptor.

   As an example you can think of a simple agent having three input variables, $x \in \{0, 1\}$ belonging the light sensor (1 is light, 0 is dark), $y \in \{0, 1\}$ belonging to the microphone (1 is sound, 0 is silence), $0 \leq z \leq 1$ that specifies the "level of hunger" and four output variables $d \in \{0, 360\}, s \in \{0, 100\}$ specifying the direction and speed of **MOVE**, $e \in \{0, 1\}$, where $e = 1$ means perform the action **EAT**, and $r, g \in \{0, 1\}$ corresponding to the red/green lamps (1 is on, 0 is off).

   We assume that we have a rich set of sensors and actions. Your task is to define an EA suitable[1] for obtaining good controllers. To this end you may make assumptions and add details on the world, the robots, actions available etc, as you wish, as long as they are consistent with the description above.

   Your answer must be formulated through specifying:

   (a) **(5p)** what "dialect" of EAs to use for this problem and why (EP, ES, GA, GP?),

   (b) **(5p)** an appropriate fitness function,

   (c) **(7p)** a representation, that is, the syntax of the chromosomes (genotypes) and a mapping between chromosomes and controllers (phenotypes),

[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.

(d) **(3p)** an appropriate crossover operator,

(e) **(3p)** an appropriate mutation operator,

(f) **(3p)** an appropriate parent selection mechanism,

(g) **(3p)** an appropriate survivor selection mechanism,

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

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

2. (a) **(5p)** Given a multi-objective optimization problem in the k dimensional space $\mathbb{R}^k$ with n objectives $f_1, \ldots, f_n$ to be maximized, what is the definition of dominance between two given candidate solutions?

   (b) **(3p)** What is the Pareto front belonging to this problem?

3. (a) **(9p)** What are free optimization problems (FOP), constraint satisfaction problems (CSP), and constrained optimization problems (COP) and how is a solution of such problems defined?

   (b) **(3p)** What is the essential difficulty of solving CSPs with EAs?

   (c) **(7p)** Consider the 8-queens problem (a CSP as treated during the lectures) and describe a suitable approaches to solve it with EAs. Be specific about what (kind of) constraints this problem has and explain how they are treated by your solution.

4. (a) **(2p)** What is permutation representation?

   (b) **(5p)** Describe how Partially Mapped Crossover works. Illustrate it with an example.

   (c) **(3p)** Describe how Scramble Mutation works. Illustrate it with an example.

5. **(5p)** Consider the following statement:

   Wikipedia is an evolutionary system.

   Is this statement correct or not? Motivate your answer.

6. We have an objective function $f(x)$ and a population of three candidate solutions a, b, c with $f(a) = 2$, $f(b) = 3$, and $f(c) = 5$.

   (a) **(3p)** Calculate the selection probabilities of a, b, c if fitness proportional selection is used. Give your answer in percentages (%).

   (b) **(3p)** Consider $g(x) = f(x) + 10$ and calculate the selection probabilities of a, b, c based on g and fitness proportional selection. Give your answer in percentages (%).

   (c) **(6p)** Calculate the selection probabilities of a, b, c if linear ranking selection is used (with $s = 2$ and assigning rank 1 to the worst individual).

   (d) **(3p)** Which selection mechanism is preferable. Why?