Universiteit Leiden

Exam, Natural Computing, Spring 2013

For Computer Science (including Informatica en Economie) Students

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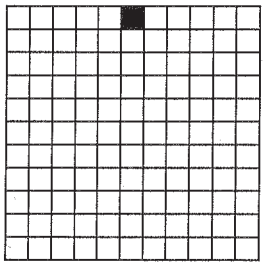
- Please write readable, and write your name and student identification number on every single sheet of paper for unique identification!
- Don't spend much time writing long stories – that's really not necessary. Don't panic! You ARE able to make it!
- Take a look at the whole exam first to get an overview, and do those assignments first which you feel are doable for you.
- Good success and all the best for your studies!

1. (**Natural Computing, total: 6**) To start with, please give a definition of natural computing, i.e., what is natural computing? Name and explain two advantages of natural computing algorithms.

2. (**Cellular Automata, total: 14**) A 1-dimensional cellular automaton with 11 binary states, connected boundaries and initial state is given.

   2.1. **(8)** Assuming a neighbourhood radius r = 1 and assuming that the CA operates using Wolfram rule number 30, simulate the dynamics of the CA for ten time steps by filling in the boxes below:



   2.2. **(6)** Explain the four classes of behaviour of CAs that were introduced in the course. Which class could Wolfram's rule 30 CA belong to? Give reasons for your answer.

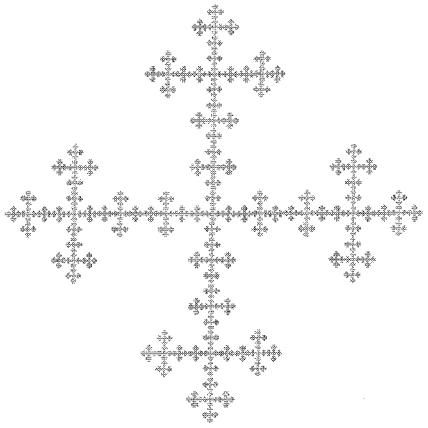
3. (**Simulated Annealing, Evolutionary Algorithms, total: 10**) Compare the working principle of selection in simulated annealing and evolutionary algorithms. In particular, consider selection in SA, (μ,λ)-selection, and proportional selection. What are the similarities and differences? How do these operators address the problem of local optima?

4. (**Simulated Annealing, Evolutionary Algorithms, total: 5**) Assume you want to incorporate concepts from Simulated Annealing into Evolutionary Algorithms. How would you do that? Which concepts would you choose? Why?

5. (**Fractals, Total: 8**) Fractals occur in nature as well as in mathematical abstractions, and we have discussed a few examples in the class.

   5.1. **(3)** Explain the main characteristics of fractals, and explain the difference between a fractal occurring in nature and the mathematical abstraction of a fractal. Give some examples for natural and mathematical fractals.

   5.2. **(5)** The Vicsek fractal, shown below, is a typical example of a mathematical fractal. Calculate the self-similarity dimension of the Vicsek fractal (to one digit after the decimal point). You might find the small table of logarithms useful for calculating the self-similarity dimension. Explain how this dimension is calculated!



n	Log(n)
2	0,301
3	0,477
4	0,602
5	0,699
6	0,778
7	0,845
8	0,903
9	0,954

6. (**Evolutionary Algorithms, total: 10**) Two instances of evolutionary algorithms have been discussed in the class, genetic algorithms and evolutionary strategies.

   6.1. **(5)** Outline the key differences between an evolutionary strategy and a genetic algorithm. Explain what this specifically means for the mutation operator by giving an outline of the simplest mutation operator possible in an evolutionary strategy and contrasting it to the mutation operator used in a genetic algorithm.

   6.2. **(2)** Assume a binary string (0000000000) of length 10 is given in a genetic algorithm. Given a mutation rate p per bit, give an expression for the probability that this string is mutated into the binary string (1010111111).

   6.3. **(3)** For which value of p is this probability, which you just calculated, maximal?

7. (**Artificial Immune Systems, total: 6**) Name and explain two key features of immune systems which are adopted for artificial immune system algorithms (such as, e.g., the clonal selection algorithm).

8. (**Swarm Intelligence, total: 12**) Give some key properties of swarm intelligence. Which algorithmic implementations of swarm intelligence do you know? Give the update rules for one swarm intelligence algorithm of your choice, and explain the algorithm.

Total: 71 Points possible.