HERIOT WATT UNIVERSITY

SCHOOL OF MATHEMATICAL AND COMPUTER SCIENCES

Computer Science

F20BC

BIOLOGICALLY INSPIRED COMPUTATION

Semester 1 2015/16

Duration: Two Hours

ANSWER THREE QUESTIONS

Answer each question in a separate script book

Q1

Calculate the size of the neighbourhood in each of the following cases, and include a brief explanation of your answer.

(a) A candidate solution is a binary string of length *L*. The mutation operator is to choose a random gene position, and then flip its value. (2)

(b) A candidate solution is a ternary string (each value is either 0, 1, or 2) of length *L*. The mutation operator is to change every gene to a random new value (which might be the same as its original value).

(3)

(c) A candidate solution is a string of *L* numbers, each of which can be any integer value from 1 to *k* (inclusive). The mutation operator is to choose two random gene positions, ensuring that the positions are different) and then change each of these two positions to a random new (different) value.

(4)

(d) A candidate solution is a permutation of *L* items. The mutation operator works as follows, with the *L* positions in the candidate solution referred to as P1, P2, …, P*L*: the operator chooses randomly between two operations; 50% of the time, one of the positions *Pk* will be chosen, where *k* is between 1 and *L*–1, and positions P*k* and *Pk*+1 will be swapped. In the remaining 50% of the time, one of the positions *Pk* will be chosen, where *k* is between 1 and *L*−2; inversion will then be applied to the group of positions from P*k* to P*k*+2. (5)

(e) In this case, ensure that your answer gives the number of *different* solutions in the neighbourhood. A candidate solution is a binary string of length *L*, which contains *z* zeroes (*z* may be any integer from 0 to *L*). The mutation operator is to choose two positions at random (ensuring that the positions are different). The bits at these two positions will then be swapped.

(6)

Q2

For each of the following types of encoding: briefly describe the encoding, then describe two example optimization problems that you might solve by using this encoding in the context of an evolutionary algorithm. In each case, for one of your two example problems, explain how the encoding would work, and include a description of the fitness function you might use.

(a) *k*-ary encoding;

(5)

(b) permutation encoding;

(5)

(c) real-number encoding;

(5)

(d) tree-based encoding;

(5)

Q3

(a) Linear genetic programming and grammatical evolution are two different approaches to doing genetic programming.

(i) Describe, briefly, how programs are represented and executed in each of these approaches. (4)

(ii) Explain which of these approaches is most suitable for evolving a program in a high-level language such as C++.

(2)

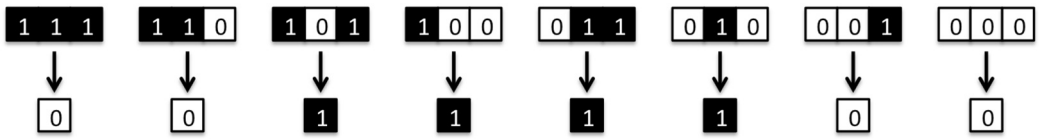
(b) Also in genetic programming, what are the following, and when might they be used?

(i) Automatically defined function (ADF)

(ii) Developmental encoding

(4)

(c) Rule 60 is an elementary cellular automata rule, defined as follows:



(i) Indicate why this is called 'Rule 60'. Then, using Rule 60, complete the space-time diagram shown below by giving the sequence of 0s and 1s that should appear in each of the rows shaded in grey. Note that this cellular automata has periodic boundary conditions.

0	1	0	0	0	0	0	0	0	0
0	1	1	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0	0
0	1	1	1	1	0	0	0	0	0
?	?	?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?	?	?
?	?	?	?	?	?	?	?	?	?

(5)

(ii) Do you think this cellular automata would be useful for carrying out computation? Why do you think this is the case?

(3)

(iii) A Boolean network is an abstract model of gene regulation. In what ways does an elementary cellular automata differ from a Boolean network? (2)

Q4

(a) A biologist wants to use an artificial neural network (ANN) to identify bacteria from a number of characteristics including size, colour and growth behaviour. In order to keep the size of the network down the biologist must use the most parsimonious solution.

Which ANN architecture would you suggest to the biologist? As a designer you will have to decide all the network parameters, such as the number of input nodes, hidden layers (if any) and its respective neurons, output nodes, including the type of connections, weights, biases, type of activation function. Discuss the wisdom of your decisions.

(6)

(b) Enumerate the main advantages of applying evolutionary techniques to train artificial neural networks? What is “evolvability”?

(4)

(c) Write the pseudocode and execution step by step of a Hopfield neural network designed to learn the pattern “0110” (draw all the matrices involved during the execution of the pseudocode both during training and execution).

(6)

(d) Execute the trained network from part (c) to recall the pattern “1001”. Could this network recall the pattern “1001” correctly? Explain why or why not.

(4)

END OF PAPER