HERIOT WATT UNIVERSITY

**SCHOOL OF MATHEMATICAL AND COMPUTER SCIENCES**

**Computer Science**

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**F21BC**

**BIOLOGICALLY INSPIRED COMPUTATION**

Semester 1 2019/20

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**December 2019**

Duration: Two Hours

ANSWER THREE QUESTIONS

Q1

(a) Write the learning and execution step by step for a Hopfield neural network designed to learn the pattern “10110”. You must draw all the matrices involved both during training and execution. You must also explain each step. (10)

(b) (i) Execute the trained network in part (a) to recall the pattern “01001”. You must draw all the matrices involved during the execution of the pseudocode. You must also explain each step. (7)

(ii) Could this network recall the pattern “01001” correctly? Explain why or why not.

(3)

Q2

(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 simple 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 advantages and disadvantages of your decisions.

(10)

(b) In the context of Artificial Neural Networks training and in particular Deep Learning, please answer the following questions:

(i) What is overfitting?

(ii) What is the relationship between overfitting and regularisation?

(iii) Give an example and a brief description of a regularisation technique.

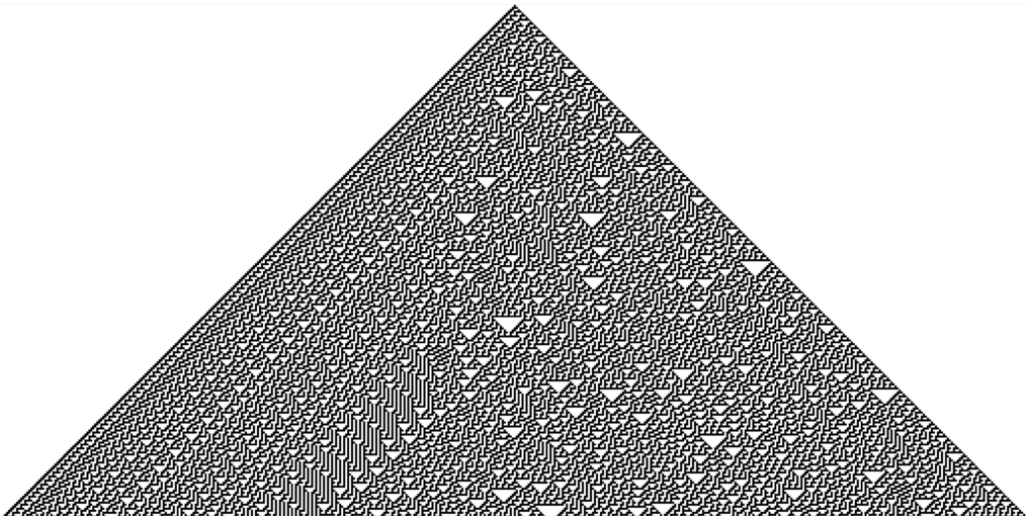
(10)

Q3

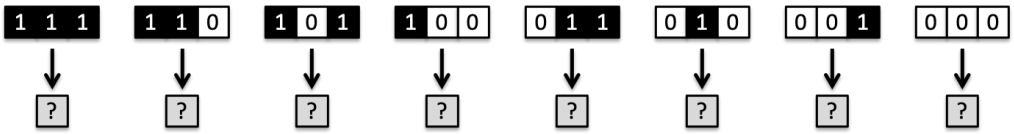
(a) What is a cellular automaton? (4)

(b) Consider the following diagram showing the behaviour of an elementary cellular automaton. The first image shows detail of time steps 0 to 6, and the second image shows its behaviour over a longer time period:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |



Complete the rule table for this cellular automaton, indicating the missing (?) target state (0 or 1) for each transition rule, from left to right:




(4)

(c) Which rule number is this? How do you know this is the case? (2)

(d) Which dynamical regime do you think this cellular automata is operating in. Why do you think this is the case? (2)

(e) In what ways does a Boolean network differ from an elementary cellular automaton? (2)

(f) Cellular automata are one example of *emergence* within biologically-inspired computing. Explain what emergence is. (2)

(g) Emergence also occurs within swarms. Give an example of a swarm computing model where emergence occurs, and explain the emergent behaviour. (4)

Q4

(a) What is genetic programming? (2)

(b) In genetic programming, describe what is meant by the following terms, and explain why they are an issue:

(i) Bloat (3)

(ii) Closure (3)

(c) Traditionally, genetic programming systems use trees as a form of representation. Explain the benefit of using graphs rather than trees, and indicate the name of a genetic programming system that uses graphs. (2)

(d) Traditionally, genetic programming systems do not use standard programming languages to express solutions.

(i) Why is this a problem? (2)

(ii) Describe how grammatical evolution solves this problem. (3)

(e) In what ways does a multiobjective evolutionary algorithm (MOEA) differ from a standard evolutionary algorithm? (3)

(f) How might an MOEA be used to deal with bloat in genetic programming? (2)

**END OF PAPER**