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THE UNIVERSITY
of LIVERPOOL

JANUARY 2002 EXAMINATIONS

Bachelor of Arts : Year 3
Bachelor of Engineering : Year 3
Bachelor of Science : Year 3
Master of Science : Year 1

BIOCOMPUTATION

TIME ALLOWED : Two Hours and a Half

INSTRUCTIONS TO CANDIDATES

Answer ***two*** questions in Section 1
Answer ***two*** question from Section 2
Section 1 is concerned with neural computation and Section 2 with evolutionary computation
Each question is worth 25 marks

If you attempt to answer more than the required number of questions (in any section), the marks awarded for the excess questions will be discarded (starting with your lowest mark).

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SECTION 1

Question 1

1(a) Consider the following statement regarding the origins of neural network research.

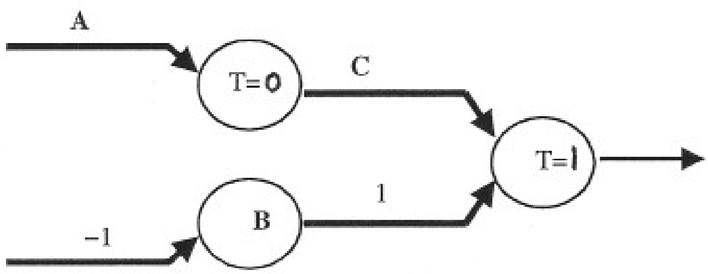
"The 1940s and early 1950s was a time when many initial developments and ideas were put in place regarding neural computation and computational neuroscience".

Discuss this statement with reference to the work of von Neumann, Hebb, Weiner, McCulloch and Pitts, and the Macy Conferences.

[6 marks]

1(b) The diagram in Figure 1 shows a network of McCulloch–Pitts (M–P) neurons that computes a NAND function for 2 inputs. Assign values to the weights (A and C) and the threshold (B).

[3 marks]



1(c) Explain why some have argued that because M–P networks can compute basic logic functions that brains are like digital computers.

[4 marks]

1(d) From your knowledge of the workings of neurones and neuronal systems explain why the previous statement regarding brains as digital computers is seriously flawed. Include in your answer references to named researchers and their contributions to this discussion.

[12 marks]

Question 2

This question is concerned with aspects of the training of a Multi–layered perceptron using Back Error Propagation.

$$A = 1/1+e^{-N} \qquad \text{Equation 1}$$
$$\Delta w_{ji} = \eta \delta_j a_i \qquad \text{Equation 2}$$
$$\delta_j = (t_j - a_j) f'(S_j) \qquad \text{Equation 3}$$

where

- η *is the learning rate*
- w *is the weight between two units*
- e *is the base of the natural logarithm*
- a *is the activation of a unit (specific unit is denoted by a subscript)*
- t *is the target response required by an output unit*

In answering this question credit will be given for appropriate use of diagrams, and reference to specific details of the Back Error Propagation process.

2(a) Equation 1 represents a typical activation function in a Multi–layered perceptron. How does this function differ from a threshold function in a M–P neuron? Explain **why** this difference is so important to the workings of the Back Error Propagation algorithm.

[7 marks]

2(b) With reference to equations 2 and 3, explain how the BEP training algorithm exhibits supervised learning.

[4 marks]

2(c) Explain why it is possible to describe a Multi–layered Perceptron that is trained with Back Error Propagation as a dynamical system that exhibits emergent computation.

[6 marks]

2(d) With reference to the equations above, explain why Hebbian learning is an example of associationism, **and** account for the Hebbian learning process in the BEP training algorithm.

[8 marks]

Question 3

3(a) Give **4** ways in which the architecture, organisation or operation of a Kohonen Self–organising Map (SOM) is different from a Multi–layered Perceptron.

[8 marks]

3(b) What is "competitive learning", **and** how does it feature in a Kohonen SOM?

[6 marks]

3(c) The selection of a particular Artificial Neural Network architecture and training algorithm will depend on the type of problem the network has to solve. With reference to the specific cases of (i) clustering, and (ii) pattern matching, explain why a Kohonen SOM would be appropriate for (i) and a MLP for (ii). Illustrate your answer with reference to the Iris data set and a sensor array (like a retina).

[13 marks]

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SECTION 2

Question 4

4(a) What are the defining characteristics of *complex* systems that makes them more than just *complicated*?

[5 Marks]

4(b) Define the meaning of the term *autocatalysis*. Give two examples of this phenomenon.

[5 Marks]

4(c) Colonies of social insects exhibit complex behaviour. Describe one example of how modelling such behaviours may yield good solutions to a computational problem (for example, routing, task allocation).

[15 marks]

Question 5

This question refers to Adleman's molecular solution to the Hamiltonian Path Problem (HPP), described in *Science,* **266**, pp. 1021–1024 (1994).

5(a) Describe the HPP, giving an example instance and solution.

[3 marks]

5(b) Show how candidate solutions to the HPP may be encoded as strands of DNA.

[7 marks]

5(c) Describe the four main experimental stages of Adleman's experiment.

[10 marks]

5(b) What are the fundamental experimental *and* theoretical limitations of this approach?

[5 Marks]

Question 6

This question refers to Unger and Moult's application of Genetic Algorithms to the problem of protein stucture optimisation, described in the *Journal of Molecular Biology* **231**, pp.75–81 (1993).

6(a) Describe the problem of protein structure optimisation, explaining its practical significance.

[5 marks]

6(b) Describe the simplified hydrophobic/hydrophilic model, and give an example protein conformation within it.

[5 marks]

6(c) Explain the energy function associated with the model and show how its value is calculated for the example conformation you gave for part (b).

[5 marks]

6(d) Show how mutation can improve the fitness of a given conformation.

[5 marks]

6(e) Show how crossover can generate a conformation that is fitter than either of its parents.

[5 marks]