PAPER CODE NO.	EXAMINER : **Dr Ray C Paton**
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JANUARY 2001 EXAMINATIONS

Bachelor of Arts : Year 3
Bachelor of Engineering : Year 3
Bachelor of Science : Year 3
Bachelor of Science : Year 4
Master of Science : Year 1

NEURAL AND EVOLUTIONARY COMPUTATION

TIME ALLOWED : Two Hours AND A Half

INSTRUCTIONS TO CANDIDATES

Credit given for the **BEST** four answers
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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QUESTION 1

Below you will find some short extracts from a research paper. Read the material and then answer the questions at the end.

"The anatomy of a Evolutionary Algorithm is quite simple and yet the genes, chromosomes and genomes which are the biological source structures are highly organised biological systems ... Simple mutations can have complex origins and quite a few 'spontaneous' mutations arise from the juxtaposition (in time) of a number of discrete events ... Some genes remain stable over many generations because if they get damaged there are cellular (enzyme) processes available to it which can correct the dysfunctional changes.

... Baeck discusses results from experiments with genetic algorithms in which mutation rate was changed from a global external parameter into an internal item which changed during the search process (as in an Evolution Strategy). He shows how
preliminary findings confirm the value of appropriate settings of environment-dependent self-adaptation in genetic algorithms and Davidor makes use of a Lamarckian operator to improve machine learning strategies based on genetic algorithms. This suggests an addition to a basic selectionist scheme in which the
environment tests but does not set a genome. If there was a sufficiently robust model of the environment and adaptor-environment interaction it would be possible to specify adaptive strategies. It would then be possible to go further and consider contexts for the occurrence of such interactions and mechanisms which could bring it about ...

Hall noted that some mutations in bacteria occur more frequently when they are advantageous to the cell for example, if the cell is in some way subject to environmentally stressful conditions ... Various mechanisms can account for this. In this sense the environment can be said to "talkback" to the genome. An example of an EA implementation of such a system would be to include operations on bit- or trit- or real number strings which execute the analogue of an enzyme repair system to fix mutated genes. At a simple level certain repairs cannot be made because the chemical materials that are used as building blocks are not available."

Adapted from R. Paton, "Evolutionary Computing at the 'Soggy' End", paper presented to the AISB Workshop on Evolutionary Computation, 1994

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QUESTION 1

1(a) Explain why an Evolutionary Algorithm is an example of a selectionist system.

[5 marks]

1(b) Why is mutation not quite so simple as often portrayed (certainly in many EA designs)?

[4 marks]

1(c) Explain what is meant by mutation rate in a GA being a "global external parameter".

[4 marks]

1(d) What is Lamarckism and explain why a Lamarckian operator in a GA would be non-selectionist ?

[4 marks]

1(e) What would be the effect of 'the analogue of a repair mechanism' on the mutation rate in a GA and suggest how it might be implemented.

[4 marks]

1(f) Explain how 'talk-back' would contravene a wholly selectionist viewpoint**.**

[4 marks]

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QUESTION 2

This question is concerned with multi-layered perceptrons. Study the following equations and then answer the questions.

$$A = 1/1+e^{-N} \qquad \text{Equation 1}$$

$$Dw_{ji} = hd_j a_i \qquad \text{Equation 2}$$

$$d_j = (t_j - a_j)\, f'(S_j) \qquad \text{Equation 3}$$

where

h	*is the learning rate*
w	*is the weight between two units*
e	*is 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*

2(a) Sketch the shape of the curve that satisfies Equation 1 and discuss its nature and occurrence from a selection of scientific subject areas.

[7 marks]

2(b) What is instructivism?

[5 marks]

2(c) Explain the importance of the delta (δ) in Equation 3 to the instructivist nature of a multi-layered perceptron (MLP) training algorithm.

[5 marks]

2(d) From the information in the three equations and your knowledge of training of MLPs, explain how weight adjustments are made in an MLP training algorithm.

[8 marks]

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QUESTION 3

3(a) Explain what is meant by the terms "emergent computation" and "dynamical system"?

[4 marks]

3(b) From your knowledge of Neural and Evolutionary Algorithms, explain why the operation of both may be described as emergent computation within a dynamical system.

[8 marks]

3(c) The rest of this question refers specifically to Multi-layered perceptrons.

The weight matrix for the units between the input and hidden layers of a MLP network (without bias units) was initialised as follows:

0.4	0.2	0.3	0.4	0.6
0.2	-0.3	**4.5**	-0.1	-0.3
-0.3	0.1	0.1	-0.1	0.4
0	0.2	-0.1	-0.3	0.5
0.1	-0.3	0.4	-0.5	-0.2

(i) How many units were in the input layer and how many units were in the hidden layer?

[2 marks]

(ii) **Two** values of this weight matrix are **highlighted** because they do not fit in with the common features of a weight matrix that are expected at initialisation. With reference to the highlighted values, state what these features are and explain their importance.

[6 marks]

(iii) As noted in question 2(c), weight adjustments in a MLP can be made by changing the δ values through an instructivist method. Suggest how a selectionist strategy for producing weight matrices could be implemented.

[5 marks]

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QUESTION 4

4(a) The Iris Data Set, as originally analysed by R A Fisher, is a valuable resource for testing the power of new methods of data analysis.

(i) Describe the nature of the data set and explain why it is of value in testing and comparing adaptive computational methods.

[4 marks]

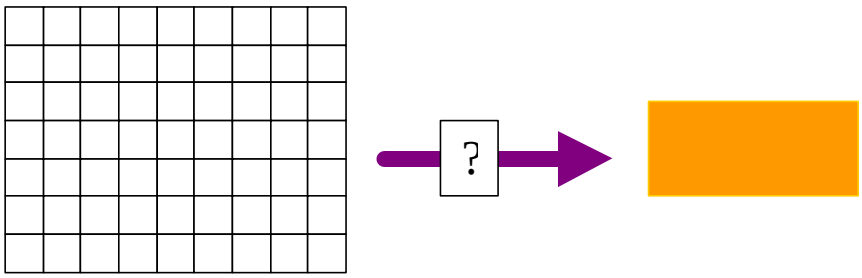
(ii) What are the limitations of reaching general conclusions about a data analysis strategy or technique when based solely on results produced from analysis of the Iris data set?

[4 marks]

(iii) Explain why a Kohonen Self-Organising Map (SOM) method would be more appropraite as a learning system than a MLP in the case of the Iris Data Set.

[4 marks]

4(b) One of the major problems for a designer of a computer system that exhibits some type of learning or adaptation concerns the representation of data with which the system has to deal. Consider the sensor array of 63 units arranged as shown in Figure XX. The box with the question mark is intended to convey the message that some preprocessing may or could take place at this stage.



(i) Discuss some of the ways information from this array could be presented to a Neural Network system that classifies the patterns on the grid into known types.

[8 marks]

(ii) Explain the reasons why a Kohonen SOM could be a better choice of ANN than MLP in this particular case.

[5 marks]

QUESTION 5

5(a) Give the structure of a Genetic Algorithm in pseudocode form. Annotate the code to clarify what is happening.

[6 marks]

5(b) Describe three GA mechanisms that can be used to recruit particular bit strings into the next generation. Discuss the advantages and disadvantages of each of these methods.

[9 marks]

(c) With reference to the work of Sumida and Hamilton, explain how ideas about random drift and spatial isolation of a natural population population could facilitate evolutionary processes in a GA.

[10 marks]

QUESTION 6

6(a) The McCulloch-Pitts (M-P) neuron takes the biological neurone to be the basic unit of information processing in the nervous system. Explain why a M-P neuron is a gross simplification of what is understood of the biological details. Illustrate your answer with appropriate diagrams.

[10 marks]

6(b) With reference to the work of Shepherd and others, give **five** ways current knowledge of the neurobiology of neurones and brains could provide valuable source ideas in the design of ANNs.

[10 marks]

6(c) Explain why it should be appropriate to consider a synapse to be the basic unit of neuronal computation.

[5 marks]