

PAPER CODE NO.
COMP305

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THE UNIVERSITY
of LIVERPOOL

JANUARY EXAMINATIONS 2007

Bachelor of Arts: Year 3
Bachelor of Engineering: Year 3
Bachelor of Science: Year 3
Bachelor of Science: Year 4
Master of Engineering: Year 3
Master of Science: Year 1
No qualification aimed for: Year 1

Biocomputation

TIME ALLOWED: Two Hours and a Half

INSTRUCTIONS TO CANDIDATES

Answer **FOUR** out the following six questions.

If you answer more than four questions, credit will be given for the **BEST** four answers.

Each question is worth 25 marks

1 History and Concepts.

- 1(a) Discuss the remits of biology, bioinformatics, and biology inspired algorithms such as Artificial Neural Networks (ANNs) and Genetic Algorithms (GAs). Draw a diagram to highlight the interactions and influences between biology, biology inspired algorithms, and bioinformatics.

[14 marks]

- 1(b) Why are biology inspired ANNs and GAs now considered part of Computer Science, not Computational Biology?

[4 marks]

- 1(c) Explain what is meant by the *unidirectional influence* of biology onto biology inspired algorithms such as ANNs and Genetic Algorithms? What is the main reason for that point of view?

[7 marks]

2 The McCulloch-Pitts neuron.

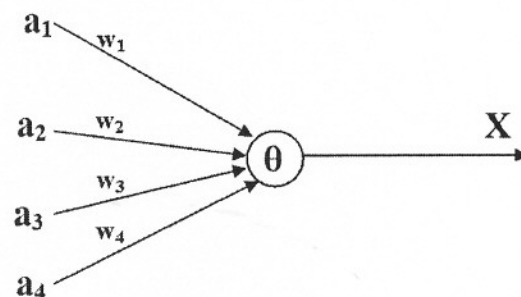
- 2(a) Draw a diagram for the McCulloch-Pitts neuron with inputs, weights of connections, threshold and an output. Why is the MP-neuron called a discrete time machine? What values can the neuron's inputs take? What values are the prohibitory and the excitatory weights of connections in the MP-neuron? What is the role of a prohibitory input in the MP-neuron?

[13 marks]

- 2(b) In electronic computers, a single "AND" or "OR" gate is usually limited to two inputs, i.e. at each instant it can only compute "a AND b", and not "a AND b AND c", for example.

M-P neurons are able to compute conjunctions (logical ANDs) and disjunctions (logical ORs) for more than two inputs.

Consider the following MP-neuron with four inputs:



What should be the weights of input connections w_1 , w_2 , w_3 , w_4 , and the threshold value θ in order to compute

“ a_1 AND a_2 AND a_3 AND a_4 ” .

Explain your answer.

[12 marks]

3 Learning rules of the Artificial Neural Networks. Hebb's Rule.

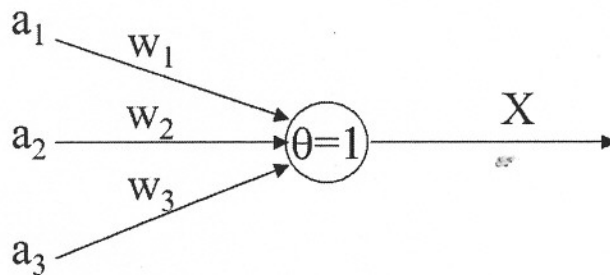
3(a) What is a learning rule of an artificial neural network?

[5 marks]

3(b) Give the simplest mathematical formulation of Hebb's learning rule, *i.e.* how to find out a correction to the weight of a connection according to the instant input and output. Why is the rule called the “activity product rule”? Why does the Hebb's rule represent unsupervised learning?

[11 marks]

3(c) The neural network below uses Hebb's learning rule.



Let the learning rate of the network $C = 0.25$.

At some instant t the network inputs a_1 , a_2 , and a_3 are as shown in the table below

a_1	a_2	a_3	w_1^t	w_2^t	w_3^t	X	Δw_1	Δw_2	Δw_3	w_1^{t+1}	w_2^{t+1}	w_3^{t+1}
1	0	0	1	1	-1							

Complete the table by calculating:

i) The output value X .

[3 marks]

ii) The changes in each of the three weights of the connections, that is, Δw_1 , Δw_2 , and Δw_3 .

[3 marks]

iii) The new weights of connections (w_n^{t+1}).

[3 marks]

4. Supervised learning. Perceptron.

4(a) Describe the two-layer fully interconnected architecture of the Perceptron.

[3 marks]

4(b) Write down the pseudo-code for a Perceptron training, stating how to find:

- a) the instant states of the Perceptron output units,
- b) the instant outputs,
- c) errors of the output units,
- d) corrections to the Perceptron weights of connection
- e) update of the weights of connections.

[15 marks]

4(c) A perceptron can compute only linear separable functions, *i.e.* the functions for which the points of the input space with function value (output) of “0” can be separated from the points with function value of “1” using a line.

On a coordinate plane for inputs a_1 and a_2 , show that the “XOR” gate, see the table below, is a linear *in*separable function. **Explain your answer.**

a_1	a_2	“XOR”
1	1	0
1	0	1
0	1	1
0	0	0

[7 marks]

5. Multilayer Perceptron (MLP).

5(a) What was the main reason to create a Multilayer Perceptron ?

[2 marks]

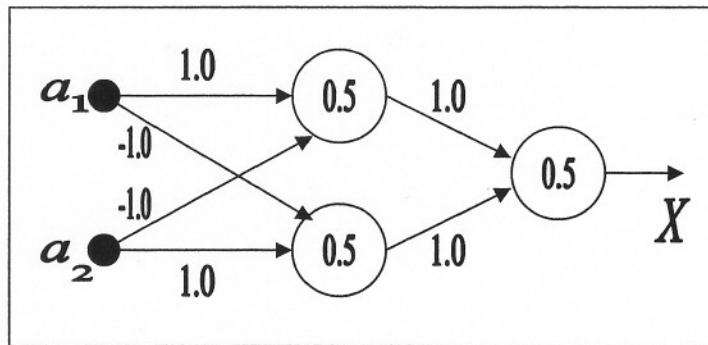
5(b) Describe the layered architecture of MLP with no feedback loops and no connections between units in a layer. What are the input layer, hidden layers, and the output layer?

[7 marks]

- 5(c) Describe the feedforward scheme of input processing in a Multilayer Perceptron.

[6 marks]

- 5(d) The 3-layer network below implements the “XOR” gate. It has weights of connections and thresholds of the processing units as shown on the picture, and uses the *feedforward* scheme to produce an output.



The output unit and both hidden units use the threshold activation step-function

$$X_j^l = f(S_j^l) = \begin{cases} 1, & S_j^l \geq \theta_j^l \\ 0, & S_j^l < \theta_j^l \end{cases}$$

where

$l=h$ for a hidden unit
 $l=o$ for the output unit

Question: At some instant the network has an input of

$$a_1=1, a_2=0.$$

Following the feedforward scheme of the input processing,

- i) find the outputs of the hidden units;

[5 marks]

- ii) find the network output.

[5 marks]

6. Genetic Algorithms.

6(a) Describe the basic structure of a Genetic Algorithm. **[10 marks]**

6(b) What is a Genetic Algorithm chromosome building block, *i.e.* schema? What characters are used to describe schemas of a binary chromosome? What is the order and the defining length of a schema? **[5 marks]**

6(c) Consider the 2bit chromosome "10".
How many schemas are there in this chromosome? List all of the schemas. **[5 marks]**

6(d) Formulate the Schema theorem. What does it say about the role of highly fit, short defining length, low order schemas in the evolution of a population of chromosomes? **[5 marks]**