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THE UNIVERSITY
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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.

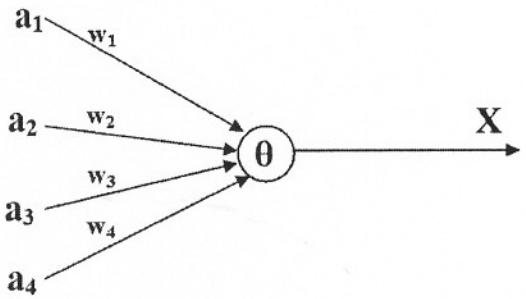
2(a) Draw a diagram for the McCulloch-Pitts neuron with inputs, weights of connections, threshold and an output. Why is the MP-neuron called a discrete time machine? What values can the neuron's inputs take? What values are the prohibitory and the excitatory weights of connections in the MP-neuron? What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

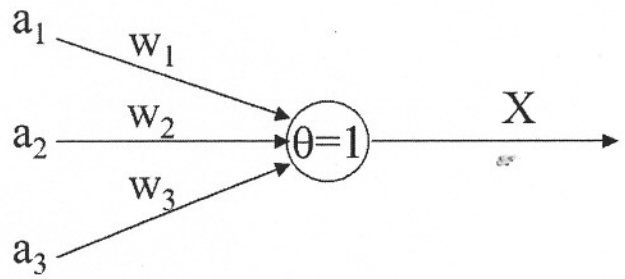
3(a) What is a learning rule of an artificial neural network?

[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]

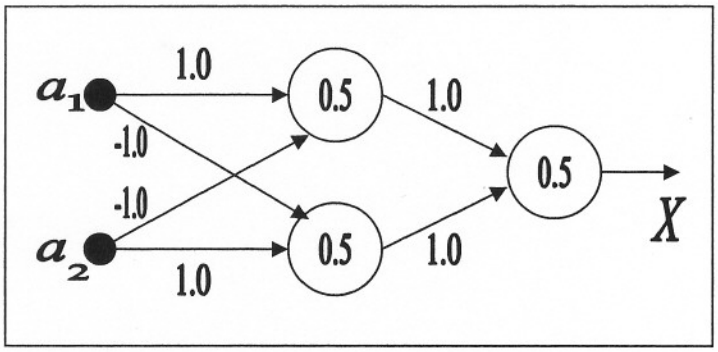
5(b) Describe the layered architecture of MLP with no feedback loops and no connections between units in a layer. What are the input layer, hidden layers, and the output layer?

[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

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

where

$l=h$ for a **h**idden unit
$l=o$ for the **o**utput 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]