Xi'an Jiaotong-Liverpool University

西交利物浦大学

PAPER CODE	EXAMINER	DEPARTMENT	TEL
INT301		INTELLIGENT SCIENCE	

1st SEMESTER 2024/2025 FINAL EXAMINATION

BACHELOR DEGREE – Year 4

Bio-Computation

TIME ALLOWED: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This is a closed-book examination.

2. Total marks available are 100. This exam will count for 80% in the final assessment.

3. Answer all questions. There is NO penalty for providing a wrong answer.

4. Answer should be written in the answer booklet(s) provided.

5. Only English solutions are accepted.

6. All materials must be returned to the exam supervisor upon completion of the exam. Failure to do so will be deemed academic misconduct and will be dealt with accordingly.

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Question 1. [4+5+6=15 MARKS]

(a) What is the difference between supervised learning and unsupervised learning?
[4 MARKS]

(b) A 2-layer feed-forward neural network with 5 input nodes, 3 hidden nodes and 2 output nodes contains how many weights (biases included)? Show your work.
[5 MARKS]

(c) Briefly explain the differences between training set, validation set and test set for supervised learning.
[6 MARKS]

Question 2. [5+6+5+6=22 MARKS]

For a feedforward neural network with two inputs and one output, please use the BP (Back Propagation) algorithm with momentum as shown below to update the weights after each of the training examples {(1, 0), 1} and {(0, 1), 0} in order (the format of the training example is {(input_1, input_2), output}).

$$\Delta w(t) = -\eta \frac{\partial E_e}{\partial w(t)} + \alpha \, \Delta w(t-1)$$

Assume the network has a single hidden layer with one neuron and all neurons use the logistic activation function. All weights (including bias) are initially equal to 1, learning rate η =0.2 and momentum term α =0.8.

(a) Show the forward process using 1st example {(1, 0), 1}.
[5 MARKS]

(b) After the forward process using 1st example, show the backward process (including weights update) using 1st example {(1, 0), 1}.
[6 MARKS]

(c) After training using 1st example, show the forward process using 2nd example {(0, 1), 0}.
[5 MARKS]

(d) After training using 1st example and the forward process using 2nd example, show the backward process (including weights update) using 2nd example {(0, 1), 0}.
[6 MARKS]

Question 3. [9+4=13 MARKS]

(a) Suppose we have a 4x4 matrix shown in Figure 1, which represents an image matrix. Define a 2x2 filter as the convolutional filter (i.e. kernel) over this image matrix, with stride=1 (step size). What is the output by applying the convolutional filter to the image matrix?
[9 MARKS]

2	1	0	2
0	1	1	0
2	1	2	1
0	1	1	0

Figure 1: a 4x4 image matrix

0	-1
1	0

Figure 2: a 2x2 convolutional filter

(b) Suppose we have a 4x4 matrix shown in Figure 3, which represents a feature map from one layer in CNN. Define a 2x2 pooling filter over this feature map and assume no region overlap in the pooling process (i.e.: stride=2). What are the outputs by applying max pooling and average pooling (i.e. mean pooling) in the 2x2 pooling filter respectively?
[4 MARKS]

1	1	2	4
5	6	7	8
3	2	1	0
1	2	3	4

Figure 3: a 4x4 feature map

Question 4. [8+4=12 MARKS]

Consider a Gaussian RBF network with a single hidden layer containing three radial basis functions. The centers of these functions are $c_1 = [1,0]$, $c_2 = [0,1]$, and $c_3 = [1,1]$. The standard deviation for each function is $\sigma = 1$.

(a) Given an input vector $x = [0.5,1]$, calculate the output of the hidden layer and list the computing process. Approximate calculations can be performed using: $\exp(-0.625) \approx 0.5353, \exp(-0.125) \approx 0.8825$.
[8 MARKS]

(b) Provide the equation for computing the final output with the hidden layer and weigh vector. Suppose that the corresponding weight vector is $w = [-2,1,6]$, calculate the final output using the hidden layer in Question (a).
[4 MARKS]

Question 5. [8+8=16 MARKS]

A Hopfield network with bipolar nodes$\{-1,1\}$ is designed to store 3 patterns $x_1=\{1,-1,1,-1\}$, $x_2=\{-1,1,-1,1\}$, and $x_3=\{1,1,-1,-1\}$.

(a) Please provide the equation for computing weight matrix of the Hopfield network and calculate the weight matrix W to store the x_1, x_2 and x_3. Assume no self-connections, meaning the diagonal elements of the weight matrix are zero.
[8 MARKS]

(b) Given the vector $x=[1,-1,1,?]$, where the last dimension is missing, describe how you would use the weight matrix W from Question 1 to recover the missing value. Please provides the update equation of the missing value and the computing process.
[8 MARKS]

Question 6. [6+5+6+5=22 MARKS]

(a) Describe the three processes involved in the SOM algorithm once the weights of the network are initialized and explain the role of each process:
[6 MARKS]

(b) Please explain the Matlab codes related to principal component analysis (PCA) below by providing the comments at the corresponding locations, and explain the meaning of matrix S.
[5 MARKS]

```
%
data = [1, 1, 0, 0; 0, 0, 0, 1; 1, 0, 0, 0; 0, 0, 1, 1];
%
[U, S, V] = svd(data);
%
figure; plot(diag(S), 'o-');
```

(c) Recurrent Neural Networks (RNN) are a class of neural networks well-suited for processing sequences of data. They can use their internal state (memory) to process sequences of inputs and are commonly applied in tasks such as natural language processing, time-series forecasting, and speech recognition. Briefly describe the structure difference between the typical RNN and the feedforward deep neural networks, why Vanishing Gradients happen in RNN training, how Long Short-Term Memory (LSTM) networks alleviate the vanishing gradient problem?
[6 MARKS]

(d) Provide an example of unsupervised learning method, and briefly explain the model/network topology, training/learning algorithm and input/output.
[5 MARKS]

END OF EXAM PAPER