NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2016-2017

CZ4042/CPE422/CSC422 – NEURAL NETWORKS

Nov/Dec 2016 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 pages.
2. Answer **ALL** questions.
3. This is a open-book examination.
4. All questions carry equal marks.

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1. (a) A discrete perceptron network receives inputs $(x_1, x_2) \in \mathbf{R}^2$ and has an output $y \in \{0, 1\}$. The decision boundary implemented by the network forms a triangle in the input space as shown in Figure Q1. Draw the network indicating weights and thresholds of the perceptrons.

(12 marks)

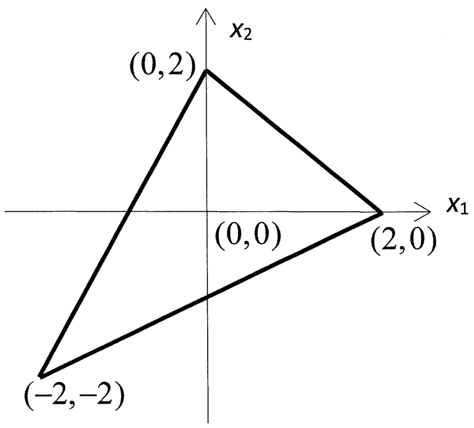


Figure Q1

Note: Question No. 1 continues on Page 2

(b) A Gaussian Radial Basis Function (GRBF) network is trained to approximate function f of inputs θ_1, θ_2, and θ_3 :

$$f(\theta_1,\theta_2,\theta_3) = 10 + \sin\theta_1 \cos(2\theta_2) + 0.5\cos^3\theta_3 \quad \text{for} \quad \theta_1,\theta_2,\theta_3 \in [0, 2\pi].$$

(i) Describe the architecture and activation flow of the network.

(6 marks)

(ii) State how you generate data points for training.

(3 marks)

(iii) Describe an approach to determine the number of hidden layer neurons.

(4 marks)

2. A three-layer perceptron network has 2 input nodes, 3 hidden neurons, and 2 output neurons. The activation functions of the hidden layer neurons and output layer neurons are g and f, respectively, where

$$g(s) = \frac{1-e^{-s}}{1+e^{-s}} \quad \text{and} \quad f(u) = \frac{1}{1+e^{-0.5u}}.$$

The weight matrices to the hidden layer $\mathbf{V}$ and output layer $\mathbf{W}$ are initialized as follows:

$$\mathbf{V} = \begin{pmatrix} 0.500 & -1.350 \\ 1.250 & 0.250 \\ -0.750 & 0.300 \end{pmatrix} \quad \text{and} \quad \mathbf{W} = \begin{pmatrix} 0.400 & -0.200 & 0.400 \\ 0.600 & 0.250 & -0.350 \end{pmatrix}.$$

The thresholds of all neurons are initialized to 0.05.

The network is trained to produce a desired output $\mathbf{d} = \begin{pmatrix} 0.00 & 1.00 \end{pmatrix}^T$ for an input pattern $\mathbf{x} = \begin{pmatrix} 0.75 & -0.80 \end{pmatrix}^T$. The learning factor is 0.2. For one iteration of training, compute

(a) the synaptic input $\mathbf{s}$ and activation $\mathbf{y}$ at the hidden layer;

(5 marks)

Note: Question No. 2 continues on Page 3

(b) the synaptic input **u** and activation **o** at the output layer;

(5 marks)

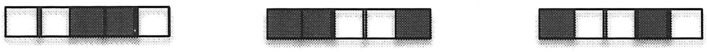
(c) the error terms δ_o and δ_y at the output layer and hidden layer, respectively;

(10 marks)

(d) the new weights and thresholds of the network.

(5 marks)

3. (a) Consider the following three patterns:



S1 S2 S3

(i) Convert each pattern into a 5-dimensional binary vector by using the notation: 'white box' = 1 and 'shaded box' = 0.

(2 marks)

(ii) Show that a linear autoassociative network cannot correctly store all three patterns.

(4 marks)

(iii) Describe how you design and train an autoencoder to store the patterns correctly.

(9 marks)

(b) A convolution neural network has an input layer of dimensions 3x3. The first hidden layer has a convolution layer consisting of two filters $\mathbf{w}_1$ and $\mathbf{w}_2$, and a mean pooling layer of pooling dimensions 2x2:

$$\mathbf{w}_1 = \begin{pmatrix} 0.6 & 0 \\ 0 & 0.6 \end{pmatrix} \text{ and } \mathbf{w}_2 = \begin{pmatrix} 0 & 0.4 \\ 0.4 & 0 \end{pmatrix}.$$

Note: Question No. 3 continues on Page 4

Input pattern $\mathbf{X}$ is presented to the input layer of the network:

$$\mathbf{X} = \begin{pmatrix} 0.10 & 0.20 & 0.00 \\ 0.10 & 0.80 & 0.10 \\ 0.40 & 0.60 & 0.20 \end{pmatrix}.$$

Determine feature maps at

(i) the first convolution layer, assuming sigmoid activation functions and thresholds of 0.1 for all neurons;

(7 marks)

(ii) the first pooling layer.

(3 marks)

4. (a) Briefly describe how the following is achieved in Kohenen's Self-Organizing Feature Maps (SOFM) network:

(i) topological ordering of leaned patterns;

(4 marks)

(ii) image compression.

(5 marks)

(b) An autoassociative neural network to store 3-dimensional inputs is designed using the Principal Component Analysis (PCA). Four training data points, and the eigenvalues and eigenvectors of their correlation matrix are given in Table Q4. If the hidden layer consists of two linear neurons, determine

(i) the mean and covariance matrix of data points;

(4 marks)

(ii) the hidden layer representations of data points;

(4 marks)

(iii) the percentage of data variance lost in the hidden layer;

(4 marks)

Note: Question No. 4 continues on Page 5

(iv) the reconstructed data points by the network.

(4 marks)

Table Q4

Four training data points			
x_1	x_2	x_3	x_4
$(5\ \ -1\ \ 2)^T$	$(-1\ \ 1\ \ -3)^T$	$(3\ \ -3\ \ 0)^T$	$(2\ \ -1\ \ -4)^T$

The PCA model	
Eigenvalue	Eigenvector
1.24	$(0.724\ \ 0.291\ \ -0.625)^T$
3.87	$(0.186\ \ -0.955\ \ -0.229)^T$
12.40	$(0.664\ \ -0.049\ \ 0.746)^T$

END OF PAPER

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Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.