ORIGINAL

NATIONAL UNIVERSITY OF SINGAPORE

FACULTY OF ENGINEERING

EXAMINATION FOR

(Semester II : 2016/2017)

EE5904R/ME5404 – NEURAL NETWORKS

April/May 2017 – Time Allowed: 2.5 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** printed pages.
2. The examination paper carries 100 marks in total. All questions are compulsory. Answer **ALL** questions.
3. This is a closed book examination. But the candidate is permitted to bring into the examination hall a single A4 size *data sheet*. The candidate may refer to this sheet during the examination.
4. Programmable calculators are not allowed.

Q.1 Imagine that you are involved in a project on building the intelligent automatic driving system. One of the critical tasks for the automatic driving system is to control the steering wheel properly. This can be achieved by building a vision-based system to recognize different road conditions and send the command for appropriate steering direction to the steering wheel control system. You are supposed to apply the multi-layer perceptron (MLP) to build a prototype of the system. The size of the gray-level image captured by the camera is assumed to be 30x20.

Suppose that you can use the MATLAB neural network toolbox, please detail the whole procedure for solving this pattern recognition problem step by step, starting from data collection and data pre-processing to system testing. Try to address all the technical issues in each step, in particular the design and training issues. Although it is not necessary to provide the MATLAB code or mathematical formulae for the training algorithms, you should try to supply all the other necessary technical details such as how to prepare the input-output pairs for training the MLP, how to choose the number of layers, neurons, and activation functions, how to train the MLP etc.

(25 marks)

Q.2 Consider the following two-dimensional pattern recognition problem. Class I contains four points: (0, 0), (0, 2), (2, 0) and (2, 2). Class II contains only one point: (1, 1).

(a) Is this two-class pattern classification problem linearly separable or nonlinearly separable? Please supply a rigorous mathematical proof for your answer.

(5 marks)

(b) Design a radial-basis function network (RBFN) to separate these two classes completely. You are free to choose any type of radial basis function to be used in the RBFN. You need to clearly specify all the design parameters including the position of the hidden neurons (centers), parameters associated with each center (the hidden neurons), and the weights in the output layer.

(10 marks)

(c) Explain why the RBFN designed in (b) can solve this pattern classification problem.

(5 marks)

(d) Give a simple clustering example to demonstrate the advantage of Self-Organizing Map (SOM) over the K-means clustering algorithm. Justify your answer.

(5 marks)

Q.3

(a) Consider the training set as given in Figure 3.1, where the label for the points denoted by "×" is -1, while the label for the points denoted by the black diamond shape is 1.

(i) For the hyperplane defined by $\mathbf{w} = [-1 \quad -1]$ and $b = 0.5$, determine the functional margin of the training set.

(5 marks)

(ii) Determine the margin of the training set.

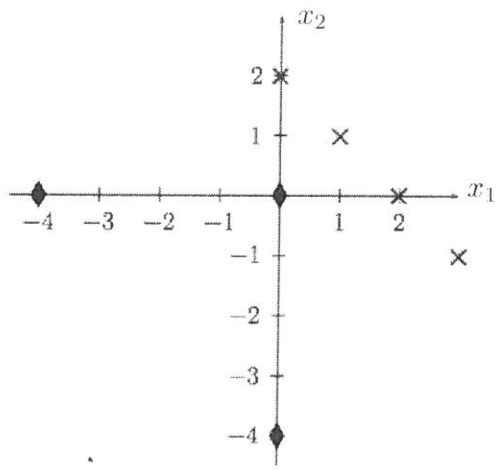

Figure 3.1

(5 marks)

(b) Consider the training set as given in Figure 3.2.

(i) Determine the optimal hyperplane.

(5 marks)

(ii) What is the minimum number of examples in the training set whose removal results in an optimal hyperplane that is different from the one obtained in (i)? Identify the possible candidate example(s) that can be removed. (Justify your answer.)

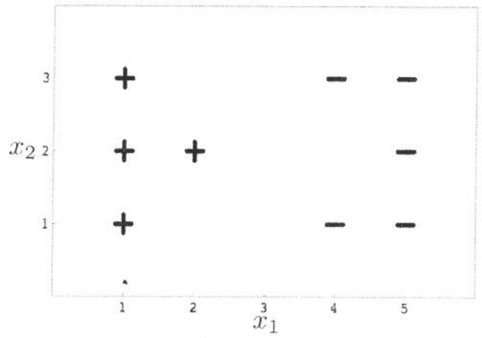

Figure 3.2

(5 marks)

(c) Consider the kernel $K(\mathbf{x}, \mathbf{y}) = \varphi^T(\mathbf{x})\varphi(\mathbf{y}) = (\mathbf{x}^T\mathbf{y})^2$, where $\mathbf{x}$ and $\mathbf{y}$ are 2D vectors. Determine the mapping φ. (Hint: Let $\mathbf{x}^{\mathrm{T}} = [x_1 \quad x_2]$ and $\mathbf{y}^{\mathrm{T}} = [y_1 \quad y_2]$. Express $(\mathbf{x}^T\mathbf{y})^2$ in terms of the elements of the vectors and then try to find a mapping φ such that $\varphi^T(\mathbf{x})\varphi(\mathbf{y}) = (\mathbf{x}^T\mathbf{y})^2$.)

(5 marks)

Q.4

(a) Consider an agent in a simple two-state world as illustrated in Figure 4.1, in which state 2 is a goal state. If the agent enters state 2 during a trial, the trial terminates. At state 1, the agent may take one of two actions, a or b. Assume a discount rate of $\gamma = 0.9$.

(i) Suppose that the transition functions are: $\bar{f}(1, a) = 2$ and $\bar{f}(1, b) = 1$, and the reward functions are: $\rho(1, a, 2) = 1$ and $\rho(1, b, 1) = 0.1$ What is the agent's optimal policy?

(5 marks)

(ii) Suppose that now the transition functions are given as follows: $f(1, a, 1) = 0.2$, $f(1, a, 2) = 0.8$, $f(1, b, 1) = 0.9$, and $f(1, b, 2) = 0.1$, and the reward functions are: $\rho(1, a, 1) = 0.1$, $\rho(1, a, 2) = 1$, and $\rho(1, b, 1) = 0.1$ $\rho(1, b, 2) = 1$. Suppose that during a trial starting at state 1, the agent is observed to have taken the action b and then the action a. What is the total reward the agent is expected to receive after taking the action sequence ba? (State your assumptions, if any, clearly.)

(10 marks)

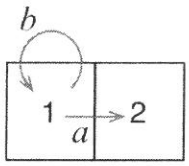

Figure 4.1

(b) Consider a reinforcement-learning system with two states (namely, s_1 and s_2) and two actions (namely, a_1 and a_2). Suppose that a Q-learning trial has been conducted with the agent transitioning through the following state sequence by taking the actions as indicated below:

$$s_1 \xrightarrow{a_1,\ 1} s_1 \xrightarrow{a_2,\ 1} s_2 \xrightarrow{a_1,\ 10} s_1 \xrightarrow{a_2,\ 1} s_2$$

where the number following the action above an arrow indicates the reward received by the agent upon taking that action. For instance, the first arrow implies that the agent at state s_1 takes action a_1, which results in the agent remaining in state s_1 and receiving a reward of 1. Complete the table below to show the values of the Q-function at the end of <u>each action</u> taken by the agent during the trial. For instance, the value of $Q(s_1, a_1)$ is to be entered in the top left empty cell in the table shown. Assume that the initial values of the Q-function are 0. Use a fixed learning rate of $\alpha = 0.5$ and a discount rate of $\gamma = 0.5$.

(Note: Show your detailed calculation steps for obtaining these Q-function values. There are four actions for this trial, so your answer should include four such tables, one for each action taken.)

Q	s_1	s_2
a_1		
a_2		

(10 marks)

END OF PAPER