ORIGINAL

NATIONAL UNIVERSITY OF SINGAPORE

FACULTY OF ENGINEERING

EXAMINATION FOR

(Semester II : 2015/2016)

EE5904R/ME5404 – NEURAL NETWORKS

April/May 2016 – 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 and carry equal marks. 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 Social robots can help the elderly people at home. Imagine that you are involved in a project on building the intelligent social robots to chat with their masters. One of the critical tasks for the robots is to recognize the emotional state of the masters so that they can start the conversation in a natural way. For instance, if the robots "feel" that their masters are sad, they may greet their masters by saying "You do not look very happy, my master. What is going wrong?". This can be achieved by building a vision-based system to recognize different facial expressions of the human beings. Assume that there are seven basic facial expressions: happy, sad, surprise, disgusted, angry, scared and normal. You are supposed to apply the multi-layer perceptron (MLP) to recognize these seven types of facial expressions based upon the images taken by the camera mounted on the robot. The size of the gray-level image is assumed to be 30x20.

(a) Assume that you are going to use the pixel values of the images directly without any feature extraction or dimension reduction. 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 choose the number of layers, neurons, and activation functions, and how to train the MLP etc.

(20 marks)

(b) In part a), only the pixel values are used as the inputs to the MLP. Suppose that you want to test whether one particular method of feature extraction can improve the recognition accuracy of the system or not. The direct way is of course by performing the feature extraction first and then using the features as the inputs to the MLP and repeating the training and testing procedure detailed in part a). This procedure might be time consuming. Before this direct test, is it possible to use the self-organizing map (SOM) to do a quick check of the effectiveness of the feature extraction method for expression recognition? Please justify your answer with brief explanation of the basic idea.

(5 marks)

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

(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. The structure of the RBFN is fixed to be 2-2-1, which means that only two hidden neurons (i.e., centers of the radial basis functions) can be used. You have the freedom to choose the 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.

(15 marks)

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

(5 marks)

Q. 3

(a) Consider a training set given in Table 3.1. Determine the margin of the training set.

i	$\mathbf{x}_i$	d_i
1	$[1 \quad 1]^T$	-1
2	$[2 \quad 1]^T$	-1
3	$[3 \quad 2]^T$	1
4	$[3 \quad 3]^T$	1

Table 3.1

(5 marks)

(b) Suppose that the example with $\mathbf{x}_5 = [1 \quad 2]^T$ and $d_5 = 1$ is added to the training set given in Table 3.1. Calculate the margin of this new training set.

(5 marks)

(c) Suppose that another example $\mathbf{x}_6 = [1.5 \quad 1]^T$ and $d_6 = 1$ is added to the training set descried in Part (b) above. Determine the element $\mathbf{K}(2,6)$ of the Gram matrix with respect to the kernel

$$K(\mathbf{x}, \mathbf{y}) = (\mathbf{x}^T \mathbf{y})^2$$

(5 marks)

(d) Suppose that the Lagrange multipliers for the dual problem involving the training set as described in Part (c) above are as shown in Table 3.2. Determine the discriminant function.

α_1	α_2	α_3	α_4	α_5	α_6
100	76	0	0	0	176

Table 3.2

(10 marks)

Q.4

(a) Consider the four-state grid environment as shown in Figure 4.1. Suppose that at each state an agent can take one of two actions, namely, a_1 (left or right) and a_2 (up or down), with the condition that the agent, when taking an action, may or may not move to a new state (depending on whether the transition is deterministic or non-deterministic) but it must stay in the grid. A reward of 1 is received by the agent when it moves to a new state whose number is smaller than that of its state before the transition. For any other movement, the reward is zero. Let the discount rate γ be 0.8. Determine the values of $Q(1, a_2)$, $Q(2, a_1)$, $Q(3, a_2)$, and $Q(4, a_1)$ for the policy $\pi(1) = a_2$, $\pi(2) = a_1$, $\pi(3) = a_2$, and $\pi(4) = a_1$, with $\bar{f}=(1, a_2) = 4$, $\bar{f}=(2, a_1) = 1$, $\bar{f}=(3, a_2) = 2$, and $\bar{f}=(4, a_1) = 3$.

1	2
4	3

Figure 4.1

(10 marks)

(b) Consider the six-state grid environment as shown in Figure 4.2. Suppose that at each state an agent can move up (denoted by a_1), down (a_2), left (a_3), or right (a_4), under the assumption that the agent stays in the grid when it takes an action, in the same fashion as described in Part (a) above. A reward of 1 is received by the agent when it moves to a new state whose number is greater than that of its state before the transition. For any other movement, the reward is zero. Let the discount rate γ be 0.8. Suppose that the sequence $5 \rightarrow 4 \rightarrow 5 \rightarrow 2 \rightarrow 1$ is executed in a trial using Q-learning with ε-greedy exploration (with $\alpha_k = 1/k$, and $\alpha_0 = 1$). Assume that the initial values of the Q-function are as shown in Figure 4.2. Calculate the values of the Q-function upon the completion of this particular trial.

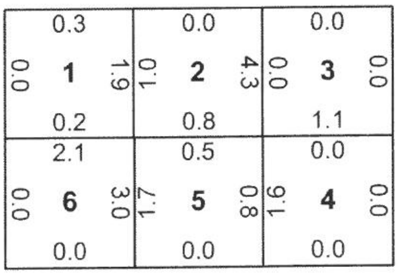

Figure 4.2

(10 marks)

(c) Describe the key steps in the proof of the convergence of the model-based value iteration algorithm for reinforcement learning.

(5 marks)

END OF PAPER