

CITY UNIVERSITY OF HONG KONG

Course code & title : EE4146 Industrial Electronics

Session : Semester B 2006/07

Time allowed : Two hours

This paper has 6 pages (including this cover page).

1. This paper consists of **4** questions.
2. Each question carries equal marks.
3. Answer any **3** questions.
4. Start each question on a new page.

Q1.

- A. In an induction machine fault detection system operating mainly at 50Hz, the vibration signal of the induction machine is captured by a vibration sensor. The captured signal is real-time interfaced with a computer to evaluate the average frequency $\bar{f}$, normalized second-order moment $NU2$, and normalized third-order moment $NU3$, which are given as follows:

$$\bar{f} = \frac{\int_0^{\infty} fP(f)df}{\int_0^{\infty} P(f)df}, \quad NU2 = \frac{\int_0^{\infty} (f - \bar{f})^2 P(f)df}{\int_0^{\infty} P(f)df}, \quad NU3 = \frac{\int_0^{\infty} (f - \bar{f})^3 P(f)df}{\int_0^{\infty} P(f)df},$$

where $P(f)$ is the power spectrum.

For the above given system, an industrial engineer designs a neural network based machine fault diagnosis system.

- i. What sensor is used for measuring the vibration signal? (3 marks)
 - ii. Select a sampling frequency for the vibration signal measurement. Explain why such a sampling frequency is selected. (4 marks)
 - iii. Based on the above three evaluated features, sketch a diagram to show how the machine fault can be diagnosed. Also sketch a diagram to show why the machine fault cannot be determined using only 2 features. (6 marks)
- B.
- i. The steepest descent algorithm is used for updating the weights, $W(k)$ at the k^{th} iteration, of a neural network. State and describe the learning rule in terms of the weight vector, $W(k)$, and the learning rate, η . Also, explain the rationale behind the selection of the learning rate, η . (7 marks)
 - ii. The initial weights vector $W(0)$ is randomized. What would be the possible effect of the initialisations on the overall training performance? (3 marks)
 - iii. Use the steepest descent method to search for the minimum of $f(x_1, x_2) = 22x_1^3 + x_2^2$ with the initials set at $X(0) = [1 \ 2]^T$, and the step size set to 0.5. State the steps and calculate $X(1)$. (10 marks)

Q2.

A.

- i. The Ma On Shan Rail, East Rail, and West Rail of KCR all use a 25KV a.c supply and d.c traction system, while most recently developed European railways use a.c traction system. Compare and describe 3 main aspects between these two systems. (12 marks)
- ii. Most conventional robust controllers are in a form of PID. Compare 4 main aspects of an PID controller with a neural based controller in terms of design and performance. (8 marks)

- B. Figure Q2. shows a simple perceptron model used for modeling an “OR” logic function. Use the given Widrow-Hoff algorithm to determine the weightings of the simple perceptron model. Set the initial weights of $\alpha = 0.5, \beta = -0.2$, $T = -0.1$, and the correction factor as $\frac{\text{error} + 0.1}{2}$. Detail the first 3 iterations of the learning process according to the sequence of $(X_1, X_2) = (0,0), (0,1), (1,0)$. (13 marks)

- a. Select a logic function from the given logic table
- b. If an error is found, determine how far the model is from the “desired” firing value
- c. Adjust the weights that are “live” and the “threshold” in order to minimize the the error
- d. Go Back to Step “1”
- e. Stop when the whole logic function is achieved.

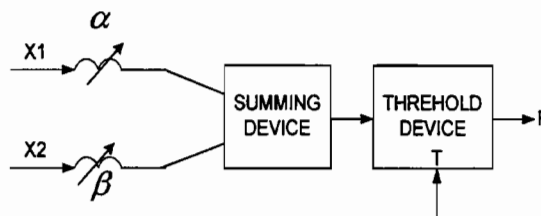


Figure Q2

Q3.

A.

- i. Initialisation, Competition, and Neighborhood function are three important processes in a Self-Organizing-Map (SOM). Briefly describe how each of these components is implemented. (6 marks)
- ii. Design a neighbourhood function for working together with the weights updating. State the function and describe the rationale behind your design. (4 marks)
- iii. An SOM has 4 neurons in the competitive layer with a two-dimensional input layer. The SOM is initialized with the following weight matrix, W . The given dataset, D , has 3 data points.

$$W = \begin{bmatrix} 1.3 & 0.0 \\ 0.8 & 0.1 \\ 1.0 & 1.0 \\ 2.0 & 0.5 \end{bmatrix}, D = \begin{bmatrix} 1.0 & 2.0 \\ 0.5 & 0.5 \\ 1.5 & 1.0 \end{bmatrix}$$

Perform one cycle of competitive learning for the SOM with a learning rate of 1.0 for the winner neuron, and 0 for other neurons. (12 marks)

B.

In an MTR Railway carriage maintenance log, the following table shows only 9 typical data points of a 7-attribute + 1 class-label attribute data file. The whole data file consists of over 10000 different maintenance records collected in the past years.

Month in service	Car-ID	Traction centre condition	Bearing	Loading type	Bogie Condition	Total Checking Duration in Hr	Fault Found
28	Car-1	Good-1	Good-1	5 (High)	Good-1	300	Nil
24	Car-1	Good-1	Good-1	5 (High)	Good-1	305	Nil
35	Car-2	Bad-1	Fine-1	3 (Medium)	Fine-1	505	F3
36	Car-7	Bad-2	Fine-1	5 (High)	Bad-1	2295	F4
42	Car-3	Good-2	Bad-1	5 (High)	Bad-1	1490	F1
46	Car-3	Good-3	Good-1	1(Low)	Good-1	1305	F4
21	Cct-3	Good-1	Bad-2	4 (Quite high)	Good-2	235	F3
37	Car-5	Fine-3	Fine-3	3 (Medium)	Bad-1	2400	F12
40	Car-6	Fine-2	Good-1	4 (Quite high)	Bad-1	3855	F2

A senior engineer uses a Self-Organising Map to perform maintenance analysis in an attempt to identify how railway-carriage fault be related to the conditions of different major equipments.

- i. Which of the above attributes should not be included in the SOM training? Justify your suggestions. (4 marks)
- ii. There are 12 types of fault denoted $F_1, F_2, \dots, F_{12}$, and Nil which means no fault under the attribute of fault found. The engineer uses an SOM with a size of 4×4 neurons, there is no clear clusters found in the SOM output feature map. What would you suggest the engineer to perform the SOM analysis again in order to obtain a nicely discriminated clusters. (4 marks)
- iii. Sketch and explain a possible SOM output feature map. (3 marks)

Q4

- A. Figure Q4 shows how a tree-structured data is used in a plagiarism detection system to model a document, where N_1 is the root node represents the whole document, N_2, N_3 are the second layer nodes used to represent pages, and N_4 to N_9 are the third level children nodes used to represent paragraphs.

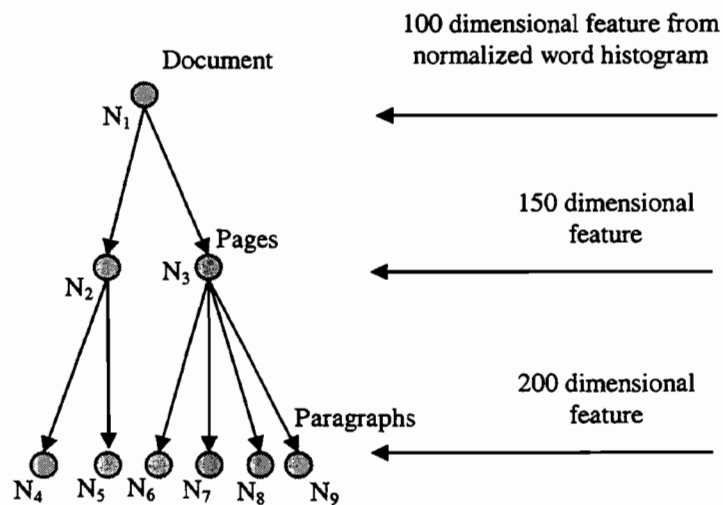


Figure Q4a

- i. Briefly describe the main differences between a flat data structure and a tree-structure. (5 marks)
- ii. Suggest a methodology to model the above tree-structured dataset for performing effective plagiarism detection. Use a diagram to elaborate your proposed system. (5 marks)

B. Figure Q4b shows a neuron with a unit step activation function, and a bias of 0.6. It has two binary inputs. Find the space of the possible values of weights (α , β) if the neuron is

- i) OFF for input (1.0, 1.0)
- ii) OFF for input (-0.6, 1.0)
- iii) ON for input (-0.6, 3).

(12 marks)

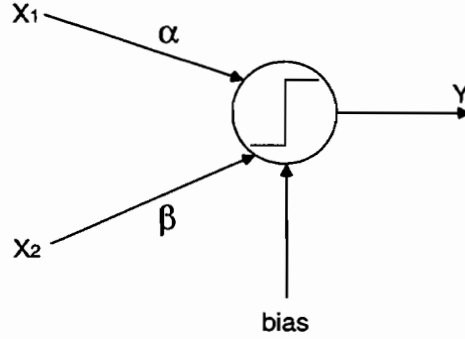


Fig. Q4b

C. Figure Q4c shows a neuron in a recurrent connection. Prove that the output $y(k)$ of the neuron is in a form of

$$y(k) = aX(k) + \sum_{m=1}^{\infty} X(gk)W_1^z W_f^j, \text{ where } m \text{ is the recurrent step.}$$

i. Hence, determine the parameters a , g , z , and j . (8 marks)

ii. Thus, determine the stability condition for $y(k)$. (3 marks)

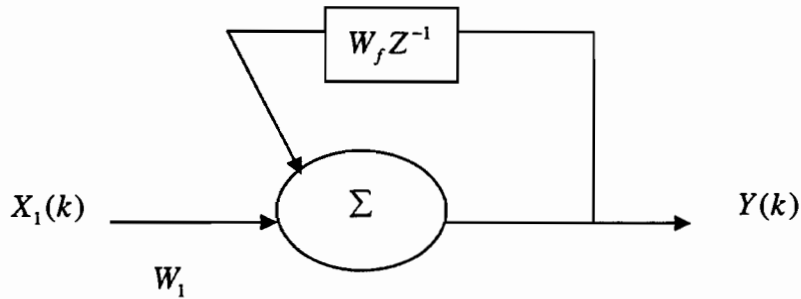


Figure Q4c