UNIVERSITY OF TECHNOLOGY, SYDNEY
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

49275 NEURAL NETWORKS AND FUZZY SYSTEMS

ASSIGNMENT 2

QUESTION ONE ***[The Generalised XOR Problem]*** [50 marks]

A neural network model with two input neurons, three hidden neurons in a single hidden layer, and an output neuron is used to learn the decision surface of the well-known generalised XOR problem:

$$d = \mathrm{sgn}(x_1 x_2)$$

The input range is [-1,1]. The desired output value is either **–**1 (corresponds to logical zero) or 1 (corresponds to logical one).

This generalised XOR problem has been utilised recently to compare the effectiveness of various neural network learning algorithms. A simplified version is used in this question. Eight input samples $\mathbf{x}_1, \mathbf{x}_2, \cdots, \mathbf{x}_7, \mathbf{x}_8$ and their corresponding target vectors $\mathbf{d}_1, \mathbf{d}_2, \cdots, \mathbf{d}_7, \mathbf{d}_8$ in the training set are:

$$\mathbf{x}_1 = \begin{bmatrix} 0.7826 \\ 0.5242 \end{bmatrix},\ \mathbf{x}_2 = \begin{bmatrix} 0.9003 \\ -0.5377 \end{bmatrix},\ \mathbf{x}_3 = \begin{bmatrix} -0.0871 \\ -0.9630 \end{bmatrix},\ \mathbf{x}_4 = \begin{bmatrix} -0.1795 \\ 0.7873 \end{bmatrix},$$
$$\mathbf{x}_5 = \begin{bmatrix} 0.2309 \\ 0.5839 \end{bmatrix},\ \mathbf{x}_6 = \begin{bmatrix} 0.2137 \\ -0.0280 \end{bmatrix},\ \mathbf{x}_7 = \begin{bmatrix} -0.6475 \\ -0.1886 \end{bmatrix},\ \mathbf{x}_8 = \begin{bmatrix} -0.6026 \\ 0.2076 \end{bmatrix}$$

$$\mathbf{d}_1 = [1],\ \mathbf{d}_2 = [-1],\ \mathbf{d}_3 = [1],\ \mathbf{d}_4 = [-1],\ \mathbf{d}_5 = [1],\ \mathbf{d}_6 = [-1],\ \mathbf{d}_7 = [1],\ \mathbf{d}_8 = [-1]$$

Assume that the network as shown in Figure 1 has 3 hidden neurons, 1 output neuron, and all continuous perceptrons use the bipolar activation function $f_2(\nu) = \dfrac{1 - e^{-\nu}}{1 + e^{-\nu}}$. Note that due to the necessary augmentation of inputs and of the hidden layer by one fixed input, the trained network should have 3 input nodes, 4 hidden neurons, and 1 output neuron. Assign -1 to all augmented inputs.

1.1 Assume that the learning constant is $\eta = 0.2$, and the initial random output layer weight matrix $W(1)$ and hidden layer weight matrix $\overline{W}(1)$ are

$$W(1) = \begin{bmatrix} 0.3443 & 0.6762 & -0.9607 & 0.3626 \end{bmatrix}$$

$$\overline{W}(1) = \begin{bmatrix} -0.2410 & 0.4189 & -0.6207 \\ 0.6636 & -0.1422 & -0.6131 \\ 0.0056 & -0.3908 & 0.3644 \end{bmatrix}$$

Using the error back propagation training, calculate the next weight updates $W(2), \overline{W}(2)$.

[25 marks]

1.2 The above training set was trained with the same set of initial random output layer weight matrix $W(1)$ and hidden layer weight matrix $\overline{W}(1)$ as above, and a learning constant of $\eta = 0.2$. The training set was recycled when necessary. Determine the final weight matrices $W_f = W(4001)$ and $\overline{W}_f = \overline{W}(4001)$ after 500 cycles. Plot the cycle error curve for this training exercise.

[20 marks]

Consider two particular input vectors of the test set

$$\mathbf{x}_{t1} = \begin{bmatrix} 0.6263 \\ -0.9803 \end{bmatrix} \qquad \text{and} \qquad \mathbf{x}_{t2} = \begin{bmatrix} 0.0700 \\ 0.0500 \end{bmatrix}$$

Classify these two test input vectors using the final weight matrices and discuss the results.

[5 marks]

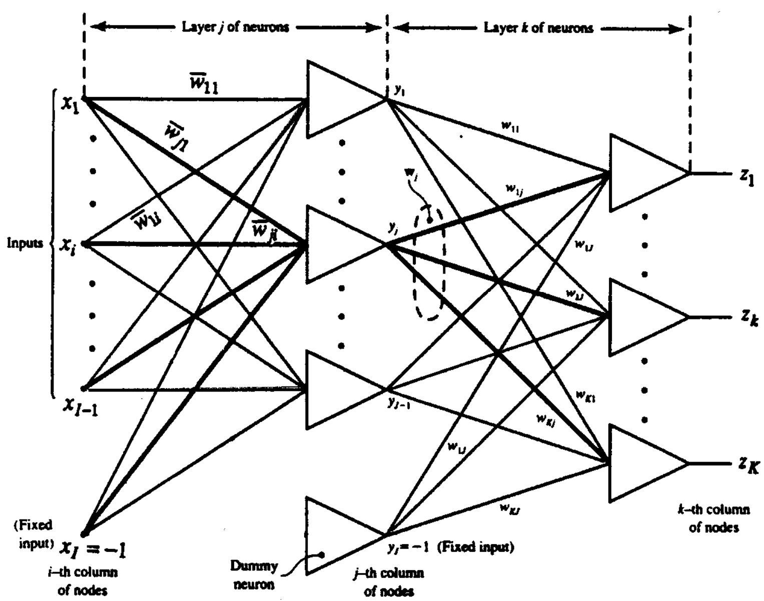

Figure 1 Multilayer Neural Network

QUESTION TWO [***Truck-Backer Upper Control***] [50 marks]

Backing up a truck to a loading dock is a nonlinear control problem. The truck and loading zone are shown in Figure 2.1. The truck position is exactly determined by the three state variables ϕ, x, y where ϕ is the angle of the truck with the horizontal. Control to the truck is the angle θ.

Only backing up is considered. The truck moves backward by a fixed unit distance every stage. For simplicity, assume that there is enough clearance between the truck and the loading dock such that y does not have to be considered as an input. The task here is to design a control system, whose inputs are $\phi \in [-90°, 270°], x \in [0, 20]$ and whose output is $\theta \in [-40°, 40°]$ such that the final stages will be $(x_f, \phi_f) = (10, 90°)$.

The dynamics of the truck backer-upper procedure can be approximated by:

$$x(k+1) = x(k) + \cos[\phi(k) + \theta(k)] + \sin[\theta(k)]\sin[\phi(k)]$$
$$y(k+1) = y(k) + \sin[\phi(k) + \theta(k)] - \sin[\theta(k)]\cos[\phi(k)]$$
$$\phi(k+1) = \phi(k) - \sin^{-1}\left[\frac{2\sin[\theta(k)]}{b}\right]$$

where b is the length of the truck. Assume that $b = 4$.

Fuzzy logic is required for this truck backer-upper control. In this simple fuzzy logic controller, a set of linguistic variables is chosen to represent 5 degrees of truck angle (ϕ) error $[-90°, 70°, 90°, 110°, 270°]$, 5 degrees of truck position (x) error $[0m, 7m, 10m, 13m, 20m]$, and 5 degrees of control angle (θ) $[-40°, -10°, 0°, 10°, 40°]$ as shown in Figure 2.2. The generic rule set in the form of "Fuzzy Associative Memories" is shown in Figure 2.3.

The initial states of this truck are assumed to be $(\phi(1), x(1), y(1)) = (35^\circ, 15m, 15m)$.

2.1 If the Centre of Area (COA) defuzzification strategy is used with the fire strength α_i of the i-th rule calculated from

$$\alpha_i = \min(\mu_{X_{1i}}(x_1), \mu_{X_{2i}}(x_2))$$

determine the defuzzified control angle $\theta(1)$ and the next state $[\phi(2), x(2), y(2)]$.

[20 marks]

2.2 If the Mean of Maximum (MOM) defuzzification strategy is used with the fire strength α_i of the i-th rule calculated from

$$\alpha_i = \mu_{X_{1i}}(x_1).\mu_{X_{2i}}(x_2)$$

determine the defuzzified control angle $\theta(1)$ and the next state $[\phi(2), x(2), y(2)]$. Then continue and calculate $\theta(2)$ and $[x(3), \phi(3), y(3)]$.

Write a computer program to calculate the system state vector $[x(k+1), \phi(k+1), y(k+1)]$ and the defuzzified control angle $\theta(k)$ for 100 consecutive sampling points. Plot the corresponding vertical truck position $y(k)$ against the horizontal truck position $x(k)$ for these 100 sampling points. Plot the defuzzified control angle $\theta(k)$ for these 100 sampling points.

[20 marks]

Find the dominant rule which contributes the highest fire strength to the control action for the defuzzified control angle $\theta(1)$. If softer control action (for slower response) is required, modify this dominant rule and recalculate the new defuzzified control angle $\theta^*(1)$ and the next state vector $[\phi(2), x(2), y(2)]$. Using the modified FAM table, plot the corresponding vertical truck position $y(k)$ against the horizontal truck position $x(k)$ for these 100 sampling points. Plot the new defuzzified control angle $\theta^*(k)$ for these 100 sampling points.

[10 marks]

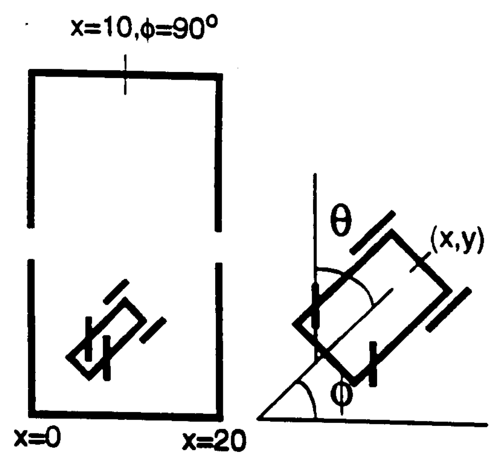

Figure 2.1 Diagram of truck and loading zone

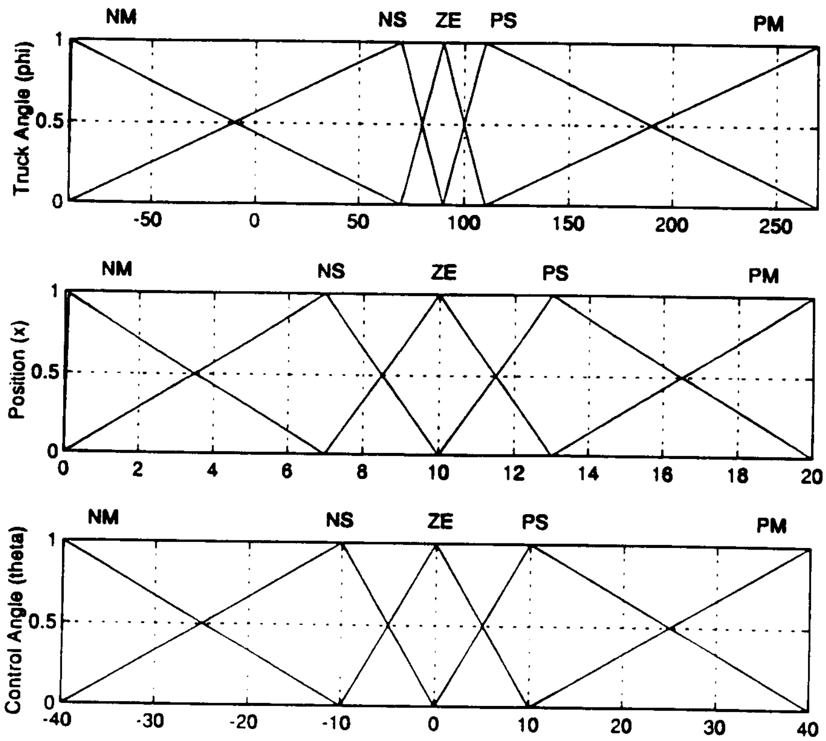

Figure 2.2 Membership functions of a truck backer-upper system

Position (X)

Truck Angle (Φ)	**NM**	**NS**	**ZE**	**PS**	**PM**
NM	ZE	NS	NM	NM	NM
NS	PS	ZE	NS	NM	NM
ZE	PM	PS	ZE	NS	NM
PS	PM	PM	PS	ZE	NS
PM	PM	PM	PM	PS	ZE

Figure 2.3 Generic Fuzzy Associative Memories

MARKING SCHEME

Assignment 2: Neural Networks and Fuzzy Logic

Student Name: ____________________ **Mark:** __________

Requirement	Criteria	Comment	
Standard "Declaration of Originality" cover page as provided by the Faculty	At front of report, completed and signed		Yes/no
Question 1 1.1 Neural Network: Back Propagation	• Presentation • $W(2)$ • $\overline{W}(2)$ • Calculation/software code		/20
Question 1 1.2 Neural Network: Training and Test	• Presentation • $W(4001)$ • $\overline{W}(4001)$ • Cycle error curve • Software code • Test samples • Improved training		/30
Section 2 2.1 Fuzzy Logic: COA defuzzification	• Fuzzification • Combined fuzzy inference • Moment calculation • Area calculation • Defuzzified control angle $\theta(1)$ • Next state vector $[\phi(2), x(2), y(2)]$		/20
Section 2 2.2 Fuzzy Logic: MOM defuzzification	• Fuzzification • Defuzzified control angle $\theta(1)$ and next state vector $[\phi(2), x(2), y(2)]$ • $\theta(2)$ and $[\phi(3), x(3), y(3)]$ • Truck position plot and defuzzified control angle plot (100 points) • Software code • Dominant rule • Modified FAM Table • New defuzzified control angle $\theta^*(1)$ • New truck position plot and defuzzified control angle plot (100 points) • Software code		/30