UNIVERSITY OF TECHNOLOGY, SYDNEY
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

49275 NEURAL NETWORKS AND FUZZY LOGIC

ASSIGNMENT 1

QUESTION ONE [*Perceptron Dichotomiser Training*] [50 marks]

Two perceptron dichotomisers are trained to recognise the following classification of six patterns **x** with known class membership *d*.

$$\mathbf{x}_1 = \begin{bmatrix} 0.8 \\ 0.5 \\ 0.0 \\ 0.1 \end{bmatrix},\ \mathbf{x}_2 = \begin{bmatrix} 0.2 \\ 0.1 \\ 1.3 \\ 0.9 \end{bmatrix},\ \mathbf{x}_3 = \begin{bmatrix} 0.9 \\ 0.7 \\ 0.3 \\ 0.3 \end{bmatrix},\ \mathbf{x}_4 = \begin{bmatrix} 0.2 \\ 0.7 \\ 0.8 \\ 0.2 \end{bmatrix},\ \mathbf{x}_5 = \begin{bmatrix} 1.0 \\ 0.8 \\ 0.5 \\ 0.7 \end{bmatrix},\ \mathbf{x}_6 = \begin{bmatrix} 0.0 \\ 0.2 \\ 0.3 \\ 0.6 \end{bmatrix}$$

$$d_1 = [1],\ d_2 = [-1],\ d_3 = [1],\ d_4 = [-1],\ d_5 = [1],\ d_6 = [-1]$$

1.1 The first dichotomiser is a discrete perceptron as shown in Figure 1.1. Assign 1 to all augmented inputs. For the training task of this dichotomiser, the variable correction rule is used with the coefficient $\lambda = 1.5$ and the initial weight vector

$$\mathbf{w}^1 = \begin{bmatrix} 0.2309 \\ 0.5839 \\ 0.8436 \\ 0.4764 \\ -0.6475 \end{bmatrix}$$

Assuming that the above training set may need to be recycled if necessary, calculate the final weight vector. Show that this weight vector provides the correct classification of the entire training set. Plot the pattern error curve and the cycle error curve for 10 cycles (60 steps).

[25 marks]

1.2 The second dichotomiser is a continuous perceptron with a bipolar logistic activation function $z = f_2(v) = \dfrac{1-e^{-v}}{1+e^{-v}}$ as shown in Figure 1.2. Assign 1 to all augmented inputs. For the training task of this dichotomiser, the delta training rule is used with an arbitrary selection of learning constant $\eta = 0.25$ with the same initial weight vector $\mathbf{w}^1$ in Question 1.1.

Assuming that the above training set may need to be recycled if necessary, calculate the weight vector $\mathbf{w}^7$ after one cycle and the weight vector $\mathbf{w}^{301}$ after 50 cycles. Obtain the cycle error at the end of each cycle and plot the cycle error curve. How would the weight vectors $\mathbf{w}^7$ and $\mathbf{w}^{301}$ classify the entire training set? Discuss your results.

[25 marks]

Note: The following formulae may be used to calculate the pattern error curve and the cycle error curve. There are 6 patterns in this question, i.e. P=6.

Pattern error: $E_p = \frac{1}{2}(d_p - z_p)^2$

Cycle error: $E_c = \frac{1}{2}\sum_{p=1}^{P}(d_p - z_p)^2 = \sum_{p=1}^{P} E_p$

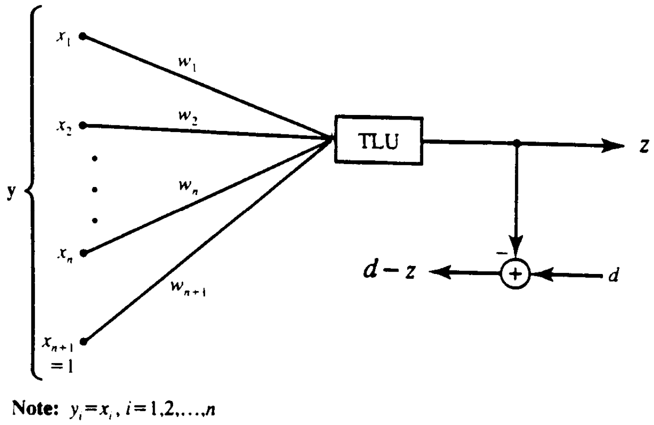

Figure 1.1 Discrete Perceptron Classifier Training

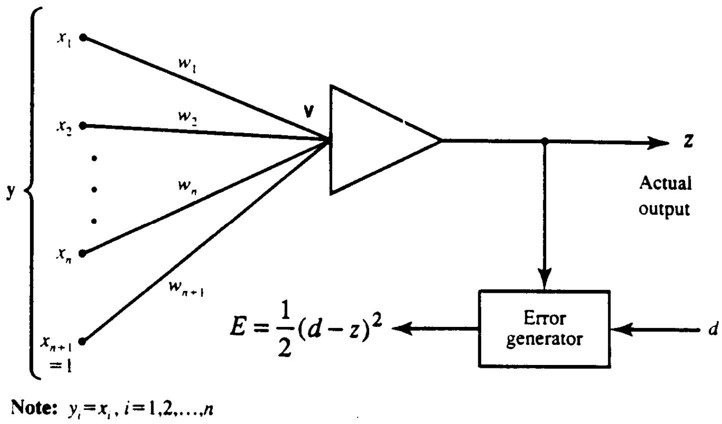

Figure 1.2 Continuous Perceptron Classifier Training

QUESTION TWO [50 marks]

2.1 [Flight Simulation] [15 marks]

A new jet aircraft are subjected to intensive flight simulation studies before they are tested under actual flight conditions. In these studies, an important relationship is that between the mach number (percent of the speed of sound) and the altitude of the aircraft. This relationship is important to the performance of the aircraft and has a definite impact in making flight plans over populated areas. If certain mach levels are reached, breaking the sound barrier (sonic booms) can result in human discomfort and light damage to glass enclosures on the earth's surface. Current rules of thumb establish crisp breakpoints for the conditions which cause performance changes in aircrafts, but in reality these breakpoints are fuzzy, because other atmospheric conditions such as the humidity and temperature also affect breakpoints in performance. For this problem, suppose the flight test data can be characterised as "near" or "approximately" or "in the region of" the crisp database breakpoints.

Define a universe of aircraft speeds near the speed of sound as $\mathbf{X} = \{0.725, 0.730, 0.735, 0.740, 0.745, 0.750, 0.755\}$ mach, and a fuzzy set $\mathbf{M}$ for the speed "near mach 0.74" where

$$\mathbf{M} = \left\{ \frac{0}{0.725} + \frac{0.25}{0.730} + \frac{0.75}{0.735} + \frac{1}{0.740} + \frac{0.75}{0.745} + \frac{0.25}{0.750} + \frac{0}{0.755} \right\}$$

and define a universe of altitudes as $\mathbf{Y} = \{8350, 8400, 8450, 8500, 8550, 8600, 8650\}$ m, and a fuzzy set $\mathbf{A}$ for the altitude "approximately 8,500 m", where

$$\mathbf{A} = \left\{ \frac{0}{8350} + \frac{0.3}{8400} + \frac{0.6}{8450} + \frac{1}{8500} + \frac{0.6}{8550} + \frac{0.3}{8600} + \frac{0}{8650} \right\}$$

2.1.1 Construct the relation $\mathbf{R} = \mathbf{M} \times \mathbf{A}$ [5 marks]

2.1.2 For another aircraft speed, say $\mathbf{M}_1$ for the speed "in the region of mach 0.74" where

$$\mathbf{M}_1 = \left\{ \frac{0}{0.725} + \frac{0.5}{0.730} + \frac{0.8}{0.735} + \frac{1}{0.740} + \frac{0.6}{0.745} + \frac{0.2}{0.750} + \frac{0}{0.755} \right\}$$

determine the corresponding altitude fuzzy set $\mathbf{A}_{1a} = \mathbf{M}_1 \circ \mathbf{R}$ using the max-min composition. [5 marks]

2.1.3 For the speed "in the region of mach 0.74" where

$$\mathbf{M}_1 = \left\{ \frac{0}{0.725} + \frac{0.5}{0.730} + \frac{0.8}{0.735} + \frac{1}{0.740} + \frac{0.6}{0.745} + \frac{0.2}{0.750} + \frac{0}{0.755} \right\}$$

determine the corresponding altitude fuzzy set $\mathbf{A}_{1b} = \mathbf{M}_1 \circ \mathbf{R}$ using the sum-product composition.

[5 marks]

2.2 [Laser Beam Alignment] [35 marks]

Fuzzy logic is used to control a two-axis mirror gimball for aligning a laser beam using a quadrant detector. Electronics sense the error in the position of the beam relative to the centre of the detector and produces two signals representing the x and y direction errors. The controller processes the error information using fuzzy logic and provides appropriate control voltages to run the motors which reposition the beam. The fuzzy logic controller for this system is shown in Figure 2.1.

To represent the error input to the controller, a set of linguistic variables is chosen to represent 5 degrees of error, 3 degrees of change of error, and 5 degrees of armature voltage. Membership functions are constructed to represent the input and output values' grades of membership as shown in Figure 2.2. The rule set in the form of "Fuzzy Associative Memories" is shown in Figure 2.3.

The controller gains are assumed to be $GE = 1, GCE = 1, GU = 1$.

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

$$\alpha_i = \mu_{E_i}(e).\mu_{CE_i}(ce)$$

calculate the defuzzified output voltages of this fuzzy controller at a particular instant. The error and the change of error at this instant are $e = 3.20$ and $ce = -0.47$.

[10 marks]

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

$$\alpha_i = \min(\mu_{E_i}(e), \mu_{CE_i}(ce))$$

calculate the corresponding defuzzified output voltage at a particular instant when the error and the change of error are $e = 3.20$ and $ce = -0.47$.

[25 marks]

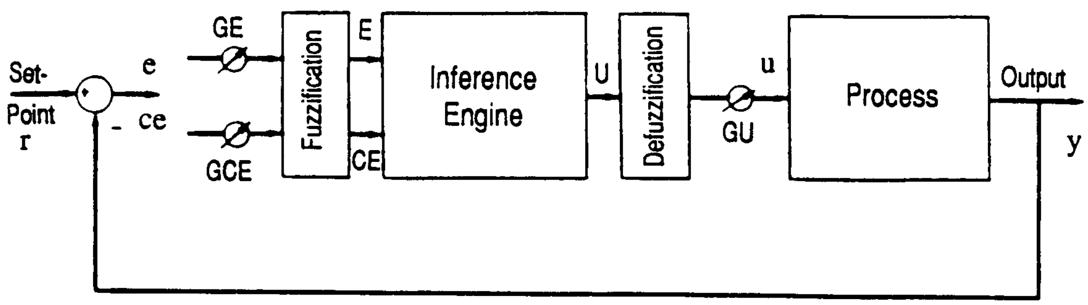

Figure 2.1 Fuzzy logic control system

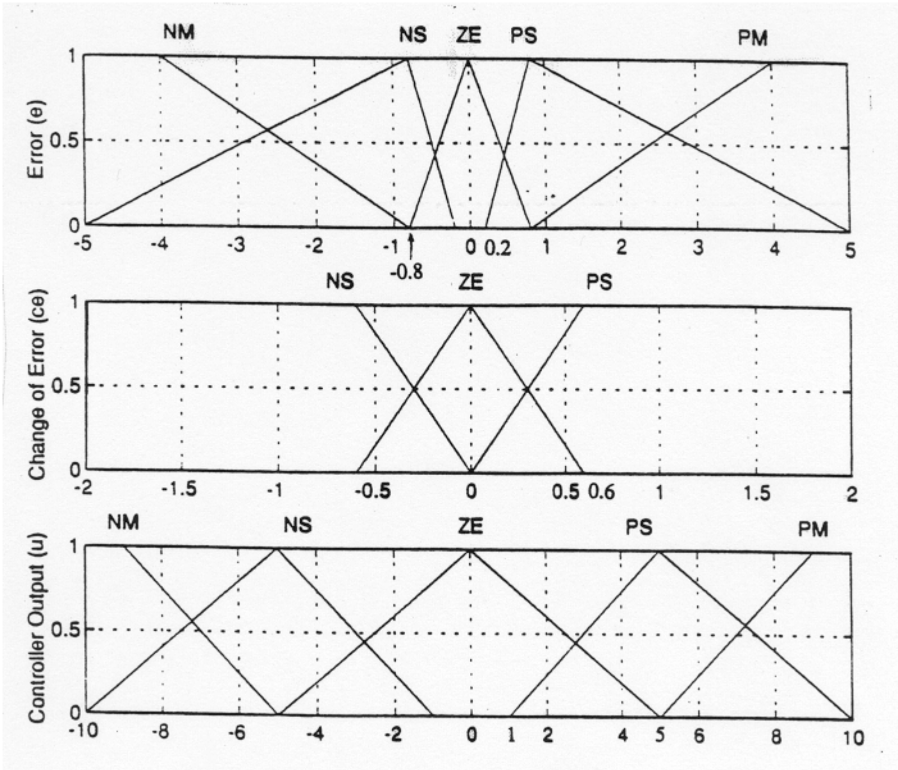

Figure 2.2 Membership functions of a laser beam alignment system

Change of Error \ Error	NM	NS	ZE	PS	PM
NS	PM	PM	PS	ZE	NS
ZE	PM	PS	ZE	NS	NM
PS	PS	ZE	NS	NM	NM

Figure 2.3 Fuzzy Associative Memories

H. T. Nguyen
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MARKING SCHEME

Assignment 1: 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 Perceptron Dichotomiser 1.1 Discrete Perceptron	• Presentation • Final weight vector • Correct classification • Pattern error curve • Cycle error curve • Calculation/software code		/25
1.2 Continuous Perceptron	• Presentation • $W(7)$ • $W(301)$ • Cycle error curve • Classification after nc=1 • Classification after nc=50 • Software code		/25
Question 2 2.1 Flight Simulation	• Presentation • Relation R=MxA • Relation R=AoE (max-min) • Relation R=AoE (sum-product) • Calculation/software code		/15
2.2 Laser Beam Alignment	• Presentation (MOM) • Fuzzification E • Fuzzification CE • Defuzzified output voltage • Calculation/software code • Presentation (COA) • Fuzzification E & CE • Total Area • Total Moment • Defuzzified output voltage • Calculation/software code		/35