UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 8 Examination in Engineering: February 2020

Module Number: EE8208 **Module Name: Intelligent Systems Design**

[Three Hours]

[Answer **all questions,** each question carries **12.5 marks]**

Q1 a) What is the advantage of using "Fuzzy" sets over "Crisp" sets? Explain by using appropriate examples.

[3.0 Marks]

b) Define Fuzzy sets and show their membership functions that would represent the level of achievement (bad, average, good, excellent) in an exam, if the marks 0 to 100 represents the Universe of Discourse.

[3.0 Marks]

c) Define operations i) Intersection (AND), ii) Union (OR), iii) Complement and iv) Lukasiewicz-OR, by using appropriate Membership Functions of the Fuzzy Sets A and B. Also interpret these operations in diagrams of Universe of Discourse vs Fuzzy Membership.

[4.0 Marks]

d) Consider the Fuzzy Sets A = {1/a, 0.3/b, 0.2/c, 0.8/d, 0/e} and B = {0.6/a, 0.9/b, 0.1/c, 0.3/d, 0.2/e} in the Universe of Discourse X={a, b, c, d, e}. Calculate the Intersection, Union and Complements of A and B.

[2.5 Marks]

Q2. A Fuzzy Logic controller is to be designed for a classical feedback control system.

a) Draw the classical feedback control diagram with Process, Fuzzy Controller and the feedback path. Define the Control Error **e(k)** and Rate of Error **r(k)** with respect to the SV (Set Value) and PV (Process Value).

[3.0 Marks]

b) Define four typical Fuzzy Rules for controlling based on the Universes of Discourse; Error **e(k)**, Rate of Error **r(k)** and Control Output **du(k)**, with appropriate linguistic variables.

[3.0 Marks]

c) Define the membership functions for the linguistic variables denied in the Universes of Discourse **e(k)**, **r(k)** and **du(k)**, and show them in appropriate diagrams.

[3.0 Marks]

d) Show how to calculate the Control Output **du(k)** for a given values of **e(k)** and **r(k)** by using a numerical example. Use the method "Center of Gravity" to calculate the final **du(k)**.

[3.5 Marks]

Q3. a) Briefly explain the followings

i. An artificial neural network.

ii. The Supervised learning of artificial neural networks.

[2.0 Marks]

b) Describe three applications of artificial neural networks.

[4.5 Marks]

c) Consider two input/output data sets of a neural network.

$$\left\{\left(\begin{bmatrix}0\\1\\1\end{bmatrix},1\right),\quad \left(\begin{bmatrix}1\\1\\0\end{bmatrix},0\right)\right\}$$

If the initial weights $W = [0.1\ -0.1\ \ 0.2]$ and bias $b = 0.2$, determine the weight vector and the bias after **two** iterations, when the network trained by the perceptron learning rule with the learning rate $m = 1$.

[6.0 Marks]

Q4. a) i. Explain what is meant by orthonormal vectors.

ii. Describe the learning process of pseudo inverse rule.

[2.0 Marks]

b) Let (x,t_1) and (x_2,t_2) be two input/output vectors such that

$$(x,t_1) = \left(\begin{bmatrix}1\\-1\\1\\0\end{bmatrix},\begin{bmatrix}1\\0\end{bmatrix}\right) \text{ and } (x_2,t_2) = \left(\begin{bmatrix}-1\\0\\1\\1\end{bmatrix},\begin{bmatrix}0\\1\end{bmatrix}\right)$$

i. Are x_1 and x_2 orthonormal?.

ii. Use pseudo inverse rule to determine the weight matrix of the network.

[2.5 Marks]

c) i. The weight update equation for hidden layers in artificial neural network with backpropagation training is

$$w_{ji}(n+1) = w_{ji}(n) + \eta_j \delta_j^h f_h(net_i)).$$

Where,

$$\delta_j^h(n) = f_h'\left(net_j^h(n)\right)\sum_{k=1}^{h_{n+1}} \delta_k^{h+1}(n) w_{kj}^{h+1}(n)$$

Describe in words what the various symbols and variables in the above two equations refer to.

ii. Write down the weight update equation for output layer neurons.

[3.0 Marks]

d) While training a fully connected neural network, output error $E(n)$ at the n^{th} training cycle was 0.22. The corresponding weight matrices were

$$W(n) = \begin{bmatrix}0.1 & 0.1\\-0.1 & 0.2\\0.2 & -0.1\end{bmatrix} \text{ and } V(n) = [0.1\ \ 0.1\ \ -0.2]$$

i. Roughly sketch the neural network architecture.

ii. If $\eta = 0.1$ and the log sigmoid and linear activation functions used for hidden and output layers respectively, compute the error $E(n+1)$ at the training cycle $n+1$.

[5.0 Marks]