Birla Institute of Technology and Science - Pilani
K. K. Birla Goa Campus
Second Semester, 2018-19
Neural Networks and Fuzzy Logic (BITS F312)
Mid-semester Exam

Full Marks: **45**, *Maximum Duration:* 90 minutes, *Component:* Regular (Closed Book)

15^{th} March 2019

Please read these instructions carefully

- Anwer *any three* out of *four* questions.
- Support your answers with simplified diagrams wherever applicable.
- Most questions require algebraic derivations. No question require descriptive answers. Some questions require short sentences or brief paragraphs.
- You would rather not attempt a question that you are not sure of than writing non-sensical descriptive answers; otherwise will certainly lead to deduction of marks, and at the discretion of the examiner.

Question 1

A three-layer feed-forward perceptron network has $\mathbf{p}_{R\times 1}$ as the input feature vector. There are S^1, S^2, S^3 neurons in the input, hidden and output layers respectively. Let W^L, n^L and a^L denote the weight matrix, net output, and actual output, respectively, of layer L of the network; $a^L = f(n^L)$, where $f(\cdot)$ is the activation function.

(i) Express the network output $a^{L=3}$ in terms of the network parameters of the preceding layers, and including the input feature vector.

(ii) How would the output (that you have derived above) evolve if all activation functions were to be defined as linear units, i.e. $f(n) = n$?

(iii) If you now apply the output of $a^{L=3}$ in (ii) to a rectifier, the effect will be that of applying a ReLU activation function. How would you re-define the actual output of the layer in terms of its net input?

(iv) Following on from the above, how would your expression in (ii) evolve by applying the rectification in (iii) to all the activation functions in the network?

(v) If you use the above neural network as a binary classifier, how would you train the weights using the perceptron learning rule? Keep your answer precise using algebraic expressions.

(3+2+2+3+5 = 15 marks)

Question 2

What is the underlying physiology of Hebb's Learning Rule for Neural Networks?
(*Use no more than 6 lines on your answer sheet, or 3 sentences, whichever is lesser. Answers exceeding this upper bound will be liable to a deduction of 0.5 marks for each exceeding line/sentence, whichever is greater.*)
You may use diagram for explanatory purposes.

(3 marks)

Apply your understanding to answer the following questions. *Remember to explain all parameters used in your algebraic expressions.*

(i) Express Hebb's Rule algebraically for Supervised Learning in neural networks.

(ii) You have applied Hebb's Supervised Learning Rule to design an Associative Memory neural network. Under what conditions will you get errors in the network? Explain algebraically.

(iii) How can you minimise the error in (ii) using Moore-Penrose Pseudo-inverse?

(iv) Use algebraic expression to demonstrate the fundamental difference between Supervised and Unsupervised Hebb's Learning Rule.

(2+3+5+2 = 12 marks)

Question 3

(i) What is Recurrence in a neural network, and what is the basic implementation strategy? Answer using diagrams and algebraic expressions.

(ii) What are Competitive Neural Networks, and how do they use Recurrent connections to implement winner-take-all competition? Explain your answer with diagram and algebraic expressions.

(iii) Explain Competitive Learning using the Instar Rule. Demonstrate your answer with vector diagrams.

(iv) What biological mechanisms underpin Competitive Neural Networks? Be specific while answering, and support your answer with diagrams.

(3+5+5+2 = 15 marks)

Question 4

(i) What are the characteristics of the neural network that constitute the Boltzmann Machine?

(ii) What is the Boltzmann Learning Rule?

(iii) Simulated Annealing is a technique that is used to find the global minimum of an Energy surface by slow, controlled temperature variation. Using algebraic expressions, show how Simulated Annealing is used in Boltzmann Machine to achieve a globally minimum energy for a specific learning task. Keep your answer precise and brief.

(5+5+5 = 15 marks)