B.E. in CSE/EE/ME/Production Engg. Fourth Year Second Semester Examination-2023

Open Elective on
Brain-Computer Interfacing

Full Marks: 70 Time: 3 Hours

Attempt any **FIVE** questions.

1. a) State the full names, location of origin in the human brain and modality of use of the following four brain signals: ERD/ERS, ErrP, P300 and SSVEP.

   b) Construct a block diagram of a Brain-Computer Interface (BCI) system, involving the following modules: Classification, Feature Selection, Feature Extraction, Pre-processing and Filtering, Controller. Justify the position of the modules in your block diagram. Also explain the functionaries of the above modules.

   c) What is the essence of signal sampling and digitization in an EEG system?

   d) Why EEG is preferred over other modalities of BCI system?

   e) State one BCI system where the controller block is necessary and a second system where the classifier is mandatory.

   f) The EEG system includes an analog filter of upper cutoff frequency 100 Hz. Still why a digital filter is needed for certain BCI operation? Explain how a digital filter works.

[4+2+2+2+2+2]

2. a) What do you understand by the phrase: Principal Components of a given data matrix, comprising data point vectors of uniform dimension?

   b) What is a Covariance matrix? How will you evaluate the Covariance matrix of a given data matrix?

   c) Why Principal Component Analysis (PCA) is important?

   d) How will you evaluate eigen values and eigen vectors of a 2 x 2 matrix? Illustrate with a real symmetric matrix.

   e) Show that the eigen vectors of a real symmetric matrix are orthogonal.

f) How does the above mentioned property of real symmetric matrix help in establishing the importance of principal components?

g) Explain how will you use PCA for feature selection?

h) Given a jack fruit, where the data points describe the coordinates on the surface of the jack fruit with respect to one end of the fruit, defined as the origin. What should be the first 2 principal components of the jack fruit? [1+2+1+2+2+2+3+1]

3. a) Generate five 2-dimensional data points (x, y) satisfying y >= 2x +1, and another five data points satisfying y<=2x – 1 on a graph paper/normal paper with manual markings with a uniform scale.

b) Can we use y=2x as a linear classifier to segregate the 2 classes of data points? If yes, explain why.

c) What is the essence of feature selection in a pattern classification problem?

d) In a pattern classification problem, data point vectors with components: u, v, w, x, y, z, and the respective classes are given. It is noted that v=f(x, y), z=g(x), where f and g are functions of the variables given in the argument. Which features should you select to design the classifier?

e) Suppose an intelligent data analyst selects u and x features only rather than all those you selected in the last part of the question. What is the basis of her selection? Answer in terms of intra- and inter class variations of the selected features in the given training instances (data points plus class information).

f) What is Gradient Descent Learning? Show graphically that Gradient Descent Learning always converges to Nearest Local Optimum from either side of the optimum for a given one dimensional function E(x).

g) A one-year old child does not know the definition of balls, balloons and teddy bears. A basket containing multiple copies of the above items is placed within the reach of the child. Let us assume that the child could be explained the meaning of *similarity* by several trials. If the child can segregate the objects of similar types, what would be the best phrase to describe the child: a good classifier or a good clustering agent? Justify your answer with reference to presence or absence of class labels.

h) Liza is 2 years old. She is given a drawing containing a square on her painting board. The coordinates of the vertices are (0, 0), (0, 1), (1, 0) and (1, 1). Suppose you need to train Liza to classify the data points {(0,0), (1,1)} and {(1,0), (0,1)}. What kind of classifier would you use: Linear or Non-linear? For your examiner, can you show graphically how to segregate the 2 classes? [1+1+1+2+2+3+2+2]

4. a) Draw the structure of an artificial neuron showing its resemblance with a biological neuron. Draw a Sigmoid function and justify why y=0 and y=1 are asymptotes to the Sigmoid function. Draw the topology of a feed-forward neural network.

b) Using Gradient Descent Learning, derive the weight adaptation formula in the last and also in the last but one layer as done in Back-Propagation algorithm.

c) Discuss how an error table is used to train a network with multiple instances for a function approximation problem.

5. a) Arnab Rakshit, a Ph.D. student of ETCE dept. developed a tiny single link robot control system in the BCI laboratory of Jadavpur University. The system employs a long arm to move over a semi-circular arc by a DC motor. A human subject needs to think Right Hand Motor Imagination to start the robot turning clockwise. When the robotic link crosses a predefined target position on the arc, the human subject generates an ErrP signal. Explain with a schematic diagram how the BCI system works.

b) Suppose you want to realize a fuzzy controller for the above system. State 2 exemplar fuzzy rules used to develop the controller. Also explain the fuzzy reasoning mechanism to determine the angular position of the robotic link.

c) What type of de-fuzzification is necessary to get back the angular position from the fuzzy inferences? Write down the de-fuzzification formula.

d) For a given rule: if x is A Then y is B, what is Diens-Rescher implication function? What is Mamdani type implication relation? Using Mamdani type implication, show how Togai and Watanabe of Bell AT and T Laboratory, USA designed a simple formula for fuzzy inference generation for realization on VLSI. Illustrate their inference generation policy using 2 fuzzy rules. [2+5+2+5]

6. Write NOTES on the following:

a) Propositional implication and its fuzzy extension

b) Binary and fuzzy relations

c) Analog versus Digital Filtering

d) Neural Networks for non-linear regression and classification

e) Classification versus Clustering problems [3+3+3+3+2]