# ECE 457 B: COMPUTATIONAL INTELLIGENCE

## ASSIGNMENT #3
## (Artificial Neural Networks)

**Due Date: Please upload in the Dropbox folder "Assignmnet#3"**

**before 11:59pm on March 29, 2017**

**NOTE: To help with the adequate marking of your assignments, please follow these rules carefully:**

1. All work should be carried out **individually**
2. The first page of the assignment must have the name and ID of the student
3. The items required must be numbered, labelled, and in numerical order.
4. The solutions can be handwritten (in very neat way) or typewritten
5. All pages must be numbered sequentially
6. Show your steps and state any additional assumptions that you make.
7. Presentation of your results and the organization of your copy count for **10% of the mark**

**Problem 1**

Derive the back-propagation training algorithm for the structure of the feed forward neural network given as multilayer perceptron structure with two inputs, two hidden layers each with two neurons, and one output layer with one output, in which the activation function is the hyperbolic tangent function $\tanh(\alpha x)$ given as:

$$f(x) = \tanh(\alpha x) = \frac{(e^{\alpha x} - e^{-\alpha x})}{(e^{\alpha x} + e^{-\alpha x})}$$

Notice that the derivative of $f(x)$ is given by:

$$\frac{\partial f}{\partial x} = \alpha \left( \frac{1}{\cosh^2(\alpha x)} \right) = \alpha \operatorname{sech}^2(\alpha x)$$

**Problem 2**

Using a feedforward back-propagation neural network that contains a single hidden layer (with a variable number of hidden nodes each having an activation function of the logistic form), investigate the outcome of the neural network for the following mappings:

- $f(x) = x * \sin(6\pi x) * \exp(-x^2)$ where $x \in [-1, 1]$
- $f(x) = \exp(-x^2) * \arctan(x) * \sin 4\pi x$ where $x \in [-2, 2]$

For each function, create two sets of *input/output* data, one for training and the other for testing (these will be random values within the interval of the variable x). You can choose the ratio as 70% of the data for training and 30% of the data for testing

a) Investigate the effect of the training patterns (samples) number *on the accuracy of the output when the number of hidden nodes is fixed (e.g., 3 hidden nodes). You can choose a number for the training data from 10 patterns to 200 patterns.

b) Investigate the effect of the number of hidden nodes on the accuracy of the output for a given fixed number of training samples (e.g., 100 training patterns). Try to find the optimal number of hidden nodes to lead to the best error.

c) Make qualitative and quantitative deductions in light of these simulations.

**Problem 3**

We need to train a MLP network for obtaining the output of the following two-to-one mapping function

$$f(x_1, x_2) = \sin(2\pi x_1) * \cos(0.5\pi x_2) * \exp(-x_1^2)$$

a) Set up two sets of data, one for network training and the other for testing (70% for training and 30% for testing). The total number of input-output data is 500 and is obtained by randomly varying the input variables $(x_1, x_2)$ within the interval [-1,1] by [-4 4].

b) First, fix the number of hidden neurons to 4 (double of the number of input nodes) and analyze the performance of the obtained network.

c) Analyze the performance of the network with more and then with fewer hidden nodes (2, 6, 8, 12, 20). Find the best number of hidden neurons leading to the least network error and discuss.

**Problem 4**

We need to develop a neural network based classifier for three various but related products. The collected data are the results of a chemical analysis of liquid products grown in the same region in Italy but derived from three different cultivars. The analysis determined the quantities of 13 constituents found in each of the three types of products. The data file provided is in text format and has fourteen dimensions, the first of which determines the class of products (product '1', product '2', product '3'), which should serve as the output of the neural network classifier. The remaining ones determine the input of the classifier and has 13 constituents as:

1. Ethanol
2. Malic acid
3. Ash
4. Alcalinity of ash
5. Magnesium
6. Total phenols
7. Flavanoids
8. Nonflavanoid phenols
9. Proanthocyanins
10. Color intensity
11. Hue
12. OD280/OD315 of diluted liquid
13. Proline

**4.1** Design a classifier ( multilayer neural network), vary its parameters (number of hidden layers without exceeding three and number of nodes in each layer) and try to find the best possible classification performance (a table illustrating various results as parameters are varied would be preferred). Please discuss.

**4.2** Once this is done, classify (determine to which product they belong) the following entries each of which has 13 attributes:

**a)** 13.72; 1.43; 2.5; 16.7; 108; 3.4; 3.67; 0.19; 2.04; 6.8; 0.89; 2.87; 1285
**b)** 12.04; 4.3; 2.38; 22; 80; 2.1; 1.75; 0.42; 1.35; 2.6; 0.79; 2.57; 580
**c)** 14.13; 4.1; 2.74; 24.5; 96; 2.05; 0.76; 0.56; 1.35; 9.2; 0.61; 1.6; 560

***Hint for implementation***: You may wish to calibrate all input data to be all between 0 and one. Also from the set of data choose 75% of the data from product 1, product 2 and product 3 as training data and remaining 25% remaining as testing. You can use existing Matlab libraries or other libraries to create the classifier, which code needs to be appended to the solutions.

**Problem 5**

We need to construct an interpolator using the Radial Basis Function (RBF) network with seed functions the Gaussian mappings where the standard deviations are all equal to $\sigma_i$. The original function is given by

$$f(x) = \sqrt{|x|}\sin(\frac{\pi}{2}x)$$

a. Build a radial basis function network and find the interpolation function $\hat{f}$(x) in the interval [-6 6] using training data at the points x=-6, x=-5, x=-2, x=0, x=1, x=3, x=5 with $\sigma_i$=1. Draw the curves comparing the two functions (the original one and the interpolated). What is the value of the estimated interpolator at x=3.6?
b. Redo the same for $\sigma_i$= 0.5, 3, 6.
c. Draw your conclusions