EAI 320

Practical Assignment 8

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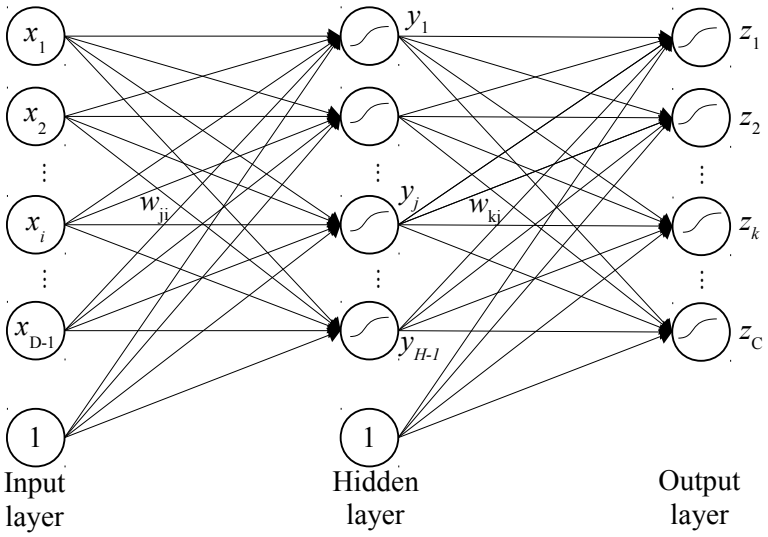
Question 1

Implement the backpropagation algorithm for artificial neural networks (ANNs) as a Python function. The function should perform backpropagation on a three layered network with D inputs, H hidden neurons and C outputs. Both the input layer and the output layer should contain a bias neuron. The general form of this neural network is illustrated in the figure below:



The function should take the following input arguments:

- The input data as a $D \times N$ array, where D is the number of features and N is the number of data samples. (Note that D includes the bias neuron).
- The target values as a $C \times N$ array, where C is the number of output classes,
- The initial values of the weights from the input layer to the hidden layer as a $D \times (H-1)$ array[1]. H is the number of neurons in the hidden layer, including the bias neuron.
- The initial values of the weights from the hidden layer to the output layer as a $H \times C$ array.
- The learning rate, η.
- The terminating conditions: number of epochs and error convergence. criterion value (see the discussion below).

The function should output the following parameters:

[1]The second dimension is $H-1$ as there are no links from the input layer to the hidden layers bias neuron

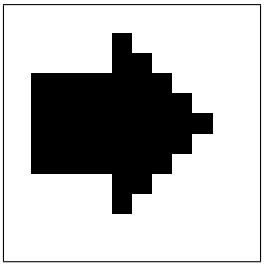
- The updated input-to-hidden layer weight array.
- The updated hidden-to-output layer weight array.
- A vector of error values for each epoch (see the discussion below).

In each epoch (training iteration), the function should compute the error $J = {}^1/_2 \sum_k (t_k - z_k)^2$. The values should be stored in a vector with a length equal to that of the total number of epochs. The error convergence criterion can be calculated as the absolute value of the difference between the current error and the previous error. When this reaches a specified threshold the algorithm terminates.

The activation function and its derivative should be implemented in separate python functions. **Always** ensure that the dataset features are normalized to the range $[0, 1]$ before passing them to the backpropagation algorithm.

Question 2

In this question you are required to demonstrate the ability of a ANN to model complex decision boundaries. Apply the backpropagation algorithm developed in Question 1 to model an arrow shaped decision boundary. For this, a dataset is created from the low resolution image illustrated below.



The input dataset consists of horizontal and vertical pixel indices. The target dataset consists of binary values of the pixel value corresponding to each pixel index. The input and target datasets are contained in the comma delimited files 'q2inputs.csv' and 'q2targets.csv' respectively. Remember to normalise the inputs.

Plot a three dimensional figure containing the two features on the horizontal axes and the class probability (ANN output) on the vertical axis. The following code may be used to plot such a figure:

```
#Generate the surface
i=0
j=0
Z = np.zeros((21,21))
for x1 in np.arange(0,1,0.05):
  i = 0
  for x2 in np.arange(0,1,0.05):
    #Calculate the output of the neural network
    #given the  input [1 x1 x2] and ANN weights, W1 and W2
    Z[i,j] = ffNeuralNet(np.array([[1], [x1], [x2]], W1, W2)
    i = i+1
  j = j+1

#Plot the surface
X = np.arange(0, 21, 1)
Y = np.arange(0, 21, 1)
X, Y = np.meshgrid(X, Y)
fig = plt.figure()
ax = fig.gca(projection='3d')
surf = ax.plot_surface(X, Y, Z, rstride=1, cstride=1, cmap=cm.coolwarm)
ax.set_zlim(0, 1)
```

Question 3

Apply the ANN to classify a wine dataset [2]. The dataset consists of 13 features describing a wine sample. These features are listed as

1. Alcohol
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 wines
13. Proline

[2] https://archive.ics.uci.edu/ml/datasets/Wine

Each sample from the dataset comes from one of three different cultivars in Italy. The objective is to train an ANN to be able to determine from which cultivar a wine sample originates, given the 13 features extracted from the wine sample. The dataset has been split into a training and test set. The task is to train the ANN on the training set and then test it using the test set. The training set inputs and target data are contained in the 'q3TrainInputs.csv' and 'q3TrainTargets.csv' files respectively. The test set inputs and target data are contained in the 'q3TestInputs.csv' and 'q3TestTargets.csv' files respectively. Note that the inputs have been normalised.

Include the following in your results:

a) Increment the number of hidden layer neurons from 1 until zero errors occur.

b) Plot the error over the training epochs.

Question 4

Apply the ANN for regression in a house value dataset[3]. The dataset consists of 14 features describing the wine. These features are listed as

1. CRIM: per capita crime rate by town
2. ZN: proportion of residential land zoned for lots over 25,000 sq.ft.
3. INDUS: proportion of non-retail business acres per town
4. CHAS: Charles River dummy variable (= 1 if tract bounds river; 0 otherwise)
5. NOX: nitric oxides concentration (parts per 10 million)
6. RM: average number of rooms per dwelling
7. AGE: proportion of owner-occupied units built prior to 1940
8. DIS: weighted distances to five Boston employment centres
9. RAD: index of accessibility to radial highways
10. TAX: full-value property-tax rate per $\$10,000$
11. PTRATIO: pupil-teacher ratio by town
12. B: $1000(Bk - 0.63)^2$ where Bk is the proportion of blacks by town
13. LSTAT: % lower status of the population
14. MEDV: Median value of owner-occupied homes in $1000's

[3] https://archive.ics.uci.edu/ml/datasets/Housing

Each sample from the dataset contains an associated continuous valued house value as a target value. The objective is to train an ANN to be able to determine a house value given a sample with the 14 features. The dataset has been split into a training and test set. The task is to train the ANN on the training set and then test it using the test set. The training set inputs and target data are contained in the 'q4TrainInputs.csv' and 'q4TrainTargets.csv' files respectively. The test set inputs and target data are contained in the 'q4TestInputs.csv' and 'q4TestTargets.csv' files respectively. Note that the inputs have been normalised.

To perform regression using a ANN, a single output neuron is required. This neuron must have a linear activation function. The linear activation function is given by $f(y) = w_2^T y$, where w_2 is the weights between the hidden and output layers and y is the outputs of the hidden layer neurons. The derivative of the linear activation function is $f'(\cdot) = 1$. All other neurons in the ANN require non-linear activation functions. This implies that the inputs must be normalised (which has been done for you). The target values need not be normalised.

Include the following in your results:

a) Provide a table that compares the target values and the ANN output values for the test samples.

b) Plot the error over the training epochs.

Deliverables

- Write a technical report on your finding for this assignment.
- Include your code in the digital submission as an appendix, but leave it out for the hardcopy submission.

Instructions

- All reports must be in PDF format and be named report.pdf.
- Place the software in a folder called SOFTWARE and the report in a folder called REPORT.
- Add the folders to a zip-archive and name it EAI320_prac1_studnr.zip.
- All reports and simulation software must be e-mailed to *EAI320.UP@gmail.com* no later than 16:00 on 31 May 2016. No late submissions will be accepted.
- Place a hard copy of your report in the box in front of Eng 3 7-25 before the deadline.
- Submit your report online on ClickUP using the TurnItIn link.

Additional Instructions

- Do not copy! The copier and the copyee (of software and/or documentation) will receive zero for both the software and the documentation. Z-e-r-o.
- For any questions of appointments email me at *EAI320.UP@gmail.com*
- Make sure that you discuss the results that are obtained. This is a large part of writing a technical report.

Marking

Your report will be marked as follow:

- 60% will be awarded for the full implementation of the practical and the subsequent results in the report. For partially completed practicals, marks will be awarded as seen fit by the marker.
- 40% will be awarded for the overall report. This includes everything from the report structure, grammar and discussion of results. The discussion will be the bulk of the marks awarded.