CS6301 MACHINE LEARNING LAB WEEK – 4 MLP

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Aim: To implement Radial Basis Function Networks with different datasets and measure the performance metrics.

ALGORITHM:

- Position the RBF centres by either:
  - using the *k*-means algorithm to initialise the positions of the RBF centres OR
  - setting the RBF centres to be randomly chosen datapoints
- Calculate the actions of the RBF nodes using Equation
  - **Gaussian function:**

$$g(\mathbf{x}, \mathbf{w}, \sigma) = \exp\left(\frac{-\|\mathbf{x} - \mathbf{w}\|^2}{2\sigma^2}\right).$$

- Train the output weights by either:
  - using the Perceptron OR
  - computing the pseudo-inverse of the activations of the RBF centres

Dataset-1: MNIST Dataset

The MNIST database is a large database of handwritten digits that is commonly used for training various image processing systems which contains 60,000 training images and 10,000 testing images. Half of the training set and half of the test set were taken from NIST's training dataset, while the other half of the training set and the other half of the test set were taken from NIST's testing dataset.

Input:

train - Notepad

File Edit Format View Help

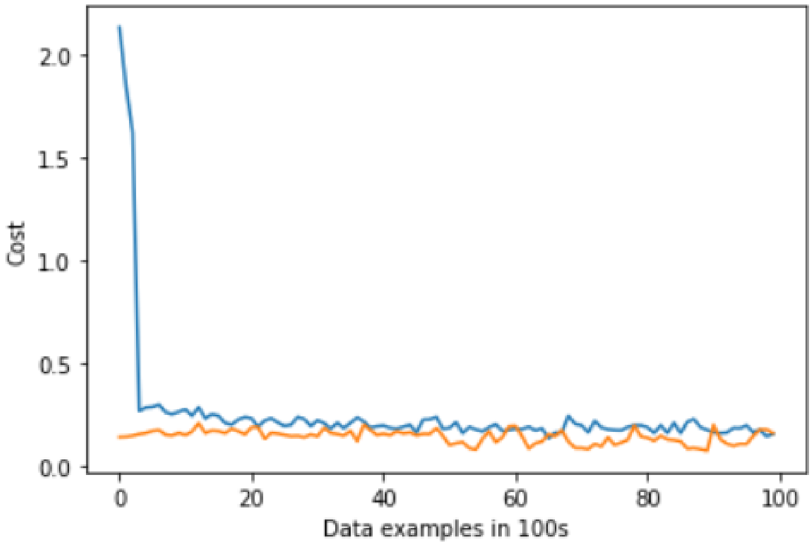
```
[   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   3  18  18  18 126 136 175  26 166 255
  247 127   0   0   0   0   0   0   0   0   0   0   0   0  30  36  94 154
  170 253 253 253 253 253 225 172 253 242 195  64   0   0   0   0   0   0
    0   0   0   0   0  49 238 253 253 253 253 253 253 253 253 251  93  82
   82  56  39   0   0   0   0   0   0   0   0   0   0   0   0  18 219 253
  253 253 253 253 198 182 247 241   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0  80 156 107 253 253 205  11   0  43 154
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0  14   1 154 253  90   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0 139 253 190   2   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0  11 190 253  70   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  35 241
  225 160 108   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0  81 240 253 253 119  25   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    0   0  45 186 253 253 150  27   0   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   0   0   0   0   0   0  16  93 252 253 187
```

Output:

Precision and Recall

	precision	recall	f1-score
0	0.89	1.00	0.94
1	0.00	0.00	0.00
2	0.00	0.00	0.00
5	0.00	0.00	0.00
7	0.00	0.00	0.00
accuracy			0.89
macro avg	0.18	0.20	0.19
weighted avg	0.80	0.89	0.84

```
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 1
Importing data for training...
60000 training examples imported in 11.86 sec
Initialzing Centers...
Training...
Training done
Training took: 97.72 sec
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 2
Enter file name containing weights (default: weights.npy): weights.npy
Importing data for testing...
Prediciting...
Total Avg. Accuracy: 90.07 %
```




```
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 3
Program exited.
```

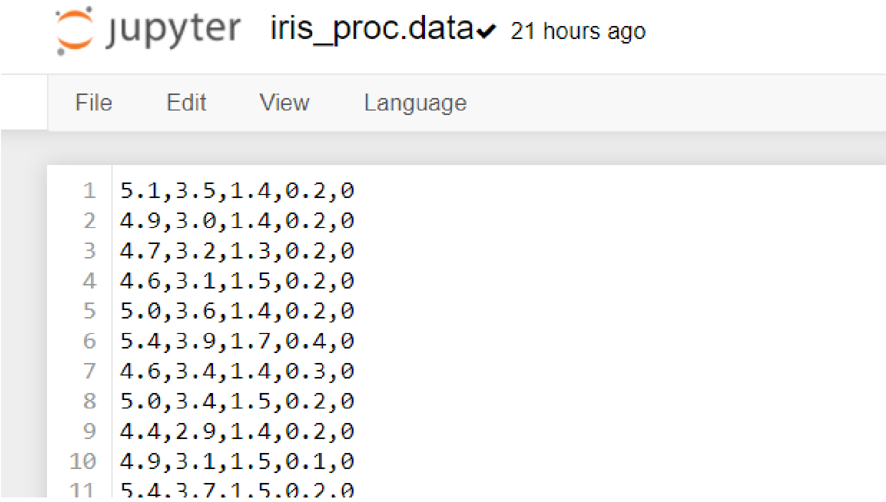
Dataset: **Iris Dataset**

Url: https://archive.ics.uci.edu/ml/datasets/iris

Description: The **Iris Dataset** contains four features (length and width of sepals and petals) of 50 samples of three species of **Iris** (**Iris** setosa, **Iris** virginica and **Iris** versicolor).

Input: The following 4 attributes

- sepal length in cm,
- sepal width in cm,
- petal length in cm,
- petal width in cm,



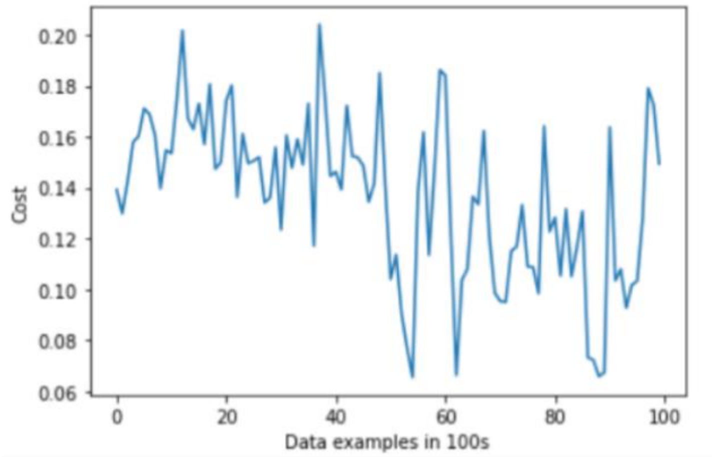
Output: decision: Multiclass classification among 3 classes of flowers: Iris Setosa, Iris Versicolour, Iris Virginica.

Precision and Recall

	precision	recall	f1-score
0	0.95	0.94	0.95
1	0.98	0.96	0.97
2	0.90	0.91	0.91
3	0.89	0.87	0.88
4	0.83	0.90	0.86
5	0.84	0.90	0.87
6	0.96	0.89	0.92
7	0.85	0.95	0.90
8	0.86	0.86	0.86
9	0.90	0.79	0.84
accuracy			0.90
macro avg	0.90	0.90	0.90
weighted avg	0.90	0.90	0.90

```
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 1
Importing data for training...
135 training examples imported in 1.07 sec
Initialzing Centers...
Training...
Training done
Training took: 0.43 sec
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 2
Enter file name containing weights (default: weights.npy): weights1.npy
Importing data for testing...
```

```
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Predicted 0      Actual 0
Total Avg. Accuracy: 89.44444444444444 %
```




```
1. Train the RBF Network
2. Predict using the RBF Network
Choose your option: 3
Program exited.
```

TABULAR INFERENCE:

DATASET	MNIST	IRIS
PRECISION	89	90
RECALL	90	79
F1-SCORE	94	84
ACCURACY	90.07 %	89.44 %

The Radial basis function neural networks are demonstrated on different datasets and their performance metrics are measured. The RBF approach requires less time for model development since no repetition is required to reach the optimum model parameters.

Code:

```
import numpy as np
import time
import re
import sys
import math
import matplotlib.pyplot as plt
np.set_printoptions(threshold=sys.maxsize, suppress=True)
np.random.seed(1)

def inputXFromFile(filename, sampleSize):
	inputArray = np.zeros(shape=(sampleSize, 784))
	with open(filename, "r") as file:
		for i in range(sampleSize):
			inputList = []
```

```
                for _ in range(44): # 44 lines of each example in file
                    line = file.readline().strip("[").replace("]", "")
                    inputList += line.split()
                inputArray[i] = inputList
        return np.divide(inputArray, 255)

def inputYFromFile(filename, sampleSize):
        inputArray = np.zeros(shape=(sampleSize, 10))
        with open(filename, "r") as file:
            for i in range(sampleSize):
                value = file.readline()
                if not value:
                    break
                inputArray[i][int(value)] = 1
        return inputArray

def kMeansClustering(K, sampleData):
        randIndices = np.random.choice(sampleData.shape[0], size=K,
        replace=False)
        centeriods = sampleData[randIndices, :]
        dataSize = 10000
        data = sampleData[:dataSize]
        for i in range(15):
            centeriodSums = np.zeros(shape=centeriods.shape)
            centeriodSumsCounter = np.zeros(shape=K)
            for x in data:
                index = np.argmin(np.square(centeriods - x).sum(axis=1))
                centeriodSums[index] += x
                centeriodSumsCounter[index] += 1
            for i in range(K):
                centeriods[i] = centeriodSums[i] / centeriodSumsCounter[i]
return centeriods

class Network:
        def __init__(self):
            self.XSize = 0
            self.HSize = 300
```

```
        self.OSize = 10
        self.X = []
        self.C = []
        self.Y = []
        self.W = []
        self.trainErrors = []
        self.testErrors = []

def loadData(self, filenameX, filenameY, sampleSize):
    self.X = inputXFromFile(filenameX, sampleSize)
    self.Y = inputYFromFile(filenameY, sampleSize)
    self.XSize = sampleSize

def initializeCenters(self, K, useKMeans):
    print("Initializing Centers...")
    self.HSize = K # Since centriods is equal to hidden layer neurons
    if useKMeans:
        self.C = kMeansClustering(K, self.X)
    else:
        self.C = self.X[: self.HSize]


def train(self, epochs=1, learnRate=0.5, K=300, useKMeans=False):

    self.initializeCenters(K, useKMeans)
    self.W = np.random.uniform(-1, 1, (self.HSize, self.OSize))
    self.trainErrors = np.zeros(shape=self.XSize) # Preallocating numpy array
    print("Training...")
    for _ in range(epochs):
        for i, x in enumerate(self.X):
            HLayer = rbf(x, self.C)
            output = np.dot(HLayer, self.W) # + self.B
            error = output - self.Y[i]
            self.W = self.W - (learnRate * np.outer(HLayer, error))
            self.trainErrors[i] = 0.5 * sum(error ** 2)
    print("Training done")
    np.save("weights", self.W)
```

```
        np.save("centers", self.C)

    def predict(self):
        self.testErrors = np.zeros(shape=self.XSize) # Preallocating numpy array
        print("Predicting...")
        totalAvg = count = correctCount = 0.0
        for count, x in enumerate(self.X):
            HLayer = rbf(x, self.C)
            output = np.dot(HLayer, self.W) # + self.B
            o = np.argmax(output)
            y = np.argmax(self.Y[count])
            if o == y:
                correctCount += 1
            error = output - self.Y[count]
            self.testErrors[count] = 0.5 * sum(error ** 2)
        totalAvg = (correctCount * 100.0) / (count + 1)
        print(f"Total Avg. Accuracy: {totalAvg} %")

    def rbf(x, C, beta=0.05):
        H = np.zeros(shape=(np.shape(C)[0]))
        for i, c in enumerate(C): # For each neuron in H layer
        H[i] = math.exp((-1 * beta) * np.dot(x - c, x - c))
        return H

    def plotLearningCurves(trainErrors, testErrors):
        avgSize = 100
        if type(trainErrors) is np.ndarray:
            Jtrain = trainErrors.reshape(-1, avgSize).mean(axis=1)
            plt.plot(Jtrain, label='Training Cost')
            Jtest = testErrors.reshape(-1, avgSize).mean(axis=1)
            plt.plot(Jtest, label='Test Cost')
            plt.xlabel(f"Data examples in {avgSize}s")
            plt.ylabel("Cost")
            plt.show()
        start = time.time()
        trainDataSize = 60000
        testDataSize = 10000
```

```
myNetwork = Network()
while True:
    print("1. Train the RBF Network\n2. Predict using the RBF
    Network")
    userInput = input("Choose your option: ")
    if userInput == "1":
        print("Importing data for training...")
        startTime = time.time()
        myNetwork.loadData("train.txt", "train-labels.txt",
        trainDataSize)
        print(
        f"{trainDataSize} training examples imported in {time.time()-
        startTime:.2f} sec"
        )
        startTrainingTime = time.time()
        myNetwork.train(epochs=1, learnRate=0.3, K=100,
        useKMeans=True)
        print(f"Training took: {time.time()-startTrainingTime:.2f}
        sec")
    elif userInput == "2":
        filename = input("Enter file name containing weights
        (default: weights.npy): ")
        myNetwork.W = np.load(filename)
        myNetwork.C = np.load("centers.npy")
        print("Importing data for testing...")
        myNetwork.loadData("test.txt", "test-labels.txt",
        testDataSize)
        myNetwork.predict()
        plotLearningCurves(myNetwork.trainErrors[:10000],
        myNetwork.testErrors[:10000])
    else:
        break
print("Program exited.")
```