February-June 2023 Semester
CS671: Deep Learning and Application
Programming Assignment 4

Date: April 03, 2024

Deadline for submission of code and report: **Thursday, April 13, 2022, 10:00 PM**

The objective of this assignment is to deepen your understanding of the **autoencoders**. The major task here is to build an autoencoder to obtain the hidden representation and use it for classification.

You are given the subset of the MNIST digit dataset for the same. Each group is given 5 classes. Given dataset is train-validation-test separated. Every image is size 28 x 28. **Flatten each image to represent it as a vector of 784-dimension (28 x 28)**. The dataset is the same as that of Assignment-3. The tasks for this assignment are as follows:

1. **Task-1**: **Dimension reduction using PCA:**
    a. Reduce the dimensions to 32, 64, 128 and 256 dimensions.
    Note:
        - The directions of projection (eigen vectors) are obtained from training data. The mean subtracted training, mean subtracted validation, and mean subtracted test data are projected onto directions of projection (eigen vectors) to get the respective reduced dimension representation.
        - To get the mean subtracted representations of validation and test data, use the mean vector from the training set.
    b. For each of the reduced dimension representations:
        i. Use the reduced dimension representation as input to a fully connected neural network (FCNN) based multi-class classification model.
        ii. Present the classification accuracy on the validation set for the different architectures of FCNN classification model.
        iii. Present the accuracy and confusion matrix on the test data for the best architecture selected based on validation accuracy.
    c. From the all the test accuracies, observe the best reduced dimension representation.
    d. Compare the result with that of the best results from the Assignment-3
2. **Task-2**: **Autoencoders for reconstructing the images:**
    a. Build autoencoders with one hidden layer and 3 hidden layer architectures. Consider 400 neurons in the first and third layers in 3 hidden layer architecture. Consider 32, 64, 128 and 256 neurons for the bottleneck (middle) layer.
    b. Train the autoencoder using Adam optimizer. Use sigmoid (either logistic or tanh – use one consistently) activation function for the nodes in all the hidden layers.
    c. Observe the average reconstruction errors for the training, validation, and test data. Average reconstruction error is computed after the model is trained.
    d. Take one image, from each class, from the training, validation, and test set. Give their reconstructed images for each of the architectures (along with original images).

3. **Task-3**: **Classification using the compressed representation from the 1-hidden layer autoencoder:**
    a. Present training data to each of the encoder of 1-hidden layer autoencoders built. Save the output of the middle layer (compressed layer). This gives the compressed representation of training data. Similarly obtain the compressed representation of validation and test data.
    Note: Different autoencoders give different reduced dimension representations. You must conduct the experiment for each of the reduced dimension representations.
    b. For each of the reduced dimension representations:
        i. Use the reduced dimension representation as input to a fully connected neural network (FCNN) based multi-class classification model.
        ii. Present the classification accuracy on the validation set for the different architectures of FCNN classification model. **Note:** Consider the same architectures you have considered in **Task-1**.
        iii. Present the accuracy and confusion matrix on the test data for the best architecture selected based on validation accuracy.
    c. From the all the test accuracies, observe the best reduced dimension representation.
    d. Compare the result with that of the best results from the Assignment-3 and Task-1.
4. **Task-4**: **Classification using the compressed representation from the 2-hidden layer autoencoder:**
    a. Present training data to each of the encoders of autoencoders built save the output of the middle layer (compressed layer). This gives the compressed representation of training data. Similarly obtain the compressed representation of validation and test data.
    Note: Different autoencoders give different reduced representations. You must conduct the experiment for each of the reduced representations.
    b. For each of the reduced representations:
        i. Use the reduced dimension representation as input to a fully connected neural network (FCNN) based multi-class classification model.
        ii. Present the classification accuracy on the validation set for the different architectures of FCNN classification model. **Note:** Consider the same architectures you have considered in **Task-1**.
        iii. Present the accuracy and confusion matrix on the test data for the best architecture selected based on validation accuracy.
    c. From the all the test accuracies, observe the best reduced dimension representation.
    d. Compare the result with that of the best results from the Assignment-3, Task-1 and Task-3.
5. **Task-5**: **Denoising autoencoders for reconstructing the images:**
    a. Build denoising autoencoders with one hidden layer with 20% noise and 40% noise. Consider number of neurons for the bottleneck (middle) layer based on the best test accuracy of the best reduced dimensional representation from 1-hidden layer autoencoder.

b. Observe the average reconstruction errors for the training, validation, and test data. Average reconstruction error is computed after the model is trained.
c. Take one image, from each class, from the training, validation, and test set. Give their reconstructed images for each of the architectures (along with original images).
d. For the reduced dimension representation:
    i. Use the reduced dimension representation as input to a fully connected neural network (FCNN) based multi-class classification model. **Note:** Consider the same best architecture you have considered in **Task-3** for this reduced representation
    ii. Present the classification accuracy on the validation and test set for the different architectures of FCNN classification model.

6. **Task-6**: **Weight visualization:**
    a. For the best compressed representation in **one hidden layer autoencoder**, plot the inputs as images that maximally activate each of the neurons of the hidden representations (plot of weights from the input layer to the compressed layer)
    b. Similarly, Plot the inputs as images that maximally activate each of the neurons of the hidden representations obtained using both the **denoising autoencoders** (plot of weights from the input layer to the compressed layer).
    c. Compare (a) and (b).

Each group of students must use the dataset identified for that group only.

You can use deep learning APIs (Tensorflow, PyTorch, Keras, etc.).

Report should be in PDF form and report by a team should also include the observations about the results of studies.

Instruction:

Upload in Moodle all your codes in a single zip file. Note that code(s) should be in a .py file, if you are coding in Python.

- **Give the name of the code folder as Group<*number*>_Assignment4_code**
  Example: Group01_Assignment4_code.
- **Give the name of the zip file as Group<*number*>_Assignment4_code.zip**
  Example: Group01_Assignment4_code.zip

Upload the report as PDF file.

- **Give the name to the report file as Group<*number*>_Assignment4_report.pdf**
  Example: Group01_Assignment4_report.pdf

We will not accept the submission if you don't follow the above instructions.