CS464 Introduction to Machine Learning
Spring 2023
Homework 2

Due: May 7, 2023 23:59

Instructions

- For this homework, you may code in any programming language of your choice.
- You are NOT allowed to use any machine learning packages, libraries, or toolboxes for this assignment (such as scikit-learn, TensorFlow, Keras, Theano, MATLAB Statistics and Machine Learning Toolbox functions, e1071, nnet, kernlab, etc.) unless otherwise stated.
- Submit a soft copy of your homework to Moodle.
- Upload your code and written answers to the related assignment section on Moodle (.TAR or .ZIP). Submitting hard copy, handwritten or scanned files is NOT allowed.
- The name of your compressed folder must be "`CS464_HW2_Firstname_Lastname`" (i.e., `CS464_HW2_sheldon_cooper`). Please do not use any Turkish characters in your compressed folder name.
- Your code should be in a format that is easy to run and must include a driver script serving as an entry point. You must also provide a README file with clear instructions on how to execute your program.
- This is an individual assignment for each student. That is, you are NOT allowed to share your work with your classmates.
- If you do not follow the submission rules, deadlines, and specifications (codes, report, etc), it will lead to a significant grade deduction.
- If you have any questions regarding this homework, you can contact: a.yildirim@bilkent.edu.tr

1 PCA & Cats [100 pts]

In this question, you are expected to analyze cat images using PCA. In this assignment, you will be working on the cat images inside both the validation and the training sets of the Animal Faces dataset[1]. You are requested to use the combined versions of these images `afhq_cat.zip`[2] instead of combining them by yourself. The provided dataset is composed of 5653 images of cats. For this question, the use of any library for PCA calculations is not allowed. You are requested to implement the PCA algorithm by yourself. It is suggested to use the `numpy.linalg.eig` function to find the eigenvalues and the eigenvectors in your calculations.
Before the analysis, resize the images to 64×64 pixels by using the bilinear interpolation method[3] implemented in the PIL library[4]. Then, flatten all images of size $64 \times 64 \times 3$ to obtain a 4096×3 matrix for each image. Remember that the PIL library reads the image files in uint8 format. Since unsigned integer values cannot be negative, the calculations in the following parts may fail. In such a case, the problem can be solved by converting the data type to int or float32.

Note that all images are 3-channel **RGB**. Create a 3-D array, X, of size $5653 \times 4096 \times 3$ by stacking flattened matrices of the images provided in the dataset. Slice X as $X_i = X[:, :, i]$, where i corresponds to the three indexes (0: **R**ed, 1: **G**reen, and 2: **B**lue), to obtain color channel matrix (5653×4096) of all images for each channel.

Question 1.1 **[30 pts]** Apply PCA on X_i's to obtain first 10 principal components for each X_i. Report the proportion of variance explained (PVE) for each of the principal components and their sum for each X_i. **Discuss your results and find the minimum number of principal components that are required to obtain at least 70% PVE for all channels.**

Question 1.2 **[30 pts]** Using the first 10 principal components found for each color channel, reshape each principal component to a 64×64 matrix. Later, normalize the values of each of them between 0 and 1 using the min-max scaling method[5]. After scaling them, stack corresponding color channels (R, G, and B) of each principal component to obtain 10 RGB images of size $64 \times 64 \times 3$, which are the visuals of eigenvectors. Display all and discuss your results.

Question 1.3 **[40 pts]** Describe how you can reconstruct a cat image using the principal components you obtained in Question 1.1. Use the first k principal components to analyze and reconstruct the second image [6] in the dataset where $k \in \{1, 50, 250, 500, 1000, 4096\}$. In order to reconstruct an image, you should first calculate the dot product with principle components and the image. Later, you project the data you obtained back onto the original space using the first k eigenvectors. Discuss your results in the report.

Hint: Do not forget to add up the mean values at the end of the reconstruction process if you subtracted them from the data in Question 1.1 to calculate the principle components.

[1] https://www.kaggle.com/datasets/andrewmvd/animal-faces
[2] https://drive.google.com/file/d/15V1NUNYtezVqOIVbLpuf8WjWjOsT2v4m/view?usp=sharing
[3] PIL.Image.open(image_path).resize((64,64), Image.BILINEAR)
[4] https://pypi.org/project/Pillow/
[5] https://www.oreilly.com/api/v2/epubs/9781788627306/files/assets/ffb3ac78-fd6f-4340-aa92-cde8ae0322d6.png
[6] The order of the images may differ in different operating systems. The name of the second image is `flickr_cat_000003.jpg`