Deep Learning: Towards Deeper Understanding **16 Sep, 2018**

Mini-Project 1. Feature Extraction and Transfer Learning

Instructor: Yuan Yao *Due: 23:59 Tuesday 6 Oct, 2018*

1 Mini-Project Requirement and Datasets

This project as a warm-up aims to explore feature extractions using existing networks, such as pre-trained deep neural networks and scattering nets, in image classifications with traditional machine learning methods.

1. Pick up ONE (or more if you like) favourite dataset below to work. If you would like to work on a different problem outside the candidates we proposed, please email course instructor about your proposal.

2. Team work: we encourage you to form small team, up to FOUR persons per group, to work on the same problem. Each team just submit ONE report, *with a clear remark on each person's contribution*. The report can be in the format of either a *technical report within 8 pages*, e.g. NIPS conference style (preferred format)

   `https://nips.cc/Conferences/2019/PaperInformation/StyleFiles`

   Python (Jupyter) Notebooks with a detailed documentation, or a *poster*, e.g.

   `https://github.com/yuany-pku/2017_math6380/blob/master/project1/DongLoXia_poster.pptx`

3. In the report, show your proposed scientific questions to explore and main results with a careful analysis supporting the results toward answering your problems. Remember: scientific analysis and reasoning are more important than merely the performance tables. Separate source codes may be submitted through email as a zip file, GitHub link, or as an appendix if it is not large.

4. Submit your report by email or paper version no later than the deadline, to the following address (deeplearning.math@gmail.com) with Title: Math 6380P: Project 1.

2 Challenge

The basic challenge is

- Feature extraction by scattering net with known invariants;
- Feature extraction by pre-trained deep neural networks, e.g. VGG19, and resnet18, etc.;
- Visualize these features using classical unsupervised learning methods, e.g. PCA/MDS, Manifold Learning, t-SNE, etc.;
- Compute the global mean of features $\Phi_i \in \mathbb{R}^p$ over all samples

$$\boldsymbol{\mu}_G \triangleq \underset{i,c}{\text{Ave}} \left\{ \boldsymbol{\Phi}_{i,c} \right\}$$

class-means

$$\boldsymbol{\mu}_c \triangleq \underset{i}{\text{Ave}} \left\{ \boldsymbol{\Phi}_{i,c} \right\}, \quad c = 1, \ldots, C$$

total covariance matrix

$$\boldsymbol{\Sigma}_T \triangleq \underset{i,c}{\text{Ave}} \left\{ \left(\boldsymbol{\Phi}_{i,c} - \boldsymbol{\mu}_G \right) \left(\boldsymbol{\Phi}_{i,c} - \boldsymbol{\mu}_G \right)^\top \right\}$$

between class covariance

$$\boldsymbol{\Sigma}_B \triangleq \underset{c}{\text{Ave}} \left\{ \left(\boldsymbol{\mu}_c - \boldsymbol{\mu}_G \right) \left(\boldsymbol{\mu}_c - \boldsymbol{\mu}_G \right)^\top \right\}$$

and within class covariance

$$\boldsymbol{\Sigma}_W \triangleq \underset{i,c}{\text{Ave}} \left\{ \left(\boldsymbol{\Phi}_{i,c} - \boldsymbol{\mu}_c \right) \left(\boldsymbol{\Phi}_{i,c} - \boldsymbol{\mu}_c \right)^\top \right\}$$

such that $\boldsymbol{\Sigma}_T = \boldsymbol{\Sigma}_B + \boldsymbol{\Sigma}_W$. Verify the contraction of within class variation (NC1),

$$\text{Tr} \left\{ \boldsymbol{\Sigma}_W \boldsymbol{\Sigma}_B^\dagger \right\} / C;$$

closeness to equal-norms of class-means

$$\text{Std}_c \left(\| \boldsymbol{\mu}_c - \boldsymbol{\mu}_G \|_2 \right) / \text{Avg}_c \left(\| \boldsymbol{\mu}_c - \boldsymbol{\mu}_G \|_2 \right),$$

equal-angularity,

$$\text{Std}_c \left(\cos_\mu \left(c, c' \right) \right) = \text{Std}_c [\langle \boldsymbol{\mu}_c - \boldsymbol{\mu}_G, \boldsymbol{\mu}_{c'} - \boldsymbol{\mu}_G \rangle / \left(\| \boldsymbol{\mu}_c - \boldsymbol{\mu}_G \|_2 \, \| \boldsymbol{\mu}_{c'} - \boldsymbol{\mu}_G \|_2 \right)]$$

closeness to maximal-angle equiangularity,

$$\text{Avg}_{c,c'} \left| \cos_\mu \left(c, c' \right) + 1/(C-1) \right|$$

- Image classifications using traditional supervised learning methods based on the features extracted, e.g. LDA, logistic regression, SVM, random forests, etc.;
- *Train the last layer or fine-tune the deep neural networks in your choice;
- Compare the results you obtained and give your own analysis on explaining the phenomena.

Below are two candidate datasets. Challenge marked by * above is only optional.

2.1 MNIST dataset – a Warmup

Yann LeCun's website contains original MNIST dataset of 60,000 training images and 10,000 test images.

`http://yann.lecun.com/exdb/mnist/`

There are various ways to download and parse MNIST files. For example, Python users may refer to the following website:

`https://github.com/datapythonista/mnist`

or MXNET tutorial on mnist

`https://mxnet.incubator.apache.org/tutorials/python/mnist.html`

2.2 Fashion-MNIST dataset

Zalando's Fashion-MNIST dataset of 60,000 training images and 10,000 test images, of size 28-by-28 in grayscale.

`https://github.com/zalandoresearch/fashion-mnist`

2.3 Identification of Raphael's paintings from the forgeries

The following data, provided by Prof. Yang WANG from HKUST,

`https://drive.google.com/folderview?id=0B-yDtwSjhaSCZ2FqN3AxQ3NJNTA&usp=sharing`

contains a 28 digital paintings of Raphael or forgeries. Note that there are both jpeg and tiff files, so be careful with the bit depth in digitization. The following file

`https://docs.google.com/document/d/1tMaaSIrYwNFZZ2cEJdx1DfFscIfERd5Dp2U7K1ekjTI/edit`

contains the labels of such paintings, which are

1 Maybe Raphael - Disputed

2 Raphael

3 Raphael

4 Raphael

5 Raphael

6 Raphael

7 Maybe Raphael - Disputed

8 Raphael

9 Raphael

10 Maybe Raphael - Disputed

11 Not Raphael

12 Not Raphael

13 Not Raphael

14 Not Raphael

15 Not Raphael

16 Not Raphael

17 Not Raphael

18 Not Raphael

19 Not Raphael

20 My Drawing (Raphael?)

21 Raphael

22 Raphael

23 Maybe Raphael - Disputed

24 Raphael

25 Maybe Raphael - Disputed

26 Maybe Raphael - Disputed

27 Raphael

28 Raphael

There are some pictures whose names are ended with alphabet like A's, which are irrelevant for the project.

The challenge of Raphael dataset is: can you exploit the known Raphael vs. Not Raphael data to predict the identity of those 6 disputed paintings (maybe Raphael)? Textures in these drawings may disclose the behaviour movements of artist in his work. One preliminary study in this project can be: *take all the known Raphael and Non-Raphael drawings and use leave-one-out test to predict the identity of the left out image; you may break the images into many small patches and use the known identity as its class.*

The following student poster report seems a good exploration

`https://github.com/yuany-pku/2017_CSIC5011/blob/master/project3/05.GuHuangSun_poster.pdf`

The following paper by Haixia Liu, Raymond Chan, and me studies Van Gogh's paintings which might be a reference for you:

`http://dx.doi.org/10.1016/j.acha.2015.11.005`

Peer Review

In this exercise of open peer review, please write down your comments of the *reports rather than of your own team* in the following format. Be considerate and careful with a precise description, avoiding offensive language.

Deadline is *11:59pm Oct. 13, 2019*. Your review assignment can be found at

`https://deeplearning-math.github.io/2019/project1/project1review_assignment.pdf`

where each student (SID) is randomly assigned with 5 group reports (excluding your own reports). You should submit reviews at least for these assignments, but more reviews are welcome with additional bonus credit.

You should put each review in a plain text separately with a title comprising the corresponding group number (**not your own group**) and your name (e.g., *rev1_group03_Ian_Goodfellow.pdf*). Submit all your reviews in a single zip file **using canvas**. Rebuttal is open afterwards.

- Summary of the report.
- Describe the strengths of the report.
- Describe the weaknesses of the report.
- Evaluation on Clarity and quality of writing (1-5): Is the report clearly written? Is there a good use of examples and figures? Is it well organized? Are there problems with style and grammar? Are there issues with typos, formatting, references, etc.? Please make suggestions to improve the clarity of the paper, and provide details of typos.
- Evaluation on Technical Quality (1-5): Are the results technically sound? Are there obvious flaws in the reasoning? Are claims well-supported by theoretical analysis or experimental results? Are the experiments well thought out and convincing? Will it be possible for other researchers to replicate these results? Is the evaluation appropriate? Did the authors clearly assess both the strengths and weaknesses of their approach? Are relevant papers cited, discussed, and compared to the presented work?
- Overall rating: (5- My vote as the best-report. 4- A good report. 3- An average one. 2- below average. 1- a poorly written one).
- Confidence on your assessment (1-3) (3- I have carefully read the paper and checked the results, 2- I just browse the paper without checking the details, 1- My assessment can be wrong)

Rebuttal

The rebuttal period starts from now, till *11:59pm Oct 20, 2019*. Restrict the number of characters of your rebuttal within **5,000**. Submit your rebuttal in PLAIN TEXT or PDF format to **canvas** with filename comprising the corresponding group number: e.g. rebuttal1_group02.pdf.

The following tips of rebuttal might be helpful for you to follow:

1. The main aim of the rebuttal is to answer any specific questions that the reviewers might have raised, or to clarify any misunderstanding of the technical content of the paper.

2. Keep your rebuttal short, to-the-point, and specific. In our experience, such rebuttals have the maximum impact.

3. Always be polite and professional. Refrain from name calling or rude comments, especially in response to negative reviews.

4. Highlight the changes in your manuscripts had you made a simple revision.