Homework #4

Deep Learning for Computer Vision

NTU, Fall 2021

110/12/14

111/01/04 (Tue.) 02:00 AM due

Outline

- Problems & Grading
  - Few-shot learning: Prototypical Network
  - Self-supervised Pre-training for Image Classification
- Datasets
- Homework policy

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Problem Description - Few-Shot & Self-Supervised Learning

- Problem 1: Few-Shot Learning - Prototypical Network (70%) [Mini-ImageNet]
- Problem 2: Self-Supervised Pre-training for Image Classification (50%)

  [Mini-ImageNet & Office-Home]

* Please refer to “Datasets” section for more details about Mini-ImageNet & Office-Home datasets.

Problem 1: Prototypical Network (70%)

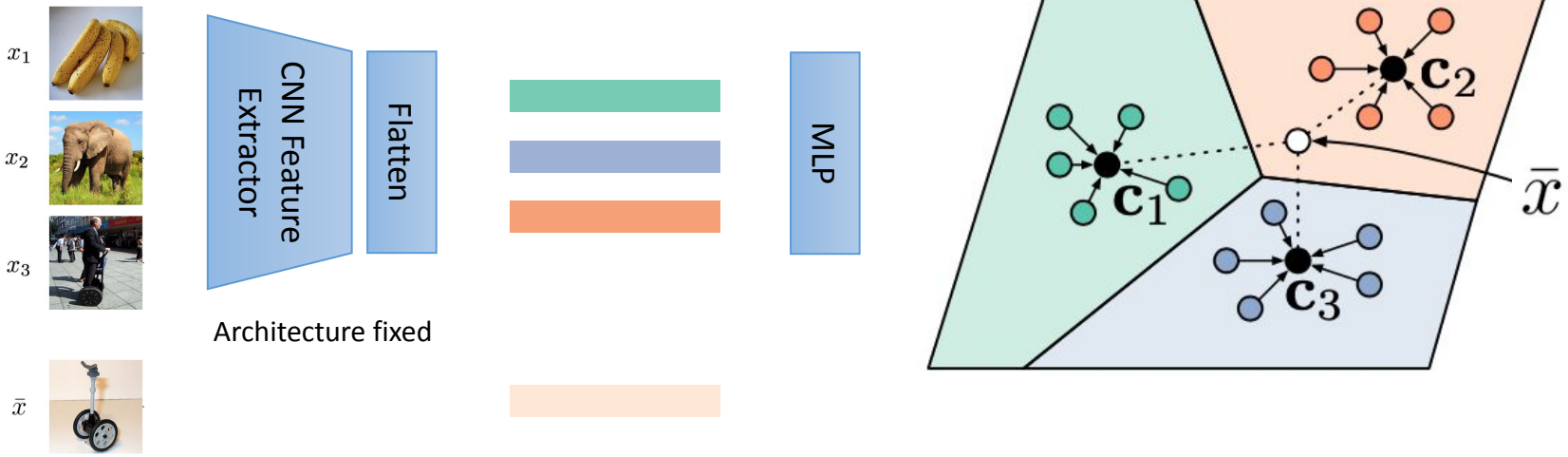
In this problem, you will have to implement the prototypical network. Prototypical Networks learn a metric space in which classification can be performed by computing distances to prototype representations of each class.

- Grading:
  - Report (50%)
  - Model Performance (20%)

Hint

(1) For the model architecture, the CNN Feature Extractor is provided in P.14. You only need to design the architecture of the MLP.

(2) For the objective function, you can only use the **cross entropy loss**.



Reference: Prototypical Networks for Few-shot Learning

Problem 1: Prototypical Network (70%) (cont'd)

Report (50%)

In Problem 1-1, you will have to implement the prototypical network as your baseline model to perform 5-way 1-shot classification.

1. (20%) Describe the architecture & implementation details of your model. (Include but not limited to the number of training episodes, distance function, learning rate schedule, data augmentation, optimizer, and N-way K-shot setting for meta-train and meta-test phase)

   Please report the accuracy on validation set under 5-way 1-shot setting (during inference).

   - **The accuracy should be the same as your model performance in P.8.**
   - **TAs will run your code to verify the performance.**

Hint

The N-way K-shot setting in the meta-train phase may be different from the one in the meta-test phase. Your model may be trained better in larger ways (e.g., 10-way 1-shot setting in the meta-train phase and 5-way 1-shot setting in the meta-test phase).

Problem 1: Prototypical Network (70%) (cont'd)

Report (50%)

For Problem 1-2 and 1-3, you will do some experiments about different distance function and different K shot settings.

2. (20%) When meta-train and meta-test under the same 5-way 1-shot setting, please report and discuss the accuracy of the prototypical network using 3 different distance function (**i.e., Euclidean distance, cosine similarity and parametric function**). You should also describe how you design your parametric function.
   - Parametric: use a learnable model to measure distance between two features
3. (10%) When meta-train and meta-test under the same 5-way K-shot setting, please report and compare the accuracy with different shots. (K=1, 5, 10)

[Hint] In order to reduce the training time, you may use a model simpler than that in Problem 1-1 for these two subproblems. For example, you can train the model with less training epochs.

Problem 1: Prototypical Network (70%) (cont'd)

Model Performance (20%)

- The mean accuracy of your model under **5-way 1-shot** setting (during inference) (Problem 1-1) should be above the baseline score.
  - On the validation set (10%): **0.42 [should be reported in Problem 1-1]**
  - On the test set (10%): **0.40**
- You **have to** use the test case provided by the TAs to calculate your mean accuracy on the validation set.
- TAs will execute your code to check if you pass the baseline.
- Only TAs have the test data.

Problem 1: Model Evaluation

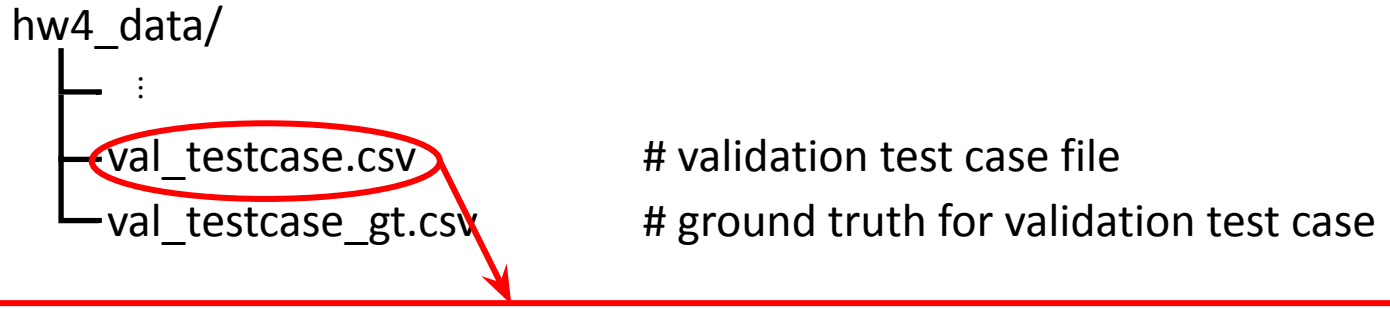
- For Problem 1-1, you have to report the 95% confidence interval of the accuracy over 600 episodes. In each episode, the accuracy is calculated over totally N * 15 query data where each way has 15 query data (N-way K-shot setting).
- We recommend you to do this in Problem 1-2 and 1-3 but not mandator.

$$\bar{x} \pm 1.96 \times \frac{\sigma}{\sqrt{600}}$$

($\bar{x}$ is the mean, σ is the standard deviation)

Problem 1: Model Evaluation – Test Case (cont'd)

- For the model performance part, we offer the validation test case which contains 600 episodes (5 way 1 shot with 75 query data) randomly sampled from the validation set. You **have to** report your **mean accuracy** on the validation set on this test case. TAs will test your model in the test set with the test case file **in the same format**. (The classes in train, val, and test set are disjoint.)
- For other parts of your report, you can calculate the accuracy by randomly sampled 600 episodes on your own rather than using this test case.



This file is for model evaluation with 600 episodes under 5-way 1-shot setting. Each row corresponds to each episode. In each episode, there are 5 support data (total 5 classes, each class contains 1 support data) and 75 query data. Each data is represented by its id that appears in val.csv .

Header in first row: <episode_id>, <class 0 support data>, …, <class 4 support data>, <query data 0>, …, <query data 74>

```
episode_id,class0_support0,class1_support0,class2_support0,class3_support0,class4_support0,query0,query1,query2,query3,query4,query5,
0,4520,6599,2606,320,3165,6209,6096,374,4556,4434,3225,2688,42,4758,2970,2592,77,367,2913,3084,6136,2817,3009,6588,4488,3378,2999,438
1,4348,6684,1892,5488,44,1800,5478,6721,182,2164,1888,4528,5624,5926,5720,111,4592,5620,7008,521,7095,1827,4255,2178,6879,6696,43,596
2,510,6888,4957,2133,3275,5307,1823,451,398,3375,7007,407,2264,5298,354,5191,190,434,6777,1901,2018,3243,69,2321,6647,4878,5051,3493,
3,5189,708,1956,1454,9484,9425,9155,1064,9171,1543,984,1498,1468,9284,5254,1265,1127,5209,5139,1852,2129,746,5091,5316,1432,5337,2017
```

Problem 1: Model Evaluation – Test Case (cont'd)

- For the model performance part, we offer the validation test case which contains 600 episodes (5 way 1 shot with 75 query data) randomly sampled from the validation set. You should report your **mean accuracy** on the validation set on this test case. TAs will test your model in the test set with the test case file in the same format. (The classes in train, val, and test set are disjoint.)
- For other parts of your report, you can calculate the accuracy by randomly sampled 600 episodes on your own rather than using this test case.

```
hw4_data/
├── ⋮
├── val_testcase.csv          # validation test case file
└── val_testcase_gt.csv       # ground truth for validation test case
```

This file contains the ground truth label for query data in val_testcase.csv. The label ranges from 0 to 4 because the test case is under the 5-way 1-shot setting.

Header in first row: <episode_id>, <label for query data 0>, …, <label for query data 74>

```
episode_id,query0,query1,query2,query3,query4,query5,query6,query7,query8,query9,query10,query11,query12,query13,query14,query15
0,1,1,3,0,0,4,2,3,0,2,2,3,3,2,4,1,2,4,1,0,4,2,3,1,3,2,3,3,1,4,3,1,4,4,1,2,2,3,1,0,4,0,4,0,4,1,3,4,3,4,1,2,0,3,1,0,0,1,2,4,2,1,0,1
1,2,3,1,4,2,2,0,3,3,3,4,0,3,1,4,1,2,0,2,1,1,4,3,2,2,1,2,0,4,3,4,2,2,0,0,4,1,1,1,1,1,4,0,3,0,0,4,4,3,4,1,3,0,4,2,2,0,4,4,3,2,1,2,0
2,2,3,0,0,4,1,0,3,2,0,2,0,0,1,3,3,4,0,3,1,2,2,4,2,0,4,4,4,0,1,1,0,2,1,3,2,2,1,4,3,4,3,1,3,3,3,3,1,1,0,2,1,0,4,0,1,1,4,3,4,2,4,2,2
3,4,4,1,4,3,1,3,3,4,0,3,1,0,0,2,2,1,0,0,3,0,2,0,0,2,3,4,1,0,3,2,4,2,4,3,1,0,0,3,4,0,1,1,1,2,3,1,1,4,3,0,2,2,1,2,3,2,3,4,3,0,2,2,1
```

Problem 1: Provided Script

- Template of testing code:
  - We provide a partially completed testing code, with a dataloader (reads the test case file and generates one task/episode in each batch) finished, and some “TODOs” unfinished.
  - After you finish all the TODOs in test_testcase.py, you can output your prediction result to a csv file.
  - Usage:

    python3 test_testcase.py [--N-way N_WAY] [--N-shot N_SHOT]
    [--N-query N_QUERY] [--load LOAD] [--test_csv TEST_CSV]
    [--test_data_dir TEST_DATA_DIR] [--testcase_csv TESTCASE_CSV]
    [--output_csv OUTPUT_CSV]

```
optional arguments:
  -h, --help            show this help message and exit
  --N-way N_WAY         N_way (default: 5)
  --N-shot N_SHOT       N_shot (default: 1)
  --N-query N_QUERY     N_query (default: 15)
  --load LOAD           Model checkpoint path
  --test_csv TEST_CSV   Testing images csv file
  --test_data_dir TEST_DATA_DIR
                        Testing images directory
  --testcase_csv TESTCASE_CSV
                        Test case csv
  --output_csv OUTPUT_CSV
                        Output filename
```

[Optional] If you have no idea about building the dataloader for training, you may also refer to test_testcase.py.

Problem 1: Provided Script (cont'd)

- Evaluation:
  - We provide the code to evaluate your model performance.
  - We use the output **mean** value to check if you pass the baseline.
  - Usage:

    python3 eval.py <path_to_the_predict_csv> <path_to_the_ground_truth_csv>

Problem 1: CNN Feature Extractor – Conv-4

- **[IMPORTANT]** For simplicity, you can **only** use Conv-4 as a feature extractor. Your Conv-4 should follow the following definition.
- The definition of Conv-4: a model that is composed of four convolutional blocks. Each block comprises a 64-filter 3 × 3 convolution, batch normalization layer, a ReLU nonlinearity and a 2 × 2 max-pooling layer.
- Note: For an 84 × 84 RGB image, the output space is 1600.
- You **cannot** use pre-trained weight, but you can initialize the model weights with Gaussian noise.

```
class Convnet(nn.Module):
    def __init__(self, in_channels=3, hid_channels=64, out_channels=64):
        super().__init__()
        self.encoder = nn.Sequential(
            conv_block(in_channels, hid_channels),
            conv_block(hid_channels, hid_channels),
            conv_block(hid_channels, hid_channels),
            conv_block(hid_channels, out_channels),
        )

    def forward(self, x):
        x = self.encoder(x)
        return x.view(x.size(0), -1)

def conv_block(in_channels, out_channels):
    bn = nn.BatchNorm2d(out_channels)
    return nn.Sequential(
        nn.Conv2d(in_channels, out_channels, 3, padding=1),
        bn,
        nn.ReLU(),
        nn.MaxPool2d(2)
    )
```

We provide the sample code of Conv-4 network for you :)

Problem 1: Training Tips

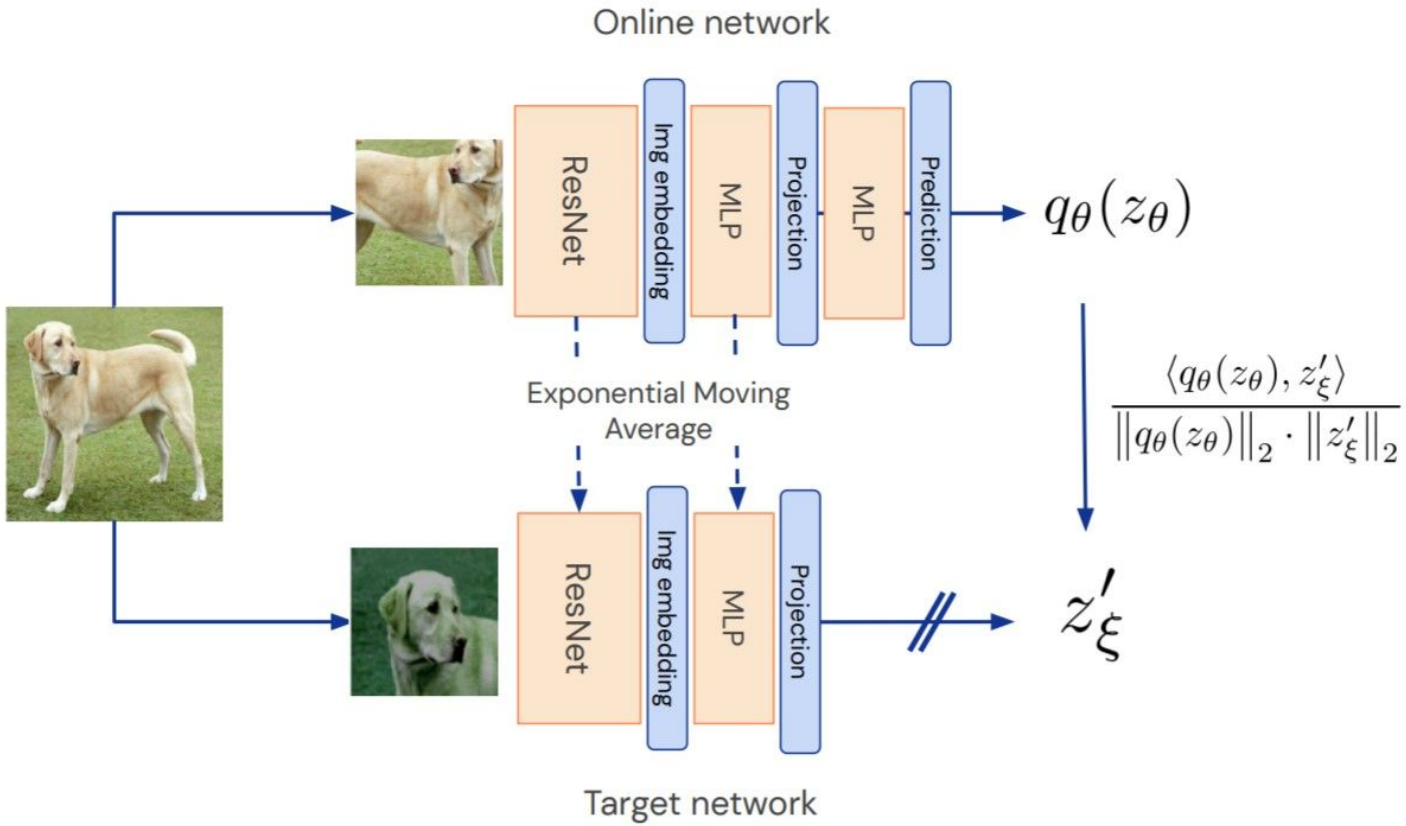
- There are many ways to sample a task, including using a custom sampler in dataloader, or sampling one task inside *__getitem__()* method in your custom dataset class, etc.
- **If you still don't know how to write a few shot learning code, you may find test_testcase.py helpful.**
- If you use any random function in *__getitem__()* method with *num_workers*>0 in your dataloader, you should set different seeds for different workers by setting *worker_init_fn* argument in dataloader. Otherwise, all the workers will generate the same sampling sequence.
- **[IMPORTANT] For each training epoch, you should sample different tasks/episodes. Otherwise, the performance of your model might be unpleasant.**

Reference: Data Loading Order and Sampler

Problem 2: Self-Supervised Pre-training for Image Classification (50%)

In this problem, you will have to pre-train your own ***ResNet50*** backbone on **Mini-ImageNet** via the recently self-supervised learning methods. After that, you need to conduct downstream task (i.e., image classification) with different settings to analyze your pre-trained backbone.

- Grading:
  - Report (30%)
  - Model Performance (20%)



Reference: [Bootstrap Your own Latent]

Problem 2: Self-Supervised Pre-training for Image Classification (50%)

1. (10%) Describe the implementation details of your SSL method for pre-training the ResNet50 backbone. (Include but not limited to the name of the SSL method you used, data augmentation for SSL, learning rate schedule, optimizer, and batch size setting for this pre-training phase)
   - **You have to pre-train the ResNet50 on the Mini-ImageNet dataset (training data only) without loading default pretrained weights.**
   - **We recommend you to use the SSL methods in the following Github. (It's easy to understand, use, and train with relatively small batch size.)**
     - **BYOL - LINK (Recommended), Barlow Twins - LINK**, etc.
     - **You are allowed to directly use these packages.**
   - **Since the pre-training phase may take weeks/months to finish under the general SSL setting, we fix the following training setting for all students to reduce the training time. (You must follow this setting in the pre-training and fine-tuning phase for fair comparison.)**
     - **Image size: 128*128**
     - **Backbone: ResNet50 (You can choose whether to use the fully-connected layer of ResNet50)**

Problem 2: Self-Supervised Pre-training for Image Classification (50%)

2. (10%) Following Problem 2-1, please conduct the Image classification on **Office-Home** dataset as the downstream task for your SSL method. Also, please complete the following Table, which contains different image classification setting, and compare the results.
   - **Please report the classification accuracy on validation set.**
   - **TAs will run your code to verify the performance of the setting C in the Table below.**
   - **The architecture of the classifier need to be consistent across all settings.**
3. (10%) Discuss or analyze the results in Problem 2-2

Setting	Pre-training (Mini-ImageNet)	Fine-tuning (Office-Home dataset)	Classification accuracy on valid set (Office-Home dataset)
A	-	Train full model (backbone + classifier)	*TODO*
B	w/ label (TAs have provided this backbone)	Train full model (backbone + classifier)	*TODO*
C	w/o label (Your SSL pre-trained backbone)	Train full model (backbone + classifier)	*TODO*
D	w/ label (TAs have provided this backbone)	Fix the backbone. Train classifier only	*TODO*
E	w/o label (Your SSL pre-trained backbone)	Fix the backbone. Train classifier only	*TODO*

Problem 2: Self-Supervised Pre-training for Image Classification (50%)

Model Performance (20%)

- Classification accuracy under setting C in Problem 2-2 should be above the baseline score to get points
  - On the validation set (10%): **0.36 [should be reported in Problem 2-2]**
  - On the test set (10%): **0.35**
- TAs will execute your code to check if you pass the baseline.
- Only TAs have the test data.

Problem 2: Provided weights

- We provide the supervised pre-trained weights, named “pretrain_model_SL.pt”, of ResNet50 (You can find it in hw4_data/) for you to analyze the setting B and D. This model is pre-trained on the Mini-ImageNet with class labels as supervision and follows the training setting below.
    - backbone: ResNet50 (resnet = torchvision.models.resnet50(pretrained=False))
    - Image size: 128 * 128
    - Transformation:

```
TRANSFORM_IMG = transforms.Compose([
    transforms.Resize(128),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406],
                         std=[0.229, 0.224, 0.225])
    ])
```

Reminder

- Please start working on this homework earlier. The training may take a few hours/**days** on a GPU or **weeks** on CPUs.
- Please follow the homework rules shown in “Homework policy” section.

Outline

- Problems & Grading
  - Few-shot learning: Prototypical Network
  - Self-supervised Pre-training for Image Classification
- Datasets
- Homework policy

Mini-ImageNet Dataset

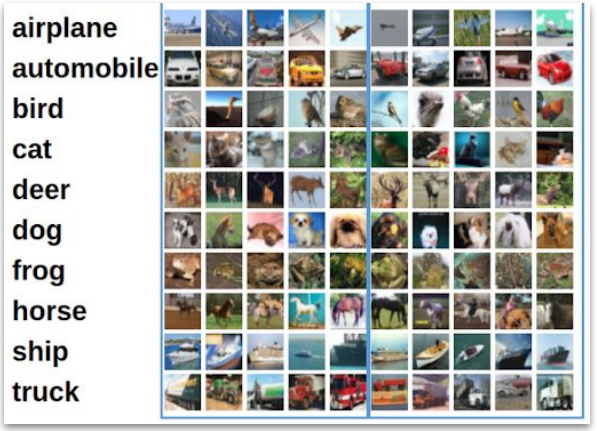
- The dataset consists of 48,000 84x84 RGB images in 80 classes.

- In the dataset, you will get

hw4_data/mini/

```
├── train/              # training images directory (64 class, each class has 600 images)
├── train.csv           # training image csv file
├── val/                # validation images directory (16 class, each class has 600 images)
├── val.csv             # validation image csv file
├── val_testcase.csv        # validation test case file
└── val_testcase_gt.csv     # ground truth for validation test case
```

- You **CANNOT** use validation data for training purposes.
- The classes in train and val set are disjoint.
- All the testing set files are in the same format as the validation set files.
  To be more specific, there are ***test/***, ***test.csv*** and ***test_testcase.csv***.



Mini-ImageNet Dataset

- The dataset consists of 48,000 84x84 RGB images in 80 classes.
- In the dataset, you will get

hw4_data/mini/

```
├── train/              # training images directory (64 class, each class has 600 images)
├── train.csv           # training image csv file
├── val/                # validation images directory (16 class, each class has 600 images)
├── val.csv             # validation image csv file
├── val_testcase.csv        # validation test case file
└── val_testcase_gt.csv     # ground truth for validation test case
```

Header in first row: <image_id>, <filename>, <label>

```
id,filename,label
0,n0153282900000005.jpg,n01532829
1,n0153282900000006.jpg,n01532829
2,n0153282900000007.jpg,n01532829
3,n0153282900000010.jpg,n01532829
```

Office-Home Dataset

- The dataset consists of 3,951/406 RGB images in 65 classes for train/valid set.
- In the dataset, you will get

hw4_data/office

```
├── train/        # training images directory (65 classes, total 3951 images)
├── val/          # validation images directory (65 classes, total 406 images)
├── train.csv     # train image csv file
└── val.csv       # validation image csv file
```

- The train.csv/val.csv files of the office-home and mini-imagenet are in the same format.
- You **CANNOT** use validation data for training purposes.
- All the testing set files are in the same format as the validation set files.

Outline

- Problems & Grading
  - Few-shot learning: Prototypical Network
  - Self-supervised Pre-training for Image Classification
- Datasets
- Homework policy

Deadline and Academic Honesty

- Report and source code deadline: **111/01/04 (Tue.) 02:00 AM (GMT+8)**
- Late policy : Up to 3 free late days in a semester (depends on your hw0 result). After that, late homework will be deducted 30% each day.
- Taking any unfair advantages over other class members (or letting anyone do so) is strictly prohibited. Violating university policy would result in F for this course.
- Students are encouraged to discuss the homework assignments, but you must complete the assignment by yourself. TA will compare the similarity of everyone's homework. Any form of cheating or plagiarism will not be tolerated, which will also result in F for students with such misconduct.

Deadline and Academic Honesty

- Searching for online materials or discussing with fellow classmates are highly encouraged. However, you must provide the code or solution by yourself.
- Please specify, if any, the references for any parts of your HW solution in your report (e.g., the name and student ID of your collaborators and/or the Internet URL you consult with). If you complete the assignment all by yourself, you must also specify “no collaborators”.

Submission

- Click the following link and sign in to your GitHub account to get your submission repository:

  https://classroom.github.com/a/vLPG6x0J

- **By default, we will only grade your last submission before the deadline (NOT your last submission). Please e-mail the TAs if you'd like to submit another version of your repository and let us know which commit to grade.**
- We will clone the **main** branch of your repository.

Submission

- In your GitHub repository, you should make sure that your submission includes at least the following files in the **root directory**
  - hw4_<studentID>.pdf
  - **hw4_download.sh**
    - **Download all the models needed for Problem 1~2. We will execute this script first.**
  - hw4_p1.sh
  - hw4_p2.sh
  - your python files (e.g., training code & testing code)
  - your model files (can be loaded by your python file)
- Don't upload the dataset.
- If any of the file format is wrong, you will get zero point.

Trained Model

- If your model is larger than GitHub's maximum capacity (100MB), you can upload your model to another cloud service (e.g., Dropbox). However, you script file should be able to download the model **automatically**.
  - (Dropbox tutorial: https://drive.google.com/file/d/1XOz69Mgxo67IZNQWnRSjT2eZAZtpUAgZ/view)
- Do not delete your trained model before the TAs disclose your homework score and before you make sure that your score is correct.
- Use the **wget** command in your script to download you model files. Do not use the curl command.
- Note that you **should NOT hard code any path** in your file or script except for the path of your trained model.

Bash Script

- TA will run your code as shown below:
  - bash hw4_download.sh
  - bash hw4_p1.sh $1 $2 $3 $4
    - $1: testing images csv file (e.g., ***hw4_data/val.csv***)
    - $2: testing images directory (e.g., ***hw4_data/val***)
    - $3: path of test case on test set (e.g., ***hw4_data/val_testcase.csv***)
    - $4: path of output csv file (predicted labels) (e.g., ***output/val_pred.csv***)
- **The output csv file MUST have the same format as 'val_testcase_gt.csv'**
- Note that you should **NOT** hard code any path in your file or script
- Your testing code have to be finished in **10 mins.**

Bash Script

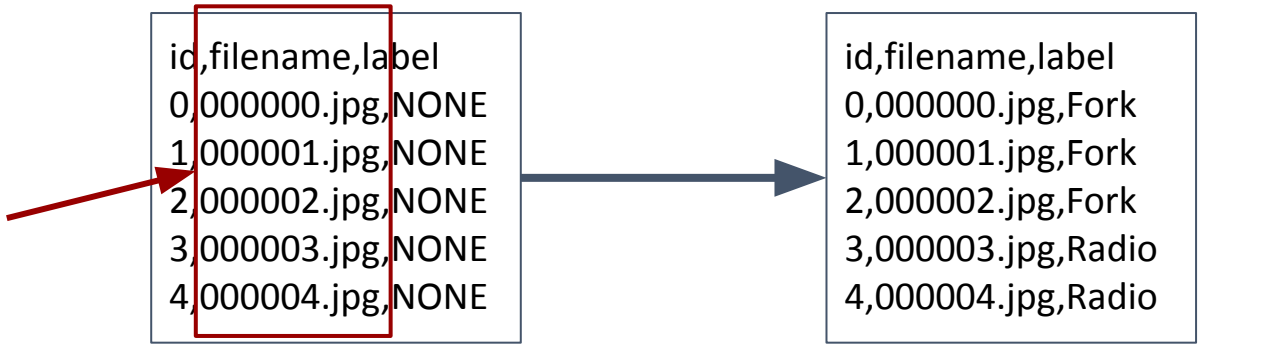
- TA will run your code as shown below:
  - bash hw4_p2.sh $1 $2 $3
    - $1: testing images csv file (e.g., ***hw4_data/val.csv***)
    - $2: testing images directory (e.g., ***hw4_data/val***)
    - $3: path of output csv file (predicted labels) (e.g., ***output/val_pred.csv***)
- **The csv file for the testing images has the same format as '*val*.csv' but the labels are filled with "NONE".**
- **The output csv file MUST have the same format as '*val*.csv'.**
- **The filenames in output csv file MUST follow the order of those in val/test.csv.**
- Note that you should **NOT** hard code any path in your file or script
- Your testing code have to be finished in **10 mins.**

Bash Script

- TA will run your code as shown below:
  - bash hw4_p2.sh $1 $2 $3
    - $1: testing images csv file (e.g., ***hw4_data/val.csv***)
    - $2: testing images directory (e.g., ***hw4_data/val***)
    - $3: path of output csv file (predicted labels) (e.g., ***output/val_pred.csv***)

- Examples of test.csv and test_pred.csv

Note that these files can be found in test/.



Example of test.csv

Example of pred_test.csv

Bash Script

- You must **not** use commands such as rm, **sudo, CUDA_VISIBLE_DEVICES**, cp, mv, mkdir, cd, pip or other commands to change the Linux environment. (Using "os" package in python code to change the system environment is also not allow.)
- In your submitted script, please use the command **python3** to execute your testing python files.
  - For example: python3 test.py
- We will execute you code on **Linux** system, so try to make sure you code can be executed on Linux system before submitting your homework.

Packages

- Python==3.8
- Please refer to **requirements.txt** on your hw4 GitHub repository.
- **Do not** use **imshow()** or **show()** in your code or your code will crash.
- Use **os.path.join** to deal with path as often as possible.
- **If you train on GPU ids other than 0, remember to deal with the "map location" issue when you load model. (More details about this issue, please refer to https://github.com/pytorch/pytorch/issues/15541)**
- **E-mail or ask TA first if you want to import other packages.**

Penalty

- If we can not reproduce your accuracy on the validation set or you use the feature extractor other than Conv-4 in problem 1, you will get 0 points in model performance.
- If we can not execute your code, we will give you only **one** chance to make minor modifications to your code. After you modify your code,
  - If we can execute your code and reproduce your results on the validation set, you will still receive a 30% penalty in your model performance score.
  - If we still cannot execute your code or cannot reproduce your accuracy on the validation set, you will still get 0 in this problem.

How to find help

- Google !
- Use TA hours (please check course website for time/location)
- Post your question under hw4 discussion in NTUCOOL
- Contact TAs by e-mail: ntudlcv@gmail.com

DOs and DONTs for the TAs (& Instructor)

- Do NOT send private messages to TAs via Facebook.
  - TAs are happy to help, but they are not your tutors 24/7.
- TAs will NOT debug for you, including addressing coding, environmental, library dependency problems.
- TAs do NOT answer questions not related to the course.
- If you cannot make the TA hours, please email the TAs to schedule an appointment instead of stopping by the lab directly.