Data loading

Import

```
!pip install kaggle
```

```
Requirement already satisfied: kaggle in /usr/local/lib/python3.6/dist-packages (1.5.10)
Requirement already satisfied: urllib3 in /usr/local/lib/python3.6/dist-packages (from kaggle) (1.24.3)
Requirement already satisfied: requests in /usr/local/lib/python3.6/dist-packages (from kaggle) (2.23.0)
Requirement already satisfied: six>=1.10 in /usr/local/lib/python3.6/dist-packages (from kaggle) (1.15.0)
Requirement already satisfied: python-slugify in /usr/local/lib/python3.6/dist-packages (from kaggle) (4.0.1)
Requirement already satisfied: python-dateutil in /usr/local/lib/python3.6/dist-packages (from kaggle) (2.8.1)
Requirement already satisfied: tqdm in /usr/local/lib/python3.6/dist-packages (from kaggle) (4.41.1)
Requirement already satisfied: certifi in /usr/local/lib/python3.6/dist-packages (from kaggle) (2020.12.5)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.6/dist-packages (from requests->kaggle) (3.0
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-packages (from requests->kaggle) (2.10)
Requirement already satisfied: text-unidecode>=1.3 in /usr/local/lib/python3.6/dist-packages (from python-slugify->kagg
```

```
pip install --upgrade kaggle
```

```
Requirement already up-to-date: kaggle in /usr/local/lib/python3.6/dist-packages (1.5.10)
Requirement already satisfied, skipping upgrade: certifi in /usr/local/lib/python3.6/dist-packages (from kaggle) (2020.
Requirement already satisfied, skipping upgrade: six>=1.10 in /usr/local/lib/python3.6/dist-packages (from kaggle) (1.1
Requirement already satisfied, skipping upgrade: tqdm in /usr/local/lib/python3.6/dist-packages (from kaggle) (4.41.1)
Requirement already satisfied, skipping upgrade: python-slugify in /usr/local/lib/python3.6/dist-packages (from kaggle)
Requirement already satisfied, skipping upgrade: requests in /usr/local/lib/python3.6/dist-packages (from kaggle) (2.23
Requirement already satisfied, skipping upgrade: python-dateutil in /usr/local/lib/python3.6/dist-packages (from kaggle
Requirement already satisfied, skipping upgrade: urllib3 in /usr/local/lib/python3.6/dist-packages (from kaggle) (1.24.
Requirement already satisfied, skipping upgrade: text-unidecode>=1.3 in /usr/local/lib/python3.6/dist-packages (from py
Requirement already satisfied, skipping upgrade: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-packages (from requests-
Requirement already satisfied, skipping upgrade: chardet<4,>=3.0.2 in /usr/local/lib/python3.6/dist-packages (from requ
```

```
!mkdir .kaggle
```

```
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Mounted at /content/gdrive
```

```
import os
os.environ['KAGGLE_CONFIG_DIR'] = "/content/gdrive/My Drive/Study/Kaggle"
```

```
%cd /content/gdrive/My Drive/Study/DL/Assignments/Project
```

```
/content/gdrive/My Drive/Study/DL/Assignments/Project
```

```
!kaggle competitions download -c final-project-dl-spring-2020
```

```
Warning: Looks like you're using an outdated API Version, please consider updating (server 1.5.10 / client 1.5.4)
404 - Not Found
```

```
!ls
```

```
 alexnet_pretrained.pt               preds_4.1.csv
 final-project-dl-spring-2020.zip    preds_4.1.gsheet
 model_5.pt                          preds_4.2.csv
 model_6.pt                          preds_4.3.csv
 model_7.pt                          preds_5.csv
 model_8.pt                          preds_6.csv
```

```
    pred_5.csv                      preds_7.csv
    preds_1.2.csv                   preds_7.gsheet
    preds_1.2.gsheet                preds_8.csv
    preds_1.3.csv                   preds_8.gsheet
    preds_1.4.csv                   Project.docx
    preds_1.6.csv                   resnet18_pretrained.pt
    preds_1.6.gsheet                resnet34_pretrained.pt
   'preds_1.7 (1).gsheet'           resnet50_pretrained.pt
    preds_1.7.csv                  '~$roject.docx'
    preds_1.7.gsheet                sample_submission.csv
    preds_1.csv                     submission.csv
    preds_1.gsheet                  test_data
    preds_3.1.csv                   train_data
    preds_3.1.gsheet
```

```
#unzipping the zip files and deleting the zip files
#!unzip \*.zip  && rm *.zip
```

```
import torch
import torch.nn as nn

import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix
from datetime import datetime
from pathlib import Path
import pandas as pd
import torch.nn.functional as F
import torchtext.data as ttd
import torchvision
from torchvision import datasets, transforms,utils


from torch.optim.lr_scheduler import StepLR, CyclicLR
```

```
folder=Path('/content/gdrive/My Drive/Study/DL/Assignments/Project')
```

Data transformation

```
transformer = transforms.Compose([
#    transforms.Resize(256),
#    transforms.RandomCrop(256),
#    transforms.RandomHorizontalFlip(),
#    transforms.RandomVerticalFlip(),
    transforms.ToTensor(),
 #   transforms.Normalize([meanR, meanG, meanB], [stdR, stdG, stdB]),
     ])
```

```
train0_ds = datasets.ImageFolder(folder/'train_data/train',transform=transformer)
test_ds = datasets.ImageFolder(folder/'test_data',transform=transformer)
```

```
train0_ds.classes
```

```
     ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9']
```

Train/val split

```
from sklearn.model_selection import StratifiedShuffleSplit

sss = StratifiedShuffleSplit(n_splits=1, train_size=0.7, random_state=0)
```

```
indices=list(range(len(train0_ds)))
y_train0=[y for _,y in train0_ds]
for train_index, val_index in sss.split(indices, y_train0):
    print("train:", train_index, "val:", val_index)
    print(len(val_index),len(train_index))
```

```
train: [5279 5574 7391 ... 8774 2047 3129] val: [1900 5887 8619 ... 5449 1106 6628]
2708 6317
```

```
from torch.utils.data import Subset

val_ds=Subset(train0_ds,val_index)
train_ds=Subset(train0_ds,train_index)
```

```
print(f'Number of training examples: {len(train_ds)}')
print(f'Number of validation examples: {len(val_ds)}')
print(f'Number of testing examples: {len(test_ds)}')
```

```
Number of training examples: 6317
Number of validation examples: 2708
Number of testing examples: 3929
```

```
import numpy as np

# RGB mean and std
meanRGB=[np.mean(x.numpy(),axis=(1,2)) for x,_ in train_ds]
stdRGB=[np.std(x.numpy(),axis=(1,2)) for x,_ in train_ds]

meanR=np.mean([m[0] for m in meanRGB])
meanG=np.mean([m[1] for m in meanRGB])
meanB=np.mean([m[2] for m in meanRGB])

stdR=np.mean([s[0] for s in stdRGB])
stdG=np.mean([s[1] for s in stdRGB])
stdB=np.mean([s[2] for s in stdRGB])

print(meanR,meanG,meanB)
print(stdR,stdG,stdB)
```

```
0.48499483 0.45491496 0.39288142
0.22034366 0.21472108 0.21670675
```

Preprocessing

```
#additional transformation changes if required

train_transformer_1 = transforms.Compose([
    transforms.Resize(512),
#    transforms.RandomHorizontalFlip(), # randomly flip and rotate
    transforms.RandomCrop(512),
#    transforms.RandomHorizontalFlip(),
#    transforms.RandomVerticalFlip(),
    transforms.ToTensor(),
#    transforms.Normalize([meanR, meanG, meanB], [stdR, stdG, stdB]),
#    transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))

     ])


test_transformer_1 = transforms.Compose([
    transforms.Resize(512),
    transforms.RandomCrop(512),
    transforms.ToTensor(),
#    transforms.Normalize([meanR, meanG, meanB], [stdR, stdG, stdB]),
#    transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))

    ])

train0_ds.transform=train_transformer_1
test_ds.transform=test_transformer_1
```

Data loader

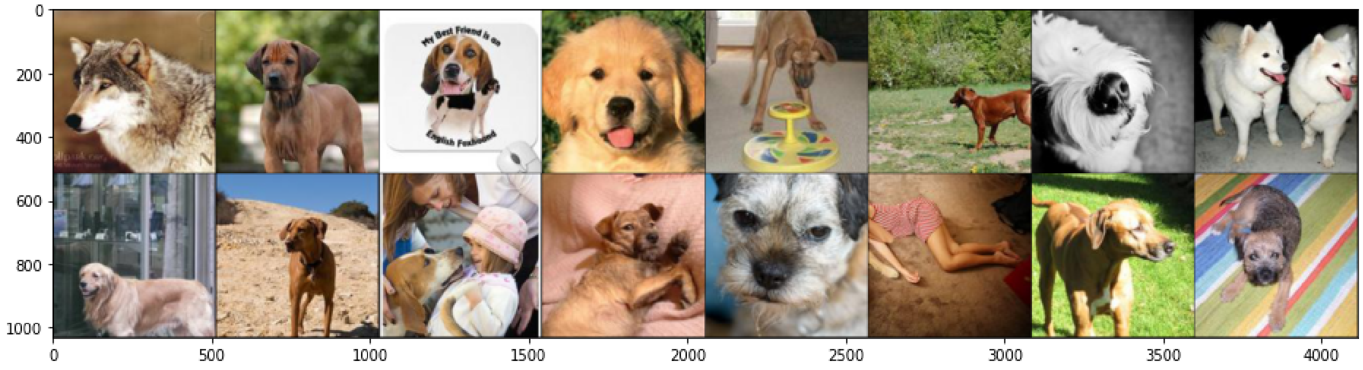
```
from torch.utils.data import DataLoader

train_dl = DataLoader(train_ds, batch_size = 32, shuffle=True, num_workers=4)
val_dl = DataLoader(val_ds, batch_size = 32, shuffle=True, num_workers=4)
test_dl = DataLoader(test_ds, batch_size = 32, shuffle=False, num_workers=4)
```

Sample check

```
samples, labels = iter(train_dl).next()
plt.figure(figsize=(16,24))
grid_imgs = torchvision.utils.make_grid(samples[:24])
np_grid_imgs = grid_imgs.numpy()
# in tensor, image is (batch, width, height), so you have to transpose it to (width, height, batch) in numpy to show it.
plt.imshow(np.transpose(np_grid_imgs, (1,2,0)))
```

```
<matplotlib.image.AxesImage at 0x7fade135e978>
```



```
# extract a batch from training data
for x, y in train_dl:
    print(x.shape)
    print(y.shape)
    break
# extract a batch from val data
for x, y in val_dl:
    print(x.shape)
    print(y.shape)
    break
```

```
torch.Size([32, 3, 512, 512])
torch.Size([32])
torch.Size([32, 3, 512, 512])
torch.Size([32])
```

```
import collections

# get labels
y_train=[y for _,y in train_ds]

# count labels
```

```
counter_train=collections.Counter(y_train)
print(counter_train)
```

```
Counter({9: 664, 7: 664, 6: 660, 8: 659, 0: 659, 5: 658, 3: 652, 1: 650, 2: 645, 4: 406})
```

Predefined functions

```
def train_val(model, params):
    # extract model parameters
    num_epochs=params["num_epochs"]
    loss_func=params["loss_func"]
    opt=params["optimizer"]
    train_dl=params["train_dl"]
    val_dl=params["val_dl"]
    sanity_check=params["sanity_check"]
    lr_scheduler=params["lr_scheduler"]
    path2weights=params["path2weights"]

    # history of loss values in each epoch
    loss_history={
        "train": [],
        "val": [],
    }

    # histroy of metric values in each epoch
    metric_history={
        "train": [],
        "val": [],
    }

    # a deep copy of weights for the best performing model
    best_model_wts = copy.deepcopy(model.state_dict())

    # initialize best loss to a large value
    best_loss=float('inf')

    # main loop
    for epoch in range(num_epochs):

        # get current learning rate
        current_lr=get_lr(opt)
        print('Epoch {}/{}, current lr={}'.format(epoch, num_epochs - 1, current_lr))

        # train model on training dataset
        model.train()
        train_loss, train_metric=loss_epoch(model,loss_func,train_dl,sanity_check,opt)

        # collect loss and metric for training dataset
        loss_history["train"].append(train_loss)
        metric_history["train"].append(train_metric)

        # evaluate model on validation dataset
        model.eval()
        with torch.no_grad():
            val_loss, val_metric=loss_epoch(model,loss_func,val_dl,sanity_check)


        # store best model
        if val_loss < best_loss:
            best_loss = val_loss
            best_model_wts = copy.deepcopy(model.state_dict())

            # store weights into a local file
            torch.save(model.state_dict(), path2weights)
            print("Copied best model weights!")
        # collect loss and metric for validation dataset
        loss_history["val"].append(val_loss)
        metric_history["val"].append(val_metric)

        # learning rate schedule
        lr_scheduler.step()

        print("train loss: %.6f, dev loss: %.6f, accuracy: %.2f" %(train_loss,val_loss,100*val_metric))
        print("-"*10)

    # load best model weights
    model.load_state_dict(best_model_wts)

    return model, loss_history, metric_history
```

```
# a helper function to compute the loss value and the performance metric for the entire dataset or an epoch.

# define device as a global variable
#device = torch.device("cuda")

def loss_epoch(model,loss_func,dataset_dl,sanity_check=False,opt=None):
    running_loss=0.0
    running_metric=0.0
    len_data=len(dataset_dl.dataset)

    for xb, yb in dataset_dl:
        # move batch to device
        xb=xb.to(device)
        yb=yb.to(device)

        # get model output
        output=model(xb)

        # get loss per batch
        loss_b,metric_b=loss_batch(loss_func, output, yb, opt)

        # update running loss
        running_loss+=loss_b

        # update running metric
        if metric_b is not None:
            running_metric+=metric_b

        # break the loop in case of sanity check
        if sanity_check is True:
            break

    # average loss value
    loss=running_loss/float(len_data)

    # average metric value
    metric=running_metric/float(len_data)

    return loss, metric
```

```
# A helper function to compute the loss value per batch of data:
def loss_batch(loss_func, output, target, opt=None):

    # get loss
    loss = loss_func(output, target)

    # get performance metric
    metric_b = metrics_batch(output,target)

    if opt is not None:
        opt.zero_grad()
        loss.backward()
        opt.step()
        opt.step()

    return loss.item(), metric_b
```

```
# A helper function to count the number of correct predictions per data batch:
def metrics_batch(output, target):
    # get output class
    pred = output.argmax(dim=1, keepdim=True)

    # compare output class with target class
    corrects=pred.eq(target.view_as(pred)).sum().item()
    return corrects
```

Model_1

Renset 18

```
from torchvision import models
import torch

# load model with random weights
model_1 = models.resnet18(pretrained=True)
```

```
print(model_1)
```

```
      (layer2): Sequential(
        (0): BasicBlock(
          (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (downsample): Sequential(
            (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
            (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          )
        )
        (1): BasicBlock(
          (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (layer3): Sequential(
        (0): BasicBlock(
          (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)

          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (downsample): Sequential(
            (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
            (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          )
        )
        (1): BasicBlock(
          (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (layer4): Sequential(
        (0): BasicBlock(
          (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (downsample): Sequential(
            (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
            (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          )
        )
        (1): BasicBlock(
          (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_1.fc.in_features
model_1.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_1.to(device)
```

```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
    (1): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer2): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer3): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
```

```
# Even though the original image sizes are diff, we need to resize them to 224*224,
# the same size that the resnet18 model was trained at.
from torchsummary import summary
summary(model_1, input_size=(3, 224, 224))
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 112, 112]           9,408
       BatchNorm2d-2         [-1, 64, 112, 112]             128
              ReLU-3         [-1, 64, 112, 112]               0
         MaxPool2d-4           [-1, 64, 56, 56]               0
            Conv2d-5           [-1, 64, 56, 56]          36,864
       BatchNorm2d-6           [-1, 64, 56, 56]             128
              ReLU-7           [-1, 64, 56, 56]               0
            Conv2d-8           [-1, 64, 56, 56]          36,864
       BatchNorm2d-9           [-1, 64, 56, 56]             128
             ReLU-10           [-1, 64, 56, 56]               0
       BasicBlock-11           [-1, 64, 56, 56]               0
           Conv2d-12           [-1, 64, 56, 56]          36,864
      BatchNorm2d-13           [-1, 64, 56, 56]             128
             ReLU-14           [-1, 64, 56, 56]               0
           Conv2d-15           [-1, 64, 56, 56]          36,864
      BatchNorm2d-16           [-1, 64, 56, 56]             128
             ReLU-17           [-1, 64, 56, 56]               0
       BasicBlock-18           [-1, 64, 56, 56]               0
           Conv2d-19          [-1, 128, 28, 28]          73,728
      BatchNorm2d-20          [-1, 128, 28, 28]             256
             ReLU-21          [-1, 128, 28, 28]               0
           Conv2d-22          [-1, 128, 28, 28]         147,456
      BatchNorm2d-23          [-1, 128, 28, 28]             256
           Conv2d-24          [-1, 128, 28, 28]           8,192
      BatchNorm2d-25          [-1, 128, 28, 28]             256
             ReLU-26          [-1, 128, 28, 28]               0
       BasicBlock-27          [-1, 128, 28, 28]               0
           Conv2d-28          [-1, 128, 28, 28]         147,456
      BatchNorm2d-29          [-1, 128, 28, 28]             256
             ReLU-30          [-1, 128, 28, 28]               0
           Conv2d-31          [-1, 128, 28, 28]         147,456
      BatchNorm2d-32          [-1, 128, 28, 28]             256
             ReLU-33          [-1, 128, 28, 28]               0
       BasicBlock-34          [-1, 128, 28, 28]               0
           Conv2d-35          [-1, 256, 14, 14]         294,912
      BatchNorm2d-36          [-1, 256, 14, 14]             512
             ReLU-37          [-1, 256, 14, 14]               0
           Conv2d-38          [-1, 256, 14, 14]         589,824
      BatchNorm2d-39          [-1, 256, 14, 14]             512
           Conv2d-40          [-1, 256, 14, 14]          32,768
      BatchNorm2d-41          [-1, 256, 14, 14]             512
             ReLU-42          [-1, 256, 14, 14]               0
       BasicBlock-43          [-1, 256, 14, 14]               0
           Conv2d-44          [-1, 256, 14, 14]         589,824
      BatchNorm2d-45          [-1, 256, 14, 14]             512
             ReLU-46          [-1, 256, 14, 14]               0
           Conv2d-47          [-1, 256, 14, 14]         589,824
      BatchNorm2d-48          [-1, 256, 14, 14]             512
             ReLU-49          [-1, 256, 14, 14]               0
       BasicBlock-50          [-1, 256, 14, 14]               0
           Conv2d-51            [-1, 512, 7, 7]       1,179,648
      BatchNorm2d-52            [-1, 512, 7, 7]           1,024
             ReLU-53            [-1, 512, 7, 7]               0
           Conv2d-54            [-1, 512, 7, 7]       2,359,296
      BatchNorm2d-55            [-1, 512, 7, 7]           1,024
           Conv2d-56            [-1, 512, 7, 7]         131,072
      BatchNorm2d-57            [-1, 512, 7, 7]           1,024
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_1.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
dict(counter_train)
```

```
{0: 753,
 1: 742,
 2: 737,
 3: 746,
 4: 464,
 5: 752,
 6: 754,
 7: 759,
 8: 754,
 9: 759}
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = np.array(list(weights.values()))
weights = weights/total_sum
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
     tensor([0.1043, 0.1028, 0.1021, 0.1033, 0.0643, 0.1042, 0.1044, 0.1051, 0.1044,
             0.1051], device='cuda:0')
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_1.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "resnet18_pretrained.pt",
}

# train and validate the model
model_1,loss_hist,metric_hist=train_val(model_1,params_train)
```

```
     Epoch 0/4, current lr=0.0001
     Copied best model weights!
     train loss: 0.066807, dev loss: 0.343475, accuracy: 89.70
     ----------
     Epoch 1/4, current lr=9.05463412215599e-05
     train loss: 0.062225, dev loss: 0.387394, accuracy: 88.59
     ----------
     Epoch 2/4, current lr=6.57963412215599e-05
     Copied best model weights!
     train loss: 0.030746, dev loss: 0.281684, accuracy: 91.41
     ----------
     Epoch 3/4, current lr=3.52036587784401e-05
     Copied best model weights!
     train loss: 0.019883, dev loss: 0.267099, accuracy: 91.63
     ----------
     Epoch 4/4, current lr=1.0453658778440105e-05
     Copied best model weights!
     train loss: 0.010560, dev loss: 0.255620, accuracy: 92.13
     ----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
     cuda:0
```

```
# load model
model_1 = models.resnet18(pretrained=True)
num_ftrs = model_1.fc.in_features
# change last layer
num_classes=10
model_1.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "resnet18_pretrained.pt"
model_1.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_1.eval()
model_1.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_1(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_1.7.csv', index=False)
```

Model_2

AlexNet

```
from torchvision import models
import torch

# load model with random weights
model_2 = models.alexnet(pretrained=True)
```

```
print(model_2)
```

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(2, 2))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (4): ReLU(inplace=True)
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (9): ReLU(inplace=True)
    (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(6, 6))
  (classifier): Sequential(
    (0): Dropout(p=0.5, inplace=False)
    (1): Linear(in_features=9216, out_features=4096, bias=True)
    (2): ReLU(inplace=True)
    (3): Dropout(p=0.5, inplace=False)
    (4): Linear(in_features=4096, out_features=4096, bias=True)
    (5): ReLU(inplace=True)
    (6): Linear(in_features=4096, out_features=1000, bias=True)
  )
)
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
model_2.classifier[-1].out_features
```

```
1000
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_2.classifier[-1].out_features
model_2.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_2.to(device)
```

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(2, 2))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (4): ReLU(inplace=True)
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (9): ReLU(inplace=True)
    (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(6, 6))
  (classifier): Sequential(
    (0): Dropout(p=0.5, inplace=False)
    (1): Linear(in_features=9216, out_features=4096, bias=True)
    (2): ReLU(inplace=True)
    (3): Dropout(p=0.5, inplace=False)
    (4): Linear(in_features=4096, out_features=4096, bias=True)
    (5): ReLU(inplace=True)
    (6): Linear(in_features=4096, out_features=1000, bias=True)
  )
  (fc): Linear(in_features=1000, out_features=10, bias=True)
)
```

```
# Even though the original image sizes are 96*96, we need to resize them to 224*224,
# the same size that the resnet18 model was trained at.
from torchsummary import summary
summary(model_2, input_size=(3, 224, 224))
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 64, 55, 55]          23,296
              ReLU-2           [-1, 64, 55, 55]               0
         MaxPool2d-3           [-1, 64, 27, 27]               0
            Conv2d-4          [-1, 192, 27, 27]         307,392
              ReLU-5          [-1, 192, 27, 27]               0
         MaxPool2d-6          [-1, 192, 13, 13]               0
            Conv2d-7          [-1, 384, 13, 13]         663,936
              ReLU-8          [-1, 384, 13, 13]               0
            Conv2d-9          [-1, 256, 13, 13]         884,992
             ReLU-10          [-1, 256, 13, 13]               0
           Conv2d-11          [-1, 256, 13, 13]         590,080
             ReLU-12          [-1, 256, 13, 13]               0
        MaxPool2d-13            [-1, 256, 6, 6]               0
```

```
AdaptiveAvgPool2d-14           [-1, 256, 6, 6]               0
          Dropout-15                 [-1, 9216]               0
           Linear-16                 [-1, 4096]      37,752,832
             ReLU-17                 [-1, 4096]               0
          Dropout-18                 [-1, 4096]               0
           Linear-19                 [-1, 4096]      16,781,312
             ReLU-20                 [-1, 4096]               0
           Linear-21                 [-1, 1000]       4,097,000
================================================================
Total params: 61,100,840
Trainable params: 61,100,840
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.57
Forward/backward pass size (MB): 8.38
Params size (MB): 233.08
Estimated Total Size (MB): 242.03
----------------------------------------------------------------
```

```
from torch import optim
opt = optim.Adam(model_2.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.
lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
```

```
lrs=[]
for i in range(10):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 5.5e-05
epoch 1, lr: 1.0e-05
epoch 2, lr: 5.5e-05
epoch 3, lr: 1.0e-04
epoch 4, lr: 5.5e-05
epoch 5, lr: 1.0e-05
epoch 6, lr: 5.5e-05
epoch 7, lr: 1.0e-04
epoch 8, lr: 5.5e-05
epoch 9, lr: 1.0e-05
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")
opt = optim.Adam(model_2.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)

params_train={
 "num_epochs": 4,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "alexnet_pretrained.pt",
}

# train and validate the model
model_2,loss_hist,metric_hist=train_val(model_2,params_train)
```

```
Epoch 0/3, current lr=0.0001
Copied best model weights!
train loss: 1.420489, dev loss: 0.610612, accuracy: 79.11
----------
Epoch 1/3, current lr=9.05463412215599e-05
Copied best model weights!
train loss: 0.571205, dev loss: 0.571547, accuracy: 81.61
----------
Epoch 2/3, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.372884, dev loss: 0.515431, accuracy: 83.49
----------
Epoch 3/3, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.238723, dev loss: 0.488585, accuracy: 85.15
----------
```

Prediction

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_2 = models.alexnet(pretrained=True)
num_ftrs = model_2.fc.in_features
# change last layer
num_classes=10
model_2.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "alexnet_pretrained.pt"
model_2.load_state_dict(torch.load(path2weights))
```

```
          5 num_classes=10
```

```
test_dl.dataset.samples[0][0][78:]
```

```
        777                  return modules[name]
```

```
model_2.eval()
model_2.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_2(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_2.1.csv', index=False)
```

Model_3

Resnet 34

```
from torchvision import models
import torch

# load model with random weights
model_3= models.resnet34(pretrained=True)
```

```
Downloading: "https://download.pytorch.org/models/resnet34-333f7ec4.pth" to /root/.cache/torch/hub/checkpoints/resnet34
```

100%   83.3M/83.3M [00:07<00:00, 11.9MB/s]

```
print(model_3)
```

```
        (downsample): Sequential(
          (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (2): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (3): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (4): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (5): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (layer4): Sequential(
      (0): BasicBlock(
        (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (downsample): Sequential(
          (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
     cuda:0
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_3.fc.in_features
model_3.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_3.to(device)
```

```
          (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (2): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (3): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (4): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
      (5): BasicBlock(
        (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (layer4): Sequential(
      (0): BasicBlock(
        (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (downsample): Sequential(
          (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): BasicBlock(
        (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
```

```
# Even though the original image sizes are diff, we need to resize them to 224*224,
# the same size that the resnet18 model was trained at.
from torchsummary import summary
summary(model_3, input_size=(3, 224, 224))
```

```
       BasicBlock-64          [-1, 256, 14, 14]               0
           Conv2d-65          [-1, 256, 14, 14]         589,824
      BatchNorm2d-66          [-1, 256, 14, 14]             512
             ReLU-67          [-1, 256, 14, 14]               0
           Conv2d-68          [-1, 256, 14, 14]         589,824
      BatchNorm2d-69          [-1, 256, 14, 14]             512
             ReLU-70          [-1, 256, 14, 14]               0
       BasicBlock-71          [-1, 256, 14, 14]               0
           Conv2d-72          [-1, 256, 14, 14]         589,824
      BatchNorm2d-73          [-1, 256, 14, 14]             512
             ReLU-74          [-1, 256, 14, 14]               0
           Conv2d-75          [-1, 256, 14, 14]         589,824
      BatchNorm2d-76          [-1, 256, 14, 14]             512
             ReLU-77          [-1, 256, 14, 14]               0
       BasicBlock-78          [-1, 256, 14, 14]               0
           Conv2d-79          [-1, 256, 14, 14]         589,824
      BatchNorm2d-80          [-1, 256, 14, 14]             512
             ReLU-81          [-1, 256, 14, 14]               0
           Conv2d-82          [-1, 256, 14, 14]         589,824
      BatchNorm2d-83          [-1, 256, 14, 14]             512
             ReLU-84          [-1, 256, 14, 14]               0
       BasicBlock-85          [-1, 256, 14, 14]               0
           Conv2d-86          [-1, 256, 14, 14]         589,824
      BatchNorm2d-87          [-1, 256, 14, 14]             512
             ReLU-88          [-1, 256, 14, 14]               0
           Conv2d-89          [-1, 256, 14, 14]         589,824
      BatchNorm2d-90          [-1, 256, 14, 14]             512
             ReLU-91          [-1, 256, 14, 14]               0
       BasicBlock-92          [-1, 256, 14, 14]               0
           Conv2d-93          [-1, 256, 14, 14]         589,824
      BatchNorm2d-94          [-1, 256, 14, 14]             512
```

```
           ReLU-95         [-1, 256, 14, 14]               0
         Conv2d-96         [-1, 256, 14, 14]         589,824
    BatchNorm2d-97         [-1, 256, 14, 14]             512
           ReLU-98         [-1, 256, 14, 14]               0
     BasicBlock-99         [-1, 256, 14, 14]               0
        Conv2d-100           [-1, 512, 7, 7]       1,179,648
   BatchNorm2d-101           [-1, 512, 7, 7]           1,024
          ReLU-102           [-1, 512, 7, 7]               0

        Conv2d-103           [-1, 512, 7, 7]       2,359,296
   BatchNorm2d-104           [-1, 512, 7, 7]           1,024
        Conv2d-105           [-1, 512, 7, 7]         131,072
   BatchNorm2d-106           [-1, 512, 7, 7]           1,024
          ReLU-107           [-1, 512, 7, 7]               0
    BasicBlock-108           [-1, 512, 7, 7]               0
        Conv2d-109           [-1, 512, 7, 7]       2,359,296
   BatchNorm2d-110           [-1, 512, 7, 7]           1,024
          ReLU-111           [-1, 512, 7, 7]               0
        Conv2d-112           [-1, 512, 7, 7]       2,359,296
   BatchNorm2d-113           [-1, 512, 7, 7]           1,024
          ReLU-114           [-1, 512, 7, 7]               0
    BasicBlock-115           [-1, 512, 7, 7]               0
        Conv2d-116           [-1, 512, 7, 7]       2,359,296
   BatchNorm2d-117           [-1, 512, 7, 7]           1,024
          ReLU-118           [-1, 512, 7, 7]               0
        Conv2d-119           [-1, 512, 7, 7]       2,359,296
   BatchNorm2d-120           [-1, 512, 7, 7]           1,024
          ReLU-121           [-1, 512, 7, 7]               0
    BasicBlock-122           [-1, 512, 7, 7]               0
AdaptiveAvgPool2d-123           [-1, 512, 1, 1]               0
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_3.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
```

```
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
Counter({0: 753,
         1: 742,
         2: 737,
         3: 746,
         4: 464,
         5: 752,
         6: 754,
         7: 759,
         8: 754,
         9: 759})
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = weights/total_sum
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
tensor([0.1043, 0.1028, 0.1021, 0.1033, 0.0643, 0.1042, 0.1044, 0.1051, 0.1044,
        0.1051], device='cuda:0')
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_3.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "resnet34_pretrained.pt",
}

# train and validate the model
model_3,loss_hist,metric_hist=train_val(model_3,params_train)
```

```
Epoch 0/4, current lr=0.0001
Copied best model weights!
train loss: 0.462817, dev loss: 0.318257, accuracy: 89.58
----------
Epoch 1/4, current lr=9.05463412215599e-05
Copied best model weights!
train loss: 0.179780, dev loss: 0.266865, accuracy: 91.19
----------
Epoch 2/4, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.069956, dev loss: 0.242825, accuracy: 92.47
----------
Epoch 3/4, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.038639, dev loss: 0.223531, accuracy: 93.35
----------
Epoch 4/4, current lr=1.0453658778440105e-05
```

```
Copied best model weights!
train loss: 0.018329, dev loss: 0.214176, accuracy: 93.57
----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_3 = models.resnet34(pretrained=True)
num_ftrs = model_3.fc.in_features
# change last layer
num_classes=10
model_3.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "resnet34_pretrained.pt"
model_3.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_3.eval()
model_3.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_3(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_3.1.csv', index=False)
```

Model_4

Resnet 50

```
from torchvision import models
import torch

# load model with random weights
model_4= models.resnet50(pretrained=True)
```

```
print(model_4)
```

```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
  )
  (layer2): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
model_4
```

```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(64, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
  )
  (layer2): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_4.fc.in_features
model_4.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_4.to(device)
```

```
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
```

```
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (3): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (4): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (5): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
    )
    (layer4): Sequential(
      (0): Bottleneck(
        (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (downsample): Sequential(
          (0): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): Bottleneck(
        (conv1): Conv2d(2048, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
# Even though the original image sizes are diff, we need to resize them to 224*224,
# the same size that the resnet18 model was trained at.
from torchsummary import summary
summary(model_4, input_size=(3, 224, 224))
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 112, 112]           9,408
       BatchNorm2d-2         [-1, 64, 112, 112]             128
              ReLU-3         [-1, 64, 112, 112]               0
         MaxPool2d-4           [-1, 64, 56, 56]               0
            Conv2d-5           [-1, 64, 56, 56]           4,096
       BatchNorm2d-6           [-1, 64, 56, 56]             128
              ReLU-7           [-1, 64, 56, 56]               0
            Conv2d-8           [-1, 64, 56, 56]          36,864
       BatchNorm2d-9           [-1, 64, 56, 56]             128
             ReLU-10           [-1, 64, 56, 56]               0
           Conv2d-11          [-1, 256, 56, 56]          16,384
      BatchNorm2d-12          [-1, 256, 56, 56]             512
           Conv2d-13          [-1, 256, 56, 56]          16,384
      BatchNorm2d-14          [-1, 256, 56, 56]             512
             ReLU-15          [-1, 256, 56, 56]               0
       Bottleneck-16          [-1, 256, 56, 56]               0
```

```
           Conv2d-17           [-1, 64, 56, 56]          16,384
      BatchNorm2d-18           [-1, 64, 56, 56]             128
             ReLU-19           [-1, 64, 56, 56]               0
           Conv2d-20           [-1, 64, 56, 56]          36,864
      BatchNorm2d-21           [-1, 64, 56, 56]             128
             ReLU-22           [-1, 64, 56, 56]               0
           Conv2d-23          [-1, 256, 56, 56]          16,384
      BatchNorm2d-24          [-1, 256, 56, 56]             512
             ReLU-25          [-1, 256, 56, 56]               0
       Bottleneck-26          [-1, 256, 56, 56]               0
           Conv2d-27           [-1, 64, 56, 56]          16,384
      BatchNorm2d-28           [-1, 64, 56, 56]             128
             ReLU-29           [-1, 64, 56, 56]               0
           Conv2d-30           [-1, 64, 56, 56]          36,864
      BatchNorm2d-31           [-1, 64, 56, 56]             128
             ReLU-32           [-1, 64, 56, 56]               0
           Conv2d-33          [-1, 256, 56, 56]          16,384
      BatchNorm2d-34          [-1, 256, 56, 56]             512
             ReLU-35          [-1, 256, 56, 56]               0
       Bottleneck-36          [-1, 256, 56, 56]               0
           Conv2d-37          [-1, 128, 56, 56]          32,768
      BatchNorm2d-38          [-1, 128, 56, 56]             256
             ReLU-39          [-1, 128, 56, 56]               0
           Conv2d-40          [-1, 128, 28, 28]         147,456
      BatchNorm2d-41          [-1, 128, 28, 28]             256
             ReLU-42          [-1, 128, 28, 28]               0
           Conv2d-43          [-1, 512, 28, 28]          65,536
      BatchNorm2d-44          [-1, 512, 28, 28]           1,024
           Conv2d-45          [-1, 512, 28, 28]         131,072
      BatchNorm2d-46          [-1, 512, 28, 28]           1,024
             ReLU-47          [-1, 512, 28, 28]               0
       Bottleneck-48          [-1, 512, 28, 28]               0
           Conv2d-49          [-1, 128, 28, 28]          65,536
      BatchNorm2d-50          [-1, 128, 28, 28]             256
             ReLU-51          [-1, 128, 28, 28]               0
           Conv2d-52          [-1, 128, 28, 28]         147,456
      BatchNorm2d-53          [-1, 128, 28, 28]             256
             ReLU-54          [-1, 128, 28, 28]               0
           Conv2d-55          [-1, 512, 28, 28]          65,536
      BatchNorm2d-56          [-1, 512, 28, 28]           1,024
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_4.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
Counter({0: 753,
         1: 742,
         2: 737,
         3: 746,
         4: 464,
         5: 752,
         6: 754,
         7: 759,
         8: 754,
         9: 759})
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = weights/total_sum
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
tensor([0.1043, 0.1028, 0.1021, 0.1033, 0.0643, 0.1042, 0.1044, 0.1051, 0.1044,
        0.1051], device='cuda:0')
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_4.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "resnet50_pretrained.pt",
}

# train and validate the model
model_4,loss_hist,metric_hist=train_val(model_4,params_train)
```

```
Epoch 0/4, current lr=0.0001
Copied best model weights!
train loss: 0.596847, dev loss: 0.329324, accuracy: 89.36
----------
Epoch 1/4, current lr=9.05463412215599e-05
Copied best model weights!
train loss: 0.293669, dev loss: 0.267223, accuracy: 91.08
----------
```

```
Epoch 2/4, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.149720, dev loss: 0.266614, accuracy: 91.02
----------
Epoch 3/4, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.067600, dev loss: 0.228830, accuracy: 93.85
----------
Epoch 4/4, current lr=1.0453658778440105e-05
Copied best model weights!
train loss: 0.038711, dev loss: 0.228743, accuracy: 92.74
----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_4 = models.resnet50(pretrained=True)
num_ftrs = model_4.fc.in_features
# change last layer
num_classes=10
model_4.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "resnet50_pretrained.pt"
model_4.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_4.eval()
model_4.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_4(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_4.3.csv', index=False)
```

Model_5

Resnet 50 - fine tuning

```
from torchvision import models
import torch

# load model with random weights
model_5= models.resnet50(pretrained=True)
```

```
Downloading: "https://download.pytorch.org/models/resnet50-19c8e357.pth" to /root/.cache/torch/hub/checkpoints/resnet50
100%                                        97.8M/97.8M [00:00<00:00, 285MB/s]
```

```
print(model_5)
```

```
    (0): Bottleneck(
      (conv1): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(512, 1024, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (3): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (4): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (5): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)

      (relu): ReLU(inplace=True)
    )
  )
  (layer4): Sequential(
```

```
# upload model to GPU
```

```
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
for param in model_5.layer4.parameters():
  param.requires_grad = True
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_5.fc.in_features
model_5.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_5.to(device)
```

```
        (relu): ReLU(inplace=True)
      )
      (2): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (3): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (4): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
      (5): Bottleneck(
        (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)

        (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
      )
    )
    (layer4): Sequential(
      (0): Bottleneck(
        (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu): ReLU(inplace=True)
        (downsample): Sequential(
          (0): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(2, 2), bias=False)
          (1): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        )
      )
      (1): Bottleneck(
        (conv1): Conv2d(2048, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
        (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_5.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
Counter({0: 753,
         1: 742,
         2: 737,
         3: 746,
         4: 464,
         5: 752,
         6: 754,
         7: 759,
         8: 754,
         9: 759})
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = weights/total_sum
weights = (torch.tensor(weights)).float().to(device)
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
tensor([0.1043, 0.1028, 0.1021, 0.1033, 0.0643, 0.1042, 0.1044, 0.1051, 0.1044,
        0.1051], device='cuda:0')
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_5.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "model_5.pt",
}

# train and validate the model
model_5,loss_hist,metric_hist=train_val(model_5,params_train)
```

```
Epoch 0/4, current lr=0.0001
Copied best model weights!
train loss: 0.591281, dev loss: 0.314889, accuracy: 90.75
----------
Epoch 1/4, current lr=9.05463412215599e-05
Copied best model weights!
train loss: 0.306739, dev loss: 0.300829, accuracy: 89.97
----------
Epoch 2/4, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.143134, dev loss: 0.262663, accuracy: 91.86
----------
Epoch 3/4, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.070000, dev loss: 0.216210, accuracy: 93.07
----------
Epoch 4/4, current lr=1.0453658778440105e-05
Copied best model weights!
train loss: 0.039831, dev loss: 0.193232, accuracy: 94.13
----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_5 = models.resnet50(pretrained=True)
num_ftrs = model_5.fc.in_features
# change last layer
num_classes=10
model_5.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "model_5.pt"
```

```
model_5.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_5.eval()
model_5.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_5(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
#submission.to_csv('submission.csv', index=False)
```

```
submission.to_csv('pred_5.csv', index=False)
```

Model_6

Resnet 152

```
from torchvision import models
import torch

# load model with random weights
model_6= models.resnet152(pretrained=True)
```

```
Downloading: "https://download.pytorch.org/models/resnet152-b121ed2d.pth" to /root/.cache/torch/hub/checkpoints/resnet1
100%                                        230M/230M [00:06<00:00, 38.6MB/s]
```

```
print(model_6)
```

```
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (18): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (19): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
```

```
    )
    (20): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (21): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (22): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)

      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (23): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (24): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track running stats=True)
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
from torch import nn
# change the output layer
num_classes=10
num_ftrs = model_6.fc.in_features
model_6.fc = nn.Linear(num_ftrs, num_classes)

#device = torch.device("cuda:0")
model_6.to(device)
```

```
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (28): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (29): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
```

```
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (30): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)

          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (31): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (32): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (33): Bottleneck(
          (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
        )
        (34): Bottleneck(
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_6.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
Counter({0: 753,
         1: 742,
         2: 737,
         3: 746,
         4: 464,
         5: 752,
         6: 754,
         7: 759,
         8: 754,
         9: 759})
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = weights/total_sum
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
tensor([0.1043, 0.1028, 0.1021, 0.1033, 0.0643, 0.1042, 0.1044, 0.1051, 0.1044,
        0.1051], device='cuda:0')
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_6.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "model_6.pt",
}

# train and validate the model
model_6,loss_hist,metric_hist=train_val(model_6,params_train)
```

```
Epoch 0/4, current lr=0.0001
Copied best model weights!
train loss: 0.587427, dev loss: 0.422705, accuracy: 85.32
----------
Epoch 1/4, current lr=9.05463412215599e-05
Copied best model weights!
```

```
train loss: 0.303875, dev loss: 0.379381, accuracy: 87.87
----------
Epoch 2/4, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.171443, dev loss: 0.330739, accuracy: 90.03
----------
Epoch 3/4, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.063638, dev loss: 0.243718, accuracy: 92.41
----------
Epoch 4/4, current lr=1.0453658778440105e-05
Copied best model weights!
train loss: 0.032323, dev loss: 0.208538, accuracy: 93.68
----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_6 = models.resnet152(pretrained=True)
num_ftrs = model_6.fc.in_features
# change last layer
num_classes=10
model_6.fc = nn.Linear(num_ftrs, num_classes)
```

```
import torch

# load state_dict into model
path2weights=folder / "model_6.pt"
model_6.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_6.eval()
model_6.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_6(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_6.csv', index=False)
```

Model_7

Densenet 161

```
from torchvision import models
import torch

# load model with random weights
model_7= models.densenet161(pretrained=True)
```

```
print(model_7)
```

```
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(96, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
          (denselayer2): _DenseLayer(
            (norm1): BatchNorm2d(144, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(144, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
          (denselayer3): _DenseLayer(
            (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(192, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
          (denselayer4): _DenseLayer(
            (norm1): BatchNorm2d(240, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(240, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
          (denselayer5): _DenseLayer(
            (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(288, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
          (denselayer6): _DenseLayer(
            (norm1): BatchNorm2d(336, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(336, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
          )
        )
        (transition1): _Transition(
          (norm): BatchNorm2d(384, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
          (relu): ReLU(inplace=True)
          (conv): Conv2d(384, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
        )
        (denseblock2): _DenseBlock(
          (denselayer1): _DenseLayer(

            (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(192, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
            (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
from torch import nn
# change the output layer
num_classes=10

model_7.classifier.out_features = num_classes

#device = torch.device("cuda:0")
model_7.to(device)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(1440, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1440, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(1488, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1488, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(1536, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1536, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(1584, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1584, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(1632, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1632, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(1680, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1680, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(1728, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1728, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer16): _DenseLayer(
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_7.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
Counter({0: 753,
         1: 742,
         2: 737,
         3: 746,
         4: 464,
         5: 752,
         6: 754,
         7: 759,
         8: 754,
         9: 759})
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = np.around(weights/total_sum,decimals=2)
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
tensor([0.1000, 0.1000, 0.1000, 0.1000, 0.0600, 0.1000, 0.1000, 0.1100, 0.1000,
        0.1100], device='cuda:0')
```

```
import copy
```

```
loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_7.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "model_7.pt",
}

# train and validate the model
model_7,loss_hist,metric_hist=train_val(model_7,params_train)
```

```
Epoch 0/4, current lr=0.0001
Copied best model weights!
train loss: 0.757316, dev loss: 0.309049, accuracy: 89.92
----------
Epoch 1/4, current lr=9.05463412215599e-05
Copied best model weights!
train loss: 0.217857, dev loss: 0.261615, accuracy: 91.19
----------
Epoch 2/4, current lr=6.57963412215599e-05
Copied best model weights!
train loss: 0.092043, dev loss: 0.246794, accuracy: 93.91
----------
Epoch 3/4, current lr=3.52036587784401e-05
Copied best model weights!
train loss: 0.041339, dev loss: 0.224900, accuracy: 93.68
----------
Epoch 4/4, current lr=1.0453658778440105e-05
Copied best model weights!
train loss: 0.020577, dev loss: 0.196145, accuracy: 94.85
----------
```

```
from torch import nn
from torchvision import models
import torch

device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
# load model
model_7 = models.densenet161(pretrained=True)

from torch import nn
# change the output layer
num_classes=10

model_7.classifier.out_features = num_classes

#device = torch.device("cuda:0")
model_7.to(device)
```

```
        (conv1): Conv2d(1344, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(1392, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1392, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(1440, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1440, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(1488, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1488, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)

        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(1536, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1536, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(1584, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1584, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(1632, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1632, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(1680, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1680, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(192, 48, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
```

```
import torch

# load state_dict into model
path2weights=folder / "model_7.pt"
model_7.load_state_dict(torch.load(path2weights))
```

```
<All keys matched successfully>
```

```
test_dl.dataset.samples[0][0][78:]
```

```
'0.JPEG'
```

```
model_7.eval()
model_7.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_7(x)
        pred = torch.argmax(output, dim=1)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_7.csv', index=False)
```

Model_8

```
from torchvision import models
import torch

# load model with random weights
model_8= models.vgg19_bn(pretrained=True)
```

```
Downloading: "https://download.pytorch.org/models/vgg19_bn-c79401a0.pth" to /root/.cache/torch/hub/checkpoints/vgg19_bn
100%                                        548M/548M [00:12<00:00, 45.7MB/s]
```

```
print(model_8)
```

```
      (3): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (4): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (5): ReLU(inplace=True)
      (6): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
      (7): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (8): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (9): ReLU(inplace=True)
      (10): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (11): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (12): ReLU(inplace=True)
      (13): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
      (14): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (15): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (16): ReLU(inplace=True)
      (17): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (18): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (19): ReLU(inplace=True)
      (20): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (21): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (22): ReLU(inplace=True)
      (23): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (24): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (25): ReLU(inplace=True)
      (26): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
      (27): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (28): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (29): ReLU(inplace=True)
      (30): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (31): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (32): ReLU(inplace=True)
      (33): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (34): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (35): ReLU(inplace=True)
      (36): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (37): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (38): ReLU(inplace=True)
      (39): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
      (40): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))

      (41): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (42): ReLU(inplace=True)
      (43): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (44): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (45): ReLU(inplace=True)
      (46): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
```

```
    (47): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (48): ReLU(inplace=True)
    (49): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (50): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (51): ReLU(inplace=True)
    (52): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (classifier): Sequential(
    (0): Linear(in_features=25088, out_features=4096, bias=True)
    (1): ReLU(inplace=True)
    (2): Dropout(p=0.5, inplace=False)
    (3): Linear(in_features=4096, out_features=4096, bias=True)
    (4): ReLU(inplace=True)
    (5): Dropout(p=0.5, inplace=False)
    (6): Linear(in_features=4096, out_features=1000, bias=True)
```

```
# upload model to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else 'cpu')
print(device)
```

```
cuda:0
```

```
#for param in model_8.classifier.parameters():
 # param.requires_grad_ = True
```

```
model_8.classifier[-1].out_features
```

```
1000
```

```
from torch import nn
# change the output layer
num_classes=10
model_8.classifier[-1].out_features = num_classes

#device = torch.device("cuda:0")
model_8.to(device)
```

```
    (4): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (5): ReLU(inplace=True)
    (6): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (7): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (8): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (9): ReLU(inplace=True)
    (10): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (12): ReLU(inplace=True)
    (13): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (14): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (15): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (16): ReLU(inplace=True)
    (17): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (18): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (19): ReLU(inplace=True)
    (20): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (21): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (22): ReLU(inplace=True)
    (23): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (24): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (25): ReLU(inplace=True)
    (26): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (27): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (28): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (29): ReLU(inplace=True)
    (30): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (31): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (32): ReLU(inplace=True)
    (33): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (34): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (35): ReLU(inplace=True)
    (36): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (37): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (38): ReLU(inplace=True)
    (39): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (40): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (41): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (42): ReLU(inplace=True)
    (43): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (44): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (45): ReLU(inplace=True)
    (46): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (47): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (48): ReLU(inplace=True)
    (49): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (50): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (51): ReLU(inplace=True)
    (52): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (classifier): Sequential(
    (0): Linear(in_features=25088, out_features=4096, bias=True)
    (1): ReLU(inplace=True)
    (2): Dropout(p=0.5, inplace=False)
    (3): Linear(in_features=4096, out_features=4096, bias=True)
    (4): ReLU(inplace=True)
    (5): Dropout(p=0.5, inplace=False)
    (6): Linear(in_features=4096, out_features=10, bias=True)
```

Training & Prediction

```
from torch import optim
opt = optim.Adam(model_8.parameters(), lr=1e-4)
```

```
# get learning rate
def get_lr(opt):
    for param_group in opt.param_groups:
        return param_group['lr']

current_lr=get_lr(opt)
print('current lr={}'.format(current_lr))
```

```
current lr=0.0001
```

```
from torch.optim.lr_scheduler import CosineAnnealingLR, StepLR

# define learning rate scheduler
# Several methods exist to adjust the learning rate. For a list of supported methods by PyTorch,
# please visit the following link: https://pytorch.org/docs/stable/optim.html.

#lr_scheduler = CosineAnnealingLR(opt,T_max=2,eta_min=1e-5)
lr_scheduler = StepLR(opt,step_size=1)
```

```
lrs=[]
for i in range(5):
    lr_scheduler.step()
    lr=get_lr(opt)
    print("epoch %s, lr: %.1e" %(i,lr))
    lrs.append(lr)
```

```
epoch 0, lr: 1.0e-05
epoch 1, lr: 1.0e-06
epoch 2, lr: 1.0e-07
epoch 3, lr: 1.0e-08
epoch 4, lr: 1.0e-09
/usr/local/lib/python3.6/dist-packages/torch/optim/lr_scheduler.py:136: UserWarning: Detected call of `lr_scheduler.ste
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
```

```
(counter_train)
```

```
from sortedcontainers import SortedDict

total_sum = sum(counter_train.values())

weights = SortedDict(dict(counter_train))
weights = np.array(list(weights.values()))
weights = np.around(weights/total_sum,decimals=2)
weights = (torch.tensor(weights)).float().to(device)
weights
```

```
import copy

loss_func = nn.CrossEntropyLoss(reduction="sum")

opt = optim.Adam(model_8.parameters(), lr=1e-4)
lr_scheduler = CosineAnnealingLR(opt,T_max=5,eta_min=1e-6)
#lr_scheduler = StepLR(opt,step_size=1)

params_train={
 "num_epochs": 5,
 "optimizer": opt,
 "loss_func": loss_func,
 "train_dl": train_dl,
 "val_dl": val_dl,
 "sanity_check": False,
 "lr_scheduler": lr_scheduler,
 "path2weights": folder / "model_8.pt",
}

# train and validate the model
model_8,loss_hist,metric_hist=train_val(model_8,params_train)
```

```
test_dl.dataset.samples[0][0][78:]
```

```
model_8.eval()
model_8.to(device)
fn_list = []
pred_list = []
for i, (x,fn) in enumerate(test_dl, 0):
    with torch.no_grad():
        x = x.to(device)
        output = model_8(x)
        pred = torch.argmax(output, dim=1)
        pred_list += [p.item() for p in pred]

for m,n in enumerate(test_dl.dataset.samples,0):
        fn_list += [n[0][78:]]

submission = pd.DataFrame({"file_names":fn_list, "target":pred_list})
submission.to_csv('preds_8.csv', index=False)
```