mamalis2_mp3_part1b

November 2, 2020

[ ]:
```
# !pip install torch==1.5.1+cu101 torchvision==0.6.1+cu101 -f https://download.
↪pytorch.org/whl/torch_stable.html
```

[ ]:
```
# from google.colab import drive
# drive.mount('/content/gdrive/')
# import os
# os.chdir("/content/gdrive/My Drive/CS 498 DL/assignment3/part1/
↪assignment3_p1_starterkit")
```

1 Assignment 3 Part 1: Developing Your Own Classifier

[ ]:
```
import os
import numpy as np
import torch
import torch.nn as nn
import torchvision
import torch.nn.functional as F

from torchvision import transforms
from sklearn.metrics import average_precision_score
from PIL import Image, ImageDraw
import matplotlib.pyplot as plt
from kaggle_submission import output_submission_csv
from classifier import Classifier  #, SimpleClassifier #, AlexNet
from voc_dataloader import VocDataset, VOC_CLASSES

%matplotlib inline
%load_ext autoreload
%autoreload 2
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

2 Part 1B: Design your own network

In this notebook, your task is to create and train your own model for multi-label classification on VOC Pascal.

2.1 What to do

1. You will make change on network architecture in `classifier.py`.
2. You may also want to change other hyperparameters to assist your training to get a better performances. Hints will be given in the below instructions.

2.2 What to submit

Check the submission template for details what to submit.

[ ]:
```
def train_classifier(train_loader, classifier, criterion, optimizer):
    classifier.train()
    loss_ = 0.0
    losses = []
    for i, (images, labels, _) in enumerate(train_loader):
        start_time = time.time()
        images, labels = images.to(device), labels.to(device)
        optimizer.zero_grad()
        logits = classifier(images)
        loss = criterion(logits, labels)
        loss.backward()
        optimizer.step()
        losses.append(loss)
    return torch.stack(losses).mean().item()
```

[ ]:
```
def test_classifier(test_loader, classifier, criterion, print_ind_classes=True,␣
↪print_total=True):
    classifier.eval()
    losses = []
    with torch.no_grad():
        y_true = np.zeros((0,21))
        y_score = np.zeros((0,21))
        for i, (images, labels, _) in enumerate(test_loader):
            start_time = time.time()
            images, labels = images.to(device), labels.to(device)
            logits = classifier(images)
            y_true = np.concatenate((y_true, labels.cpu().numpy()), axis=0)
            y_score = np.concatenate((y_score, logits.cpu().numpy()), axis=0)
            loss = criterion(logits, labels)
            losses.append(loss.item())

        aps = []
        # ignore first class which is background
        for i in range(1, y_true.shape[1]):
```

```
            ap = average_precision_score(y_true[:, i], y_score[:, i])
            if print_ind_classes:
                print('-------  Class: {:<12}     AP: {:>8.4f}  -------'.
 ↪format(VOC_CLASSES[i], ap))
            aps.append(ap)

        mAP = np.mean(aps)
        test_loss = np.mean(losses)
        if print_total:
            print('mAP: {0:.4f}'.format(mAP))
            print('Avg loss: {}'.format(test_loss))

    return mAP, test_loss, aps
```

[ ]:
```
def plot_losses(train, val, test_frequency, num_epochs):
    plt.plot(train, label="train")
    indices = [i for i in range(num_epochs) if ((i+1)%test_frequency == 0 or i␣
 ↪==0)]
    plt.plot(indices, val, label="val")
    plt.title("Loss Plot")
    plt.ylabel("Loss")
    plt.xlabel("Epoch")
    plt.legend()
    plt.show()

def plot_mAP(train, val, test_frequency, num_epochs):
    indices = [i for i in range(num_epochs) if ((i+1)%test_frequency == 0 or i␣
 ↪==0)]
    plt.plot(indices, train, label="train")
    plt.plot(indices, val, label="val")
    plt.title("mAP Plot")
    plt.ylabel("mAP")
    plt.xlabel("Epoch")
    plt.legend()
    plt.show()
```

[ ]:
```
def train(classifier, num_epochs, train_loader, val_loader, criterion,␣
 ↪optimizer, test_frequency=5):
    train_losses = []
    train_mAPs = []
    val_losses = []
    val_mAPs = []

    for epoch in range(1,num_epochs+1):
        print("Starting epoch number " + str(epoch))
        train_loss = train_classifier(train_loader, classifier, criterion,␣
 ↪optimizer)
```

```
        train_losses.append(train_loss)
        print("Loss for Training on Epoch " +str(epoch) + " is "+␣
↪str(train_loss))
        if(epoch%test_frequency==0 or epoch==1):
            mAP_train, _, _ = test_classifier(train_loader, classifier,␣
↪criterion, False, False)
            train_mAPs.append(mAP_train)
            mAP_val, val_loss, _ = test_classifier(val_loader, classifier,␣
↪criterion)
            print('Evaluating classifier')
            print("Mean Precision Score for Testing on Epoch " +str(epoch) + "␣
↪is "+ str(mAP_val))
            val_losses.append(val_loss)
            val_mAPs.append(mAP_val)

    return classifier, train_losses, val_losses, train_mAPs, val_mAPs
```

3 Developing Your Own Model

3.0.1 Goal

To meet the benchmark for this assignment you will need to improve the network. Note you should have noticed pretrained Alenxt performs really well, but training Alexnet from scratch performs much worse. We hope you can design a better architecture over both the simple classifier and AlexNet to train from scratch.

3.0.2 How to start

You may take inspiration from other published architectures and architectures discussed in lecture. However, you are NOT allowed to use predefined models (e.g. models from torchvision) or use pretrained weights. Training must be done from scratch with your own custom model.

Some hints There are a variety of different approaches you should try to improve performance from the simple classifier:

- Network architecture changes
  - Number of layers: try adding layers to make your network deeper
  - Batch normalization: adding batch norm between layers will likely give you a significant performance increase
  - Residual connections: as you increase the depth of your network, you will find that having residual connections like those in ResNet architectures will be helpful
- Optimizer: Instead of plain SGD, you may want to add a learning rate schedule, add momentum, or use one of the other optimizers you have learned about like Adam. Check the `torch.optim` package for other optimizers

- Data augmentation: You should use the `torchvision.transforms` module to try adding random resized crops and horizontal flips of the input data. Check `transforms.RandomResizedCrop` and `transforms.RandomHorizontalFlip` for this. Feel free to apply more transforms for data augmentation which can lead to better performance.
- Epochs: Once you have found a generally good hyperparameter setting try training for more epochs
- Loss function: You might want to add weighting to the `MultiLabelSoftMarginLoss` for classes that are less well represented or experiment with a different loss function

Note We will soon be providing some initial expectations of mAP values as a function of epoch so you can get an early idea whether your implementation works without waiting a long time for training to converge.

3.0.3 What to submit

Submit your best model to Kaggle and save all plots for the writeup.

[ ]:
```
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")

normalize = transforms.Normalize(mean=[0.485, 0.456, 0.406],
                                 std= [0.229, 0.224, 0.225])

train_transform = transforms.Compose([
            transforms.Resize(227),
            transforms.CenterCrop(227),
            transforms.RandomResizedCrop(227),
            transforms.RandomHorizontalFlip(p=0.5),
            transforms.ToTensor(),
            normalize
        ])

test_transform = transforms.Compose([
            transforms.Resize(227),
            transforms.CenterCrop(227),
            transforms.ToTensor(),
            normalize,
        ])
```

[ ]:
```
ds_train = VocDataset('/content/VOCdevkit_2007/VOC2007','train',train_transform)
ds_val = VocDataset('/content/VOCdevkit_2007/VOC2007','val',test_transform)
ds_test = VocDataset('/content/VOCdevkit_2007/VOC2007test','test',␣
 ↪test_transform)
```

[ ]:
```
num_epochs = 100
test_frequency = 10
batch_size = 10

train_loader = torch.utils.data.DataLoader(dataset=ds_train,
                                           batch_size=batch_size,
```

```
                                                shuffle=True,
                                                num_workers=1)

val_loader = torch.utils.data.DataLoader(dataset=ds_val,
                                                batch_size=batch_size,
                                                shuffle=True,
                                                num_workers=1)

test_loader = torch.utils.data.DataLoader(dataset=ds_test,
                                                batch_size=batch_size,
                                                shuffle=False,
                                                num_workers=1)
```

[ ]:
```
# TODO: Run your own classifier here
# classifier = SimpleClassifier().to(device)
classifier = Classifier().to(device)
# You can can use this function to reload a network you have already saved␣
 ↪previously
# classifier.load_state_dict(torch.load('voc_classifier.pth'))


criterion = nn.MultiLabelSoftMarginLoss()
# optimizer = torch.optim.SGD(classifier.parameters(), lr=0.01, momentum=0.9)
optimizer = torch.optim.Adam(classifier.parameters(), lr=1e-4)
classifier, train_losses, val_losses, train_mAPs, val_mAPs = train(classifier,␣
 ↪num_epochs, train_loader, val_loader, criterion, optimizer, test_frequency)
```

```
Starting epoch number 1
Loss for Training on Epoch 1 is 0.2525351047515869
-------  Class: aeroplane        AP:   0.3784  -------
-------  Class: bicycle          AP:   0.1019  -------
-------  Class: bird             AP:   0.1444  -------
-------  Class: boat             AP:   0.2072  -------
-------  Class: bottle           AP:   0.0653  -------
-------  Class: bus              AP:   0.1093  -------
-------  Class: car              AP:   0.3296  -------
-------  Class: cat              AP:   0.2260  -------
-------  Class: chair            AP:   0.2197  -------
-------  Class: cow              AP:   0.0443  -------
-------  Class: diningtable      AP:   0.1343  -------
-------  Class: dog              AP:   0.1798  -------
-------  Class: horse            AP:   0.1546  -------
-------  Class: motorbike        AP:   0.1481  -------
-------  Class: person           AP:   0.5242  -------
-------  Class: pottedplant      AP:   0.0942  -------
-------  Class: sheep            AP:   0.0805  -------
-------  Class: sofa             AP:   0.1381  -------
-------  Class: train            AP:   0.1585  -------
```

```
-------  Class: tvmonitor        AP:   0.1043  -------
mAP: 0.1771
Avg loss: 0.21883660703303803
Evaluating classifier
Mean Precision Score for Testing on Epoch 1 is 0.17713494261607135
Starting epoch number 2
Loss for Training on Epoch 2 is 0.22206319868564606
Starting epoch number 3
Loss for Training on Epoch 3 is 0.21682456135749817
Starting epoch number 4
Loss for Training on Epoch 4 is 0.2162458449602127
Starting epoch number 5
Loss for Training on Epoch 5 is 0.2156069427728653
Starting epoch number 6
Loss for Training on Epoch 6 is 0.21238814294338226
Starting epoch number 7
Loss for Training on Epoch 7 is 0.20931175351142883
Starting epoch number 8
Loss for Training on Epoch 8 is 0.2062024176120758
Starting epoch number 9
Loss for Training on Epoch 9 is 0.20514293015003204
Starting epoch number 10
Loss for Training on Epoch 10 is 0.20148813724517822
-------  Class: aeroplane        AP:   0.4732  -------
-------  Class: bicycle          AP:   0.1866  -------
-------  Class: bird             AP:   0.1786  -------
-------  Class: boat             AP:   0.2768  -------
-------  Class: bottle           AP:   0.1720  -------
-------  Class: bus              AP:   0.1501  -------
-------  Class: car              AP:   0.4763  -------
-------  Class: cat              AP:   0.2823  -------
-------  Class: chair            AP:   0.3754  -------
-------  Class: cow              AP:   0.1222  -------
-------  Class: diningtable      AP:   0.2627  -------
-------  Class: dog              AP:   0.2251  -------
-------  Class: horse            AP:   0.3044  -------
-------  Class: motorbike        AP:   0.2071  -------
-------  Class: person           AP:   0.6849  -------
-------  Class: pottedplant      AP:   0.1325  -------
-------  Class: sheep            AP:   0.1217  -------
-------  Class: sofa             AP:   0.2735  -------
-------  Class: train            AP:   0.3482  -------
-------  Class: tvmonitor        AP:   0.1981  -------
mAP: 0.2726
Avg loss: 0.20339444089695752
Evaluating classifier
Mean Precision Score for Testing on Epoch 10 is 0.2725780931703911
Starting epoch number 11
```

```
Loss for Training on Epoch 11 is 0.20292484760284424
Starting epoch number 12
Loss for Training on Epoch 12 is 0.19948141276836395
Starting epoch number 13
Loss for Training on Epoch 13 is 0.19902671873569489
Starting epoch number 14
Loss for Training on Epoch 14 is 0.19825531542301178
Starting epoch number 15
Loss for Training on Epoch 15 is 0.1946266144514084
Starting epoch number 16
Loss for Training on Epoch 16 is 0.1947449892759323
Starting epoch number 17
Loss for Training on Epoch 17 is 0.19270794093608856
Starting epoch number 18
Loss for Training on Epoch 18 is 0.19271917641162872
Starting epoch number 19
Loss for Training on Epoch 19 is 0.19228683412075043
Starting epoch number 20
Loss for Training on Epoch 20 is 0.19127127528190613
-------  Class: aeroplane        AP:   0.5073  -------
-------  Class: bicycle          AP:   0.2560  -------
-------  Class: bird             AP:   0.2064  -------
-------  Class: boat             AP:   0.3174  -------
-------  Class: bottle           AP:   0.1386  -------
-------  Class: bus              AP:   0.1966  -------
-------  Class: car              AP:   0.5165  -------
-------  Class: cat              AP:   0.2699  -------
-------  Class: chair            AP:   0.3690  -------
-------  Class: cow              AP:   0.1744  -------
-------  Class: diningtable      AP:   0.2520  -------
-------  Class: dog              AP:   0.2560  -------
-------  Class: horse            AP:   0.4648  -------
-------  Class: motorbike        AP:   0.2342  -------
-------  Class: person           AP:   0.7075  -------
-------  Class: pottedplant      AP:   0.1568  -------
-------  Class: sheep            AP:   0.1433  -------
-------  Class: sofa             AP:   0.2639  -------
-------  Class: train            AP:   0.4017  -------
-------  Class: tvmonitor        AP:   0.2955  -------
mAP: 0.3064
Avg loss: 0.1954644859668268
Evaluating classifier
Mean Precision Score for Testing on Epoch 20 is 0.3063916997884528
Starting epoch number 21
Loss for Training on Epoch 21 is 0.18837730586528778
Starting epoch number 22
Loss for Training on Epoch 22 is 0.1886983960866928
Starting epoch number 23
```

```
Loss for Training on Epoch 23 is 0.1874159276485443
Starting epoch number 24
Loss for Training on Epoch 24 is 0.18587124347686768
Starting epoch number 25
Loss for Training on Epoch 25 is 0.18422415852546692
Starting epoch number 26
Loss for Training on Epoch 26 is 0.18525439500808716
Starting epoch number 27
Loss for Training on Epoch 27 is 0.18381570279598236
Starting epoch number 28
Loss for Training on Epoch 28 is 0.18336907029151917
Starting epoch number 29
Loss for Training on Epoch 29 is 0.1824934333562851
Starting epoch number 30
Loss for Training on Epoch 30 is 0.18088246881961823
-------  Class: aeroplane        AP:   0.5488  -------
-------  Class: bicycle          AP:   0.3398  -------
-------  Class: bird             AP:   0.2484  -------
-------  Class: boat             AP:   0.2964  -------
-------  Class: bottle           AP:   0.1839  -------
-------  Class: bus              AP:   0.2947  -------
-------  Class: car              AP:   0.5138  -------
-------  Class: cat              AP:   0.2869  -------
-------  Class: chair            AP:   0.4420  -------
-------  Class: cow              AP:   0.1466  -------
-------  Class: diningtable      AP:   0.3286  -------
-------  Class: dog              AP:   0.2634  -------
-------  Class: horse            AP:   0.4859  -------
-------  Class: motorbike        AP:   0.3242  -------
-------  Class: person           AP:   0.7371  -------
-------  Class: pottedplant      AP:   0.1330  -------
-------  Class: sheep            AP:   0.1471  -------
-------  Class: sofa             AP:   0.2714  -------
-------  Class: train            AP:   0.4618  -------
-------  Class: tvmonitor        AP:   0.2661  -------
mAP: 0.3360
Avg loss: 0.18682698098074393
Evaluating classifier
Mean Precision Score for Testing on Epoch 30 is 0.33599328305455434
Starting epoch number 31
Loss for Training on Epoch 31 is 0.18006978929042816
Starting epoch number 32
Loss for Training on Epoch 32 is 0.17933622002601624
Starting epoch number 33
Loss for Training on Epoch 33 is 0.17790988087654114
Starting epoch number 34
Loss for Training on Epoch 34 is 0.17928354442119598
Starting epoch number 35
```

```
Loss for Training on Epoch 35 is 0.17592696845531464
Starting epoch number 36
Loss for Training on Epoch 36 is 0.1749102920293808
Starting epoch number 37
Loss for Training on Epoch 37 is 0.17453575134277344
Starting epoch number 38
Loss for Training on Epoch 38 is 0.17624682188034058
Starting epoch number 39
Loss for Training on Epoch 39 is 0.17257605493068695
Starting epoch number 40
Loss for Training on Epoch 40 is 0.1717541217803955
-------  Class: aeroplane        AP:   0.5931  -------
-------  Class: bicycle          AP:   0.3361  -------
-------  Class: bird             AP:   0.2410  -------
-------  Class: boat             AP:   0.4022  -------
-------  Class: bottle           AP:   0.1734  -------
-------  Class: bus              AP:   0.2918  -------
-------  Class: car              AP:   0.5138  -------
-------  Class: cat              AP:   0.3311  -------
-------  Class: chair            AP:   0.4496  -------
-------  Class: cow              AP:   0.1711  -------
-------  Class: diningtable      AP:   0.3157  -------
-------  Class: dog              AP:   0.2788  -------
-------  Class: horse            AP:   0.5218  -------
-------  Class: motorbike        AP:   0.3355  -------
-------  Class: person           AP:   0.7376  -------
-------  Class: pottedplant      AP:   0.1856  -------
-------  Class: sheep            AP:   0.1341  -------
-------  Class: sofa             AP:   0.2892  -------
-------  Class: train            AP:   0.4917  -------
-------  Class: tvmonitor        AP:   0.3260  -------
mAP: 0.3559
Avg loss: 0.1861154686110428
Evaluating classifier
Mean Precision Score for Testing on Epoch 40 is 0.35594963172840094
Starting epoch number 41
Loss for Training on Epoch 41 is 0.17228543758392334
Starting epoch number 42
Loss for Training on Epoch 42 is 0.17077521979808807
Starting epoch number 43
Loss for Training on Epoch 43 is 0.1721191108226776
Starting epoch number 44
Loss for Training on Epoch 44 is 0.1697174310684204
Starting epoch number 45
Loss for Training on Epoch 45 is 0.16867704689502716
Starting epoch number 46
Loss for Training on Epoch 46 is 0.16818712651729584
Starting epoch number 47
```

```
Loss for Training on Epoch 47 is 0.16687549650669098
Starting epoch number 48
Loss for Training on Epoch 48 is 0.16720540821552277
Starting epoch number 49
Loss for Training on Epoch 49 is 0.16621457040309906
Starting epoch number 50
Loss for Training on Epoch 50 is 0.16438904404640198
-------  Class: aeroplane        AP:   0.6167  -------
-------  Class: bicycle          AP:   0.3641  -------
-------  Class: bird             AP:   0.2713  -------
-------  Class: boat             AP:   0.4327  -------
-------  Class: bottle           AP:   0.1845  -------
-------  Class: bus              AP:   0.2814  -------
-------  Class: car              AP:   0.5490  -------
-------  Class: cat              AP:   0.3325  -------
-------  Class: chair            AP:   0.4602  -------
-------  Class: cow              AP:   0.1514  -------
-------  Class: diningtable      AP:   0.3394  -------
-------  Class: dog              AP:   0.2522  -------
-------  Class: horse            AP:   0.5228  -------
-------  Class: motorbike        AP:   0.4040  -------
-------  Class: person           AP:   0.7587  -------
-------  Class: pottedplant      AP:   0.1732  -------
-------  Class: sheep            AP:   0.1400  -------
-------  Class: sofa             AP:   0.3221  -------
-------  Class: train            AP:   0.5151  -------
-------  Class: tvmonitor        AP:   0.3710  -------
mAP: 0.3721
Avg loss: 0.1901857066320708
Evaluating classifier
Mean Precision Score for Testing on Epoch 50 is 0.37212214182769743
Starting epoch number 51
Loss for Training on Epoch 51 is 0.16517673432826996
Starting epoch number 52
Loss for Training on Epoch 52 is 0.16474226117134094
Starting epoch number 53
Loss for Training on Epoch 53 is 0.16447585821151733
Starting epoch number 54
Loss for Training on Epoch 54 is 0.16405938565731049
Starting epoch number 55
Loss for Training on Epoch 55 is 0.16418874263763428
Starting epoch number 56
Loss for Training on Epoch 56 is 0.16282887756824493
Starting epoch number 57
Loss for Training on Epoch 57 is 0.16036149859428406
Starting epoch number 58
Loss for Training on Epoch 58 is 0.16182339191436768
Starting epoch number 59
```

```
Loss for Training on Epoch 59 is 0.1627502739429474
Starting epoch number 60
Loss for Training on Epoch 60 is 0.16033555567264557
-------  Class: aeroplane        AP:   0.6247  -------
-------  Class: bicycle          AP:   0.3377  -------
-------  Class: bird             AP:   0.2804  -------
-------  Class: boat             AP:   0.4279  -------
-------  Class: bottle           AP:   0.1788  -------
-------  Class: bus              AP:   0.2344  -------
-------  Class: car              AP:   0.5532  -------
-------  Class: cat              AP:   0.3557  -------
-------  Class: chair            AP:   0.4526  -------
-------  Class: cow              AP:   0.1790  -------
-------  Class: diningtable      AP:   0.3601  -------
-------  Class: dog              AP:   0.2977  -------
-------  Class: horse            AP:   0.5145  -------
-------  Class: motorbike        AP:   0.3800  -------
-------  Class: person           AP:   0.7659  -------
-------  Class: pottedplant      AP:   0.1648  -------
-------  Class: sheep            AP:   0.1415  -------
-------  Class: sofa             AP:   0.2939  -------
-------  Class: train            AP:   0.5116  -------
-------  Class: tvmonitor        AP:   0.3515  -------
mAP: 0.3703
Avg loss: 0.19313905910547985
Evaluating classifier
Mean Precision Score for Testing on Epoch 60 is 0.37029857652495934
Starting epoch number 61
Loss for Training on Epoch 61 is 0.15794581174850464
Starting epoch number 62
Loss for Training on Epoch 62 is 0.1577681005001068
Starting epoch number 63
Loss for Training on Epoch 63 is 0.15923959016799927
Starting epoch number 64
Loss for Training on Epoch 64 is 0.15841718018054962
Starting epoch number 65
Loss for Training on Epoch 65 is 0.1565692126750946
Starting epoch number 66
Loss for Training on Epoch 66 is 0.1562134027481079
Starting epoch number 67
Loss for Training on Epoch 67 is 0.1577518731355667
Starting epoch number 68
Loss for Training on Epoch 68 is 0.1542491614818573
Starting epoch number 69
Loss for Training on Epoch 69 is 0.1532611846923828
Starting epoch number 70
Loss for Training on Epoch 70 is 0.15439757704734802
-------  Class: aeroplane        AP:   0.5961  -------
```

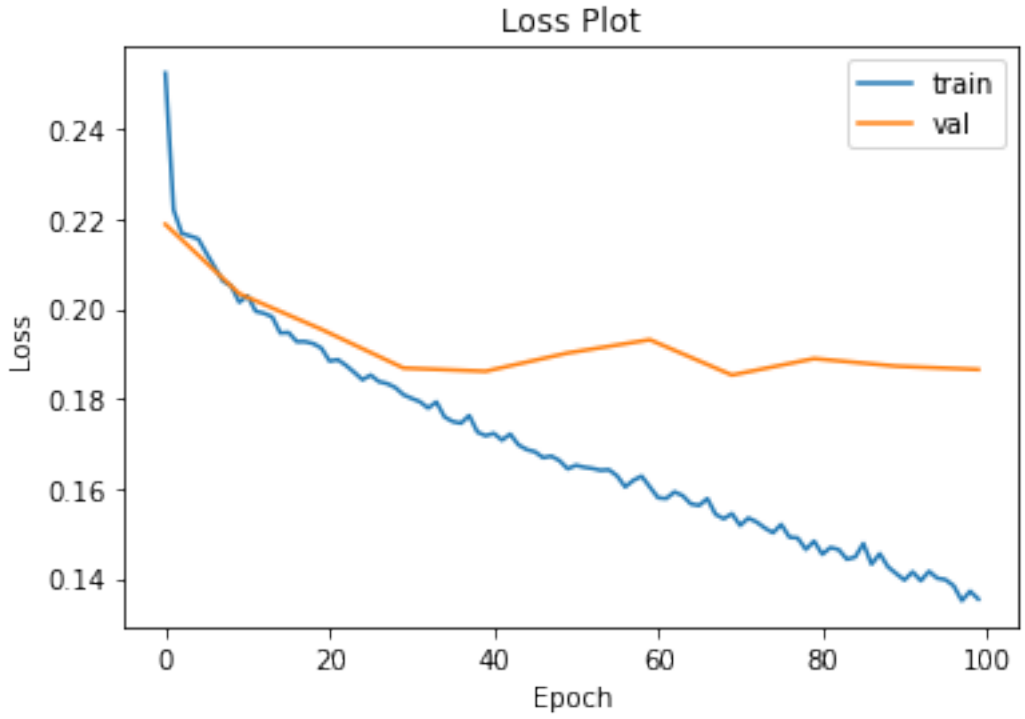
```
-------  Class: bicycle          AP:   0.3797  -------
-------  Class: bird             AP:   0.2843  -------
-------  Class: boat             AP:   0.3870  -------
-------  Class: bottle           AP:   0.1645  -------
-------  Class: bus              AP:   0.3119  -------
-------  Class: car              AP:   0.5848  -------
-------  Class: cat              AP:   0.3600  -------
-------  Class: chair            AP:   0.4761  -------
-------  Class: cow              AP:   0.1632  -------
-------  Class: diningtable      AP:   0.3686  -------
-------  Class: dog              AP:   0.2810  -------
-------  Class: horse            AP:   0.5427  -------
-------  Class: motorbike        AP:   0.3960  -------
-------  Class: person           AP:   0.7800  -------
-------  Class: pottedplant      AP:   0.2039  -------
-------  Class: sheep            AP:   0.1579  -------
-------  Class: sofa             AP:   0.2969  -------
-------  Class: train            AP:   0.5362  -------
-------  Class: tvmonitor        AP:   0.3702  -------
mAP: 0.3820
Avg loss: 0.1852684940296815
Evaluating classifier
Mean Precision Score for Testing on Epoch 70 is 0.3820450746110665
Starting epoch number 71
Loss for Training on Epoch 71 is 0.1517629623413086
Starting epoch number 72
Loss for Training on Epoch 72 is 0.15342122316360474
Starting epoch number 73
Loss for Training on Epoch 73 is 0.1525437831878662
Starting epoch number 74
Loss for Training on Epoch 74 is 0.15120182931423187
Starting epoch number 75
Loss for Training on Epoch 75 is 0.15013368427753448
Starting epoch number 76
Loss for Training on Epoch 76 is 0.15199534595012665
Starting epoch number 77
Loss for Training on Epoch 77 is 0.1491439938545227
Starting epoch number 78
Loss for Training on Epoch 78 is 0.1489977389574051
Starting epoch number 79
Loss for Training on Epoch 79 is 0.14642255008220673
Starting epoch number 80
Loss for Training on Epoch 80 is 0.1482785940170288
-------  Class: aeroplane        AP:   0.5935  -------
-------  Class: bicycle          AP:   0.4085  -------
-------  Class: bird             AP:   0.3653  -------
-------  Class: boat             AP:   0.4027  -------
-------  Class: bottle           AP:   0.1686  -------
```

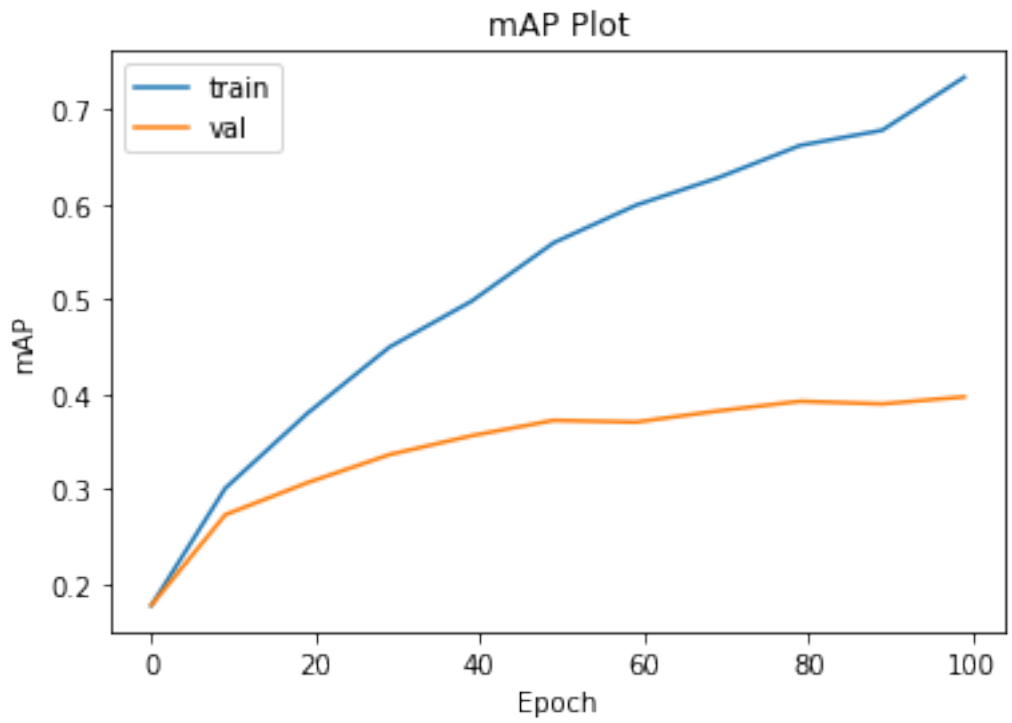
```
-------  Class: bus              AP:   0.2681  -------
-------  Class: car              AP:   0.5810  -------
-------  Class: cat              AP:   0.3923  -------
-------  Class: chair            AP:   0.4876  -------
-------  Class: cow              AP:   0.1831  -------
-------  Class: diningtable      AP:   0.3959  -------
-------  Class: dog              AP:   0.3038  -------
-------  Class: horse            AP:   0.5558  -------
-------  Class: motorbike        AP:   0.4012  -------
-------  Class: person           AP:   0.7682  -------
-------  Class: pottedplant      AP:   0.1844  -------
-------  Class: sheep            AP:   0.1449  -------
-------  Class: sofa             AP:   0.3103  -------
-------  Class: train            AP:   0.5701  -------
-------  Class: tvmonitor        AP:   0.3592  -------
mAP: 0.3922
Avg loss: 0.18893541544082154
Evaluating classifier
Mean Precision Score for Testing on Epoch 80 is 0.39223052427035665
Starting epoch number 81
Loss for Training on Epoch 81 is 0.1453533172607422
Starting epoch number 82
Loss for Training on Epoch 82 is 0.14686113595962524
Starting epoch number 83
Loss for Training on Epoch 83 is 0.146394282579422
Starting epoch number 84
Loss for Training on Epoch 84 is 0.14424927532672882
Starting epoch number 85
Loss for Training on Epoch 85 is 0.14471927285194397
Starting epoch number 86
Loss for Training on Epoch 86 is 0.14773347973823547
Starting epoch number 87
Loss for Training on Epoch 87 is 0.14313775300979614
Starting epoch number 88
Loss for Training on Epoch 88 is 0.1454884260892868
Starting epoch number 89
Loss for Training on Epoch 89 is 0.14254023134708405
Starting epoch number 90
Loss for Training on Epoch 90 is 0.14104636013507843
-------  Class: aeroplane        AP:   0.5696  -------
-------  Class: bicycle          AP:   0.3676  -------
-------  Class: bird             AP:   0.3354  -------
-------  Class: boat             AP:   0.4000  -------
-------  Class: bottle           AP:   0.1681  -------
-------  Class: bus              AP:   0.2775  -------
-------  Class: car              AP:   0.5948  -------
-------  Class: cat              AP:   0.3377  -------
-------  Class: chair            AP:   0.5086  -------
```

```
-------  Class: cow              AP:   0.1519  -------
-------  Class: diningtable      AP:   0.4239  -------
-------  Class: dog              AP:   0.2795  -------
-------  Class: horse            AP:   0.5590  -------
-------  Class: motorbike        AP:   0.4424  -------
-------  Class: person           AP:   0.7562  -------
-------  Class: pottedplant      AP:   0.2103  -------
-------  Class: sheep            AP:   0.1543  -------
-------  Class: sofa             AP:   0.3167  -------
-------  Class: train            AP:   0.5622  -------
-------  Class: tvmonitor        AP:   0.3728  -------
mAP: 0.3894
Avg loss: 0.18724965158686696
Evaluating classifier
Mean Precision Score for Testing on Epoch 90 is 0.3894266777695525
Starting epoch number 91
Loss for Training on Epoch 91 is 0.1396164745092392
Starting epoch number 92
Loss for Training on Epoch 92 is 0.14142097532749176
Starting epoch number 93
Loss for Training on Epoch 93 is 0.1394633650779724
Starting epoch number 94
Loss for Training on Epoch 94 is 0.1415458470582962
Starting epoch number 95
Loss for Training on Epoch 95 is 0.14002040028572083
Starting epoch number 96
Loss for Training on Epoch 96 is 0.1397014856338501
Starting epoch number 97
Loss for Training on Epoch 97 is 0.13832907378673553
Starting epoch number 98
Loss for Training on Epoch 98 is 0.13502049446105957
Starting epoch number 99
Loss for Training on Epoch 99 is 0.13710856437683105
Starting epoch number 100
Loss for Training on Epoch 100 is 0.13538771867752075
-------  Class: aeroplane        AP:   0.6567  -------
-------  Class: bicycle          AP:   0.3431  -------
-------  Class: bird             AP:   0.3520  -------
-------  Class: boat             AP:   0.3922  -------
-------  Class: bottle           AP:   0.1553  -------
-------  Class: bus              AP:   0.2816  -------
-------  Class: car              AP:   0.5942  -------
-------  Class: cat              AP:   0.3636  -------
-------  Class: chair            AP:   0.5044  -------
-------  Class: cow              AP:   0.1616  -------
-------  Class: diningtable      AP:   0.3842  -------
-------  Class: dog              AP:   0.3032  -------
-------  Class: horse            AP:   0.5407  -------
```

```
-------  Class: motorbike        AP:   0.4670  -------
-------  Class: person           AP:   0.7757  -------
-------  Class: pottedplant      AP:   0.2085  -------
-------  Class: sheep            AP:   0.1718  -------
-------  Class: sofa             AP:   0.3397  -------
-------  Class: train            AP:   0.5774  -------
-------  Class: tvmonitor        AP:   0.3660  -------
mAP: 0.3969
Avg loss: 0.18650758806690276
Evaluating classifier
Mean Precision Score for Testing on Epoch 100 is 0.3969351084990019
```

[ ]:
```
plot_losses(train_losses, val_losses, test_frequency, num_epochs)
plot_mAP(train_mAPs, val_mAPs, test_frequency, num_epochs)
```





[ ]:
```
mAP_test, test_loss, test_aps = test_classifier(test_loader, classifier,␣
 ↪criterion)
print(mAP_test)
```

```
-------  Class: aeroplane        AP:   0.6255  -------
-------  Class: bicycle          AP:   0.3513  -------
-------  Class: bird             AP:   0.3433  -------
-------  Class: boat             AP:   0.3956  -------
-------  Class: bottle           AP:   0.1298  -------
-------  Class: bus              AP:   0.3074  -------
-------  Class: car              AP:   0.5965  -------
-------  Class: cat              AP:   0.3433  -------
-------  Class: chair            AP:   0.4206  -------
-------  Class: cow              AP:   0.1800  -------
-------  Class: diningtable      AP:   0.2417  -------
-------  Class: dog              AP:   0.2631  -------
-------  Class: horse            AP:   0.6800  -------
-------  Class: motorbike        AP:   0.4702  -------
-------  Class: person           AP:   0.7757  -------
-------  Class: pottedplant      AP:   0.2270  -------
-------  Class: sheep            AP:   0.2291  -------
-------  Class: sofa             AP:   0.3241  -------
-------  Class: train            AP:   0.5123  -------
-------  Class: tvmonitor        AP:   0.3415  -------
```

```
mAP: 0.3879
Avg loss: 0.187670374424347
0.3879064461391576
```

[ ]:
```
torch.save(classifier.state_dict(), './voc_my_best_classifier.pth')
output_submission_csv('my_solution.csv', test_aps)
```