

## part1b

April 5, 2022

# 1 Assignment 3 Part 1: Developing Your Own Classifier

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

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 SimpleClassifier, Classifier#, AlexNet
from voc_dataloader import VocDataset, VOC_CLASSES

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

## 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.

```
[2]: def train_classifier(train_loader, classifier, criterion, optimizer):
    classifier.train()
    loss_ = 0.0
```

```

losses = []
for i, (images, labels) in enumerate(train_loader):
    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()

```

```

[3]: 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):
            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

```

```

[4]: 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()

```

```

[5]: 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 AlexNet 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.

```
[6]: 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.ToTensor(),
    normalize
])

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

ds_train = VocDataset('VOCdevkit_2007/VOC2007/', 'train', train_transform)
ds_val = VocDataset('VOCdevkit_2007/VOC2007/', 'val', test_transform)
ds_test = VocDataset('VOCdevkit_2007/VOC2007test/', 'test', test_transform)

```

/home/venkatasainarayana/voc\_data\_loader.py:137: VisibleDeprecationWarning: Creating an ndarray from ragged nested sequences (which is a list-or-tuple of lists-or-tuples-or ndarrays with different lengths or shapes) is deprecated. If you meant to do this, you must specify 'dtype=object' when creating the ndarray  
 np.array(box\_indices),

```

[7]: num_epochs = 100
    test_frequency = 5
    batch_size = 64

    train_loader = torch.utils.data.DataLoader(dataset=ds_train,
                                                batch_size=batch_size,
                                                shuffle=True,
                                                num_workers=1, drop_last=True)

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

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

```

```

[8]: # TODO: Run your own classifier here
    classifier = Classifier().to(device)

    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 0.3261222839355469

-----	Class: aeroplane	AP:	0.0466	-----
-----	Class: bicycle	AP:	0.0915	-----
-----	Class: bird	AP:	0.0646	-----
-----	Class: boat	AP:	0.0364	-----
-----	Class: bottle	AP:	0.0511	-----
-----	Class: bus	AP:	0.0664	-----
-----	Class: car	AP:	0.2079	-----
-----	Class: cat	AP:	0.0514	-----
-----	Class: chair	AP:	0.1117	-----
-----	Class: cow	AP:	0.0336	-----
-----	Class: diningtable	AP:	0.0595	-----
-----	Class: dog	AP:	0.0708	-----
-----	Class: horse	AP:	0.0894	-----
-----	Class: motorbike	AP:	0.0946	-----
-----	Class: person	AP:	0.4866	-----
-----	Class: pottedplant	AP:	0.0758	-----
-----	Class: sheep	AP:	0.0180	-----
-----	Class: sofa	AP:	0.0562	-----
-----	Class: train	AP:	0.0974	-----
-----	Class: tvmonitor	AP:	0.0462	-----

mAP: 0.0928

Avg loss: 0.23846278626185197

Evaluating classifier

Mean Precision Score for Testing on Epoch 1 is 0.09278997086110669

Starting epoch number 2

Loss for Training on Epoch 2 is 0.242740198969841

Starting epoch number 3

Loss for Training on Epoch 3 is 0.2361624836921692

Starting epoch number 4

Loss for Training on Epoch 4 is 0.23168963193893433

Starting epoch number 5

Loss for Training on Epoch 5 is 0.22635142505168915

-----	Class: aeroplane	AP:	0.4495	-----
-----	Class: bicycle	AP:	0.1412	-----
-----	Class: bird	AP:	0.1332	-----
-----	Class: boat	AP:	0.1803	-----
-----	Class: bottle	AP:	0.1079	-----
-----	Class: bus	AP:	0.1456	-----
-----	Class: car	AP:	0.3116	-----

-----	Class: cat	AP:	0.2197	-----
-----	Class: chair	AP:	0.2490	-----
-----	Class: cow	AP:	0.0400	-----
-----	Class: diningtable	AP:	0.2210	-----
-----	Class: dog	AP:	0.1724	-----
-----	Class: horse	AP:	0.1256	-----
-----	Class: motorbike	AP:	0.1600	-----
-----	Class: person	AP:	0.5611	-----
-----	Class: pottedplant	AP:	0.0998	-----
-----	Class: sheep	AP:	0.0552	-----
-----	Class: sofa	AP:	0.1836	-----
-----	Class: train	AP:	0.2046	-----
-----	Class: tvmonitor	AP:	0.0938	-----

mAP: 0.1928

Avg loss: 0.21703190604845682

Evaluating classifier

Mean Precision Score for Testing on Epoch 5 is 0.19275055815766448

Starting epoch number 6

Loss for Training on Epoch 6 is 0.2200540006160736

Starting epoch number 7

Loss for Training on Epoch 7 is 0.21606682240962982

Starting epoch number 8

Loss for Training on Epoch 8 is 0.21209491789340973

Starting epoch number 9

Loss for Training on Epoch 9 is 0.2071833312511444

Starting epoch number 10

Loss for Training on Epoch 10 is 0.20251953601837158

-----	Class: aeroplane	AP:	0.4867	-----
-----	Class: bicycle	AP:	0.2225	-----
-----	Class: bird	AP:	0.1724	-----
-----	Class: boat	AP:	0.1825	-----
-----	Class: bottle	AP:	0.1187	-----
-----	Class: bus	AP:	0.1640	-----
-----	Class: car	AP:	0.4225	-----
-----	Class: cat	AP:	0.2616	-----
-----	Class: chair	AP:	0.3098	-----
-----	Class: cow	AP:	0.0714	-----
-----	Class: diningtable	AP:	0.2230	-----
-----	Class: dog	AP:	0.1927	-----
-----	Class: horse	AP:	0.3213	-----
-----	Class: motorbike	AP:	0.1906	-----
-----	Class: person	AP:	0.6303	-----
-----	Class: pottedplant	AP:	0.1188	-----
-----	Class: sheep	AP:	0.1308	-----
-----	Class: sofa	AP:	0.2008	-----
-----	Class: train	AP:	0.2853	-----
-----	Class: tvmonitor	AP:	0.1276	-----

mAP: 0.2417

Avg loss: 0.20228115717569986  
 Evaluating classifier  
 Mean Precision Score for Testing on Epoch 10 is 0.24165263755238606  
 Starting epoch number 11  
 Loss for Training on Epoch 11 is 0.19934067130088806  
 Starting epoch number 12  
 Loss for Training on Epoch 12 is 0.19624918699264526  
 Starting epoch number 13  
 Loss for Training on Epoch 13 is 0.1937280148267746  
 Starting epoch number 14  
 Loss for Training on Epoch 14 is 0.18954530358314514  
 Starting epoch number 15  
 Loss for Training on Epoch 15 is 0.18569821119308472  

-----	Class: aeroplane	AP: 0.5060	-----
-----	Class: bicycle	AP: 0.2147	-----
-----	Class: bird	AP: 0.1736	-----
-----	Class: boat	AP: 0.2095	-----
-----	Class: bottle	AP: 0.1282	-----
-----	Class: bus	AP: 0.1360	-----
-----	Class: car	AP: 0.4449	-----
-----	Class: cat	AP: 0.3054	-----
-----	Class: chair	AP: 0.3790	-----
-----	Class: cow	AP: 0.0985	-----
-----	Class: diningtable	AP: 0.2652	-----
-----	Class: dog	AP: 0.2231	-----
-----	Class: horse	AP: 0.3414	-----
-----	Class: motorbike	AP: 0.2164	-----
-----	Class: person	AP: 0.6395	-----
-----	Class: pottedplant	AP: 0.1485	-----
-----	Class: sheep	AP: 0.1588	-----
-----	Class: sofa	AP: 0.2389	-----
-----	Class: train	AP: 0.2526	-----
-----	Class: tvmonitor	AP: 0.2147	-----

 mAP: 0.2647  
 Avg loss: 0.19988374488475996  
 Evaluating classifier  
 Mean Precision Score for Testing on Epoch 15 is 0.2647458324501704  
 Starting epoch number 16  
 Loss for Training on Epoch 16 is 0.18193870782852173  
 Starting epoch number 17  
 Loss for Training on Epoch 17 is 0.17829957604408264  
 Starting epoch number 18  
 Loss for Training on Epoch 18 is 0.1749361753463745  
 Starting epoch number 19  
 Loss for Training on Epoch 19 is 0.1722014993429184  
 Starting epoch number 20  
 Loss for Training on Epoch 20 is 0.1679358184337616  

-----	Class: aeroplane	AP: 0.5471	-----
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-----	Class: bicycle	AP:	0.2842	-----
-----	Class: bird	AP:	0.1900	-----
-----	Class: boat	AP:	0.3068	-----
-----	Class: bottle	AP:	0.1232	-----
-----	Class: bus	AP:	0.1908	-----
-----	Class: car	AP:	0.5042	-----
-----	Class: cat	AP:	0.3561	-----
-----	Class: chair	AP:	0.4095	-----
-----	Class: cow	AP:	0.1197	-----
-----	Class: diningtable	AP:	0.2699	-----
-----	Class: dog	AP:	0.2439	-----
-----	Class: horse	AP:	0.4456	-----
-----	Class: motorbike	AP:	0.2325	-----
-----	Class: person	AP:	0.6952	-----
-----	Class: pottedplant	AP:	0.1400	-----
-----	Class: sheep	AP:	0.1728	-----
-----	Class: sofa	AP:	0.2591	-----
-----	Class: train	AP:	0.3761	-----
-----	Class: tvmonitor	AP:	0.2568	-----

mAP: 0.3062

Avg loss: 0.19186551639666924

Evaluating classifier

Mean Precision Score for Testing on Epoch 20 is 0.3061748916493948

Starting epoch number 21

Loss for Training on Epoch 21 is 0.16496416926383972

Starting epoch number 22

Loss for Training on Epoch 22 is 0.16020429134368896

Starting epoch number 23

Loss for Training on Epoch 23 is 0.15520164370536804

Starting epoch number 24

Loss for Training on Epoch 24 is 0.15156738460063934

Starting epoch number 25

Loss for Training on Epoch 25 is 0.1470477432012558

-----	Class: aeroplane	AP:	0.5721	-----
-----	Class: bicycle	AP:	0.2817	-----
-----	Class: bird	AP:	0.2065	-----
-----	Class: boat	AP:	0.3317	-----
-----	Class: bottle	AP:	0.1403	-----
-----	Class: bus	AP:	0.2061	-----
-----	Class: car	AP:	0.5375	-----
-----	Class: cat	AP:	0.3681	-----
-----	Class: chair	AP:	0.4121	-----
-----	Class: cow	AP:	0.1237	-----
-----	Class: diningtable	AP:	0.3024	-----
-----	Class: dog	AP:	0.2704	-----
-----	Class: horse	AP:	0.4514	-----
-----	Class: motorbike	AP:	0.3269	-----
-----	Class: person	AP:	0.7070	-----

```

----- Class: pottedplant      AP:  0.1649 -----
----- Class: sheep           AP:  0.1914 -----
----- Class: sofa            AP:  0.2498 -----
----- Class: train           AP:  0.4497 -----
----- Class: tvmonitor       AP:  0.2245 -----
mAP: 0.3259
Avg loss: 0.1895951529343923
Evaluating classifier
Mean Precision Score for Testing on Epoch 25 is 0.32590063065017894
Starting epoch number 26
Loss for Training on Epoch 26 is 0.14263027906417847
Starting epoch number 27
Loss for Training on Epoch 27 is 0.1370270997285843
Starting epoch number 28
Loss for Training on Epoch 28 is 0.13318781554698944
Starting epoch number 29
Loss for Training on Epoch 29 is 0.12753036618232727
Starting epoch number 30
Loss for Training on Epoch 30 is 0.12153816223144531
----- Class: aeroplane      AP:  0.5993 -----
----- Class: bicycle       AP:  0.3394 -----
----- Class: bird          AP:  0.2107 -----
----- Class: boat          AP:  0.3888 -----
----- Class: bottle        AP:  0.1236 -----
----- Class: bus           AP:  0.2707 -----
----- Class: car           AP:  0.5421 -----
----- Class: cat           AP:  0.3933 -----
----- Class: chair         AP:  0.4201 -----
----- Class: cow           AP:  0.1395 -----
----- Class: diningtable   AP:  0.2938 -----
----- Class: dog           AP:  0.2780 -----
----- Class: horse         AP:  0.4819 -----
----- Class: motorbike     AP:  0.3180 -----
----- Class: person        AP:  0.7174 -----
----- Class: pottedplant   AP:  0.1506 -----
----- Class: sheep         AP:  0.1588 -----
----- Class: sofa          AP:  0.2723 -----
----- Class: train         AP:  0.5074 -----
----- Class: tvmonitor     AP:  0.2861 -----
mAP: 0.3446
Avg loss: 0.19432394206523895
Evaluating classifier
Mean Precision Score for Testing on Epoch 30 is 0.3445747904797344
Starting epoch number 31
Loss for Training on Epoch 31 is 0.1156056746840477
Starting epoch number 32
Loss for Training on Epoch 32 is 0.11056983470916748
Starting epoch number 33

```

Loss for Training on Epoch 33 is 0.10504446178674698

Starting epoch number 34

Loss for Training on Epoch 34 is 0.10153231024742126

Starting epoch number 35

Loss for Training on Epoch 35 is 0.09717424213886261

-----	Class: aeroplane	AP: 0.5921	-----
-----	Class: bicycle	AP: 0.3279	-----
-----	Class: bird	AP: 0.2021	-----
-----	Class: boat	AP: 0.4391	-----
-----	Class: bottle	AP: 0.1465	-----
-----	Class: bus	AP: 0.2571	-----
-----	Class: car	AP: 0.5319	-----
-----	Class: cat	AP: 0.4072	-----
-----	Class: chair	AP: 0.4258	-----
-----	Class: cow	AP: 0.1464	-----
-----	Class: diningtable	AP: 0.3333	-----
-----	Class: dog	AP: 0.2812	-----
-----	Class: horse	AP: 0.4591	-----
-----	Class: motorbike	AP: 0.3443	-----
-----	Class: person	AP: 0.6959	-----
-----	Class: pottedplant	AP: 0.1577	-----
-----	Class: sheep	AP: 0.1830	-----
-----	Class: sofa	AP: 0.2636	-----
-----	Class: train	AP: 0.5009	-----
-----	Class: tvmonitor	AP: 0.3146	-----

mAP: 0.3505

Avg loss: 0.1988640492543196

Evaluating classifier

Mean Precision Score for Testing on Epoch 35 is 0.3504844842728266

Starting epoch number 36

Loss for Training on Epoch 36 is 0.09085910767316818

Starting epoch number 37

Loss for Training on Epoch 37 is 0.08825396746397018

Starting epoch number 38

Loss for Training on Epoch 38 is 0.08402431011199951

Starting epoch number 39

Loss for Training on Epoch 39 is 0.07919809222221375

Starting epoch number 40

Loss for Training on Epoch 40 is 0.07482399046421051

-----	Class: aeroplane	AP: 0.6137	-----
-----	Class: bicycle	AP: 0.3496	-----
-----	Class: bird	AP: 0.2480	-----
-----	Class: boat	AP: 0.4470	-----
-----	Class: bottle	AP: 0.1449	-----
-----	Class: bus	AP: 0.2890	-----
-----	Class: car	AP: 0.5201	-----
-----	Class: cat	AP: 0.3655	-----
-----	Class: chair	AP: 0.4112	-----

-----	Class: cow	AP:	0.1359	-----
-----	Class: diningtable	AP:	0.3236	-----
-----	Class: dog	AP:	0.2890	-----
-----	Class: horse	AP:	0.4667	-----
-----	Class: motorbike	AP:	0.3943	-----
-----	Class: person	AP:	0.7232	-----
-----	Class: pottedplant	AP:	0.1880	-----
-----	Class: sheep	AP:	0.2174	-----
-----	Class: sofa	AP:	0.2525	-----
-----	Class: train	AP:	0.4699	-----
-----	Class: tvmonitor	AP:	0.2707	-----

mAP: 0.3560

Avg loss: 0.20697717024729803

Evaluating classifier

Mean Precision Score for Testing on Epoch 40 is 0.35601497954192607

Starting epoch number 41

Loss for Training on Epoch 41 is 0.07047977298498154

Starting epoch number 42

Loss for Training on Epoch 42 is 0.06453641504049301

Starting epoch number 43

Loss for Training on Epoch 43 is 0.060409002006053925

Starting epoch number 44

Loss for Training on Epoch 44 is 0.05565370246767998

Starting epoch number 45

Loss for Training on Epoch 45 is 0.054079312831163406

-----	Class: aeroplane	AP:	0.6103	-----
-----	Class: bicycle	AP:	0.3704	-----
-----	Class: bird	AP:	0.1974	-----
-----	Class: boat	AP:	0.4567	-----
-----	Class: bottle	AP:	0.1428	-----
-----	Class: bus	AP:	0.2658	-----
-----	Class: car	AP:	0.5441	-----
-----	Class: cat	AP:	0.3804	-----
-----	Class: chair	AP:	0.4045	-----
-----	Class: cow	AP:	0.1258	-----
-----	Class: diningtable	AP:	0.3277	-----
-----	Class: dog	AP:	0.2929	-----
-----	Class: horse	AP:	0.4812	-----
-----	Class: motorbike	AP:	0.4048	-----
-----	Class: person	AP:	0.7239	-----
-----	Class: pottedplant	AP:	0.1689	-----
-----	Class: sheep	AP:	0.1808	-----
-----	Class: sofa	AP:	0.2772	-----
-----	Class: train	AP:	0.4979	-----
-----	Class: tvmonitor	AP:	0.2458	-----

mAP: 0.3550

Avg loss: 0.22880576589168647

Evaluating classifier

Mean Precision Score for Testing on Epoch 45 is 0.35495960579132746

Starting epoch number 46

Loss for Training on Epoch 46 is 0.0509827621281147

Starting epoch number 47

Loss for Training on Epoch 47 is 0.05184018239378929

Starting epoch number 48

Loss for Training on Epoch 48 is 0.04441952332854271

Starting epoch number 49

Loss for Training on Epoch 49 is 0.042003609240055084

Starting epoch number 50

Loss for Training on Epoch 50 is 0.039009977132081985

----- Class: aeroplane	AP: 0.6104	-----
----- Class: bicycle	AP: 0.3405	-----
----- Class: bird	AP: 0.2240	-----
----- Class: boat	AP: 0.4351	-----
----- Class: bottle	AP: 0.1450	-----
----- Class: bus	AP: 0.2538	-----
----- Class: car	AP: 0.4906	-----
----- Class: cat	AP: 0.3172	-----
----- Class: chair	AP: 0.3782	-----
----- Class: cow	AP: 0.1292	-----
----- Class: diningtable	AP: 0.3127	-----
----- Class: dog	AP: 0.2925	-----
----- Class: horse	AP: 0.4737	-----
----- Class: motorbike	AP: 0.4056	-----
----- Class: person	AP: 0.6902	-----
----- Class: pottedplant	AP: 0.1810	-----
----- Class: sheep	AP: 0.1952	-----
----- Class: sofa	AP: 0.2401	-----
----- Class: train	AP: 0.5210	-----
----- Class: tvmonitor	AP: 0.2590	-----

mAP: 0.3447

Avg loss: 0.23552966652772364

Evaluating classifier

Mean Precision Score for Testing on Epoch 50 is 0.34474159025673917

Starting epoch number 51

Loss for Training on Epoch 51 is 0.03800530731678009

Starting epoch number 52

Loss for Training on Epoch 52 is 0.03519938141107559

Starting epoch number 53

Loss for Training on Epoch 53 is 0.03200111165642738

Starting epoch number 54

Loss for Training on Epoch 54 is 0.031172852963209152

Starting epoch number 55

Loss for Training on Epoch 55 is 0.028384264558553696

----- Class: aeroplane	AP: 0.6170	-----
----- Class: bicycle	AP: 0.3724	-----
----- Class: bird	AP: 0.2168	-----

-----	Class: boat	AP: 0.4292	-----
-----	Class: bottle	AP: 0.1099	-----
-----	Class: bus	AP: 0.2339	-----
-----	Class: car	AP: 0.4943	-----
-----	Class: cat	AP: 0.3125	-----
-----	Class: chair	AP: 0.3906	-----
-----	Class: cow	AP: 0.1111	-----
-----	Class: diningtable	AP: 0.2870	-----
-----	Class: dog	AP: 0.2370	-----
-----	Class: horse	AP: 0.4970	-----
-----	Class: motorbike	AP: 0.3664	-----
-----	Class: person	AP: 0.7071	-----
-----	Class: pottedplant	AP: 0.1827	-----
-----	Class: sheep	AP: 0.1826	-----
-----	Class: sofa	AP: 0.2543	-----
-----	Class: train	AP: 0.5180	-----
-----	Class: tvmonitor	AP: 0.2236	-----

mAP: 0.3372

Avg loss: 0.2696652037975116

Evaluating classifier

Mean Precision Score for Testing on Epoch 55 is 0.3371659696584664

Starting epoch number 56

Loss for Training on Epoch 56 is 0.02765483781695366

Starting epoch number 57

Loss for Training on Epoch 57 is 0.0251813642680645

Starting epoch number 58

Loss for Training on Epoch 58 is 0.023639574646949768

Starting epoch number 59

Loss for Training on Epoch 59 is 0.021762428805232048

Starting epoch number 60

Loss for Training on Epoch 60 is 0.019969958811998367

-----	Class: aeroplane	AP: 0.6278	-----
-----	Class: bicycle	AP: 0.3654	-----
-----	Class: bird	AP: 0.2066	-----
-----	Class: boat	AP: 0.4350	-----
-----	Class: bottle	AP: 0.1156	-----
-----	Class: bus	AP: 0.1986	-----
-----	Class: car	AP: 0.5152	-----
-----	Class: cat	AP: 0.3339	-----
-----	Class: chair	AP: 0.3847	-----
-----	Class: cow	AP: 0.1172	-----
-----	Class: diningtable	AP: 0.3182	-----
-----	Class: dog	AP: 0.2691	-----
-----	Class: horse	AP: 0.4782	-----
-----	Class: motorbike	AP: 0.3675	-----
-----	Class: person	AP: 0.6914	-----
-----	Class: pottedplant	AP: 0.1303	-----
-----	Class: sheep	AP: 0.1935	-----

```

----- Class: sofa          AP:  0.2621 -----
----- Class: train         AP:  0.5047 -----
----- Class: tvmonitor     AP:  0.2147 -----
mAP: 0.3365
Avg loss: 0.2834214327427057
Evaluating classifier
Mean Precision Score for Testing on Epoch 60 is 0.336485153724333
Starting epoch number 61
Loss for Training on Epoch 61 is 0.019220596179366112
Starting epoch number 62
Loss for Training on Epoch 62 is 0.018785562366247177
Starting epoch number 63
Loss for Training on Epoch 63 is 0.017051685601472855
Starting epoch number 64
Loss for Training on Epoch 64 is 0.016073627397418022
Starting epoch number 65
Loss for Training on Epoch 65 is 0.015133521519601345
----- Class: aeroplane     AP:  0.6193 -----
----- Class: bicycle       AP:  0.3532 -----
----- Class: bird          AP:  0.2143 -----
----- Class: boat          AP:  0.4279 -----
----- Class: bottle        AP:  0.0967 -----
----- Class: bus           AP:  0.2267 -----
----- Class: car           AP:  0.5311 -----
----- Class: cat           AP:  0.3710 -----
----- Class: chair         AP:  0.3764 -----
----- Class: cow           AP:  0.1180 -----
----- Class: diningtable   AP:  0.2687 -----
----- Class: dog           AP:  0.2660 -----
----- Class: horse         AP:  0.5035 -----
----- Class: motorbike     AP:  0.3927 -----
----- Class: person        AP:  0.7147 -----
----- Class: pottedplant    AP:  0.1510 -----
----- Class: sheep         AP:  0.1880 -----
----- Class: sofa          AP:  0.2390 -----
----- Class: train         AP:  0.5164 -----
----- Class: tvmonitor     AP:  0.2519 -----
mAP: 0.3413
Avg loss: 0.2934949890925334
Evaluating classifier
Mean Precision Score for Testing on Epoch 65 is 0.3413346999389678
Starting epoch number 66
Loss for Training on Epoch 66 is 0.014448856934905052
Starting epoch number 67
Loss for Training on Epoch 67 is 0.014003018848598003
Starting epoch number 68
Loss for Training on Epoch 68 is 0.013741343282163143
Starting epoch number 69

```

Loss for Training on Epoch 69 is 0.012412233278155327

Starting epoch number 70

Loss for Training on Epoch 70 is 0.01245160587131977

-----	Class: aeroplane	AP:	0.6280	-----
-----	Class: bicycle	AP:	0.3493	-----
-----	Class: bird	AP:	0.2175	-----
-----	Class: boat	AP:	0.4394	-----
-----	Class: bottle	AP:	0.1064	-----
-----	Class: bus	AP:	0.2582	-----
-----	Class: car	AP:	0.5112	-----
-----	Class: cat	AP:	0.3315	-----
-----	Class: chair	AP:	0.3889	-----
-----	Class: cow	AP:	0.1181	-----
-----	Class: diningtable	AP:	0.2882	-----
-----	Class: dog	AP:	0.2797	-----
-----	Class: horse	AP:	0.4812	-----
-----	Class: motorbike	AP:	0.4036	-----
-----	Class: person	AP:	0.7139	-----
-----	Class: pottedplant	AP:	0.1492	-----
-----	Class: sheep	AP:	0.1915	-----
-----	Class: sofa	AP:	0.2458	-----
-----	Class: train	AP:	0.5113	-----
-----	Class: tvmonitor	AP:	0.2505	-----

mAP: 0.3432

Avg loss: 0.29923890913144136

Evaluating classifier

Mean Precision Score for Testing on Epoch 70 is 0.343163431676048

Starting epoch number 71

Loss for Training on Epoch 71 is 0.011279970407485962

Starting epoch number 72

Loss for Training on Epoch 72 is 0.012354048900306225

Starting epoch number 73

Loss for Training on Epoch 73 is 0.011348461732268333

Starting epoch number 74

Loss for Training on Epoch 74 is 0.01155288890004158

Starting epoch number 75

Loss for Training on Epoch 75 is 0.009849588386714458

-----	Class: aeroplane	AP:	0.6294	-----
-----	Class: bicycle	AP:	0.3614	-----
-----	Class: bird	AP:	0.2162	-----
-----	Class: boat	AP:	0.4387	-----
-----	Class: bottle	AP:	0.1271	-----
-----	Class: bus	AP:	0.2423	-----
-----	Class: car	AP:	0.5141	-----
-----	Class: cat	AP:	0.3614	-----
-----	Class: chair	AP:	0.3873	-----
-----	Class: cow	AP:	0.1125	-----
-----	Class: diningtable	AP:	0.3079	-----



-----	Class: dog	AP:	0.2659	-----
-----	Class: horse	AP:	0.5009	-----
-----	Class: motorbike	AP:	0.3952	-----
-----	Class: person	AP:	0.7136	-----
-----	Class: pottedplant	AP:	0.1746	-----
-----	Class: sheep	AP:	0.1940	-----
-----	Class: sofa	AP:	0.2590	-----
-----	Class: train	AP:	0.5194	-----
-----	Class: tvmonitor	AP:	0.2507	-----

mAP: 0.3486

Avg loss: 0.2934356247767424

Evaluating classifier

Mean Precision Score for Testing on Epoch 75 is 0.34858847308859764

Starting epoch number 76

Loss for Training on Epoch 76 is 0.008819323033094406

Starting epoch number 77

Loss for Training on Epoch 77 is 0.008729231543838978

Starting epoch number 78

Loss for Training on Epoch 78 is 0.008703017607331276

Starting epoch number 79

Loss for Training on Epoch 79 is 0.009421891532838345

Starting epoch number 80

Loss for Training on Epoch 80 is 0.00755684869363904

-----	Class: aeroplane	AP:	0.6187	-----
-----	Class: bicycle	AP:	0.4025	-----
-----	Class: bird	AP:	0.2008	-----
-----	Class: boat	AP:	0.4211	-----
-----	Class: bottle	AP:	0.1148	-----
-----	Class: bus	AP:	0.2351	-----
-----	Class: car	AP:	0.5097	-----
-----	Class: cat	AP:	0.3328	-----
-----	Class: chair	AP:	0.3722	-----
-----	Class: cow	AP:	0.1043	-----
-----	Class: diningtable	AP:	0.3245	-----
-----	Class: dog	AP:	0.2841	-----
-----	Class: horse	AP:	0.4958	-----
-----	Class: motorbike	AP:	0.4212	-----
-----	Class: person	AP:	0.7124	-----
-----	Class: pottedplant	AP:	0.1789	-----
-----	Class: sheep	AP:	0.1907	-----
-----	Class: sofa	AP:	0.2484	-----
-----	Class: train	AP:	0.5097	-----
-----	Class: tvmonitor	AP:	0.2562	-----

mAP: 0.3467

Avg loss: 0.31131676336129505

Evaluating classifier

Mean Precision Score for Testing on Epoch 80 is 0.3466972876736467

Starting epoch number 81

Loss for Training on Epoch 81 is 0.007962847128510475  
 Starting epoch number 82  
 Loss for Training on Epoch 82 is 0.007868748158216476  
 Starting epoch number 83  
 Loss for Training on Epoch 83 is 0.007849828340113163  
 Starting epoch number 84  
 Loss for Training on Epoch 84 is 0.007137167267501354  
 Starting epoch number 85  
 Loss for Training on Epoch 85 is 0.006583154201507568  

-----	Class: aeroplane	AP:	0.6232	-----
-----	Class: bicycle	AP:	0.3686	-----
-----	Class: bird	AP:	0.1989	-----
-----	Class: boat	AP:	0.4192	-----
-----	Class: bottle	AP:	0.1132	-----
-----	Class: bus	AP:	0.2375	-----
-----	Class: car	AP:	0.5122	-----
-----	Class: cat	AP:	0.3357	-----
-----	Class: chair	AP:	0.3654	-----
-----	Class: cow	AP:	0.1046	-----
-----	Class: diningtable	AP:	0.3166	-----
-----	Class: dog	AP:	0.2656	-----
-----	Class: horse	AP:	0.4729	-----
-----	Class: motorbike	AP:	0.3910	-----
-----	Class: person	AP:	0.7157	-----
-----	Class: pottedplant	AP:	0.1640	-----
-----	Class: sheep	AP:	0.1912	-----
-----	Class: sofa	AP:	0.2443	-----
-----	Class: train	AP:	0.5304	-----
-----	Class: tvmonitor	AP:	0.2183	-----

 mAP: 0.3394  
 Avg loss: 0.3240400736148541  
 Evaluating classifier  
 Mean Precision Score for Testing on Epoch 85 is 0.3394309849532998  
 Starting epoch number 86  
 Loss for Training on Epoch 86 is 0.006103161722421646  
 Starting epoch number 87  
 Loss for Training on Epoch 87 is 0.006290299352258444  
 Starting epoch number 88  
 Loss for Training on Epoch 88 is 0.005934158340096474  
 Starting epoch number 89  
 Loss for Training on Epoch 89 is 0.0055081103928387165  
 Starting epoch number 90  
 Loss for Training on Epoch 90 is 0.005783922038972378  

-----	Class: aeroplane	AP:	0.6379	-----
-----	Class: bicycle	AP:	0.3816	-----
-----	Class: bird	AP:	0.2238	-----
-----	Class: boat	AP:	0.4053	-----
-----	Class: bottle	AP:	0.1043	-----

-----	Class: bus	AP:	0.2250	-----
-----	Class: car	AP:	0.4864	-----
-----	Class: cat	AP:	0.3144	-----
-----	Class: chair	AP:	0.3799	-----
-----	Class: cow	AP:	0.1142	-----
-----	Class: diningtable	AP:	0.3261	-----
-----	Class: dog	AP:	0.2585	-----
-----	Class: horse	AP:	0.5082	-----
-----	Class: motorbike	AP:	0.3850	-----
-----	Class: person	AP:	0.7094	-----
-----	Class: pottedplant	AP:	0.1604	-----
-----	Class: sheep	AP:	0.1794	-----
-----	Class: sofa	AP:	0.2323	-----
-----	Class: train	AP:	0.5241	-----
-----	Class: tvmonitor	AP:	0.2193	-----

mAP: 0.3388

Avg loss: 0.34791381924580306

Evaluating classifier

Mean Precision Score for Testing on Epoch 90 is 0.33877435679765394

Starting epoch number 91

Loss for Training on Epoch 91 is 0.0054518734104931355

Starting epoch number 92

Loss for Training on Epoch 92 is 0.0049376823008060455

Starting epoch number 93

Loss for Training on Epoch 93 is 0.005663557443767786

Starting epoch number 94

Loss for Training on Epoch 94 is 0.005310773849487305

Starting epoch number 95

Loss for Training on Epoch 95 is 0.005256166681647301

-----	Class: aeroplane	AP:	0.6462	-----
-----	Class: bicycle	AP:	0.3920	-----
-----	Class: bird	AP:	0.2132	-----
-----	Class: boat	AP:	0.4472	-----
-----	Class: bottle	AP:	0.1115	-----
-----	Class: bus	AP:	0.2200	-----
-----	Class: car	AP:	0.5064	-----
-----	Class: cat	AP:	0.3362	-----
-----	Class: chair	AP:	0.3689	-----
-----	Class: cow	AP:	0.1159	-----
-----	Class: diningtable	AP:	0.3156	-----
-----	Class: dog	AP:	0.2659	-----
-----	Class: horse	AP:	0.4900	-----
-----	Class: motorbike	AP:	0.4130	-----
-----	Class: person	AP:	0.7077	-----
-----	Class: pottedplant	AP:	0.1539	-----
-----	Class: sheep	AP:	0.1625	-----
-----	Class: sofa	AP:	0.2448	-----
-----	Class: train	AP:	0.5342	-----

```

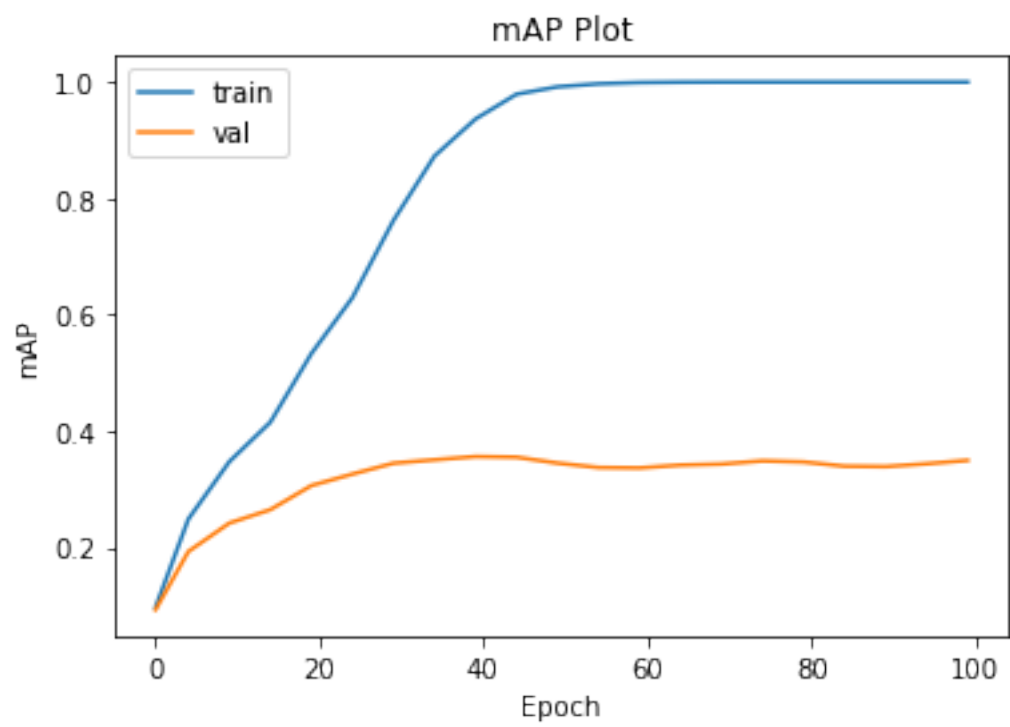
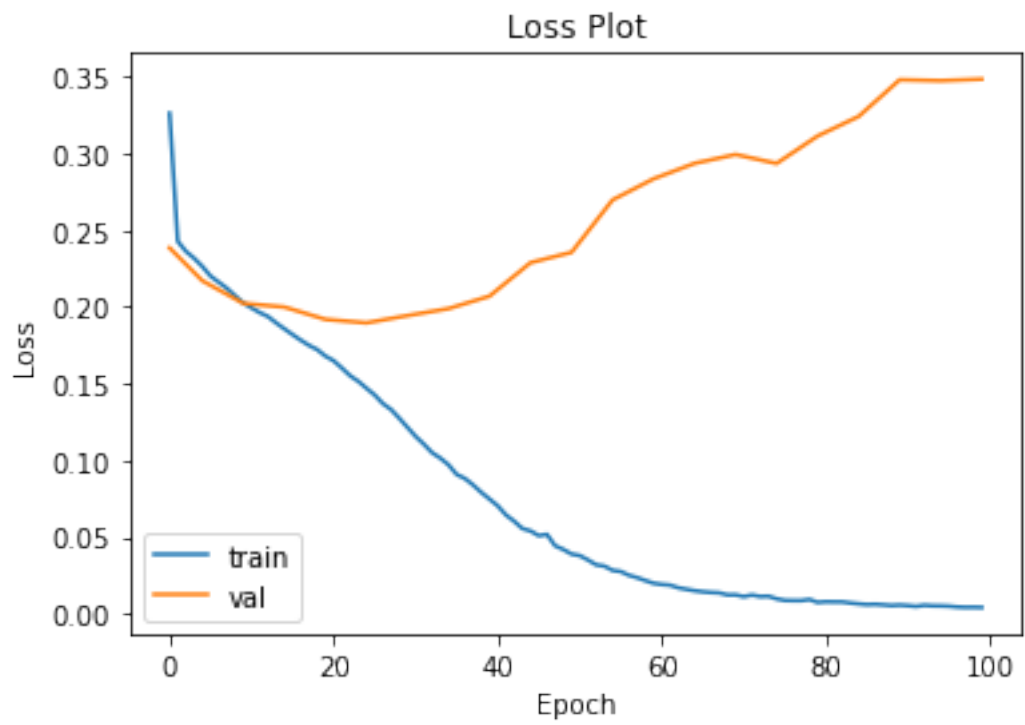
----- Class: tvmonitor          AP:  0.2275 -----
mAP: 0.3436
Avg loss: 0.3473464113015395
Evaluating classifier
Mean Precision Score for Testing on Epoch 95 is 0.3436364604410381
Starting epoch number 96
Loss for Training on Epoch 96 is 0.005061406642198563
Starting epoch number 97
Loss for Training on Epoch 97 is 0.004540518391877413
Starting epoch number 98
Loss for Training on Epoch 98 is 0.004313879180699587
Starting epoch number 99
Loss for Training on Epoch 99 is 0.004356455523520708
Starting epoch number 100
Loss for Training on Epoch 100 is 0.004217569250613451
----- Class: aeroplane          AP:  0.6313 -----
----- Class: bicycle            AP:  0.3897 -----
----- Class: bird                AP:  0.2174 -----
----- Class: boat                AP:  0.4365 -----
----- Class: bottle              AP:  0.1121 -----
----- Class: bus                 AP:  0.2618 -----
----- Class: car                 AP:  0.5130 -----
----- Class: cat                 AP:  0.3216 -----
----- Class: chair               AP:  0.3867 -----
----- Class: cow                 AP:  0.1189 -----
----- Class: diningtable         AP:  0.2944 -----
----- Class: dog                 AP:  0.2832 -----
----- Class: horse               AP:  0.5212 -----
----- Class: motorbike           AP:  0.4051 -----
----- Class: person              AP:  0.7240 -----
----- Class: pottedplant         AP:  0.1609 -----
----- Class: sheep               AP:  0.1776 -----
----- Class: sofa                AP:  0.2459 -----
----- Class: train               AP:  0.5559 -----
----- Class: tvmonitor           AP:  0.2329 -----
mAP: 0.3495
Avg loss: 0.34832198115495533
Evaluating classifier
Mean Precision Score for Testing on Epoch 100 is 0.349504624447436

```

```

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

```



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

```

----- Class: aeroplane      AP:  0.6164  -----
----- Class: bicycle        AP:  0.2746  -----
----- Class: bird            AP:  0.2336  -----
----- Class: boat            AP:  0.4195  -----
----- Class: bottle          AP:  0.1182  -----
----- Class: bus              AP:  0.2171  -----
----- Class: car              AP:  0.5479  -----
----- Class: cat              AP:  0.3167  -----
----- Class: chair            AP:  0.3876  -----
----- Class: cow              AP:  0.1869  -----
----- Class: diningtable     AP:  0.2463  -----
----- Class: dog              AP:  0.2746  -----
----- Class: horse            AP:  0.6492  -----
----- Class: motorbike        AP:  0.3664  -----
----- Class: person           AP:  0.7210  -----
----- Class: pottedplant      AP:  0.1544  -----
----- Class: sheep            AP:  0.2375  -----
----- Class: sofa              AP:  0.2626  -----
----- Class: train            AP:  0.5602  -----
----- Class: tvmonitor        AP:  0.2444  -----
mAP: 0.3518
Avg loss: 0.3383213159365532
0.35176812906649035
```

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

```
[ ]:
```