In [ ]:
```
from google.colab import drive
drive.mount("/content/gdrive")
import os
os.chdir("/content/gdrive/My Drive/CS747_Assignment2")
import torch
a = torch.Tensor([1]).cuda()
print(a)
```

```
Drive already mounted at /content/gdrive; to attempt to forcibly remount, ca
ll drive.mount("/content/gdrive", force_remount=True).
tensor([1.], device='cuda:0')
```

Assignment 2 Part 2: Developing Your Own Classifier

In [ ]:
```
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
```

Part 2: Design your own network

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

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.

What to submit

Check the submission template for details what to submit.

In [ ]:
```
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()
```

In [ ]:
```
def test_classifier(test_loader, classifier, criterion, print_ind_classes=Tr
    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}  -------'.for
            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
```

In [ ]:
```
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
    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
    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()
```

In [ ]:
```
def train(classifier, num_epochs, train_loader, val_loader, criterion, optim
    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, c
        train_losses.append(train_loss)
        print("Loss for Training on Epoch " +str(epoch) + " is "+ str(train_
        if(epoch%test_frequency==0 or epoch==1):
            mAP_train, _, _ = test_classifier(train_loader, classifier, crit
            train_mAPs.append(mAP_train)
            mAP_val, val_loss, _ = test_classifier(val_loader, classifier, c
            print('Evaluating classifier')
            print("Mean Precision Score for Testing on Epoch " +str(epoch) +
            val_losses.append(val_loss)
            val_mAPs.append(mAP_val)

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

Developing Your Own Model

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.

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.

What to submit

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

In [ ]:
```
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)
```

```
/content/gdrive/MyDrive/CS747_Assignment2/voc_dataloader.py:137: VisibleDepr
ecationWarning: Creating an ndarray from ragged nested sequences (which is a
list-or-tuple of lists-or-tuples-or ndarrays with different lengths or shape
s) is deprecated. If you meant to do this, you must specify 'dtype=object' w
hen creating the ndarray.
  np.array(box_indices),
```

In [ ]:
```
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)

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)
```

In [ ]:
```
# TODO: Run your own classifier here
classifier = Classifier().to(device)
# classifier.load_state_dict(torch.load('voc_my_best_classifier.pth'))
criterion = nn.MultiLabelSoftMarginLoss()
optimizer = torch.optim.SGD(classifier.parameters(), lr=0.01, momentum=0.99)
# optimizer = torch.optim.Adam(classifier.parameters(), lr=1e-4)

classifier, train_losses, val_losses, train_mAPs, val_mAPs = train(classifie
```

```
Starting epoch number 1
Loss for Training on Epoch 1 is 0.6618753671646118
-------  Class: aeroplane        AP:   0.0472  -------
-------  Class: bicycle          AP:   0.0638  -------
-------  Class: bird             AP:   0.1210  -------
-------  Class: boat             AP:   0.0961  -------
-------  Class: bottle           AP:   0.0376  -------
-------  Class: bus              AP:   0.0290  -------
-------  Class: car              AP:   0.1144  -------
-------  Class: cat              AP:   0.0934  -------
-------  Class: chair            AP:   0.1100  -------
-------  Class: cow              AP:   0.0336  -------
-------  Class: diningtable      AP:   0.0465  -------
-------  Class: dog              AP:   0.0709  -------
-------  Class: horse            AP:   0.0507  -------
-------  Class: motorbike        AP:   0.0385  -------
-------  Class: person           AP:   0.3392  -------
-------  Class: pottedplant      AP:   0.0591  -------
-------  Class: sheep            AP:   0.0293  -------
-------  Class: sofa             AP:   0.0753  -------
-------  Class: train            AP:   0.0373  -------
-------  Class: tvmonitor        AP:   0.0519  -------
mAP: 0.0772
Avg loss: 0.594076831638813
Evaluating classifier
Mean Precision Score for Testing on Epoch 1 is 0.07724042283815173
Starting epoch number 2
Loss for Training on Epoch 2 is 0.4018048942089081
Starting epoch number 3
Loss for Training on Epoch 3 is 0.2763325273990631
Starting epoch number 4
Loss for Training on Epoch 4 is 0.24948115646839142
Starting epoch number 5
Loss for Training on Epoch 5 is 0.23832900822162628
-------  Class: aeroplane        AP:   0.1677  -------
-------  Class: bicycle          AP:   0.0746  -------
-------  Class: bird             AP:   0.0782  -------
-------  Class: boat             AP:   0.0702  -------
-------  Class: bottle           AP:   0.0399  -------
-------  Class: bus              AP:   0.0361  -------
-------  Class: car              AP:   0.1235  -------
-------  Class: cat              AP:   0.0762  -------
-------  Class: chair            AP:   0.1049  -------
-------  Class: cow              AP:   0.0348  -------
```

```
-------  Class: diningtable      AP:   0.0481  -------
-------  Class: dog              AP:   0.0965  -------
-------  Class: horse            AP:   0.0597  -------
-------  Class: motorbike        AP:   0.0439  -------
-------  Class: person           AP:   0.4443  -------
-------  Class: pottedplant      AP:   0.0408  -------
-------  Class: sheep            AP:   0.0202  -------
-------  Class: sofa             AP:   0.0629  -------
-------  Class: train            AP:   0.0433  -------
-------  Class: tvmonitor        AP:   0.0504  -------
mAP: 0.0858
Avg loss: 0.23554992340505124
Evaluating classifier
Mean Precision Score for Testing on Epoch 5 is 0.08580206994548849
Starting epoch number 6
Loss for Training on Epoch 6 is 0.23883786797523499
Starting epoch number 7
Loss for Training on Epoch 7 is 0.23620419204235077
Starting epoch number 8
Loss for Training on Epoch 8 is 0.23756161332130432
Starting epoch number 9
Loss for Training on Epoch 9 is 0.23717188835144043
Starting epoch number 10
Loss for Training on Epoch 10 is 0.23801513016223907
-------  Class: aeroplane        AP:   0.2772  -------
-------  Class: bicycle          AP:   0.0660  -------
-------  Class: bird             AP:   0.0741  -------
-------  Class: boat             AP:   0.0949  -------
-------  Class: bottle           AP:   0.0350  -------
-------  Class: bus              AP:   0.0443  -------
-------  Class: car              AP:   0.1274  -------
-------  Class: cat              AP:   0.0601  -------
-------  Class: chair            AP:   0.1277  -------
-------  Class: cow              AP:   0.0338  -------
-------  Class: diningtable      AP:   0.0431  -------
-------  Class: dog              AP:   0.0800  -------
-------  Class: horse            AP:   0.0530  -------
-------  Class: motorbike        AP:   0.0424  -------
-------  Class: person           AP:   0.4615  -------
-------  Class: pottedplant      AP:   0.0406  -------
-------  Class: sheep            AP:   0.0204  -------
-------  Class: sofa             AP:   0.0854  -------
-------  Class: train            AP:   0.0661  -------
-------  Class: tvmonitor        AP:   0.0573  -------
mAP: 0.0945
Avg loss: 0.2318179588764906
Evaluating classifier
Mean Precision Score for Testing on Epoch 10 is 0.094524485004175
Starting epoch number 11
Loss for Training on Epoch 11 is 0.23562310636043549
Starting epoch number 12
Loss for Training on Epoch 12 is 0.2359856218099594
Starting epoch number 13
```

```
Loss for Training on Epoch 13 is 0.23702387511730194
Starting epoch number 14
Loss for Training on Epoch 14 is 0.2360825389623642
Starting epoch number 15
Loss for Training on Epoch 15 is 0.23809342086315155
-------  Class: aeroplane        AP:   0.2095  -------
-------  Class: bicycle          AP:   0.0555  -------
-------  Class: bird             AP:   0.0479  -------
-------  Class: boat             AP:   0.0901  -------
-------  Class: bottle           AP:   0.0354  -------
-------  Class: bus              AP:   0.0702  -------
-------  Class: car              AP:   0.1307  -------
-------  Class: cat              AP:   0.0603  -------
-------  Class: chair            AP:   0.1367  -------
-------  Class: cow              AP:   0.0360  -------
-------  Class: diningtable      AP:   0.0428  -------
-------  Class: dog              AP:   0.0702  -------
-------  Class: horse            AP:   0.0566  -------
-------  Class: motorbike        AP:   0.0513  -------
-------  Class: person           AP:   0.4677  -------
-------  Class: pottedplant      AP:   0.0538  -------
-------  Class: sheep            AP:   0.0309  -------
-------  Class: sofa             AP:   0.1018  -------
-------  Class: train            AP:   0.1137  -------
-------  Class: tvmonitor        AP:   0.0659  -------
mAP: 0.0963
Avg loss: 0.23192720748484136
Evaluating classifier
Mean Precision Score for Testing on Epoch 15 is 0.09634982185573784
Starting epoch number 16
Loss for Training on Epoch 16 is 0.2352171242237091
Starting epoch number 17
Loss for Training on Epoch 17 is 0.23515276610851288
Starting epoch number 18
Loss for Training on Epoch 18 is 0.23537015914916992
Starting epoch number 19
Loss for Training on Epoch 19 is 0.23492634296417236
Starting epoch number 20
Loss for Training on Epoch 20 is 0.23366665840148926
-------  Class: aeroplane        AP:   0.3236  -------
-------  Class: bicycle          AP:   0.0559  -------
-------  Class: bird             AP:   0.0480  -------
-------  Class: boat             AP:   0.1218  -------
-------  Class: bottle           AP:   0.0401  -------
-------  Class: bus              AP:   0.0691  -------
-------  Class: car              AP:   0.1345  -------
-------  Class: cat              AP:   0.0669  -------
-------  Class: chair            AP:   0.1388  -------
-------  Class: cow              AP:   0.0334  -------
-------  Class: diningtable      AP:   0.0443  -------
-------  Class: dog              AP:   0.0696  -------
-------  Class: horse            AP:   0.0721  -------
-------  Class: motorbike        AP:   0.0606  -------
```

```
-------  Class: person           AP:   0.4983  -------
-------  Class: pottedplant      AP:   0.0711  -------
-------  Class: sheep            AP:   0.0351  -------
-------  Class: sofa             AP:   0.0977  -------
-------  Class: train            AP:   0.1373  -------
-------  Class: tvmonitor        AP:   0.0576  -------
mAP: 0.1088
Avg loss: 0.22930268123745917
Evaluating classifier
Mean Precision Score for Testing on Epoch 20 is 0.10877909638553603
Starting epoch number 21
Loss for Training on Epoch 21 is 0.23290196061134338
Starting epoch number 22
Loss for Training on Epoch 22 is 0.23065005242824554
Starting epoch number 23
Loss for Training on Epoch 23 is 0.2288135141134262
Starting epoch number 24
Loss for Training on Epoch 24 is 0.22571924328804016
Starting epoch number 25
Loss for Training on Epoch 25 is 0.22337189316749573
-------  Class: aeroplane        AP:   0.3199  -------
-------  Class: bicycle          AP:   0.0560  -------
-------  Class: bird             AP:   0.0545  -------
-------  Class: boat             AP:   0.1344  -------
-------  Class: bottle           AP:   0.0638  -------
-------  Class: bus              AP:   0.0665  -------
-------  Class: car              AP:   0.2700  -------
-------  Class: cat              AP:   0.0833  -------
-------  Class: chair            AP:   0.1762  -------
-------  Class: cow              AP:   0.0326  -------
-------  Class: diningtable      AP:   0.0913  -------
-------  Class: dog              AP:   0.0854  -------
-------  Class: horse            AP:   0.0831  -------
-------  Class: motorbike        AP:   0.0533  -------
-------  Class: person           AP:   0.5679  -------
-------  Class: pottedplant      AP:   0.0699  -------
-------  Class: sheep            AP:   0.0211  -------
-------  Class: sofa             AP:   0.1016  -------
-------  Class: train            AP:   0.1479  -------
-------  Class: tvmonitor        AP:   0.0847  -------
mAP: 0.1282
Avg loss: 0.22672861032187938
Evaluating classifier
Mean Precision Score for Testing on Epoch 25 is 0.12815796620891232
Starting epoch number 26
Loss for Training on Epoch 26 is 0.22062687575817108
Starting epoch number 27
Loss for Training on Epoch 27 is 0.2151934653520584
Starting epoch number 28
Loss for Training on Epoch 28 is 0.2155390977859497
Starting epoch number 29
Loss for Training on Epoch 29 is 0.21104200184345245
Starting epoch number 30
```

```
Loss for Training on Epoch 30 is 0.2006346732378006
-------  Class: aeroplane        AP:   0.2571  -------
-------  Class: bicycle          AP:   0.0740  -------
-------  Class: bird             AP:   0.0789  -------
-------  Class: boat             AP:   0.1294  -------
-------  Class: bottle           AP:   0.0665  -------
-------  Class: bus              AP:   0.0692  -------
-------  Class: car              AP:   0.2821  -------
-------  Class: cat              AP:   0.0886  -------
-------  Class: chair            AP:   0.1512  -------
-------  Class: cow              AP:   0.0324  -------
-------  Class: diningtable      AP:   0.0814  -------
-------  Class: dog              AP:   0.1181  -------
-------  Class: horse            AP:   0.1037  -------
-------  Class: motorbike        AP:   0.0649  -------
-------  Class: person           AP:   0.5397  -------
-------  Class: pottedplant      AP:   0.0713  -------
-------  Class: sheep            AP:   0.0227  -------
-------  Class: sofa             AP:   0.0937  -------
-------  Class: train            AP:   0.1137  -------
-------  Class: tvmonitor        AP:   0.0803  -------
mAP: 0.1260
Avg loss: 0.2439603552222252
Evaluating classifier
Mean Precision Score for Testing on Epoch 30 is 0.12595386213520054
Starting epoch number 31
Loss for Training on Epoch 31 is 0.18875019252300262
Starting epoch number 32
Loss for Training on Epoch 32 is 0.17889150977134705
Starting epoch number 33
Loss for Training on Epoch 33 is 0.16161774098873138
Starting epoch number 34
Loss for Training on Epoch 34 is 0.1472356617450714
Starting epoch number 35
Loss for Training on Epoch 35 is 0.13166777789592743
-------  Class: aeroplane        AP:   0.2449  -------
-------  Class: bicycle          AP:   0.0702  -------
-------  Class: bird             AP:   0.0752  -------
-------  Class: boat             AP:   0.1226  -------
-------  Class: bottle           AP:   0.0472  -------
-------  Class: bus              AP:   0.0779  -------
-------  Class: car              AP:   0.3036  -------
-------  Class: cat              AP:   0.1086  -------
-------  Class: chair            AP:   0.1475  -------
-------  Class: cow              AP:   0.0334  -------
-------  Class: diningtable      AP:   0.0804  -------
-------  Class: dog              AP:   0.1139  -------
-------  Class: horse            AP:   0.1161  -------
-------  Class: motorbike        AP:   0.0824  -------
-------  Class: person           AP:   0.5204  -------
-------  Class: pottedplant      AP:   0.0702  -------
-------  Class: sheep            AP:   0.0214  -------
-------  Class: sofa             AP:   0.0850  -------
```

```
-------  Class: train            AP:   0.0940  -------
-------  Class: tvmonitor        AP:   0.0781  -------
mAP: 0.1247
Avg loss: 0.34129832312464714
Evaluating classifier
Mean Precision Score for Testing on Epoch 35 is 0.12465992482428803
Starting epoch number 36
Loss for Training on Epoch 36 is 0.11644482612609863
Starting epoch number 37
Loss for Training on Epoch 37 is 0.10084845870733261
Starting epoch number 38
Loss for Training on Epoch 38 is 0.08401017636060715
Starting epoch number 39
Loss for Training on Epoch 39 is 0.06783231347799301
Starting epoch number 40
Loss for Training on Epoch 40 is 0.06226510927081108
-------  Class: aeroplane        AP:   0.2606  -------
-------  Class: bicycle          AP:   0.0828  -------
-------  Class: bird             AP:   0.0847  -------
-------  Class: boat             AP:   0.1059  -------
-------  Class: bottle           AP:   0.0476  -------
-------  Class: bus              AP:   0.0502  -------
-------  Class: car              AP:   0.2737  -------
-------  Class: cat              AP:   0.0873  -------
-------  Class: chair            AP:   0.1391  -------
-------  Class: cow              AP:   0.0400  -------
-------  Class: diningtable      AP:   0.0638  -------
-------  Class: dog              AP:   0.1122  -------
-------  Class: horse            AP:   0.0977  -------
-------  Class: motorbike        AP:   0.0621  -------
-------  Class: person           AP:   0.4948  -------
-------  Class: pottedplant      AP:   0.0590  -------
-------  Class: sheep            AP:   0.0271  -------
-------  Class: sofa             AP:   0.0978  -------
-------  Class: train            AP:   0.1009  -------
-------  Class: tvmonitor        AP:   0.0852  -------
mAP: 0.1186
Avg loss: 0.5742081008851528
Evaluating classifier
Mean Precision Score for Testing on Epoch 40 is 0.11862239630104185
Starting epoch number 41
Loss for Training on Epoch 41 is 0.055474329739809036
Starting epoch number 42
Loss for Training on Epoch 42 is 0.050565849989652634
Starting epoch number 43
Loss for Training on Epoch 43 is 0.05061877891421318
Starting epoch number 44
Loss for Training on Epoch 44 is 0.04709113389253616
Starting epoch number 45
Loss for Training on Epoch 45 is 0.04098362848162651
-------  Class: aeroplane        AP:   0.2103  -------
-------  Class: bicycle          AP:   0.0572  -------
-------  Class: bird             AP:   0.0941  -------
```

```
-------  Class: boat            AP:   0.0990  -------
-------  Class: bottle          AP:   0.0468  -------
-------  Class: bus             AP:   0.0601  -------
-------  Class: car             AP:   0.2643  -------
-------  Class: cat             AP:   0.0913  -------
-------  Class: chair           AP:   0.1407  -------
-------  Class: cow             AP:   0.0361  -------
-------  Class: diningtable     AP:   0.0657  -------
-------  Class: dog             AP:   0.1096  -------
-------  Class: horse           AP:   0.0804  -------
-------  Class: motorbike       AP:   0.0575  -------
-------  Class: person          AP:   0.4901  -------
-------  Class: pottedplant     AP:   0.0634  -------
-------  Class: sheep           AP:   0.0311  -------
-------  Class: sofa            AP:   0.1089  -------
-------  Class: train           AP:   0.1070  -------
-------  Class: tvmonitor       AP:   0.0756  -------
mAP: 0.1145
Avg loss: 0.6889748409390449
Evaluating classifier
Mean Precision Score for Testing on Epoch 45 is 0.11445650228254911
Starting epoch number 46
Loss for Training on Epoch 46 is 0.033145297318696976
Starting epoch number 47
Loss for Training on Epoch 47 is 0.027222871780395508
Starting epoch number 48
Loss for Training on Epoch 48 is 0.02271697111427784
Starting epoch number 49
Loss for Training on Epoch 49 is 0.022417549043893814
Starting epoch number 50
Loss for Training on Epoch 50 is 0.02164188027381897
-------  Class: aeroplane       AP:   0.2384  -------
-------  Class: bicycle         AP:   0.0658  -------
-------  Class: bird            AP:   0.0840  -------
-------  Class: boat            AP:   0.0953  -------
-------  Class: bottle          AP:   0.0467  -------
-------  Class: bus             AP:   0.0566  -------
-------  Class: car             AP:   0.2748  -------
-------  Class: cat             AP:   0.0918  -------
-------  Class: chair           AP:   0.1412  -------
-------  Class: cow             AP:   0.0423  -------
-------  Class: diningtable     AP:   0.0695  -------
-------  Class: dog             AP:   0.1110  -------
-------  Class: horse           AP:   0.0773  -------
-------  Class: motorbike       AP:   0.0739  -------
-------  Class: person          AP:   0.4959  -------
-------  Class: pottedplant     AP:   0.0614  -------
-------  Class: sheep           AP:   0.0305  -------
-------  Class: sofa            AP:   0.1077  -------
-------  Class: train           AP:   0.0983  -------
-------  Class: tvmonitor       AP:   0.0704  -------
mAP: 0.1166
Avg loss: 1.0502803489565848
```

```
Evaluating classifier
Mean Precision Score for Testing on Epoch 50 is 0.11664134888364412
Starting epoch number 51
Loss for Training on Epoch 51 is 0.024382883682847023
Starting epoch number 52
Loss for Training on Epoch 52 is 0.02628924325108528
Starting epoch number 53
Loss for Training on Epoch 53 is 0.024311188608407974
Starting epoch number 54
Loss for Training on Epoch 54 is 0.017885569483041763
Starting epoch number 55
Loss for Training on Epoch 55 is 0.019837720319628716
-------  Class: aeroplane        AP:   0.2193  -------
-------  Class: bicycle          AP:   0.0655  -------
-------  Class: bird             AP:   0.0827  -------
-------  Class: boat             AP:   0.0870  -------
-------  Class: bottle           AP:   0.0472  -------
-------  Class: bus              AP:   0.0590  -------
-------  Class: car              AP:   0.2407  -------
-------  Class: cat              AP:   0.0975  -------
-------  Class: chair            AP:   0.1437  -------
-------  Class: cow              AP:   0.0397  -------
-------  Class: diningtable      AP:   0.0723  -------
-------  Class: dog              AP:   0.1070  -------
-------  Class: horse            AP:   0.0897  -------
-------  Class: motorbike        AP:   0.0481  -------
-------  Class: person           AP:   0.4880  -------
-------  Class: pottedplant      AP:   0.0701  -------
-------  Class: sheep            AP:   0.0235  -------
-------  Class: sofa             AP:   0.0885  -------
-------  Class: train            AP:   0.0917  -------
-------  Class: tvmonitor        AP:   0.0742  -------
mAP: 0.1118
Avg loss: 0.968587002158165
Evaluating classifier
Mean Precision Score for Testing on Epoch 55 is 0.11177726651880068
Starting epoch number 56
Loss for Training on Epoch 56 is 0.01879909075796604
Starting epoch number 57
Loss for Training on Epoch 57 is 0.01744692586362362
Starting epoch number 58
Loss for Training on Epoch 58 is 0.014446884393692017
Starting epoch number 59
Loss for Training on Epoch 59 is 0.009262611158192158
Starting epoch number 60
Loss for Training on Epoch 60 is 0.008328844793140888
-------  Class: aeroplane        AP:   0.2471  -------
-------  Class: bicycle          AP:   0.0594  -------
-------  Class: bird             AP:   0.0791  -------
-------  Class: boat             AP:   0.0957  -------
-------  Class: bottle           AP:   0.0511  -------
-------  Class: bus              AP:   0.0565  -------
-------  Class: car              AP:   0.2774  -------
```

```
-------  Class: cat              AP:   0.0886  -------
-------  Class: chair            AP:   0.1358  -------
-------  Class: cow              AP:   0.0532  -------
-------  Class: diningtable      AP:   0.0694  -------
-------  Class: dog              AP:   0.1027  -------
-------  Class: horse            AP:   0.0865  -------
-------  Class: motorbike        AP:   0.0520  -------
-------  Class: person           AP:   0.4991  -------
-------  Class: pottedplant      AP:   0.0609  -------
-------  Class: sheep            AP:   0.0326  -------
-------  Class: sofa             AP:   0.0979  -------
-------  Class: train            AP:   0.1031  -------
-------  Class: tvmonitor        AP:   0.0785  -------
mAP: 0.1163
Avg loss: 1.350517112016678
Evaluating classifier
Mean Precision Score for Testing on Epoch 60 is 0.11632815715935485
Starting epoch number 61
Loss for Training on Epoch 61 is 0.007495991885662079
Starting epoch number 62
Loss for Training on Epoch 62 is 0.006065479014068842
Starting epoch number 63
Loss for Training on Epoch 63 is 0.008679911494255066
Starting epoch number 64
Loss for Training on Epoch 64 is 0.008069484494626522
Starting epoch number 65
Loss for Training on Epoch 65 is 0.008486062288284302
-------  Class: aeroplane        AP:   0.2558  -------
-------  Class: bicycle          AP:   0.0609  -------
-------  Class: bird             AP:   0.0897  -------
-------  Class: boat             AP:   0.0958  -------
-------  Class: bottle           AP:   0.0495  -------
-------  Class: bus              AP:   0.0648  -------
-------  Class: car              AP:   0.2563  -------
-------  Class: cat              AP:   0.0896  -------
-------  Class: chair            AP:   0.1381  -------
-------  Class: cow              AP:   0.0544  -------
-------  Class: diningtable      AP:   0.0705  -------
-------  Class: dog              AP:   0.1069  -------
-------  Class: horse            AP:   0.0800  -------
-------  Class: motorbike        AP:   0.0573  -------
-------  Class: person           AP:   0.4916  -------
-------  Class: pottedplant      AP:   0.0649  -------
-------  Class: sheep            AP:   0.0316  -------
-------  Class: sofa             AP:   0.0946  -------
-------  Class: train            AP:   0.1014  -------
-------  Class: tvmonitor        AP:   0.0739  -------
mAP: 0.1164
Avg loss: 1.2319686442613602
Evaluating classifier
Mean Precision Score for Testing on Epoch 65 is 0.11638101585740006
Starting epoch number 66
Loss for Training on Epoch 66 is 0.007731571327894926
```

```
Starting epoch number 67
Loss for Training on Epoch 67 is 0.008038897998631
Starting epoch number 68
Loss for Training on Epoch 68 is 0.006638219114392996
Starting epoch number 69
Loss for Training on Epoch 69 is 0.006922425236552954
Starting epoch number 70
Loss for Training on Epoch 70 is 0.009232929907739162
-------  Class: aeroplane        AP:   0.2747  -------
-------  Class: bicycle          AP:   0.0583  -------
-------  Class: bird             AP:   0.0850  -------
-------  Class: boat             AP:   0.0965  -------
-------  Class: bottle           AP:   0.0467  -------
-------  Class: bus              AP:   0.0586  -------
-------  Class: car              AP:   0.2574  -------
-------  Class: cat              AP:   0.0788  -------
-------  Class: chair            AP:   0.1394  -------
-------  Class: cow              AP:   0.0455  -------
-------  Class: diningtable      AP:   0.0629  -------
-------  Class: dog              AP:   0.1040  -------
-------  Class: horse            AP:   0.0787  -------
-------  Class: motorbike        AP:   0.0594  -------
-------  Class: person           AP:   0.5010  -------
-------  Class: pottedplant      AP:   0.0614  -------
-------  Class: sheep            AP:   0.0312  -------
-------  Class: sofa             AP:   0.0901  -------
-------  Class: train            AP:   0.1123  -------
-------  Class: tvmonitor        AP:   0.0710  -------
mAP: 0.1156
Avg loss: 1.318940246105194
Evaluating classifier
Mean Precision Score for Testing on Epoch 70 is 0.11563773930526515
Starting epoch number 71
Loss for Training on Epoch 71 is 0.0063477992080152035
Starting epoch number 72
Loss for Training on Epoch 72 is 0.008334500715136528
Starting epoch number 73
Loss for Training on Epoch 73 is 0.006965375039726496
Starting epoch number 74
Loss for Training on Epoch 74 is 0.01204280648380518
Starting epoch number 75
Loss for Training on Epoch 75 is 0.014061695896089077
-------  Class: aeroplane        AP:   0.2420  -------
-------  Class: bicycle          AP:   0.0574  -------
-------  Class: bird             AP:   0.0804  -------
-------  Class: boat             AP:   0.0978  -------
-------  Class: bottle           AP:   0.0510  -------
-------  Class: bus              AP:   0.0614  -------
-------  Class: car              AP:   0.2319  -------
-------  Class: cat              AP:   0.0903  -------
-------  Class: chair            AP:   0.1348  -------
-------  Class: cow              AP:   0.0393  -------
-------  Class: diningtable      AP:   0.0744  -------
```

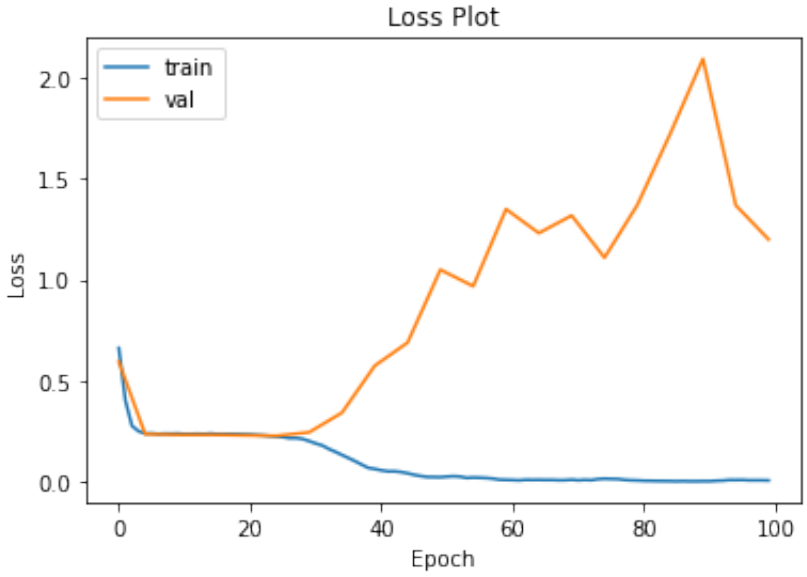
```
-------  Class: dog              AP:   0.1039  -------
-------  Class: horse            AP:   0.0794  -------
-------  Class: motorbike        AP:   0.0672  -------
-------  Class: person           AP:   0.4969  -------
-------  Class: pottedplant      AP:   0.0571  -------
-------  Class: sheep            AP:   0.0302  -------
-------  Class: sofa             AP:   0.0930  -------
-------  Class: train            AP:   0.0960  -------
-------  Class: tvmonitor        AP:   0.0802  -------
mAP: 0.1132
Avg loss: 1.1101321637630464
Evaluating classifier
Mean Precision Score for Testing on Epoch 75 is 0.11323703918208072
Starting epoch number 76
Loss for Training on Epoch 76 is 0.012929259799420834
Starting epoch number 77
Loss for Training on Epoch 77 is 0.012524259276688099
Starting epoch number 78
Loss for Training on Epoch 78 is 0.008463496342301369
Starting epoch number 79
Loss for Training on Epoch 79 is 0.006329900119453669
Starting epoch number 80
Loss for Training on Epoch 80 is 0.005703719798475504
-------  Class: aeroplane        AP:   0.2405  -------
-------  Class: bicycle          AP:   0.0604  -------
-------  Class: bird             AP:   0.0813  -------
-------  Class: boat             AP:   0.0976  -------
-------  Class: bottle           AP:   0.0509  -------
-------  Class: bus              AP:   0.0630  -------
-------  Class: car              AP:   0.2415  -------
-------  Class: cat              AP:   0.0871  -------
-------  Class: chair            AP:   0.1339  -------
-------  Class: cow              AP:   0.0372  -------
-------  Class: diningtable      AP:   0.0746  -------
-------  Class: dog              AP:   0.1041  -------
-------  Class: horse            AP:   0.0780  -------
-------  Class: motorbike        AP:   0.0576  -------
-------  Class: person           AP:   0.4835  -------
-------  Class: pottedplant      AP:   0.0700  -------
-------  Class: sheep            AP:   0.0294  -------
-------  Class: sofa             AP:   0.0865  -------
-------  Class: train            AP:   0.1152  -------
-------  Class: tvmonitor        AP:   0.0657  -------
mAP: 0.1129
Avg loss: 1.370905837416649
Evaluating classifier
Mean Precision Score for Testing on Epoch 80 is 0.11291218541768608
Starting epoch number 81
Loss for Training on Epoch 81 is 0.003950363025069237
Starting epoch number 82
Loss for Training on Epoch 82 is 0.0036384984850883484
Starting epoch number 83
Loss for Training on Epoch 83 is 0.002881722990423441
```

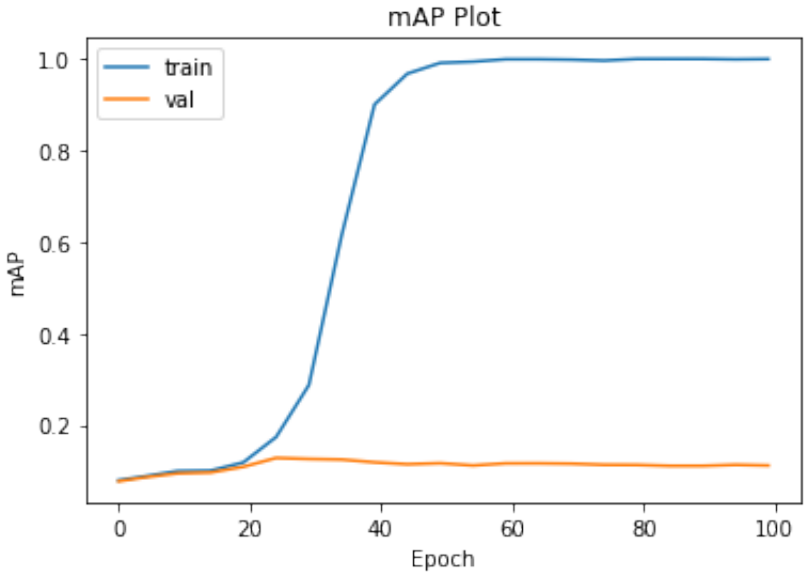
```
Starting epoch number 84
Loss for Training on Epoch 84 is 0.0025793209206312895
Starting epoch number 85
Loss for Training on Epoch 85 is 0.0022132222075015306
-------  Class: aeroplane        AP:   0.2163  -------
-------  Class: bicycle          AP:   0.0630  -------
-------  Class: bird             AP:   0.0887  -------
-------  Class: boat             AP:   0.0943  -------
-------  Class: bottle           AP:   0.0483  -------
-------  Class: bus              AP:   0.0529  -------
-------  Class: car              AP:   0.2293  -------
-------  Class: cat              AP:   0.0825  -------
-------  Class: chair            AP:   0.1306  -------
-------  Class: cow              AP:   0.0380  -------
-------  Class: diningtable      AP:   0.0654  -------
-------  Class: dog              AP:   0.1046  -------
-------  Class: horse            AP:   0.0833  -------
-------  Class: motorbike        AP:   0.0624  -------
-------  Class: person           AP:   0.4881  -------
-------  Class: pottedplant      AP:   0.0603  -------
-------  Class: sheep            AP:   0.0340  -------
-------  Class: sofa             AP:   0.0975  -------
-------  Class: train            AP:   0.1159  -------
-------  Class: tvmonitor        AP:   0.0621  -------
mAP: 0.1109
Avg loss: 1.7234398812055587
Evaluating classifier
Mean Precision Score for Testing on Epoch 85 is 0.11087405169110323
Starting epoch number 86
Loss for Training on Epoch 86 is 0.0015199847985059023
Starting epoch number 87
Loss for Training on Epoch 87 is 0.0022154266480356455
Starting epoch number 88
Loss for Training on Epoch 88 is 0.0014280687319114804
Starting epoch number 89
Loss for Training on Epoch 89 is 0.0013606747379526496
Starting epoch number 90
Loss for Training on Epoch 90 is 0.0019801624584943056
-------  Class: aeroplane        AP:   0.2157  -------
-------  Class: bicycle          AP:   0.0657  -------
-------  Class: bird             AP:   0.0813  -------
-------  Class: boat             AP:   0.0824  -------
-------  Class: bottle           AP:   0.0505  -------
-------  Class: bus              AP:   0.0536  -------
-------  Class: car              AP:   0.2444  -------
-------  Class: cat              AP:   0.0806  -------
-------  Class: chair            AP:   0.1342  -------
-------  Class: cow              AP:   0.0419  -------
-------  Class: diningtable      AP:   0.0692  -------
-------  Class: dog              AP:   0.1037  -------
-------  Class: horse            AP:   0.0835  -------
-------  Class: motorbike        AP:   0.0594  -------
-------  Class: person           AP:   0.4895  -------
```

```
-------  Class: pottedplant      AP:   0.0707  -------
-------  Class: sheep            AP:   0.0297  -------
-------  Class: sofa             AP:   0.0989  -------
-------  Class: train            AP:   0.1058  -------
-------  Class: tvmonitor        AP:   0.0573  -------
mAP: 0.1109
Avg loss: 2.0956179767847063
Evaluating classifier
Mean Precision Score for Testing on Epoch 90 is 0.11090132944472979
Starting epoch number 91
Loss for Training on Epoch 91 is 0.0017421141965314746
Starting epoch number 92
Loss for Training on Epoch 92 is 0.003886497812345624
Starting epoch number 93
Loss for Training on Epoch 93 is 0.004843223374336958
Starting epoch number 94
Loss for Training on Epoch 94 is 0.007773980498313904
Starting epoch number 95
Loss for Training on Epoch 95 is 0.007554568350315094
-------  Class: aeroplane        AP:   0.2004  -------
-------  Class: bicycle          AP:   0.0618  -------
-------  Class: bird             AP:   0.0832  -------
-------  Class: boat             AP:   0.0902  -------
-------  Class: bottle           AP:   0.0546  -------
-------  Class: bus              AP:   0.0617  -------
-------  Class: car              AP:   0.2640  -------
-------  Class: cat              AP:   0.0836  -------
-------  Class: chair            AP:   0.1352  -------
-------  Class: cow              AP:   0.0456  -------
-------  Class: diningtable      AP:   0.0686  -------
-------  Class: dog              AP:   0.1075  -------
-------  Class: horse            AP:   0.0797  -------
-------  Class: motorbike        AP:   0.0638  -------
-------  Class: person           AP:   0.4912  -------
-------  Class: pottedplant      AP:   0.0681  -------
-------  Class: sheep            AP:   0.0319  -------
-------  Class: sofa             AP:   0.1003  -------
-------  Class: train            AP:   0.1039  -------
-------  Class: tvmonitor        AP:   0.0681  -------
mAP: 0.1132
Avg loss: 1.3699791699647903
Evaluating classifier
Mean Precision Score for Testing on Epoch 95 is 0.11316572249582404
Starting epoch number 96
Loss for Training on Epoch 96 is 0.008094235323369503
Starting epoch number 97
Loss for Training on Epoch 97 is 0.006360695697367191
Starting epoch number 98
Loss for Training on Epoch 98 is 0.006410904228687286
Starting epoch number 99
Loss for Training on Epoch 99 is 0.006282405462116003
Starting epoch number 100
Loss for Training on Epoch 100 is 0.005633760709315538
```

```
-------  Class: aeroplane        AP:   0.2331  -------
-------  Class: bicycle          AP:   0.0573  -------
-------  Class: bird             AP:   0.0764  -------
-------  Class: boat             AP:   0.0978  -------
-------  Class: bottle           AP:   0.0504  -------
-------  Class: bus              AP:   0.0651  -------
-------  Class: car              AP:   0.2436  -------
-------  Class: cat              AP:   0.0786  -------
-------  Class: chair            AP:   0.1308  -------
-------  Class: cow              AP:   0.0432  -------
-------  Class: diningtable      AP:   0.0713  -------
-------  Class: dog              AP:   0.1062  -------
-------  Class: horse            AP:   0.0796  -------
-------  Class: motorbike        AP:   0.0558  -------
-------  Class: person           AP:   0.4872  -------
-------  Class: pottedplant      AP:   0.0598  -------
-------  Class: sheep            AP:   0.0332  -------
-------  Class: sofa             AP:   0.0924  -------
-------  Class: train            AP:   0.0969  -------
-------  Class: tvmonitor        AP:   0.0755  -------
mAP: 0.1117
Avg loss: 1.2005734220147133
Evaluating classifier
Mean Precision Score for Testing on Epoch 100 is 0.11170441446971435
```

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





In [ ]:
```
mAP_test, test_loss, test_aps = test_classifier(test_loader, classifier, cri
print(mAP_test)
```

```
-------  Class: aeroplane        AP:   0.1934  -------
-------  Class: bicycle          AP:   0.0685  -------
-------  Class: bird             AP:   0.0755  -------
-------  Class: boat             AP:   0.0935  -------
-------  Class: bottle           AP:   0.0530  -------
-------  Class: bus              AP:   0.0472  -------
-------  Class: car              AP:   0.2696  -------
-------  Class: cat              AP:   0.0822  -------
-------  Class: chair            AP:   0.1319  -------
-------  Class: cow              AP:   0.0352  -------
-------  Class: diningtable      AP:   0.0592  -------
-------  Class: dog              AP:   0.1076  -------
-------  Class: horse            AP:   0.1035  -------
-------  Class: motorbike        AP:   0.0902  -------
-------  Class: person           AP:   0.5088  -------
-------  Class: pottedplant      AP:   0.0589  -------
-------  Class: sheep            AP:   0.0248  -------
-------  Class: sofa             AP:   0.0895  -------
-------  Class: train            AP:   0.0980  -------
-------  Class: tvmonitor        AP:   0.0710  -------
mAP: 0.1131
Avg loss: 1.1636863152186077
0.11306311093998558
```

In [13]:
```
torch.save(classifier.state_dict(), './voc_my_best_classifier.pth')
output_submission_csv('my_solution.csv', test_aps)
```

In [ ]:
```
```