In [95]:

```
import torch
import torch.nn as nn
import torch.optim as optim
from torch.optim import lr_scheduler
from torch.autograd import Variable
import torchvision
from torchvision import datasets, models, transforms
from torch.utils.data import Dataset, DataLoader, ConcatDataset
from skimage import io, transform,data
from torchvision import transforms, utils
import numpy as np
import math
import glob
import matplotlib.pyplot as plt
import time
import os
import copy
import sklearn.svm
import cv2
from matplotlib import pyplot as plt
import numpy as np
from os.path import exists
import pandas as pd
import PIL
import random
from google.colab import drive
from sklearn.metrics.cluster import completeness_score
from sklearn.cluster import KMeans
from tqdm import tqdm, tqdm_notebook
from functools import partial
from torchsummary import summary
from torchvision.datasets import ImageFolder
from torch.utils.data.sampler import SubsetRandomSampler

#cuda_output = !ldconfig -p|grep cudart.so|sed -e 's/.*\.\([0-9]*\)\.\([0-9]*\)$/cu\1\2/'
#accelerator = cuda_output[0] if exists('/dev/nvidia0') else 'cpu'

#print("Accelerator type = ",accelerator)
#print("Pytorch verision: ", torch.__version__)
```

In [9]:

```
!pip install tifffile
```

```
Requirement already satisfied: tifffile in /usr/local/lib/python3.7/dist-packages (2021.4
.8)
Requirement already satisfied: numpy>=1.15.1 in /usr/local/lib/python3.7/dist-packages (f
rom tifffile) (1.19.5)
```

Import Drive

In [2]:

```
# This will prompt for authorization.
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

Sentinel-2 Land-Cover Subet Dataset with 5 Categories, having 100 images each

In [206]:

```
import tifffile
```

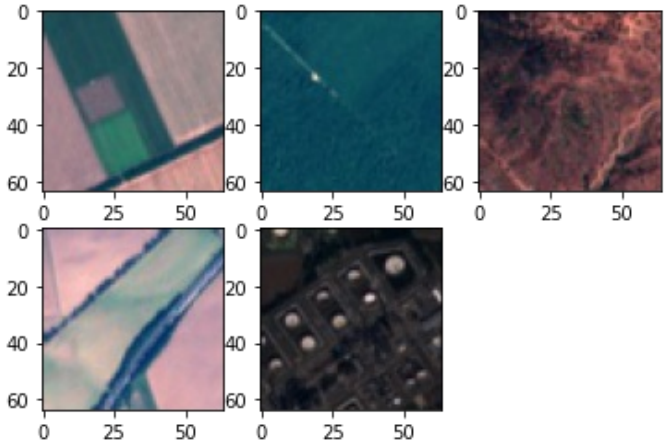
```
from PIL import Image
from torchvision.transforms import ToTensor

files_0 = os.listdir(aerial_path+'/0/')
files_1 = os.listdir(aerial_path+'/1/')
files_2 = os.listdir(aerial_path+'/2/')
files_3 = os.listdir(aerial_path+'/3/')
files_4 = os.listdir(aerial_path+'/4/')



img_rgb_0  = Image.open(aerial_path + '/0/' + files[5])
img_rgb_1  = Image.open(aerial_path + '/1/' + files[15])
img_rgb_2  = Image.open(aerial_path + '/2/' + files[45])
img_rgb_3  = Image.open(aerial_path + '/3/' + files[30])
img_rgb_4  = Image.open(aerial_path + '/4/' + files[70])
```

In [207]:

```
plt.subplot(231)
plt.imshow(img_rgb_0)
plt.subplot(232)
plt.imshow(img_rgb_1)
plt.subplot(233)
plt.imshow(img_rgb_2)
plt.subplot(234)
plt.imshow(img_rgb_3)
plt.subplot(235)
plt.imshow(img_rgb_4)
```

Out[207]:

```
<matplotlib.image.AxesImage at 0x7f14106a1a50>
```



Path to Aerial Dataset

(A combination of samples from Small Village and Industrial Datasets from Sensefly)

In [129]:

```
aerial_path = '/content/drive/MyDrive/sentinel-2_rgb'
```

Aerial Dataset Class

In [4]:

```
def get_sat_data(folder_path,transforms=None):
  if transforms:
    dataset_full = ImageFolder(folder_path,preprocessor)
  else:
    dataset_full = ImageFolder(folder_path,preprocessor)
```

```
  return dataset_full
```

In [128]:

```
'''
target = '/content/drive/MyDrive/sentinel-2_rgb/4/'
files = os.listdir(aerial_path+'/4/')
files.sort()
for file in tqdm(files):
  img_13  = tifffile.imread(aerial_path + '/4/' + file)
  img_bgr = img_13[:,:,1:4]
  #img = img_bgr[::-1]
  img = cv2.normalize(img_bgr, None, 0, 255, cv2.NORM_MINMAX, dtype=cv2.CV_8U)

  cv2.imwrite(target+file.split('.')[0]+'.jpg',img)
'''
```

```
100%|██████████| 101/101 [00:48<00:00,  2.07it/s]
```

In [86]:

```
'''
def find_classes(dir):
    classes = [d for d in os.listdir(dir) if os.path.isdir(os.path.join(dir, d))]
    classes.sort()
    class_to_idx = {classes[i]: i for i in range(len(classes))}
    return classes, class_to_idx

IMG_EXTENSIONS = [
    '.jpg', '.JPG', '.jpeg', '.JPEG',
    '.png', '.PNG', '.ppm', '.PPM', '.bmp', '.BMP','.tif'
]

def is_image_file(filename):
    return any(filename.endswith(extension) for extension in IMG_EXTENSIONS)


def make_dataset(dir, class_to_idx):
    images = []
    dir = os.path.expanduser(dir)
    for target in sorted(os.listdir(dir)):
        d = os.path.join(dir, target)
        if not os.path.isdir(d):
            continue

        for root, _, fnames in sorted(os.walk(d)):
            for fname in sorted(fnames):
                if is_image_file(fname):
                    path = os.path.join(root, fname)
                    item = (path, class_to_idx[target])
                    images.append(item)

    return images

class ImageFolder(torch.utils.data.Dataset):

  def __init__(self, root, transform=None, target_transform=None):
      classes, class_to_idx = find_classes(root)
      imgs = make_dataset(root, class_to_idx)
      if len(imgs) == 0:
          raise(RuntimeError("Found 0 images in subfolders of: " + root + "\n"
                             "Supported image extensions are: " + ",".join(IMG_EXTENSIO
NS)))

      self.root = root
      self.imgs = imgs
      self.classes = classes
      self.class_to_idx = class_to_idx
      self.transform = transform
      self.target_transform = target_transform
```

```
  def __getitem__(self, index):

      path, target = self.imgs[index]
      #print(ok)
      #img = self.loader(path)
      img_13  = tifffile.imread(path)
      img_bgr = img_13[:,:,1:4]
      img = img_bgr[::-1]
      img = cv2.normalize(img, None, 0, 255, cv2.NORM_MINMAX, dtype=cv2.CV_8U)
      if self.transform is not None:
          img = self.transform(img)
      if self.target_transform is not None:
          target = self.target_transform(target)
      return img, target

  def __len__(self):
      return len(self.imgs)
'''
```

Dataset and Dataloader initialization

In [133]:

```
#Pre processing the data
normalize = transforms.Normalize(mean = [0.485,0.456,0.406],
                                 std = [0.229,0.224,0.225])
resize = transforms.Resize((224,224))



preprocessor = transforms.Compose([ resize, transforms.ToTensor(), normalize
                                  ])

aerial_dataset_full = get_sat_data(aerial_path,preprocessor)

# Creating data indices for training and validation splits:
dataset_size = len(aerial_dataset_full)
indices = list(range(dataset_size))
validation_split = 0.2
split = int(np.floor(validation_split * dataset_size))
shuffle_dataset = True
random_seed= 101

if shuffle_dataset :
    np.random.seed(random_seed)
    np.random.shuffle(indices)
train_indices, val_indices = indices[split:], indices[:split]

# Creating PT data samplers and loaders:
train_sampler = SubsetRandomSampler(train_indices)
valid_sampler = SubsetRandomSampler(val_indices)

aerial_train_loader = torch.utils.data.DataLoader(aerial_dataset_full, batch_size=16,
                                                  sampler=train_sampler)
aerial_validation_loader = torch.utils.data.DataLoader(aerial_dataset_full, batch_size=16
,
                                                       sampler=valid_sampler)
```

In [134]:

```
print(aerial_dataset_full[0])
```

```
(tensor([[[-1.6898, -1.6898, -1.6898,  ...,  0.3994,  0.3823,  0.3823],
         [-1.6898, -1.6898, -1.6898,  ...,  0.3994,  0.3823,  0.3823],
         [-1.6898, -1.6898, -1.6898,  ...,  0.3823,  0.3652,  0.3652],
         ...,
         [-2.0494, -2.0494, -2.0494,  ...,  1.0844,  1.1015,  1.1015],
         [-2.0494, -2.0494, -2.0494,  ...,  1.1015,  1.1187,  1.1187],
         [-2.0494, -2.0494, -2.0494,  ...,  1.1015,  1.1187,  1.1187]],
```

```
        [[-0.5651, -0.5651, -0.5651,  ..., -0.1800, -0.1975, -0.1975],
         [-0.5651, -0.5651, -0.5651,  ..., -0.1800, -0.1975, -0.1975],
         [-0.5651, -0.5651, -0.5651,  ..., -0.1975, -0.2150, -0.2150],
         ...,
         [-1.3004, -1.3004, -1.3004,  ...,  0.1702,  0.1877,  0.1877],
         [-1.2829, -1.2829, -1.2829,  ...,  0.1877,  0.2052,  0.2052],
         [-1.2829, -1.2829, -1.2829,  ...,  0.1877,  0.2052,  0.2052]],

        [[-0.6541, -0.6541, -0.6541,  ..., -0.2707, -0.2881, -0.2881],
         [-0.6541, -0.6541, -0.6541,  ..., -0.2707, -0.2881, -0.2881],
         [-0.6541, -0.6541, -0.6541,  ..., -0.2881, -0.3055, -0.3055],
         ...,
         [-0.9330, -0.9330, -0.9330,  ...,  0.0779,  0.0953,  0.0953],
         [-0.9330, -0.9330, -0.9330,  ...,  0.0953,  0.1128,  0.1128],
         [-0.9330, -0.9330, -0.9330,  ...,  0.0953,  0.1128,  0.1128]]]), 0)
```

In [131]:

```
num_classes = 5
```

Training and Validation/Test loop

In [150]:

```
def training_and_validation_loop(epochs,xp_lr_scheduler,model,optmizer,aerial_train_loade
r,aerial_validation_loader,best_acc,best_model_wts,saved_model_name):

  train_loss = []
  test_loss = []
  accuracy = []

  for e in range(epochs):
        step_lr_scheduler.step()

        #put model in training mode
        model.train()
        avg_loss = 0

        for i, (x,y) in enumerate(aerial_train_loader):
              optimizer.zero_grad()

              if gpu_flag:
                    img_var = Variable(x).cuda()
                    label_actual = Variable(y).cuda()
              else:
                    img_var = Variable(x)
                    label_actual = Variable(y)

              label_predicted = model.forward(img_var)
              loss = criterion(label_predicted,label_actual)
              loss.backward()

              if(i%10 == 0):
                    print(i, loss.item())
              avg_loss+=loss.item()
              optimizer.step()

        print("Done Training")
        train_loss.append(avg_loss*1.0/(i+1))

        #set model in evaluation mode
        model.eval()
        avg_loss = 0
        correct_pred = 0
        total_pred = 0

        for i, (x_test,y_test) in enumerate(aerial_validation_loader):
```

```
            if gpu_flag:
                img_test_var = Variable(x_test).cuda()
                label_test_var = Variable(y_test).cuda()
            else:
                img_test_var = Variable(x_test)
                label_test_var = Variable(y_test)

            label_predicted_test = model.forward(img_test_var)
            loss = criterion(label_predicted_test,label_test_var)
            avg_loss+=loss.item()
            vals, label_predicted = torch.max(label_predicted_test,1)

            correct_pred += (label_predicted.cpu().data.numpy()==label_test_var.cpu().da
ta.numpy()).sum()
            total_pred += len(label_predicted_test.cpu())

        test_loss.append(avg_loss*1.0/i)
        accuracy.append(correct_pred*100.0/total_pred)
        print("Epoch: ", e, "Train Loss: ", train_loss[-1], "Test Loss: ", test_loss[-1]
, "Accuracy: ", accuracy[-1])

        #replace model saved
        if accuracy[-1]>best_acc:
            best_acc = accuracy[-1]
            best_model_wts = copy.deepcopy(model.state_dict())
            model.load_state_dict(best_model_wts)
            torch.save(model,f'/content/drive/My Drive/sentinel-2/{saved_model_name}.pt'
)
            print("Saved model with accuracy: ", best_acc)

  return train_loss,test_loss,accuracy
```

VGG-16 Model Initialization

In [151]:

```
# Initialize the model
model = models.vgg16(pretrained=True)

# Change the device to GPU
device = torch.device('cuda:0' if torch.cuda.is_available() else "cpu")
```

In [152]:

```
# Freeze training for all layers
for param in model.features.parameters():
    param.require_grad = False


num_features = model.classifier[6].in_features
# Remove last layer
features = list(model.classifier.children())[:-1]

# Add our layer with 10 outputs
features.extend([nn.Linear(num_features, num_classes)])

# Replace the model classifier
model.classifier = nn.Sequential(*features)

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.001, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer, step_size=7, gamma=0.1)


#preprocessor = transforms.Compose([resize,transforms.ToTensor(),normalize])
```

In [153]:

```
gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()
    criterion = criterion.cuda()

print(model)
```

```
True
VGG(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (1): ReLU(inplace=True)
    (2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (3): ReLU(inplace=True)
    (4): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (5): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (6): ReLU(inplace=True)
    (7): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (8): ReLU(inplace=True)
    (9): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (10): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (13): ReLU(inplace=True)
    (14): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (15): ReLU(inplace=True)
    (16): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (17): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (18): ReLU(inplace=True)
    (19): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (20): ReLU(inplace=True)
    (21): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (22): ReLU(inplace=True)
    (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
    (24): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (25): ReLU(inplace=True)
    (26): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (27): ReLU(inplace=True)
    (28): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (29): ReLU(inplace=True)
    (30): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(7, 7))
  (classifier): Sequential(
    (0): Linear(in_features=25088, out_features=4096, bias=True)
    (1): ReLU(inplace=True)
    (2): Dropout(p=0.5, inplace=False)
    (3): Linear(in_features=4096, out_features=4096, bias=True)
    (4): ReLU(inplace=True)
    (5): Dropout(p=0.5, inplace=False)
    (6): Linear(in_features=4096, out_features=5, bias=True)
  )
)
```

In [142]:

```
tqdm = partial(tqdm, position=0, leave=True)
```

VGG16 Model Training and Validation

In [154]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_vgg,test_loss_vgg,accuracy_vgg = training_and_validation_loop(epochs,step_lr_s
```

```
cheduler,model,optimizer,aerial_train_loader,aerial_validation_loader,best_acc,best_model_wts,'vgg16')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Detected call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later, you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step()`.  Failure to do this will result in PyTorch skipping the first value of the learning rate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.5527842044830322
10 1.1667479276657104
20 0.4904910922050476
Done Training
Epoch:  0 Train Loss:  0.7880626530028306 Test Loss:  0.48988191597163677 Accuracy:  86.13861386138613
Saved model with accuracy:  86.13861386138613
0 0.49932748079299927
10 0.5737537741661072
20 0.31253236532211304
Done Training
Epoch:  1 Train Loss:  0.4315136923956183 Test Loss:  0.19656771731873354 Accuracy:  97.02970297029702
Saved model with accuracy:  97.02970297029702
0 0.2683732509613037
10 0.030051369220018387
20 0.023899676278233528
Done Training
Epoch:  2 Train Loss:  0.16336509306879285 Test Loss:  0.20336214414176843 Accuracy:  94.05940594059406
0 0.4393337070941925
10 0.021655520424246788
20 0.07452696561813354
Done Training
Epoch:  3 Train Loss:  0.17263744227910557 Test Loss:  0.3493415353198846 Accuracy:  93.06930693069307
0 0.06903021782636642
10 0.024842623621225357
20 0.19570061564445496
Done Training
Epoch:  4 Train Loss:  0.06718521419231994 Test Loss:  0.1708200064022094 Accuracy:  98.01980198019803
Saved model with accuracy:  98.01980198019803
0 0.015900788828730583
10 0.01582414284348488
20 0.16407975554466248
Done Training
Epoch:  5 Train Loss:  0.032973583098142766 Test Loss:  0.2692276057059644 Accuracy:  96.03960396039604
0 0.0057505345903337
10 0.00110455765388906
20 0.0022066733799874783
Done Training
Epoch:  6 Train Loss:  0.016668705225478895 Test Loss:  0.36249972550043214 Accuracy:  96.03960396039604
0 0.0008651029784232378
10 0.003201031591743231
20 0.0007410083780996501
Done Training
Epoch:  7 Train Loss:  0.006345281222400865 Test Loss:  0.23956618032146557 Accuracy:  96.03960396039604
0 0.005501323379576206
10 0.004438275471329689
20 0.001072247396223247
Done Training
Epoch:  8 Train Loss:  0.0022743612241286496 Test Loss:  0.23154676596944532 Accuracy:  96.03960396039604
0 0.0022516895551234484
10 0.0040488713420927525
20 0.00182342529296875
Done Training
```

Epoch: 9 Train Loss: 0.005463913257906147 Test Loss: 0.22332368377343906 Accuracy: 9
6.03960396039604

Resnet-50 Model Training and Validation

In [158]:

```
gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.resnet50(pretrained = True)

#append a new last layer
model.fc = nn.Linear(2048,num_classes)

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

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

```
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fal
se)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
      (conv3): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
  )
  (layer2): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
    (3): Bottleneck(
      (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
  )
  (layer3): Sequential(
    (0): Bottleneck(
```

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

```
rue)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
  )
  (layer4): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(2048, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(2048, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=F
alse)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=2048, out_features=5, bias=True)
)
```

In [159]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_resnet,test_loss_resnet,accuracy_resnet = training_and_validation_loop(epochs,
step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loader,best_acc,b
est_model_wts,'resnet50')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Dete
cted call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later
```

```
you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step(
)`.  Failure to do this will result in PyTorch skipping the first value of the learning r
ate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjus
t-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.6110183000564575
10 0.5589222311973572
20 1.349152684211731
Done Training
Epoch:  0 Train Loss:  0.9287485717437588 Test Loss:  0.9159820924202601 Accuracy:  72.27
722772277228
Saved model with accuracy:  72.27722772277228
0 1.3665858507156372
10 0.2676994204521179
20 0.4635784924030304
Done Training
Epoch:  1 Train Loss:  0.5461058244109154 Test Loss:  1.049634374678135 Accuracy:  75.247
52475247524
Saved model with accuracy:  75.24752475247524
0 0.3235670328140259
10 0.03906668722629547
20 0.2946530282497406
Done Training
Epoch:  2 Train Loss:  0.42483941780833095 Test Loss:  0.8813686346014341 Accuracy:  80.1
980198019802
Saved model with accuracy:  80.1980198019802
0 1.0905179977416992
10 0.3394052982330322
20 0.44129037857055664
Done Training
Epoch:  3 Train Loss:  0.34826357662677765 Test Loss:  0.3741537357370059 Accuracy:  84.1
5841584158416
Saved model with accuracy:  84.15841584158416
0 0.23335310816764832
10 0.015993745997548103
20 0.22321070730686188
Done Training
Epoch:  4 Train Loss:  0.165728610008955 Test Loss:  0.25290432991459966 Accuracy:  96.03
960396039604
Saved model with accuracy:  96.03960396039604
0 0.015189481899142265
10 0.09379495680332184
20 0.030404366552829742
Done Training
Epoch:  5 Train Loss:  0.09600810106628789 Test Loss:  0.3074860156048089 Accuracy:  95.0
4950495049505
0 0.03764432296156883
10 0.1498563587665558
20 0.007877579890191555
Done Training
Epoch:  6 Train Loss:  0.07369136228226125 Test Loss:  0.41468999123511213 Accuracy:  95.
04950495049505
0 0.057389602065086365
10 0.021660560742020607
20 0.06330671161413193
Done Training
Epoch:  7 Train Loss:  0.08703623591170001 Test Loss:  0.47049053634206456 Accuracy:  95.
04950495049505
0 0.006919586565345526
10 0.033407341688871384
20 0.01770119182765484
Done Training
Epoch:  8 Train Loss:  0.037812725349795 07 Test Loss:  0.3121490275952965 Accuracy:  95.0
4950495049505
0 0.012149544432759285
10 0.03099174238741398
20 0.007940023206174374
Done Training
Epoch:  9 Train Loss:  0.024119627487380058 Test Loss:  0.30220169263581437 Accuracy:  96
.03960396039604
```

Densenet (121) Model Training and Validation

In [161]:

```
gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.densenet121(pretrained = True)

#append a new last layer
model.fc = nn.Linear(1024,num_classes)

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
DenseNet(
  (features): Sequential(
    (conv0): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
    (norm0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    (relu0): ReLU(inplace=True)
    (pool0): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
    (denseblock1): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stat
s=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(96, eps=1e-05, momentum=0.1, affine=True, track_running_stat
s=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(96, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer4): _DenseLayer(
```

```
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
    )
    (transition1): _Transition(
      (norm): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock2): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
```

```
False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
    )
    (transition2): _Transition(
      (norm): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock3): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer4): _DenseLayer(
```

```
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer17): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1, affine=True, track_running_sta
```

```
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer18): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer19): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer20): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer21): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer22): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer23): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer24): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
    )
    (transition3): _Transition(
      (norm): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats
=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
```

```
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_sta
ts=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=
False)
      )
    )
    (norm5): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
  )
  (classifier): Linear(in_features=1024, out_features=1000, bias=True)
  (fc): Linear(in_features=1024, out_features=5, bias=True)
)
```

In [162]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_densenet,test_loss_densenet,accuracy_densenet = training_and_validation_loop(e
pochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loader,best
_acc,best_model_wts,'densenet121')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Detected call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later, you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step()`.  Failure to do this will result in PyTorch skipping the first value of the learning rate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 9.705202102661133
10 1.8997547626495361
20 0.2708981931209564
Done Training
Epoch:  0 Train Loss:  2.325413996210465 Test Loss:  4.114207178354263 Accuracy:  53.46534653465346
Saved model with accuracy:  53.46534653465346
0 0.655325710773468
10 1.1922310590744019
20 0.2323516458272934
Done Training
Epoch:  1 Train Loss:  0.8417523835714047 Test Loss:  1.111289491256078 Accuracy:  68.31683168316832
Saved model with accuracy:  68.31683168316832
0 0.8691451549530029
10 0.8151715993881226
20 1.1121634244918823
Done Training
Epoch:  2 Train Loss:  0.8161684715977082 Test Loss:  0.7000947905083498 Accuracy:  88.11881188118812
Saved model with accuracy:  88.11881188118812
0 0.10334624350070953
10 0.4691743850708008
20 0.027096794918179512
Done Training
Epoch:  3 Train Loss:  0.8315990215453964 Test Loss:  0.7349641422430674 Accuracy:  77.22772277227723
0 0.021810298785567284
10 0.11064959317445755
20 0.9100956320762634
Done Training
Epoch:  4 Train Loss:  0.5999822888093499 Test Loss:  0.4965669612089793 Accuracy:  93.06930693069307
Saved model with accuracy:  93.06930693069307
0 0.20059028267860413
10 0.15047284960746765
20 0.5790111422538757
Done Training
Epoch:  5 Train Loss:  0.22976944065437868 Test Loss:  0.2640717608543734 Accuracy:  90.0990099009901
0 0.007777201011776924
10 0.787854790687561
20 0.142087921500206
Done Training
Epoch:  6 Train Loss:  0.16637964783093104 Test Loss:  0.25434550767143566 Accuracy:  91.08910891089108
0 0.17004606127738953
10 0.21045733988285065
20 0.1657445728778839
Done Training
Epoch:  7 Train Loss:  0.1393758445046842 Test Loss:  0.3628948579231898 Accuracy:  95.04950495049505
Saved model with accuracy:  95.04950495049505
0 0.004513930529356003
10 0.16530217230319977
20 0.031200917437672615
Done Training
Epoch:  8 Train Loss:  0.13758672763092014 Test Loss:  0.20719012493888536 Accuracy:  94.05940594059406
0 0.06431688368320465
10 0.02816973254084587
20 0.005277049727737904
Done Training
Epoch:  9 Train Loss:  0.04339828609059063 Test Loss:  0.27611384928847355 Accuracy:  95.
```

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ShuffleNet Model Training and Validation

In [175]:

```
gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.shufflenet_v2_x1_0(pretrained = True)
#append a new last layer
model.fc = nn.Linear(1024,num_classes)

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
ShuffleNetV2(
  (conv1): Sequential(
    (0): Conv2d(3, 24, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
    (1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU(inplace=True)
  )
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (stage2): Sequential(
    (0): InvertedResidual(
      (branch1): Sequential(
        (0): Conv2d(24, 24, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=24,
bias=False)
        (1): BatchNorm2d(24, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (2): Conv2d(24, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (3): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (4): ReLU(inplace=True)
      )
      (branch2): Sequential(
        (0): Conv2d(24, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (2): ReLU(inplace=True)
        (3): Conv2d(58, 58, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=58,
bias=False)
        (4): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (5): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (7): ReLU(inplace=True)
      )
    )
    (1): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (2): ReLU(inplace=True)
```

```
        (3): Conv2d(58, 58, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=58,
bias=False)
        (4): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (5): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (7): ReLU(inplace=True)
      )
    )
    (2): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (2): ReLU(inplace=True)
        (3): Conv2d(58, 58, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=58,
bias=False)
        (4): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (5): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (7): ReLU(inplace=True)
      )
    )
    (3): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (2): ReLU(inplace=True)
        (3): Conv2d(58, 58, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=58,
bias=False)
        (4): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (5): Conv2d(58, 58, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(58, eps=1e-05, momentum=0.1, affine=True, track_running_stats=Tr
ue)
        (7): ReLU(inplace=True)
      )
    )
  )
  (stage3): Sequential(
    (0): InvertedResidual(
      (branch1): Sequential(
        (0): Conv2d(116, 116, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=1
16, bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (3): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (4): ReLU(inplace=True)
      )
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (1): InvertedResidual(
```

```
    (1): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (2): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (3): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (4): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (5): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
```

```
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (6): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (7): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(116, 116, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
16, bias=False)
        (4): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(116, 116, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(116, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
  )
  (stage4): Sequential(
    (0): InvertedResidual(
      (branch1): Sequential(
        (0): Conv2d(232, 232, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=2
32, bias=False)
        (1): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (3): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (4): ReLU(inplace=True)
      )
      (branch2): Sequential(
        (0): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(232, 232, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=2
32, bias=False)
        (4): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
```

```
        (7): ReLU(inplace=True)
      )
    )
    (1): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(232, 232, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=2
32, bias=False)
        (4): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (2): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(232, 232, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=2
32, bias=False)
        (4): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
    (3): InvertedResidual(
      (branch1): Sequential()
      (branch2): Sequential(
        (0): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (2): ReLU(inplace=True)
        (3): Conv2d(232, 232, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=2
32, bias=False)
        (4): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (5): Conv2d(232, 232, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (6): BatchNorm2d(232, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
        (7): ReLU(inplace=True)
      )
    )
  )
  (conv5): Sequential(
    (0): Conv2d(464, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True
)
    (2): ReLU(inplace=True)
  )
  (fc): Linear(in_features=1024, out_features=5, bias=True)
)
```

In [176]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_shufflenet,test_loss_shufflenet,accuracy_shufflenet = training_and_validation_
loop(epochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loade
r,best_acc,best_model_wts,'shufflenet')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Detected call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later, you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step()`.  Failure to do this will result in PyTorch skipping the first value of the learning rate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.6033337116241455
10 1.6107604503631592
20 1.5923737287521362
Done Training
Epoch:  0 Train Loss:  1.6067176919717054 Test Loss:  1.8734468420346577 Accuracy:  13.861386138613861
Saved model with accuracy:  13.861386138613861
0 1.5837866067886353
10 1.582115650177002
20 1.582777976989746
Done Training
Epoch:  1 Train Loss:  1.596213868031135 Test Loss:  1.861076295375824 Accuracy:  13.861386138613861
0 1.6032180786132812
10 1.5895551443099976
20 1.6050935983657837
Done Training
Epoch:  2 Train Loss:  1.583980408998636 Test Loss:  1.8472758332888286 Accuracy:  31.683168316831683
Saved model with accuracy:  31.683168316831683
0 1.5536614656448364
10 1.56793212890625
20 1.5777385234832764
Done Training
Epoch:  3 Train Loss:  1.570602563711313 Test Loss:  1.8322415947914124 Accuracy:  34.65346534653465
Saved model with accuracy:  34.65346534653465
0 1.564038634300232
10 1.5339574813842773
20 1.5721039772033691
Done Training
Epoch:  4 Train Loss:  1.5625664316690886 Test Loss:  1.8287366429964702 Accuracy:  35.64356435643565
Saved model with accuracy:  35.64356435643565
0 1.5709927082061768
10 1.5568150281906128
20 1.5404891967773438
Done Training
Epoch:  5 Train Loss:  1.5554108161192675 Test Loss:  1.8219211896260579 Accuracy:  41.584158415841586
Saved model with accuracy:  41.584158415841586
0 1.5704905986785889
10 1.5494848489761353
20 1.5431454181671143
Done Training
Epoch:  6 Train Loss:  1.5522752037415137 Test Loss:  1.8143902222315471 Accuracy:  45.54455445544554
Saved model with accuracy:  45.54455445544554
0 1.5349936485290527
10 1.541061520576477
20 1.5467309951782227
Done Training
Epoch:  7 Train Loss:  1.544596763757559 Test Loss:  1.8095630009969075 Accuracy:  44.554455445544555
0 1.5348665714263916
10 1.5333999395370483
20 1.5395089387893677
Done Training
Epoch:  8 Train Loss:  1.5413180818924537 Test Loss:  1.794878363609314 Accuracy:  47.524752475247524
Saved model with accuracy:  47.524752475247524
0 1.5470981597900391
10 1.5344599485397339
20 1.5345213413238525
```

```
Done Training
Epoch:  9 Train Loss:  1.5399072903853197 Test Loss:  1.795938531557719 Accuracy:  48.514
85148514851
Saved model with accuracy:  48.51485148514851
```

SqueezeNet Model Training and Validation

In [179]:

```
gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.squeezenet1_1(pretrained = True)
#append a new last layer
#model.fc = nn.Linear(1024,num_classes)

# Freeze training for all layers
for param in model.features.parameters():
    param.require_grad = False


# num_features = model.classifier[6].in_features
model.classifier[1] = nn.Conv2d(512, num_classes, kernel_size=(1,1), stride=(1,1))
model.num_classes = num_classes

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
SqueezeNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(2, 2))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=True)
    (3): Fire(
      (squeeze): Conv2d(64, 16, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(16, 64, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(16, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (4): Fire(
      (squeeze): Conv2d(128, 16, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(16, 64, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(16, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=True)
    (6): Fire(
      (squeeze): Conv2d(128, 32, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(32, 128, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(32, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
```

```
    )
    (7): Fire(
      (squeeze): Conv2d(256, 32, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(32, 128, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(32, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (8): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=True)
    (9): Fire(
      (squeeze): Conv2d(256, 48, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(48, 192, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(48, 192, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (10): Fire(
      (squeeze): Conv2d(384, 48, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(48, 192, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(48, 192, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (11): Fire(
      (squeeze): Conv2d(384, 64, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(64, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
    (12): Fire(
      (squeeze): Conv2d(512, 64, kernel_size=(1, 1), stride=(1, 1))
      (squeeze_activation): ReLU(inplace=True)
      (expand1x1): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1))
      (expand1x1_activation): ReLU(inplace=True)
      (expand3x3): Conv2d(64, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (expand3x3_activation): ReLU(inplace=True)
    )
  )
  (classifier): Sequential(
    (0): Dropout(p=0.5, inplace=False)
    (1): Conv2d(512, 5, kernel_size=(1, 1), stride=(1, 1))
    (2): ReLU(inplace=True)
    (3): AdaptiveAvgPool2d(output_size=(1, 1))
  )
)
```

In [180]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_squeezenet,test_loss_squeezenet,accuracy_squeezenet = training_and_validation_
loop(epochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loade
r,best_acc,best_model_wts,'squeezenet')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Dete
cted call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later,
you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step(
)`.  Failure to do this will result in PyTorch skipping the first value of the learning r
ate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjus
t-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.7215379476547241
10 1.6010282039642334
20 1.4354884624481201
Done Training
```

```
Epoch:  0 Train Loss:  1.4422244085715368 Test Loss:  1.635127862294515 Accuracy:  35.643
56435643565
Saved model with accuracy:  35.64356435643565
0 1.3008087873458862
10 1.2585126161575317
20 0.783483624458313
Done Training
Epoch:  1 Train Loss:  1.208700737127891 Test Loss:  1.1290804743766785 Accuracy:  53.465
34653465346
Saved model with accuracy:  53.46534653465346
0 1.0218905210494995
10 1.1352678537368774
20 1.1979849338531494
Done Training
Epoch:  2 Train Loss:  1.0654778755628145 Test Loss:  1.1282269656658173 Accuracy:  63.36
6336633663366
Saved model with accuracy:  63.366336633663366
0 0.9712321162223816
10 1.3727526664733887
20 1.3082871437072754
Done Training
Epoch:  3 Train Loss:  1.1262206114255464 Test Loss:  0.9444511830806732 Accuracy:  73.26
732673267327
Saved model with accuracy:  73.26732673267327
0 1.116815209388733
10 0.6448909044265747
20 0.477353572845459
Done Training
Epoch:  4 Train Loss:  0.812299424639115 Test Loss:  0.7945498277743658 Accuracy:  77.227
72277227723
Saved model with accuracy:  77.22772277227723
0 0.9044416546821594
10 0.43160927295684814
20 0.6947808861732483
Done Training
Epoch:  5 Train Loss:  0.6539827894705993 Test Loss:  0.7696951727072397 Accuracy:  78.21
782178217822
Saved model with accuracy:  78.21782178217822
0 0.3752029538154602
10 0.5891660451889038
20 0.291564404964447
Done Training
Epoch:  6 Train Loss:  0.5745096917335804 Test Loss:  0.45032640794912976 Accuracy:  86.1
3861386138613
Saved model with accuracy:  86.13861386138613
0 0.5270010232925415
10 0.46165716648101807
20 0.6236396431922913
Done Training
Epoch:  7 Train Loss:  0.522449747301065 Test Loss:  0.5495490295191606 Accuracy:  79.207
92079207921
0 0.3170940577983856
10 0.47029057145118713
20 0.3927542567253113
Done Training
Epoch:  8 Train Loss:  0.45165283060990846 Test Loss:  0.4318101741373539 Accuracy:  87.1
2871287128714
Saved model with accuracy:  87.12871287128714
0 0.2743155360221863
10 0.22817355394363403
20 0.473066121339798
Done Training
Epoch:  9 Train Loss:  0.3533420834976893 Test Loss:  0.45879171291987103 Accuracy:  85.1
4851485148515
```

Mobilenet-V3 Model Training and Validation

In [183]:

```
gpu_flag = torch.cuda.is_available()
```

```
#preloading Resnet18
model = models.mobilenet_v3_large(pretrained = True)
#append a new last layer


# Freeze training for all layers
for param in model.features.parameters():
    param.require_grad = False

model.classifier[3] = nn.Linear(1280,num_classes)
# num_features = model.classifier[6].in_features
#model.classifier[1] = nn.Conv2d(512, num_classes, kernel_size=(1,1), stride=(1,1))
#model.num_classes = num_classes

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
MobileNetV3(
  (features): Sequential(
    (0): ConvBNActivation(
      (0): Conv2d(3, 16, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (1): BatchNorm2d(16, eps=0.001, momentum=0.01, affine=True, track_running_stats=Tru
e)
      (2): Hardswish()
    )
    (1): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(16, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=1
6, bias=False)
          (1): BatchNorm2d(16, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(16, 16, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(16, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (2): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(16, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(64, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(64, 64, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups=6
4, bias=False)
          (1): BatchNorm2d(64, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (2): ConvBNActivation(
```

```
          (0): Conv2d(64, 24, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(24, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (3): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(72, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(72, 72, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups=7
2, bias=False)
          (1): BatchNorm2d(72, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (2): ConvBNActivation(
          (0): Conv2d(72, 24, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(24, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (4): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(72, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(72, 72, kernel_size=(5, 5), stride=(2, 2), padding=(2, 2), groups=7
2, bias=False)
          (1): BatchNorm2d(72, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): ReLU(inplace=True)
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(72, 24, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(24, 72, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(72, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(40, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (5): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(40, 120, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(120, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(120, 120, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), groups
=120, bias=False)
          (1): BatchNorm2d(120, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): ReLU(inplace=True)
```

```
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(120, 32, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(32, 120, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(120, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(40, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (6): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(40, 120, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(120, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): ReLU(inplace=True)
        )
        (1): ConvBNActivation(
          (0): Conv2d(120, 120, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), groups
=120, bias=False)
          (1): BatchNorm2d(120, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): ReLU(inplace=True)
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(120, 32, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(32, 120, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(120, 40, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(40, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (7): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(40, 240, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(240, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(240, 240, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups
=240, bias=False)
          (1): BatchNorm2d(240, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): ConvBNActivation(
          (0): Conv2d(240, 80, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(80, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (8): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(80, 200, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(200, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
```

```
        )
        (1): ConvBNActivation(
          (0): Conv2d(200, 200, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=200, bias=False)
          (1): BatchNorm2d(200, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): ConvBNActivation(
          (0): Conv2d(200, 80, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(80, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (9): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(80, 184, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(184, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(184, 184, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=184, bias=False)
          (1): BatchNorm2d(184, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): ConvBNActivation(
          (0): Conv2d(184, 80, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(80, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (10): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(80, 184, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(184, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(184, 184, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=184, bias=False)
          (1): BatchNorm2d(184, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): ConvBNActivation(
          (0): Conv2d(184, 80, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(80, eps=0.001, momentum=0.01, affine=True, track_running_stats
=True)
          (2): Identity()
        )
      )
    )
    (11): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(80, 480, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(480, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(480, 480, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
```

```
=480, bias=False)
          (1): BatchNorm2d(480, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(480, 120, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(120, 480, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(480, 112, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(112, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Identity()
        )
      )
    )
    (12): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(112, 672, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(672, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(672, 672, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=672, bias=False)
          (1): BatchNorm2d(672, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(672, 168, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(168, 672, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(672, 112, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(112, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Identity()
        )
      )
    )
    (13): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(112, 672, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(672, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(672, 672, kernel_size=(5, 5), stride=(2, 2), padding=(2, 2), groups
=672, bias=False)
          (1): BatchNorm2d(672, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(672, 168, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(168, 672, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(672, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(160, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Identity()
        )
```

```
      )
    )
    (14): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(960, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(960, 960, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), groups
=960, bias=False)
          (1): BatchNorm2d(960, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(960, 240, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(240, 960, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(960, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(160, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Identity()
        )
      )
    )
    (15): InvertedResidual(
      (block): Sequential(
        (0): ConvBNActivation(
          (0): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(960, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (1): ConvBNActivation(
          (0): Conv2d(960, 960, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), groups
=960, bias=False)
          (1): BatchNorm2d(960, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Hardswish()
        )
        (2): SqueezeExcitation(
          (fc1): Conv2d(960, 240, kernel_size=(1, 1), stride=(1, 1))
          (relu): ReLU(inplace=True)
          (fc2): Conv2d(240, 960, kernel_size=(1, 1), stride=(1, 1))
        )
        (3): ConvBNActivation(
          (0): Conv2d(960, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
          (1): BatchNorm2d(160, eps=0.001, momentum=0.01, affine=True, track_running_stat
s=True)
          (2): Identity()
        )
      )
    )
    (16): ConvBNActivation(
      (0): Conv2d(160, 960, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (1): BatchNorm2d(960, eps=0.001, momentum=0.01, affine=True, track_running_stats=Tr
ue)
      (2): Hardswish()
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=1)
  (classifier): Sequential(
    (0): Linear(in_features=960, out_features=1280, bias=True)
    (1): Hardswish()
    (2): Dropout(p=0.2, inplace=True)
    (3): Linear(in_features=1280, out_features=5, bias=True)
  )
```

)

In [184]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_mobilenetv3,test_loss_mobilenetv3,accuracy_mobilenetv3 = training_and_validati
on_loop(epochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_lo
ader,best_acc,best_model_wts,'mobilenetv3')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Dete
cted call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later,
you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step(
)`.  Failure to do this will result in PyTorch skipping the first value of the learning r
ate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjus
t-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.6962727308273315
10 0.9379370808601379
20 0.5122504830360413
Done Training
Epoch:  0 Train Loss:  0.9164435823376362 Test Loss:  1.0266722242037456 Accuracy:  66.33
663366336634
Saved model with accuracy:  66.33663366336634
0 0.36596229672431946
10 0.2600838541984558
20 0.3212284445762634
Done Training
Epoch:  1 Train Loss:  0.22065730765461922 Test Loss:  0.6730715930461884 Accuracy:  77.2
2772277227723
Saved model with accuracy:  77.22772277227723
0 0.10982154309749603
10 0.09889861196279526
20 0.004817329812794924
Done Training
Epoch:  2 Train Loss:  0.10280085442802654 Test Loss:  0.4956468492746353 Accuracy:  79.2
0792079207921
Saved model with accuracy:  79.20792079207921
0 0.023399077355861664
10 0.042387496680021286
20 0.17555740475654602
Done Training
Epoch:  3 Train Loss:  0.09921029331878974 Test Loss:  0.45173787077267963 Accuracy:  86.
13861386138613
Saved model with accuracy:  86.13861386138613
0 0.004938613623380661
10 0.060320060700178146
20 0.05156673863530159
Done Training
Epoch:  4 Train Loss:  0.0688504070813696 Test Loss:  0.3266122452914715 Accuracy:  90.09
90099009901
Saved model with accuracy:  90.0990099009901
0 0.04229728505015373
10 0.24877209961414337
20 0.010873413644731045
Done Training
Epoch:  5 Train Loss:  0.06131853037871993 Test Loss:  0.25344367573658627 Accuracy:  95.
04950495049505
Saved model with accuracy:  95.04950495049505
0 0.017235731706023216
10 0.005363339092582464
20 0.0073574078269302845
Done Training
Epoch:  6 Train Loss:  0.06692946499858338 Test Loss:  0.3183552209908764 Accuracy:  96.0
3960396039604
Saved model with accuracy:  96.03960396039604
0 0.01606336049735546
10 0.02280532568693161
20 0.12902143597602844
Done Training
```

```
Epoch:  7 Train Loss:  0.04032459910600845 Test Loss:  0.17884549995263418 Accuracy:  94
.05940594059406
0 0.008088252507150173
10 0.021131040528416634
20 0.03559727966785431
Done Training
Epoch:  8 Train Loss:  0.06713643131885104 Test Loss:  0.26746055235465366 Accuracy:  94.
05940594059406
0 0.012187538668513298
10 0.11401718854904175
20 0.020706210285425186
Done Training
Epoch:  9 Train Loss:  0.03098501429821436 Test Loss:  0.17229785692567626 Accuracy:  95.
04950495049505
```

Resnext50 Model Training and Validation

In [188]:

```
gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.resnext50_32x4d(pretrained = True)
#append a new last layer


# Freeze training for all layers
#for param in model.features.parameters():
#    param.require_grad = False

model.fc = nn.Linear(2048,num_classes)
# num_features = model.classifier[6].in_features
#model.classifier[1] = nn.Conv2d(512, num_classes, kernel_size=(1,1), stride=(1,1))
#model.num_classes = num_classes

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
        (0): Conv2d(64, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(128, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
  )
  (layer2): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(256, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
      (conv3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
    (3): Bottleneck(
      (conv1): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(256, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (relu): ReLU(inplace=True)
    )
  )
  (layer3): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(512, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(512, 1024, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (3): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
      (conv3): Conv2d(1024, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (4): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (5): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), groups
=32, bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=T
rue)
      (conv3): Conv2d(512, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
  )
  (layer4): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(1024, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv2): Conv2d(1024, 1024, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), grou
ps=32, bias=False)
      (bn2): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv3): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
      (downsample): Sequential(
        (0): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      )
    )
    (1): Bottleneck(
      (conv1): Conv2d(2048, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv2): Conv2d(1024, 1024, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), grou
ps=32, bias=False)
      (bn2): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv3): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
    (2): Bottleneck(
      (conv1): Conv2d(2048, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv2): Conv2d(1024, 1024, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), grou
ps=32, bias=False)
      (bn2): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (conv3): Conv2d(1024, 2048, kernel_size=(1, 1), stride=(1, 1), bias=False)
```

```
      (bn3): BatchNorm2d(2048, eps=1e-05, momentum=0.1, affine=True, track_running_stats=
True)
      (relu): ReLU(inplace=True)
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=2048, out_features=5, bias=True)
)
```

In [189]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_resnext50,test_loss_resnext50,accuracy_resnext50 = training_and_validation_loo
p(epochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loader,b
est_acc,best_model_wts,'resnext50')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Dete
cted call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later,
you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step(
)`.  Failure to do this will result in PyTorch skipping the first value of the learning r
ate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjus
t-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.6011916399002075
10 1.0162638425827026
20 0.2314624786376953
Done Training
Epoch:  0 Train Loss:  0.9264364407326167 Test Loss:  0.3514340395728747 Accuracy:  92.07
920792079207
Saved model with accuracy:  92.07920792079207
0 0.1070927232503891
10 0.19874049723148346
20 0.017556529492139816
Done Training
Epoch:  1 Train Loss:  0.2772250609436574 Test Loss:  1.289975549094379 Accuracy:  89.108
91089108911
0 0.28347036242485046
10 0.08403738588094711
20 0.9381603598594666
Done Training
Epoch:  2 Train Loss:  0.5000027325004339 Test Loss:  0.5131245429317156 Accuracy:  88.11
881188118812
0 0.7235650420188904
10 0.15493351221084595
20 0.6514920592308044
Done Training
Epoch:  3 Train Loss:  0.5695049930363894 Test Loss:  0.6332099844391147 Accuracy:  83.16
831683168317
0 0.04096861183643341
10 0.1745675653219223
20 1.43146812915802
Done Training
Epoch:  4 Train Loss:  0.267289810670683 Test Loss:  0.10521493883182605 Accuracy:  96.03
960396039604
Saved model with accuracy:  96.03960396039604
0 0.07244125008583069
10 0.1705205738544464
20 0.02601541578769684
Done Training
Epoch:  5 Train Loss:  0.128083876781882 Test Loss:  0.1065621489348511 Accuracy:  97.029
70297029702
Saved model with accuracy:  97.02970297029702
0 0.009709823876619339
10 0.11867626011371613
20 0.04265532270073891
Done Training
Epoch:  6 Train Loss:  0.08838373793360706 Test Loss:  0.11272055958397686 Accuracy:  95.
04950495049505
0 0.0171968974173069
```

```
10 0.015890110284090042
20 0.09912033379077911
Done Training
Epoch:  7 Train Loss:  0.1321186474703539 Test Loss:  0.09160041188200314 Accuracy:  97.0
2970297029702
0 0.16895270347595215
10 0.0885232612490654
20 0.02021438628435135
Done Training
Epoch:  8 Train Loss:  0.0989963800753825 Test Loss:  0.10930849860111873 Accuracy:  98.0
1980198019803
Saved model with accuracy:  98.01980198019803
0 0.06568863242864609
10 0.019072074443101883
20 0.0017813225276768208
Done Training
Epoch:  9 Train Loss:  0.06514420984491992 Test Loss:  0.07508201338350773 Accuracy:  96.
03960396039604
```

In [218]:

```
#Pre processing the data
normalize = transforms.Normalize(mean = [0.485,0.456,0.406],
                                 std = [0.229,0.224,0.225])
resize = transforms.Resize((299,299))



preprocessor = transforms.Compose([ resize, transforms.ToTensor(), normalize
                                  ])

aerial_dataset_full = get_sat_data(aerial_path,preprocessor)

# Creating data indices for training and validation splits:
dataset_size = len(aerial_dataset_full)
indices = list(range(dataset_size))
validation_split = 0.2
split = int(np.floor(validation_split * dataset_size))
shuffle_dataset = True
random_seed= 101

if shuffle_dataset :
    np.random.seed(random_seed)
    np.random.shuffle(indices)
train_indices, val_indices = indices[split:], indices[:split]

# Creating PT data samplers and loaders:
train_sampler = SubsetRandomSampler(train_indices)
valid_sampler = SubsetRandomSampler(val_indices)

aerial_train_loader = torch.utils.data.DataLoader(aerial_dataset_full, batch_size=16,
                                                  sampler=train_sampler)
aerial_validation_loader = torch.utils.data.DataLoader(aerial_dataset_full, batch_size=16
,
                                                       sampler=valid_sampler)



gpu_flag = torch.cuda.is_available()

#preloading Resnet18
model = models.inception_v3(pretrained = True)
#append a new last layer


# Freeze training for all layers
#for param in model.features.parameters():
#    param.require_grad = False

model.fc = nn.Linear(2048,num_classes)
# num_features = model.classifier[6].in_features
```

```
#model.classifier[1] = nn.Conv2d(512, num_classes, kernel_size=(1,1), stride=(1,1))
#model.num_classes = num_classes
model.aux_logits=False

# define loss function
criterion = nn.CrossEntropyLoss()

# setup SGD
optimizer = torch.optim.SGD(model.parameters(), lr=0.004, momentum=0.9)

step_lr_scheduler = lr_scheduler.StepLR(optimizer,5,.3)

gpu_flag = torch.cuda.is_available()
print(gpu_flag)
if gpu_flag:
    model = model.cuda()

print(model)
```

```
True
Inception3(
  (Conv2d_1a_3x3): BasicConv2d(
    (conv): Conv2d(3, 32, kernel_size=(3, 3), stride=(2, 2), bias=False)
    (bn): BatchNorm2d(32, eps=0.001, momentum=0.1, affine=True, track_running_stats=True)
  )
  (Conv2d_2a_3x3): BasicConv2d(
    (conv): Conv2d(32, 32, kernel_size=(3, 3), stride=(1, 1), bias=False)
    (bn): BatchNorm2d(32, eps=0.001, momentum=0.1, affine=True, track_running_stats=True)
  )
  (Conv2d_2b_3x3): BasicConv2d(
    (conv): Conv2d(32, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
    (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=True)
  )
  (maxpool1): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
  (Conv2d_3b_1x1): BasicConv2d(
    (conv): Conv2d(64, 80, kernel_size=(1, 1), stride=(1, 1), bias=False)
    (bn): BatchNorm2d(80, eps=0.001, momentum=0.1, affine=True, track_running_stats=True)
  )
  (Conv2d_4a_3x3): BasicConv2d(
    (conv): Conv2d(80, 192, kernel_size=(3, 3), stride=(1, 1), bias=False)
    (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=True
)
  )
  (maxpool2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
  (Mixed_5b): InceptionA(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(192, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_1): BasicConv2d(
      (conv): Conv2d(192, 48, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(48, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_2): BasicConv2d(
      (conv): Conv2d(48, 64, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), bias=Fals
e)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(192, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(64, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
```

```
    (branch3x3dbl_3): BasicConv2d(
      (conv): Conv2d(96, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(192, 32, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(32, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
  )
  (Mixed_5c): InceptionA(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_1): BasicConv2d(
      (conv): Conv2d(256, 48, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(48, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_2): BasicConv2d(
      (conv): Conv2d(48, 64, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), bias=Fals
e)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(64, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_3): BasicConv2d(
      (conv): Conv2d(96, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(256, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
  )
  (Mixed_5d): InceptionA(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(288, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_1): BasicConv2d(
      (conv): Conv2d(288, 48, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(48, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch5x5_2): BasicConv2d(
      (conv): Conv2d(48, 64, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2), bias=Fals
e)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(288, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
```

```
e)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(64, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_3): BasicConv2d(
      (conv): Conv2d(96, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(288, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
  )
  (Mixed_6a): InceptionB(
    (branch3x3): BasicConv2d(
      (conv): Conv2d(288, 384, kernel_size=(3, 3), stride=(2, 2), bias=False)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(288, 64, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(64, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(64, 96, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fals
e)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
    (branch3x3dbl_3): BasicConv2d(
      (conv): Conv2d(96, 96, kernel_size=(3, 3), stride=(2, 2), bias=False)
      (bn): BatchNorm2d(96, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tru
e)
    )
  )
  (Mixed_6b): InceptionC(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_1): BasicConv2d(
      (conv): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_2): BasicConv2d(
      (conv): Conv2d(128, 128, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_3): BasicConv2d(
      (conv): Conv2d(128, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_1): BasicConv2d(
      (conv): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_2): BasicConv2d(
```

```
      (conv): Conv2d(128, 128, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_3): BasicConv2d(
      (conv): Conv2d(128, 128, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_4): BasicConv2d(
      (conv): Conv2d(128, 128, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_5): BasicConv2d(
      (conv): Conv2d(128, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (Mixed_6c): InceptionC(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_1): BasicConv2d(
      (conv): Conv2d(768, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_2): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_3): BasicConv2d(
      (conv): Conv2d(160, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_1): BasicConv2d(
      (conv): Conv2d(768, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_2): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_3): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_4): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
```

```
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_5): BasicConv2d(
      (conv): Conv2d(160, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (Mixed_6d): InceptionC(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_1): BasicConv2d(
      (conv): Conv2d(768, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_2): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_3): BasicConv2d(
      (conv): Conv2d(160, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_1): BasicConv2d(
      (conv): Conv2d(768, 160, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_2): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_3): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_4): BasicConv2d(
      (conv): Conv2d(160, 160, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(160, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_5): BasicConv2d(
      (conv): Conv2d(160, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
```

```
  )
  (Mixed_6e): InceptionC(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_2): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7_3): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_2): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_3): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_4): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7dbl_5): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (AuxLogits): InceptionAux(
    (conv0): BasicConv2d(
      (conv): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(128, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (conv1): BasicConv2d(
      (conv): Conv2d(128, 768, kernel_size=(5, 5), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(768, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (fc): Linear(in_features=768, out_features=1000, bias=True)
  )
```

```
  (Mixed_7a): InceptionD(
    (branch3x3_1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_2): BasicConv2d(
      (conv): Conv2d(192, 320, kernel_size=(3, 3), stride=(2, 2), bias=False)
      (bn): BatchNorm2d(320, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7x3_1): BasicConv2d(
      (conv): Conv2d(768, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7x3_2): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(1, 7), stride=(1, 1), padding=(0, 3), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7x3_3): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(7, 1), stride=(1, 1), padding=(3, 0), bias=Fa
lse)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch7x7x3_4): BasicConv2d(
      (conv): Conv2d(192, 192, kernel_size=(3, 3), stride=(2, 2), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (Mixed_7b): InceptionE(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(1280, 320, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(320, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_1): BasicConv2d(
      (conv): Conv2d(1280, 384, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_2a): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(1, 3), stride=(1, 1), padding=(0, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_2b): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(3, 1), stride=(1, 1), padding=(1, 0), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(1280, 448, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(448, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(448, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_3a): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(1, 3), stride=(1, 1), padding=(0, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
```

```
ue)
    )
    (branch3x3dbl_3b): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(3, 1), stride=(1, 1), padding=(1, 0), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(1280, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (Mixed_7c): InceptionE(
    (branch1x1): BasicConv2d(
      (conv): Conv2d(2048, 320, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(320, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_1): BasicConv2d(
      (conv): Conv2d(2048, 384, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_2a): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(1, 3), stride=(1, 1), padding=(0, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3_2b): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(3, 1), stride=(1, 1), padding=(1, 0), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_1): BasicConv2d(
      (conv): Conv2d(2048, 448, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(448, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_2): BasicConv2d(
      (conv): Conv2d(448, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_3a): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(1, 3), stride=(1, 1), padding=(0, 1), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch3x3dbl_3b): BasicConv2d(
      (conv): Conv2d(384, 384, kernel_size=(3, 1), stride=(1, 1), padding=(1, 0), bias=Fa
lse)
      (bn): BatchNorm2d(384, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
    (branch_pool): BasicConv2d(
      (conv): Conv2d(2048, 192, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn): BatchNorm2d(192, eps=0.001, momentum=0.1, affine=True, track_running_stats=Tr
ue)
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (dropout): Dropout(p=0.5, inplace=False)
  (fc): Linear(in_features=2048, out_features=5, bias=True)
)
```

In [219]:

```
epochs=10
best_model_wts = copy.deepcopy(model.state_dict())
best_acc = 0.0
train_loss_inceptionv3,test_loss_inceptionv3,accuracy_inceptionv3= training_and_validatio
n_loop(epochs,step_lr_scheduler,model,optimizer,aerial_train_loader,aerial_validation_loa
der,best_acc,best_model_wts,'inceptionv3')
```

```
/usr/local/lib/python3.7/dist-packages/torch/optim/lr_scheduler.py:134: UserWarning: Dete
cted call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later,
you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step(
)`.  Failure to do this will result in PyTorch skipping the first value of the learning r
ate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjus
t-learning-rate
  "https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate", UserWarning)
0 1.694513201713562
10 1.0917048454284668
20 0.49491679668426514
Done Training
Epoch:  0 Train Loss:  1.0073338030622556 Test Loss:  0.3565973962346713 Accuracy:  91.08
910891089108
Saved model with accuracy:  91.08910891089108
0 0.520588755607605
10 0.2112034410238266
20 0.060612358152866364
Done Training
Epoch:  1 Train Loss:  0.3076208070493661 Test Loss:  0.54404117166996 Accuracy:  85.1485
1485148515
0 0.41368117928504944
10 0.42476990818977356
20 0.5938020944595337
Done Training
Epoch:  2 Train Loss:  0.4169445474847005 Test Loss:  0.5692161619663239 Accuracy:  84.15
841584158416
0 0.5391332507133484
10 0.10983309149742126
20 0.6402960419654846
Done Training
Epoch:  3 Train Loss:  0.34146898268507075 Test Loss:  0.29244164874156314 Accuracy:  94.
05940594059406
Saved model with accuracy:  94.05940594059406
0 0.020844949409365654
10 0.24728870391845703
20 0.08756891638040543
Done Training
Epoch:  4 Train Loss:  0.21987662808253214 Test Loss:  0.13971334944168726 Accuracy:  98.
01980198019803
Saved model with accuracy:  98.01980198019803
0 0.09229560941457748
10 0.1156827062368393
20 0.07667431980371475
Done Training
Epoch:  5 Train Loss:  0.1309989677527203 Test Loss:  0.08099470722178619 Accuracy:  97.0
2970297029702
0 0.019800426438450813
10 0.00872484128922224
20 0.0453021377325058
Done Training
Epoch:  6 Train Loss:  0.1386321228212462 Test Loss:  0.09129184950143099 Accuracy:  97.0
2970297029702
0 0.044308796525001526
10 0.05256880074739456
20 0.018832072615623474
Done Training
Epoch:  7 Train Loss:  0.0753283197633349 Test Loss:  0.09106522053480148 Accuracy:  98.0
1980198019803
0 0.020167671144008636
10 0.12418577075004578
20 0.03628227487206459
Done Training
Epoch:  8 Train Loss:  0.08867174145192482 Test Loss:  0.07429948410329719 Accuracy:  98.
```

```
0198019801980
0 0.008196840062737465
10 0.2795017659664154
20 0.09500784426927567
Done Training
Epoch:  9 Train Loss:  0.09433283988171472 Test Loss:  0.0757292954561611 Accuracy:  99.0
0990099009901
Saved model with accuracy:  99.00990099009901
```

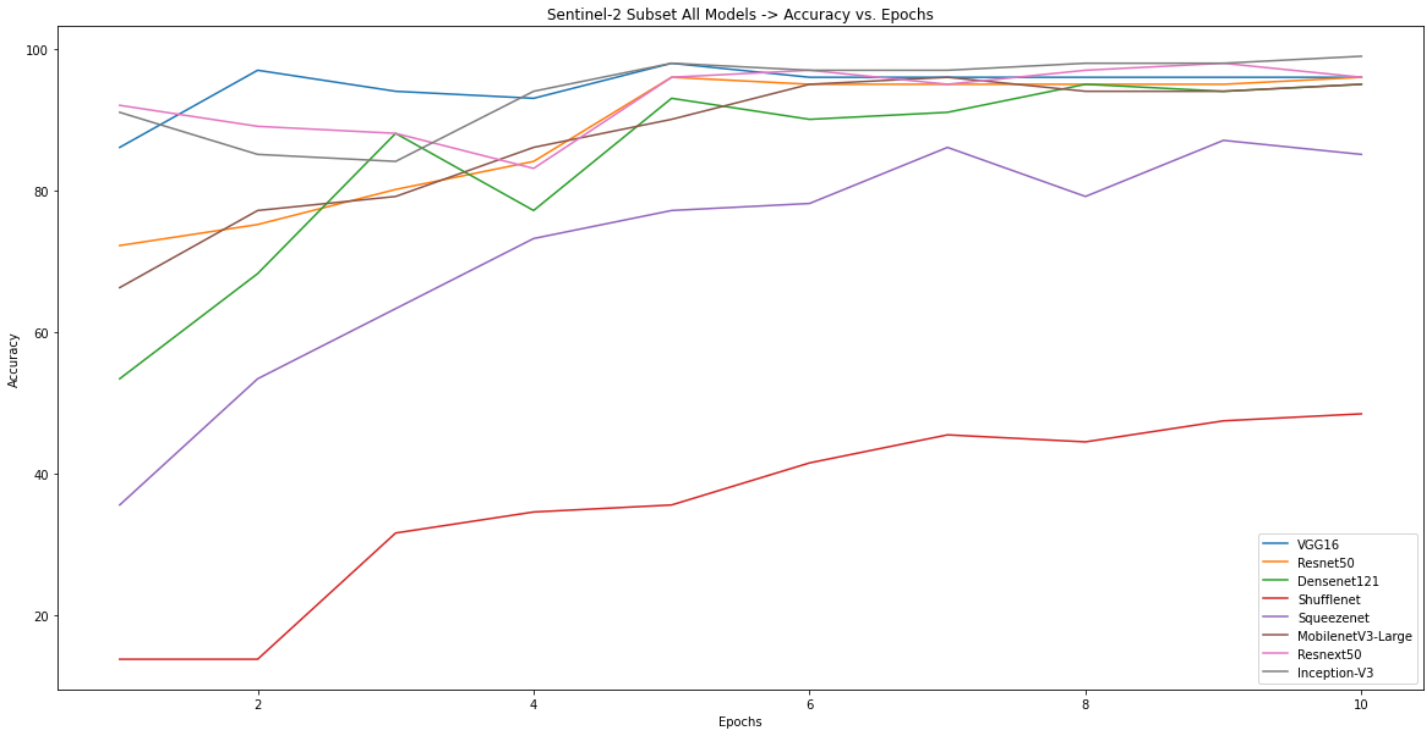
Accuracy Plot vs Epochs for All Models

In [220]:

```
list_epochs = [i+1 for i in range(10)]

plt.figure(figsize = (20,10))


plt.plot(list_epochs,accuracy_vgg,label='VGG16')
plt.plot(list_epochs,accuracy_resnet,label='Resnet50')
plt.plot(list_epochs,accuracy_densenet,label='Densenet121')
plt.plot(list_epochs,accuracy_shufflenet,label='Shufflenet')
plt.plot(list_epochs,accuracy_squeezenet,label='Squeezenet')
plt.plot(list_epochs,accuracy_mobilenetv3,label='MobilenetV3-Large')
plt.plot(list_epochs,accuracy_resnext50,label='Resnext50')
plt.plot(list_epochs,accuracy_inceptionv3,label='Inception-V3')


plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Sentinel-2 Subset All Models -> Accuracy vs. Epochs')
plt.legend()
```

Out[220]:

```
<matplotlib.legend.Legend at 0x7f141185fd90>
```



Training Loss Plot vs Epochs for All Models

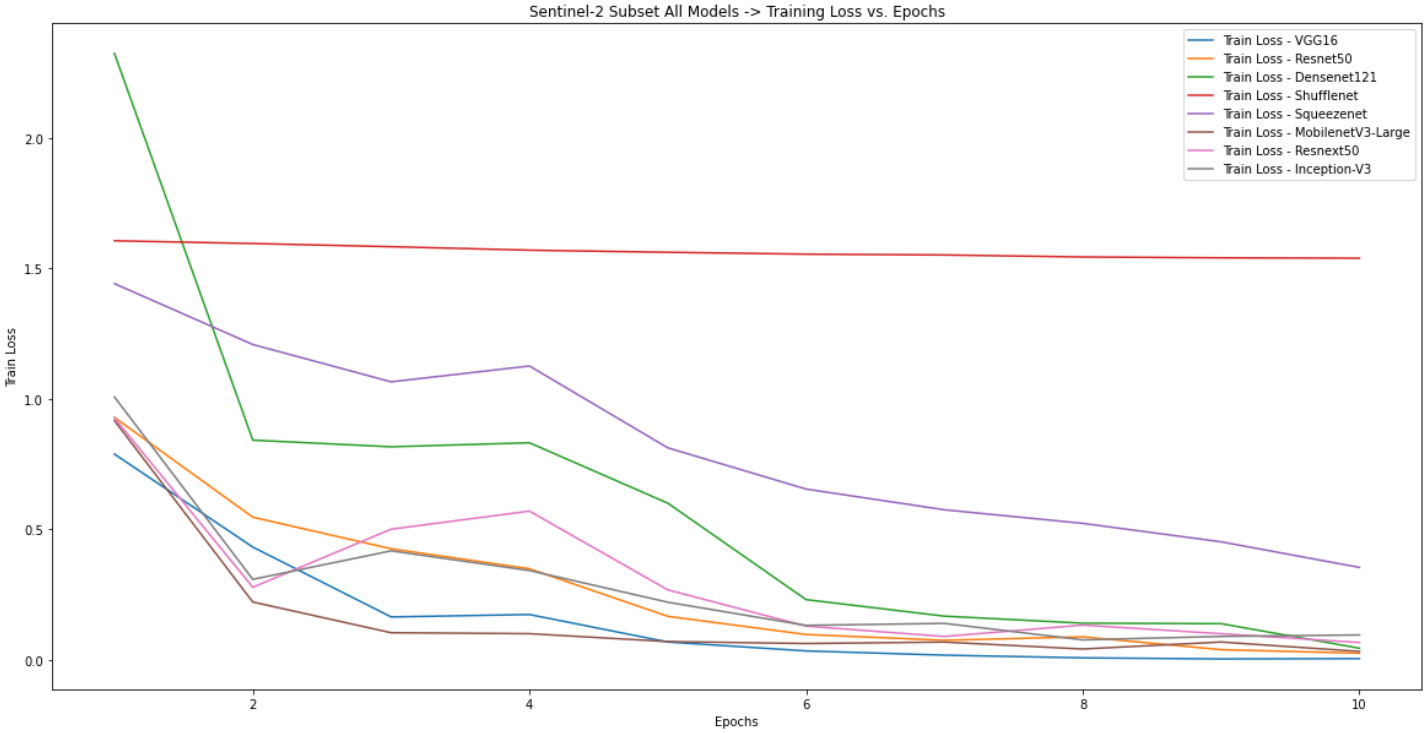
In [221]:

```
plt.figure(figsize = (20,10))
```

```
plt.plot(list_epochs,train_loss_vgg,label='Train Loss - VGG16')
plt.plot(list_epochs,train_loss_resnet,label='Train Loss - Resnet50')
plt.plot(list_epochs,train_loss_densenet,label='Train Loss - Densenet121')
plt.plot(list_epochs,train_loss_shufflenet,label='Train Loss - Shufflenet')
plt.plot(list_epochs,train_loss_squeezenet,label='Train Loss - Squeezenet')
plt.plot(list_epochs,train_loss_mobilenetv3,label='Train Loss - MobilenetV3-Large')
plt.plot(list_epochs,train_loss_resnext50,label='Train Loss - Resnext50')
plt.plot(list_epochs,train_loss_inceptionv3,label='Train Loss - Inception-V3')


plt.xlabel('Epochs')
plt.ylabel('Train Loss')
plt.title('Sentinel-2 Subset All Models -> Training Loss vs. Epochs')
plt.legend()
```

Out[221]:

```
<matplotlib.legend.Legend at 0x7f108dfbba50>
```



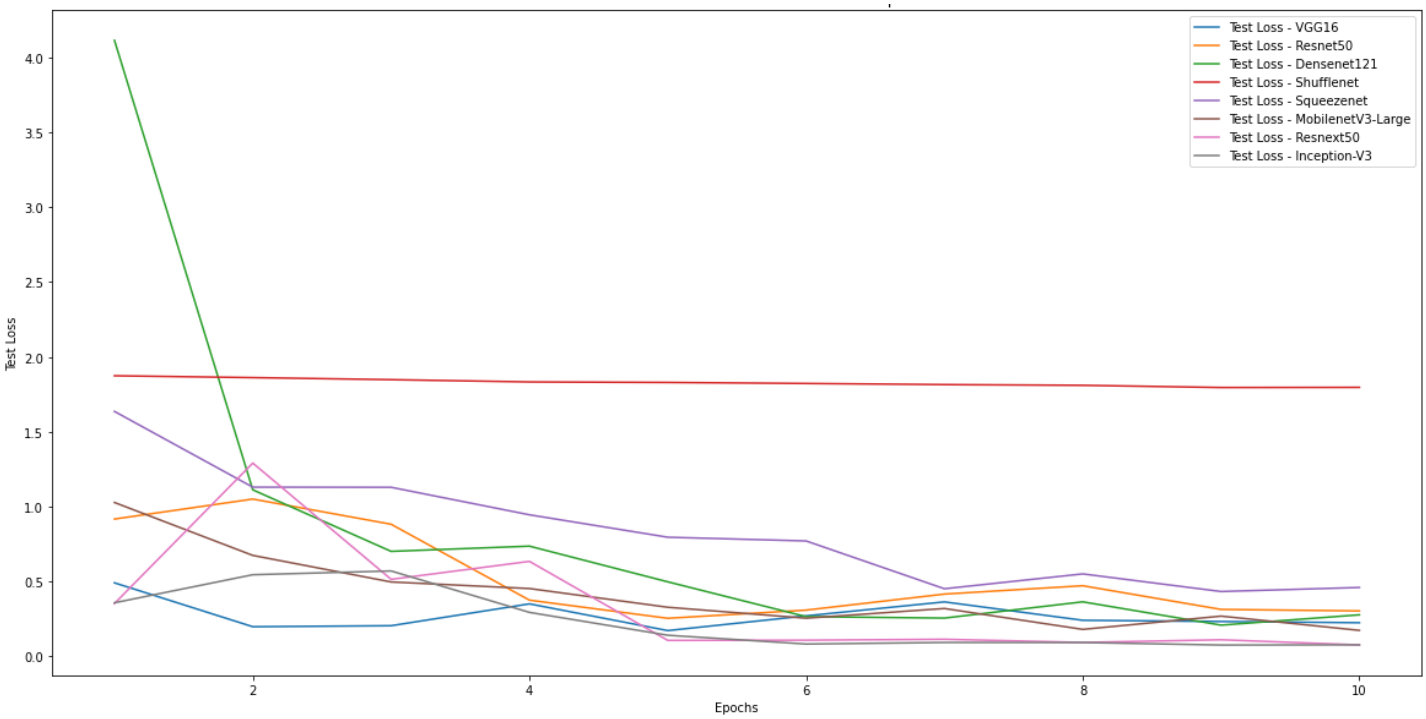
Test Loss Plot vs Epochs for All Models

In [222]:

```
plt.figure(figsize = (20,10))


plt.plot(list_epochs,test_loss_vgg,label='Test Loss - VGG16')
plt.plot(list_epochs,test_loss_resnet,label='Test Loss - Resnet50')
plt.plot(list_epochs,test_loss_densenet,label='Test Loss - Densenet121')
plt.plot(list_epochs,test_loss_shufflenet,label='Test Loss - Shufflenet')
plt.plot(list_epochs,test_loss_squeezenet,label='Test Loss - Squeezenet')
plt.plot(list_epochs,test_loss_mobilenetv3,label='Test Loss - MobilenetV3-Large')
plt.plot(list_epochs,test_loss_resnext50,label='Test Loss - Resnext50')
plt.plot(list_epochs,test_loss_inceptionv3,label='Test Loss - Inception-V3')


plt.xlabel('Epochs')
plt.ylabel('Test Loss')
plt.title('Sentinel-2 Subset All Models -> Test Loss vs. Epochs')

plt.legend()
```

Out[222]:

```
<matplotlib.legend.Legend at 0x7f108df3a810>
```



Reference

https://pytorch.org/vision/stable/models.html

In [ ]: