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May 9, 2025

COVID-19 detection with Heat-map visualization

[1]:
```
from google.colab import drive
    drive.mount('/content/drive')
```

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

[2]:
```
import zipfile

    zip_path = '/content/drive/MyDrive/Colab Notebooks/Sanjana.zip' # Replace␣
 ↪with the actual path

    with zipfile.ZipFile(zip_path, 'r') as zip_ref:
        zip_ref.extractall('/content/') # Replace with desired extraction path
```

[3]:
```
!pip install opencv-python
import os
import sys
import random
import subprocess
import cv2 #After installation, this line should work

import numpy as np
import pandas as pd
from sklearn.preprocessing import OneHotEncoder
from collections import OrderedDict

import scipy
import scipy.ndimage as ndimage
import scipy.ndimage.filters as filters
from scipy.ndimage import binary_dilation
import matplotlib.patches as patches

import torch
import torch.nn as nn
import torch.backends.cudnn as cudnn
from torch.nn import functional as F
import torchvision
```

```
import torchvision.transforms as transforms
from torch.autograd import Variable
from sklearn.metrics import roc_auc_score
import torch.optim as optim
from torch.utils.data.sampler import SubsetRandomSampler
from torch.utils.data import Dataset

from sklearn.model_selection import train_test_split

import matplotlib.pyplot as plt
from PIL import Image
```

```
Collecting opencv-python
  Downloading opencv_python-4.11.0.86-cp37-abi3-manylinux_2_17_x86_64.manylinux2
014_x86_64.whl.metadata (20 kB)
Requirement already satisfied: numpy>=1.21.2 in /usr/local/lib/python3.11/dist-
packages (from opencv-python) (2.0.2)
Downloading
opencv_python-4.11.0.86-cp37-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl
(63.0 MB)
                           63.0/63.0 MB
20.4 MB/s eta 0:00:00
Installing collected packages: opencv-python
Successfully installed opencv-python-4.11.0.86
```

[4]:
```
random_seed= 42
np.random.seed(random_seed)
torch.manual_seed(random_seed)
torch.cuda.manual_seed(random_seed)
torch.backends.cudnn.deterministic=True
torch.backends.cudnn.benchmark = True
batch_size = 64
validation_split = .34
shuffle_dataset = True
```

[5]:
```
def run_cmd(cmd, stderr=subprocess.STDOUT):
    out = None
    try:
        out = subprocess.check_output(
            [cmd],
            shell=True,
            stderr=subprocess.STDOUT,
            universal_newlines=True,
        )
    except subprocess.CalledProcessError as e:
        print(f'ERROR {e.returncode}: {cmd}\n\t{e.output}', flush=True,␣
 ↪file=sys.stderr)
```

```
        raise e
    return out
```

[6]:
```
def clone_data(data_root):
    clone_uri = 'https://github.com/ieee8023/covid-chestxray-dataset.git'
    if os.path.exists(data_root):
        assert os.path.isdir(data_root), \
        f'{data_root} should be cloned from {clone_uri}'
    else:
        print(
            'Cloning the covid chestxray dataset. It may take a while\n...\n',
            flush=True
        )
        run_cmd(f'git clone {clone_uri} {data_root}')
```

[7]:
```
data_root = "./data"
mgpath=f'{data_root}/images',
csvpath=f'{data_root}//content/metadata.csv',
```

[8]:
```
csvpath
```

[8]:
```
('./data//content/metadata.csv',)
```

[9]:
```
clone_data(data_root)
```

```
Cloning the covid chestxray dataset. It may take a while
…
```

[10]:
```
meta = pd.read_csv('/content/metadata.csv')
```

[11]:
```
meta['view'].value_counts(dropna=False)
```

[11]:
```
view
PA               195
AP                58
AP Supine         45
Axial             41
L                 29
Coronal            3
AP semi erect      1
Name: count, dtype: int64
```

[12]:
```
for x in meta['filename']:
    if x.split('.')[-1]=='gz':
        meta.drop(meta.index[meta['filename']==x],
                  inplace=True)
```

[13]:
```
meta = meta[(meta['finding']=='COVID-19')
            |(meta['finding']=='SARS')
            |(meta['finding']=='Pneumocystis')
            |(meta['finding']=='Streptococcus')
            |(meta['finding']=='COVID-19, ARDS')
            |(meta['finding']=='ARDS')]
meta = meta[meta['view']=='PA']
```

[14]:
```
meta['finding'].value_counts(dropna=False)
```

[14]:
```
finding
COVID-19          141
Streptococcus      13
Pneumocystis       12
COVID-19, ARDS     11
SARS                8
ARDS                4
Name: count, dtype: int64
```

[15]:
```
X_train_val, features_test = train_test_split(␣
  ↪meta[meta['finding']=='COVID-19'], test_size=0.85, random_state=random_seed)
meta.drop(features_test.index, inplace=True)
meta.reset_index(drop=True, inplace=True)
```

[16]:
```
meta['finding'].value_counts(dropna=False)
```

[16]:
```
finding
COVID-19          21
Streptococcus     13
Pneumocystis      12
COVID-19, ARDS    11
SARS               8
ARDS               4
Name: count, dtype: int64
```

[17]:
```
dataset_size = len(meta)
indices = list(range(dataset_size))
split = int(np.floor(validation_split * dataset_size))
if shuffle_dataset :
    np.random.seed(random_seed)
    np.random.shuffle(indices)
train_indices, val_indices = indices[split:], indices[:split]
```

[18]:
```
train_sampler = SubsetRandomSampler(train_indices)
valid_sampler = SubsetRandomSampler(val_indices)
```

[19]:
```
Labels = np.array(meta['finding']).reshape(len(meta['finding']),1)
encode = OneHotEncoder()
encode.fit(Labels)
labels_enc = encode.transform(Labels).toarray()
```

[20]:
```
transform=transforms.Compose([
                              transforms.ToPILImage(),
                              transforms.RandomCrop(224),
                              transforms.ToTensor(),
                              transforms.Normalize([0.485, 0.456, 0.406],[0.
 ↪229, 0.224, 0.225])
                                          ])
```

[21]:
```
class_names = [
    'COVID-19',
    'SARS ',
    'Pneumocystis',
    'Streptococcus',
    'COVID-19, ARDS',
    'ARDS',
]
```

[22]:
```
class ChestXrayDataSet(Dataset):
    def __init__(self,csvpath,mgpath,labels_enc,transform=None):
        self.meta_data = pd.read_csv(csvpath)
        self.root_dir = mgpath
        self.labels = self.meta_data['finding']
        self.transform = transform
        for x in self.meta_data['filename']:
            if x.split('.')[-1]=='gz':
                self.meta_data.drop(self.meta_data.index[self.
 ↪meta_data['filename']==x],
                                    inplace=True)

        self.meta_data = self.meta_data[(self.meta_data['finding']=='COVID-19')
                                        |(self.meta_data['finding']=='SARS')
                                        |(self.
 ↪meta_data['finding']=='Pneumocystis')
                                        |(self.
 ↪meta_data['finding']=='Streptococcus')
                                        |(self.meta_data['finding']=='COVID-19,␣
 ↪ARDS')
                                        |(self.meta_data['finding']=='ARDS')]
        self.meta_data = self.meta_data[self.meta_data['view']=='PA']
        self.meta_data.drop(features_test.index, inplace=True)
        self.meta_data.reset_index(drop=True, inplace=True)
```

```
    def __len__(self):
        return len(self.meta_data)

    def __getitem__(self, idx):
        if torch.is_tensor(idx):
            idx = idx.tolist()
        img_name = os.path.join(self.root_dir,
                                self.meta_data.loc[idx,'filename'])
        image = Image.open(img_name).convert('RGB')
        image = np.array(image.resize((256,256)))
        image = image[:,:,0]
        image = np.uint8(((np.array(image)/255).reshape(256,256,1))*255*255)
        image = np.tile(image,3)
        label = labels_enc[idx]
        if self.transform is not None:
            image = self.transform(image)
        return image, label, idx
```

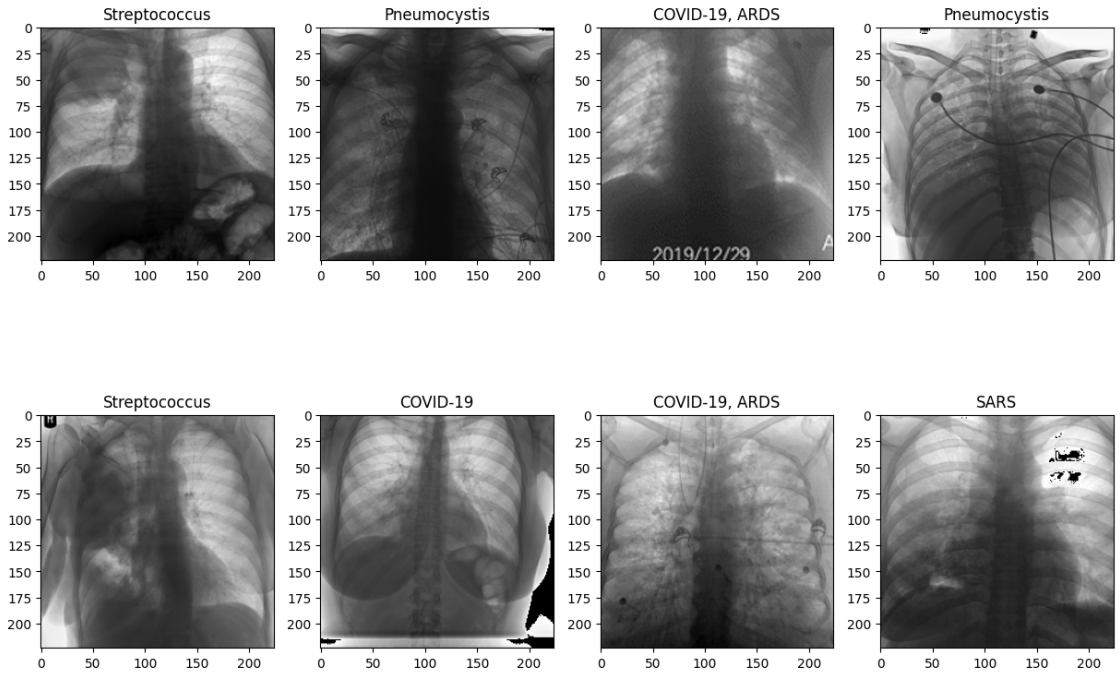
[23]:
```
dataset = ChestXrayDataSet('/content/metadata.
 ↪csv',mgpath[0],labels_enc,transform)
```

[24]:
```
train_loader = torch.utils.data.DataLoader(dataset,
                                           batch_size=batch_size,
                                           sampler=train_sampler)
validation_loader = torch.utils.data.DataLoader(dataset,
                                                batch_size=batch_size,
                                                sampler=valid_sampler)
```

[25]:
```
def img_display(img):
    img = img*0.229+0.485   # unnormalize (inp = inp*std + mean)
    npimg = img.numpy()[0]

    return npimg
```

[26]:
```
# get some random training images
dataiter = iter(train_loader)
images, labels, id_ = next(dataiter) # Use next(dataiter) instead of dataiter.
 ↪next()
# Viewing data examples used for training
fig, axis = plt.subplots(2, 4, figsize=(15, 10))
for i, ax in enumerate(axis.flat):
    with torch.no_grad():
        image, label, _ = images[i], labels[i], id_[i]
        ax.imshow(img_display(image),cmap='gray') # add image
        ax.set(title = f"{meta['finding'][_.item()]}") # add label
```



[27]:
```
# construct model
class DenseNet121(nn.Module):
    def __init__(self, out_size):
        super(DenseNet121, self).__init__()
        self.densenet121 = torchvision.models.densenet121(pretrained=True)
        num_ftrs = self.densenet121.classifier.in_features
        self.densenet121.classifier = nn.Sequential(
            nn.Linear(num_ftrs, out_size),
            nn.Sigmoid() #This activation function is for multi-label␣
 ↪classification
        ).cuda()
    def forward(self, x):
        x = self.densenet121(x)
        return x
```

[28]:
```
import torch
import torch.nn as nn
import torchvision.models as models

cudnn.benchmark = True
N_CLASSES = 6
```

[29]:
```
def compute_AUCs(gt, pred):
    AUROCs = []
    gt_np = gt.cpu().numpy()
```

```
    pred_np = pred.cpu().numpy()
    for i in range(N_CLASSES):
        AUROCs.append(roc_auc_score(gt_np[:, i], pred_np[:, i]))
    return AUROCs
```

[30]:
```
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print("Using device:", device)
```

```
Using device: cpu
```

[31]:
```
base_model = models.densenet121(pretrained=True)

# Modify the classifier for your number of output classes
# DenseNet121 uses a classifier as the final fully connected layer
num_ftrs = base_model.classifier.in_features
base_model.classifier = nn.Linear(num_ftrs, N_CLASSES)

# Send the model to the selected device
model = base_model.to(device)

# Print model summary (optional)
print(model)
```

```
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208:
UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be
removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:223:
UserWarning: Arguments other than a weight enum or `None` for 'weights' are
deprecated since 0.13 and may be removed in the future. The current behavior is
equivalent to passing `weights=DenseNet121_Weights.IMAGENET1K_V1`. You can also
use `weights=DenseNet121_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/densenet121-a639ec97.pth" to
/root/.cache/torch/hub/checkpoints/densenet121-a639ec97.pth
100%|      | 30.8M/30.8M [00:00<00:00, 164MB/s]

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=True)
    (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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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_stats=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=6, bias=True)
)
```

[32]:
```
optimizer = optim.Adam(model.parameters(),lr=0.0007)
criterion = nn.BCEWithLogitsLoss()
criterion = criterion.cuda(device)
```

[34]:
```
import torch
import numpy as np
from torch.autograd import Variable

save_best = 0.0

for epoch in range(100):
    print("Epoch:", epoch)
    running_loss = 0.0

    model.train()
    for batch_idx, (data_, target_, _) in enumerate(train_loader):
        target_ = target_.type(torch.float)
        data_, target_ = data_.to(device), target_.to(device)

        optimizer.zero_grad()
        outputs = model(data_)
        loss = criterion(outputs, target_)
        loss.backward()
        optimizer.step()

        running_loss += loss.item()

    # ======== validation ========
    with torch.no_grad():
        model.eval()
        gt = torch.FloatTensor().to(device)
        pred = torch.FloatTensor().to(device)

        for i, (data_t, target_t, _t) in enumerate(validation_loader):
            target_t = target_t.type(torch.float)
            data_t, target_t = data_t.to(device), target_t.to(device)

            gt = torch.cat((gt, target_t), 0)

            input_var = Variable(data_t.view(-1, 3, 224, 224)).to(device)
            output = model(input_var)
            pred = torch.cat((pred, output.data), 0)

        AUROCs = compute_AUCs(gt, pred)
        AUROC_avg = np.array(AUROCs).mean()
        print('The average AUROC is {:.3f}'.format(AUROC_avg))
```

```
        if AUROC_avg > save_best:
            save_best = AUROC_avg
            torch.save(model.state_dict(), 'Covid_detection.pt')
            print('Detected network improvement, saving current model')

        for i in range(N_CLASSES):
            print('The AUROC of {} is {:.3f}'.format(class_names[i], AUROCs[i]))


    print("==========================================================================\n")

print('Finished Training')
```

```
Epoch: 0
The average AUROC is 0.623
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.833
The AUROC of SARS  is 0.559
The AUROC of Pneumocystis is 0.829
The AUROC of Streptococcus is 0.355
The AUROC of COVID-19, ARDS is 0.256
The AUROC of ARDS is 0.905
==========================================================================

Epoch: 1
The average AUROC is 0.632
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.755
The AUROC of Pneumocystis is 0.789
The AUROC of Streptococcus is 0.329
The AUROC of COVID-19, ARDS is 0.444
The AUROC of ARDS is 0.810
==========================================================================

Epoch: 2
The average AUROC is 0.674
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.857
The AUROC of SARS  is 0.745
The AUROC of Pneumocystis is 0.829
The AUROC of Streptococcus is 0.447
The AUROC of COVID-19, ARDS is 0.667
The AUROC of ARDS is 0.500
==========================================================================

Epoch: 3
```

```
The average AUROC is 0.682
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.895
The AUROC of Streptococcus is 0.461
The AUROC of COVID-19, ARDS is 0.667
The AUROC of ARDS is 0.524
==========================================================================

Epoch: 4
The average AUROC is 0.670
The AUROC of COVID-19 is 0.643
The AUROC of SARS  is 0.843
The AUROC of Pneumocystis is 0.868
The AUROC of Streptococcus is 0.487
The AUROC of COVID-19, ARDS is 0.656
The AUROC of ARDS is 0.524
==========================================================================

Epoch: 5
The average AUROC is 0.692
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.804
The AUROC of Pneumocystis is 0.816
The AUROC of Streptococcus is 0.474
The AUROC of COVID-19, ARDS is 0.656
The AUROC of ARDS is 0.810
==========================================================================

Epoch: 6
The average AUROC is 0.744
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.863
The AUROC of Pneumocystis is 0.908
The AUROC of Streptococcus is 0.526
The AUROC of COVID-19, ARDS is 0.811
The AUROC of ARDS is 0.690
==========================================================================

Epoch: 7
The average AUROC is 0.795
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.842
```

```
The AUROC of Streptococcus is 0.645
The AUROC of COVID-19, ARDS is 0.956
The AUROC of ARDS is 0.810
==========================================================================

Epoch: 8
The average AUROC is 0.844
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.690
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.658
The AUROC of COVID-19, ARDS is 0.944
The AUROC of ARDS is 0.881
==========================================================================

Epoch: 9
The average AUROC is 0.822
The AUROC of COVID-19 is 0.738
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.895
The AUROC of Streptococcus is 0.539
The AUROC of COVID-19, ARDS is 0.967
The AUROC of ARDS is 0.881
==========================================================================

Epoch: 10
The average AUROC is 0.852
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.738
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.592
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.881
==========================================================================

Epoch: 11
The average AUROC is 0.818
The AUROC of COVID-19 is 0.714
The AUROC of SARS  is 0.824
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.539
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.833
==========================================================================

Epoch: 12
```

```
The average AUROC is 0.844
The AUROC of COVID-19 is 0.690
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.566
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.905
==========================================================================

Epoch: 13
The average AUROC is 0.835
The AUROC of COVID-19 is 0.762
The AUROC of SARS  is 0.853
The AUROC of Pneumocystis is 0.934
The AUROC of Streptococcus is 0.539
The AUROC of COVID-19, ARDS is 0.967
The AUROC of ARDS is 0.952
==========================================================================

Epoch: 14
The average AUROC is 0.844
The AUROC of COVID-19 is 0.690
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.605
The AUROC of COVID-19, ARDS is 0.989
The AUROC of ARDS is 0.929
==========================================================================

Epoch: 15
The average AUROC is 0.843
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.618
The AUROC of COVID-19, ARDS is 0.967
The AUROC of ARDS is 0.929
==========================================================================

Epoch: 16
The average AUROC is 0.840
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.833
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.697
The AUROC of COVID-19, ARDS is 0.967
The AUROC of ARDS is 0.929
==========================================================================
```

```
Epoch: 17
The average AUROC is 0.841
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.658
The AUROC of COVID-19, ARDS is 0.989
The AUROC of ARDS is 0.952
==========================================================================

Epoch: 18
The average AUROC is 0.866
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.671
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 19
The average AUROC is 0.866
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.684
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
==========================================================================

Epoch: 20
The average AUROC is 0.836
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.605
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 21
The average AUROC is 0.853
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.961
The AUROC of Pneumocystis is 0.974
```

```
The AUROC of Streptococcus is 0.671
The AUROC of COVID-19, ARDS is 0.989
The AUROC of ARDS is 0.976
======================================================================

Epoch: 22
The average AUROC is 0.865
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.684
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 23
The average AUROC is 0.863
The AUROC of COVID-19 is 0.643
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.684
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 24
The average AUROC is 0.869
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 25
The average AUROC is 0.862
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.711
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 26
The average AUROC is 0.847
```

```
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.711
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 27
The average AUROC is 0.864
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.711
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 28
The average AUROC is 0.888
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.961
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 29
The average AUROC is 0.862
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.724
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 30
The average AUROC is 0.880
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================
```

```
Epoch: 31
The average AUROC is 0.878
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 32
The average AUROC is 0.860
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.724
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 33
The average AUROC is 0.878
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.737
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 34
The average AUROC is 0.856
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.873
The AUROC of Pneumocystis is 0.908
The AUROC of Streptococcus is 0.737
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 35
The average AUROC is 0.866
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
```

```
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 36
The average AUROC is 0.867
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 37
The average AUROC is 0.876
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 38
The average AUROC is 0.881
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 39
The average AUROC is 0.876
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.803
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 40
The average AUROC is 0.861
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.974
```

```
The AUROC of Streptococcus is 0.724
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 41
The average AUROC is 0.873
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 42
The average AUROC is 0.851
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.711
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 43
The average AUROC is 0.878
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.961
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 44
The average AUROC is 0.878
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.842
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
======================================================================

Epoch: 45
The average AUROC is 0.874
The AUROC of COVID-19 is 0.619
```

```
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.737
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 46
The average AUROC is 0.858
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 47
The average AUROC is 0.857
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.724
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 48
The average AUROC is 0.878
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.971
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 49
The average AUROC is 0.886
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.951
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.816
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 50
```

```
The average AUROC is 0.873
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 51
The average AUROC is 0.868
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 52
The average AUROC is 0.863
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.711
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 53
The average AUROC is 0.858
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.934
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 54
The average AUROC is 0.855
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================
```

```
Epoch: 55
The average AUROC is 0.870
The AUROC of COVID-19 is 0.500
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.974
The AUROC of Streptococcus is 0.816
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 56
The average AUROC is 0.848
The AUROC of COVID-19 is 0.500
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.737
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 57
The average AUROC is 0.866
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
==========================================================================

Epoch: 58
The average AUROC is 0.880
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 59
The average AUROC is 0.862
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
```

```
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 60
The average AUROC is 0.852
The AUROC of COVID-19 is 0.500
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 61
The average AUROC is 0.857
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 62
The average AUROC is 0.869
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.803
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 63
The average AUROC is 0.883
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 64
The average AUROC is 0.849
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.961
```

```
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 65
The average AUROC is 0.885
The AUROC of COVID-19 is 0.667
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 66
The average AUROC is 0.867
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 67
The average AUROC is 0.836
The AUROC of COVID-19 is 0.476
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.737
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
======================================================================

Epoch: 68
The average AUROC is 0.877
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 69
The average AUROC is 0.873
The AUROC of COVID-19 is 0.524
```

```
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.803
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 70
The average AUROC is 0.878
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.829
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 71
The average AUROC is 0.885
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.816
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 72
The average AUROC is 0.856
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
======================================================================

Epoch: 73
The average AUROC is 0.874
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.922
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 74
```

```
The average AUROC is 0.891
Detected network improvement, saving current model
The AUROC of COVID-19 is 0.643
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 75
The average AUROC is 0.868
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
======================================================================

Epoch: 76
The average AUROC is 0.878
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
======================================================================

Epoch: 77
The average AUROC is 0.864
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
======================================================================

Epoch: 78
The average AUROC is 0.889
The AUROC of COVID-19 is 0.643
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
```

```
==========================================================================

Epoch: 79
The average AUROC is 0.869
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 80
The average AUROC is 0.856
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.863
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 81
The average AUROC is 0.874
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.829
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 82
The average AUROC is 0.877
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 83
The average AUROC is 0.885
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.941
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.776
```

```
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 84
The average AUROC is 0.870
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.987
The AUROC of Streptococcus is 0.803
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 85
The average AUROC is 0.858
The AUROC of COVID-19 is 0.524
The AUROC of SARS  is 0.873
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 86
The average AUROC is 0.865
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 87
The average AUROC is 0.864
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 88
The average AUROC is 0.884
The AUROC of COVID-19 is 0.643
The AUROC of SARS  is 0.922
```

```
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 89
The average AUROC is 0.861
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.816
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.952
==========================================================================

Epoch: 90
The average AUROC is 0.868
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.912
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 91
The average AUROC is 0.873
The AUROC of COVID-19 is 0.595
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.947
The AUROC of Streptococcus is 0.816
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 92
The average AUROC is 0.860
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.863
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 93
The average AUROC is 0.873
```

```
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.892
The AUROC of Pneumocystis is 1.000
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 94
The average AUROC is 0.867
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.902
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.789
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 95
The average AUROC is 0.855
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.882
The AUROC of Pneumocystis is 0.934
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Epoch: 96
The average AUROC is 0.857
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.873
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 97
The average AUROC is 0.863
The AUROC of COVID-19 is 0.619
The AUROC of SARS  is 0.843
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.776
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================
```

```
Epoch: 98
The average AUROC is 0.861
The AUROC of COVID-19 is 0.548
The AUROC of SARS  is 0.931
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.750
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 0.976
==========================================================================

Epoch: 99
The average AUROC is 0.858
The AUROC of COVID-19 is 0.571
The AUROC of SARS  is 0.853
The AUROC of Pneumocystis is 0.961
The AUROC of Streptococcus is 0.763
The AUROC of COVID-19, ARDS is 1.000
The AUROC of ARDS is 1.000
==========================================================================

Finished Training
```

[35]:
```
model.load_state_dict(torch.load('Covid_detection.pt'))
```

[35]:
```
<All keys matched successfully>
```

[36]:
```
class ChestXrayDataSet_plot(Dataset):
    def __init__(self, input_X, transform=None):
        self.data = input_X#np.uint8(test_X*255)
        self.transform = transform
        self.root_dir = mgpath[0]
        self.transform = transform

    def __getitem__(self, index):
        if torch.is_tensor(index):
            index = index.tolist()
        img_name = os.path.join(self.root_dir,self.data.loc[index,'filename'])
        image = Image.open(img_name).convert('RGB')
        image = np.array(image.resize((256,256)))
        image = np.uint8(image*255)
        image = self.transform(image)
        return image

    def __len__(self):
        return len(self.data)
```

[37]:
```
features_test.reset_index(drop=True, inplace=True)
test_dataset = ChestXrayDataSet_plot(input_X =␣
 ↪features_test,transform=transforms.Compose([
                                        transforms.ToPILImage(),
                                        transforms.ToTensor(),
                                        transforms.Normalize([0.485, 0.456, 0.
 ↪406],[0.229, 0.224, 0.225])
                                        ]))
```

[38]:
```
print("generate heatmap .........")
# ======= Grad CAM Function =========
class PropagationBase(object):
    def __init__(self, model, cuda=True):
        self.model = model
        self.model.eval()
        if cuda:
            self.model.cuda()
        self.cuda = cuda
        self.all_fmaps = OrderedDict()
        self.all_grads = OrderedDict()
        self._set_hook_func()
        self.image = None

    def _set_hook_func(self):
        raise NotImplementedError

    def _encode_one_hot(self, idx):
        one_hot = torch.FloatTensor(1, self.preds.size()[-1]).zero_()
        one_hot[0][idx] = 1.0
        return one_hot.cuda() if self.cuda else one_hot

    def forward(self, image):
        self.image = image
        self.preds = self.model.forward(self.image)
        #self.probs = F.softmax(self.preds, dim=1)[0]
        #self.prob, self.idx = self.preds[0].data.sort(0, True)

        return self.preds.cpu().data.numpy()

    def backward(self, idx):
        self.model.zero_grad()
        one_hot = self._encode_one_hot(idx)
        self.preds.backward(gradient=one_hot, retain_graph=True)
```

```
generate heatmap …
```

[39]:
```
class GradCAM(PropagationBase):
    def _set_hook_func(self):
        def func_f(module, input, output):
            self.all_fmaps[id(module)] = output.data.cpu()

        def func_b(module, grad_in, grad_out):
            self.all_grads[id(module)] = grad_out[0].cpu()

        for module in self.model.named_modules():
            module[1].register_forward_hook(func_f)
            module[1].register_backward_hook(func_b)

    def _find(self, outputs, target_layer):
        for key, value in outputs.items():
            for module in self.model.named_modules():
                if id(module[1]) == key:
                    if module[0] == target_layer:
                        return value
        raise ValueError('Invalid layer name: {}'.format(target_layer))

    def _normalize(self, grads):
        l2_norm = torch.sqrt(torch.mean(torch.pow(grads, 2))) + 1e-5
        return grads / l2_norm.item()

    def _compute_grad_weights(self, grads):
        grads = self._normalize(grads)
        self.map_size = grads.size()[2:]
        return nn.AvgPool2d(self.map_size)(grads)

    def generate(self, target_layer):
        fmaps = self._find(self.all_fmaps, target_layer)
        grads = self._find(self.all_grads, target_layer)
        weights = self._compute_grad_weights(grads)
        gcam = torch.FloatTensor(self.map_size).zero_()
        for fmap, weight in zip(fmaps[0], weights[0]):
            gcam += fmap * weight.data

        gcam = F.relu(Variable(gcam))
        gcam = gcam.data.cpu().numpy()
        gcam -= gcam.min()
        gcam /= gcam.max()
        gcam = cv2.resize(gcam, (self.image.size(3), self.image.size(2)))
        return gcam

    def FinalImage(self, gcam, raw_image):
        raw_image = raw_image*0.229+0.485
        gcam = cv2.applyColorMap(np.uint8(gcam * 255.0), cv2.COLORMAP_JET)
```

```
        gcam = np.float32(gcam) / 600
        gcam = gcam.astype(float) + raw_image.numpy()[0].astype(float).
 ↪reshape(256,256,1)
        gcam = gcam / gcam.max()

        return np.uint8(gcam * 255.0)
```

[40]:
```
import os
print(os.path.exists('./data/images/4-x-day1.jpg'))
```

```
False
```

[41]:
```
heatmap_output = []
image_id = []
output_class = []

thresholds = 0.1
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
gcam = GradCAM(model=model, cuda=torch.cuda.is_available())

for index in range(len(test_dataset)):
    try:
        img_tensor, label, _ = test_dataset[index]
    except FileNotFoundError as e:
        print(f"Skipping index {index} due to missing file: {e}")
        continue

    if img_tensor.ndim == 2:
        img_tensor = img_tensor.unsqueeze(0)
    if img_tensor.shape[0] == 1:
        img_tensor = img_tensor.expand(3, -1, -1)

    input_img = img_tensor.unsqueeze(0).to(device)
    input_img = Variable(input_img, requires_grad=True)

    probs = gcam.forward(input_img)
    activate_classes = np.where((probs > thresholds)[0] == True)[0]

    for activate_class in activate_classes:
        gcam.backward(idx=activate_class)
        output = gcam.generate(target_layer="features.denseblock4.denselayer16.
 ↪conv2")
        if np.sum(np.isnan(output)) > 0:
            continue
        img = gcam.FinalImage(output, img_tensor)
        heatmap_output.append(img)
        image_id.append(index)
```

```
        output_class.append(activate_class)

    print("testing_data", str(index), "finished")
```

```
/usr/local/lib/python3.11/dist-packages/torch/nn/modules/module.py:1830:
FutureWarning: Using a non-full backward hook when the forward contains multiple
autograd Nodes is deprecated and will be removed in future versions. This hook
will be missing some grad_input. Please use register_full_backward_hook to get
the documented behavior.
  self._maybe_warn_non_full_backward_hook(args, result, grad_fn)
/usr/local/lib/python3.11/dist-packages/torch/nn/modules/module.py:1830:
FutureWarning: Using non-full backward hooks on a Module that does not take as
input a single Tensor or a tuple of Tensors is deprecated and will be removed in
future versions. This hook will be missing some of the grad_input. Please use
register_full_backward_hook to get the documented behavior.
  self._maybe_warn_non_full_backward_hook(args, result, grad_fn)
```

```
testing_data 0 finished
testing_data 1 finished
testing_data 2 finished
testing_data 3 finished
testing_data 4 finished
testing_data 5 finished
testing_data 6 finished
testing_data 7 finished
testing_data 8 finished
testing_data 9 finished
testing_data 10 finished
testing_data 11 finished
testing_data 12 finished
testing_data 13 finished
testing_data 14 finished
testing_data 15 finished
testing_data 16 finished
testing_data 17 finished
testing_data 18 finished
testing_data 19 finished
testing_data 20 finished
testing_data 21 finished
testing_data 22 finished
testing_data 23 finished
testing_data 24 finished
testing_data 25 finished
testing_data 26 finished
testing_data 27 finished
testing_data 28 finished
testing_data 29 finished
testing_data 30 finished
```

```
testing_data 31 finished
testing_data 32 finished
testing_data 33 finished
testing_data 34 finished
testing_data 35 finished
testing_data 36 finished
testing_data 37 finished
testing_data 38 finished
testing_data 39 finished
testing_data 40 finished
testing_data 41 finished
testing_data 42 finished
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testing_data 55 finished
testing_data 56 finished
testing_data 57 finished
testing_data 58 finished
testing_data 59 finished
testing_data 60 finished
testing_data 61 finished
testing_data 62 finished
testing_data 63 finished
testing_data 64 finished
Skipping index 65 due to missing file: [Errno 2] No such file or directory:
'./data/images/4-x-day1.jpg'
testing_data 66 finished
testing_data 67 finished
testing_data 68 finished
testing_data 69 finished
testing_data 70 finished
testing_data 71 finished
testing_data 72 finished
testing_data 73 finished
testing_data 74 finished
testing_data 75 finished
testing_data 76 finished
testing_data 77 finished
```

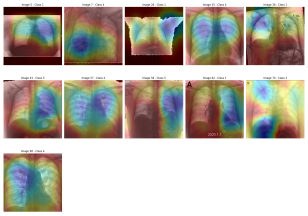
```
testing_data 78 finished
testing_data 79 finished
testing_data 80 finished
testing_data 81 finished
testing_data 82 finished
testing_data 83 finished
testing_data 84 finished
testing_data 85 finished
testing_data 86 finished
testing_data 87 finished
testing_data 88 finished
testing_data 89 finished
testing_data 90 finished
testing_data 91 finished
testing_data 92 finished
testing_data 93 finished
testing_data 94 finished
testing_data 95 finished
Skipping index 96 due to missing file: [Errno 2] No such file or directory:
'./data/images/ciaa199.pdf-001-c.png'
testing_data 97 finished
testing_data 98 finished
testing_data 99 finished
testing_data 100 finished
testing_data 101 finished
testing_data 102 finished
testing_data 103 finished
testing_data 104 finished
testing_data 105 finished
testing_data 106 finished
testing_data 107 finished
testing_data 108 finished
testing_data 109 finished
testing_data 110 finished
testing_data 111 finished
testing_data 112 finished
testing_data 113 finished
testing_data 114 finished
testing_data 115 finished
testing_data 116 finished
testing_data 117 finished
testing_data 118 finished
testing_data 119 finished
```

[42]:
```
heatmap_output_1 = heatmap_output[:130]
heatmap_output_2 = heatmap_output[130:]
```

[47]:
```
fig, axis = plt.subplots(26, 5, figsize=(20, 125))

for i, ax in enumerate(axis.flat):
    if i < len(heatmap_output_1):
        ax.imshow(heatmap_output_1[i])
        ax.axis('off')
        ax.set_title(f"Image {image_id[i]} - Class {output_class[i]}")
    else:
        ax.axis('off')  # Hide unused axes

plt.tight_layout()
plt.show()
```



[45]:
```
fig, axis = plt.subplots(11, 5, figsize=(20, 50))

for i, ax in enumerate(axis.flat):
    if i < len(heatmap_output_1):
        ax.imshow(heatmap_output_1[i])
        ax.axis('off')
        ax.set_title(f"Image {image_id[i]} - Class {output_class[i]}")
    else:
        ax.axis('off')  # Hide unused axes

plt.tight_layout()
plt.show()
```

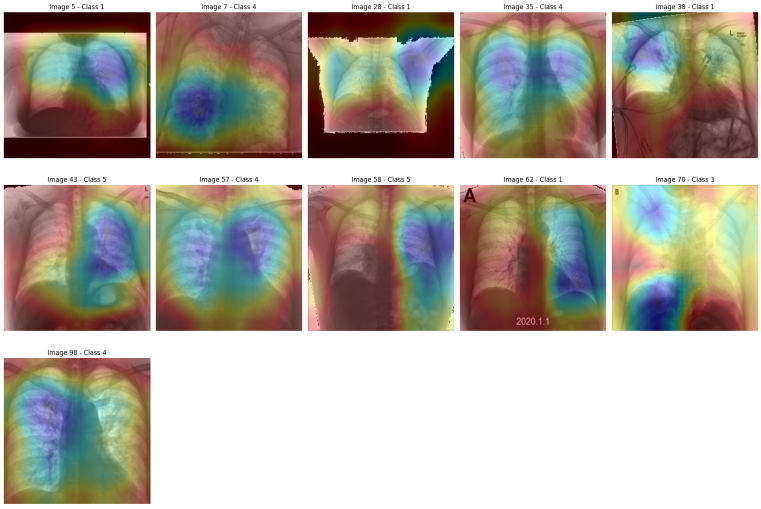


Image 5 - Class 1
Image 7 - Class 4
Image 28 - Class 1
Image 35 - Class 4
Image 38 - Class 1
Image 43 - Class 5
Image 57 - Class 4
Image 58 - Class 5
Image 62 - Class 1
Image 70 - Class 3
Image 98 - Class 4