Complete Notebook

January 28, 2025

1 Detecting COVID-19 with Chest X Ray using PyTorch

Image classification of Chest X Rays in one of three classes: Normal, Viral Pneumonia, COVID-19

Notebook created for the guided project Detecting COVID-19 with Chest X Ray using PyTorch on Coursera

Dataset from COVID-19 Radiography Dataset on Kaggle

2 Importing Libraries

[1]:
```
%matplotlib inline

import os
import shutil
import random
import torch
import torchvision
import numpy as np

from PIL import Image
from matplotlib import pyplot as plt

torch.manual_seed(0)

print('Using PyTorch version', torch.__version__)
```

```
Using PyTorch version 2.3.1+cu121
```

3 Preparing Training and Test Sets

[2]:
```
class_names = ['normal', 'viral', 'covid']
root_dir = 'COVID-19 Radiography Database'
source_dirs = ['NORMAL', 'Viral Pneumonia', 'COVID-19']

if os.path.isdir(os.path.join(root_dir, source_dirs[1])):
    os.mkdir(os.path.join(root_dir, 'test'))
```

```
    for i, d in enumerate(source_dirs):
        os.rename(os.path.join(root_dir, d), os.path.join(root_dir,␣
↪class_names[i]))

    for c in class_names:
        os.mkdir(os.path.join(root_dir, 'test', c))

    for c in class_names:
        images = [x for x in os.listdir(os.path.join(root_dir, c)) if x.lower().
↪endswith('png')]
        selected_images = random.sample(images, 30)
        for image in selected_images:
            source_path = os.path.join(root_dir, c, image)
            target_path = os.path.join(root_dir, 'test', c, image)
            shutil.move(source_path, target_path)
```

4 Creating Custom Dataset

[3]:
```
class ChestXRayDataset(torch.utils.data.Dataset):
    def __init__(self, image_dirs, transform):
        def get_images(class_name):
            images = [x for x in os.listdir(image_dirs[class_name]) if x[-3:].
↪lower().endswith('png')]
            print(f'Found {len(images)} {class_name} examples')
            return images

        self.images = {}
        self.class_names = ['normal', 'viral', 'covid']

        for class_name in self.class_names:
            self.images[class_name] = get_images(class_name)

        self.image_dirs = image_dirs
        self.transform = transform


    def __len__(self):
        return sum([len(self.images[class_name]) for class_name in self.
↪class_names])


    def __getitem__(self, index):
        class_name = random.choice(self.class_names)
        index = index % len(self.images[class_name])
        image_name = self.images[class_name][index]
```

```
        image_path = os.path.join(self.image_dirs[class_name], image_name)
        image = Image.open(image_path).convert('RGB')
        return self.transform(image), self.class_names.index(class_name)
```

5 Image Transformations

[4]:
```
train_transform = torchvision.transforms.Compose([
    torchvision.transforms.Resize(size=(224, 224)),
    torchvision.transforms.RandomHorizontalFlip(),
    torchvision.transforms.ToTensor(),
    torchvision.transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.
 ↪224, 0.225])
])

test_transform = torchvision.transforms.Compose([
    torchvision.transforms.Resize(size=(224, 224)),
    torchvision.transforms.ToTensor(),
    torchvision.transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.
 ↪225])
])
```

6 Prepare DataLoader

[5]:
```
train_dirs = {
    'normal': 'COVID-19 Radiography Database/normal',
    'viral': 'COVID-19 Radiography Database/viral',
    'covid': 'COVID-19 Radiography Database/covid'
}

train_dataset = ChestXRayDataset(train_dirs, train_transform)
```

```
Found 1311 normal examples
Found 1315 viral examples
Found 189 covid examples
```

[6]:
```
test_dirs = {
    'normal': 'COVID-19 Radiography Database/test/normal',
    'viral': 'COVID-19 Radiography Database/test/viral',
    'covid': 'COVID-19 Radiography Database/test/covid'
}

test_dataset = ChestXRayDataset(test_dirs, test_transform)
```

```
Found 30 normal examples
Found 30 viral examples
```

```
Found 30 covid examples
```

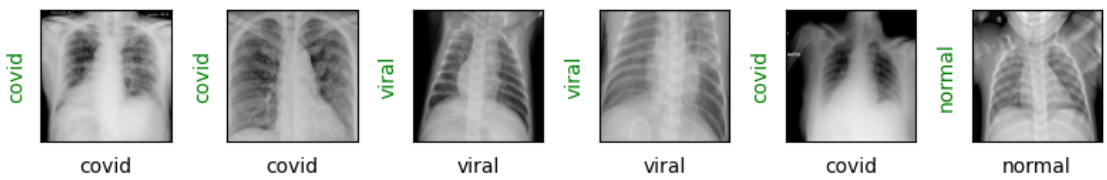
[7]:
```
batch_size = 6

dl_train = torch.utils.data.DataLoader(train_dataset, batch_size=batch_size,␣
 ↪shuffle=True)
dl_test = torch.utils.data.DataLoader(test_dataset, batch_size=batch_size,␣
 ↪shuffle=True)

print('Number of training batches', len(dl_train))
print('Number of test batches', len(dl_test))
```

```
Number of training batches 470
Number of test batches 15
```

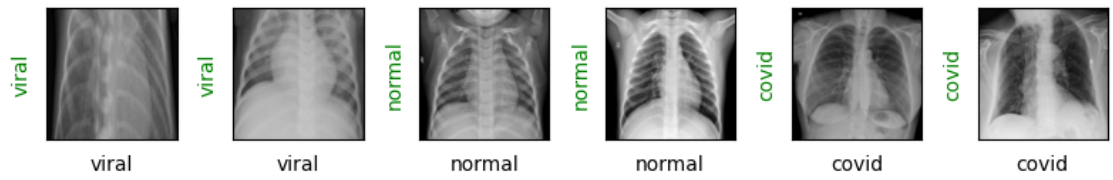
7 Data Visualization

[8]:
```
class_names = train_dataset.class_names


def show_images(images, labels, preds):
    plt.figure(figsize=(8, 4))
    for i, image in enumerate(images):
        plt.subplot(1, 6, i + 1, xticks=[], yticks=[])
        image = image.numpy().transpose((1, 2, 0))
        mean = np.array([0.485, 0.456, 0.406])
        std = np.array([0.229, 0.224, 0.225])
        image = image * std + mean
        image = np.clip(image, 0., 1.)
        plt.imshow(image)
        col = 'green'
        if preds[i] != labels[i]:
            col = 'red'

        plt.xlabel(f'{class_names[int(labels[i].numpy())]}')
        plt.ylabel(f'{class_names[int(preds[i].numpy())]}', color=col)
    plt.tight_layout()
    plt.show()
```

[9]:
```
images, labels = next(iter(dl_train))
show_images(images, labels, labels)
```



[10]:
```
images, labels = next(iter(dl_test))
show_images(images, labels, labels)
```



8 Creating the Model

[11]:
```
resnet18 = torchvision.models.resnet18(pretrained=True)

print(resnet18)
```

```
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to
/home/jovyan/.cache/torch/hub/checkpoints/resnet18-f37072fd.pth
100%|      | 44.7M/44.7M [00:00<00:00, 209MB/s]
```

```
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): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
    (1): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
```

```
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer2): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer3): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
```

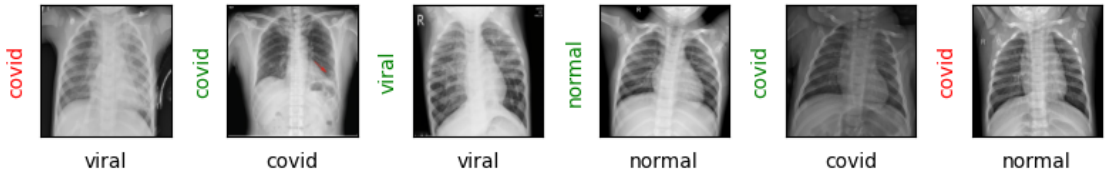
```
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2), bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer4): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=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=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
```

```
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=512, out_features=1000, bias=True)
)
```

[12]:
```
resnet18.fc = torch.nn.Linear(in_features=512, out_features=3)
loss_fn = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(resnet18.parameters(), lr=3e-5)
```

[13]:
```
def show_preds():
    resnet18.eval()
    images, labels = next(iter(dl_test))
    outputs = resnet18(images)
    _, preds = torch.max(outputs, 1)
    show_images(images, labels, preds)
```

[14]:
```
show_preds()
```



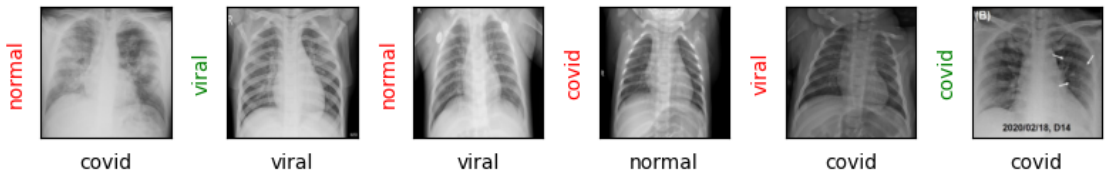
9 Training the Model

[15]:
```
def train(epochs):
    print('Starting training..')
    for e in range(0, epochs):
        print('='*20)
        print(f'Starting epoch {e + 1}/{epochs}')
        print('='*20)

        train_loss = 0.
        val_loss = 0.

        resnet18.train() # set model to training phase

        for train_step, (images, labels) in enumerate(dl_train):
            optimizer.zero_grad()
            outputs = resnet18(images)
            loss = loss_fn(outputs, labels)
            loss.backward()
```

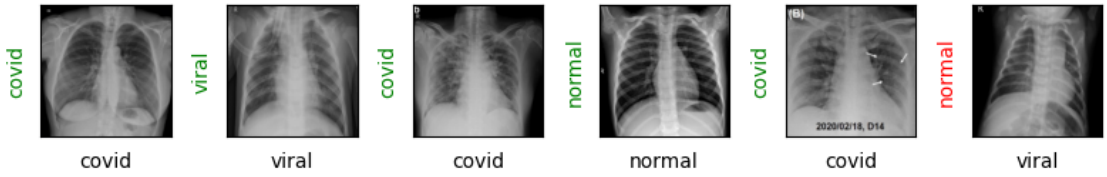
```
            optimizer.step()
            train_loss += loss.item()
            if train_step % 20 == 0:
                print('Evaluating at step', train_step)

                accuracy = 0

                resnet18.eval() # set model to eval phase

                for val_step, (images, labels) in enumerate(dl_test):
                    outputs = resnet18(images)
                    loss = loss_fn(outputs, labels)
                    val_loss += loss.item()

                    _, preds = torch.max(outputs, 1)
                    accuracy += sum((preds == labels).numpy())

                val_loss /= (val_step + 1)
                accuracy = accuracy/len(test_dataset)
                print(f'Validation Loss: {val_loss:.4f}, Accuracy: {accuracy:.
↪4f}')

                show_preds()

                resnet18.train()

                if accuracy >= 0.95:
                    print('Performance condition satisfied, stopping..')
                    return

        train_loss /= (train_step + 1)

        print(f'Training Loss: {train_loss:.4f}')
    print('Training complete..')
```

[16]:
```
%%time

train(epochs=1)
```

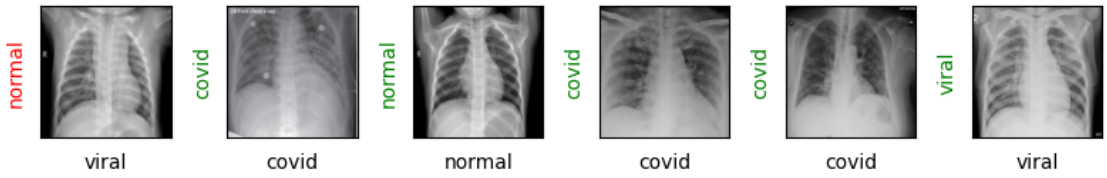
```
Starting training..
====================
Starting epoch 1/1
====================
Evaluating at step 0
Validation Loss: 1.1999, Accuracy: 0.2778
```



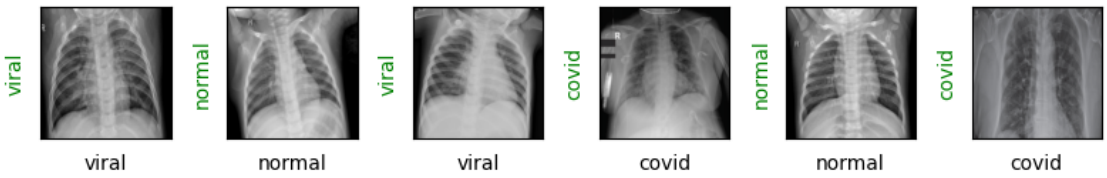

```
Evaluating at step 20
Validation Loss: 0.6683, Accuracy: 0.8111
```



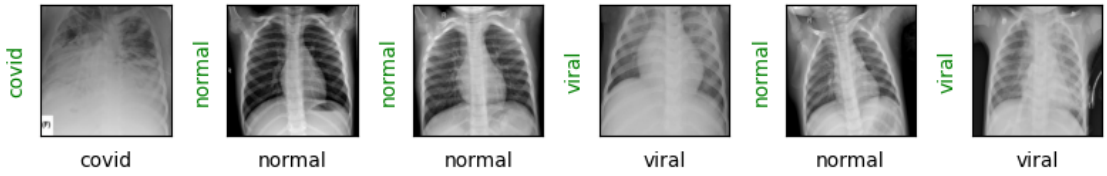

```
Evaluating at step 40
Validation Loss: 0.3543, Accuracy: 0.9000
```



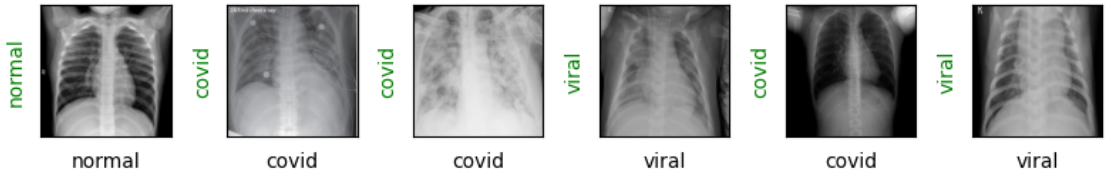

```
Evaluating at step 60
Validation Loss: 0.2334, Accuracy: 0.9222
```



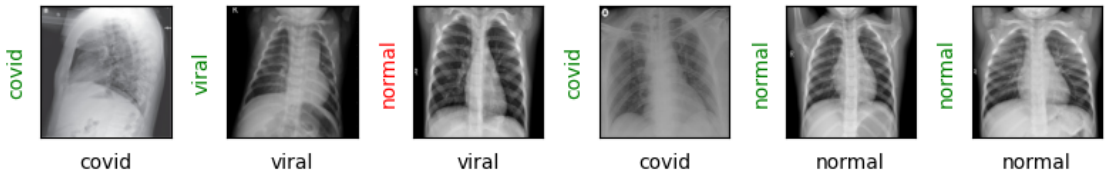

```
Evaluating at step 80
Validation Loss: 0.2209, Accuracy: 0.9111
```



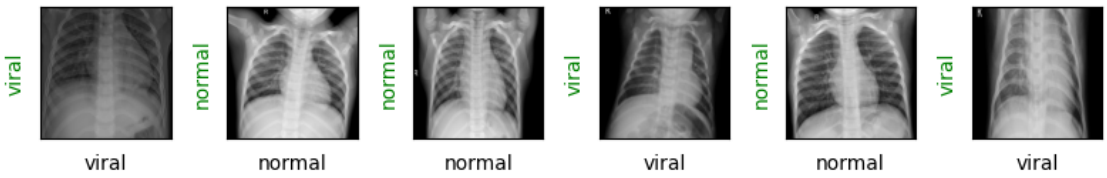

```
Evaluating at step 100
Validation Loss: 0.2008, Accuracy: 0.9222
```




```
Evaluating at step 120
Validation Loss: 0.2258, Accuracy: 0.9222
```



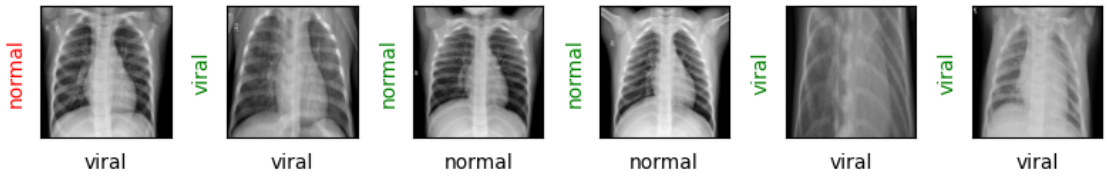

```
Evaluating at step 140
Validation Loss: 0.1033, Accuracy: 0.9889
```




```
Performance condition satisfied, stopping..
CPU times: user 11min 16s, sys: 13.2 s, total: 11min 29s
Wall time: 5min 45s
```

10 Final Results

[17]:
```
show_preds()
```



[ ]:
```

```