```
import os                       # for working with files
import numpy as np              # for numerical computationss
import pandas as pd             # for working with dataframes
import torch                    # Pytorch module
import matplotlib.pyplot as plt # for plotting informations on graph and images using tensors
import torch.nn as nn           # for creating  neural networks
from torch.utils.data import DataLoader # for dataloaders
from PIL import Image           # for checking images
import torch.nn.functional as F # for functions for calculating loss
import torchvision.transforms as transforms   # for transforming images into tensors
from torchvision.utils import make_grid       # for data checking
from torchvision.datasets import ImageFolder  # for working with classes and images
from torchsummary import summary              # for getting the summary of our model

%matplotlib inline
```

[1] ✓ 42.5s Python

```
data_dir = "D:\\Projects & coding\\Project\\Plant Disease Detectifier\\archive\\New Plant Diseases Dataset(Augmented)\\New Plant Diseases Dataset(Augmented)"
train_dir = data_dir + "/train"
valid_dir = data_dir + "/valid"
diseases = os.listdir(train_dir)
```

[2] ✓ 0.1s Python

```
print(diseases)
```

[3] ✓ 0.1s Python

```
['Apple___Apple_scab', 'Apple___Black_rot', 'Apple___Cedar_apple_rust', 'Apple___healthy', 'Blueberry___healthy', 'Cherry_(including_sour)___healthy', 'Cherry_(including_
```

```
print("Total disease classes are: {}".format(len(diseases)))
```

[4] ✓ 0.1s Python

```
Total disease classes are: 38
```

+ Code + Markdown

```
plants = []
NumberOfDiseases = 0
for plant in diseases:
    if plant.split('___')[0] not in plants:
        plants.append(plant.split('___')[0])
    if plant.split('___')[1] != 'healthy':
        NumberOfDiseases += 1
```

[5] ✓ 0.1s Python

```
# unique plants in the dataset
print(f"Unique Plants are: \n{plants}")
```

[6] ✓ 0.1s Python

```
Unique Plants are:
['Apple', 'Blueberry', 'Cherry_(including_sour)', 'Corn_(maize)', 'Grape', 'Orange', 'Peach', 'Pepper,_bell', 'Potato', 'Raspberry', 'Soybean', 'Squash', 'Strawberry', 'T
```

```
# number of unique plants
print("Number of plants: {}".format(len(plants)))
```

[7] ✓ 0.1s Python

```
Number of plants: 14
```

```
# number of unique diseases
print("Number of diseases: {}".format(NumberOfDiseases))
```

[8] ✓ 0.1s Python

```
Number of diseases: 26
```

```python
# Number of images for each disease
nums = {}
for disease in diseases:
    nums[disease] = len(os.listdir(train_dir + '/' + disease))

# converting the nums dictionary to pandas dataframe passing index as plant name and number of images as column

img_per_class = pd.DataFrame(nums.values(), index=nums.keys(), columns=["no. of images"])
img_per_class
```

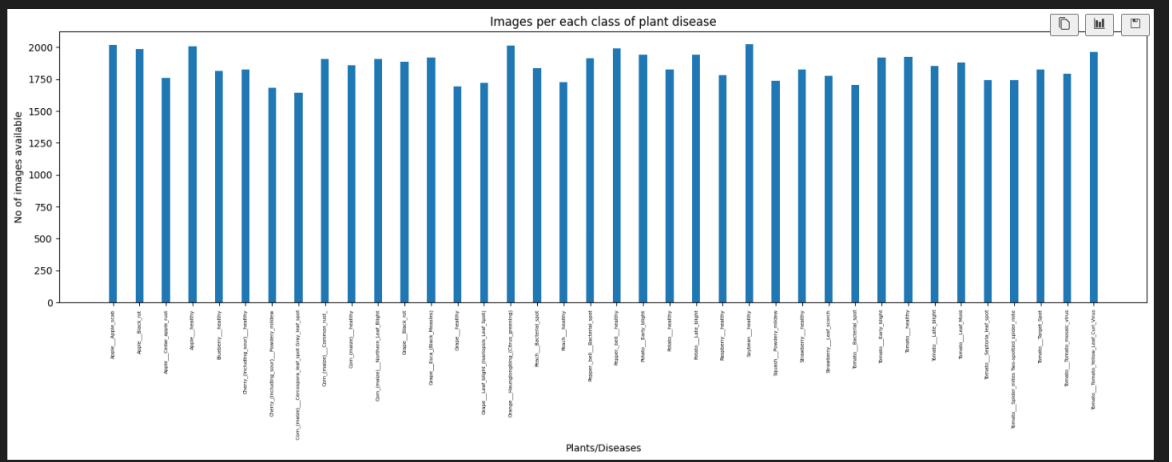
[9] ✓ 0.3s

	no. of images
Apple___Apple_scab	2016
Apple___Black_rot	1987
Apple___Cedar_apple_rust	1760
Apple___healthy	2008
Blueberry___healthy	1816
Cherry_(including_sour)___healthy	1826
Cherry_(including_sour)___Powdery_mildew	1683
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot	1642
Corn_(maize)___Common_rust_	1907
Corn_(maize)___healthy	1859
Corn_(maize)___Northern_Leaf_Blight	1908
Grape___Black_rot	1888
Grape___Esca_(Black_Measles)	1920
Grape___healthy	1692
Grape___Leaf_blight_(Isariopsis_Leaf_Spot)	1722
Orange___Haunglongbing_(Citrus_greening)	2010
Peach___Bacterial_spot	1838
Peach___healthy	1728
Pepper,_bell___Bacterial_spot	1913
Pepper,_bell___healthy	1988
Potato___Early_blight	1939

```python
# plotting number of images available for each disease
index = [n for n in range(38)]
plt.figure(figsize=(20, 5))
plt.bar(index, [n for n in nums.values()], width=0.3)
plt.xlabel('Plants/Diseases', fontsize=10)
plt.ylabel('No of images available', fontsize=10)
plt.xticks(index, diseases, fontsize=5, rotation=90)
plt.title('Images per each class of plant disease')
```

[10] ✓ 2.1s Python

```
Text(0.5, 1.0, 'Images per each class of plant disease')
```



+ Code + Markdown

```
n_train = 0
for value in nums.values():
    n_train += value
print(f"There are {n_train} images for training")
```

[11] ✓ 0.0s

```
There are 70295 images for training
```

```
# datasets for validation and training
train = ImageFolder(train_dir, transform=transforms.ToTensor())
valid = ImageFolder(valid_dir, transform=transforms.ToTensor())
```

[12] ✓ 0.6s

+ Code + Markdown

```
img, label = train[0]
print(img.shape, label)
```

[13] ✓ 0.0s

```
torch.Size([3, 256, 256]) 0
```

```
# total number of classes in train set
len(train.classes)
```

[14] ✓ 0.0s

```
38
```

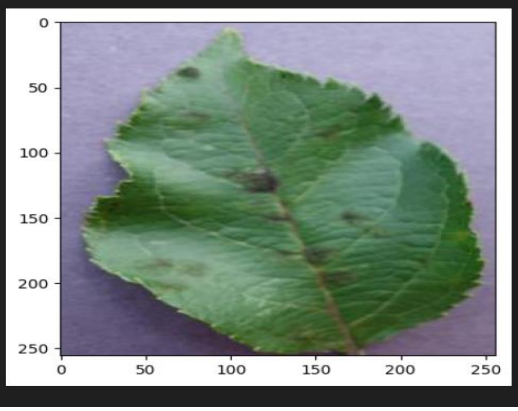
```
# for checking some images from training dataset
def show_image(image, label):
    print("Label :" + train.classes[label] + "(" + str(label) + ")")
    plt.imshow(image.permute(1, 2, 0))
```

[15] ✓ 0.0s

```
show_image(*train[0])
```

[16] ✓ 0.4s

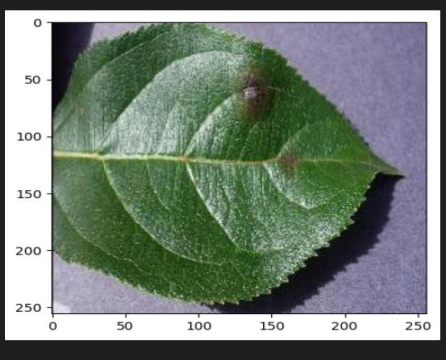
```
Label :Apple___Apple_scab(0)
```




```
show_image(*train[100])
```

[17] ✓ 0.4s

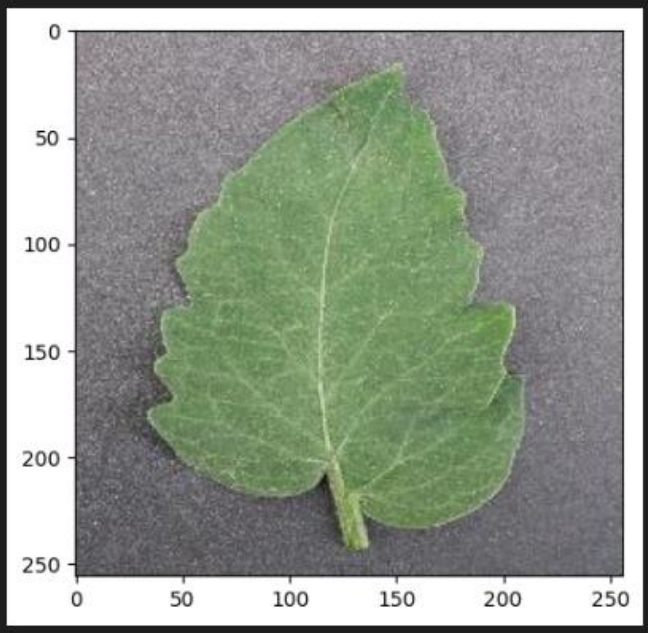
```
Label :Apple___Apple_scab(0)
```



```
show_image(*train[70000])
```

[18] ✓ 0.3s

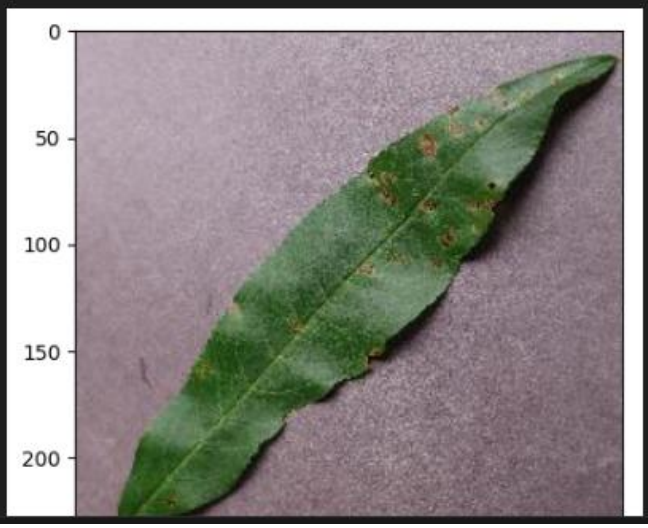
```
Label :Tomato___healthy(37)
```




```
show_image(*train[30000])
```

[19] ✓ 0.3s

```
Label :Peach___Bacterial_spot(16)
```



```python
# Setting the seed value
random_seed = 7
torch.manual_seed(random_seed)
```

[20] ✓ 0.0s Python

```
<torch._C.Generator at 0x2021ee263d0>
```

```python
# setting the batch size
batch_size = 8
```

[21] ✓ 0.0s Python

```python
# DataLoaders for training and validation
train_dl = DataLoader(train, batch_size, shuffle=True, num_workers=2, pin_memory=True)
valid_dl = DataLoader(valid, batch_size, num_workers=2, pin_memory=True)
```

[22] ✓ 0.0s Python

```python
# helper function to show a batch of training instances
def show_batch(data):
    for images, labels in data:
        fig, ax = plt.subplots(figsize=(30, 30))
        ax.set_xticks([]); ax.set_yticks([])
        ax.imshow(make_grid(images, nrow=8).permute(1, 2, 0))
        break
```

[23] ✓ 0.0s Python

```python
# Images for first batch of training
show_batch(train_dl)
```

[24] ✓ 21.3s Python

```python
# for moving data into GPU (if available)
def get_default_device():
    """Pick GPU if available, else CPU"""
    if torch.cuda.is_available:
        return torch.device("cuda")
    else:
        return torch.device("cpu")

# for moving data to device (CPU or GPU)
def to_device(data, device):
    """Move tensor(s) to chosen device"""
    if isinstance(data, (list,tuple)):
        return [to_device(x, device) for x in data]
    return data.to(device, non_blocking=True)

# for loading in the device (GPU if available else CPU)
class DeviceDataLoader():
    """Wrap a dataloader to move data to a device"""
    def __init__(self, dl, device):
        self.dl = dl
        self.device = device

    def __iter__(self):
        """Yield a batch of data after moving it to device"""
        for b in self.dl:
            yield to_device(b, self.device)

    def __len__(self):
        """Number of batches"""
        return len(self.dl)
```

[25] ✓ 0.0s

```python
device = get_default_device()
device
```

[26] ✓ 0.0s

```
device(type='cuda')
```

```python
# Moving data into GPU
train_dl = DeviceDataLoader(train_dl, device)
valid_dl = DeviceDataLoader(valid_dl, device)
```

[27] ✓ 0.0s

```python
class SimpleResidualBlock(nn.Module):
    def __init__(self):
        super().__init__()
        self.conv1 = nn.Conv2d(in_channels=3, out_channels=3, kernel_size=3, stride=1, padding=1)
        self.relu1 = nn.ReLU()
        self.conv2 = nn.Conv2d(in_channels=3, out_channels=3, kernel_size=3, stride=1, padding=1)
        self.relu2 = nn.ReLU()

    def forward(self, x):
        out = self.conv1(x)
        out = self.relu1(out)
        out = self.conv2(out)
        return self.relu2(out) + x # ReLU can be applied before or after adding the input
```

[28] ✓ 0.0s

```python
# for calculating the accuracy
def accuracy(outputs, labels):
    _, preds = torch.max(outputs, dim=1)
    return torch.tensor(torch.sum(preds == labels).item() / len(preds))


# base class for the model
class ImageClassificationBase(nn.Module):

    def training_step(self, batch):
        images, labels = batch
        out = self(images)                  # Generate predictions
        loss = F.cross_entropy(out, labels) # Calculate loss
        return loss

    def validation_step(self, batch):
        images, labels = batch
        out = self(images)                    # Generate prediction
        loss = F.cross_entropy(out, labels)  # Calculate loss
        acc = accuracy(out, labels)           # Calculate accuracy
        return {"val_loss": loss.detach(), "val_accuracy": acc}

    def validation_epoch_end(self, outputs):
        batch_losses = [x["val_loss"] for x in outputs]
        batch_accuracy = [x["val_accuracy"] for x in outputs]
        epoch_loss = torch.stack(batch_losses).mean()       # Combine loss
        epoch_accuracy = torch.stack(batch_accuracy).mean()
        return {"val_loss": epoch_loss, "val_accuracy": epoch_accuracy} # Combine accuracies

    def epoch_end(self, epoch, result):
        print("Epoch [{}], last_lr: {:.5f}, train_loss: {:.4f}, val_loss: {:.4f}, val_acc: {:.4f}".format(
            epoch, result['lrs'][-1], result['train_loss'], result['val_loss'], result['val_accuracy']))
```

[29] ✓ 0.0s

```python
# Architecture for training

# convolution block with BatchNormalization
def ConvBlock(in_channels, out_channels, pool=False):
    layers = [nn.Conv2d(in_channels, out_channels, kernel_size=3, padding=1),
              nn.BatchNorm2d(out_channels),
              nn.ReLU(inplace=True)]
    if pool:
        layers.append(nn.MaxPool2d(4))
    return nn.Sequential(*layers)


# resnet architecture
class ResNet9(ImageClassificationBase):
    def __init__(self, in_channels, num_diseases):
        super().__init__()

        self.conv1 = ConvBlock(in_channels, 64)
        self.conv2 = ConvBlock(64, 128, pool=True) # out_dim : 128 x 64 x 64
        self.res1 = nn.Sequential(ConvBlock(128, 128), ConvBlock(128, 128))

        self.conv3 = ConvBlock(128, 256, pool=True) # out_dim : 256 x 16 x 16
        self.conv4 = ConvBlock(256, 512, pool=True) # out_dim : 512 x 4 x 44
        self.res2 = nn.Sequential(ConvBlock(512, 512), ConvBlock(512, 512))

        self.classifier = nn.Sequential(nn.MaxPool2d(4),
                                        nn.Flatten(),
                                        nn.Linear(512, num_diseases))

    def forward(self, xb): # xb is the loaded batch
        out = self.conv1(xb)
        out = self.conv2(out)
        out = self.res1(out) + out
        out = self.conv3(out)
        out = self.conv4(out)
        out = self.res2(out) + out
        out = self.classifier(out)
        return out
```

[30] ✓ 0.0s

```
# defining the model and moving it to the GPU
model = to_device(ResNet9(3, len(train.classes)), device)
model
```

[31] ✓ 0.1s

```
ResNet9(
  (conv1): Sequential(
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU(inplace=True)
  )
  (conv2): Sequential(
    (0): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    (2): ReLU(inplace=True)
    (3): MaxPool2d(kernel_size=4, stride=4, padding=0, dilation=1, ceil_mode=False)
  )
  (res1): Sequential(
    (0): Sequential(
      (0): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (2): ReLU(inplace=True)
    )
    (1): Sequential(
      (0): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (2): ReLU(inplace=True)
    )
  )
  (conv3): Sequential(
...
    (0): MaxPool2d(kernel_size=4, stride=4, padding=0, dilation=1, ceil_mode=False)
    (1): Flatten(start_dim=1, end_dim=-1)
    (2): Linear(in_features=512, out_features=38, bias=True)
  )
)
```

Output is truncated. View as a scrollable element or open in a text editor. Adjust cell output settings...

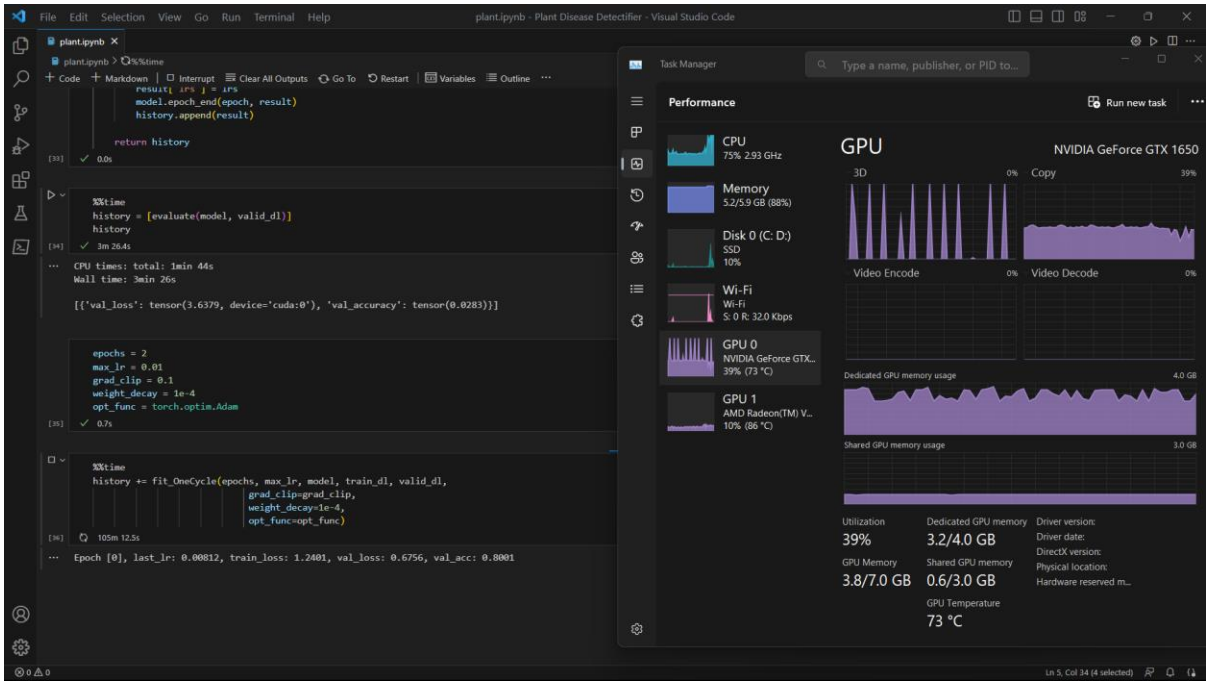
```python
# getting summary of the model
INPUT_SHAPE = (3, 256, 256)
print(summary(model.cuda(), (INPUT_SHAPE)))
```

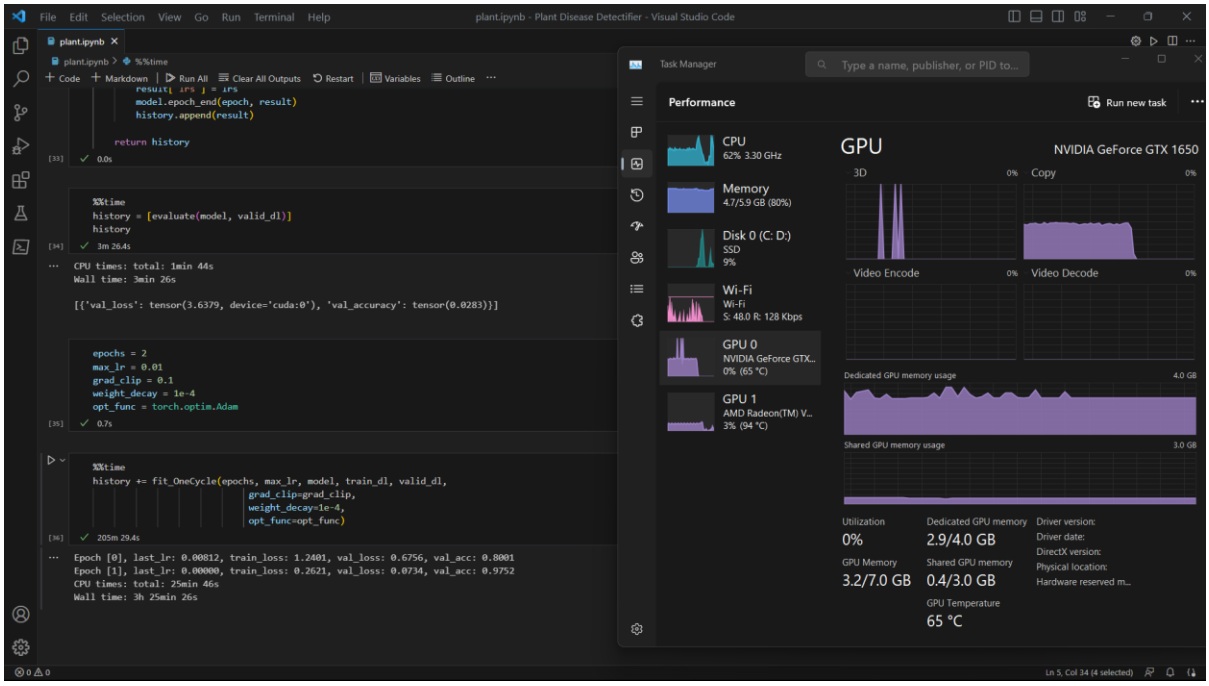
[32] ✓ 7.9s

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 256, 256]           1,792
       BatchNorm2d-2         [-1, 64, 256, 256]             128
              ReLU-3         [-1, 64, 256, 256]               0
            Conv2d-4        [-1, 128, 256, 256]          73,856
       BatchNorm2d-5        [-1, 128, 256, 256]             256
              ReLU-6        [-1, 128, 256, 256]               0
         MaxPool2d-7          [-1, 128, 64, 64]               0
            Conv2d-8          [-1, 128, 64, 64]         147,584
       BatchNorm2d-9          [-1, 128, 64, 64]             256
             ReLU-10          [-1, 128, 64, 64]               0
           Conv2d-11          [-1, 128, 64, 64]         147,584
      BatchNorm2d-12          [-1, 128, 64, 64]             256
             ReLU-13          [-1, 128, 64, 64]               0
           Conv2d-14          [-1, 256, 64, 64]         295,168
      BatchNorm2d-15          [-1, 256, 64, 64]             512
             ReLU-16          [-1, 256, 64, 64]               0
         MaxPool2d-17          [-1, 256, 16, 16]               0
           Conv2d-18          [-1, 512, 16, 16]       1,180,160
      BatchNorm2d-19          [-1, 512, 16, 16]           1,024
             ReLU-20          [-1, 512, 16, 16]               0
         MaxPool2d-21            [-1, 512, 4, 4]               0
           Conv2d-22            [-1, 512, 4, 4]       2,359,808
...
Params size (MB): 25.14
Estimated Total Size (MB): 369.83
----------------------------------------------------------------
None
```

Output is truncated. View as a scrollable element or open in a text editor. Adjust cell output settings...

```python
# for training
@torch.no_grad()
def evaluate(model, val_loader):
    model.eval()
    outputs = [model.validation_step(batch) for batch in val_loader]
    return model.validation_epoch_end(outputs)


def get_lr(optimizer):
    for param_group in optimizer.param_groups:
        return param_group['lr']


def fit_OneCycle(epochs, max_lr, model, train_loader, val_loader, weight_decay=0,
                 grad_clip=None, opt_func=torch.optim.SGD):
    torch.cuda.empty_cache()
    history = []

    optimizer = opt_func(model.parameters(), max_lr, weight_decay=weight_decay)
    # scheduler for one cycle learniing rate
    sched = torch.optim.lr_scheduler.OneCycleLR(optimizer, max_lr, epochs=epochs, steps_per_epoch=len(train_loader))


    for epoch in range(epochs):
        # Training
        model.train()
        train_losses = []
        lrs = []
        for batch in train_loader:
            loss = model.training_step(batch)
            train_losses.append(loss)
            loss.backward()

            # gradient clipping
            if grad_clip:
                nn.utils.clip_grad_value_(model.parameters(), grad_clip)

            optimizer.step()
            optimizer.zero_grad()

            # recording and updating learning rates
            lrs.append(get_lr(optimizer))
            sched.step()


        # validation
        result = evaluate(model, val_loader)
        result['train_loss'] = torch.stack(train_losses).mean().item()
        result['lrs'] = lrs
        model.epoch_end(epoch, result)
        history.append(result)

    return history
```






```
%%time
history = [evaluate(model, valid_dl)]
history
```

[34] ✓ 3m 26.4s

```
CPU times: total: 1min 44s
Wall time: 3min 26s

[{'val_loss': tensor(3.6379, device='cuda:0'), 'val_accuracy': tensor(0.0283)}]
```

```
epochs = 2
max_lr = 0.01
grad_clip = 0.1
weight_decay = 1e-4
opt_func = torch.optim.Adam
```

[35] ✓ 0.7s

```
%%time
history += fit_OneCycle(epochs, max_lr, model, train_dl, valid_dl,
                        grad_clip=grad_clip,
                        weight_decay=1e-4,
                        opt_func=opt_func)
```

[36] ✓ 205m 29.4s

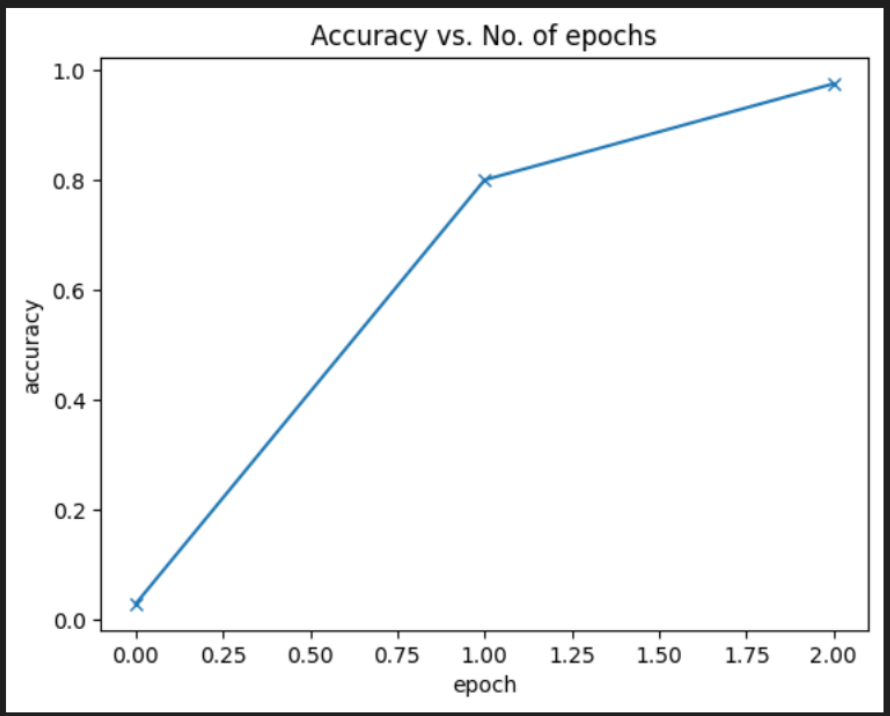
```
Epoch [0], last_lr: 0.00812, train_loss: 1.2401, val_loss: 0.6756, val_acc: 0.8001
Epoch [1], last_lr: 0.00000, train_loss: 0.2621, val_loss: 0.0734, val_acc: 0.9752
CPU times: total: 25min 46s
Wall time: 3h 25min 26s
```

```python
def plot_accuracies(history):
    accuracies = [x['val_accuracy'] for x in history]
    plt.plot(accuracies, '-x')
    plt.xlabel('epoch')
    plt.ylabel('accuracy')
    plt.title('Accuracy vs. No. of epochs');

def plot_losses(history):
    train_losses = [x.get('train_loss') for x in history]
    val_losses = [x['val_loss'] for x in history]
    plt.plot(train_losses, '-bx')
    plt.plot(val_losses, '-rx')
    plt.xlabel('epoch')
    plt.ylabel('loss')
    plt.legend(['Training', 'Validation'])
    plt.title('Loss vs. No. of epochs');

def plot_lrs(history):
    lrs = np.concatenate([x.get('lrs', []) for x in history])
    plt.plot(lrs)
    plt.xlabel('Batch no.')
    plt.ylabel('Learning rate')
    plt.title('Learning Rate vs. Batch no.');
```

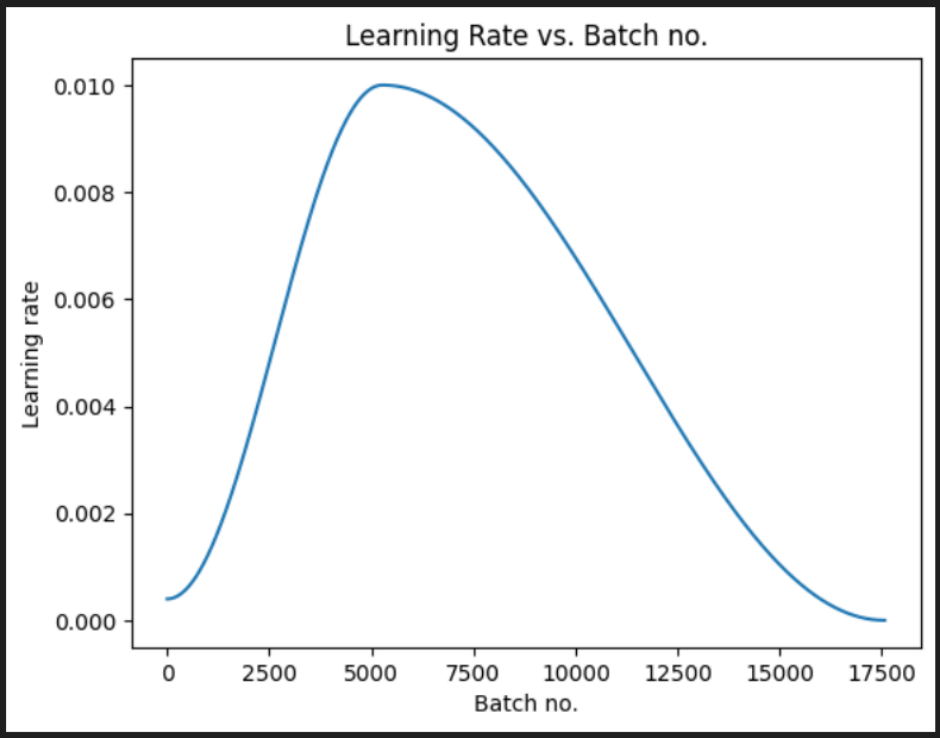
[62]

```python
plot_accuracies(history)
```

[ ]



```
plot_lrs(history)
```




```
test_dir = "D:/Projects & coding/Project/Plant Disease Detectifier/archive/test"
test = ImageFolder(test_dir, transform=transforms.ToTensor())
```

```
test_images = sorted(os.listdir(test_dir + '/test')) # since images in test folder are in alphabetical order
test_images
```

```
['AppleCedarRust1.JPG',
 'AppleCedarRust2.JPG',
 'AppleCedarRust3.JPG',
 'AppleCedarRust4.JPG',
 'AppleScab1.JPG',
 'AppleScab2.JPG',
 'AppleScab3.JPG',
 'CornCommonRust1.JPG',
 'CornCommonRust2.JPG',
 'CornCommonRust3.JPG',
 'PotatoEarlyBlight1.JPG',
 'PotatoEarlyBlight2.JPG',
 'PotatoEarlyBlight3.JPG',
 'PotatoEarlyBlight4.JPG',
 'PotatoEarlyBlight5.JPG',
 'PotatoHealthy1.JPG',
 'PotatoHealthy2.JPG',
 'TomatoEarlyBlight1.JPG',
 'TomatoEarlyBlight2.JPG',
 'TomatoEarlyBlight3.JPG',
 'TomatoEarlyBlight4.JPG',
 'TomatoEarlyBlight5.JPG',
 'TomatoEarlyBlight6.JPG',
 'TomatoHealthy1.JPG',
 'TomatoHealthy2.JPG',
...
 'TomatoYellowCurlVirus2.JPG',
 'TomatoYellowCurlVirus3.JPG',
 'TomatoYellowCurlVirus4.JPG',
 'TomatoYellowCurlVirus5.JPG',
 'TomatoYellowCurlVirus6.JPG']
```

Output is truncated. View as a scrollable element or open in a text editor. Adjust cell output settings...

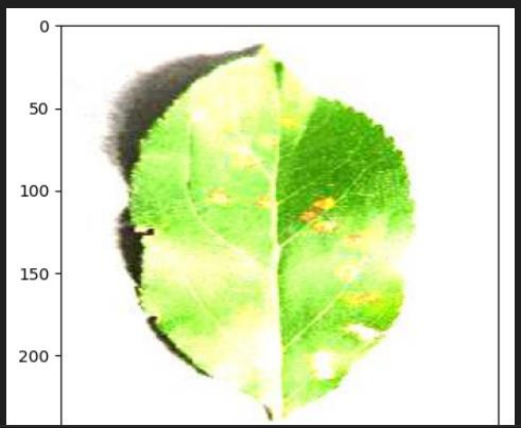
```python
def predict_image(img, model):
    """Converts image to array and return the predicted class
        with highest probability"""
    # Convert to a batch of 1
    xb = to_device(img.unsqueeze(0), device)
    # Get predictions from model
    yb = model(xb)
    # Pick index with highest probability
    _, preds  = torch.max(yb, dim=1)
    # Retrieve the class label

    return train.classes[preds[0].item()]
```

[ ]

```python
# predicting first image
img, label = test[0]
plt.imshow(img.permute(1, 2, 0))
print('Label:', test_images[0], ', Predicted:', predict_image(img, model))
```

[ ]

```
Label: AppleCedarRust1.JPG , Predicted: Apple___Cedar_apple_rust
```




```python
# getting all predictions (actual label vs predicted)
for i, (img, label) in enumerate(test):
    print('Label:', test_images[i], ', Predicted:', predict_image(img, model))
```

[ ]

```
Label: AppleCedarRust1.JPG , Predicted: Apple___Cedar_apple_rust
Label: AppleCedarRust2.JPG , Predicted: Apple___Cedar_apple_rust
Label: AppleCedarRust3.JPG , Predicted: Apple___Cedar_apple_rust
Label: AppleCedarRust4.JPG , Predicted: Apple___Cedar_apple_rust
Label: AppleScab1.JPG , Predicted: Grape___healthy
Label: AppleScab2.JPG , Predicted: Apple___Apple_scab
Label: AppleScab3.JPG , Predicted: Apple___Apple_scab
Label: CornCommonRust1.JPG , Predicted: Corn_(maize)___Common_rust_
Label: CornCommonRust2.JPG , Predicted: Corn_(maize)___Common_rust_
Label: CornCommonRust3.JPG , Predicted: Corn_(maize)___Common_rust_
Label: PotatoEarlyBlight1.JPG , Predicted: Potato___Early_blight
Label: PotatoEarlyBlight2.JPG , Predicted: Potato___Early_blight
Label: PotatoEarlyBlight3.JPG , Predicted: Potato___Early_blight
Label: PotatoEarlyBlight4.JPG , Predicted: Potato___Early_blight
Label: PotatoEarlyBlight5.JPG , Predicted: Potato___Early_blight
Label: PotatoHealthy1.JPG , Predicted: Potato___healthy
Label: PotatoHealthy2.JPG , Predicted: Potato___healthy
Label: TomatoEarlyBlight1.JPG , Predicted: Tomato___Early_blight
Label: TomatoEarlyBlight2.JPG , Predicted: Tomato___Late_blight
Label: TomatoEarlyBlight3.JPG , Predicted: Tomato___Early_blight
Label: TomatoEarlyBlight4.JPG , Predicted: Tomato___Early_blight
Label: TomatoEarlyBlight5.JPG , Predicted: Tomato___Early_blight
Label: TomatoEarlyBlight6.JPG , Predicted: Tomato___Early_blight
Label: TomatoHealthy1.JPG , Predicted: Tomato___healthy
Label: TomatoHealthy2.JPG , Predicted: Tomato___healthy
...
Label: TomatoYellowCurlVirus3.JPG , Predicted: Tomato___Tomato_Yellow_Leaf_Curl_Virus
Label: TomatoYellowCurlVirus4.JPG , Predicted: Tomato___Tomato_Yellow_Leaf_Curl_Virus
Label: TomatoYellowCurlVirus5.JPG , Predicted: Tomato___Tomato_Yellow_Leaf_Curl_Virus
Label: TomatoYellowCurlVirus6.JPG , Predicted: Tomato___Tomato_Yellow_Leaf_Curl_Virus
```

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