resnet_explore-2

April 22, 2024

1 Imported Modules

[ ]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch.utils.data import DataLoader, TensorDataset
from torchvision.models import resnet50, ResNet50_Weights
import torchvision.transforms as T

import os
import math as m
from PIL import Image as I
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix as cm

from ray import train, tune
from ray.tune.schedulers import ASHAScheduler
from ray.train import Checkpoint
from ray.tune.search.optuna import OptunaSearch
```

2 Model Initialization, Layer Replacement, Device Location

[ ]:
```
x = resnet50(weights=ResNet50_Weights.DEFAULT)

for param in x.parameters():
    param.requires_grad = False

x.fc = nn.Linear(2048, 12)
nn.init.kaiming_uniform_(x.fc.weight, nonlinearity='relu')
x.fc.requires_grad = True

if torch.cuda.is_available():
    device = "cuda"
```

```
elif getattr(torch, 'has_mps', False):
    device = "mps"
else:
    device = "cpu"

x = x.to(device)
```

```
/var/folders/yj/n5srfxb951l5x6hcn4jcx3000000gn/T/ipykernel_51918/4026304798.py:1
2: UserWarning: 'has_mps' is deprecated, please use
'torch.backends.mps.is_built()'
  elif getattr(torch, 'has_mps', False):
```

3 Unnormalization Class

[ ]:
```
class Unnormalize(object):
    def __init__(self, mean=None, std=None):
        self.mean = mean
        self.std = std

    def __call__(self, tensor):
        for t, m, s in zip(tensor, self.mean, self.std):
            t.mul_(s).add_(m)
        return tensor
```

4 Data Loading Function

[ ]:
```
data_labels = {}
unnorm = Unnormalize()

def load_images():
    #Bunch of arrays for storing and moving data
    aux_img = []
    aux_labels = []
    train_imgs = []
    train_labels = []
    test_imgs = []
    test_labels = []
    val_imgs = []
    val_labels = []
    idx = 0

    crop = T.CenterCrop((128, 128))

    #Cycle through various folders for images
    for folder in range(len(sorted(os.listdir('Users/thomassigler/
 ↪DeepLearningProject/Data')))):
```

```
        if sorted(os.listdir('Users/thomassigler/DeepLearningProject/
↪Data'))[folder] == '.DS_Store':
            continue
        else:
            aux_img = os.listdir('Users/thomassigler/DeepLearningProject/Data/
↪'+sorted(os.listdir('Users/thomassigler/DeepLearningProject/Data'))[folder])

            for i in range(len(aux_img)):
                #Remove .DS_Store file from data
                if aux_img[i] == '.DS_Store':
                    aux_img.pop(i)
                    break

            #Resize Image and Convert Channels
            for i in range(len(aux_img)):
                try:
                    with I.open('Users/thomassigler/DeepLearningProject/Data/
↪'+sorted(os.listdir('Users/thomassigler/DeepLearningProject/
↪Data'))[folder]+'/'+aux_img[i]) as img:
                        img = crop(img)

                        if img.mode != 'RGB':
                            img = img.convert('RGB')

                        img = np.array(img)
                        aux_img[i] = img
                except Exception as e:
                    print(f"{i}")
            aux_labels = []

            #Generate Labels
            for i in range(len(aux_img)):
                aux_labels.append(idx)
            idx += 1

            #Divide Data and Labels into Training, Testing, and Validation Sets
            train_imgs += aux_img[:int(m.ceil(len(aux_img)*0.6))]
            aux_img = aux_img[int(m.ceil(len(aux_img)*0.6)):]
            val_imgs += aux_img[:int(m.ceil(len(aux_img)*0.75))]
            aux_img = aux_img[int(m.ceil(len(aux_img)*0.75)):]
            test_imgs += aux_img

            train_labels += aux_labels[:int(m.ceil(len(aux_labels)*0.6))]
            aux_labels = aux_labels[int(m.ceil(len(aux_labels)*0.6)):]
            val_labels += aux_labels[:int(m.ceil(len(aux_labels)*0.75))]
            aux_labels = aux_labels[int(m.ceil(len(aux_labels)*0.75)):]
            test_labels += aux_labels
```

```
        data_labels[folder-1] = sorted(os.listdir('./DeepLearningProject/
↪Data'))[folder]

    #Data Normalization RGB -> [0, 1]
    aux_img = []
    aux_img = train_imgs + test_imgs + val_imgs
    mu = np.mean(aux_img, axis=(0, 1, 2))
    sigma = np.std(aux_img, axis=(0, 1, 2))
    unnorm.mean = mu
    unnorm.std = sigma

    normalize = T.Compose([
        T.Normalize(mu, sigma)
    ])

    #Conversion to tensors and recast data
    train_imgs, test_imgs, val_imgs = torch.tensor(train_imgs).to(torch.
↪float32), torch.tensor(test_imgs).to(torch.float32), torch.tensor(val_imgs).
↪to(torch.float32)
    train_labels, test_labels, val_labels = torch.tensor(train_labels), torch.
↪tensor(test_labels), torch.tensor(val_labels)

    #Shuffle Images Sets
    train_imgs, train_labels = shuffle_imgs(train_imgs, train_labels)
    test_imgs, test_labels = shuffle_imgs(test_imgs, test_labels)
    val_imgs, val_labels = shuffle_imgs(val_imgs, val_labels)

    #Normalize and Reorder Data for Processing
    train_imgs = normalize(train_imgs.permute(0, 3, 1, 2))
    test_imgs = normalize(test_imgs.permute(0, 3, 1, 2))
    val_imgs = normalize(val_imgs.permute(0, 3, 1, 2))

    train_set, test_set, val_set = TensorDataset(train_imgs, train_labels),␣
↪TensorDataset(test_imgs, test_labels), TensorDataset(val_imgs, val_labels)

    trainloader, testloader, valloader = DataLoader(dataset=train_set,␣
↪shuffle=True, batch_size=128), DataLoader(dataset=test_set, shuffle=True,␣
↪batch_size=64), DataLoader(dataset=val_set, shuffle=True, batch_size=64)

    return trainloader, testloader, valloader

#Shuffle Images according to Random Noise Generation
def shuffle_imgs(imgs, labels):
    B = imgs.size(0)
    shuffle = torch.randperm(B)
    return imgs[shuffle], labels[shuffle]
```

[ ]:
```
trainloader, testloader, valloader = load_images()
print(data_labels)
```

```
{0: 'apples', 1: 'coconuts', 2: 'grapes', 3: 'guavas', 4: 'lemons', 5: 'limes',
6: 'mango', 7: 'oranges', 8: 'peaches', 9: 'starfruit', 10: 'strawberries', 11:
'watermelons'}
```

5 Train, Test, and Finetuning Functions

[ ]:
```
#Training Method with Adam Optimizer
def trainfunc(model, traindata, valdata, epochs):
    optimizer = optim.Adam(model.parameters(), lr=0.006349288161821683, eps=6.
 ↪5131448417080975e-09)
    #optimizer = optim.SGD(model.parameters(), lr=0.006349288161821683)
    lr_optim = optim.lr_scheduler.CosineAnnealingLR(optimizer, T_max=10)
    loss_list = []
    loss_list_aux = []
    validation_loss = []
    validation_loss_aux = []

    for i in range(epochs):
        tot = 0
        div = 0
        for imgs, labels in traindata:
            imgs = imgs.to(device)
            labels = labels.to(device)
            optimizer.zero_grad()

            logits = model(imgs)
            loss = F.cross_entropy(logits, labels)
            loss_list_aux.append(loss.item())

            tot += (torch.argmax(logits, axis=1) == labels).float().sum().item()
            div += imgs.shape[0]

            loss.backward()
            optimizer.step()
        print('Training Accuracy (epoch ', i, '): ', tot/div*100, '%')
        print('Mean Training Loss: ', torch.mean(torch.tensor(loss_list_aux)))
        loss_list.append(torch.mean(torch.tensor(loss_list_aux)))
        lr_optim.step()

        with torch.no_grad():
            div = 0
            tot = 0
            for imgs, labels in valdata:
                imgs = imgs.to(device)
```

```
                labels = labels.to(device)
                val_logits = model(imgs)
                validation_loss_aux.append(F.cross_entropy(val_logits, labels).
 ↪item())
                val_logits = nn.Softmax()(val_logits)
                pred = torch.argmax(val_logits, axis=1)
                tot += (pred == labels).float().sum().item()
                div += imgs.shape[0]
            validation_loss.append(torch.mean(torch.
 ↪tensor(validation_loss_aux)))
            print('Mean Validation Loss: ', torch.mean(torch.
 ↪tensor(validation_loss_aux)))
            print("Validation Accuracy: ", tot/div*100, "%")

    return model, loss_list, validation_loss

#Finetune Function
def finetune(model, data, valdata, epochs):
    model.fc.requires_grad = False
    model.avgpool.requires_grad = True
    model.layer4.requires_grad = True
    model.layer3.requires_grad = True
    model.layer2.requires_grad = True
    model.layer1.requires_grad = True
    model.maxpool.requires_grad = True
    model.conv1.requires_grad = True

    optimizer = optim.Adam(model.parameters(), lr=0.001)
    lr_sched = optim.lr_scheduler.StepLR(optimizer, step_size=2)
    loss_list = []
    loss_list_aux = []

    for i in range(epochs):
        for imgs, labels in data:
            imgs = imgs.to(device)
            labels = labels.to(device)
            optimizer.zero_grad()

            logits = model(imgs)
            loss = F.cross_entropy(logits, labels)
            loss_list_aux.append(loss.item())

            loss.backward()
            optimizer.step()

        loss_list.append(torch.mean(torch.tensor(loss_list_aux)))
```

```
        div = 0
        tot = 0
        for imgs, labels in valdata:
            imgs = imgs.to(device)
            labels = labels.to(device)
            val_logits = model(imgs)
            val_logits = nn.Softmax()(val_logits)
            pred = torch.argmax(val_logits, axis=1)
            tot += (pred == labels).float().sum().item()
            div += imgs.shape[0]
        print("Validation Accuracy: ", tot/div*100, "%")
        lr_sched.step()
    return model, loss_list

def test(model, data):
    div = 0
    total = 0

    for imgs, labels in data:
        imgs = imgs.to(device)
        labels = labels.to(device)
        logits = model(imgs)
        logits = nn.Softmax()(logits)
        pred = torch.argmax(logits, axis=1)
        div += imgs.shape[0]
        total += (pred == labels).float().sum().item()
    print("Accuracy: ", total/div*100, "%")
```

6 Confusion Matrix Function

[ ]:
```
def confusion_matrix(model, data):
    total_pred = []
    total_labels = []

    for imgs, labels in data:
        imgs = imgs.to(device)
        labels = labels.to(device)

        logits = model(imgs)
        logits = nn.Softmax()(logits)
        pred = torch.argmax(logits, axis=1)

        total_pred += list(pred.to('cpu'))
        total_labels += list(labels.to('cpu'))

    con_mat = cm(total_labels, total_pred)
```

```
    labels = [data_labels[i] for i in range(len(con_mat))]
    plt.figure(figsize=(10, 8))
    ax = sns.heatmap(con_mat, annot=True, cmap="inferno", xticklabels=labels,␣
 ↪yticklabels=labels)
    plt.title(f'ResNet50 Accuracy')
    plt.ylabel('True Labels')
    plt.xlabel('Predicted Labels')
    plt.show()
    plt.clf()
```

7 Hyperparameter Tuning Functions

[ ]:
```
def hfinetunetrain(model, data, optimizer, lr_sched):
    for imgs, labels in data:
        imgs, labels = imgs.to(device), labels.to(device)

        pred = model(imgs)
        optimizer.zero_grad()
        loss = F.cross_entropy(pred, labels)
        loss.backward()
        optimizer.step()
        lr_sched.step()
    if device == "cuda":
        torch.cuda.empty_cache()
    elif device == "mps":
        torch.mps.empty_cache()

def hfinetunetest(model, data):
    model.eval()
    correct = 0
    total = 0

    for imgs, labels in data:
        imgs, labels = imgs.to(device), labels.to(device)

        outputs = model(imgs)

        pred = torch.argmax(outputs, axis=1)

        total += imgs.shape[0]
        correct += (pred == labels).float().sum().item()
    if device == "cuda":
        torch.cuda.empty_cache()
    elif device == "mps":
        torch.mps.empty_cache()
    return correct/total
```

```
def objective(config):
    train_loader, test_loader, val_loader = load_images()

    model = resnet50(weights=ResNet50_Weights.DEFAULT).to(device)
    for param in x.parameters():
        param.requires_grad = False

    model.fc = nn.Sequential(nn.Linear(2048, config["l1"]),
                                        nn.ReLU(),
                                        nn.Linear(config["l1"], config["l2"]),
                                        nn.ReLU(),
                                        nn.Linear(config["l2"], 12)
                                        ).to(device)
    nn.init.kaiming_uniform_(x.fc.weight, nonlinearity='relu')
    x.fc.requires_grad = True

    optimizer = optim.Adam(model.parameters(), lr=config["lr"],␣
 ↪eps=config["eps"])
    lr_sched = optim.lr_scheduler.StepLR(optimizer,␣
 ↪step_size=config["lr_sched_step"])

    for epoch in range(10):
        hfinetunetrain(model, train_loader, optimizer, lr_sched)
        acc = hfinetunetest(model, val_loader)

        checkpoint = None
        if (epoch+1)%5 == 0:
            torch.save(model.state_dict(),
                       "Users/thomassigler/DeepLearningProject/
 ↪TuningCheckpoints/model.pth")
            checkpoint = Checkpoint.from_directory("Users/thomassigler/
 ↪DeepLearningProject/TuningCheckpoints")
        train.report({"mean_accuracy": acc}, checkpoint=checkpoint)

        if device == "cuda":
            torch.cuda.empty_cache()
        elif device == "mps":
            torch.mps.empty_cache()
```

8 Model Benchmark with Replaced Layer

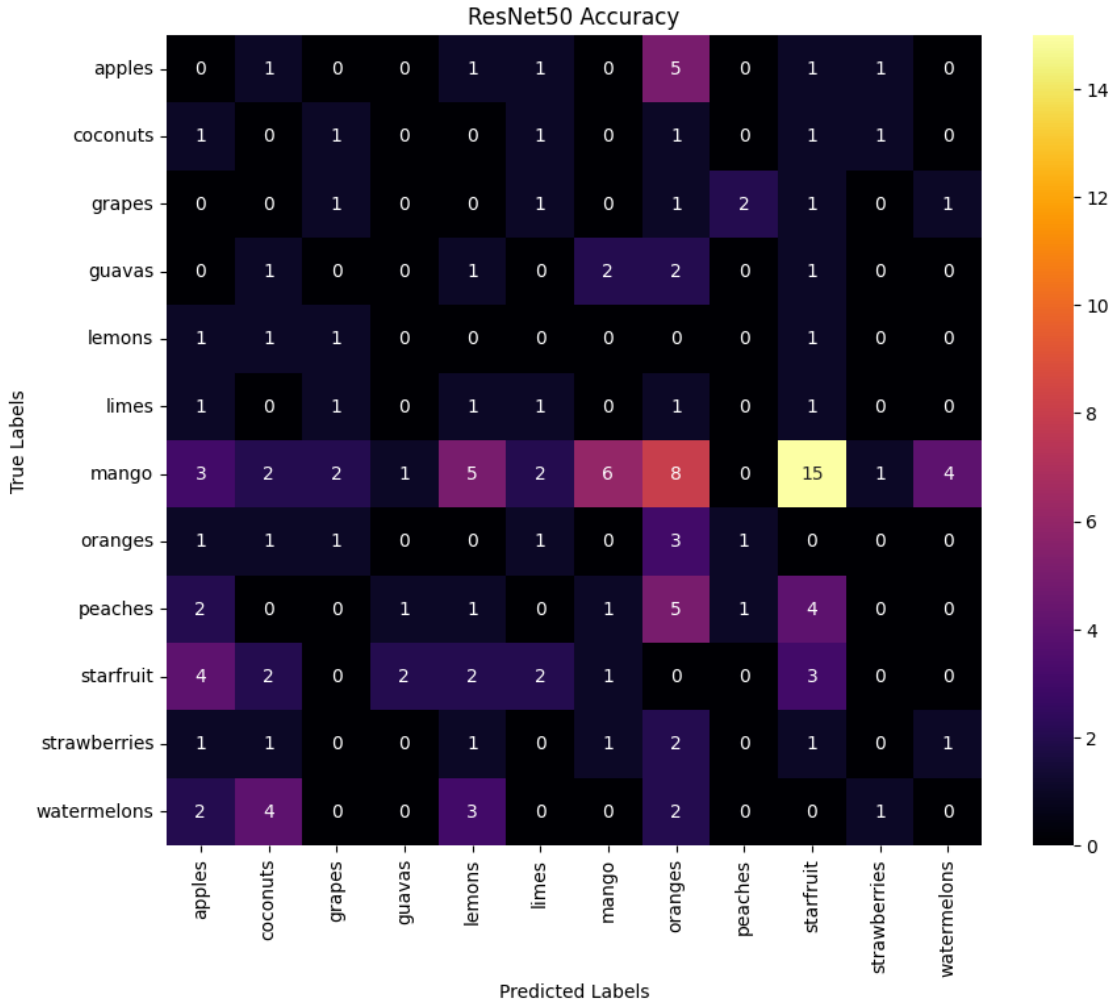
[ ]:
```
test(x, testloader)

confusion_matrix(x, testloader)
```

/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-

```
packages/torch/nn/modules/module.py:1511: UserWarning: Implicit dimension choice
for softmax has been deprecated. Change the call to include dim=X as an
argument.
  return self._call_impl(*args, **kwargs)

Accuracy:  8.108108108108109 %
```




```
<Figure size 640x480 with 0 Axes>
```

9 Training ResNet50 FC Layer

[ ]:
```
x, loss_list, val_loss = trainfunc(x, trainloader, valloader, 200)
test(x, testloader)

confusion_matrix(x, testloader)
```

```
Training Accuracy (epoch  0 ):  36.67745415318231 %
Mean Training Loss:  tensor(1.8886)

/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
packages/torch/nn/modules/module.py:1511: UserWarning: Implicit dimension choice
for softmax has been deprecated. Change the call to include dim=X as an
argument.
  return self._call_impl(*args, **kwargs)

Mean Validation Loss:  tensor(1.2270)
Validation Accuracy:  64.64208242950107 %
Training Accuracy (epoch  1 ):  84.46601941747572 %
Mean Training Loss:  tensor(1.3071)
Mean Validation Loss:  tensor(1.0424)
Validation Accuracy:  74.62039045553145 %
Training Accuracy (epoch  2 ):  91.8015102481122 %
Mean Training Loss:  tensor(0.9962)
Mean Validation Loss:  tensor(0.9315)
Validation Accuracy:  77.87418655097615 %
Training Accuracy (epoch  3 ):  96.87162891046385 %
Mean Training Loss:  tensor(0.8044)
Mean Validation Loss:  tensor(0.8995)
Validation Accuracy:  79.39262472885032 %
Training Accuracy (epoch  4 ):  98.70550161812298 %
Mean Training Loss:  tensor(0.6768)
Mean Validation Loss:  tensor(0.8583)
Validation Accuracy:  80.4772234273319 %
Training Accuracy (epoch  5 ):  99.67637540453075 %
Mean Training Loss:  tensor(0.5845)
Mean Validation Loss:  tensor(0.8309)
Validation Accuracy:  78.52494577006507 %
Training Accuracy (epoch  6 ):  100.0 %
Mean Training Loss:  tensor(0.5173)
Mean Validation Loss:  tensor(0.8053)
Validation Accuracy:  79.82646420824295 %
Training Accuracy (epoch  7 ):  99.78425026968716 %
Mean Training Loss:  tensor(0.4655)
Mean Validation Loss:  tensor(0.7808)
Validation Accuracy:  81.77874186550976 %
Training Accuracy (epoch  8 ):  100.0 %
Mean Training Loss:  tensor(0.4249)
Mean Validation Loss:  tensor(0.7626)
Validation Accuracy:  81.34490238611714 %
Training Accuracy (epoch  9 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.3923)
Mean Validation Loss:  tensor(0.7467)
Validation Accuracy:  80.26030368763557 %
Training Accuracy (epoch  10 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.3654)
```

```
Mean Validation Loss:  tensor(0.7372)
Validation Accuracy:  79.39262472885032 %
Training Accuracy (epoch  11 ):  99.46062567421791 %
Mean Training Loss:  tensor(0.3435)
Mean Validation Loss:  tensor(0.7248)
Validation Accuracy:  81.12798264642083 %
Training Accuracy (epoch  12 ):  99.67637540453075 %
Mean Training Loss:  tensor(0.3246)
Mean Validation Loss:  tensor(0.7135)
Validation Accuracy:  80.26030368763557 %
Training Accuracy (epoch  13 ):  100.0 %
Mean Training Loss:  tensor(0.3082)
Mean Validation Loss:  tensor(0.7070)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  14 ):  100.0 %
Mean Training Loss:  tensor(0.2936)
Mean Validation Loss:  tensor(0.7053)
Validation Accuracy:  81.56182212581345 %
Training Accuracy (epoch  15 ):  99.56850053937433 %
Mean Training Loss:  tensor(0.2820)
Mean Validation Loss:  tensor(0.7036)
Validation Accuracy:  81.12798264642083 %
Training Accuracy (epoch  16 ):  99.56850053937433 %
Mean Training Loss:  tensor(0.2707)
Mean Validation Loss:  tensor(0.6995)
Validation Accuracy:  80.26030368763557 %
Training Accuracy (epoch  17 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.2595)
Mean Validation Loss:  tensor(0.6935)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  18 ):  100.0 %
Mean Training Loss:  tensor(0.2485)
Mean Validation Loss:  tensor(0.6903)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  19 ):  100.0 %
Mean Training Loss:  tensor(0.2384)
Mean Validation Loss:  tensor(0.6895)
Validation Accuracy:  81.12798264642083 %
Training Accuracy (epoch  20 ):  100.0 %
Mean Training Loss:  tensor(0.2289)
Mean Validation Loss:  tensor(0.6876)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  21 ):  100.0 %
Mean Training Loss:  tensor(0.2202)
Mean Validation Loss:  tensor(0.6836)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  22 ):  100.0 %
Mean Training Loss:  tensor(0.2121)
```

```
Mean Validation Loss:  tensor(0.6791)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  23 ):  100.0 %
Mean Training Loss:  tensor(0.2045)
Mean Validation Loss:  tensor(0.6757)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  24 ):  100.0 %
Mean Training Loss:  tensor(0.1973)
Mean Validation Loss:  tensor(0.6728)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  25 ):  100.0 %
Mean Training Loss:  tensor(0.1908)
Mean Validation Loss:  tensor(0.6683)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  26 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.1850)
Mean Validation Loss:  tensor(0.6650)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  27 ):  100.0 %
Mean Training Loss:  tensor(0.1793)
Mean Validation Loss:  tensor(0.6602)
Validation Accuracy:  84.3817787418655 %
Training Accuracy (epoch  28 ):  100.0 %
Mean Training Loss:  tensor(0.1738)
Mean Validation Loss:  tensor(0.6602)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  29 ):  100.0 %
Mean Training Loss:  tensor(0.1689)
Mean Validation Loss:  tensor(0.6595)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  30 ):  100.0 %
Mean Training Loss:  tensor(0.1643)
Mean Validation Loss:  tensor(0.6604)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  31 ):  100.0 %
Mean Training Loss:  tensor(0.1599)
Mean Validation Loss:  tensor(0.6596)
Validation Accuracy:  84.3817787418655 %
Training Accuracy (epoch  32 ):  100.0 %
Mean Training Loss:  tensor(0.1557)
Mean Validation Loss:  tensor(0.6573)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  33 ):  100.0 %
Mean Training Loss:  tensor(0.1517)
Mean Validation Loss:  tensor(0.6552)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  34 ):  100.0 %
Mean Training Loss:  tensor(0.1480)
```

```
Mean Validation Loss:  tensor(0.6536)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  35 ):  100.0 %
Mean Training Loss:  tensor(0.1445)
Mean Validation Loss:  tensor(0.6506)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  36 ):  100.0 %
Mean Training Loss:  tensor(0.1412)
Mean Validation Loss:  tensor(0.6496)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  37 ):  99.78425026968716 %
Mean Training Loss:  tensor(0.1385)
Mean Validation Loss:  tensor(0.6486)
Validation Accuracy:  84.81561822125813 %
Training Accuracy (epoch  38 ):  100.0 %
Mean Training Loss:  tensor(0.1355)
Mean Validation Loss:  tensor(0.6483)
Validation Accuracy:  81.56182212581345 %
Training Accuracy (epoch  39 ):  100.0 %
Mean Training Loss:  tensor(0.1327)
Mean Validation Loss:  tensor(0.6478)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  40 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.1300)
Mean Validation Loss:  tensor(0.6466)
Validation Accuracy:  81.34490238611714 %
Training Accuracy (epoch  41 ):  100.0 %
Mean Training Loss:  tensor(0.1275)
Mean Validation Loss:  tensor(0.6443)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  42 ):  100.0 %
Mean Training Loss:  tensor(0.1249)
Mean Validation Loss:  tensor(0.6418)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  43 ):  100.0 %
Mean Training Loss:  tensor(0.1224)
Mean Validation Loss:  tensor(0.6395)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  44 ):  100.0 %
Mean Training Loss:  tensor(0.1200)
Mean Validation Loss:  tensor(0.6374)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  45 ):  100.0 %
Mean Training Loss:  tensor(0.1177)
Mean Validation Loss:  tensor(0.6370)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  46 ):  100.0 %
Mean Training Loss:  tensor(0.1155)
```

```
Mean Validation Loss:  tensor(0.6394)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  47 ):  100.0 %
Mean Training Loss:  tensor(0.1134)
Mean Validation Loss:  tensor(0.6373)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  48 ):  100.0 %
Mean Training Loss:  tensor(0.1112)
Mean Validation Loss:  tensor(0.6381)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  49 ):  100.0 %
Mean Training Loss:  tensor(0.1092)
Mean Validation Loss:  tensor(0.6368)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  50 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.1075)
Mean Validation Loss:  tensor(0.6358)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  51 ):  100.0 %
Mean Training Loss:  tensor(0.1056)
Mean Validation Loss:  tensor(0.6356)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  52 ):  100.0 %
Mean Training Loss:  tensor(0.1039)
Mean Validation Loss:  tensor(0.6348)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  53 ):  100.0 %
Mean Training Loss:  tensor(0.1022)
Mean Validation Loss:  tensor(0.6385)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  54 ):  100.0 %
Mean Training Loss:  tensor(0.1005)
Mean Validation Loss:  tensor(0.6371)
Validation Accuracy:  81.34490238611714 %
Training Accuracy (epoch  55 ):  100.0 %
Mean Training Loss:  tensor(0.0989)
Mean Validation Loss:  tensor(0.6389)
Validation Accuracy:  81.56182212581345 %
Training Accuracy (epoch  56 ):  100.0 %
Mean Training Loss:  tensor(0.0974)
Mean Validation Loss:  tensor(0.6390)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  57 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.0960)
Mean Validation Loss:  tensor(0.6382)
Validation Accuracy:  80.91106290672451 %
Training Accuracy (epoch  58 ):  100.0 %
Mean Training Loss:  tensor(0.0946)
```

```
Mean Validation Loss:  tensor(0.6374)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  59 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.0932)
Mean Validation Loss:  tensor(0.6372)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  60 ):  100.0 %
Mean Training Loss:  tensor(0.0919)
Mean Validation Loss:  tensor(0.6378)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  61 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.0906)
Mean Validation Loss:  tensor(0.6363)
Validation Accuracy:  84.81561822125813 %
Training Accuracy (epoch  62 ):  100.0 %
Mean Training Loss:  tensor(0.0894)
Mean Validation Loss:  tensor(0.6356)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  63 ):  100.0 %
Mean Training Loss:  tensor(0.0881)
Mean Validation Loss:  tensor(0.6351)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  64 ):  100.0 %
Mean Training Loss:  tensor(0.0869)
Mean Validation Loss:  tensor(0.6356)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  65 ):  100.0 %
Mean Training Loss:  tensor(0.0857)
Mean Validation Loss:  tensor(0.6346)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  66 ):  100.0 %
Mean Training Loss:  tensor(0.0847)
Mean Validation Loss:  tensor(0.6347)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  67 ):  100.0 %
Mean Training Loss:  tensor(0.0836)
Mean Validation Loss:  tensor(0.6341)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  68 ):  100.0 %
Mean Training Loss:  tensor(0.0825)
Mean Validation Loss:  tensor(0.6347)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  69 ):  100.0 %
Mean Training Loss:  tensor(0.0815)
Mean Validation Loss:  tensor(0.6339)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  70 ):  100.0 %
Mean Training Loss:  tensor(0.0804)
```

```
Mean Validation Loss:  tensor(0.6341)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  71 ):  100.0 %
Mean Training Loss:  tensor(0.0794)
Mean Validation Loss:  tensor(0.6336)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  72 ):  100.0 %
Mean Training Loss:  tensor(0.0785)
Mean Validation Loss:  tensor(0.6335)
Validation Accuracy:  81.12798264642083 %
Training Accuracy (epoch  73 ):  100.0 %
Mean Training Loss:  tensor(0.0775)
Mean Validation Loss:  tensor(0.6329)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  74 ):  100.0 %
Mean Training Loss:  tensor(0.0766)
Mean Validation Loss:  tensor(0.6323)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  75 ):  100.0 %
Mean Training Loss:  tensor(0.0756)
Mean Validation Loss:  tensor(0.6320)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  76 ):  100.0 %
Mean Training Loss:  tensor(0.0748)
Mean Validation Loss:  tensor(0.6319)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  77 ):  100.0 %
Mean Training Loss:  tensor(0.0739)
Mean Validation Loss:  tensor(0.6314)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  78 ):  100.0 %
Mean Training Loss:  tensor(0.0731)
Mean Validation Loss:  tensor(0.6314)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  79 ):  100.0 %
Mean Training Loss:  tensor(0.0723)
Mean Validation Loss:  tensor(0.6312)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  80 ):  100.0 %
Mean Training Loss:  tensor(0.0715)
Mean Validation Loss:  tensor(0.6314)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  81 ):  100.0 %
Mean Training Loss:  tensor(0.0707)
Mean Validation Loss:  tensor(0.6304)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  82 ):  100.0 %
Mean Training Loss:  tensor(0.0699)
```

```
Mean Validation Loss:  tensor(0.6302)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  83 ):  100.0 %
Mean Training Loss:  tensor(0.0692)
Mean Validation Loss:  tensor(0.6306)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  84 ):  100.0 %
Mean Training Loss:  tensor(0.0685)
Mean Validation Loss:  tensor(0.6305)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  85 ):  100.0 %
Mean Training Loss:  tensor(0.0678)
Mean Validation Loss:  tensor(0.6305)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  86 ):  100.0 %
Mean Training Loss:  tensor(0.0670)
Mean Validation Loss:  tensor(0.6309)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  87 ):  100.0 %
Mean Training Loss:  tensor(0.0664)
Mean Validation Loss:  tensor(0.6304)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  88 ):  100.0 %
Mean Training Loss:  tensor(0.0657)
Mean Validation Loss:  tensor(0.6298)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  89 ):  100.0 %
Mean Training Loss:  tensor(0.0650)
Mean Validation Loss:  tensor(0.6288)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  90 ):  100.0 %
Mean Training Loss:  tensor(0.0644)
Mean Validation Loss:  tensor(0.6290)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  91 ):  100.0 %
Mean Training Loss:  tensor(0.0637)
Mean Validation Loss:  tensor(0.6276)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  92 ):  100.0 %
Mean Training Loss:  tensor(0.0631)
Mean Validation Loss:  tensor(0.6278)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  93 ):  100.0 %
Mean Training Loss:  tensor(0.0625)
Mean Validation Loss:  tensor(0.6275)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  94 ):  100.0 %
Mean Training Loss:  tensor(0.0619)
```

```
Mean Validation Loss:  tensor(0.6272)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  95 ):  100.0 %
Mean Training Loss:  tensor(0.0613)
Mean Validation Loss:  tensor(0.6260)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  96 ):  99.78425026968716 %
Mean Training Loss:  tensor(0.0608)
Mean Validation Loss:  tensor(0.6254)
Validation Accuracy:  84.81561822125813 %
Training Accuracy (epoch  97 ):  100.0 %
Mean Training Loss:  tensor(0.0602)
Mean Validation Loss:  tensor(0.6249)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  98 ):  100.0 %
Mean Training Loss:  tensor(0.0597)
Mean Validation Loss:  tensor(0.6260)
Validation Accuracy:  81.56182212581345 %
Training Accuracy (epoch  99 ):  100.0 %
Mean Training Loss:  tensor(0.0592)
Mean Validation Loss:  tensor(0.6261)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  100 ):  100.0 %
Mean Training Loss:  tensor(0.0586)
Mean Validation Loss:  tensor(0.6264)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  101 ):  100.0 %
Mean Training Loss:  tensor(0.0581)
Mean Validation Loss:  tensor(0.6263)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  102 ):  100.0 %
Mean Training Loss:  tensor(0.0576)
Mean Validation Loss:  tensor(0.6261)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  103 ):  100.0 %
Mean Training Loss:  tensor(0.0570)
Mean Validation Loss:  tensor(0.6261)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  104 ):  100.0 %
Mean Training Loss:  tensor(0.0565)
Mean Validation Loss:  tensor(0.6258)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  105 ):  100.0 %
Mean Training Loss:  tensor(0.0560)
Mean Validation Loss:  tensor(0.6254)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  106 ):  100.0 %
Mean Training Loss:  tensor(0.0556)
```

```
Mean Validation Loss:  tensor(0.6252)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  107 ):  100.0 %
Mean Training Loss:  tensor(0.0551)
Mean Validation Loss:  tensor(0.6270)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  108 ):  100.0 %
Mean Training Loss:  tensor(0.0546)
Mean Validation Loss:  tensor(0.6265)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  109 ):  100.0 %
Mean Training Loss:  tensor(0.0541)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  110 ):  100.0 %
Mean Training Loss:  tensor(0.0537)
Mean Validation Loss:  tensor(0.6264)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  111 ):  100.0 %
Mean Training Loss:  tensor(0.0533)
Mean Validation Loss:  tensor(0.6255)
Validation Accuracy:  84.81561822125813 %
Training Accuracy (epoch  112 ):  100.0 %
Mean Training Loss:  tensor(0.0528)
Mean Validation Loss:  tensor(0.6261)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  113 ):  100.0 %
Mean Training Loss:  tensor(0.0524)
Mean Validation Loss:  tensor(0.6259)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  114 ):  100.0 %
Mean Training Loss:  tensor(0.0520)
Mean Validation Loss:  tensor(0.6256)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  115 ):  100.0 %
Mean Training Loss:  tensor(0.0516)
Mean Validation Loss:  tensor(0.6257)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  116 ):  100.0 %
Mean Training Loss:  tensor(0.0512)
Mean Validation Loss:  tensor(0.6253)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  117 ):  100.0 %
Mean Training Loss:  tensor(0.0508)
Mean Validation Loss:  tensor(0.6253)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  118 ):  100.0 %
Mean Training Loss:  tensor(0.0504)
```

```
Mean Validation Loss:  tensor(0.6251)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  119 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.0501)
Mean Validation Loss:  tensor(0.6254)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  120 ):  100.0 %
Mean Training Loss:  tensor(0.0497)
Mean Validation Loss:  tensor(0.6264)
Validation Accuracy:  80.26030368763557 %
Training Accuracy (epoch  121 ):  100.0 %
Mean Training Loss:  tensor(0.0493)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  122 ):  100.0 %
Mean Training Loss:  tensor(0.0490)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  123 ):  100.0 %
Mean Training Loss:  tensor(0.0486)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  124 ):  100.0 %
Mean Training Loss:  tensor(0.0482)
Mean Validation Loss:  tensor(0.6265)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  125 ):  100.0 %
Mean Training Loss:  tensor(0.0479)
Mean Validation Loss:  tensor(0.6265)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  126 ):  100.0 %
Mean Training Loss:  tensor(0.0475)
Mean Validation Loss:  tensor(0.6261)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  127 ):  100.0 %
Mean Training Loss:  tensor(0.0472)
Mean Validation Loss:  tensor(0.6263)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  128 ):  100.0 %
Mean Training Loss:  tensor(0.0469)
Mean Validation Loss:  tensor(0.6258)
Validation Accuracy:  84.3817787418655 %
Training Accuracy (epoch  129 ):  100.0 %
Mean Training Loss:  tensor(0.0465)
Mean Validation Loss:  tensor(0.6258)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  130 ):  100.0 %
Mean Training Loss:  tensor(0.0462)
```

```
Mean Validation Loss:  tensor(0.6255)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  131 ):  100.0 %
Mean Training Loss:  tensor(0.0459)
Mean Validation Loss:  tensor(0.6257)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  132 ):  100.0 %
Mean Training Loss:  tensor(0.0456)
Mean Validation Loss:  tensor(0.6254)
Validation Accuracy:  84.59869848156181 %
Training Accuracy (epoch  133 ):  100.0 %
Mean Training Loss:  tensor(0.0453)
Mean Validation Loss:  tensor(0.6254)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  134 ):  100.0 %
Mean Training Loss:  tensor(0.0450)
Mean Validation Loss:  tensor(0.6252)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  135 ):  100.0 %
Mean Training Loss:  tensor(0.0446)
Mean Validation Loss:  tensor(0.6258)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  136 ):  100.0 %
Mean Training Loss:  tensor(0.0443)
Mean Validation Loss:  tensor(0.6257)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  137 ):  100.0 %
Mean Training Loss:  tensor(0.0440)
Mean Validation Loss:  tensor(0.6255)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  138 ):  100.0 %
Mean Training Loss:  tensor(0.0437)
Mean Validation Loss:  tensor(0.6253)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  139 ):  100.0 %
Mean Training Loss:  tensor(0.0435)
Mean Validation Loss:  tensor(0.6252)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  140 ):  100.0 %
Mean Training Loss:  tensor(0.0432)
Mean Validation Loss:  tensor(0.6251)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  141 ):  100.0 %
Mean Training Loss:  tensor(0.0429)
Mean Validation Loss:  tensor(0.6247)
Validation Accuracy:  81.99566160520607 %
Training Accuracy (epoch  142 ):  100.0 %
Mean Training Loss:  tensor(0.0426)
```

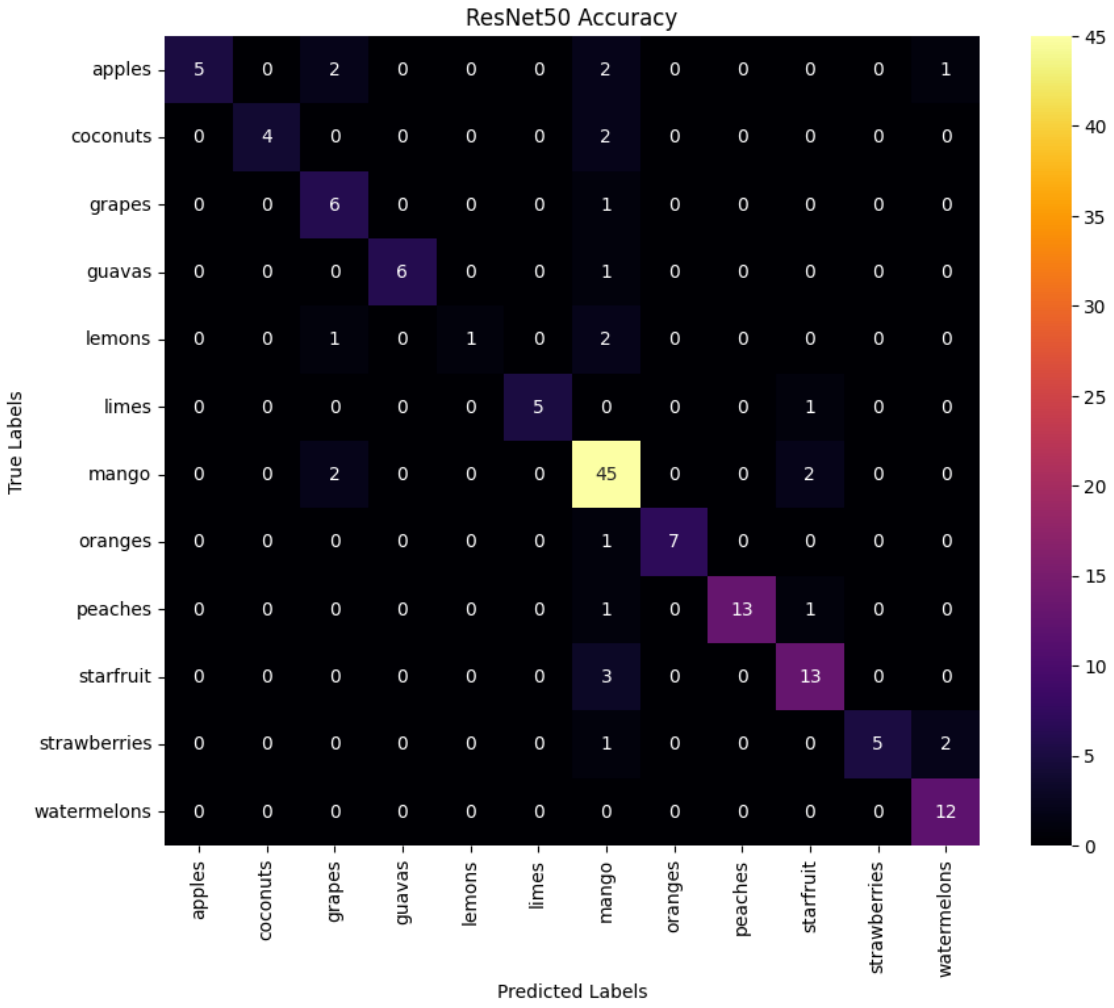
```
Mean Validation Loss:  tensor(0.6250)
Validation Accuracy:  81.77874186550976 %
Training Accuracy (epoch  143 ):  100.0 %
Mean Training Loss:  tensor(0.0423)
Mean Validation Loss:  tensor(0.6251)
Validation Accuracy:  80.91106290672451 %
Training Accuracy (epoch  144 ):  100.0 %
Mean Training Loss:  tensor(0.0421)
Mean Validation Loss:  tensor(0.6257)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  145 ):  100.0 %
Mean Training Loss:  tensor(0.0418)
Mean Validation Loss:  tensor(0.6255)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  146 ):  100.0 %
Mean Training Loss:  tensor(0.0416)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  81.77874186550976 %
Training Accuracy (epoch  147 ):  100.0 %
Mean Training Loss:  tensor(0.0413)
Mean Validation Loss:  tensor(0.6264)
Validation Accuracy:  84.59869848156181 %
Training Accuracy (epoch  148 ):  100.0 %
Mean Training Loss:  tensor(0.0411)
Mean Validation Loss:  tensor(0.6270)
Validation Accuracy:  81.56182212581345 %
Training Accuracy (epoch  149 ):  100.0 %
Mean Training Loss:  tensor(0.0408)
Mean Validation Loss:  tensor(0.6267)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  150 ):  100.0 %
Mean Training Loss:  tensor(0.0406)
Mean Validation Loss:  tensor(0.6266)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  151 ):  100.0 %
Mean Training Loss:  tensor(0.0403)
Mean Validation Loss:  tensor(0.6273)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  152 ):  100.0 %
Mean Training Loss:  tensor(0.0401)
Mean Validation Loss:  tensor(0.6277)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  153 ):  100.0 %
Mean Training Loss:  tensor(0.0398)
Mean Validation Loss:  tensor(0.6281)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  154 ):  100.0 %
Mean Training Loss:  tensor(0.0396)
```

```
Mean Validation Loss:  tensor(0.6282)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  155 ):  100.0 %
Mean Training Loss:  tensor(0.0394)
Mean Validation Loss:  tensor(0.6280)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  156 ):  100.0 %
Mean Training Loss:  tensor(0.0391)
Mean Validation Loss:  tensor(0.6275)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  157 ):  100.0 %
Mean Training Loss:  tensor(0.0389)
Mean Validation Loss:  tensor(0.6273)
Validation Accuracy:  81.12798264642083 %
Training Accuracy (epoch  158 ):  100.0 %
Mean Training Loss:  tensor(0.0387)
Mean Validation Loss:  tensor(0.6273)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  159 ):  100.0 %
Mean Training Loss:  tensor(0.0384)
Mean Validation Loss:  tensor(0.6272)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  160 ):  100.0 %
Mean Training Loss:  tensor(0.0382)
Mean Validation Loss:  tensor(0.6272)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  161 ):  100.0 %
Mean Training Loss:  tensor(0.0380)
Mean Validation Loss:  tensor(0.6274)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  162 ):  100.0 %
Mean Training Loss:  tensor(0.0378)
Mean Validation Loss:  tensor(0.6271)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  163 ):  100.0 %
Mean Training Loss:  tensor(0.0376)
Mean Validation Loss:  tensor(0.6271)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  164 ):  100.0 %
Mean Training Loss:  tensor(0.0373)
Mean Validation Loss:  tensor(0.6268)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  165 ):  100.0 %
Mean Training Loss:  tensor(0.0371)
Mean Validation Loss:  tensor(0.6268)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  166 ):  100.0 %
Mean Training Loss:  tensor(0.0369)
```

```
Mean Validation Loss:  tensor(0.6267)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  167 ):  100.0 %
Mean Training Loss:  tensor(0.0367)
Mean Validation Loss:  tensor(0.6264)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  168 ):  100.0 %
Mean Training Loss:  tensor(0.0365)
Mean Validation Loss:  tensor(0.6269)
Validation Accuracy:  84.3817787418655 %
Training Accuracy (epoch  169 ):  100.0 %
Mean Training Loss:  tensor(0.0363)
Mean Validation Loss:  tensor(0.6270)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  170 ):  100.0 %
Mean Training Loss:  tensor(0.0361)
Mean Validation Loss:  tensor(0.6269)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  171 ):  100.0 %
Mean Training Loss:  tensor(0.0359)
Mean Validation Loss:  tensor(0.6271)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  172 ):  100.0 %
Mean Training Loss:  tensor(0.0357)
Mean Validation Loss:  tensor(0.6272)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  173 ):  100.0 %
Mean Training Loss:  tensor(0.0356)
Mean Validation Loss:  tensor(0.6275)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  174 ):  100.0 %
Mean Training Loss:  tensor(0.0354)
Mean Validation Loss:  tensor(0.6277)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  175 ):  100.0 %
Mean Training Loss:  tensor(0.0352)
Mean Validation Loss:  tensor(0.6278)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  176 ):  100.0 %
Mean Training Loss:  tensor(0.0350)
Mean Validation Loss:  tensor(0.6281)
Validation Accuracy:  82.646420824295 %
Training Accuracy (epoch  177 ):  100.0 %
Mean Training Loss:  tensor(0.0348)
Mean Validation Loss:  tensor(0.6278)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  178 ):  100.0 %
Mean Training Loss:  tensor(0.0346)
```

```
Mean Validation Loss:  tensor(0.6282)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  179 ):  100.0 %
Mean Training Loss:  tensor(0.0345)
Mean Validation Loss:  tensor(0.6282)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  180 ):  100.0 %
Mean Training Loss:  tensor(0.0343)
Mean Validation Loss:  tensor(0.6277)
Validation Accuracy:  84.1648590021692 %
Training Accuracy (epoch  181 ):  100.0 %
Mean Training Loss:  tensor(0.0341)
Mean Validation Loss:  tensor(0.6279)
Validation Accuracy:  84.81561822125813 %
Training Accuracy (epoch  182 ):  100.0 %
Mean Training Loss:  tensor(0.0339)
Mean Validation Loss:  tensor(0.6280)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  183 ):  100.0 %
Mean Training Loss:  tensor(0.0337)
Mean Validation Loss:  tensor(0.6288)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  184 ):  100.0 %
Mean Training Loss:  tensor(0.0336)
Mean Validation Loss:  tensor(0.6288)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  185 ):  100.0 %
Mean Training Loss:  tensor(0.0334)
Mean Validation Loss:  tensor(0.6289)
Validation Accuracy:  82.4295010845987 %
Training Accuracy (epoch  186 ):  100.0 %
Mean Training Loss:  tensor(0.0332)
Mean Validation Loss:  tensor(0.6285)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  187 ):  100.0 %
Mean Training Loss:  tensor(0.0331)
Mean Validation Loss:  tensor(0.6286)
Validation Accuracy:  81.77874186550976 %
Training Accuracy (epoch  188 ):  100.0 %
Mean Training Loss:  tensor(0.0329)
Mean Validation Loss:  tensor(0.6283)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  189 ):  100.0 %
Mean Training Loss:  tensor(0.0328)
Mean Validation Loss:  tensor(0.6280)
Validation Accuracy:  82.86334056399133 %
Training Accuracy (epoch  190 ):  100.0 %
Mean Training Loss:  tensor(0.0326)
```

```
Mean Validation Loss:  tensor(0.6282)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  191 ):  100.0 %
Mean Training Loss:  tensor(0.0324)
Mean Validation Loss:  tensor(0.6283)
Validation Accuracy:  83.08026030368764 %
Training Accuracy (epoch  192 ):  100.0 %
Mean Training Loss:  tensor(0.0323)
Mean Validation Loss:  tensor(0.6286)
Validation Accuracy:  83.51409978308027 %
Training Accuracy (epoch  193 ):  100.0 %
Mean Training Loss:  tensor(0.0321)
Mean Validation Loss:  tensor(0.6283)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  194 ):  100.0 %
Mean Training Loss:  tensor(0.0320)
Mean Validation Loss:  tensor(0.6285)
Validation Accuracy:  83.94793926247289 %
Training Accuracy (epoch  195 ):  100.0 %
Mean Training Loss:  tensor(0.0318)
Mean Validation Loss:  tensor(0.6284)
Validation Accuracy:  83.73101952277658 %
Training Accuracy (epoch  196 ):  100.0 %
Mean Training Loss:  tensor(0.0317)
Mean Validation Loss:  tensor(0.6282)
Validation Accuracy:  82.21258134490239 %
Training Accuracy (epoch  197 ):  99.89212513484358 %
Mean Training Loss:  tensor(0.0315)
Mean Validation Loss:  tensor(0.6291)
Validation Accuracy:  85.24945770065075 %
Training Accuracy (epoch  198 ):  100.0 %
Mean Training Loss:  tensor(0.0314)
Mean Validation Loss:  tensor(0.6287)
Validation Accuracy:  83.29718004338395 %
Training Accuracy (epoch  199 ):  100.0 %
Mean Training Loss:  tensor(0.0313)
Mean Validation Loss:  tensor(0.6299)
Validation Accuracy:  84.81561822125813 %
Accuracy:  81.08108108108108 %
```




```
<Figure size 640x480 with 0 Axes>
```

10 Finetuning Pre-trained Layers

[ ]:
```
x, loss_list_val = finetune(x, valloader, valloader, 200)
test(x, testloader)
```

```
/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
packages/torch/nn/modules/module.py:1511: UserWarning: Implicit dimension choice
for softmax has been deprecated. Change the call to include dim=X as an
argument.
  return self._call_impl(*args, **kwargs)

Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  86.55097613882863 %
```

```
Validation Accuracy:  84.59869848156181 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  88.06941431670282 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  88.06941431670282 %
Validation Accuracy:  87.41865509761388 %
Validation Accuracy:  86.55097613882863 %
Validation Accuracy:  86.55097613882863 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  83.94793926247289 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  86.55097613882863 %
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Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  86.55097613882863 %
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Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  86.55097613882863 %
Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  87.85249457700651 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  85.46637744034707 %
```

```
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  84.1648590021692 %
Validation Accuracy:  87.41865509761388 %
Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  84.81561822125813 %
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Validation Accuracy:  86.33405639913232 %
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Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  86.55097613882863 %
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Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  86.76789587852495 %
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Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  84.59869848156181 %
Validation Accuracy:  87.63557483731019 %
```

```
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  87.41865509761388 %
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Validation Accuracy:  87.20173535791757 %
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Validation Accuracy:  85.90021691973969 %
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Validation Accuracy:  85.03253796095444 %
Validation Accuracy:  85.03253796095444 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  86.98481561822126 %
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Validation Accuracy:  86.33405639913232 %
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Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  85.03253796095444 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  86.11713665943601 %
```

```
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  87.41865509761388 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  88.28633405639913 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  87.85249457700651 %
Validation Accuracy:  86.98481561822126 %
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Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  85.68329718004338 %
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Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  87.41865509761388 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  87.41865509761388 %
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  85.90021691973969 %
Validation Accuracy:  88.93709327548807 %
Validation Accuracy:  85.03253796095444 %
Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  86.98481561822126 %
Validation Accuracy:  87.63557483731019 %
Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  84.81561822125813 %
Validation Accuracy:  86.76789587852495 %
Validation Accuracy:  85.46637744034707 %
Validation Accuracy:  86.55097613882863 %
Validation Accuracy:  87.20173535791757 %
Validation Accuracy:  85.24945770065075 %
Validation Accuracy:  87.85249457700651 %
```

```
Validation Accuracy:  85.68329718004338 %
Validation Accuracy:  86.55097613882863 %
Validation Accuracy:  86.11713665943601 %
Validation Accuracy:  86.33405639913232 %
Validation Accuracy:  86.76789587852495 %
Accuracy:  85.8108108108108 %
```

11 Hyperparameter Tuning

[ ]:
```
search_space = {"lr": tune.loguniform(1e-4, 1e-1), "eps": tune.
 ↪loguniform(1e-10, 1e-6), "l1": tune.randint(50, 2049), "l2": tune.
 ↪randint(12, 101), "lr_sched_step": tune.randint(1, 21)}
tuner = tune.Tuner(objective, tune_config=tune.
 ↪TuneConfig(metric="mean_accuracy", mode="max", search_alg=OptunaSearch(),␣
 ↪num_samples=2), param_space=search_space)

results = tuner.fit()
print("Best Config is: ", results.get_best_result().config)
```

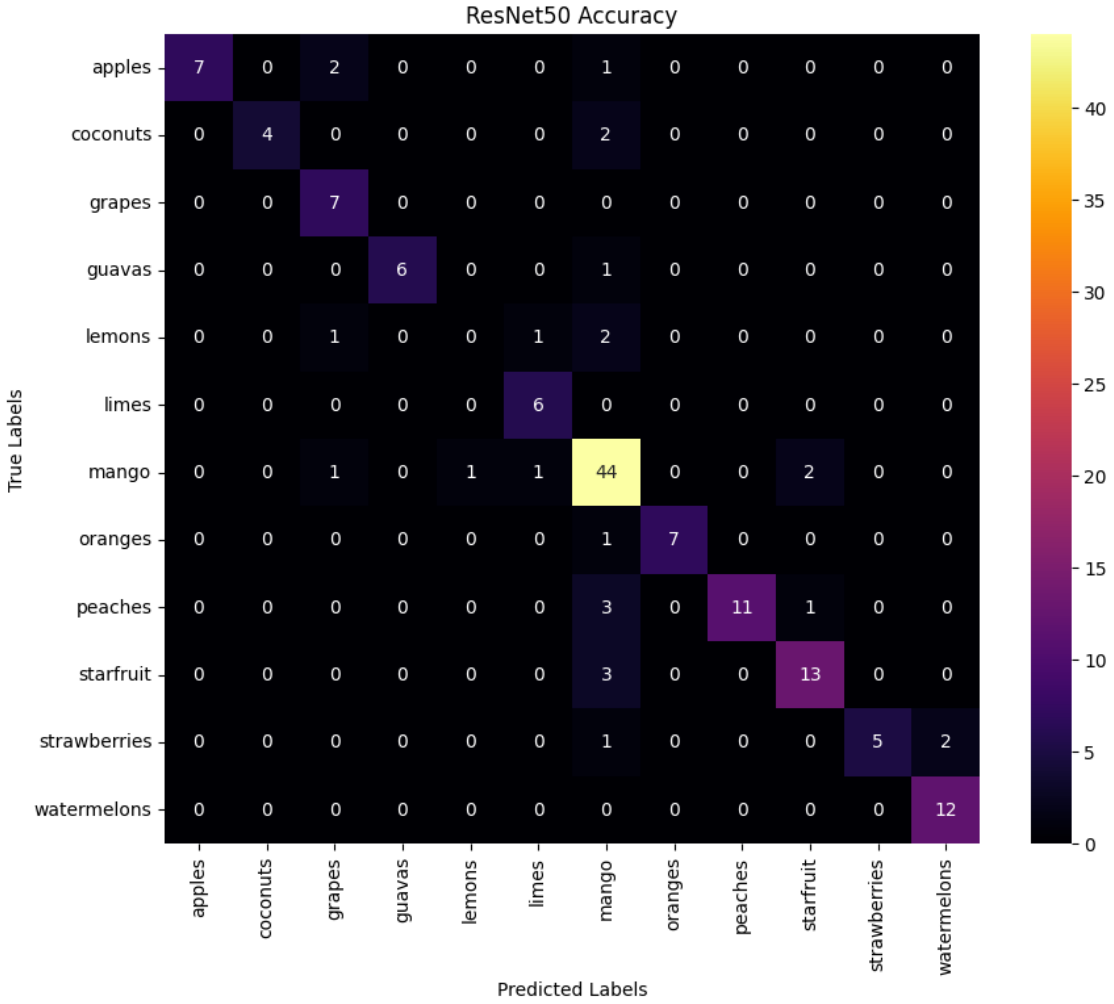
```
<IPython.core.display.HTML object>

(raylet) Warning: The actor ImplicitFunc is very large (90 MiB). Check
that its definition is not implicitly capturing a large array or other object in
scope. Tip: use ray.put() to put large objects in the Ray object store.

(objective pid=50259) /var/folders/yj/n5srfxb951l5x6hcn4jcx3000000gn/T/
ipykernel_51918/3592750841.py:78: UserWarning: Creating a tensor from a list of
numpy.ndarrays is extremely slow. Please consider converting the list to a
single numpy.ndarray with numpy.array() before converting to a tensor.
(Triggered internally at
/Users/runner/work/pytorch/pytorch/pytorch/torch/csrc/utils/tensor_new.cpp:278.)
(objective pid=50277) /var/folders/yj/n5srfxb951l5x6hcn4jcx3000000gn/T/
ipykernel_51918/3592750841.py:78: UserWarning: Creating a tensor from a list of
numpy.ndarrays is extremely slow. Please consider converting the list to a
single numpy.ndarray with numpy.array() before converting to a tensor.
(Triggered internally at
/Users/runner/work/pytorch/pytorch/pytorch/torch/csrc/utils/tensor_new.cpp:278.)
2024-04-22 18:10:08,284 WARNING util.py:202 -- The `on_step_begin` operation
took 0.550 s, which may be a performance bottleneck.
(objective pid=50259) Checkpoint successfully created at:
Checkpoint(filesystem=local, path=/Users/thomassigler/ray_results/objective_2024
-04-22_17-59-
50/objective_b9f0a4dd_1_eps=0.0000,l1=1881,l2=42,lr=0.0002,lr_sched_step=6_2024-
04-22_17-59-55/checkpoint_000000)
(objective pid=50277) Checkpoint successfully created at:
Checkpoint(filesystem=local, path=/Users/thomassigler/ray_results/objective_2024
-04-22_17-59-
50/objective_f4523408_2_eps=0.0000,l1=719,l2=72,lr=0.0125,lr_sched_step=6_2024-
```

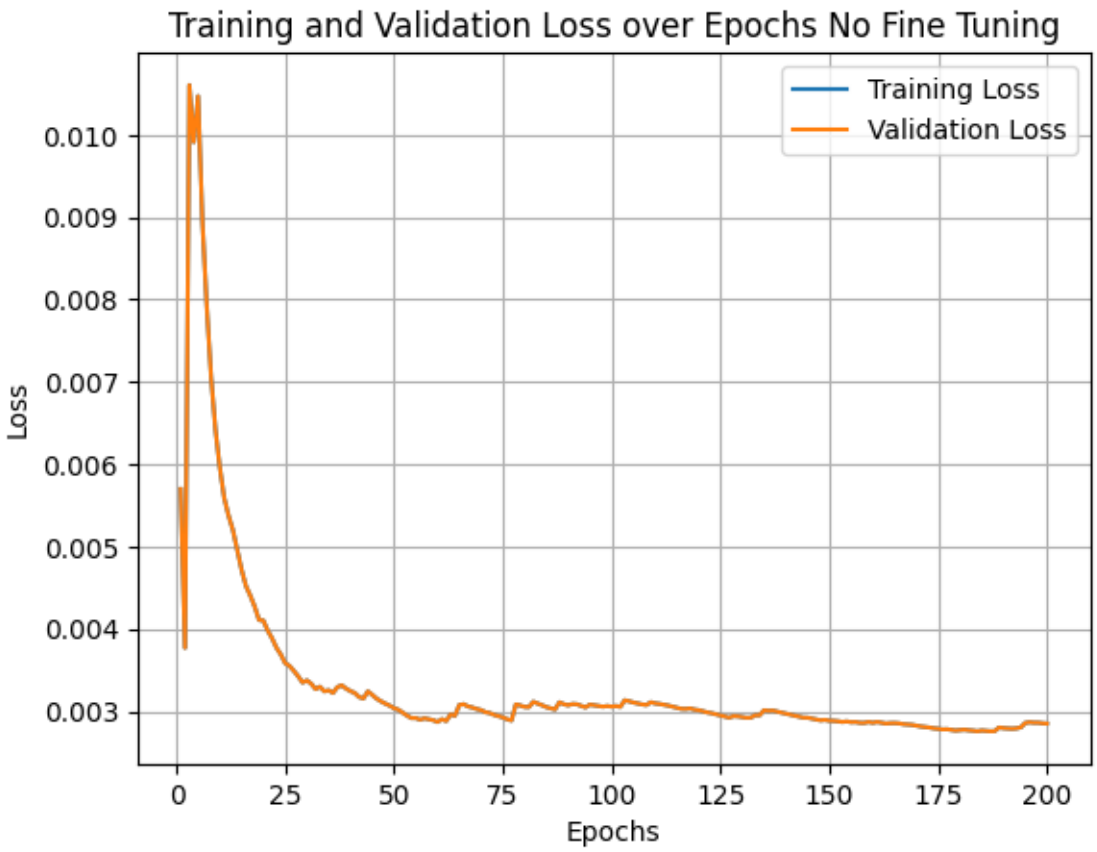
```
04-22_18-00-11/checkpoint_000000)
(objective pid=50259) Checkpoint successfully created at:
Checkpoint(filesystem=local, path=/Users/thomassigler/ray_results/objective_2024
-04-22_17-59-
50/objective_b9f0a4dd_1_eps=0.0000,l1=1881,l2=42,lr=0.0002,lr_sched_step=6_2024-
04-22_17-59-55/checkpoint_000001)
(objective pid=50277) Checkpoint successfully created at:
Checkpoint(filesystem=local, path=/Users/thomassigler/ray_results/objective_2024
-04-22_17-59-
50/objective_f4523408_2_eps=0.0000,l1=719,l2=72,lr=0.0125,lr_sched_step=6_2024-
04-22_18-00-11/checkpoint_000001)
2024-04-22 18:27:02,663 INFO tune.py:1016 -- Wrote the latest version of all
result files and experiment state to
'/Users/thomassigler/ray_results/objective_2024-04-22_17-59-50' in 0.0138s.
2024-04-22 18:27:02,697 INFO tune.py:1048 -- Total run time: 1632.33 seconds
(1630.50 seconds for the tuning loop).

Best Config is:  {'lr': 0.00023301901230003848, 'eps': 2.887185712485118e-09,
'l1': 1881, 'l2': 42, 'lr_sched_step': 6}
```

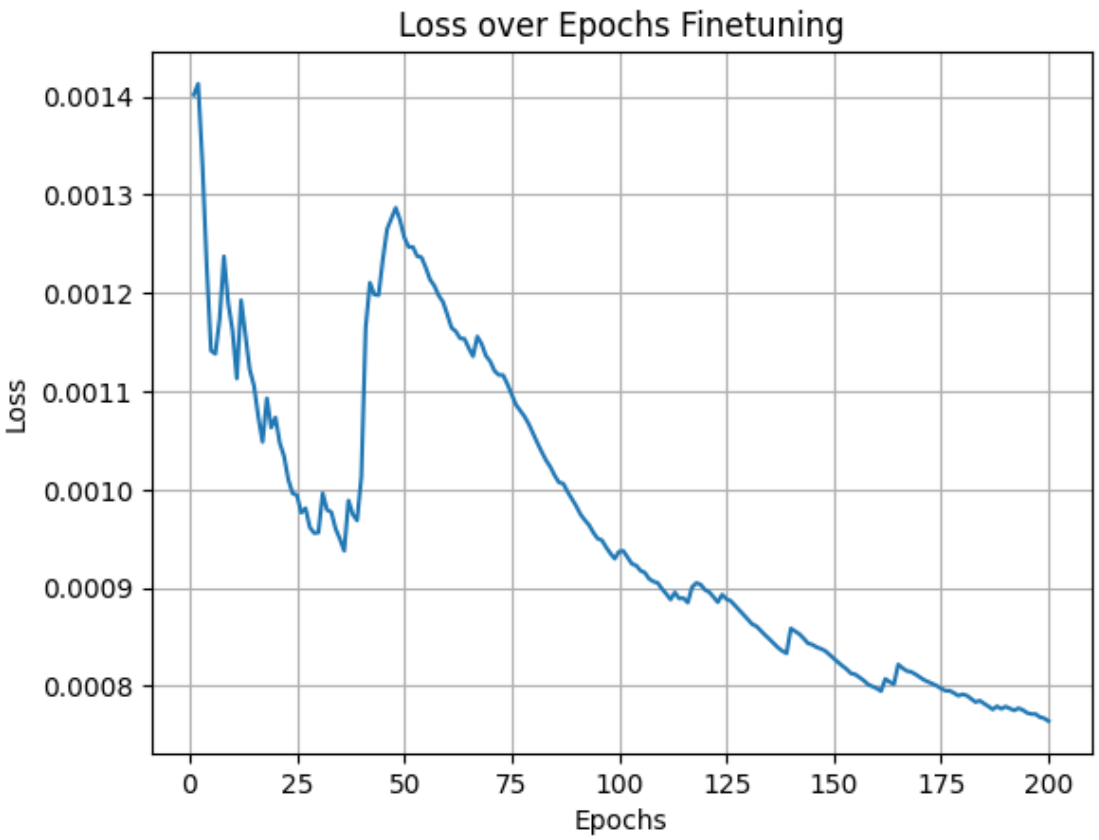
12 Plotting Graphs

[ ]:
```
confusion_matrix(x, testloader)

plt.plot(np.linspace(1, len(loss_list), len(loss_list)), loss_list,␣
 ↪label='Training Loss')
plt.plot(np.linspace(1, len(val_loss), len(loss_list)), loss_list,␣
 ↪label='Validation Loss')
plt.title('Training and Validation Loss over Epochs No Fine Tuning')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.grid(True)
plt.legend()
plt.show()
plt.clf()

plt.plot(np.linspace(1, len(loss_list_val), len(loss_list_val)), loss_list_val)
plt.title('Loss over Epochs Finetuning')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.grid(True)
plt.show()
```

```
/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
packages/torch/nn/modules/module.py:1511: UserWarning: Implicit dimension choice
for softmax has been deprecated. Change the call to include dim=X as an
argument.
  return self._call_impl(*args, **kwargs)
```


ResNet50 Accuracy
True Labels
Predicted Labels
apples
coconuts
grapes
guavas
lemons
limes
mango
oranges
peaches
starfruit
strawberries
watermelons
7 0 2 0 0 0 1 0 0 0 0 0
0 4 0 0 0 0 2 0 0 0 0 0
0 0 7 0 0 0 0 0 0 0 0 0
0 0 0 6 0 0 1 0 0 0 0 0
0 0 1 0 0 1 2 0 0 0 0 0
0 0 0 0 0 6 0 0 0 0 0 0
0 0 1 0 1 1 44 0 0 2 0 0
0 0 0 0 0 0 1 7 0 0 0 0
0 0 0 0 0 0 3 0 11 1 0 0
0 0 0 0 0 0 3 0 0 13 0 0
0 0 0 0 0 0 1 0 0 0 5 2
0 0 0 0 0 0 0 0 0 0 0 12
40
35
30
25
20
15
10
5
0


Training and Validation Loss over Epochs No Fine Tuning
Training Loss
Validation Loss
Loss
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0
25
50
75
100
125
150
175
200
Epochs


Loss over Epochs Finetuning
Loss
Epochs
0.0014
0.0013
0.0012
0.0011
0.0010
0.0009
0.0008
0
25
50
75
100
125
150
175
200