

## EN3160 - Assignment 3

- 210097M
- De Silva A.N.T
- [https://github.com/NavinduTharupathi/neural\\_networks\\_EN3160](https://github.com/NavinduTharupathi/neural_networks_EN3160)

### Q1

```
import torch
import torch.nn as nn
import torchvision
import torchvision.transforms as transforms
import matplotlib.pyplot as plt

# Check if CUDA is available
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"Using device: {device}")

# 1. Data loading and transformation
transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))
])

batch_size = 50
trainset = torchvision.datasets.CIFAR10(root='./data', train=True,
download=True, transform=transform)
trainloader = torch.utils.data.DataLoader(trainset,
batch_size=batch_size, shuffle=True, num_workers=2)

testset = torchvision.datasets.CIFAR10(root='./data', train=False,
download=True, transform=transform)
testloader = torch.utils.data.DataLoader(testset,
batch_size=batch_size, shuffle=False, num_workers=2)

# Class names
classes = ('plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog',
'horse', 'ship', 'truck')

# 2. Define the neural network as a proper PyTorch module
class SimpleNet(nn.Module):
    def __init__(self, input_size, hidden_size, num_classes):
        super(SimpleNet, self).__init__()
        self.flatten = nn.Flatten()
        self.fc1 = nn.Linear(input_size, hidden_size)
        self.sigmoid = nn.Sigmoid()
        self.fc2 = nn.Linear(hidden_size, num_classes)

    def forward(self, x):
        x = self.flatten(x)
```

```

        x = self.sigmoid(self.fc1(x))
        x = self.fc2(x)
        return x

# Initialize network and move to device
Din = 3 * 32 * 32 # Input size (flattened CIFAR-10 image size)
H = 100           # Hidden layer size
K = 10           # Output size (number of classes)
model = SimpleNet(Din, H, K).to(device)

# Define loss function and optimizer
criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters(), lr=0.001)

# Training settings
epochs = 10
loss_history = []

# 3. Training Loop
for epoch in range(epochs):
    running_loss = 0.0
    for i, data in enumerate(trainloader, 0):
        inputs, labels = data
        inputs, labels = inputs.to(device), labels.to(device)

        # Zero the gradients
        optimizer.zero_grad()

        # Forward pass
        outputs = model(inputs)

        # Calculate loss
        loss = criterion(outputs, labels)
        loss_history.append(loss.item())
        running_loss += loss.item()

        # Backward pass and optimize
        loss.backward()
        optimizer.step()

    print(f"Epoch {epoch + 1}/{epochs}, Loss: {running_loss /
len(trainloader)}")

# 4. Plotting the Loss History
plt.figure(figsize=(10, 5))
plt.plot(loss_history)
plt.title("Loss History")
plt.xlabel("Iteration")
plt.ylabel("Loss")
plt.show()

```

```

# 5. Calculate Accuracy on Training Set
model.eval() # Set the model to evaluation mode
correct_train = 0
total_train = 0
with torch.no_grad():
    for data in trainloader:
        inputs, labels = data
        inputs, labels = inputs.to(device), labels.to(device)
        outputs = model(inputs)
        _, predicted = torch.max(outputs.data, 1)
        total_train += labels.size(0)
        correct_train += (predicted == labels).sum().item()

train_acc = 100 * correct_train / total_train
print(f"Training accuracy: {train_acc:.2f}%")

```

```

# 6. Calculate Accuracy on Test Set
correct_test = 0
total_test = 0
with torch.no_grad():
    for data in testloader:
        inputs, labels = data
        inputs, labels = inputs.to(device), labels.to(device)
        outputs = model(inputs)
        _, predicted = torch.max(outputs.data, 1)
        total_test += labels.size(0)
        correct_test += (predicted == labels).sum().item()

test_acc = 100 * correct_test / total_test
print(f"Test accuracy: {test_acc:.2f}%")

```

Using device: cpu

Downloading <https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz> to  
./data/cifar-10-python.tar.gz

100%|██████████| 170M/170M [00:04<00:00, 39.4MB/s]

Extracting ./data/cifar-10-python.tar.gz to ./data

Files already downloaded and verified

Epoch 1/10, Loss: 1.7635284322500229

Epoch 2/10, Loss: 1.6274038333892822

Epoch 3/10, Loss: 1.5648831684589386

Epoch 4/10, Loss: 1.5182182710170746

Epoch 5/10, Loss: 1.4739888511896133

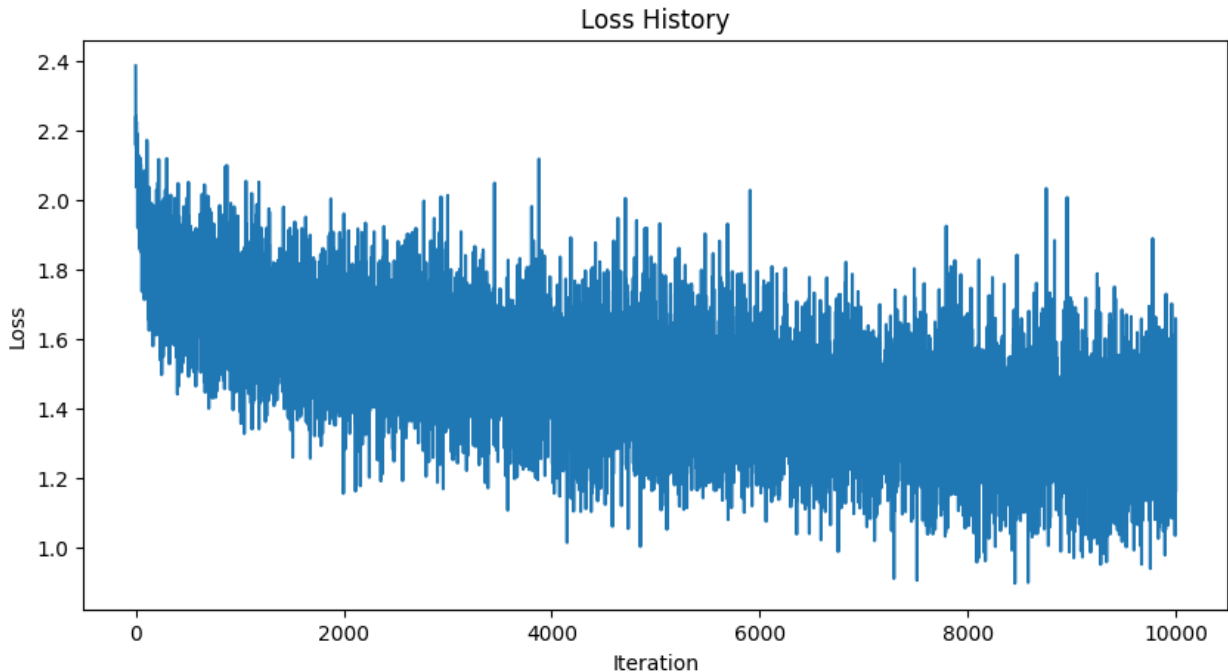
Epoch 6/10, Loss: 1.4401074006557464

Epoch 7/10, Loss: 1.4068551120758057

Epoch 8/10, Loss: 1.376381821155548

Epoch 9/10, Loss: 1.3462000078558922

Epoch 10/10, Loss: 1.3196825578808784



Training accuracy: 56.53%  
Test accuracy: 46.68%

## Q2

```
import torch
import torch.nn as nn
import torch.optim as optim
import torchvision
import torchvision.transforms as transforms
import matplotlib.pyplot as plt

# Check if CUDA is available
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"Using device: {device}")

# 1. Data loading and transformation for MNIST
transform = transforms.Compose([
    transforms.Resize((32, 32)), # LeNet-5 uses 32x32 input
    transforms.ToTensor(),
    transforms.Normalize((0.5,), (0.5,))
])

batch_size = 64
trainset = torchvision.datasets.MNIST(root='./data', train=True,
download=True, transform=transform)
trainloader = torch.utils.data.DataLoader(trainset,
batch_size=batch_size, shuffle=True, num_workers=2)
```

```

testset = torchvision.datasets.MNIST(root='./data', train=False,
download=True, transform=transform)
testloader = torch.utils.data.DataLoader(testset,
batch_size=batch_size, shuffle=False, num_workers=2)

# 2. Define LeNet-5 Model
class LeNet5(nn.Module):
    def __init__(self):
        super(LeNet5, self).__init__()
        # First convolutional layer: 1 input channel, 6 output
        channels, 5x5 kernel
        self.conv1 = nn.Conv2d(1, 6, kernel_size=5) # Remove
padding=2
        # Second convolutional layer: 6 input channels, 16 output
        channels, 5x5 kernel
        self.conv2 = nn.Conv2d(6, 16, kernel_size=5)
        # Fully connected layers
        self.fc1 = nn.Linear(16 * 5 * 5, 120) # The 5x5 is the size
of the feature maps after conv2
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        # First conv + activation + pooling
        x = torch.tanh(self.conv1(x)) # Output: 6 x 28 x 28
        x = torch.max_pool2d(x, 2) # Output: 6 x 14 x 14

        # Second conv + activation + pooling
        x = torch.tanh(self.conv2(x)) # Output: 16 x 10 x 10
        x = torch.max_pool2d(x, 2) # Output: 16 x 5 x 5

        # Flatten the feature maps
        x = x.view(-1, 16 * 5 * 5) # Output: batch_size x
400

        # Fully connected layers
        x = torch.tanh(self.fc1(x))
        x = torch.tanh(self.fc2(x))
        x = self.fc3(x)
        return x

# Move the model to the selected device
model = LeNet5().to(device)

# Define the loss function and optimizer
criterion = nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(), lr=0.001)

# 3. Training the LeNet-5 Model

```

```

epochs = 10
train_losses = []

for epoch in range(epochs):
    running_loss = 0.0
    for i, data in enumerate(trainloader, 0):
        inputs, labels = data
        inputs, labels = inputs.to(device), labels.to(device)

        # Zero the parameter gradients
        optimizer.zero_grad()

        # Forward pass
        outputs = model(inputs)
        loss = criterion(outputs, labels)

        # Backward pass and optimize
        loss.backward()
        optimizer.step()

        running_loss += loss.item()

    # Log the loss for this epoch
    epoch_loss = running_loss / len(trainloader)
    train_losses.append(epoch_loss)
    print(f"Epoch {epoch + 1}/{epochs}, Loss: {epoch_loss:.4f}")

# 4. Plotting the Training Loss History
plt.figure(figsize=(10, 5))
plt.plot(train_losses, label='Training Loss')
plt.title("Training Loss History")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.legend()
plt.show()

# 5. Calculate Training Accuracy
model.eval() # Set model to evaluation mode
correct_train = 0
total_train = 0
with torch.no_grad():
    for data in trainloader:
        images, labels = data
        images, labels = images.to(device), labels.to(device)
        outputs = model(images)
        _, predicted = torch.max(outputs.data, 1)
        total_train += labels.size(0)
        correct_train += (predicted == labels).sum().item()

train_accuracy = 100 * correct_train / total_train

```

```
print(f"Training accuracy: {train_accuracy:.2f}%")
```

```
# 6. Calculate Test Accuracy
```

```
correct_test = 0
```

```
total_test = 0
```

```
with torch.no_grad():
```

```
    for data in testloader:
```

```
        images, labels = data
```

```
        images, labels = images.to(device), labels.to(device)
```

```
        outputs = model(images)
```

```
        _, predicted = torch.max(outputs.data, 1)
```

```
        total_test += labels.size(0)
```

```
        correct_test += (predicted == labels).sum().item()
```

```
test_accuracy = 100 * correct_test / total_test
```

```
print(f"Test accuracy: {test_accuracy:.2f}%")
```

```
Using device: cpu
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
```

```
Failed to download (trying next):
```

```
HTTP Error 403: Forbidden
```

```
Downloading https://oss-ci-datasets.s3.amazonaws.com/mnist/train-images-idx3-ubyte.gz
```

```
Downloading https://oss-ci-datasets.s3.amazonaws.com/mnist/train-images-idx3-ubyte.gz to ./data/MNIST/raw/train-images-idx3-ubyte.gz
```

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Extracting ./data/MNIST/raw/train-images-idx3-ubyte.gz to  
./data/MNIST/raw
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz
```

```
Failed to download (trying next):
```

```
HTTP Error 403: Forbidden
```

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Downloading https://oss-ci-datasets.s3.amazonaws.com/mnist/train-labels-idx1-ubyte.gz
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Downloading https://oss-ci-datasets.s3.amazonaws.com/mnist/train-labels-idx1-ubyte.gz to ./data/MNIST/raw/train-labels-idx1-ubyte.gz
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./data/MNIST/raw
```

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Downloading http://yann.lecun.com/exdb/mnist/t10k-images-idx3-ubyte.gz
```

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HTTP Error 403: Forbidden

Downloading <https://oss-ci-datasets.s3.amazonaws.com/mnist/t10k-images-idx3-ubyte.gz>

Downloading <https://oss-ci-datasets.s3.amazonaws.com/mnist/t10k-images-idx3-ubyte.gz> to ./data/MNIST/raw/t10k-images-idx3-ubyte.gz

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./data/MNIST/raw

Downloading <http://yann.lecun.com/exdb/mnist/t10k-labels-idx1-ubyte.gz>

Failed to download (trying next):

HTTP Error 403: Forbidden

Downloading <https://oss-ci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz>

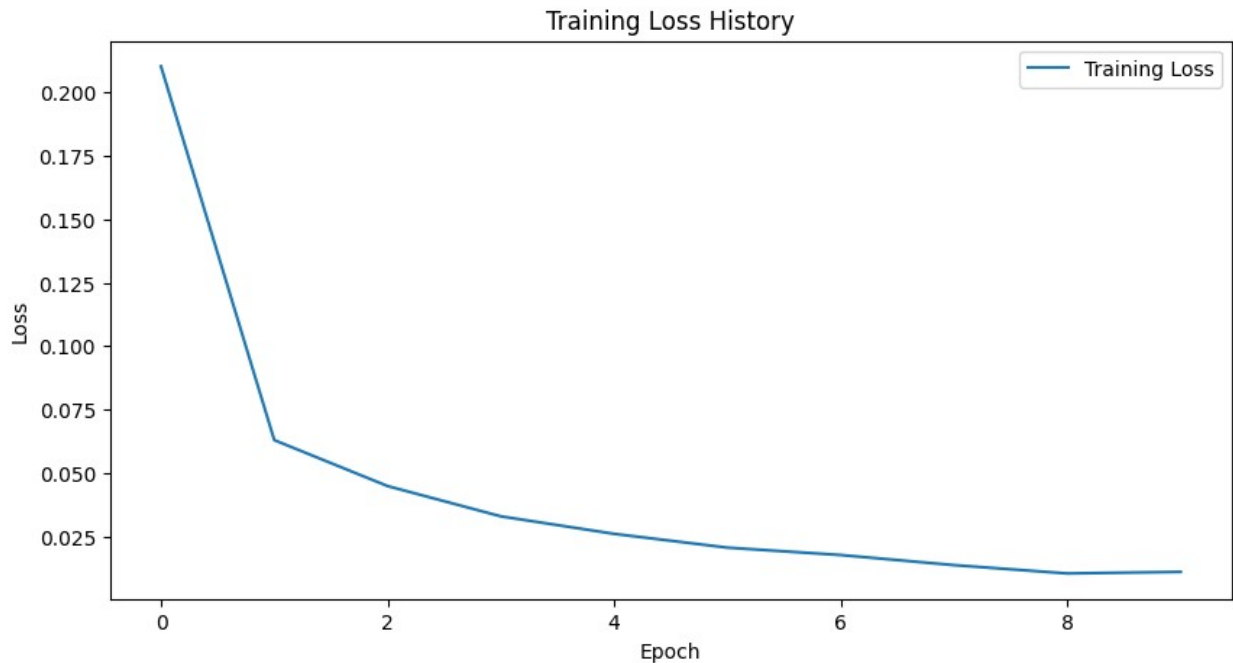
Downloading <https://oss-ci-datasets.s3.amazonaws.com/mnist/t10k-labels-idx1-ubyte.gz> to ./data/MNIST/raw/t10k-labels-idx1-ubyte.gz

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Extracting ./data/MNIST/raw/t10k-labels-idx1-ubyte.gz to  
./data/MNIST/raw

Epoch 1/10, Loss: 0.2102  
Epoch 2/10, Loss: 0.0630  
Epoch 3/10, Loss: 0.0449  
Epoch 4/10, Loss: 0.0330  
Epoch 5/10, Loss: 0.0261  
Epoch 6/10, Loss: 0.0206  
Epoch 7/10, Loss: 0.0177  
Epoch 8/10, Loss: 0.0138  
Epoch 9/10, Loss: 0.0105  
Epoch 10/10, Loss: 0.0111





Training accuracy: 99.71%  
Test accuracy: 98.73%

### Q3

*# getting the dataset in*

```
!wget https://download.pytorch.org/tutorial/hymenoptera_data.zip
```

```
--2024-11-14 13:44:32--
```

```
https://download.pytorch.org/tutorial/hymenoptera_data.zip
```

```
Resolving download.pytorch.org (download.pytorch.org)...
```

```
18.165.116.45, 18.165.116.18, 18.165.116.36, ...
```

```
Connecting to download.pytorch.org (download.pytorch.org)|
```

```
18.165.116.45|:443... connected.
```

```
HTTP request sent, awaiting response... 200 OK
```

```
Length: 47286322 (45M) [application/zip]
```

```
Saving to: 'hymenoptera_data.zip'
```

```
hymenoptera_data.zip 100%[=====>] 45.10M 34.6MB/s in  
1.3s
```

```
2024-11-14 13:44:34 (34.6 MB/s) - 'hymenoptera_data.zip' saved
```

```
[47286322/47286322]
```

*# unzipping the dataset*

```
!unzip hymenoptera_data.zip -d /content/data
```

```
Archive:  hymenoptera_data.zip
  creating: /content/data/hymenoptera_data/
  creating: /content/data/hymenoptera_data/train/
  creating: /content/data/hymenoptera_data/train/ants/
  inflating: /content/data/hymenoptera_data/train/ants/0013035.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1030023514_aad5c608f9.jpg
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  inflating: /content/data/hymenoptera_data/train/ants/175998972.jpg
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8834-800wi.jpg  
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```

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import torch
import torch.nn as nn
import torch.optim as optim
import torchvision
import torchvision.transforms as transforms
import torchvision.datasets as datasets
from torchvision import models
import matplotlib.pyplot as plt

# Check if CUDA is available
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"Using device: {device}")

# 1. Data loading and transformation for Hymenoptera dataset
data_dir = './data/hymenoptera_data'
input_size = 224
batch_size = 8

data_transforms = {
    'train': transforms.Compose([
        transforms.RandomResizedCrop(input_size),
        transforms.RandomHorizontalFlip(),
        transforms.ToTensor(),
        transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
    ]),
    'val': transforms.Compose([
        transforms.Resize(input_size),
        transforms.CenterCrop(input_size),
        transforms.ToTensor(),
        transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
    ]),
}

image_datasets = {x: datasets.ImageFolder(root=f"{data_dir}/{x}",
transform=data_transforms[x]) for x in ['train', 'val']}
dataloaders = {x: torch.utils.data.DataLoader(image_datasets[x],
batch_size=batch_size, shuffle=True, num_workers=4) for x in ['train',
'val']}
dataset_sizes = {x: len(image_datasets[x]) for x in ['train', 'val']}
class_names = image_datasets['train'].classes

# 2. Load the pre-trained ResNet-18 model
model_ft = models.resnet18(pretrained=True)

```

```

# Fine-tuning: Set requires_grad = True for all parameters to train
the whole model
for param in model_ft.parameters():
    param.requires_grad = True

# Modify the final layer to match the number of classes in the
Hymenoptera dataset (2 classes)
num_fters = model_ft.fc.in_features
model_ft.fc = nn.Linear(num_fters, len(class_names))

# Move the model to the selected device
model_ft = model_ft.to(device)

# Define loss function and optimizer for fine-tuning
criterion = nn.CrossEntropyLoss()
optimizer_ft = optim.SGD(model_ft.parameters(), lr=0.001,
momentum=0.9)
exp_lr_scheduler = optim.lr_scheduler.StepLR(optimizer_ft,
step_size=7, gamma=0.1)

# 3. Training Function
def train_model(model, criterion, optimizer, scheduler,
num_epochs=10):
    train_losses = []
    val_accuracies = []

    for epoch in range(num_epochs):
        print(f"Epoch {epoch + 1}/{num_epochs}")
        print("-" * 10)

        # Each epoch has a training and validation phase
        for phase in ['train', 'val']:
            if phase == 'train':
                model.train() # Set model to training mode
            else:
                model.eval() # Set model to evaluate mode

            running_loss = 0.0
            running_corrects = 0

            # Iterate over data
            for inputs, labels in dataloaders[phase]:
                inputs, labels = inputs.to(device), labels.to(device)

                # Zero the parameter gradients
                optimizer.zero_grad()

                # Forward pass
                with torch.set_grad_enabled(phase == 'train'):
                    outputs = model(inputs)

```

```

        _, preds = torch.max(outputs, 1)
        loss = criterion(outputs, labels)

        # Backward pass and optimize in training phase
        if phase == 'train':
            loss.backward()
            optimizer.step()

        # Statistics
        running_loss += loss.item() * inputs.size(0)
        running_corrects += torch.sum(preds == labels.data)

    epoch_loss = running_loss / dataset_sizes[phase]
    epoch_acc = running_corrects.double() /
dataset_sizes[phase]

    if phase == 'train':
        scheduler.step()
        train_losses.append(epoch_loss)
    else:
        val_accuracies.append(epoch_acc.item())

    print(f"{phase} Loss: {epoch_loss:.4f} Acc:
{epoch_acc:.4f}")

    return model, train_losses, val_accuracies

# Train and evaluate the model
model_ft, train_losses, val_accuracies = train_model(model_ft,
criterion, optimizer_ft, exp_lr_scheduler, num_epochs=10)

# Plotting Training Loss and Validation Accuracy
plt.figure(figsize=(10, 5))
plt.subplot(1, 2, 1)
plt.plot(train_losses, label="Training Loss")
plt.xlabel("Epoch")
plt.ylabel("Loss")
plt.title("Training Loss")
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(val_accuracies, label="Validation Accuracy")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.title("Validation Accuracy")
plt.legend()
plt.show()

# 4. Feature Extraction: Freeze all layers except the final fully
connected layer

```

```

model_ft = models.resnet18(pretrained=True)
for param in model_ft.parameters():
    param.requires_grad = False # Freeze parameters

# Replace the final layer
model_ft.fc = nn.Linear(num_fts, len(class_names))
model_ft = model_ft.to(device)

# Define optimizer for feature extraction (only updates final layer)
optimizer_fe = optim.SGD(model_ft.fc.parameters(), lr=0.001,
momentum=0.9)

# Train the model again using feature extraction
model_fe, _, val_accuracies_fe = train_model(model_ft, criterion,
optimizer_fe, exp_lr_scheduler, num_epochs=10)

# Plot Validation Accuracy for Feature Extraction
plt.plot(val_accuracies_fe, label="Validation Accuracy (Feature
Extraction)")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.title("Validation Accuracy (Feature Extraction)")
plt.legend()
plt.show()

```

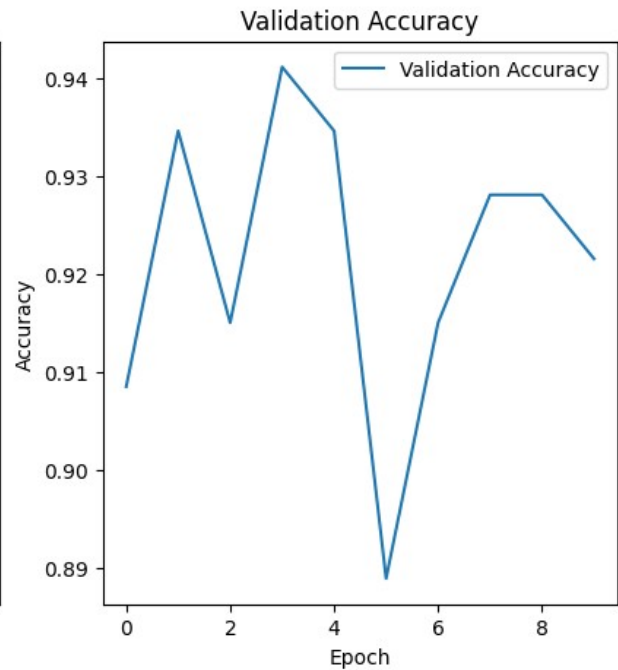
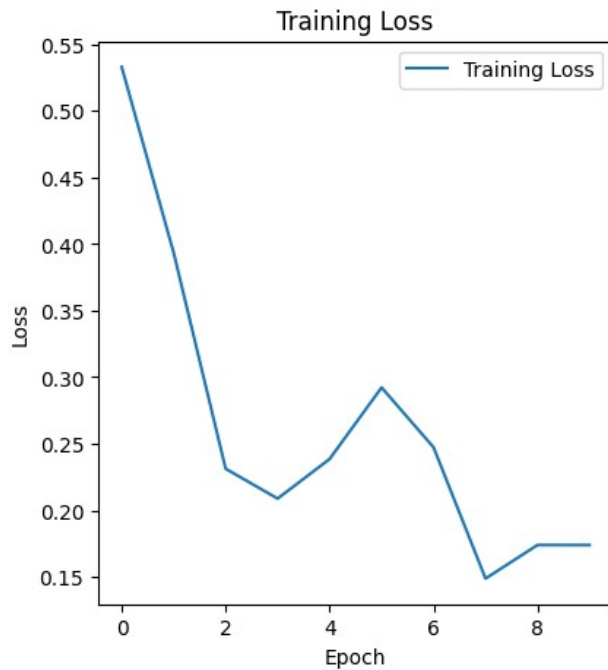
Using device: cpu

```

/usr/local/lib/python3.10/dist-packages/torch/utils/data/
dataloader.py:617: UserWarning: This DataLoader will create 4 worker
processes in total. Our suggested max number of worker in current
system is 2, which is smaller than what this DataLoader is going to
create. Please be aware that excessive worker creation might get
DataLoader running slow or even freeze, lower the worker number to
avoid potential slowness/freeze if necessary.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:2
08: UserWarning: The parameter 'pretrained' is deprecated since 0.13
and may be removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:2
23: UserWarning: Arguments other than a weight enum or `None` for
'weights' are deprecated since 0.13 and may be removed in the future.
The current behavior is equivalent to passing
`weights=ResNet18_Weights.IMAGENET1K_V1`. You can also use
`weights=ResNet18_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet18-
f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-
f37072fd.pth
100%|██████████| 44.7M/44.7M [00:00<00:00, 124MB/s]

```

```
Epoch 1/10
-----
train Loss: 0.5331 Acc: 0.6762
val Loss: 0.2713 Acc: 0.9085
Epoch 2/10
-----
train Loss: 0.3935 Acc: 0.8033
val Loss: 0.2010 Acc: 0.9346
Epoch 3/10
-----
train Loss: 0.2312 Acc: 0.9221
val Loss: 0.1939 Acc: 0.9150
Epoch 4/10
-----
train Loss: 0.2088 Acc: 0.9057
val Loss: 0.1612 Acc: 0.9412
Epoch 5/10
-----
train Loss: 0.2385 Acc: 0.9016
val Loss: 0.1913 Acc: 0.9346
Epoch 6/10
-----
train Loss: 0.2923 Acc: 0.8648
val Loss: 0.2944 Acc: 0.8889
Epoch 7/10
-----
train Loss: 0.2473 Acc: 0.9180
val Loss: 0.2079 Acc: 0.9150
Epoch 8/10
-----
train Loss: 0.1487 Acc: 0.9303
val Loss: 0.2141 Acc: 0.9281
Epoch 9/10
-----
train Loss: 0.1739 Acc: 0.9385
val Loss: 0.2181 Acc: 0.9281
Epoch 10/10
-----
train Loss: 0.1739 Acc: 0.9262
val Loss: 0.2167 Acc: 0.9216
```



Epoch 1/10

-----

train Loss: 0.5902 Acc: 0.6434

val Loss: 0.2593 Acc: 0.9150

Epoch 2/10

-----

train Loss: 0.3473 Acc: 0.8689

val Loss: 0.2240 Acc: 0.9281

Epoch 3/10

-----

train Loss: 0.3263 Acc: 0.8361

val Loss: 0.1880 Acc: 0.9412

Epoch 4/10

-----

train Loss: 0.3914 Acc: 0.8279

val Loss: 0.1884 Acc: 0.9477

Epoch 5/10

-----

train Loss: 0.4363 Acc: 0.8197

val Loss: 0.1934 Acc: 0.9412

Epoch 6/10

-----

train Loss: 0.2737 Acc: 0.8811

val Loss: 0.1724 Acc: 0.9477

Epoch 7/10

-----

train Loss: 0.2824 Acc: 0.8893

val Loss: 0.2021 Acc: 0.9216

Epoch 8/10

```
-----  
train Loss: 0.4051 Acc: 0.8361  
val Loss: 0.1814 Acc: 0.9477  
Epoch 9/10  
-----  
train Loss: 0.2163 Acc: 0.9221  
val Loss: 0.1733 Acc: 0.9542  
Epoch 10/10  
-----  
train Loss: 0.2162 Acc: 0.9057  
val Loss: 0.2116 Acc: 0.9281
```

