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Github - https://github.com/pulinduvidmal/Machine-Vision-Experiments/tree/main/Assignments/Neural%20Networks

```
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"Using device: {device}")
```

```
Using device: cuda
```

Question 1

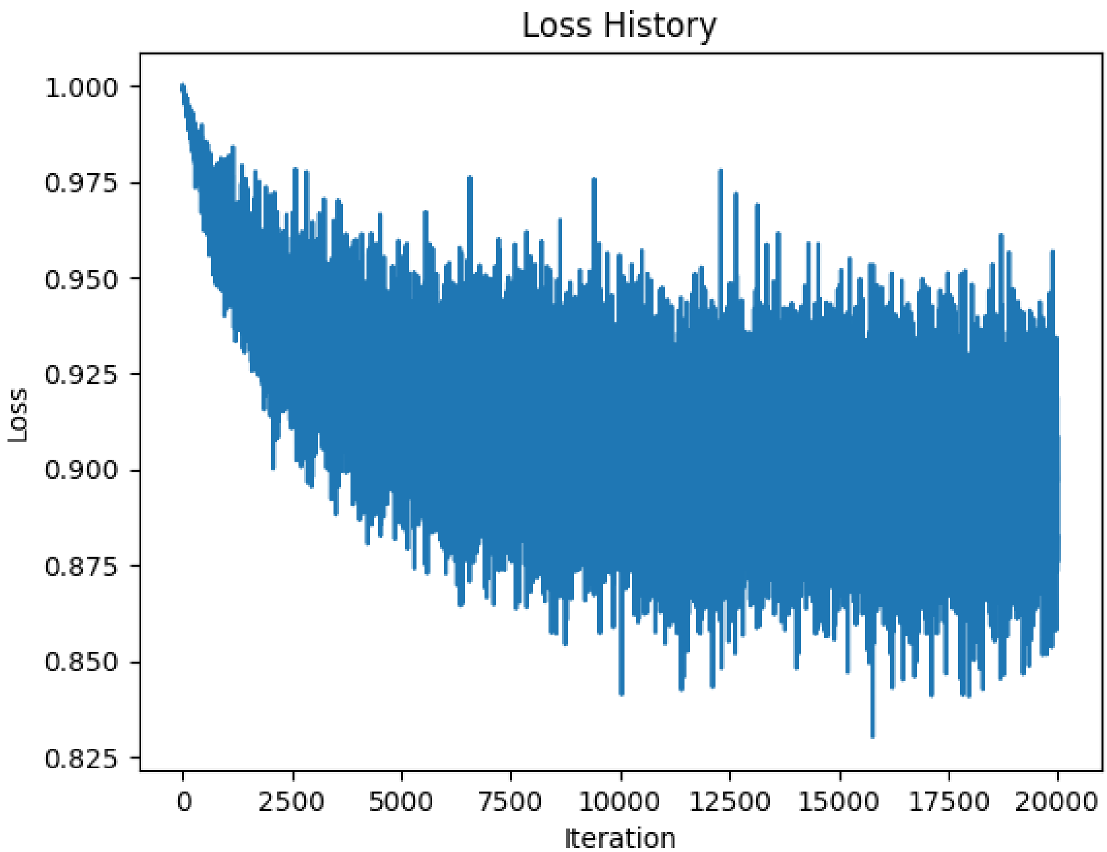
Given code

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

 # 1. Dataloading
 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)
 classes = ('plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog',
'horse', 'ship', 'truck')

 # 2. Define Network Parameters
 Din = 3 * 32 * 32  # Input size (flattened CIFAR-10 image size)
 K = 10  # Output size (number of classes in CIFAR-10)
 std = 1e-5

 # Initialize weights and biases
 w = torch.randn(Din, K) * std  # One layer: directly map input to
output
 b = torch.zeros(K)
```

```python
# Hyperparameters
iterations = 20
lr = 2e-6  # Learning rate
lr_decay = 0.9  # Learning rate decay
reg = 0  # Regularization
loss_history = []

# 3. Training Loop
for t in range(iterations):
   running_loss = 0.0
   for i, data in enumerate(trainloader, 0):
       # Get inputs and labels
       inputs, labels = data
       Ntr = inputs.shape[0]  # Batch size
       x_train = inputs.view(Ntr, -1)  # Flatten input to (Ntr, Din)
       y_train_onehot = nn.functional.one_hot(labels, K).float()  #
Convert labels to one-hot encoding
       # Forward pass
       y_pred = x_train.mm(w) + b  # Output layer activation
       # Loss calculation (Mean Squared Error with regularization)
       loss = (1 / Ntr) * torch.sum((y_pred - y_train_onehot) ** 2) +
reg * torch.sum(w ** 2)
       loss_history.append(loss.item())
       running_loss += loss.item()
       # Backpropagation
       dy_pred = (2.0 / Ntr) * (y_pred - y_train_onehot)
       dw = x_train.t().mm(dy_pred) + reg * w
       db = dy_pred.sum(dim=0)
       # Parameter update
       w -= lr * dw
       b -= lr * db
   # Print loss for every epoch
   if t % 1 == 0:
       print(f"Epoch {t + 1} / {iterations}, Loss: {running_loss /
len(trainloader)}")
   # Learning rate decay
   lr *= lr_decay

# 4. Plotting the Loss History
plt.plot(loss_history)
plt.title("Loss History")
plt.xlabel("Iteration")
plt.ylabel("Loss")
plt.show()

# 5. Calculate Accuracy on Training Set
correct_train = 0
total_train = 0
with torch.no_grad():
   for data in trainloader:
```

```python
        inputs, labels = data
        Ntr = inputs.shape[0]
        x_train = inputs.view(Ntr, -1)
        y_train_pred = x_train.mm(w) + b
        predicted_train = torch.argmax(y_train_pred, dim=1)
        total_train += labels.size(0)
        correct_train += (predicted_train == 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
        Nte = inputs.shape[0]
        x_test = inputs.view(Nte, -1)
        y_test_pred = x_test.mm(w) + b
        predicted_test = torch.argmax(y_test_pred, dim=1)
        total_test += labels.size(0)
        correct_test += (predicted_test == labels).sum().item()
test_acc = 100 * correct_test / total_test
print(f"Test accuracy: {test_acc:.2f}%")
```

```
Files already downloaded and verified
Files already downloaded and verified
Epoch 1 / 20, Loss: 0.9769273951649666
Epoch 2 / 20, Loss: 0.9498199351429939
Epoch 3 / 20, Loss: 0.9360875483751298
Epoch 4 / 20, Loss: 0.9275446828603745
Epoch 5 / 20, Loss: 0.9216102967858315
Epoch 6 / 20, Loss: 0.9172078065276146
Epoch 7 / 20, Loss: 0.9137956157922745
Epoch 8 / 20, Loss: 0.9110679520964623
Epoch 9 / 20, Loss: 0.9088385291099549
Epoch 10 / 20, Loss: 0.9069846845865249
Epoch 11 / 20, Loss: 0.9054242988228798
Epoch 12 / 20, Loss: 0.9040969612002373
Epoch 13 / 20, Loss: 0.9029580265283584
Epoch 14 / 20, Loss: 0.9019746145009995
Epoch 15 / 20, Loss: 0.9011204718351364
Epoch 16 / 20, Loss: 0.9003753411769867
Epoch 17 / 20, Loss: 0.8997225344777108
Epoch 18 / 20, Loss: 0.8991491733193397
Epoch 19 / 20, Loss: 0.8986435873508454
Epoch 20 / 20, Loss: 0.8981969069242477
```




```
Training accuracy: 32.20%
Test accuracy: 32.36%
```

Modification Code

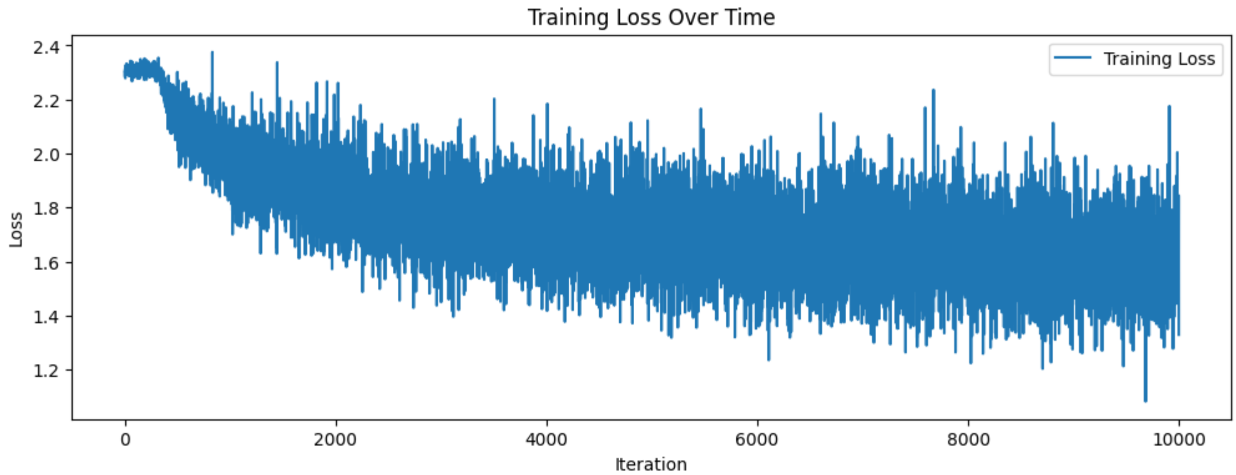
```
import torch
import torch.nn as nn
import torchvision
import torchvision.transforms as transforms
import matplotlib.pyplot as plt

# 1. Dataloading
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=0)
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=0)
classes = ('plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog',
'horse', 'ship', 'truck')

# 2. Define Network Parameters
Din = 3 * 32 * 32  # Input size (flattened CIFAR-10 image size)
H = 100            # Number of nodes in hidden layer
K = 10             # Output size (number of classes in CIFAR-10)
std = 1e-5

# Initialize weights and biases for both layers and move them to the
GPU
w1 = torch.randn(Din, H, device=device) * std  # Input to hidden layer
weights
b1 = torch.zeros(H, device=device)             # Bias for hidden layer
w2 = torch.randn(H, K, device=device) * std    # Hidden to output
layer weights
b2 = torch.zeros(K, device=device)             # Bias for output layer

# Hyperparameters
epochs = 10
lr = 1e-3        # Learning rate
lr_decay = 0.9   # Learning rate decay
reg = 0          # Regularization term
loss_history = []
train_acc_history = []
test_acc_history = []

# Define cross-entropy loss function
def cross_entropy_loss(y_pred, y_true):
    return -torch.sum(y_true * torch.log(y_pred + 1e-9)) /
y_true.shape[0]

# Sigmoid Activation Function
def sigmoid(x):
    return 1 / (1 + torch.exp(-x))

# 3. Training Loop
for epoch in range(epochs):
    running_loss = 0.0
    correct_train = 0
    total_train = 0

    for i, data in enumerate(trainloader, 0):
        # Get inputs and labels and move them to the GPU
        inputs, labels = data[0].to(device), data[1].to(device)
        Ntr = inputs.shape[0]  # Batch size
        x_train = inputs.view(Ntr, -1)  # Flatten input to (Ntr, Din)
        y_train_onehot = nn.functional.one_hot(labels, K).float()  #
```

```
Convert labels to one-hot encoding

        # Forward pass: Layer 1
        hidden_layer = torch.sigmoid(x_train.mm(w1) + b1)
        # Forward pass: Layer 2 (output layer)
        y_pred = torch.softmax(hidden_layer.mm(w2) + b2, dim=1)  #
Output layer activation

        # Loss calculation (Cross-Entropy Loss with regularization)
        loss = cross_entropy_loss(y_pred, y_train_onehot) + reg *
(torch.sum(w1**2) + torch.sum(w2**2))
        loss_history.append(loss.item())
        running_loss += loss.item()

        # Backpropagation
        dy_pred = y_pred - y_train_onehot
        dw2 = hidden_layer.t().mm(dy_pred) + reg * w2
        db2 = dy_pred.sum(dim=0)
        dhidden = dy_pred.mm(w2.t()) * hidden_layer * (1 -
hidden_layer)
        dw1 = x_train.t().mm(dhidden) + reg * w1
        db1 = dhidden.sum(dim=0)

        # Parameter update
        w1 -= lr * dw1
        b1 -= lr * db1
        w2 -= lr * dw2
        b2 -= lr * db2

        # Calculate training accuracy for the batch
        predicted_train = torch.argmax(y_pred, dim=1)
        total_train += labels.size(0)
        correct_train += (predicted_train == labels).sum().item()

    # Calculate and store accuracy for the entire epoch
    train_acc = 100 * correct_train / total_train
    train_acc_history.append(train_acc)
    print(f"Epoch {epoch + 1}/{epochs}, Loss: {running_loss /
len(trainloader):.4f}, Training Accuracy: {train_acc:.2f}%")

    # Learning rate decay
    lr *= lr_decay

    # Calculate test accuracy for the epoch
    correct_test = 0
    total_test = 0
    with torch.no_grad():
        for data in testloader:
            inputs, labels = data[0].to(device), data[1].to(device)
            Nte = inputs.shape[0]
```

```
            x_test = inputs.view(Nte, -1)

            # Forward pass
            hidden_output = sigmoid(x_test.mm(w1) + b1)
            y_test_pred = torch.softmax(hidden_output.mm(w2) + b2,
dim=1)
            predicted_test = torch.argmax(y_test_pred, dim=1)

            total_test += labels.size(0)
            correct_test += (predicted_test == labels).sum().item()

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

# Plotting the loss, training, and test accuracy over epochs
plt.figure(figsize=(12, 4))

# Loss plot
plt.plot(loss_history, label="Training Loss")
plt.xlabel("Iteration")
plt.ylabel("Loss")
plt.title("Training Loss Over Time")
plt.legend()
plt.show()
```

```
Files already downloaded and verified
Files already downloaded and verified
Epoch 1/10, Loss: 2.1610, Training Accuracy: 16.80%
Test Accuracy: 25.52%
Epoch 2/10, Loss: 1.9035, Training Accuracy: 30.71%
Test Accuracy: 34.32%
Epoch 3/10, Loss: 1.8025, Training Accuracy: 35.80%
Test Accuracy: 36.27%
Epoch 4/10, Loss: 1.7453, Training Accuracy: 38.37%
Test Accuracy: 39.06%
Epoch 5/10, Loss: 1.7055, Training Accuracy: 40.12%
Test Accuracy: 40.77%
Epoch 6/10, Loss: 1.6766, Training Accuracy: 41.52%
Test Accuracy: 41.27%
Epoch 7/10, Loss: 1.6544, Training Accuracy: 42.35%
Test Accuracy: 42.27%
Epoch 8/10, Loss: 1.6366, Training Accuracy: 43.14%
Test Accuracy: 42.34%
Epoch 9/10, Loss: 1.6209, Training Accuracy: 43.78%
Test Accuracy: 42.98%
Epoch 10/10, Loss: 1.6070, Training Accuracy: 44.33%
Test Accuracy: 43.31%
```




By introducing a middle layer with 100 nodes and a sigmoid activation, along with a cross-entropy loss function, the model's performance improved over 10 epochs. The updated model achieved 44.33% accuracy on the training set and 43.31% on the test set, compared to the original model's accuracy of 32.20% for training and 32.36% for testing.

Question 2

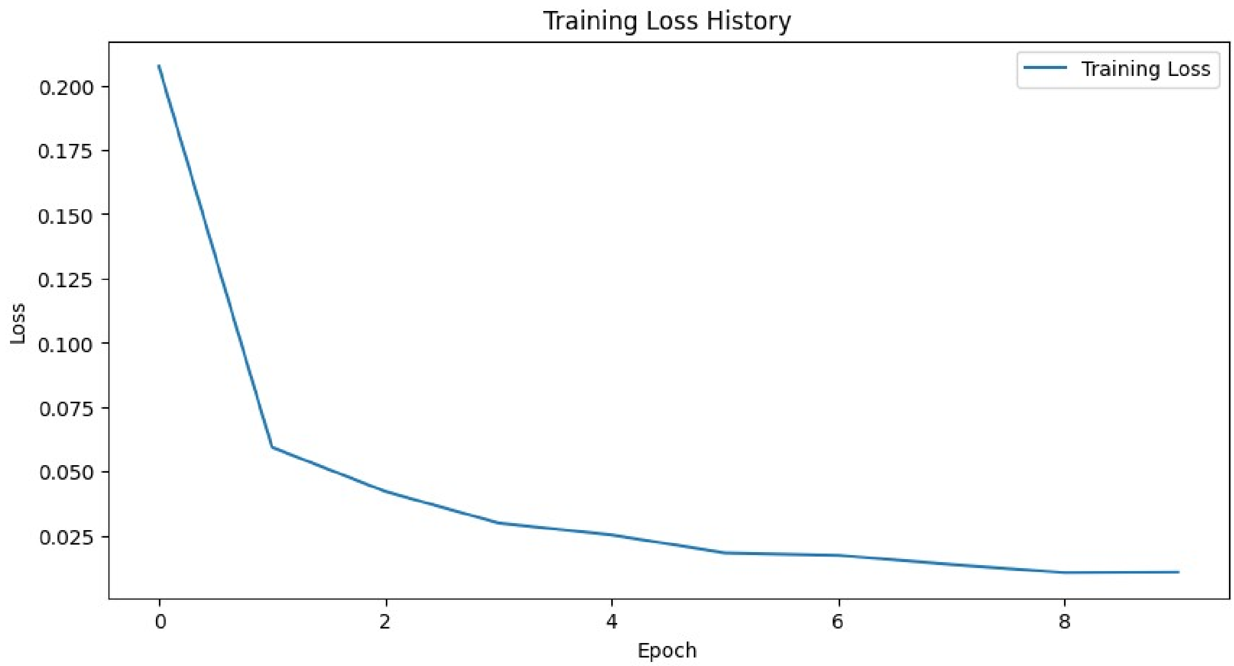
```
import torch
import torch.nn as nn
import torch.optim as optim
import torchvision
import torchvision.transforms as transforms
import matplotlib.pyplot as plt

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

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

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

# Define LeNet-5 Model
class LeNet5Model(nn.Module):
    def __init__(self):
```

```
        super(LeNet5Model, self).__init__()
        self.conv1 = nn.Conv2d(1, 6, kernel_size=5)
        self.conv2 = nn.Conv2d(6, 16, kernel_size=5)
        self.fc1 = nn.Linear(16 * 5 * 5, 120)
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        x = torch.tanh(self.conv1(x))        # Output: 6 x 28 x 28
        x = torch.max_pool2d(x, 2)           # Output: 6 x 14 x 14
        x = torch.tanh(self.conv2(x))        # Output: 16 x 10 x 10
        x = torch.max_pool2d(x, 2)           # Output: 16 x 5 x 5
        x = x.view(-1, 16 * 5 * 5)           # Flatten
        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
lenet_model = LeNet5Model().to(device)

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

# Training the LeNet-5 Model
epochs = 10
training_loss_history = []

for epoch in range(epochs):
    epoch_loss_total = 0.0
    for i, batch in enumerate(train_loader, 0):
        batch_inputs, batch_labels = batch
        batch_inputs, batch_labels = batch_inputs.to(device),
batch_labels.to(device)

        optimizer.zero_grad()  # Zero the parameter gradients

        # Forward pass
        predictions = lenet_model(batch_inputs)
        loss = loss_function(predictions, batch_labels)

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

        epoch_loss_total += loss.item()

    # Log the loss for this epoch
    epoch_avg_loss = epoch_loss_total / len(train_loader)
```

```
    training_loss_history.append(epoch_avg_loss)
    print(f"Epoch {epoch + 1}/{epochs}, Loss: {epoch_avg_loss:.4f}")

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

# Calculate Training Accuracy
lenet_model.eval()  # Set model to evaluation mode
correct_train_preds = 0
total_train_samples = 0
with torch.no_grad():
    for batch in train_loader:
        train_images, train_labels = batch
        train_images, train_labels = train_images.to(device),
train_labels.to(device)
        train_outputs = lenet_model(train_images)
        _, train_preds = torch.max(train_outputs.data, 1)
        total_train_samples += train_labels.size(0)
        correct_train_preds += (train_preds ==
train_labels).sum().item()

train_accuracy = 100 * correct_train_preds / total_train_samples
print(f"Training accuracy: {train_accuracy:.2f}%")

# Calculate Test Accuracy
correct_test_preds = 0
total_test_samples = 0
with torch.no_grad():
    for batch in test_loader:
        test_images, test_labels = batch
        test_images, test_labels = test_images.to(device),
test_labels.to(device)
        test_outputs = lenet_model(test_images)
        _, test_preds = torch.max(test_outputs.data, 1)
        total_test_samples += test_labels.size(0)
        correct_test_preds += (test_preds == test_labels).sum().item()

test_accuracy = 100 * correct_test_preds / total_test_samples
print(f"Test accuracy: {test_accuracy:.2f}%")
```

```
Epoch 1/10, Loss: 0.2075
Epoch 2/10, Loss: 0.0594
Epoch 3/10, Loss: 0.0423
Epoch 4/10, Loss: 0.0300
```

```
Epoch 5/10, Loss: 0.0254
Epoch 6/10, Loss: 0.0184
Epoch 7/10, Loss: 0.0175
Epoch 8/10, Loss: 0.0139
Epoch 9/10, Loss: 0.0107
Epoch 10/10, Loss: 0.0109
```




```
Training accuracy: 99.66%
Test accuracy: 98.80%
```

Looking at the loss and accuracy graphs, we can see that the model is doing well. Both the training and test losses go down, while the accuracies go up with each epoch. After five epochs, the model reached a test accuracy of 98.8%. This is expected because the MNIST dataset is easy, and LeNet-5 works well with it. We stopped at five epochs because the model started to overfit after that

Question 3

```
import torch
import torch.nn as nn
import torch.optim as optim
from torch.optim import lr_scheduler
import numpy as np
import torchvision
from torchvision import datasets, models, transforms
import matplotlib.pyplot as plt
import time
import os
```

```
from PIL import Image
from tempfile import TemporaryDirectory

plt.ion()  # Interactive mode
```

```
<contextlib.ExitStack at 0x78fbbdad5ba0>
```

```
!wget https://download.pytorch.org/tutorial/hymenoptera_data.zip
#unzip
!unzip hymenoptera_data.zip -d /content/data
```

```
--2024-11-14 15:29:54--
https://download.pytorch.org/tutorial/hymenoptera_data.zip
Resolving download.pytorch.org (download.pytorch.org)... 3.165.102.62,
3.165.102.113, 3.165.102.31, ...
Connecting to download.pytorch.org (download.pytorch.org)|
3.165.102.62|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 47286322 (45M) [application/zip]
Saving to: ‘hymenoptera_data.zip’

 hymenoptera_data.zi   0%[                    ]       0  --.-KB/s
hymenoptera_data.zi 100%[===================>]  45.10M  --.-KB/s    in
0.1s

2024-11-14 15:29:54 (389 MB/s) - ‘hymenoptera_data.zip’ saved
[47286322/47286322]

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
  inflating:
/content/data/hymenoptera_data/train/ants/1095476100_3906d8afde.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1099452230_d1949d3250.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/116570827_e9c126745d.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1225872729_6f0856588f.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1262877379_64fcada201.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1269756697_0bce92cdab.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1286984635_5119e80de1.jpg
  inflating:
```

```
/content/data/hymenoptera_data/train/ants/132478121_2a430adea2.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1360291657_dc248c5eea.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1368913450_e146e2fb6d.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1473187633_63ccaacea6.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/148715752_302c84f5a4.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1489674356_09d48dde0a.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/149244013_c529578289.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/150801003_3390b73135.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/150801171_cd86f17ed8.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/154124431_65460430f2.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/162603798_40b51f1654.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1660097129_384bf54490.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/167890289_dd5ba923f3.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1693954099_46d4c20605.jpg
  inflating: /content/data/hymenoptera_data/train/ants/175998972.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/178538489_bec7649292.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1804095607_0341701e1c.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1808777855_2a895621d7.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/188552436_605cc9b36b.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1917341202_d00a7f9af5.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/1924473702_daa9aacdbe.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/196057951_63bf063b92.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/196757565_326437f5fe.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/201558278_fe4caecc76.jpg
  inflating:
/content/data/hymenoptera_data/train/ants/201790779_527f4c0168.jpg
  inflating:
```

```
/content/data/hymenoptera_data/train/ants/2019439677_2db655d361.jpg
  inflating: 
/content/data/hymenoptera_data/train/ants/207947948_3ab29d7207.jpg
  inflating: 
/content/data/hymenoptera_data/train/ants/20935278_9190345f6b.jpg
  inflating: 
/content/data/hymenoptera_data/train/ants/224655713_3956f7d39a.jpg
  inflating: 
/content/data/hymenoptera_data/train/ants/2265824718_2c96f485da.jpg
  inflating: 
/content/data/hymenoptera_data/train/ants/2265825502_fff99cfd2d.jpg
  inflating: 
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8834-800wi.jpg
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/content/data/hymenoptera_data/val/bees/936182217_c4caa5222d.jpg
  inflating: /content/data/hymenoptera_data/val/bees/abeja.jpg

# Data loading
data_transforms = {
    'train': transforms.Compose([
        transforms.RandomResizedCrop(224),
        transforms.RandomHorizontalFlip(),
        transforms.ToTensor(),
        transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
```

```python
    ]),
    'val': transforms.Compose([
        transforms.Resize(256),
        transforms.CenterCrop(224),
        transforms.ToTensor(),
        transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
    ]),
}
data_dir = 'data/hymenoptera_data'
image_datasets = {x:
torchvision.datasets.ImageFolder(os.path.join(data_dir, x),
data_transforms[x]) for x in ['train', 'val']}
dataloaders = {x: torch.utils.data.DataLoader(image_datasets[x],
batch_size=4, 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

# Load pre-trained ResNet18
resnet18 = models.resnet18(pretrained=True)

# Modify the final layer
num_ftrs = resnet18.fc.in_features
resnet18.fc = nn.Linear(num_ftrs, 2)

# Transfer learning setup
criterion = nn.CrossEntropyLoss()
optimizer = optim.SGD(resnet18.parameters(), lr=0.001, momentum=0.9)
exp_lr_scheduler = optim.lr_scheduler.StepLR(optimizer, step_size=7,
gamma=0.1)

# Training loop
def train_model(model, criterion, optimizer, scheduler,
num_epochs=10):
    train_losses = []
    val_accuracies = []
    for epoch in range(num_epochs):
        print(f'Epoch {epoch}/{num_epochs-1}')
        print('-' * 10)

        for phase in ['train', 'val']:
            if phase == 'train':
                model.train()
            else:
                model.eval()

            running_loss = 0.0
            running_corrects = 0

            for inputs, labels in dataloaders[phase]:
```

```
                optimizer.zero_grad()

                with torch.set_grad_enabled(phase == 'train'):
                    outputs = model(inputs)
                    loss = criterion(outputs, labels)
                    _, preds = torch.max(outputs, 1)

                    if phase == 'train':
                        loss.backward()
                        optimizer.step()

                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 the fine-tuned model
model_ft, train_losses, val_accuracies  = train_model(resnet18,
criterion, optimizer, 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()


# Calculate accuracy
def calculate_accuracy(loader, model):
    correct = 0
    total = 0
    with torch.no_grad():
        for data in loader:
            inputs, labels = data
            outputs = model(inputs)
            _, predicted = torch.max(outputs.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
    return 100 * correct / total

train_accuracy = calculate_accuracy(dataloaders['train'], model_ft)
val_accuracy = calculate_accuracy(dataloaders['val'], model_ft)

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

```
Epoch 0/9
----------
train Loss: 0.7074 Acc: 0.6680
val Loss: 0.3195 Acc: 0.8627
Epoch 1/9
----------
train Loss: 0.4839 Acc: 0.8238
val Loss: 0.3115 Acc: 0.8889
Epoch 2/9
----------
train Loss: 0.7328 Acc: 0.7418
val Loss: 0.3387 Acc: 0.8824
Epoch 3/9
----------
train Loss: 0.4729 Acc: 0.7869
val Loss: 0.3117 Acc: 0.8693
Epoch 4/9
----------
train Loss: 0.3686 Acc: 0.8443
val Loss: 0.4337 Acc: 0.8039
Epoch 5/9
----------
train Loss: 0.4993 Acc: 0.8074
val Loss: 0.3724 Acc: 0.8824
Epoch 6/9
----------
train Loss: 0.5287 Acc: 0.8074
```

```
val Loss: 0.4628 Acc: 0.8562
Epoch 7/9
----------
train Loss: 0.3491 Acc: 0.8484
val Loss: 0.3345 Acc: 0.9020
Epoch 8/9
----------
train Loss: 0.3859 Acc: 0.8689
val Loss: 0.3652 Acc: 0.9020
Epoch 9/9
----------
train Loss: 0.4298 Acc: 0.8443
val Loss: 0.2786 Acc: 0.9216
```


```
Training accuracy: 95.90%
Validation accuracy: 92.16%
```

In this task, I applied transfer learning to classify images of bees and ants using a pre-trained ResNet18 model, originally trained on ImageNet. The model was fine-tuned on the hymenoptera dataset by replacing the final fully connected layer to output two classes (bees and ants). Data augmentation techniques, including random resizing and horizontal flipping, were used on the training images to enhance model robustness, while validation images were resized and center-cropped. The model was trained for 10 epochs, achieving a high training accuracy of 95.90% and a validation accuracy of 92.16%, indicating effective transfer learning for this binary classification task.

Use ResNet18 as a Feature Extractor

```
resnet18_fe = models.resnet18(pretrained=True)

for param in resnet18_fe.parameters():
  param.requires_grad = False

num_ftrs = resnet18_fe.fc.in_features
resnet18_fe.fc = nn.Linear(num_ftrs, 2)

optimizer = optim.SGD(resnet18_fe.fc.parameters(), lr=0.001,
momentum=0.9)
model_fe, train_losses_fe, val_accuracies_fe= train_model(resnet18_fe,
criterion, optimizer, exp_lr_scheduler,num_epochs=10)

train_accuracy_fe = calculate_accuracy(dataloaders['train'], model_fe)
val_accuracy_fe = calculate_accuracy(dataloaders['val'], model_fe)

print(f"Training accuracy (Feature Extractor): {train_accuracy_fe:.2f}
%")
print(f"Validation accuracy (Feature Extractor): {val_accuracy_fe:.2f}
%")

# 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()
```

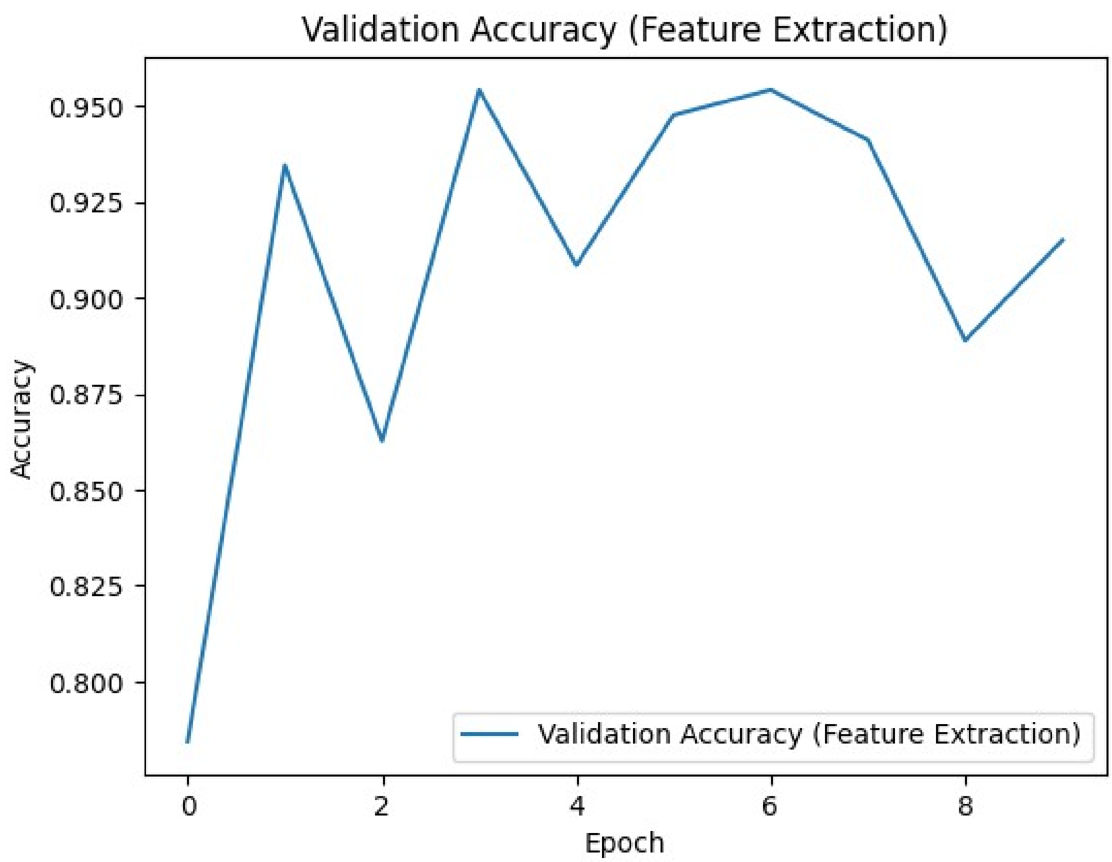
```
/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated
since 0.13 and may be removed in the future, please use 'weights'
instead.
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:2
23: UserWarning: 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)

Epoch 0/9
----------

/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(

train Loss: 0.7204 Acc: 0.6066
val Loss: 0.4257 Acc: 0.7843
Epoch 1/9
----------
train Loss: 0.7237 Acc: 0.6926
val Loss: 0.1973 Acc: 0.9346
Epoch 2/9
----------
train Loss: 0.5084 Acc: 0.7664
val Loss: 0.3490 Acc: 0.8627
Epoch 3/9
----------
train Loss: 0.5496 Acc: 0.7869
val Loss: 0.1713 Acc: 0.9542
Epoch 4/9
----------
train Loss: 0.4501 Acc: 0.8279
val Loss: 0.2233 Acc: 0.9085
Epoch 5/9
----------
train Loss: 0.4931 Acc: 0.7787
val Loss: 0.1684 Acc: 0.9477
Epoch 6/9
----------
train Loss: 0.4704 Acc: 0.8074
val Loss: 0.1849 Acc: 0.9542
Epoch 7/9
----------
train Loss: 0.4982 Acc: 0.8074
val Loss: 0.2095 Acc: 0.9412
Epoch 8/9
----------
train Loss: 0.7783 Acc: 0.7172
val Loss: 0.2989 Acc: 0.8889
Epoch 9/9
----------
train Loss: 0.4469 Acc: 0.8361
val Loss: 0.2258 Acc: 0.9150
Training accuracy (Feature Extractor): 91.39%
Validation accuracy (Feature Extractor): 91.50%
```




In the feature extraction approach, the pre-trained ResNet18 model was adapted for the hymenoptera dataset by freezing all convolutional layers to retain learned representations from ImageNet. Only the final fully connected layer was modified and trained to classify the two target classes (bees and ants). This setup allowed the model to leverage its pre-trained feature extraction capabilities while updating only the final layer for the new classification task. After training for 10 epochs, the model achieved a training accuracy of 91.39% and a validation accuracy of 91.50%, demonstrating that using ResNet18 as a fixed feature extractor can effectively perform binary classification with minimal adjustment.