CS 795 Assignment 4 - ADAM Optimizer

April 7, 2022

[1]:
```
import torch
```

[2]:
```
# Device configuration
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
device
```

[2]:
```
device(type='cuda')
```

[3]:
```
from torchvision import datasets
from torchvision.transforms import ToTensor
train_data = datasets.MNIST(
    root = 'data',
    train = True,
    transform = ToTensor(),
    download = True,
)
test_data = datasets.MNIST(
    root = 'data',
    train = False,
    transform = ToTensor()
)
```

[4]:
```
print(train_data)
```

```
Dataset MNIST
    Number of datapoints: 60000
    Root location: data
    Split: Train
    StandardTransform
Transform: ToTensor()
```

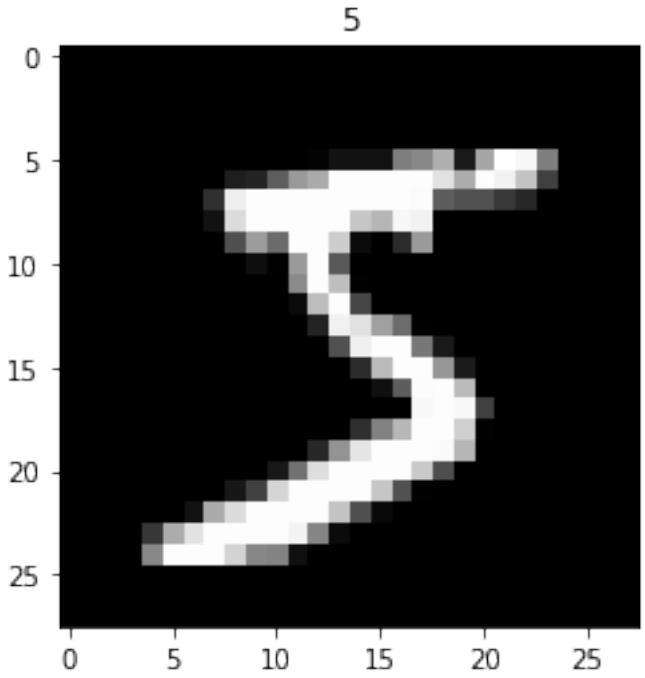
[5]:
```
print(test_data)
```

```
Dataset MNIST
    Number of datapoints: 10000
    Root location: data
    Split: Test
    StandardTransform
Transform: ToTensor()
```

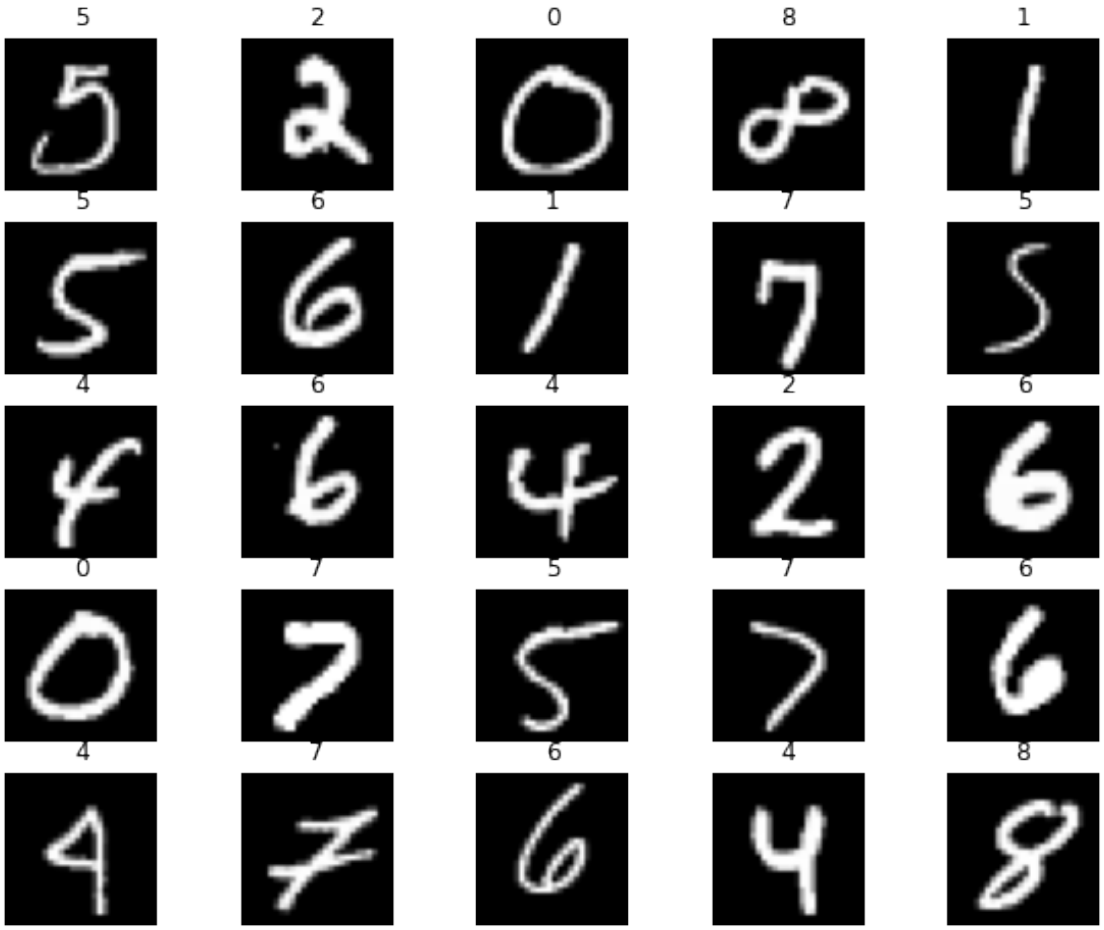
[6]:
```
print(train_data.data.size())
```

```
torch.Size([60000, 28, 28])
```

[7]:
```
import matplotlib.pyplot as plt
plt.imshow(train_data.data[0], cmap='gray')
plt.title('%i' % train_data.targets[0])
plt.show()
```



[8]:
```
figure = plt.figure(figsize=(10, 8))
cols, rows = 5, 5
for i in range(1, cols * rows + 1):
    sample_idx = torch.randint(len(train_data), size=(1,)).item()
    img, label = train_data[sample_idx]
    figure.add_subplot(rows, cols, i)
    plt.title(label)
    plt.axis("off")
    plt.imshow(img.squeeze(), cmap="gray")
plt.show()
```



[9]:
```
from torch.utils.data import DataLoader
loaders = {
    'train' : torch.utils.data.DataLoader(train_data,
                                          batch_size=100,
                                          shuffle=True,
                                          num_workers=1),

    'test'  : torch.utils.data.DataLoader(test_data,
                                          batch_size=100,
                                          shuffle=True,
                                          num_workers=1),
}
loaders
```

[9]:
```
{'train': <torch.utils.data.dataloader.DataLoader at 0x7f5200106be0>,
 'test': <torch.utils.data.dataloader.DataLoader at 0x7f5200106bb0>}
```

[10]:
```
import torch.nn as nn
class CNN(nn.Module):
    def __init__(self):
        super(CNN, self).__init__()
        self.conv1 = nn.Sequential(
            nn.Conv2d(
                in_channels=1,
                out_channels=16,
                kernel_size=5,
                stride=1,
                padding=2,
            ),
            nn.ReLU(),
            nn.MaxPool2d(kernel_size=2),
        )
        self.conv2 = nn.Sequential(
            nn.Conv2d(16, 32, 5, 1, 2),
            nn.ReLU(),
            nn.MaxPool2d(2),
        )
        # fully connected layer, output 10 classes
        self.out = nn.Linear(32 * 7 * 7, 10)
    def forward(self, x):
        x = self.conv1(x)
        x = self.conv2(x)
        # flatten the output of conv2 to (batch_size, 32 * 7 * 7)
        x = x.view(x.size(0), -1)
        output = self.out(x)
        return output, x    # return x for visualization
```

[11]:
```
cnn = CNN()
print(cnn)
```

```
CNN(
  (conv1): Sequential(
    (0): Conv2d(1, 16, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  )
  (conv2): Sequential(
    (0): Conv2d(16, 32, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (1): ReLU()
    (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  )
  (out): Linear(in_features=1568, out_features=10, bias=True)
)
```

[12]:
```
loss_func = nn.CrossEntropyLoss()
loss_func
```

[12]:
```
CrossEntropyLoss()
```

[13]:
```
import math
from torch.optim import Optimizer

class ADAMOptimizer(Optimizer):
    """
    implements ADAM Algorithm, as a preceding step.
    """
    def __init__(self, params, lr=1e-3, betas=(0.9, 0.99), eps=1e-8,␣
↪weight_decay=0):
        defaults = dict(lr=lr, betas=betas, eps=eps, weight_decay=weight_decay)
        super(ADAMOptimizer, self).__init__(params, defaults)

    def step(self):
        """
        Performs a single optimization step.
        """
        loss = None
        for group in self.param_groups:
            #print(group.keys())
            #print (self.param_groups[0]['params'][0].size()), First param (W)␣
↪size: torch.Size([10, 784])
            #print (self.param_groups[0]['params'][1].size()), Second param(b)␣
↪size: torch.Size([10])
            for p in group['params']:
                grad = p.grad.data
                state = self.state[p]

                # State initialization
                if len(state) == 0:
                    state['step'] = 0
                    # Momentum (Exponential MA of gradients)
                    state['exp_avg'] = torch.zeros_like(p.data)
                    #print(p.data.size())
                    # RMS Prop componenet. (Exponential MA of squared␣
↪gradients). Denominator.
                    state['exp_avg_sq'] = torch.zeros_like(p.data)

                exp_avg, exp_avg_sq = state['exp_avg'], state['exp_avg_sq']

                b1, b2 = group['betas']
                state['step'] += 1
```

```
                # L2 penalty. Gotta add to Gradient as well.
                if group['weight_decay'] != 0:
                    grad = grad.add(group['weight_decay'], p.data)

                # Momentum
                exp_avg = torch.mul(exp_avg, b1) + (1 - b1)*grad
                # RMS
                exp_avg_sq = torch.mul(exp_avg_sq, b2) + (1-b2)*(grad*grad)

                denom = exp_avg_sq.sqrt() + group['eps']

                bias_correction1 = 1 / (1 - b1 ** state['step'])
                bias_correction2 = 1 / (1 - b2 ** state['step'])

                adapted_learning_rate = group['lr'] * bias_correction1 / math.
↪sqrt(bias_correction2)

                p.data = p.data - adapted_learning_rate * exp_avg / denom

                if state['step']  % 10000 ==0:
                    print ("group:", group)
                    print("p: ",p)
                    print("p.data: ", p.data) # W = p.data

        return loss
```

[16]:
```
from torch import optim
optimizer = ADAMOptimizer(cnn.parameters(), lr = 0.01)
optimizer
```

[16]:
```
ADAMOptimizer (
Parameter Group 0
    betas: (0.9, 0.99)
    eps: 1e-08
    lr: 0.01
    weight_decay: 0
)
```

[17]:
```
from torch.autograd import Variable
num_epochs = 30
history = []
def test():
    # Test the model
    cnn.eval()
    with torch.no_grad():
        correct = 0
        total = 0
```

```
        for images, labels in loaders['test']:
            test_output, last_layer = cnn(images)
            b_y = Variable(labels)
            loss = loss_func(test_output, b_y)
            pred_y = torch.max(test_output, 1)[1].data.squeeze()
            accuracy = (pred_y == labels).sum().item() / float(labels.size(0))
            pass
        print('Test Accuracy of the model on the 10000 test images: %.2f' %␣
↪accuracy)
        print('Test Loss: {:.4f}', loss.item())

    return accuracy, loss.item()


def train(num_epochs, cnn, loaders):

    cnn.train()

    # Train the model
    total_step = len(loaders['train'])

    for epoch in range(num_epochs):
        for i, (images, labels) in enumerate(loaders['train']):

            # gives batch data, normalize x when iterate train_loader
            b_x = Variable(images)   # batch x
            b_y = Variable(labels)   # batch y
            output = cnn(b_x)[0]
            loss = loss_func(output, b_y)

            # clear gradients for this training step
            optimizer.zero_grad()

            # backpropagation, compute gradients
            loss.backward()
            # apply gradients
            optimizer.step()

            pred_y = torch.max(output, 1)[1].data.squeeze()
            accuracy = (pred_y == labels).sum().item() / float(labels.size(0))
            if (i+1) % 100 == 0:
                print ('Epoch [{}/{}], Step [{}/{}], Acc: {:.4f} Loss: {:.4f}'
                       .format(epoch + 1, num_epochs, i + 1, total_step,␣
↪accuracy, loss.item()))
                pass

        history.append([(accuracy, loss.item()), test()])
```

```
    pass
train(num_epochs, cnn, loaders)
```

```
Epoch [1/30], Step [100/600], Acc: 0.9200 Loss: 0.2266
Epoch [1/30], Step [200/600], Acc: 0.9700 Loss: 0.1237
Epoch [1/30], Step [300/600], Acc: 0.9800 Loss: 0.1635
Epoch [1/30], Step [400/600], Acc: 0.9600 Loss: 0.1664
Epoch [1/30], Step [500/600], Acc: 0.9200 Loss: 0.0992
Epoch [1/30], Step [600/600], Acc: 0.9400 Loss: 0.1553
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.0512511171400547
Epoch [2/30], Step [100/600], Acc: 0.9500 Loss: 0.0971
Epoch [2/30], Step [200/600], Acc: 0.9200 Loss: 0.6379
Epoch [2/30], Step [300/600], Acc: 0.9300 Loss: 0.2885
Epoch [2/30], Step [400/600], Acc: 0.9800 Loss: 0.0881
Epoch [2/30], Step [500/600], Acc: 0.9600 Loss: 0.6130
Epoch [2/30], Step [600/600], Acc: 0.9800 Loss: 0.0394
Test Accuracy of the model on the 10000 test images: 1.00
Test Loss: {:.4f} 0.00023371019051410258
Epoch [3/30], Step [100/600], Acc: 0.9500 Loss: 0.2540
Epoch [3/30], Step [200/600], Acc: 0.9500 Loss: 0.3485
Epoch [3/30], Step [300/600], Acc: 0.9600 Loss: 0.6943
Epoch [3/30], Step [400/600], Acc: 0.9700 Loss: 0.1563
Epoch [3/30], Step [500/600], Acc: 0.9900 Loss: 0.0170
Epoch [3/30], Step [600/600], Acc: 0.9100 Loss: 0.2782
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.11388557404279709
Epoch [4/30], Step [100/600], Acc: 0.9800 Loss: 0.2033
Epoch [4/30], Step [200/600], Acc: 0.9700 Loss: 0.0750
Epoch [4/30], Step [300/600], Acc: 1.0000 Loss: 0.0000
Epoch [4/30], Step [400/600], Acc: 0.9600 Loss: 0.6963
Epoch [4/30], Step [500/600], Acc: 0.9800 Loss: 0.1962
Epoch [4/30], Step [600/600], Acc: 0.9500 Loss: 0.3407
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.07184675335884094
Epoch [5/30], Step [100/600], Acc: 0.9600 Loss: 0.2735
Epoch [5/30], Step [200/600], Acc: 0.9500 Loss: 0.4871
Epoch [5/30], Step [300/600], Acc: 0.9600 Loss: 0.6051
Epoch [5/30], Step [400/600], Acc: 0.9300 Loss: 0.4184
Epoch [5/30], Step [500/600], Acc: 0.9800 Loss: 0.0353
Epoch [5/30], Step [600/600], Acc: 0.9400 Loss: 0.3148
Test Accuracy of the model on the 10000 test images: 0.96
Test Loss: {:.4f} 0.21676920354366302
Epoch [6/30], Step [100/600], Acc: 0.9300 Loss: 1.6076
Epoch [6/30], Step [200/600], Acc: 0.9700 Loss: 0.1688
Epoch [6/30], Step [300/600], Acc: 0.9900 Loss: 0.1325
Epoch [6/30], Step [400/600], Acc: 0.9300 Loss: 0.7345
Epoch [6/30], Step [500/600], Acc: 0.9700 Loss: 0.1850
```

```
Epoch [6/30], Step [600/600], Acc: 0.9700 Loss: 0.2558
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.03142736852169037
Epoch [7/30], Step [100/600], Acc: 0.9600 Loss: 0.5643
Epoch [7/30], Step [200/600], Acc: 0.9800 Loss: 0.2801
Epoch [7/30], Step [300/600], Acc: 0.9400 Loss: 0.5013
Epoch [7/30], Step [400/600], Acc: 0.9500 Loss: 0.5621
Epoch [7/30], Step [500/600], Acc: 0.9700 Loss: 0.4394
Epoch [7/30], Step [600/600], Acc: 0.9500 Loss: 0.9493
Test Accuracy of the model on the 10000 test images: 0.92
Test Loss: {:.4f} 1.0261163711547852
Epoch [8/30], Step [100/600], Acc: 0.9600 Loss: 1.4998
Epoch [8/30], Step [200/600], Acc: 0.9500 Loss: 0.3398
Epoch [8/30], Step [300/600], Acc: 0.9800 Loss: 0.4567
Epoch [8/30], Step [400/600], Acc: 0.9900 Loss: 0.0144
Epoch [8/30], Step [500/600], Acc: 0.9300 Loss: 1.0193
Epoch [8/30], Step [600/600], Acc: 0.9400 Loss: 0.7930
Test Accuracy of the model on the 10000 test images: 0.97
Test Loss: {:.4f} 0.16902516782283783
Epoch [9/30], Step [100/600], Acc: 1.0000 Loss: 0.0001
Epoch [9/30], Step [200/600], Acc: 0.9900 Loss: 0.0696
Epoch [9/30], Step [300/600], Acc: 0.9400 Loss: 0.2253
Epoch [9/30], Step [400/600], Acc: 0.9500 Loss: 0.1255
Epoch [9/30], Step [500/600], Acc: 0.9800 Loss: 0.2168
Epoch [9/30], Step [600/600], Acc: 0.9700 Loss: 0.7003
Test Accuracy of the model on the 10000 test images: 0.97
Test Loss: {:.4f} 0.2651878297328949
Epoch [10/30], Step [100/600], Acc: 0.9300 Loss: 0.8446
Epoch [10/30], Step [200/600], Acc: 1.0000 Loss: 0.0004
Epoch [10/30], Step [300/600], Acc: 0.9300 Loss: 0.9741
Epoch [10/30], Step [400/600], Acc: 0.9700 Loss: 0.8822
Epoch [10/30], Step [500/600], Acc: 0.9600 Loss: 0.5041
Epoch [10/30], Step [600/600], Acc: 0.9500 Loss: 0.8095
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.3003269135951996
Epoch [11/30], Step [100/600], Acc: 0.9600 Loss: 1.3306
Epoch [11/30], Step [200/600], Acc: 0.9900 Loss: 0.1436
Epoch [11/30], Step [300/600], Acc: 0.9600 Loss: 0.5653
Epoch [11/30], Step [400/600], Acc: 0.9600 Loss: 0.6872
Epoch [11/30], Step [500/600], Acc: 0.9500 Loss: 0.6989
Epoch [11/30], Step [600/600], Acc: 0.9400 Loss: 0.6543
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.34890294075012207
Epoch [12/30], Step [100/600], Acc: 0.9800 Loss: 0.1180
Epoch [12/30], Step [200/600], Acc: 0.9900 Loss: 0.1874
Epoch [12/30], Step [300/600], Acc: 0.9600 Loss: 1.2871
Epoch [12/30], Step [400/600], Acc: 0.9700 Loss: 0.7561
Epoch [12/30], Step [500/600], Acc: 0.9800 Loss: 0.6754
```

```
Epoch [12/30], Step [600/600], Acc: 0.9600 Loss: 0.2552
Test Accuracy of the model on the 10000 test images: 0.97
Test Loss: {:.4f} 0.3752167522907257
Epoch [13/30], Step [100/600], Acc: 0.9900 Loss: 0.2403
Epoch [13/30], Step [200/600], Acc: 0.9500 Loss: 0.8916
Epoch [13/30], Step [300/600], Acc: 0.9300 Loss: 0.9640
Epoch [13/30], Step [400/600], Acc: 0.9300 Loss: 2.7633
Epoch [13/30], Step [500/600], Acc: 0.9800 Loss: 0.8984
Epoch [13/30], Step [600/600], Acc: 0.9500 Loss: 1.5785
Test Accuracy of the model on the 10000 test images: 0.95
Test Loss: {:.4f} 0.580963671207428
Epoch [14/30], Step [100/600], Acc: 0.9800 Loss: 0.5668
Epoch [14/30], Step [200/600], Acc: 0.9600 Loss: 0.3298
Epoch [14/30], Step [300/600], Acc: 0.9300 Loss: 0.4602
Epoch [14/30], Step [400/600], Acc: 0.9600 Loss: 0.2945
Epoch [14/30], Step [500/600], Acc: 0.9600 Loss: 0.6254
Epoch [14/30], Step [600/600], Acc: 0.9600 Loss: 0.2371
Test Accuracy of the model on the 10000 test images: 0.99
Test Loss: {:.4f} 0.40758758783340454
Epoch [15/30], Step [100/600], Acc: 0.9400 Loss: 0.6196
Epoch [15/30], Step [200/600], Acc: 0.9200 Loss: 0.6788
Epoch [15/30], Step [300/600], Acc: 0.9900 Loss: 0.0618
Epoch [15/30], Step [400/600], Acc: 0.9400 Loss: 1.9661
Epoch [15/30], Step [500/600], Acc: 0.9500 Loss: 1.5188
Epoch [15/30], Step [600/600], Acc: 0.9700 Loss: 0.8194
Test Accuracy of the model on the 10000 test images: 0.99
Test Loss: {:.4f} 0.07882282882928848
Epoch [16/30], Step [100/600], Acc: 0.9800 Loss: 0.3731
Epoch [16/30], Step [200/600], Acc: 0.9700 Loss: 1.0506
Epoch [16/30], Step [300/600], Acc: 0.9400 Loss: 1.2406
Epoch [16/30], Step [400/600], Acc: 0.9900 Loss: 0.0130
Epoch [16/30], Step [500/600], Acc: 0.9400 Loss: 0.6305
Epoch [16/30], Step [600/600], Acc: 0.9800 Loss: 1.5873
Test Accuracy of the model on the 10000 test images: 0.99
Test Loss: {:.4f} 0.09901030361652374
Epoch [17/30], Step [100/600], Acc: 0.9700 Loss: 0.5237
Epoch [17/30], Step [200/600], Acc: 0.9800 Loss: 0.5417
Epoch [17/30], Step [300/600], Acc: 0.9800 Loss: 0.2390
group: {'params': [Parameter containing:
tensor([[[[-1.7181e-01, -1.8375e-01, -8.0490e-02, -1.2732e-01,  2.9061e-01],
          [-7.6712e-02, -2.5455e-01, -3.3912e-01,  1.5475e-01,  1.9507e-01],
          [-1.3525e-01, -1.1663e+00,  2.8240e-01, -7.6930e-02,  2.7594e-01],
          [-7.0898e-01, -2.3115e-01, -9.5718e-01,  8.1987e-02,  2.8557e-01],
          [ 7.8406e-01, -3.6767e-01,  1.6108e-01, -2.1768e-01, -2.0527e-01]]],


        [[[-4.9106e-01,  1.4271e-01, -1.6007e-01, -7.7877e-03,  3.5855e-01],
          [-1.6672e-02,  1.7518e-01,  2.8491e-01,  2.5025e-01,  2.5883e-01],
```

```
  [ 2.1946e-01, -7.9136e-02, -2.3771e-01, -1.2485e+00, -1.1605e-01],
  [ 6.6657e-02,  2.1305e-01,  1.4156e-01, -1.6039e-01, -7.9491e-02],
  [-2.8900e-01,  6.0192e-01,  5.6856e-01,  6.6823e-03,  1.2857e-01]]],


[[[ 5.8108e-02,  1.8688e-01,  1.9464e-01, -7.3452e-02, -3.7659e-02],
  [-5.1303e-01, -1.6386e-01, -3.4951e-01,  1.4331e-02, -1.2112e-01],
  [-4.1719e-01, -2.2183e-01, -1.1679e-01,  2.3659e-02,  1.1557e-01],
  [-7.0020e-02,  3.3953e-02, -3.3554e-01, -1.0379e-01, -1.1942e-01],
  [-1.6900e-01, -2.4182e-01,  8.1828e-02, -6.2917e-02,  1.5077e-01]]],


[[[-8.0466e-02,  1.6631e-02, -2.0591e-02,  1.2844e-01, -1.1294e-01],
  [-7.2116e-02, -4.4641e-02, -9.2713e-02, -1.8620e-01, -1.2935e-01],
  [-2.4069e-01, -1.9368e-01,  8.8938e-02,  1.9779e-02, -7.1927e-02],
  [-1.1647e-01, -2.2324e-01,  6.7465e-02, -1.8377e-01,  1.9988e-01],
  [-2.3014e-01,  2.0478e-01,  4.0339e-02, -4.6369e-01, -5.5426e-02]]],


[[[-1.7413e-01, -8.9781e-02, -7.8260e-01,  3.6655e-02, -1.0063e+00],
  [-8.9118e-03,  1.8217e-01, -2.1452e-02,  2.2662e-01, -5.0296e-01],
  [-7.2706e-01,  8.0169e-03, -1.7612e-01,  1.4225e-02,  3.3865e-02],
  [-1.5390e-02,  1.1289e-01,  5.8402e-03, -8.4730e-02,  2.2434e-01],
  [-1.3407e-01,  2.0537e-01, -8.5343e-02, -4.3570e-01, -1.5704e-02]]],


[[[ 1.6783e-01, -1.7163e-01, -1.1810e-01, -1.3341e-01, -5.0721e-01],
  [-5.1440e-02, -3.3308e-02,  4.8333e-02,  1.4244e-01, -5.5247e-02],
  [-2.3483e-02, -1.7042e-01, -8.4688e-02, -7.6472e-03, -6.3422e-02],
  [-1.3631e-02, -2.4260e-01,  7.8145e-02, -1.4664e-03,  1.2160e-01],
  [-3.6778e-01, -4.8763e-02, -3.6140e-02,  8.0141e-03,  6.0765e-02]]],


[[[ 5.2013e-02, -6.8886e-02, -5.7749e-02, -5.1377e-01, -8.7829e-02],
  [-3.2265e-01, -1.0701e-01, -1.0178e-01, -1.0164e-01,  3.1060e-01],
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       requires_grad=True), Parameter containing:
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          [-6.1997e-02, -5.4165e-02, -4.3456e-02,  1.3695e-02, -5.4990e-03],
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[[[ 3.4849e+00,  4.6774e+00,  4.1566e-02, -3.1418e-01,  2.1050e+00],
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  [-1.4548e+00, -2.7318e+00, -3.2741e-01,  1.4267e+00,  5.2370e+00],
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 [[ 6.0532e-01,  4.3588e-01, -7.8541e-01, -8.6212e-01,  3.4024e-01],
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  [ 1.5525e-01,  4.9875e-02,  2.4034e-01, -4.5917e-03,  1.6542e-01],
  [ 8.5632e-02, -1.7923e-01, -4.9862e-01,  1.6854e-01,  2.2620e-01],
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  [-3.9312e-02, -1.3243e-02,  4.7651e-02, -1.5097e-01, -1.0272e-01]],

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  [-6.1282e-01,  3.4604e-01,  7.0732e-01, -3.2243e-01, -5.5176e-01],
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  [-9.9301e-01, -5.1767e-01,  4.5080e-02,  2.4471e-01,  6.0488e-01],
  [-5.9032e-01,  6.2748e-01,  6.4247e-01,  1.5291e-01,  1.0950e-01]],

 [[ 8.5344e-01,  3.0455e-01,  8.6240e-01,  8.1623e-01, -9.4462e-01],
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          [-1.6606e+00,  1.1350e+00,  5.6729e-01, -1.2537e+00, -8.9747e-01],
          [ 4.4762e-01,  9.0501e-02,  3.9603e-01,  2.6356e-01, -1.4767e-01],
          [ 7.9404e-01,  1.0251e-02, -3.9621e-01, -5.8200e-01, -8.4536e-02]]]],
       requires_grad=True), Parameter containing:
tensor([-0.0635, -0.6256, -1.3296, -0.2923,  0.0053, -0.4906, -0.0578, -0.4660,
        -0.0731, -0.3763, -0.0477, -0.2753, -1.0111, -1.4100, -0.9403, -1.1307,
        -0.2776, -0.0390, -0.0441, -0.0457, -0.5923, -0.8682,  0.9448, -1.4574,
        -0.2576, -0.0503, -1.0895, -0.0399, -0.0229, -0.0588, -0.0391, -0.2954],
       requires_grad=True), Parameter containing:
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        [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
         -4.1590e+00, -2.4777e+00],
        [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
         -4.3766e+00, -2.0868e+00],
        …,
        [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
         -4.0891e+00, -4.3018e+00],
        [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
         -3.2169e+00, -1.3723e+00],
        [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
         -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
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        -2.1218, -3.0725], requires_grad=True)], 'lr': 0.01, 'betas': (0.9,
0.99), 'eps': 1e-08, 'weight_decay': 0}
p:  Parameter containing:
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          [-7.6712e-02, -2.5455e-01, -3.3912e-01,  1.5475e-01,  1.9507e-01],
          [-1.3525e-01, -1.1663e+00,  2.8240e-01, -7.6930e-02,  2.7594e-01],
          [-7.0898e-01, -2.3115e-01, -9.5718e-01,  8.1987e-02,  2.8557e-01],
          [ 7.8406e-01, -3.6767e-01,  1.6108e-01, -2.1768e-01, -2.0527e-01]]],


        [[[-4.9106e-01,  1.4271e-01, -1.6007e-01, -7.7877e-03,  3.5855e-01],
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          [ 2.1946e-01, -7.9136e-02, -2.3771e-01, -1.2485e+00, -1.1605e-01],
          [ 6.6657e-02,  2.1305e-01,  1.4156e-01, -1.6039e-01, -7.9491e-02],
          [-2.8900e-01,  6.0192e-01,  5.6856e-01,  6.6823e-03,  1.2857e-01]]],


        [[[ 5.8108e-02,  1.8688e-01,  1.9464e-01, -7.3452e-02, -3.7659e-02],
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          [-7.0020e-02,  3.3953e-02, -3.3554e-01, -1.0379e-01, -1.1942e-01],
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  [-1.1647e-01, -2.2324e-01,  6.7465e-02, -1.8377e-01,  1.9988e-01],
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[[[-1.7413e-01, -8.9781e-02, -7.8260e-01,  3.6655e-02, -1.0063e+00],
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  [-1.3407e-01,  2.0537e-01, -8.5343e-02, -4.3570e-01, -1.5704e-02]]],


[[[ 1.6783e-01, -1.7163e-01, -1.1810e-01, -1.3341e-01, -5.0721e-01],
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  [-1.3631e-02, -2.4260e-01,  7.8145e-02, -1.4664e-03,  1.2160e-01],
  [-3.6778e-01, -4.8763e-02, -3.6140e-02,  8.0141e-03,  6.0765e-02]]],


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  [-5.4266e-01, -6.2449e-01,  1.9404e-01,  4.5906e-01, -6.8948e-01],
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[[[ 3.1306e-01, -5.8572e-01, -7.7614e-01, -2.8024e-01, -1.2667e-01],
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[[[ 2.8507e-01, -2.5481e-01, -5.5377e-01, -3.5774e-01, -7.3237e-01],
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          [-3.0056e-01, -5.1349e-02, -5.4547e-03, -1.2153e-02,  4.1104e-02],
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        [[[ 1.6816e-01,  4.6956e-01,  1.8892e-01,  5.2589e-01,  2.7310e-01],
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        [[[ 5.3823e-01, -3.9912e-01, -7.1345e-01,  3.4083e-01,  1.6489e-01],
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        [[[ 2.1467e-01,  8.5025e-02,  1.8998e-01,  4.9180e-01, -1.3873e-02],
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          [ 1.3640e-01,  1.9933e-01,  1.9815e-02, -1.0822e-01, -8.4117e-01],
          [ 1.6918e-01, -3.6901e-01,  4.4954e-02,  1.1328e-01, -2.5843e-01],
          [-1.3340e-01, -2.0641e-01,  6.5386e-01,  6.8466e-01, -5.8478e-01]]]],
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p.data:  tensor([[[[-1.7181e-01, -1.8375e-01, -8.0490e-02, -1.2732e-01,
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          [-7.0898e-01, -2.3115e-01, -9.5718e-01,  8.1987e-02,  2.8557e-01],
          [ 7.8406e-01, -3.6767e-01,  1.6108e-01, -2.1768e-01, -2.0527e-01]]],
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  [ 2.1946e-01, -7.9136e-02, -2.3771e-01, -1.2485e+00, -1.1605e-01],
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        -0.2776, -0.0390, -0.0441, -0.0457, -0.5923, -0.8682,  0.9448, -1.4574,
        -0.2576, -0.0503, -1.0895, -0.0399, -0.0229, -0.0588, -0.0391, -0.2954],
       requires_grad=True), Parameter containing:
tensor([[[-2.0731e-02, -1.4453e-02, -5.1883e-04,  …, -7.8631e+00,
          -4.8086e+00, -2.7759e+00],
         [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
          -4.1590e+00, -2.4777e+00],
         [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
          -4.3766e+00, -2.0868e+00],
         …,
         [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
          -4.0891e+00, -4.3018e+00],
         [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
          -3.2169e+00, -1.3723e+00],
         [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
          -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
tensor([-5.8647, -1.3174, -3.8040, -4.5523, -3.6857, -4.5678, -6.3360, -4.3163,
        -2.1218, -3.0725], requires_grad=True)], 'lr': 0.01, 'betas': (0.9,
0.99), 'eps': 1e-08, 'weight_decay': 0}
p:  Parameter containing:
tensor([-0.5798, -0.4699, -0.5302, -0.3251, -0.5173, -0.3805, -0.4823, -0.4242,
        -0.2819, -0.6181, -0.6394,  1.1976, -1.3630, -0.3718, -0.8765, -0.5770],
```

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       requires_grad=True)
p.data:  tensor([-0.5798, -0.4699, -0.5302, -0.3251, -0.5173, -0.3805, -0.4823,
-0.4242,
        -0.2819, -0.6181, -0.6394,  1.1976, -1.3630, -0.3718, -0.8765, -0.5770])
group: {'params': [Parameter containing:
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          [-7.0898e-01, -2.3115e-01, -9.5718e-01,  8.1987e-02,  2.8557e-01],
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        [[[-4.9106e-01,  1.4271e-01, -1.6007e-01, -7.7877e-03,  3.5855e-01],
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          [ 6.6657e-02,  2.1305e-01,  1.4156e-01, -1.6039e-01, -7.9491e-02],
          [-2.8900e-01,  6.0192e-01,  5.6856e-01,  6.6823e-03,  1.2857e-01]]],


        [[[ 5.8108e-02,  1.8688e-01,  1.9464e-01, -7.3452e-02, -3.7659e-02],
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          [-7.0020e-02,  3.3953e-02, -3.3554e-01, -1.0379e-01, -1.1942e-01],
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        [[[-8.0466e-02,  1.6631e-02, -2.0591e-02,  1.2844e-01, -1.1294e-01],
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          [-2.3014e-01,  2.0478e-01,  4.0339e-02, -4.6369e-01, -5.5426e-02]]],


        [[[-1.7413e-01, -8.9781e-02, -7.8260e-01,  3.6655e-02, -1.0063e+00],
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          [-1.5390e-02,  1.1289e-01,  5.8402e-03, -8.4730e-02,  2.2434e-01],
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        [[[ 1.6783e-01, -1.7163e-01, -1.1810e-01, -1.3341e-01, -5.0721e-01],
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          [-2.3483e-02, -1.7042e-01, -8.4688e-02, -7.6472e-03, -6.3422e-02],
          [-1.3631e-02, -2.4260e-01,  7.8145e-02, -1.4664e-03,  1.2160e-01],
          [-3.6778e-01, -4.8763e-02, -3.6140e-02,  8.0141e-03,  6.0765e-02]]],


        [[[ 5.2013e-02, -6.8886e-02, -5.7749e-02, -5.1377e-01, -8.7829e-02],
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  [-7.9561e-02,  1.7293e-01, -1.0074e-01,  7.6123e-02, -1.9215e-01],
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[[[ 2.5943e-01,  2.6826e-01,  2.3717e-01,  4.7436e-01, -2.5379e-01],
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[[[ 2.8507e-01, -2.5481e-01, -5.5377e-01, -3.5774e-01, -7.3237e-01],
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  [-3.0056e-01, -5.1349e-02, -5.4547e-03, -1.2153e-02,  4.1104e-02],
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[[[ 1.6816e-01,  4.6956e-01,  1.8892e-01,  5.2589e-01,  2.7310e-01],
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          [-2.2729e-01, -1.3373e-02,  3.0793e-02, -1.8900e-01,  8.8839e-02],
          [-6.0247e-02, -1.3960e-01,  4.3944e-02, -6.5704e-03,  1.4900e-02],
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        [[[ 5.0987e-02, -8.0802e-02, -2.1856e-01,  3.3909e-01, -1.8042e-01],
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        [[[ 2.1467e-01,  8.5025e-02,  1.8998e-01,  4.9180e-01, -1.3873e-02],
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         [[ 4.6986e-03, -1.5853e-02, -8.6363e-02, -2.4292e-03, -6.8606e-02],
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         …,

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 …,

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  [ 1.9722e+00,  2.7665e+00,  2.2662e+00, -3.2408e-01,  1.8197e+00],
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  [-1.6466e-02, -1.4666e-02, -3.1504e-02, -3.3324e-02,  1.7529e-02]],

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  [-1.0699e-02,  5.4232e-03, -7.8695e-03, -1.0654e-01,  1.2287e-02],
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       requires_grad=True), Parameter containing:
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        -0.2776, -0.0390, -0.0441, -0.0457, -0.5923, -0.8682,  0.9448, -1.4574,
        -0.2576, -0.0503, -1.0895, -0.0399, -0.0229, -0.0588, -0.0391, -0.2954],
       requires_grad=True), Parameter containing:
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         -4.1590e+00, -2.4777e+00],
        [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
         -4.3766e+00, -2.0868e+00],
        …,
        [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
         -4.0891e+00, -4.3018e+00],
        [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
         -3.2169e+00, -1.3723e+00],
        [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
         -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
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          [-7.8909e-02,  2.5176e-03, -5.3599e-02, -1.2680e-02, -3.7355e-02],
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        -0.2819, -0.6181, -0.6394,  1.1976, -1.3630, -0.3718, -0.8765, -0.5770],
       requires_grad=True), Parameter containing:
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          [-1.5648e-02, -5.4026e-02, -5.8677e-03,  6.2388e-04, -4.1126e-02],
          [-6.1997e-02, -5.4165e-02, -4.3456e-02,  1.3695e-02, -5.4990e-03],
          [-7.8909e-02,  2.5176e-03, -5.3599e-02, -1.2680e-02, -3.7355e-02],
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  [[[ 3.4749e+00,  4.6776e+00,  4.1566e-02, -3.1418e-01,  2.1050e+00],
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   [[ 8.4344e-01,  3.1455e-01,  8.6240e-01,  8.1623e-01, -9.4462e-01],
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requires_grad=True), Parameter containing:
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        -0.2776, -0.0390, -0.0441, -0.0457, -0.5823, -0.8582,  0.9348, -1.4674,
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         -4.3766e+00, -2.0868e+00],
        …,
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         -3.2169e+00, -1.3723e+00],
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         -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
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        -0.2776, -0.0390, -0.0441, -0.0457, -0.5823, -0.8582,  0.9348, -1.4674,
        -0.2576, -0.0503, -1.0895, -0.0399, -0.0229, -0.0588, -0.0391, -0.2854],
       requires_grad=True)
p.data:  tensor([-0.0635, -0.6156, -1.3196, -0.2823,  0.0053, -0.4806, -0.0578,
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group: {'params': [Parameter containing:
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        [[[-4.9106e-01,  1.4271e-01, -1.6007e-01, -7.7877e-03,  3.5855e-01],
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  [ 1.3000e-01,  2.3582e-01,  6.8328e-01,  1.2434e-01,  1.1378e-01],
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[[[-3.4130e-01, -3.0249e-02,  4.2326e-02, -1.3526e-01,  4.2669e-02],
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  [-2.2729e-01, -1.3373e-02,  3.0793e-02, -1.8900e-01,  8.8839e-02],
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[[[ 5.0987e-02, -8.0802e-02, -2.1856e-01,  3.3909e-01, -1.8042e-01],
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  [-6.9098e-02, -9.0912e-01, -4.2828e-01, -3.6068e-02,  2.3664e-01],
  [ 3.1391e-01,  8.6210e-02, -4.2351e-01, -2.1919e-01,  2.0048e-01]]],


[[[ 2.1467e-01,  8.5025e-02,  1.8998e-01,  4.9180e-01, -1.3873e-02],
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  [ 1.3640e-01,  1.9933e-01,  1.9815e-02, -1.0822e-01, -8.4117e-01],
  [ 1.6918e-01, -3.6901e-01,  4.4954e-02,  1.1328e-01, -2.5843e-01],
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requires_grad=True), Parameter containing:
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```
tensor([-0.5798, -0.4699, -0.5302, -0.3251, -0.5173, -0.3805, -0.4823, -0.4242,
        -0.2819, -0.6181, -0.6394,  1.1976, -1.3630, -0.3718, -0.8765, -0.5770],
       requires_grad=True), Parameter containing:
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          [-6.1997e-02, -5.4165e-02, -4.3456e-02,  1.3695e-02, -5.4990e-03],
          [-7.8909e-02,  2.5176e-03, -5.3599e-02, -1.2680e-02, -3.7355e-02],
          [-7.8414e-03,  5.6345e-02, -7.0011e-02, -1.2198e-02,  3.1331e-02]],

         [[-1.5120e-02, -7.0177e-02,  1.1537e-03, -1.8049e-02, -3.5756e-02],
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          [-6.6801e-02, -3.2293e-02, -4.6492e-02, -2.2975e-02,  2.0524e-02],
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          [-4.2079e-02, -6.7316e-02,  7.7326e-03,  3.5436e-02, -6.0779e-03],
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          [-1.4834e-02, -6.7969e-03,  1.6155e-02, -2.1015e-02,  2.3897e-02],
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          [-5.4545e-03,  2.0822e-02,  3.7806e-02,  1.2539e-02, -4.9356e-02]]],


        [[[-1.5777e+00, -1.5536e+00, -1.8640e+00, -2.2343e+00, -5.2697e-01],
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  [ 1.4713e-01,  1.7911e+00,  1.9727e+00,  1.0049e+00, -9.4672e-01],
  [-2.4449e-01,  3.6619e-02,  3.9140e-01, -1.2737e+00, -3.1039e+00],
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  [ 6.6463e-01,  2.9019e-01,  5.0718e-01, -6.2083e-01, -1.7577e+00],
  [ 8.5095e-01,  7.7586e-01, -4.1850e-01, -6.1369e-01, -1.2178e+00],
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 …,

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  [-1.6466e-02, -1.4666e-02, -3.1504e-02, -3.3324e-02,  1.7529e-02]],

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[[[ 6.8691e-03,  7.1583e-02,  1.9478e-02, -3.8470e-02, -2.8183e-02],
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        [[[ 3.4749e+00,  4.6776e+00,  4.1566e-02, -3.1418e-01,  2.1050e+00],
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          [ 3.9965e+00,  2.8375e+00, -7.0791e-01, -6.9960e-01,  1.8607e+00],
          [-1.4548e+00, -2.7318e+00, -3.2741e-01,  1.4367e+00,  5.2470e+00],
          [-2.7642e+00, -1.9451e+00, -1.7674e+00,  4.6773e-01,  3.8230e+00]],

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          [-1.3562e+00, -1.8643e+00, -1.6091e+00, -1.0525e+00, -1.2302e+00],
          [-1.0853e+00, -3.1496e-01, -4.9779e-02, -3.0734e-01, -5.5174e-01]],

         [[ 6.0532e-01,  4.3588e-01, -7.8541e-01, -8.6212e-01,  3.4024e-01],
          [ 1.8867e-01, -5.1085e-01, -1.4745e-01, -5.3365e-01, -4.7699e-02],
          [-5.5365e-01, -1.2886e-01, -1.9305e-01, -4.9583e-01, -9.2746e-01],
          [ 1.0830e-01,  4.5374e-01,  1.7288e-01, -4.3502e-01, -2.7221e-01],
          [ 1.5622e-01,  3.1555e-01,  6.3203e-01,  4.9695e-01,  2.2957e-01]],

         …,

         [[-8.3091e-02,  1.7897e-01,  2.2224e-01, -1.2460e-01,  1.6183e-01],
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          [-1.3161e-01, -4.3531e-01,  1.7428e-02,  8.0013e-02, -7.2802e-02],
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          [-9.9301e-01, -5.1767e-01,  4.5080e-02,  2.4471e-01,  6.0488e-01],
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         [[ 8.4344e-01,  3.1455e-01,  8.6240e-01,  8.1623e-01, -9.4462e-01],
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          [ 7.9404e-01,  2.5119e-04, -3.9621e-01, -5.8200e-01, -8.4536e-02]]]],
       requires_grad=True), Parameter containing:
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        -0.0731, -0.3763, -0.0477, -0.2753, -1.0111, -1.4200, -0.9503, -1.1407,
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        -0.2576, -0.0503, -1.0895, -0.0399, -0.0229, -0.0588, -0.0391, -0.2854],
       requires_grad=True), Parameter containing:
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         -4.8086e+00, -2.7759e+00],
        [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
         -4.1590e+00, -2.4777e+00],
        [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
         -4.3766e+00, -2.0868e+00],
        …,
        [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
         -4.0891e+00, -4.3018e+00],
        [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
         -3.2169e+00, -1.3723e+00],
        [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
         -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
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        -2.1218, -3.0725], requires_grad=True)], 'lr': 0.01, 'betas': (0.9,
0.99), 'eps': 1e-08, 'weight_decay': 0}
p:  Parameter containing:
tensor([[-2.0731e-02, -1.4453e-02, -5.1883e-04,  …, -7.8631e+00,
         -4.8086e+00, -2.7759e+00],
        [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
         -4.1590e+00, -2.4777e+00],
        [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
         -4.3766e+00, -2.0868e+00],
        …,
        [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
         -4.0891e+00, -4.3018e+00],
        [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
         -3.2169e+00, -1.3723e+00],
        [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
         -2.2120e+00, -1.1118e+00]], requires_grad=True)
p.data:  tensor([[-2.0731e-02, -1.4453e-02, -5.1883e-04,  …, -7.8631e+00,
         -4.8086e+00, -2.7759e+00],
        [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
         -4.1590e+00, -2.4777e+00],
        [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
         -4.3766e+00, -2.0868e+00],
        …,
        [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
         -4.0891e+00, -4.3018e+00],
        [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
         -3.2169e+00, -1.3723e+00],
        [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
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group: {'params': [Parameter containing:
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        [[[-4.9106e-01,  1.4271e-01, -1.6007e-01, -7.7877e-03,  3.5855e-01],
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          [-2.8900e-01,  6.0192e-01,  5.6856e-01,  6.6823e-03,  1.2857e-01]]],


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        [[[-8.0466e-02,  1.6631e-02, -2.0591e-02,  1.2844e-01, -1.1294e-01],
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          [-1.1647e-01, -2.2324e-01,  6.7465e-02, -1.8377e-01,  1.9988e-01],
          [-2.3014e-01,  2.0478e-01,  4.0339e-02, -4.6369e-01, -5.5426e-02]]],


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        [[[ 1.6783e-01, -1.7163e-01, -1.1810e-01, -1.3341e-01, -5.0721e-01],
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        [[[ 5.2013e-02, -6.8886e-02, -5.7749e-02, -5.1377e-01, -8.7829e-02],
          [-3.2265e-01, -1.0701e-01, -1.0178e-01, -1.0164e-01,  3.1060e-01],
          [-5.7413e-02, -2.8633e-01,  8.8271e-02,  6.6195e-03,  1.0750e-02],
          [-7.9561e-02,  1.7293e-01, -1.0074e-01,  7.6123e-02, -1.9215e-01],
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[[[ 3.1306e-01, -5.8572e-01, -7.7614e-01, -2.8024e-01, -1.2667e-01],
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[[[ 2.8507e-01, -2.5481e-01, -5.5377e-01, -3.5774e-01, -7.3237e-01],
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[[[ 8.1748e-02, -6.7113e-02, -3.8841e-02, -2.4762e-01, -4.5554e-01],
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[[[ 1.6816e-01,  4.6956e-01,  1.8892e-01,  5.2589e-01,  2.7310e-01],
  [ 3.4186e-01,  4.9586e-01, -9.5828e-01, -7.2106e-02,  3.7995e-01],
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  [ 8.7465e-02, -5.7465e-01,  6.3181e-01, -1.4294e-01, -2.2889e-01],
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  [ 2.7796e-01, -5.9538e-01,  2.0597e-01,  6.2618e-01,  5.5854e-02],
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[[[-3.4130e-01, -3.0249e-02,  4.2326e-02, -1.3526e-01,  4.2669e-02],
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  [-6.0247e-02, -1.3960e-01,  4.3944e-02, -6.5704e-03,  1.4900e-02],
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        [[[ 2.1467e-01,  8.5025e-02,  1.8998e-01,  4.9180e-01, -1.3873e-02],
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          [ 1.6918e-01, -3.6901e-01,  4.4954e-02,  1.1328e-01, -2.5843e-01],
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          [-6.1997e-02, -5.4165e-02, -4.3456e-02,  1.3695e-02, -5.4990e-03],
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          [-6.6801e-02, -3.2293e-02, -4.6492e-02, -2.2975e-02,  2.0524e-02],
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         [[ 4.6986e-03, -1.5853e-02, -8.6363e-02, -2.4292e-03, -6.8606e-02],
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         …,

         [[ 1.0442e-02, -4.5476e-02, -2.5854e-02, -3.9499e-02, -6.3439e-02],
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tensor([[[-2.0731e-02, -1.4453e-02, -5.1883e-04,  …, -7.8631e+00,
          -4.8086e+00, -2.7759e+00],
         [-2.2037e-02, -3.6387e-03, -7.6505e-03,  …, -3.6198e+00,
          -4.1590e+00, -2.4777e+00],
         [-1.3324e-02, -1.7820e-02,  3.7923e-02,  …, -7.2954e+00,
          -4.3766e+00, -2.0868e+00],
         …,
         [-1.9467e-03,  3.2024e-02,  2.4679e-02,  …, -2.1963e+00,
          -4.0891e+00, -4.3018e+00],
         [ 2.1002e-03, -1.3206e-02,  6.5986e-03,  …, -7.8599e+00,
          -3.2169e+00, -1.3723e+00],
         [-1.2797e-02,  1.8820e-03, -2.8647e-02,  …, -3.3872e+00,
          -2.2120e+00, -1.1118e+00]], requires_grad=True), Parameter containing:
tensor([-5.8747, -1.3174, -3.7940, -4.5623, -3.6757, -4.5778, -6.3260, -4.3263,
        -2.1118, -3.0725], requires_grad=True)], 'lr': 0.01, 'betas': (0.9,
0.99), 'eps': 1e-08, 'weight_decay': 0}
p:  Parameter containing:
tensor([-5.8747, -1.3174, -3.7940, -4.5623, -3.6757, -4.5778, -6.3260, -4.3263,
        -2.1118, -3.0725], requires_grad=True)
p.data:  tensor([-5.8747, -1.3174, -3.7940, -4.5623, -3.6757, -4.5778, -6.3260,
-4.3263,
        -2.1118, -3.0725])
Epoch [17/30], Step [400/600], Acc: 0.9400 Loss: 1.2867
Epoch [17/30], Step [500/600], Acc: 0.9600 Loss: 0.4247
Epoch [17/30], Step [600/600], Acc: 0.9900 Loss: 0.0990
Test Accuracy of the model on the 10000 test images: 1.00
Test Loss: {:.4f} 0.0
Epoch [18/30], Step [100/600], Acc: 0.9800 Loss: 0.7643
Epoch [18/30], Step [200/600], Acc: 0.9700 Loss: 0.4344
```

```
Epoch [18/30], Step [300/600], Acc: 0.9500 Loss: 1.2524
Epoch [18/30], Step [400/600], Acc: 0.9900 Loss: 0.9781
Epoch [18/30], Step [500/600], Acc: 0.9100 Loss: 1.1249
Epoch [18/30], Step [600/600], Acc: 0.9900 Loss: 0.2399
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 1.3600866794586182
Epoch [19/30], Step [100/600], Acc: 0.9400 Loss: 2.5171
Epoch [19/30], Step [200/600], Acc: 0.9600 Loss: 0.6840
Epoch [19/30], Step [300/600], Acc: 0.9800 Loss: 0.4200
Epoch [19/30], Step [400/600], Acc: 0.9500 Loss: 1.5232
Epoch [19/30], Step [500/600], Acc: 0.9800 Loss: 0.3669
Epoch [19/30], Step [600/600], Acc: 0.9600 Loss: 0.4542
Test Accuracy of the model on the 10000 test images: 0.91
Test Loss: {:.4f} 1.4133572578430176
Epoch [20/30], Step [100/600], Acc: 0.9800 Loss: 0.2816
Epoch [20/30], Step [200/600], Acc: 0.9700 Loss: 0.6179
Epoch [20/30], Step [300/600], Acc: 0.9500 Loss: 1.6446
Epoch [20/30], Step [400/600], Acc: 0.9900 Loss: 0.1460
Epoch [20/30], Step [500/600], Acc: 0.9600 Loss: 0.9574
Epoch [20/30], Step [600/600], Acc: 0.9700 Loss: 1.3947
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.42429134249687195
Epoch [21/30], Step [100/600], Acc: 1.0000 Loss: 0.0004
Epoch [21/30], Step [200/600], Acc: 0.9800 Loss: 0.6793
Epoch [21/30], Step [300/600], Acc: 0.9700 Loss: 0.1079
Epoch [21/30], Step [400/600], Acc: 0.9900 Loss: 0.3161
Epoch [21/30], Step [500/600], Acc: 0.9800 Loss: 0.1653
Epoch [21/30], Step [600/600], Acc: 0.9600 Loss: 0.6421
Test Accuracy of the model on the 10000 test images: 0.96
Test Loss: {:.4f} 0.8857026100158691
Epoch [22/30], Step [100/600], Acc: 0.9500 Loss: 0.9321
Epoch [22/30], Step [200/600], Acc: 0.9700 Loss: 1.0103
Epoch [22/30], Step [300/600], Acc: 0.9800 Loss: 0.7715
Epoch [22/30], Step [400/600], Acc: 0.9800 Loss: 0.0560
Epoch [22/30], Step [500/600], Acc: 0.9900 Loss: 0.2444
Epoch [22/30], Step [600/600], Acc: 0.9400 Loss: 1.0488
Test Accuracy of the model on the 10000 test images: 0.99
Test Loss: {:.4f} 0.07310611009597778
Epoch [23/30], Step [100/600], Acc: 0.9500 Loss: 0.6981
Epoch [23/30], Step [200/600], Acc: 0.9900 Loss: 0.0084
Epoch [23/30], Step [300/600], Acc: 0.9800 Loss: 0.8472
Epoch [23/30], Step [400/600], Acc: 1.0000 Loss: 0.0000
Epoch [23/30], Step [500/600], Acc: 0.9600 Loss: 0.8085
Epoch [23/30], Step [600/600], Acc: 0.9700 Loss: 0.7574
Test Accuracy of the model on the 10000 test images: 0.96
Test Loss: {:.4f} 0.6194711923599243
Epoch [24/30], Step [100/600], Acc: 0.9900 Loss: 0.0543
Epoch [24/30], Step [200/600], Acc: 0.9900 Loss: 0.4112
```

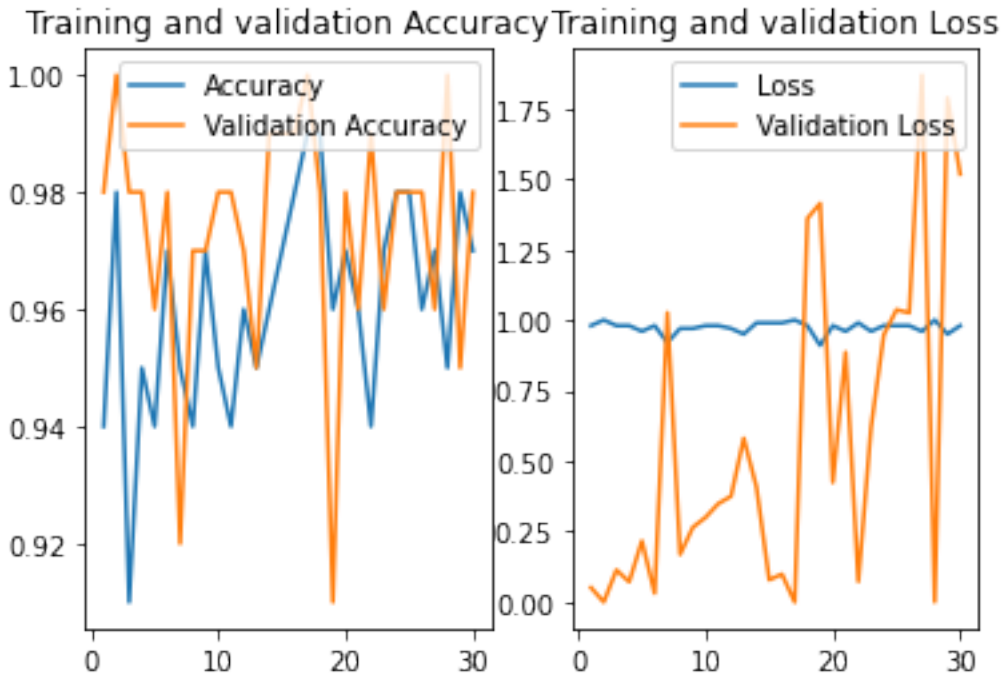
```
Epoch [24/30], Step [300/600], Acc: 0.9900 Loss: 0.4793
Epoch [24/30], Step [400/600], Acc: 0.9600 Loss: 0.9340
Epoch [24/30], Step [500/600], Acc: 0.9500 Loss: 0.8566
Epoch [24/30], Step [600/600], Acc: 0.9800 Loss: 1.2131
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 0.947405993938446
Epoch [25/30], Step [100/600], Acc: 0.9500 Loss: 0.8121
Epoch [25/30], Step [200/600], Acc: 0.9800 Loss: 0.4048
Epoch [25/30], Step [300/600], Acc: 1.0000 Loss: 0.0062
Epoch [25/30], Step [400/600], Acc: 0.9500 Loss: 2.3036
Epoch [25/30], Step [500/600], Acc: 1.0000 Loss: 0.0034
Epoch [25/30], Step [600/600], Acc: 0.9800 Loss: 0.3964
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 1.0363484621047974
Epoch [26/30], Step [100/600], Acc: 0.9800 Loss: 1.8558
Epoch [26/30], Step [200/600], Acc: 1.0000 Loss: 0.0000
Epoch [26/30], Step [300/600], Acc: 0.9900 Loss: 0.1666
Epoch [26/30], Step [400/600], Acc: 0.9800 Loss: 0.6717
Epoch [26/30], Step [500/600], Acc: 0.9700 Loss: 2.2457
Epoch [26/30], Step [600/600], Acc: 0.9600 Loss: 0.2153
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 1.02531099319458
Epoch [27/30], Step [100/600], Acc: 0.9800 Loss: 0.7895
Epoch [27/30], Step [200/600], Acc: 0.9600 Loss: 2.9149
Epoch [27/30], Step [300/600], Acc: 0.9900 Loss: 0.5655
Epoch [27/30], Step [400/600], Acc: 0.9900 Loss: 0.1530
Epoch [27/30], Step [500/600], Acc: 0.9600 Loss: 1.9158
Epoch [27/30], Step [600/600], Acc: 0.9700 Loss: 2.3261
Test Accuracy of the model on the 10000 test images: 0.96
Test Loss: {:.4f} 1.868557095527649
Epoch [28/30], Step [100/600], Acc: 0.9600 Loss: 0.5891
Epoch [28/30], Step [200/600], Acc: 0.9700 Loss: 1.3618
Epoch [28/30], Step [300/600], Acc: 0.9900 Loss: 0.0225
Epoch [28/30], Step [400/600], Acc: 1.0000 Loss: 0.0063
Epoch [28/30], Step [500/600], Acc: 1.0000 Loss: 0.0000
Epoch [28/30], Step [600/600], Acc: 0.9500 Loss: 0.4104
Test Accuracy of the model on the 10000 test images: 1.00
Test Loss: {:.4f} 0.000630711845587939
Epoch [29/30], Step [100/600], Acc: 0.9600 Loss: 0.4753
Epoch [29/30], Step [200/600], Acc: 0.9800 Loss: 1.1036
Epoch [29/30], Step [300/600], Acc: 0.9700 Loss: 0.9471
Epoch [29/30], Step [400/600], Acc: 0.9900 Loss: 0.2758
Epoch [29/30], Step [500/600], Acc: 0.9600 Loss: 0.9599
Epoch [29/30], Step [600/600], Acc: 0.9800 Loss: 0.1726
Test Accuracy of the model on the 10000 test images: 0.95
Test Loss: {:.4f} 1.787406325340271
Epoch [30/30], Step [100/600], Acc: 1.0000 Loss: 0.0000
Epoch [30/30], Step [200/600], Acc: 0.9700 Loss: 1.6293
```

```
Epoch [30/30], Step [300/600], Acc: 0.9800 Loss: 0.7402
Epoch [30/30], Step [400/600], Acc: 0.9700 Loss: 1.1115
Epoch [30/30], Step [500/600], Acc: 0.9800 Loss: 0.2950
Epoch [30/30], Step [600/600], Acc: 0.9700 Loss: 0.5006
Test Accuracy of the model on the 10000 test images: 0.98
Test Loss: {:.4f} 1.5171868801116943
```

[18]:
```
x = range(1, num_epochs+1)
acc = [i[0][0] for i in history]
val_acc = [i[1][0] for i in history]
loss = [i[1][0] for i in history]
val_loss = [i[1][1] for i in history]
plt.subplot(1, 2, 1)
plt.plot(x, acc, label="Accuracy")
plt.plot(x, val_acc, label="Validation Accuracy")
plt.legend(loc='upper right')
plt.title("Training and validation Accuracy")

plt.subplot(1, 2, 2)
plt.plot(x, loss, label="Loss")
plt.plot(x, val_loss, label="Validation Loss")
plt.legend(loc='upper right')
plt.title("Training and validation Loss")

plt.show()
```



[ ]:

[ ]: