lab6

February 20, 2025

[1]:
```
import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import Dataset, DataLoader
import numpy as np
import matplotlib.pyplot as plt
from sklearn.metrics import accuracy_score
from sklearn import metrics
import torchvision
from torchvision import transforms, datasets
import torch.nn.functional as F
```

[2]:
```
transform = transforms.Compose([transforms.ToTensor(), transforms.Normalize((0.
 ↪5,), (0.5,))])

batch_size = 4
train_set = torchvision.datasets.MNIST(root='./data/', train=True,␣
 ↪download=True, transform=transform)
train_loader = DataLoader(train_set, batch_size=batch_size, shuffle=True,␣
 ↪num_workers=2)

test_set = torchvision.datasets.MNIST(root='./data/', train=False,␣
 ↪download=True, transform=transform)
test_loader = DataLoader(test_set, batch_size=batch_size, shuffle=False,␣
 ↪num_workers=2)
```

```
Downloading http://yann.lecun.com/exdb/mnist/train-images-idx3-ubyte.gz
Failed to download (trying next):
HTTP Error 403: Forbidden

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

100%|                    | 9.91M/9.91M [00:50<00:00, 195kB/s]

Extracting ./data/MNIST/raw/train-images-idx3-ubyte.gz to ./data/MNIST/raw
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Downloading http://yann.lecun.com/exdb/mnist/train-labels-idx1-ubyte.gz
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Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-labels-
idx1-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/train-labels-
idx1-ubyte.gz to ./data/MNIST/raw/train-labels-idx1-ubyte.gz

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

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Extracting ./data/MNIST/raw/t10k-images-idx3-ubyte.gz to ./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://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-
idx1-ubyte.gz
Downloading https://ossci-datasets.s3.amazonaws.com/mnist/t10k-labels-
idx1-ubyte.gz to ./data/MNIST/raw/t10k-labels-idx1-ubyte.gz

100%|                    | 4.54k/4.54k [00:00<00:00, 37.8MB/s]

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

[3]:
```
device = 'cuda' if torch.cuda.is_available() else 'cpu'

class CNNNetwork(nn.Module):
    def __init__(self):
        super(CNNNetwork, self).__init__()
        self.feature_extractor = nn.Sequential(nn.Conv2d(1, 10, kernel_size=5),
                                               nn.MaxPool2d((2, 2), stride=None),
                                               nn.ReLU(),
                                               nn.Conv2d(10, 20, kernel_size=5),
```

```
                                                #nn.Dropout2d(),
                                                nn.MaxPool2d((2, 2), stride=None),
                                                nn.ReLU()
                                                )
        self.flatten = nn.Flatten()
        self.classification_head = nn.Sequential(nn.Linear(320, 64, bias=True),
                                                 nn.ReLU(),
                                                 nn.Linear(64, 10, bias=True))


    def forward(self, x):
        x = self.feature_extractor(x)
        x = self.flatten(x)    # x = x.view(-1, 320)
        x = self.classification_head(x)
        x = F.log_softmax(x, dim=1)
        return x



model = CNNNetwork().to(device)
model.train()

criterion = F.nll_loss
optimizer = optim.Adam(model.parameters(), lr=1e-3)
```

[4]:
```
losses = []
num_epochs = 3
model.train()

for epoch in range(1, num_epochs+1):
    epoch_loss = 0
    for idx, (x_batch, y_batch) in enumerate(train_loader):
        batch_size = len(x_batch)
        loader_size = len(train_loader)

        x_batch, y_batch = x_batch.to(device), y_batch.to(device)
        y_pred = model(x_batch)
        y_pred = y_pred.reshape(batch_size,-1)

        loss = criterion(y_pred, y_batch)
        loss.backward()
        optimizer.step()
        optimizer.zero_grad()

        epoch_loss += loss

        if (idx % 1000 == 0):
```

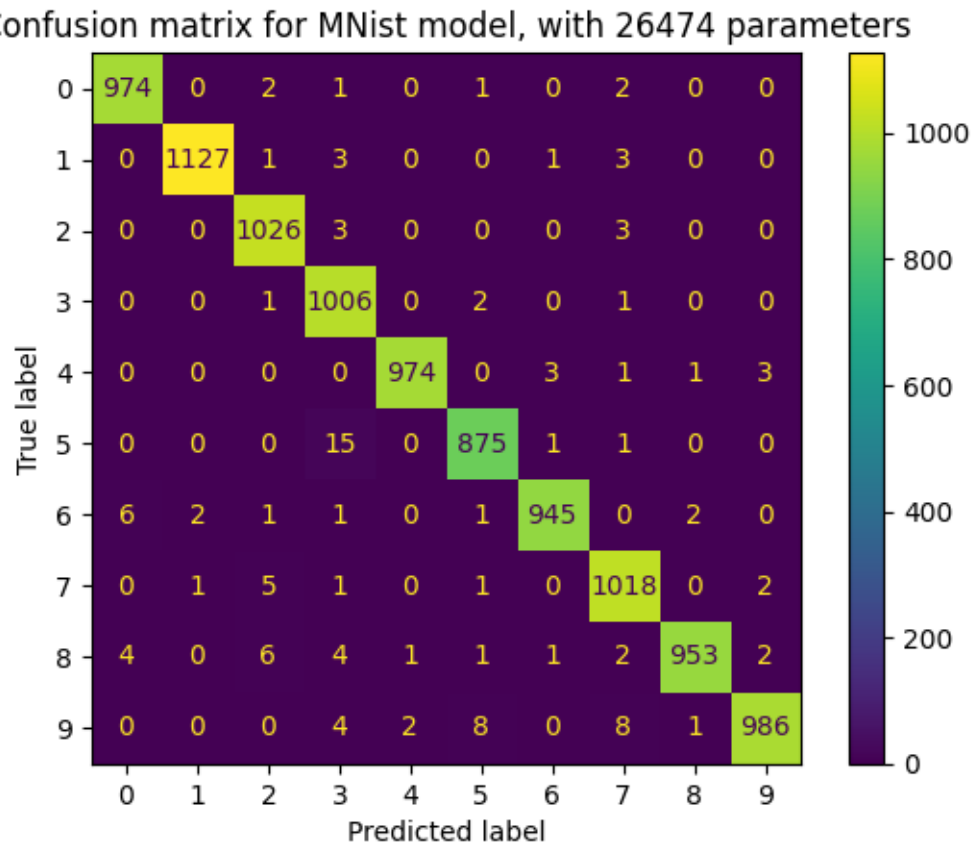
```
            progress = (idx / loader_size)
            print(f"{idx * batch_size} / {loader_size * batch_size} : Progress␣
↪= {progress:.2%}")

    if epoch%1 == 0:
        losses.append(epoch_loss.detach().cpu())
        print(f"Epoch {epoch}: Loss = {epoch_loss}")
```

```
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 1: Loss = 1742.9490966796875
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 2: Loss = 778.3883056640625
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
```

```
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 3: Loss = 590.4749755859375
```

[5]:
```python
model.eval()

losses = []
y_eval, y_preds = [], []


for x_batch, y_batch in test_loader:
    x_batch, y_batch = x_batch.to(device), y_batch.to(device)
    y_pred = model(x_batch)
    y_pred = y_pred.argmax(dim=1)

    y_eval += y_batch.detach().cpu().numpy().tolist()
    y_preds += y_pred.detach().cpu().numpy().tolist()


total_params = sum(p.numel() for p in model.parameters())
print(f"Number of parameters: {total_params}")

confusion_matrix = metrics.confusion_matrix(y_eval, y_preds)

cm_display = metrics.ConfusionMatrixDisplay(confusion_matrix =␣
 ↪confusion_matrix, display_labels = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9])

cm_display.plot()

plt.title(f"Confusion matrix for MNist model, with {total_params} parameters")
plt.show()

acc1 = accuracy_score(y_preds, y_eval)

f"{accuracy_score(y_preds, y_eval):.2%}"
```

```
Number of parameters: 26474
```



[5]: '98.84%'

[6]:
```
print("Model's state dict:")
for param_tensor in model.state_dict():
    print(param_tensor, "\t", model.state_dict()[param_tensor].size())

print("Optimizer's state dict:")
for var_name in optimizer.state_dict():
    print(var_name, "\t", optimizer.state_dict()[var_name])
```

```
Model's state dict:
feature_extractor.0.weight      torch.Size([10, 1, 5, 5])
feature_extractor.0.bias        torch.Size([10])
feature_extractor.3.weight      torch.Size([20, 10, 5, 5])
feature_extractor.3.bias        torch.Size([20])
classification_head.0.weight    torch.Size([64, 320])
classification_head.0.bias      torch.Size([64])
classification_head.2.weight    torch.Size([10, 64])
classification_head.2.bias      torch.Size([10])
Optimizer's state dict:
```

```
state    {0: {'step': tensor(45000.), 'exp_avg': tensor([[[[ 5.9395e-04,
-2.5405e-03, -2.5326e-03,  2.8868e-03, -3.6589e-03],
          [ 2.3277e-03,  8.8792e-05,  5.8034e-03,  7.7230e-03, -2.8851e-03],
          [-2.0003e-04, -2.8577e-03,  9.2847e-03,  6.5774e-03, -7.2076e-03],
          [-7.4372e-03, -8.0123e-03,  2.3022e-03, -1.3013e-03, -3.8307e-03],
          [-7.1725e-03, -6.9612e-03, -4.3974e-03, -9.3733e-04, -3.1843e-03]]],


        [[[ 6.0175e-03,  1.3476e-02,  2.5649e-02,  1.5866e-02,  7.6610e-03],
          [-5.7837e-03,  6.5175e-03,  1.0883e-02,  2.8940e-03, -4.8822e-03],
          [-5.7124e-03,  1.1340e-03,  2.8654e-03,  2.4404e-03, -1.0586e-02],
          [-2.3117e-03, -7.5987e-03, -1.8277e-03, -9.1777e-03, -1.2611e-02],
          [ 9.2007e-04, -1.6096e-03, -1.6028e-03, -1.3477e-02, -1.0514e-02]]],


        [[[ 1.8275e-02,  5.5715e-03, -8.7258e-03, -1.0734e-02, -7.5948e-03],
          [ 1.3527e-02,  6.4665e-03, -7.8348e-03, -9.0626e-03,  5.9020e-04],
          [ 1.0772e-02,  5.4534e-03, -3.5474e-03,  3.5611e-03,  6.5766e-03],
          [ 4.8645e-03,  1.1767e-03,  3.0604e-03, -3.3649e-04,  7.2366e-03],
          [-2.5089e-03, -3.1497e-03, -3.5327e-03,  2.3505e-03,  8.7156e-03]]],


        [[[ 3.0521e-03, -6.0719e-04,  1.8250e-04,  4.1379e-03,  4.3279e-03],
          [ 2.5124e-03,  2.6795e-03,  4.7256e-05, -3.6890e-03, -6.5033e-03],
          [-1.3997e-03,  5.0055e-03, -7.9583e-04,  2.7281e-03, -4.6484e-03],
          [-1.0678e-03,  4.0158e-03,  5.2227e-03,  6.0156e-03, -4.5618e-04],
          [ 4.0437e-03,  6.0477e-03,  2.7417e-03, -5.5872e-03, -4.2512e-04]]],


        [[[ 5.0612e-03, -2.3468e-03, -7.7911e-03, -3.7735e-03,  7.2000e-03],
          [ 7.1942e-04, -8.9734e-03, -6.0676e-03,  6.3674e-03,  1.4278e-02],
          [-7.3794e-03, -1.5646e-02,  2.9098e-04,  1.3601e-02,  1.5581e-02],
          [-1.8338e-02, -9.4652e-03,  1.1094e-02,  1.4857e-02,  1.8511e-02],
          [-1.9209e-02,  2.6619e-03,  1.1950e-02,  1.6825e-02,  1.2233e-02]]],


        [[[-6.6162e-04, -8.4559e-04, -9.0842e-04, -3.2750e-03, -3.1962e-03],
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          [ 2.1244e-03, -1.5193e-04, -6.4552e-04,  3.4180e-03,  3.8922e-03],
          [ 2.4330e-05, -2.2963e-03, -8.9370e-04,  2.1281e-03,  1.7666e-03]]],


        [[[ 1.4513e-03,  9.7305e-03,  1.6806e-02,  7.1418e-03, -3.0536e-03],
          [-1.0747e-03,  1.0469e-02,  1.4940e-02,  3.9115e-04, -8.9077e-03],
          [-3.9308e-03,  1.3943e-03,  2.1413e-03, -4.8926e-03, -6.8188e-03],
          [ 6.5439e-04,  5.9002e-04, -1.0472e-02, -8.8506e-03,  3.2903e-03],
          [ 7.9233e-03,  2.8615e-03, -1.1279e-02, -4.3866e-03,  2.7185e-03]]],
```

```
        [[[ 6.0027e-04,  1.6049e-03,  7.4404e-03,  1.0460e-02,  1.6805e-02],
          [-3.2249e-03,  2.5889e-03,  7.3548e-03,  9.1547e-03,  7.0016e-03],
          [-6.8606e-03,  4.0367e-03,  1.4987e-02,  1.8249e-02,  1.2042e-02],
          [ 1.6011e-03,  1.1102e-02,  2.1541e-02,  2.3550e-02,  1.1897e-02],
          [-9.7489e-04,  5.6323e-03,  2.0639e-02,  1.9211e-02,  1.2908e-02]]],


        [[[-5.5874e-03, -3.5702e-03,  2.2915e-04,  6.4013e-03,  1.7711e-02],
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          [-1.2582e-02, -1.2000e-02,  5.2497e-03,  1.2442e-02,  1.0440e-02]]],


        [[[ 5.9185e-03,  4.6382e-03, -1.3333e-02, -1.9846e-02, -1.7183e-03],
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          [-4.5027e-03, -1.6634e-02, -1.6967e-02,  1.3806e-03,  1.8121e-02],
          [-8.1766e-03, -1.0396e-02, -3.7186e-03,  8.1669e-03,  2.0170e-02],
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          [0.0077, 0.0063, 0.0051, 0.0057, 0.0058]]],


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        [[[0.0064, 0.0051, 0.0050, 0.0049, 0.0053],
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          [0.0066, 0.0059, 0.0050, 0.0050, 0.0061]]],
```

```
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            [0.0107, 0.0098, 0.0107, 0.0099, 0.0087]]],


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          [[[0.0126, 0.0121, 0.0127, 0.0108, 0.0137],
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            [0.0095, 0.0177, 0.0102, 0.0110, 0.0228],
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            [0.0125, 0.0111, 0.0112, 0.0160, 0.0209]]]], device='cuda:0')}, 1:
{'step': tensor(45000.), 'exp_avg': tensor([ 0.0095, -0.0022, -0.0167, -0.0053,
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         0.0129, -0.0203], device='cuda:0'), 'exp_avg_sq': tensor([0.0086,
0.0137, 0.0213, 0.0085, 0.0089, 0.0030, 0.0126, 0.0142, 0.0123,
        0.0323], device='cuda:0')}, 2: {'step': tensor(45000.), 'exp_avg':
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```

```
  [-1.7967e-04, -1.5533e-04, -2.2462e-04,  3.4399e-03,  5.5605e-08],
  [ 5.8682e-04,  8.5214e-04, -1.5929e-04,  8.6588e-04, -4.8490e-06],
  [ 6.8016e-04,  2.9170e-03, -5.2024e-05,  1.4798e-03,  4.8249e-05],
  [-1.6248e-04,  1.7014e-03, -2.9512e-05,  2.4779e-03,  4.5150e-04]],

 [[-2.6649e-05,  5.9015e-05, -6.1717e-06,  8.9757e-04,  7.3170e-04],
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  [ 4.4401e-04, -1.8365e-05,  8.9194e-04,  5.0804e-06,  5.0506e-04],
  [ 1.0708e-03,  1.1225e-05,  7.4298e-05,  4.0634e-05,  1.5588e-03]],

 [[-5.5120e-04,  4.0957e-04,  3.0030e-04, -1.9605e-05,  4.8449e-06],
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  [ 3.5581e-03,  3.2589e-05, -2.1215e-04,  4.1003e-04,  2.7937e-03],
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      device='cuda:0'), 'exp_avg_sq': tensor([0.0003, 0.0003, 0.0005, 0.0004,
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```

[9]:
```
import os
os.makedirs("./ModelFiles", exist_ok=True)
torch.save(model, "./ModelFiles/MNISTmodel.pt")
```

[10]:
```
torch.save(model.state_dict(), './ModelFiles/MNISTmodel.pth')
```

[11]:
```
mnist_train = datasets.FashionMNIST(root='./data', train=True, download=True,␣
 ↪transform=transforms.ToTensor())
train_loader = DataLoader(mnist_train, batch_size=batch_size, shuffle=False)

mnist_test = datasets.FashionMNIST(root='./data', train=False, download=True,␣
 ↪transform=transforms.ToTensor())
test_loader = DataLoader(mnist_test, batch_size=batch_size, shuffle=False)
```

```
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-
images-idx3-ubyte.gz
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-
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100%|                    | 26.4M/26.4M [00:02<00:00, 9.50MB/s]

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

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100%|                     | 29.5k/29.5k [00:00<00:00, 156kB/s]

Extracting ./data/FashionMNIST/raw/train-labels-idx1-ubyte.gz to
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100%|                    | 4.42M/4.42M [00:01<00:00, 2.83MB/s]

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100%|                    | 5.15k/5.15k [00:00<00:00, 2.55MB/s]

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

[12]:
```
model = CNNNetwork()
model = torch.load('./ModelFiles/MNISTmodel.pt')
model.to(device)

optimizer = optim.Adam(model.parameters(), lr=1e-2)
```

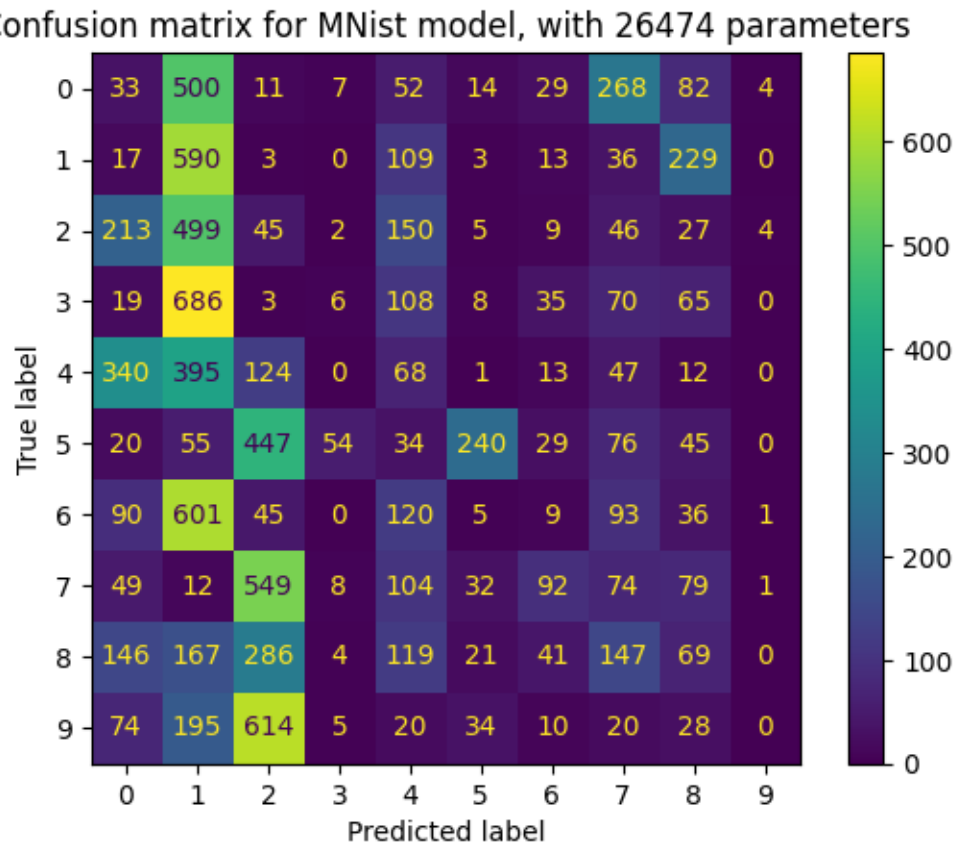
```
/tmp/ipykernel_40797/3878080169.py:2: FutureWarning: You are using `torch.load`
with `weights_only=False` (the current default value), which uses the default
pickle module implicitly. It is possible to construct malicious pickle data
which will execute arbitrary code during unpickling (See
https://github.com/pytorch/pytorch/blob/main/SECURITY.md#untrusted-models for
more details). In a future release, the default value for `weights_only` will be
flipped to `True`. This limits the functions that could be executed during
unpickling. Arbitrary objects will no longer be allowed to be loaded via this
mode unless they are explicitly allowlisted by the user via
`torch.serialization.add_safe_globals`. We recommend you start setting
`weights_only=True` for any use case where you don't have full control of the
loaded file. Please open an issue on GitHub for any issues related to this
experimental feature.
  model = torch.load('./ModelFiles/MNISTmodel.pt')
```

[13]:
```
print("Model's state dict:")
for param_tensor in model.state_dict():
    print(param_tensor, "\t", model.state_dict()[param_tensor].size())
```

```
Model's state dict:
```

```
feature_extractor.0.weight      torch.Size([10, 1, 5, 5])
feature_extractor.0.bias        torch.Size([10])
feature_extractor.3.weight      torch.Size([20, 10, 5, 5])
feature_extractor.3.bias        torch.Size([20])
classification_head.0.weight    torch.Size([64, 320])
classification_head.0.bias      torch.Size([64])
classification_head.2.weight    torch.Size([10, 64])
classification_head.2.bias      torch.Size([10])
```

[14]:
```python
model.eval()

losses = []
y_eval, y_preds = [], []


for x_batch, y_batch in test_loader:
    x_batch, y_batch = x_batch.to(device), y_batch.to(device)
    y_pred = model(x_batch)
    y_pred = y_pred.argmax(dim=1)

    y_eval += y_batch.detach().cpu().numpy().tolist()
    y_preds += y_pred.detach().cpu().numpy().tolist()


confusion_matrix = metrics.confusion_matrix(y_eval, y_preds)

cm_display = metrics.ConfusionMatrixDisplay(confusion_matrix =␣
 ↪confusion_matrix, display_labels = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9])

cm_display.plot()

plt.title(f"Confusion matrix for MNist model, with {total_params} parameters")
plt.show()

acc1 = accuracy_score(y_preds, y_eval)

f"{accuracy_score(y_preds, y_eval):.2%}"
```



[14]:
```
'11.34%'
```

[15]:
```
losses = []
num_epochs = 5
model.train()

for epoch in range(1, num_epochs+1):
    epoch_loss = 0
    for idx, (x_batch, y_batch) in enumerate(train_loader):
        batch_size = len(x_batch)
        loader_size = len(train_loader)

        x_batch, y_batch = x_batch.to(device), y_batch.to(device)
        y_pred = model(x_batch)
        y_pred = y_pred.reshape(batch_size,-1)

        loss = criterion(y_pred, y_batch)
        loss.backward()
        optimizer.step()
        optimizer.zero_grad()
```

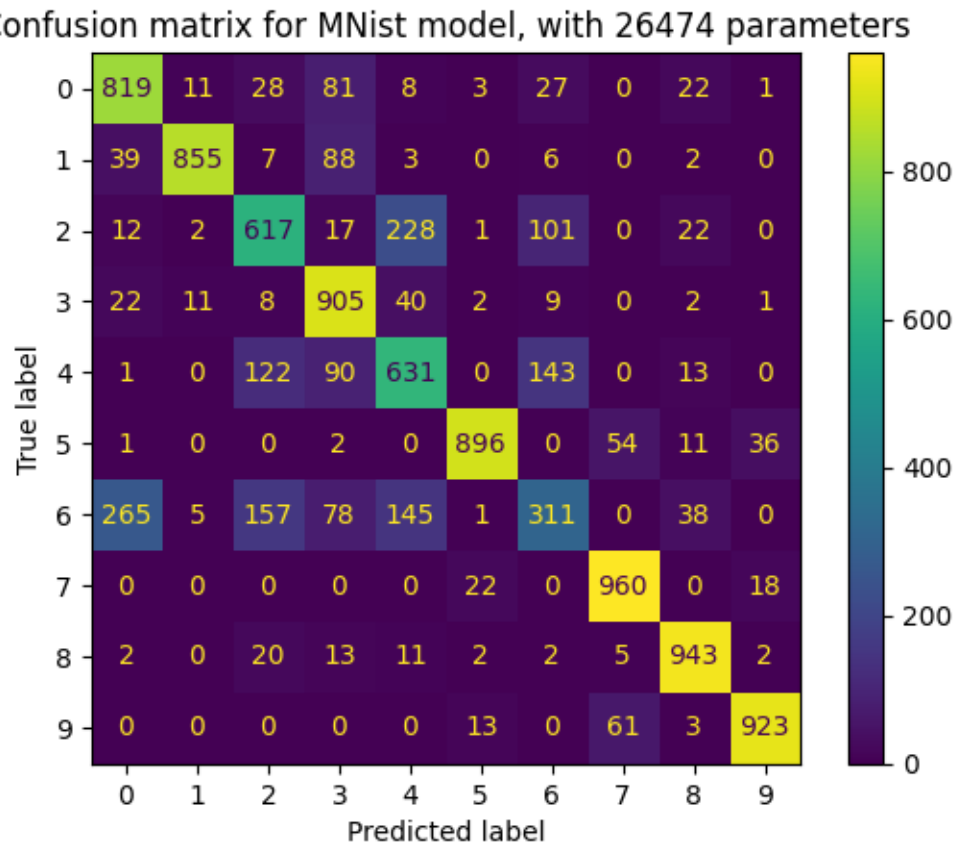
```
        epoch_loss += loss

        if (idx % 1000 == 0):
            progress = (idx / loader_size)
            print(f"{idx * batch_size} / {loader_size * batch_size} : Progress␣
↪= {progress:.2%}")

    if epoch%1 == 0:
        losses.append(epoch_loss.detach().cpu())
        print(f"Epoch {epoch}: Loss = {epoch_loss}")
```

```
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 1: Loss = 9315.986328125
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 2: Loss = 8791.5732421875
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
```

```
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 3: Loss = 8960.255859375
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 4: Loss = 9032.974609375
0 / 60000 : Progress = 0.00%
4000 / 60000 : Progress = 6.67%
8000 / 60000 : Progress = 13.33%
12000 / 60000 : Progress = 20.00%
16000 / 60000 : Progress = 26.67%
20000 / 60000 : Progress = 33.33%
24000 / 60000 : Progress = 40.00%
28000 / 60000 : Progress = 46.67%
32000 / 60000 : Progress = 53.33%
36000 / 60000 : Progress = 60.00%
40000 / 60000 : Progress = 66.67%
44000 / 60000 : Progress = 73.33%
48000 / 60000 : Progress = 80.00%
52000 / 60000 : Progress = 86.67%
56000 / 60000 : Progress = 93.33%
Epoch 5: Loss = 9067.96484375
```

[16]:
```
model.eval()
```

```
losses = []
y_eval, y_preds = [], []


for x_batch, y_batch in test_loader:
    x_batch, y_batch = x_batch.to(device), y_batch.to(device)
    y_pred = model(x_batch)
    y_pred = y_pred.argmax(dim=1)

    y_eval += y_batch.detach().cpu().numpy().tolist()
    y_preds += y_pred.detach().cpu().numpy().tolist()


confusion_matrix = metrics.confusion_matrix(y_eval, y_preds)

cm_display = metrics.ConfusionMatrixDisplay(confusion_matrix =␣
 ↪confusion_matrix, display_labels = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9])

cm_display.plot()

plt.title(f"Confusion matrix for MNist model, with {total_params} parameters")
plt.show()

acc1 = accuracy_score(y_preds, y_eval)

f"{accuracy_score(y_preds, y_eval):.2%}"
```



[16]:
```
'78.60%'
```

[17]:
```
torch.save(model.state_dict(), './ModelFiles/MNISTFashionModel.pth')
```

[18]:
```
import os
from PIL import Image
```

[21]:
```
class imgDataset(Dataset):
    def __init__(self, dir="/home/student/Desktop/220962049_aiml/
 ↪cats_and_dogs_filtered/train/"):
        cats_dir = os.path.join(dir, "cats/")
        dogs_dir = os.path.join(dir, "dogs/")
        self.x = [os.path.join(cats_dir, f) for f in os.listdir(cats_dir) if f.
 ↪endswith(".jpg")] + [os.path.join(dogs_dir, f) for f in os.listdir(dogs_dir)␣
 ↪if f.endswith(".jpg")]
        self.y = [0 for f in os.listdir(cats_dir) if f.endswith(".jpg")] + [1␣
 ↪for f in os.listdir(dogs_dir) if f.endswith(".jpg")]
        self.y = torch.tensor(self.y)
        self.transform = transforms.Compose([transforms.Resize(256),
```

```
                                                transforms.CenterCrop(224),
                                                transforms.ToTensor(),
                                                transforms.Normalize(mean=[0.485,␣
 ↪0.456, 0.406], std=[0.229, 0.224, 0.225]),])

    def __len__(self):
        return len(self.x)

    def __getitem__(self, idx):
        img = Image.open(self.x[idx]).convert('RGB')
        tensor = self.transform(img)
        return tensor.to(device), self.y[idx].to(device)
```

[23]:
```
batch_size = 4
train_set = imgDataset()
val_set = imgDataset(dir="/home/student/Desktop/220962049_aiml/
 ↪cats_and_dogs_filtered/validation/")

train_loader = DataLoader(train_set, batch_size=batch_size, shuffle=True)
val_loader = DataLoader(val_set, batch_size=batch_size, shuffle=False)
```

[26]:
```
len([f for f in os.listdir("/home/student/Desktop/220962049_aiml/
 ↪cats_and_dogs_filtered/train/cats") if f.endswith(".jpg")] + [f for f in os.
 ↪listdir("/home/student/Desktop/220962049_aiml/cats_and_dogs_filtered/train/
 ↪dogs") if f.endswith(".jpg")])
```

[26]:
```
2000
```

[28]:
```
from torchvision.models import AlexNet_Weights

#model = torch.hub.load('pytorch/vision:v0.10.0', model='alexnet',␣
 ↪weights=AlexNet_Weights.DEFAULT)
model = torch.hub.load('pytorch/vision:v0.10.0', 'alexnet', pretrained=True)

model.classifier[6] = torch.nn.Linear(in_features=4096, out_features=2)
model = model.to(device)

loss_fn = torch.nn.CrossEntropyLoss()

optimizer = torch.optim.SGD(model.parameters(), lr=1e-3)
```

```
Downloading: "https://github.com/pytorch/vision/zipball/v0.10.0" to
/home/student/.cache/torch/hub/v0.10.0.zip
/home/student/Desktop/220962049_aiml/.venv/lib/python3.12/site-
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(
```

```
/home/student/Desktop/220962049_aiml/.venv/lib/python3.12/site-
packages/torchvision/models/_utils.py:223: 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=AlexNet_Weights.IMAGENET1K_V1`. You can also use
`weights=AlexNet_Weights.DEFAULT` to get the most up-to-date weights.
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/alexnet-owt-7be5be79.pth" to
/home/student/.cache/torch/hub/checkpoints/alexnet-owt-7be5be79.pth
100%|                      | 233M/233M [02:46<00:00, 1.47MB/s]
```

[29]:
```
for idx, (x_batch, y_batch) in enumerate(train_loader):
    with torch.no_grad():
        output = model(x_batch)
    # Tensor of shape 1000, with confidence scores over ImageNet's 1000 classes
    print(output[0])
    # The output has unnormalized scores. To get probabilities, you can run a␣
 ↪softmax on it.
    probabilities = torch.nn.functional.softmax(output[0], dim=0)
    print(probabilities)
    break
```

```
tensor([0.0444, 0.2377], device='cuda:0')
tensor([0.4518, 0.5482], device='cuda:0')
```

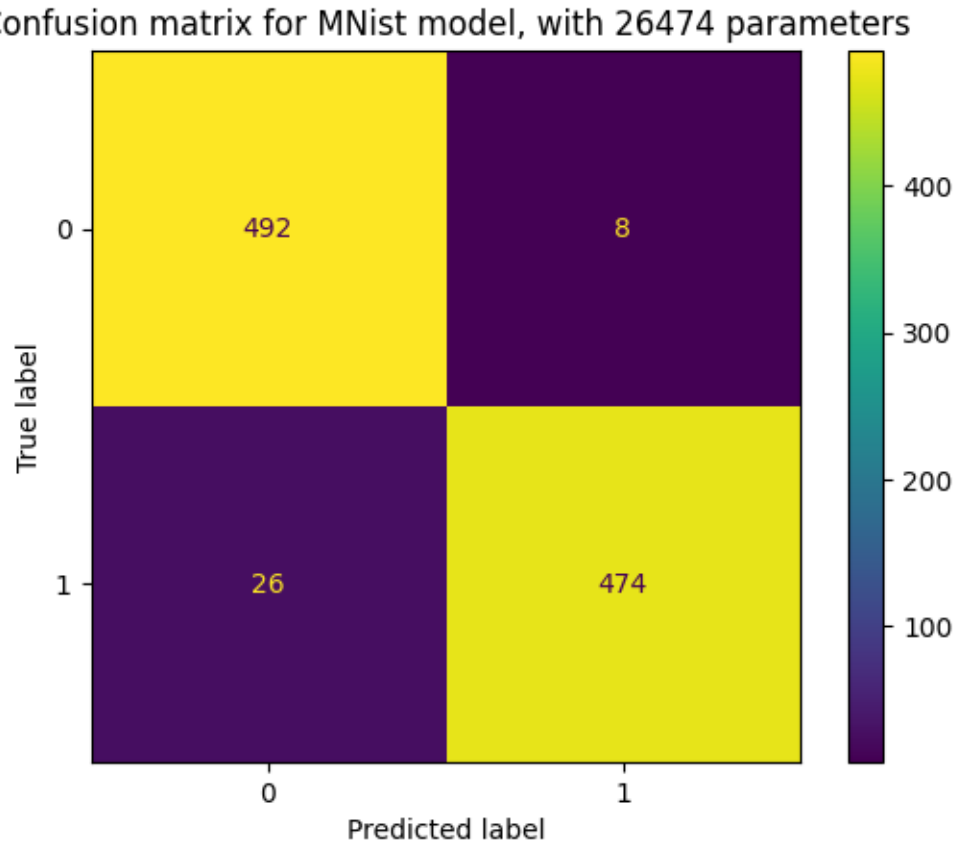
[30]:
```
NUM_EPOCHS = 5
losses = []
model.train()

for epoch in range(1, NUM_EPOCHS+1):
    epoch_loss = 0
    for idx, (x_batch, y_batch) in enumerate(train_loader):
        batch_size = y_batch.shape[0]
        loader_size = len(train_loader)
        output = model(x_batch)
        y_pred = torch.nn.functional.softmax(output, dim=1)

        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()
        optimizer.zero_grad()

        epoch_loss += loss

        if (idx % 200 == 0):
            progress = (idx / loader_size)
            print(f"{idx * batch_size} / {loader_size * batch_size} : Progress␣
 ↪= {progress:.2%}")
```

```
    if epoch%1 == 0:
        losses.append(epoch_loss.detach().cpu())
        print(f"Epoch {epoch}: Loss = {epoch_loss}")
```

```
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 1: Loss = 194.6973876953125
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 2: Loss = 176.95059204101562
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 3: Loss = 171.05784606933594
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 4: Loss = 169.0035400390625
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 5: Loss = 167.19216918945312
```

[31]:
```
model.eval()

losses = []
y_eval, y_preds = [], []


for x_batch, y_batch in val_loader:
    x_batch, y_batch = x_batch.to(device), y_batch.to(device)
    output = model(x_batch)
    y_pred = F.softmax(output, dim=1)
    y_pred = y_pred.argmax(dim=1)

    y_eval += y_batch.detach().cpu().numpy().tolist()
    y_preds += y_pred.detach().cpu().numpy().tolist()


confusion_matrix = metrics.confusion_matrix(y_eval, y_preds)

cm_display = metrics.ConfusionMatrixDisplay(confusion_matrix =␣
 ↪confusion_matrix, display_labels = [0, 1])
```

```
cm_display.plot()

plt.title(f"Confusion matrix for MNist model, with {total_params} parameters")
plt.show()

acc1 = accuracy_score(y_preds, y_eval)

f"{accuracy_score(y_preds, y_eval):.2%}"
```



[31]: '96.60%'

[32]:
```
torch.save({'epoch': NUM_EPOCHS,
            'model_state_dict': model.state_dict(),
            'optimizer_state_dict': optimizer.state_dict(),
            'loss': epoch_loss},
           './ModelFiles/CustomAlex_1.pth')
```

[33]:
```
CHECKPOINT_PATH = './ModelFiles/CustomAlex_1.pth'

model = torch.hub.load('pytorch/vision:v0.10.0', 'alexnet', pretrained=False)
```

```
model.classifier[6] = torch.nn.Linear(in_features=4096, out_features=2)

optimizer = optim.SGD(model.parameters(), lr=1e-3)


checkpoint = torch.load(CHECKPOINT_PATH)
model.load_state_dict(checkpoint['model_state_dict'])
optimizer.load_state_dict(checkpoint['optimizer_state_dict'])
epoch = checkpoint['epoch']
loss = checkpoint['loss']

model.to(device)
```

```
Using cache found in /home/student/.cache/torch/hub/pytorch_vision_v0.10.0
/home/student/Desktop/220962049_aiml/.venv/lib/python3.12/site-
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(
/home/student/Desktop/220962049_aiml/.venv/lib/python3.12/site-
packages/torchvision/models/_utils.py:223: 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=None`.
  warnings.warn(msg)
/tmp/ipykernel_40797/3809406884.py:9: FutureWarning: You are using `torch.load`
with `weights_only=False` (the current default value), which uses the default
pickle module implicitly. It is possible to construct malicious pickle data
which will execute arbitrary code during unpickling (See
https://github.com/pytorch/pytorch/blob/main/SECURITY.md#untrusted-models for
more details). In a future release, the default value for `weights_only` will be
flipped to `True`. This limits the functions that could be executed during
unpickling. Arbitrary objects will no longer be allowed to be loaded via this
mode unless they are explicitly allowlisted by the user via
`torch.serialization.add_safe_globals`. We recommend you start setting
`weights_only=True` for any use case where you don't have full control of the
loaded file. Please open an issue on GitHub for any issues related to this
experimental feature.
  checkpoint = torch.load(CHECKPOINT_PATH)
```

[33]:
```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(2, 2))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (4): ReLU(inplace=True)
```

```
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (9): ReLU(inplace=True)
    (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1,
ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(6, 6))
  (classifier): Sequential(
    (0): Dropout(p=0.5, inplace=False)
    (1): Linear(in_features=9216, out_features=4096, bias=True)
    (2): ReLU(inplace=True)
    (3): Dropout(p=0.5, inplace=False)
    (4): Linear(in_features=4096, out_features=4096, bias=True)
    (5): ReLU(inplace=True)
    (6): Linear(in_features=4096, out_features=2, bias=True)
  )
)
```

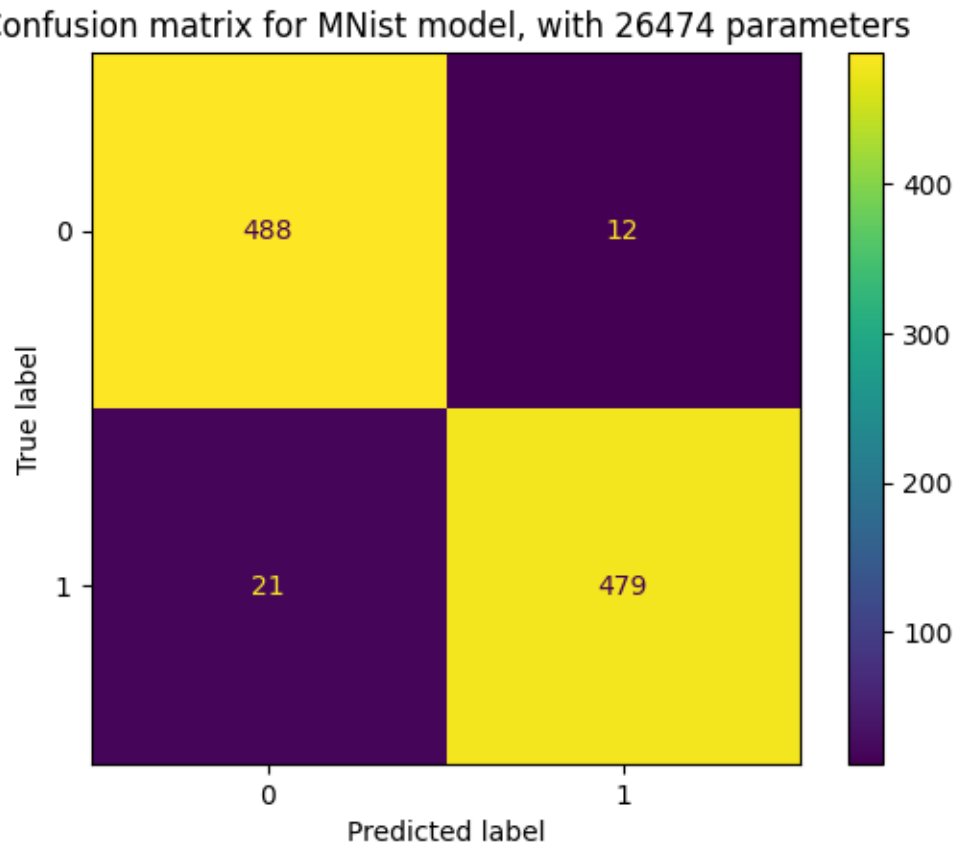
[34]:
```
NUM_EPOCHS = 15
losses = []
model.train()

for epoch in range(epoch+1, epoch+NUM_EPOCHS+1):
    epoch_loss = 0
    for idx, (x_batch, y_batch) in enumerate(train_loader):
        batch_size = y_batch.shape[0]
        loader_size = len(train_loader)
        output = model(x_batch)
        y_pred = torch.nn.functional.softmax(output, dim=1)

        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()
        optimizer.zero_grad()

        epoch_loss += loss

        if (idx % 200 == 0):
            progress = (idx / loader_size)
            print(f"{idx * batch_size} / {loader_size * batch_size} : Progress␣
 ↪= {progress:.2%}")
```

```
    if epoch%1 == 0:
        losses.append(epoch_loss.detach().cpu())
        print(f"Epoch {epoch}: Loss = {epoch_loss}")
```

```
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 6: Loss = 164.65228271484375
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 7: Loss = 164.41830444335938
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 8: Loss = 161.91432189941406
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 9: Loss = 161.81333923339844
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 10: Loss = 161.7922821044922
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 11: Loss = 160.76625061035156
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 12: Loss = 160.68064880371094
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 13: Loss = 159.85540771484375
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 14: Loss = 159.89569091796875
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 15: Loss = 159.346435546875
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 16: Loss = 159.41331481933594
```

```
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 17: Loss = 159.31260681152344
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 18: Loss = 158.78424072265625
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 19: Loss = 158.9048614501953
0 / 2000 : Progress = 0.00%
800 / 2000 : Progress = 40.00%
1600 / 2000 : Progress = 80.00%
Epoch 20: Loss = 158.00303649902344
```

[35]:
```python
model.eval()

losses = []
y_eval, y_preds = [], []


for x_batch, y_batch in val_loader:
    x_batch, y_batch = x_batch.to(device), y_batch.to(device)
    output = model(x_batch)
    y_pred = F.softmax(output, dim=1)
    y_pred = y_pred.argmax(dim=1)

    y_eval += y_batch.detach().cpu().numpy().tolist()
    y_preds += y_pred.detach().cpu().numpy().tolist()


confusion_matrix = metrics.confusion_matrix(y_eval, y_preds)

cm_display = metrics.ConfusionMatrixDisplay(confusion_matrix =␣
 ↪confusion_matrix, display_labels = [0, 1])

cm_display.plot()

plt.title(f"Confusion matrix for MNist model, with {total_params} parameters")
plt.show()

acc1 = accuracy_score(y_preds, y_eval)

f"{accuracy_score(y_preds, y_eval):.2%}"
```



[35]:
```
'96.70%'
```

[36]:
```
torch.save({'epoch': NUM_EPOCHS,
            'model_state_dict': model.state_dict(),
            'optimizer_state_dict': optimizer.state_dict(),
            'loss': epoch_loss},
           './ModelFiles/CustomAlex_2.pth')
```

[ ]:
```

```