Homework 2

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Problem 1

Part 1

In [1]:
```
# Required imports
import torch
from PIL import Image
from torchvision import transforms
from torchvision import datasets
%matplotlib inline
from matplotlib import pyplot as plt
import torch.optim as optim
import pandas as pd
import numpy as np
import torch.nn as nn
import time
from sklearn.metrics import ConfusionMatrixDisplay, confusion_matrix
```

In [2]:
```
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
print("Using device: ", device)
print()
if device.type == 'cuda':
    print(torch.cuda.get_device_name())
    print("Memory Usage:")
    print("\tAllocated:", round(torch.cuda.memory_allocated()/1024**3,1), "GB")
    print("\tCached:", round(torch.cuda.memory_reserved()/1024**3,1), "GB")
#device = torch.device('cpu')
```

```
Using device:  cuda

NVIDIA GeForce GTX 1070
Memory Usage:
        Allocated: 0.0 GB
        Cached: 0.0 GB
```

In [3]:
```
housing = pd.DataFrame(pd.read_csv("../Data/Homework2/Housing.csv"))
housing.head()
```

Out[3]:

	price	area	bedrooms	bathrooms	stories	mainroad	guestroom	basement	hotwaterheati
0	13300000	7420	4	2	3	yes	no	no	
1	12250000	8960	4	4	4	yes	no	no	
2	12250000	9960	3	2	2	yes	no	yes	
3	12215000	7500	4	2	2	yes	no	yes	
4	11410000	7420	4	1	2	yes	yes	yes	

In [4]:
```
# Get the area, bedrooms, bathrooms, stories, parking, and price
num_vars = ['area', 'bedrooms', 'bathrooms', 'stories', 'parking','price']
housing = housing[num_vars]
housing.head()
```

Out[4]:

	area	bedrooms	bathrooms	stories	parking	price
0	7420	4	2	3	2	13300000
1	8960	4	4	4	3	12250000
2	9960	3	2	2	2	12250000
3	7500	4	2	2	3	12215000
4	7420	4	1	2	2	11410000

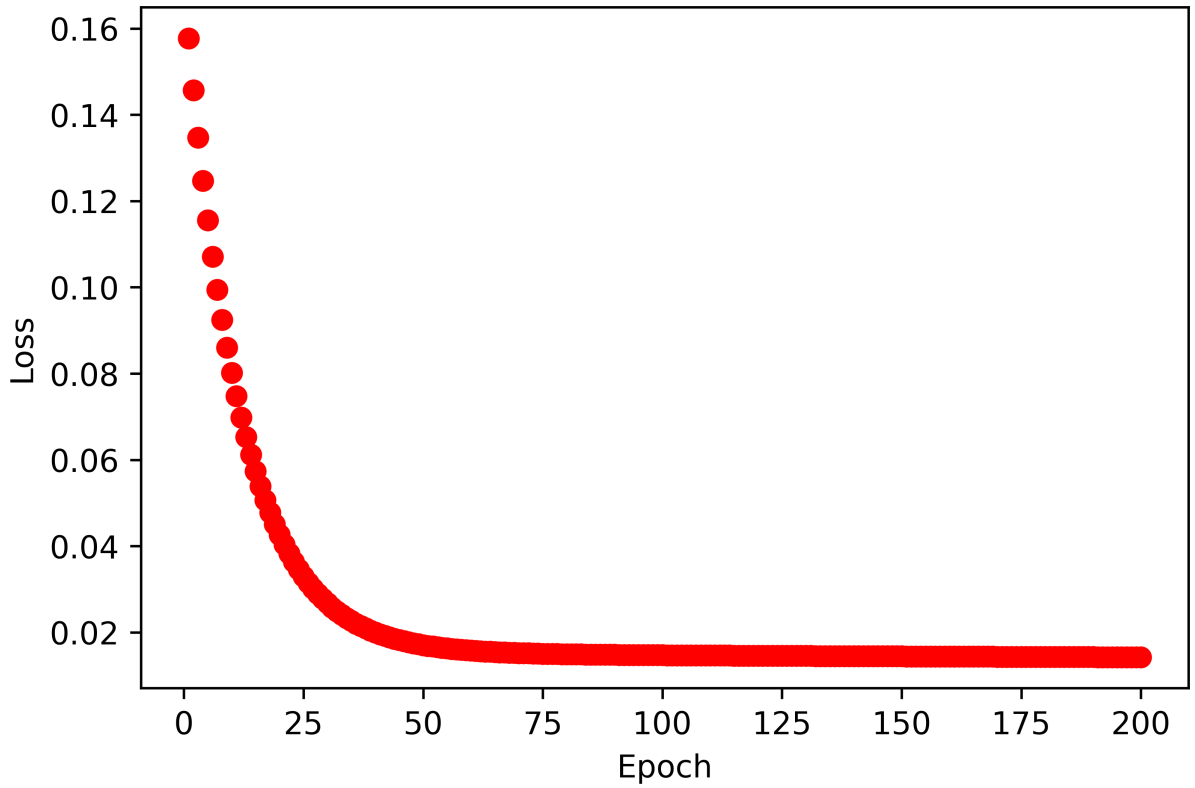
In [5]:
```
split = int(len(housing)*0.8)
# Convert Panda to tensor
ht_t = housing.iloc[:split,:5]
hp_t = housing.iloc[:split,5]
ht_t = torch.from_numpy(ht_t.to_numpy())
hp_t = torch.from_numpy(hp_t.to_numpy())
ht_t = ht_t.float()
hp_t = hp_t.float()

ht_v = housing.iloc[split:,:5]
hp_v = housing.iloc[split:,5]
ht_v = torch.from_numpy(ht_v.to_numpy())
hp_v = torch.from_numpy(hp_v.to_numpy())
ht_v = ht_v.float()
hp_v = hp_v.float()
```

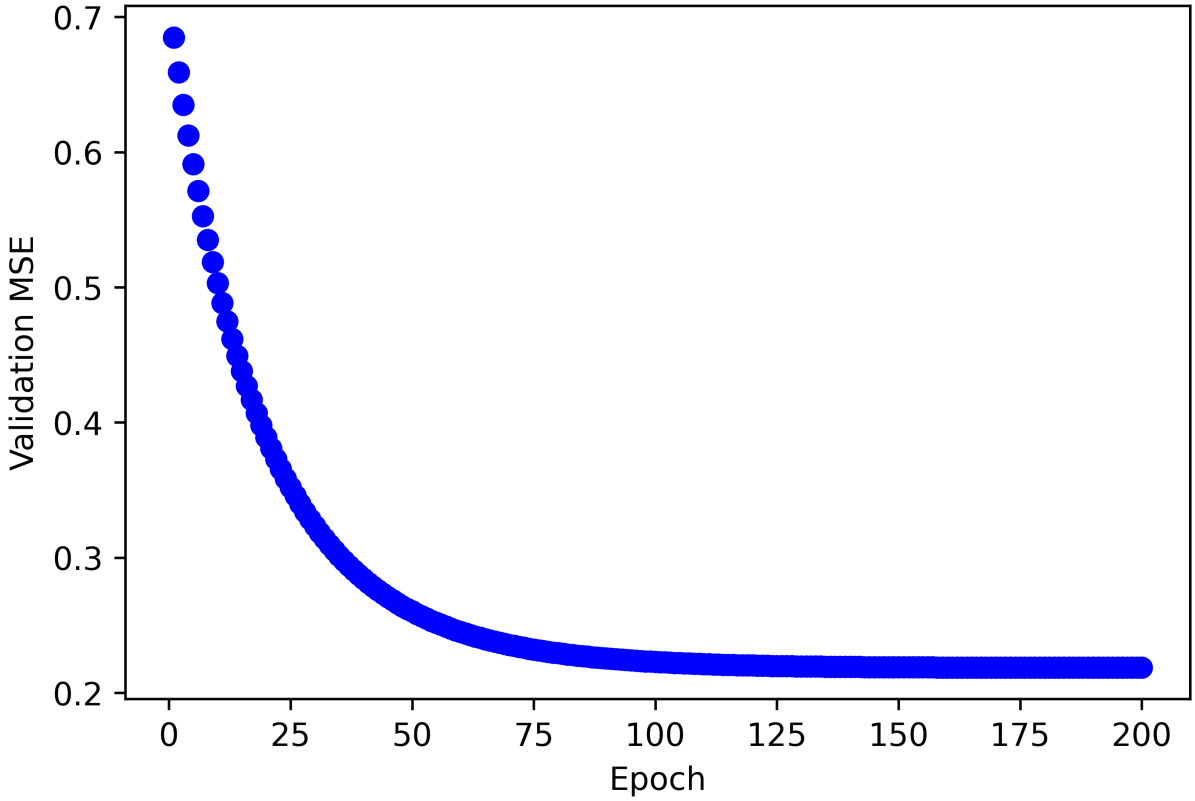
In [6]:
```
# Normalize input and output
ht_tn = ht_t
for idx in range(5):
    ht_tn[:,idx] = ht_t[:,idx]/ht_t[:,idx].max()
    #ht_tn[:,idx] = (ht_t[:,idx] - ht_t.mean())/ht_t.std()
hp_tn = hp_t/hp_t.max()
#hp_tn = (hp_t-hp_t.mean())/hp_t.std()

ht_vn = ht_v
for idx in range(5):
    ht_vn[:,idx] = ht_v[:,idx]/ht_v[:,idx].max()
    #ht_vn[:,idx] = (ht_v[:,idx] - ht_v.mean())/ht_v.std()
hp_vn = hp_v/hp_v.max()
#hp_vn = (hp_v-hp_v.mean())/hp_v.std()
```

In [7]:
```
def training_loopH(n_epochs, optimizer, model, loss_fn, ht, htp, hv, hvp):
    temp_t = []
    temp_v = []
    tic = time.time()
    for epoch in range(1, n_epochs + 1):
        cost_p = model(ht)
        loss_t = loss_fn(cost_p, htp)

        with torch.no_grad():
            cost_v = model(hv)
            loss_v = loss_fn(cost_v, hvp)
            #loss_v = 1-(torch.abs(hvp-cost_v).mean()/hvp.mean())

        optimizer.zero_grad()
        loss_t.backward()
        optimizer.step()

        #print("Epoch %d, Train Loss %f, Val Loss %f" % (epoch, float(loss_t), fl
        temp_t.append(float(loss_t))
        temp_v.append(float(loss_v))
    print("Time to complete training: %f" % float(time.time()-tic))
    fig = plt.figure(dpi=600)
    plt.xlabel("Epoch")
    plt.ylabel("Loss")
    plt.plot(range(1,n_epochs+1), temp_t, 'ro')
    fig2 = plt.figure(dpi=600)
    plt.xlabel("Epoch")
    plt.ylabel("Validation MSE")
    plt.plot(range(1,n_epochs+1), temp_v,'bo')
```

In [8]:
```
modelH = nn.Sequential(
    nn.Linear(5,8),
    nn.Tanh(),
    nn.Linear(8,1)
)

optimizerH = optim.SGD(
    modelH.parameters(),
    lr=1e-2
)

training_loopH(
    n_epochs=200,
    optimizer=optimizerH,
    model=modelH,
    loss_fn = nn.MSELoss(),
    ht=ht_tn,
    htp=hp_tn.unsqueeze(1),
    hv=ht_vn,
    hvp=hp_vn.unsqueeze(1)
)
```

```
Time to complete training: 0.078974
```

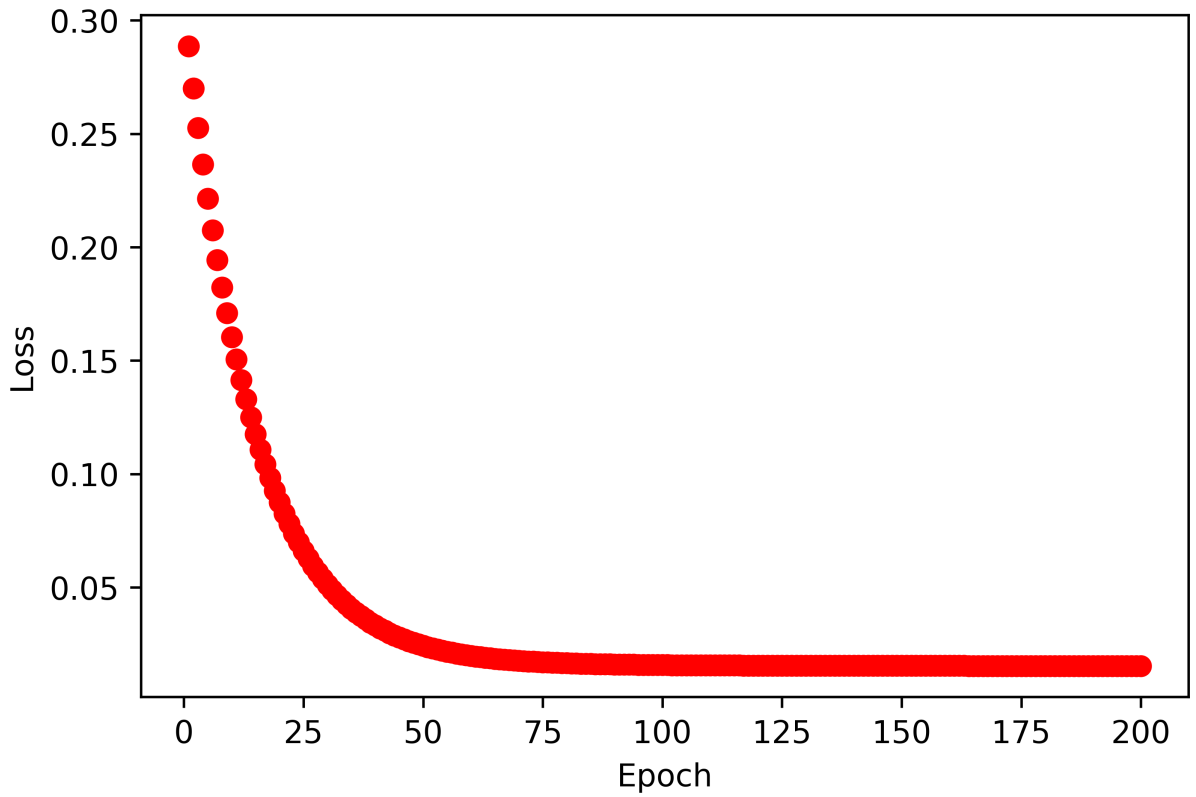


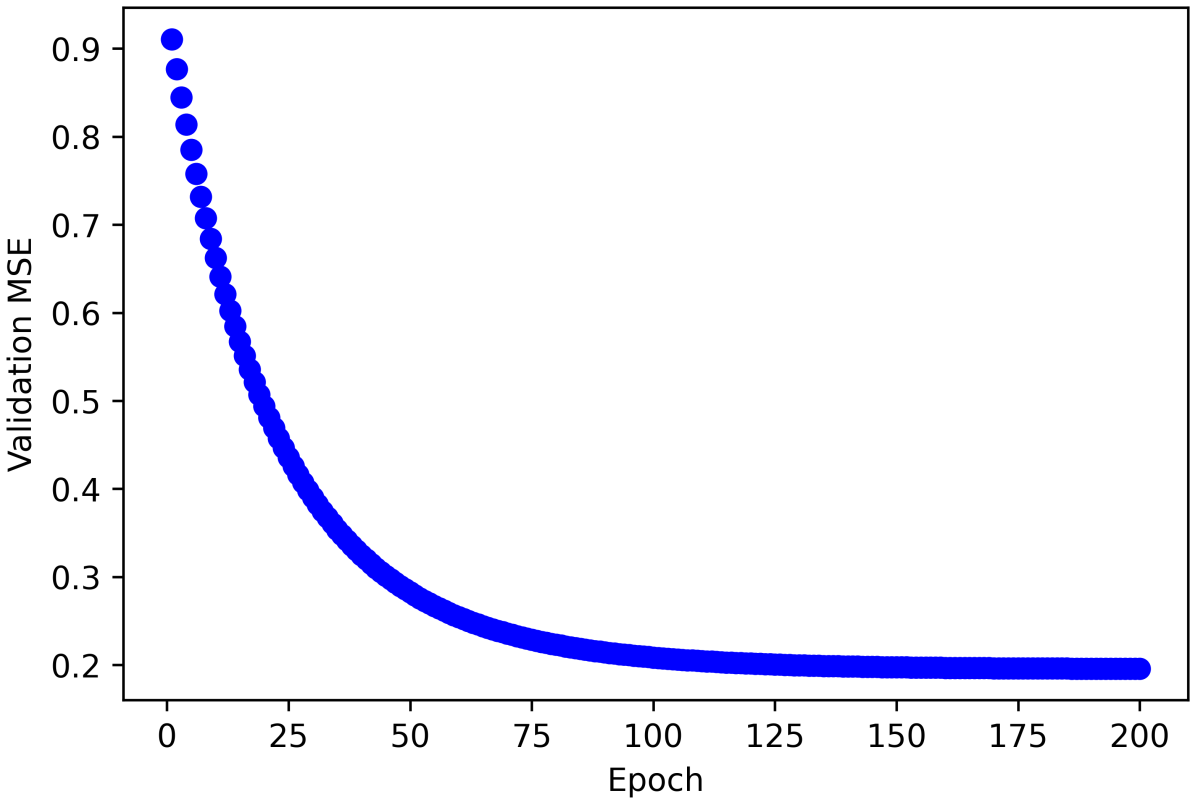

0.7
0.6
0.5
0.4
0.3
0.2
Validation MSE
0
25
50
75
100
125
150
175
200
Epoch

Part 2

In [9]:
```
modelH2 = nn.Sequential(
    nn.Linear(5,8),
    nn.Tanh(),
    nn.Linear(8,4),
    nn.Tanh(),
    nn.Linear(4,2),
    nn.Tanh(),
    nn.Linear(2,1)
)

optimizerH2 = optim.SGD(
    modelH2.parameters(),
    lr=1e-2
)

training_loopH(
    n_epochs=200,
    optimizer=optimizerH2,
    model=modelH2,
    loss_fn = nn.MSELoss(),
    ht=ht_tn,
    htp=hp_tn.unsqueeze(1),
    hv=ht_vn,
    hvp=hp_vn.unsqueeze(1)
)
```

```
Time to complete training: 0.123006
```





Problem 2

Part 1

In [10]:
```
import ssl
ssl._create_default_https_context = ssl._create_unverified_context
data_path = '../Data/Homework2/'
cifar10 = datasets.CIFAR10(data_path, train=True, download=True,transform=transfo
cifar10_val = datasets.CIFAR10(data_path, train=False, download=True,transform=tr
```

```
Files already downloaded and verified
Files already downloaded and verified
```

In [11]:
```
imgs = torch.stack([img_t for img_t, _ in cifar10], dim=3)
imgs_val = torch.stack([img_t for img_t,_ in cifar10_val], dim=3)
train_mean = imgs.view(3,-1).mean(dim=1)
train_std = imgs.view(3,-1).std(dim=1)
val_mean = imgs_val.view(3,-1).mean(dim=1)
val_std = imgs_val.view(3,-1).std(dim=1)
```

In [12]:
```
norm_cifar10 = datasets.CIFAR10(data_path, train=True, download=False, transform=
    transforms.ToTensor(),
    transforms.Normalize(train_mean,train_std)
]))
norm_cifar10_val = datasets.CIFAR10(data_path, train=False, download=False, trans
    transforms.ToTensor(),
    transforms.Normalize(val_mean,val_std)
]))
```

In [13]:
```
train_loader = torch.utils.data.DataLoader(norm_cifar10, batch_size=1000, shuffle
val_loader = torch.utils.data.DataLoader(norm_cifar10_val, batch_size=1000, shuff
```

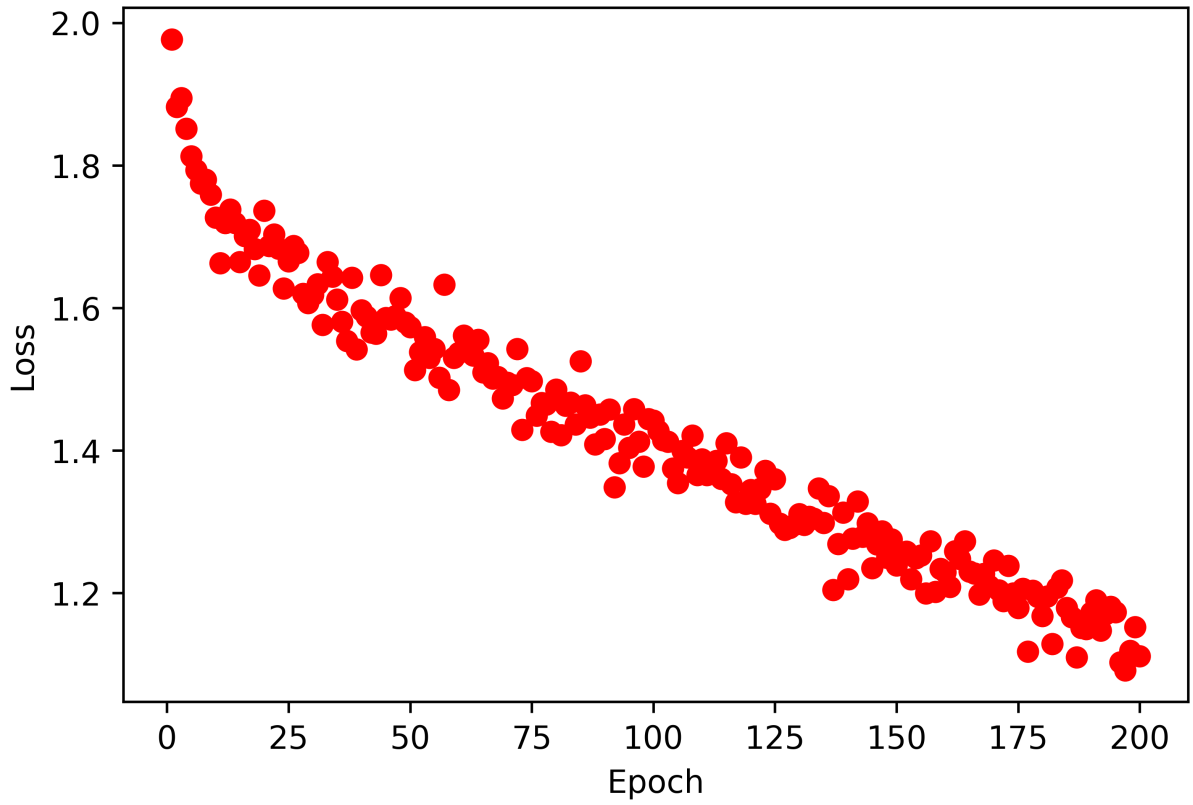
In [14]:
```
def training_loop(n_epochs, optimizer, model, loss_fn, train_load, val_load):
    temp_t = []
    temp_v = []
    tic = time.time()
    for epoch in range(1, n_epochs + 1):
        total = 0
        correct = 0
        for imgs, labels in train_loader:
            imgs, labels = imgs.to(device), labels.to(device)

            batch_size = imgs.shape[0]
            outputs = model(imgs.view(batch_size,-1))
            loss = loss_fn(outputs, labels)
            optimizer.zero_grad()
            loss.backward()
            optimizer.step()
        with torch.no_grad():
            for imgs, labels in val_loader:
                imgs, labels = imgs.to(device), labels.to(device)

                batch_size = imgs.shape[0]
                outputs = model(imgs.view(batch_size,-1))
                _, predicted = torch.max(outputs,dim=1)
                total += labels.shape[0]
                correct += int((predicted==labels).sum())

        if epoch % 10 == 0:
            print("Epoch %d, Train Loss: %f, Val Accuracy: %f" % (epoch, float(lo
        temp_t.append(float(loss))
        temp_v.append(float(correct/total))
    print("Time to complete training: %f" % float(time.time()-tic))
    fig = plt.figure(dpi=600)
    plt.xlabel("Epoch")
    plt.ylabel("Loss")
    plt.plot(range(1,n_epochs+1), temp_t, 'ro')
    fig2 = plt.figure(dpi=600)
    plt.xlabel("Epoch")
    plt.ylabel("Accuracy")
    plt.plot(range(1,n_epochs+1), temp_v,'bo')
```

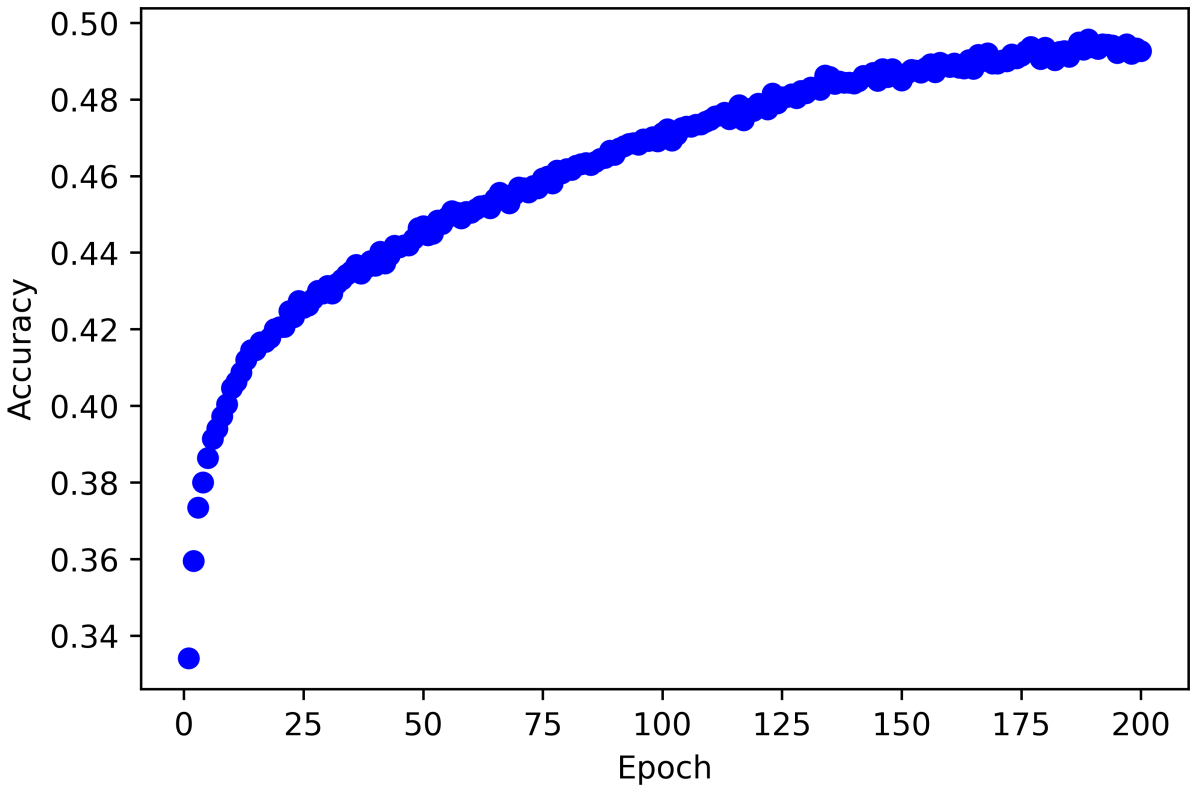
In [15]:
```
modelC = nn.Sequential(
    nn.Linear(3072,512),
    nn.Tanh(),
    nn.Linear(512,10),
    nn.LogSoftmax(dim=1)
).to(device)

learning_rate = 1e-2

optimizer = optim.SGD(modelC.parameters(),lr=learning_rate)

loss_fn = nn.NLLLoss().to(device)

n_epochs = 200

training_loop(
    n_epochs=n_epochs,
    optimizer=optimizer,
    model=modelC,
    loss_fn=loss_fn,
    train_load=train_loader,
    val_load=val_loader
)

gt_array = []
pred_array = []
with torch.no_grad():
    for imgs, labels in val_loader:
        imgs, labels = imgs.to(device), labels.to(device)

        batch_size = imgs.shape[0]
        outputs = modelC(imgs.view(batch_size,-1))
        _, predicted = torch.max(outputs,dim=1)
        gt_array.append(labels)
        pred_array.append(predicted)

gt_array = torch.concat(gt_array)
pred_array = torch.concat(pred_array)
ConfusionMatrixDisplay(confusion_matrix(gt_array.to('cpu'),pred_array.to('cpu')))
```

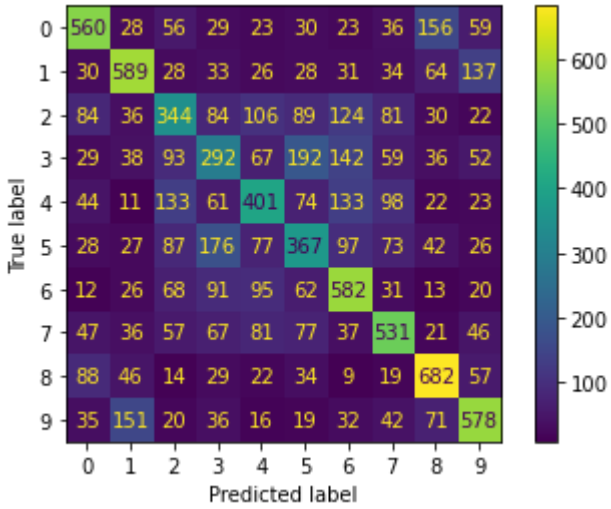
```
Epoch 10, Train Loss: 1.726674, Val Accuracy: 0.404600
Epoch 20, Train Loss: 1.736355, Val Accuracy: 0.420500
Epoch 30, Train Loss: 1.618338, Val Accuracy: 0.431300
Epoch 40, Train Loss: 1.597028, Val Accuracy: 0.436600
Epoch 50, Train Loss: 1.572947, Val Accuracy: 0.446900
Epoch 60, Train Loss: 1.537423, Val Accuracy: 0.450400
Epoch 70, Train Loss: 1.495255, Val Accuracy: 0.457000
Epoch 80, Train Loss: 1.485376, Val Accuracy: 0.461800
Epoch 90, Train Loss: 1.416507, Val Accuracy: 0.465600
Epoch 100, Train Loss: 1.441943, Val Accuracy: 0.471200
Epoch 110, Train Loss: 1.388025, Val Accuracy: 0.474700
Epoch 120, Train Loss: 1.344957, Val Accuracy: 0.478900
Epoch 130, Train Loss: 1.310756, Val Accuracy: 0.481600
Epoch 140, Train Loss: 1.219319, Val Accuracy: 0.484200
Epoch 150, Train Loss: 1.238972, Val Accuracy: 0.485000
Epoch 160, Train Loss: 1.229063, Val Accuracy: 0.488500
Epoch 170, Train Loss: 1.245791, Val Accuracy: 0.489400
```

```
Epoch 180, Train Loss: 1.167827, Val Accuracy: 0.493500
Epoch 190, Train Loss: 1.172547, Val Accuracy: 0.493600
Epoch 200, Train Loss: 1.111720, Val Accuracy: 0.492600
Time to complete training: 2090.384011
```

Out[15]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x226c69b1eb0
>






True label
Predicted label
0 560 28 56 29 23 30 23 36 156 59
1 30 589 28 33 26 28 31 34 64 137
2 84 36 344 84 106 89 124 81 30 22
3 29 38 93 292 67 192 142 59 36 52
4 44 11 133 61 401 74 133 98 22 23
5 28 27 87 176 77 367 97 73 42 26
6 12 26 68 91 95 62 582 31 13 20
7 47 36 57 67 81 77 37 531 21 46
8 88 46 14 29 22 34 9 19 682 57
9 35 151 20 36 16 19 32 42 71 578
0 1 2 3 4 5 6 7 8 9
600
500
400
300
200
100

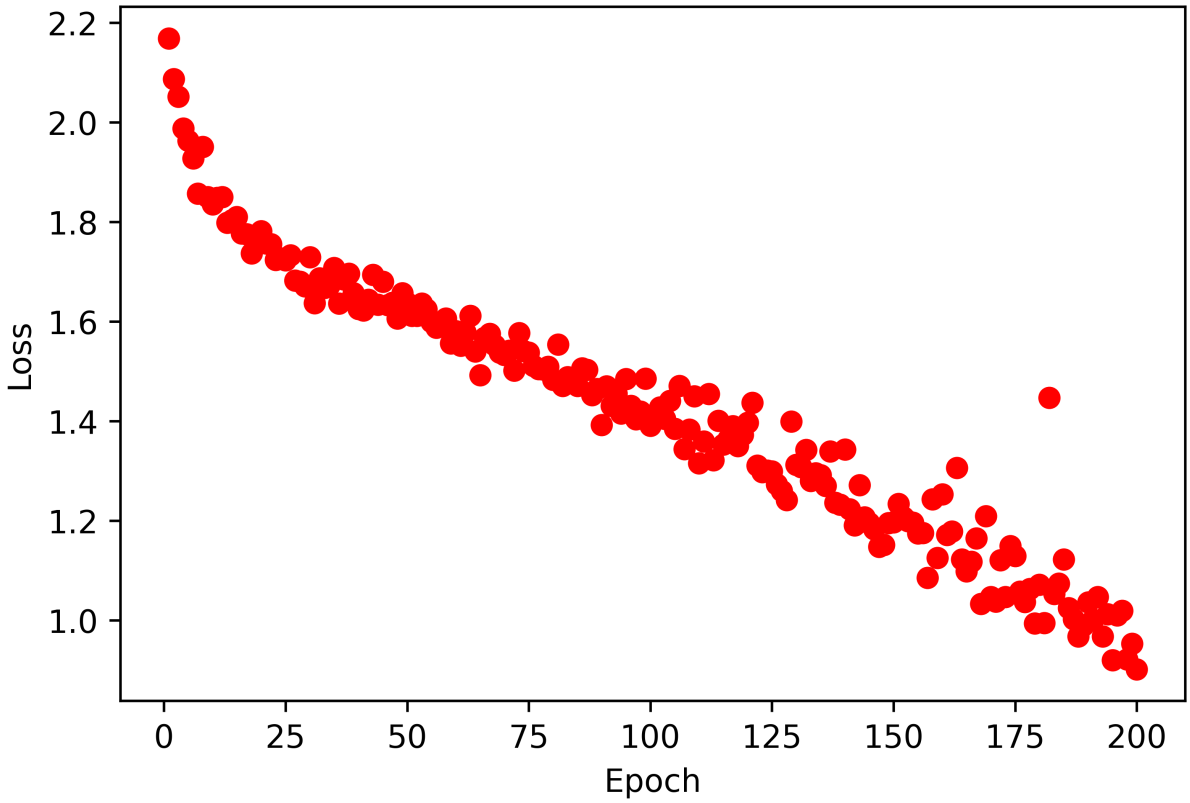
Part 2

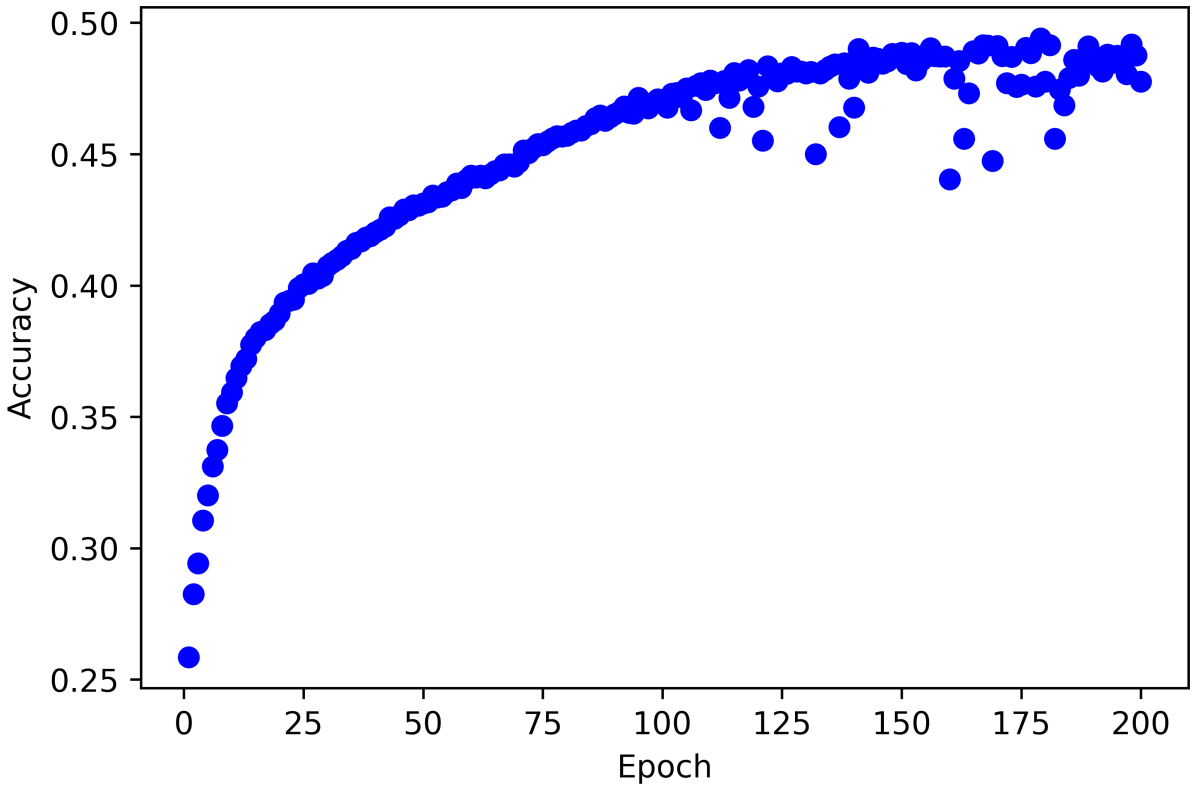
In [16]:
```
modelC2 = nn.Sequential(
    nn.Linear(3072,512),
    nn.Tanh(),
    nn.Linear(512,256),
    nn.Tanh(),
    nn.Linear(256,128),
    nn.Tanh(),
    nn.Linear(128,10),
    nn.LogSoftmax(dim=1)
).to(device)

learning_rate = 1e-2

optimizer2 = optim.SGD(modelC2.parameters(),lr=learning_rate)

loss_fn = nn.NLLLoss().to(device)

n_epochs = 200

training_loop(
    n_epochs=n_epochs,
    optimizer=optimizer2,
    model=modelC2,
    loss_fn=loss_fn,
    train_load=train_loader,
    val_load=val_loader
)

gt_array = []
pred_array = []
with torch.no_grad():
    for imgs, labels in val_loader:
        imgs, labels = imgs.to(device), labels.to(device)

        batch_size = imgs.shape[0]
        outputs = modelC2(imgs.view(batch_size,-1))
        _, predicted = torch.max(outputs,dim=1)
        gt_array.append(labels)
        pred_array.append(predicted)

gt_array = torch.concat(gt_array)
pred_array = torch.concat(pred_array)
ConfusionMatrixDisplay(confusion_matrix(gt_array.to('cpu'),pred_array.to('cpu')))
```

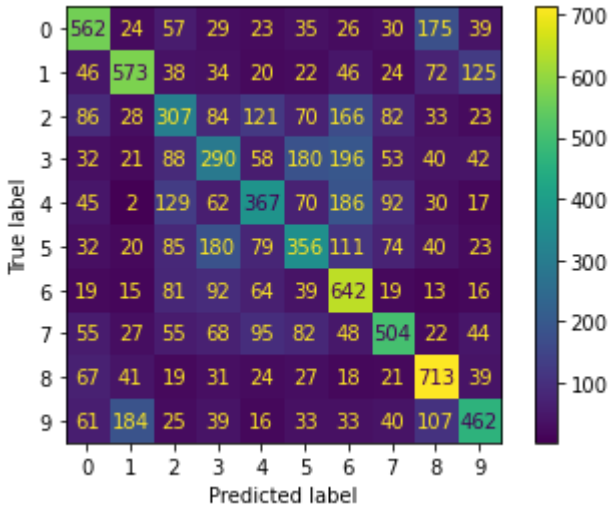
```
Epoch 10, Train Loss: 1.835418, Val Accuracy: 0.359300
Epoch 20, Train Loss: 1.781455, Val Accuracy: 0.389400
Epoch 30, Train Loss: 1.729753, Val Accuracy: 0.407400
Epoch 40, Train Loss: 1.625753, Val Accuracy: 0.420200
Epoch 50, Train Loss: 1.637026, Val Accuracy: 0.431200
Epoch 60, Train Loss: 1.581051, Val Accuracy: 0.441800
Epoch 70, Train Loss: 1.533412, Val Accuracy: 0.446800
Epoch 80, Train Loss: 1.483232, Val Accuracy: 0.457000
Epoch 90, Train Loss: 1.392807, Val Accuracy: 0.465100
Epoch 100, Train Loss: 1.391321, Val Accuracy: 0.470600
Epoch 110, Train Loss: 1.315632, Val Accuracy: 0.478100
Epoch 120, Train Loss: 1.397245, Val Accuracy: 0.475800
Epoch 130, Train Loss: 1.312929, Val Accuracy: 0.480700
```

```
Epoch 140, Train Loss: 1.343461, Val Accuracy: 0.467700
Epoch 150, Train Loss: 1.197175, Val Accuracy: 0.488600
Epoch 160, Train Loss: 1.253503, Val Accuracy: 0.440400
Epoch 170, Train Loss: 1.047514, Val Accuracy: 0.491200
Epoch 180, Train Loss: 1.072170, Val Accuracy: 0.477600
Epoch 190, Train Loss: 1.036252, Val Accuracy: 0.484800
Epoch 200, Train Loss: 0.901894, Val Accuracy: 0.477600
Time to complete training: 2164.579936
```

Out[16]: <sklearn.metrics._plot.confusion_matrix.ConfusionMatrixDisplay at 0x226dd1a16a0>




0.50
0.45
0.40
0.35
0.30
0.25
Accuracy
0
25
50
75
100
125
150
175
200
Epoch


0 562 24 57 29 23 35 26 30 175 39
1 46 573 38 34 20 22 46 24 72 125
2 86 28 307 84 121 70 166 82 33 23
3 32 21 88 290 58 180 196 53 40 42
4 45 2 129 62 367 70 186 92 30 17
5 32 20 85 180 79 356 111 74 40 23
6 19 15 81 92 64 39 642 19 13 16
7 55 27 55 68 95 82 48 504 22 44
8 67 41 19 31 24 27 18 21 713 39
9 61 184 25 39 16 33 33 40 107 462
True label
0 1 2 3 4 5 6 7 8 9
Predicted label
700
600
500
400
300
200
100