EE5179 : Deep Learning for Imaging
Programming Assignment 2: Convolutional Neural Networks

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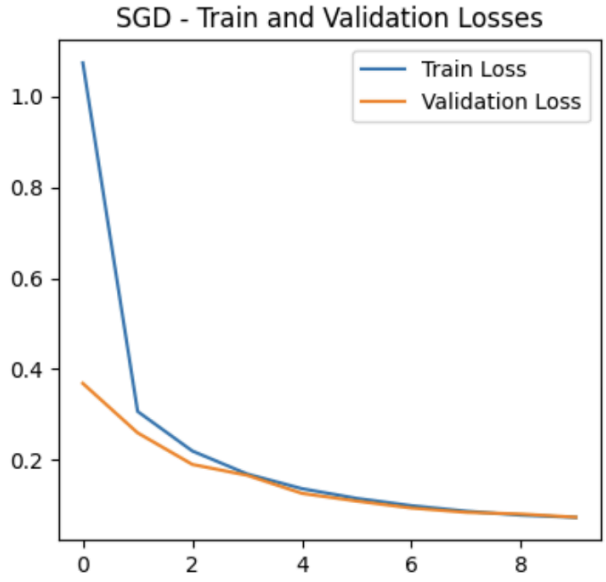
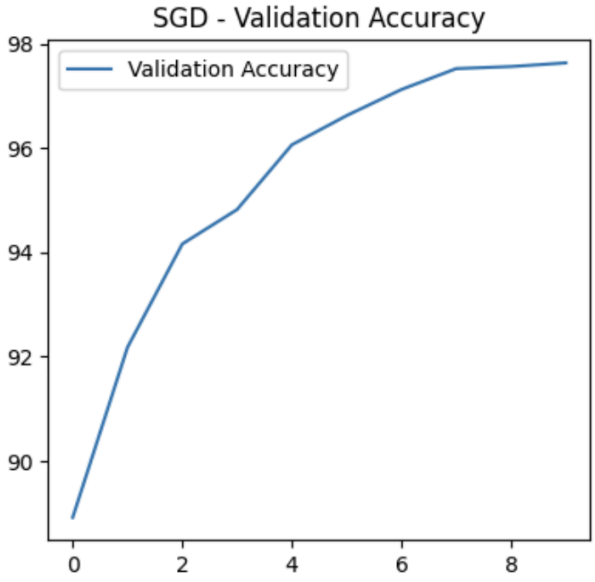
Stochastic gradient descent optimizer

```
Epoch: 1/10, Train Loss: 1.0738, Val Loss: 0.3685, Val Accuracy: 88.92%
Epoch: 2/10, Train Loss: 0.3068, Val Loss: 0.2597, Val Accuracy: 92.18%
Epoch: 3/10, Train Loss: 0.2196, Val Loss: 0.1901, Val Accuracy: 94.16%
Epoch: 4/10, Train Loss: 0.1691, Val Loss: 0.1662, Val Accuracy: 94.82%
Epoch: 5/10, Train Loss: 0.1369, Val Loss: 0.1265, Val Accuracy: 96.06%
Epoch: 6/10, Train Loss: 0.1155, Val Loss: 0.1096, Val Accuracy: 96.62%
Epoch: 7/10, Train Loss: 0.0994, Val Loss: 0.0942, Val Accuracy: 97.12%
Epoch: 8/10, Train Loss: 0.0873, Val Loss: 0.0848, Val Accuracy: 97.52%
Epoch: 9/10, Train Loss: 0.0784, Val Loss: 0.0810, Val Accuracy: 97.56%
Epoch: 10/10, Train Loss: 0.0736, Val Loss: 0.0740, Val Accuracy: 97.63%
Training using SGD with BatchNorm=False took 98.45 seconds.
```



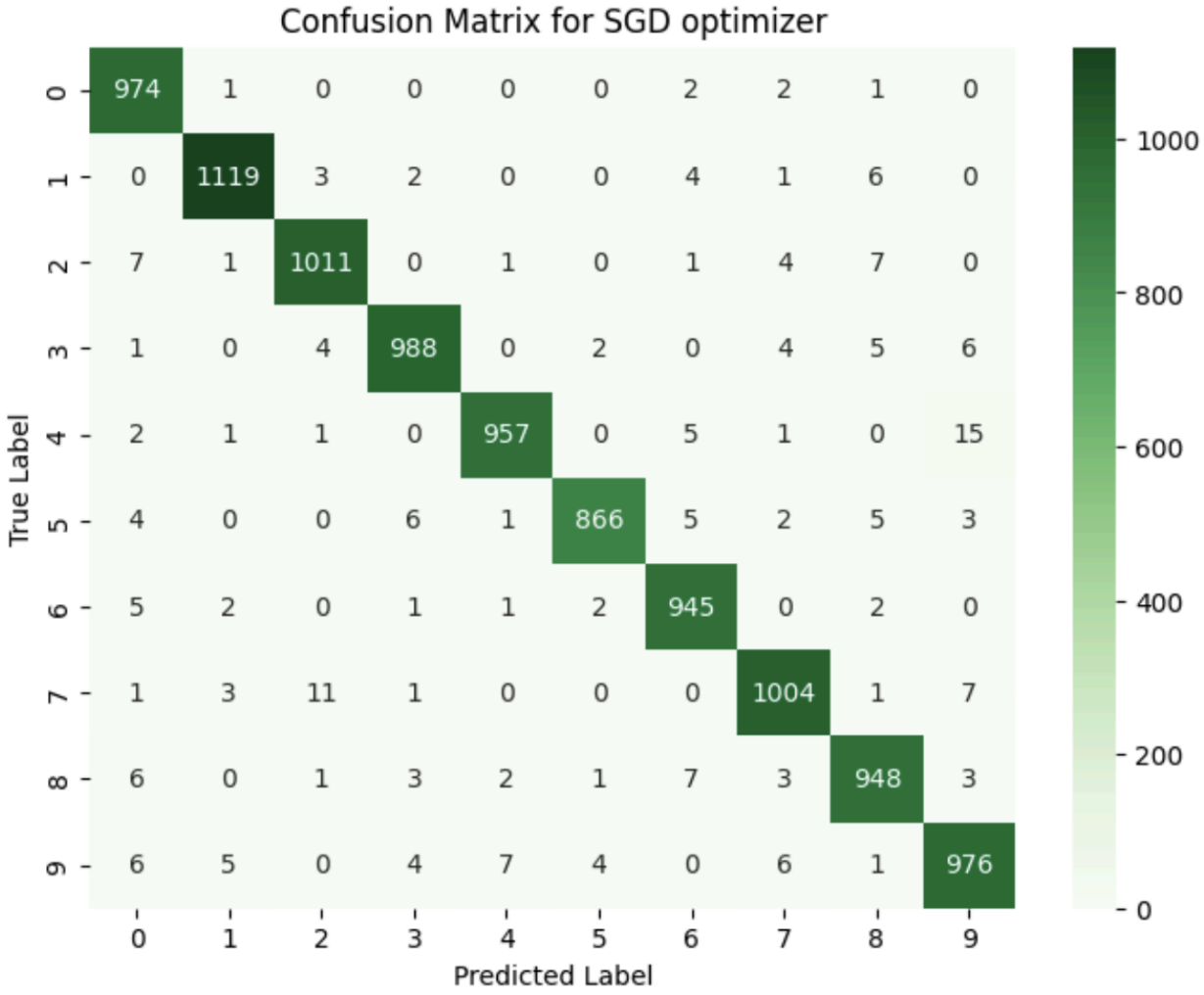


Adam optimizer

```
Epoch: 1/10, Train Loss: 0.1742, Val Loss: 0.0609, Val Accuracy: 98.01%
Epoch: 2/10, Train Loss: 0.0471, Val Loss: 0.0504, Val Accuracy: 98.51%
Epoch: 3/10, Train Loss: 0.0320, Val Loss: 0.0393, Val Accuracy: 98.91%
Epoch: 4/10, Train Loss: 0.0246, Val Loss: 0.0335, Val Accuracy: 99.02%
Epoch: 5/10, Train Loss: 0.0184, Val Loss: 0.0326, Val Accuracy: 99.13%
Epoch: 6/10, Train Loss: 0.0141, Val Loss: 0.0446, Val Accuracy: 99.00%
Epoch: 7/10, Train Loss: 0.0116, Val Loss: 0.0462, Val Accuracy: 98.91%
Epoch: 8/10, Train Loss: 0.0106, Val Loss: 0.0487, Val Accuracy: 98.79%
Epoch: 9/10, Train Loss: 0.0080, Val Loss: 0.0436, Val Accuracy: 98.93%
Epoch: 10/10, Train Loss: 0.0073, Val Loss: 0.0541, Val Accuracy: 98.85%
Training using Adam with BatchNorm=False took 86.69 seconds.
```

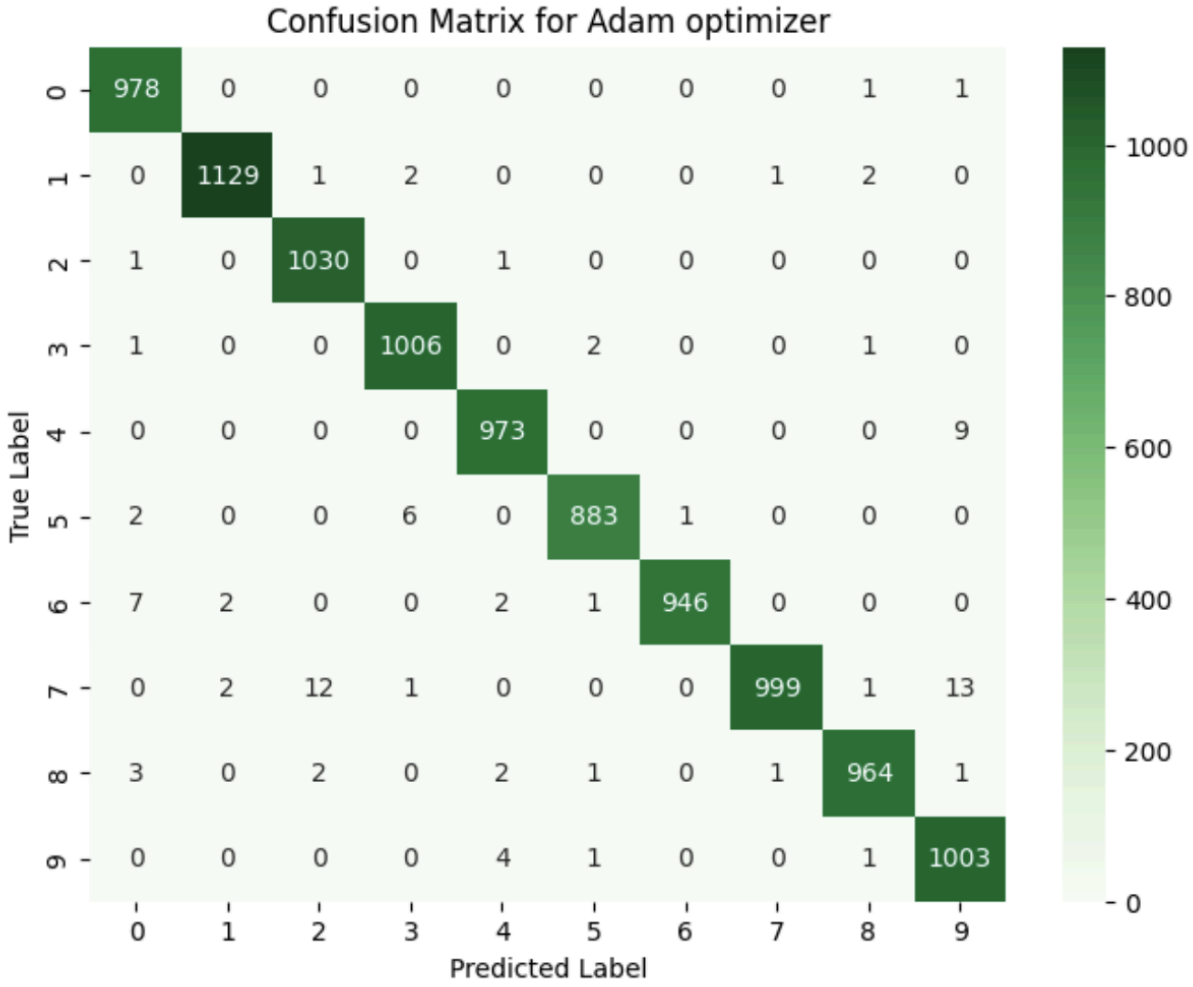
Confusion matrix - SGD optimizer

```
Results for SGD optimizer:
Accuracy: 97.88%
```

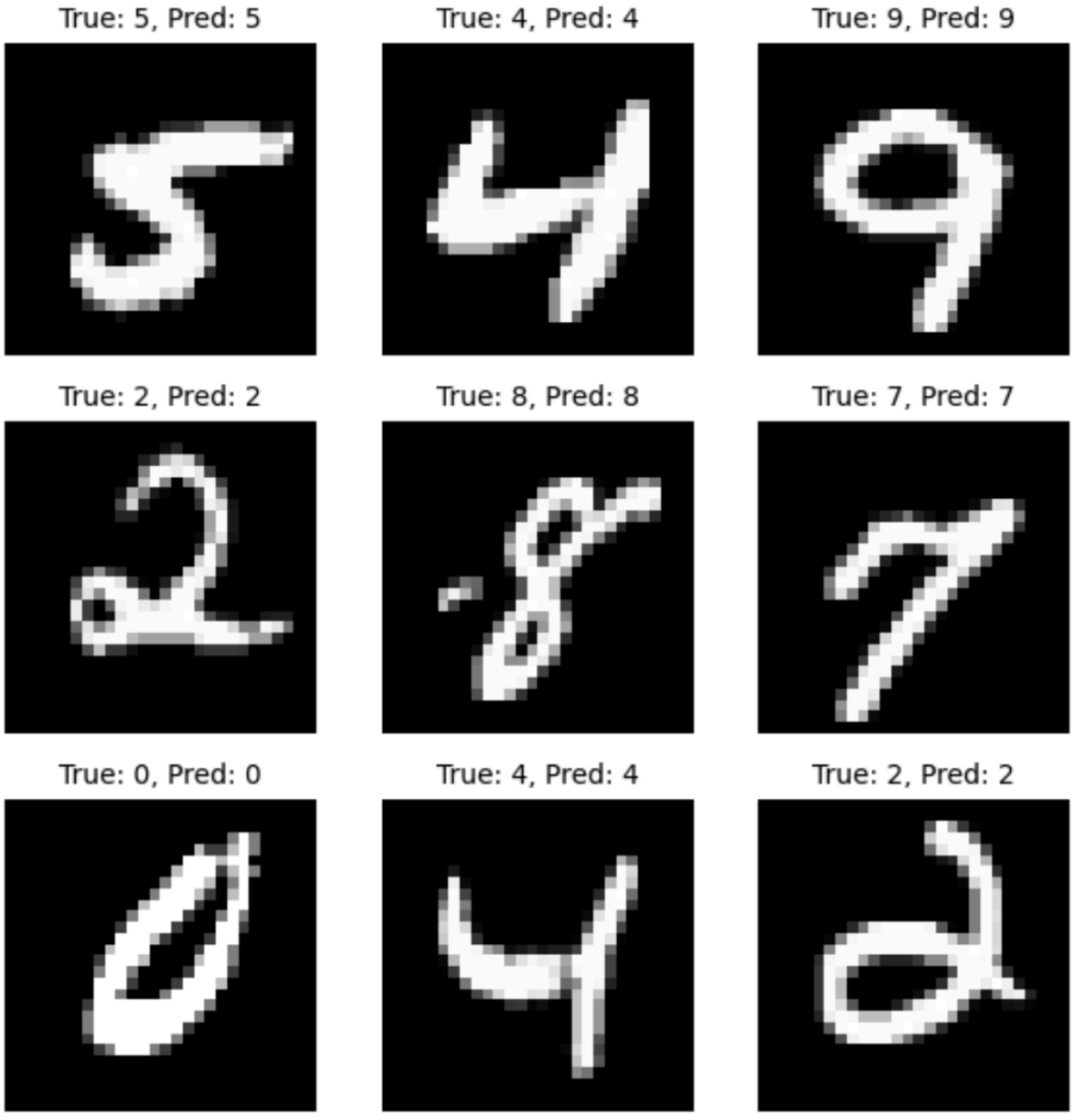


Confusion matrix - Adam optimizer

```
Results for Adam optimizer:
Accuracy: 99.11%
```



Random images



Dimensions of the input and output at each layer.

[21] `summary(top_model, input_size=(1, 28, 28))`

0s

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 32, 28, 28]             320
              ReLU-2           [-1, 32, 28, 28]               0
         MaxPool2d-3           [-1, 32, 14, 14]               0
            Conv2d-4           [-1, 32, 14, 14]           9,248
              ReLU-5           [-1, 32, 14, 14]               0
         MaxPool2d-6             [-1, 32, 7, 7]               0
            Linear-7                  [-1, 500]         784,500
              ReLU-8                  [-1, 500]               0
            Linear-9                   [-1, 10]           5,010
================================================================
Total params: 799,078
Trainable params: 799,078
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.00
Forward/backward pass size (MB): 0.55
Params size (MB): 3.05
Estimated Total Size (MB): 3.60
----------------------------------------------------------------
```

Number of parameters and neurons

```
[22] count_parameters_and_neurons(top_model)
```

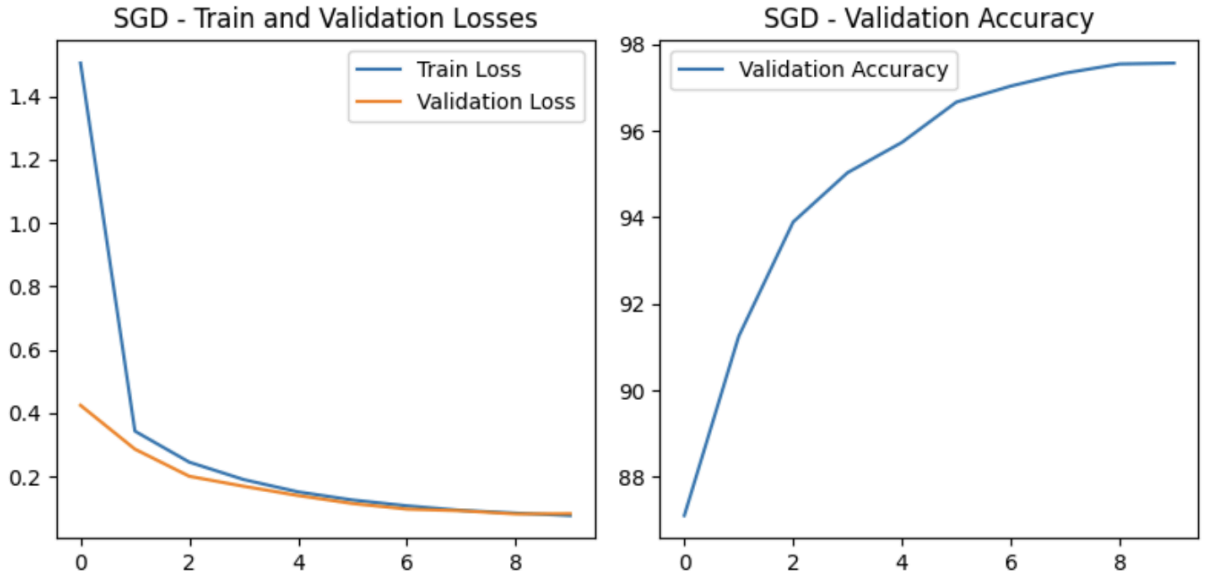
0s

```
Total parameters: 799078
Parameters in FC layers: 789510
Parameters in Conv layers: 9568
Total neurons: 31870
Neurons in FC layers: 510
Neurons in Conv layers: 31360
{'total_parameters': 799078,
 'fc_parameters': 789510,
 'conv_parameters': 9568,
 'total_neurons': 31870,
 'fc_neurons': 510,
 'conv_neurons': 31360}
```

With Batch Normalization

SGD optimizer

```
Epoch: 1/10, Train Loss: 1.5040, Val Loss: 0.4241, Val Accuracy: 87.11%
Epoch: 2/10, Train Loss: 0.3426, Val Loss: 0.2857, Val Accuracy: 91.25%
Epoch: 3/10, Train Loss: 0.2446, Val Loss: 0.2000, Val Accuracy: 93.89%
Epoch: 4/10, Train Loss: 0.1897, Val Loss: 0.1685, Val Accuracy: 95.03%
Epoch: 5/10, Train Loss: 0.1509, Val Loss: 0.1393, Val Accuracy: 95.73%
Epoch: 6/10, Train Loss: 0.1253, Val Loss: 0.1141, Val Accuracy: 96.66%
Epoch: 7/10, Train Loss: 0.1069, Val Loss: 0.0965, Val Accuracy: 97.03%
Epoch: 8/10, Train Loss: 0.0924, Val Loss: 0.0913, Val Accuracy: 97.33%
Epoch: 9/10, Train Loss: 0.0839, Val Loss: 0.0812, Val Accuracy: 97.54%
Epoch: 10/10, Train Loss: 0.0761, Val Loss: 0.0822, Val Accuracy: 97.56%
Training using SGD with BatchNorm=True took 88.57 seconds.
```

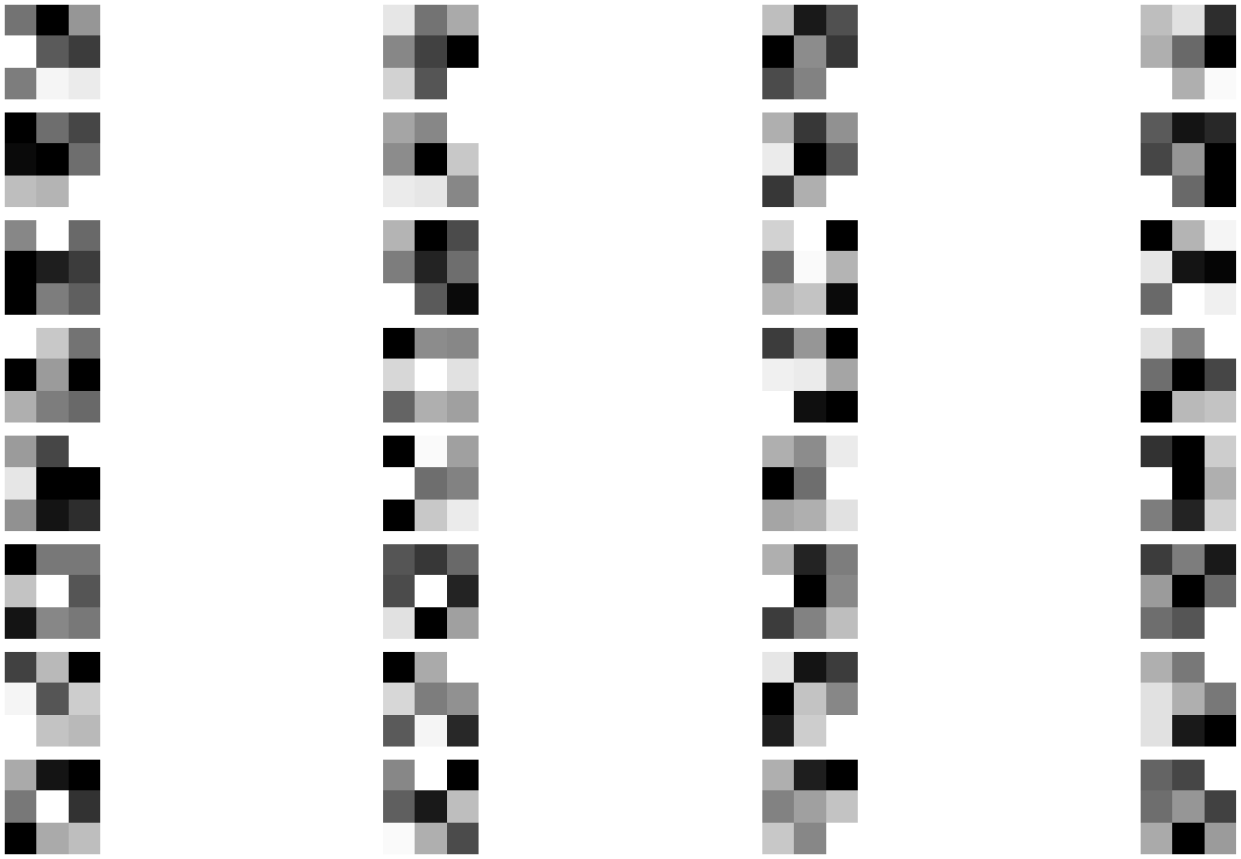


Adam optimizer

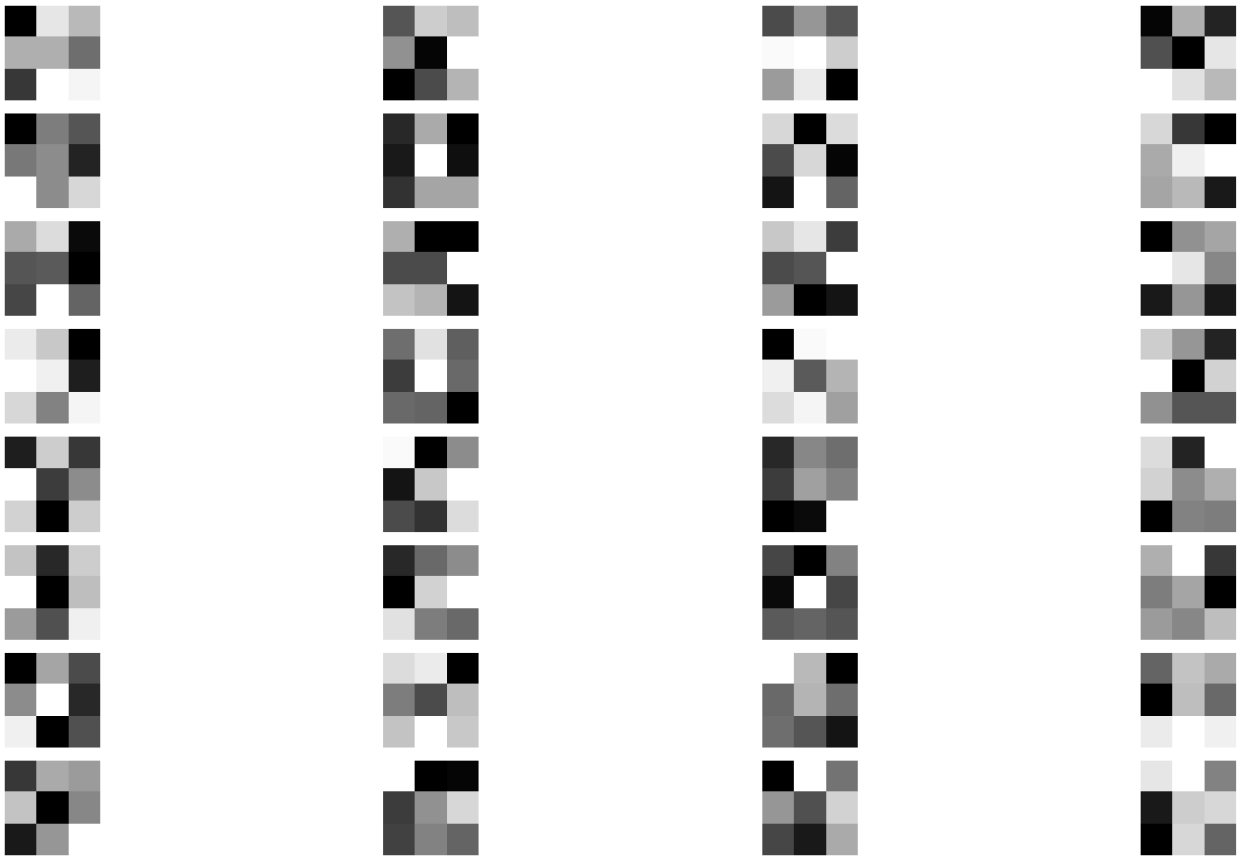
```
Epoch: 1/10, Train Loss: 0.1983, Val Loss: 0.0849, Val Accuracy: 97.43%
Epoch: 2/10, Train Loss: 0.0538, Val Loss: 0.0527, Val Accuracy: 98.37%
Epoch: 3/10, Train Loss: 0.0373, Val Loss: 0.0418, Val Accuracy: 98.65%
Epoch: 4/10, Train Loss: 0.0274, Val Loss: 0.0410, Val Accuracy: 98.93%
Epoch: 5/10, Train Loss: 0.0204, Val Loss: 0.0409, Val Accuracy: 98.73%
Epoch: 6/10, Train Loss: 0.0176, Val Loss: 0.0421, Val Accuracy: 98.77%
Epoch: 7/10, Train Loss: 0.0122, Val Loss: 0.0377, Val Accuracy: 99.02%
Epoch: 8/10, Train Loss: 0.0121, Val Loss: 0.0495, Val Accuracy: 98.84%
Epoch: 9/10, Train Loss: 0.0090, Val Loss: 0.0475, Val Accuracy: 98.77%
Epoch: 10/10, Train Loss: 0.0084, Val Loss: 0.0388, Val Accuracy: 99.08%
Training using Adam with BatchNorm=True took 87.72 seconds.
```

Visualizing Convolutional Neural Network

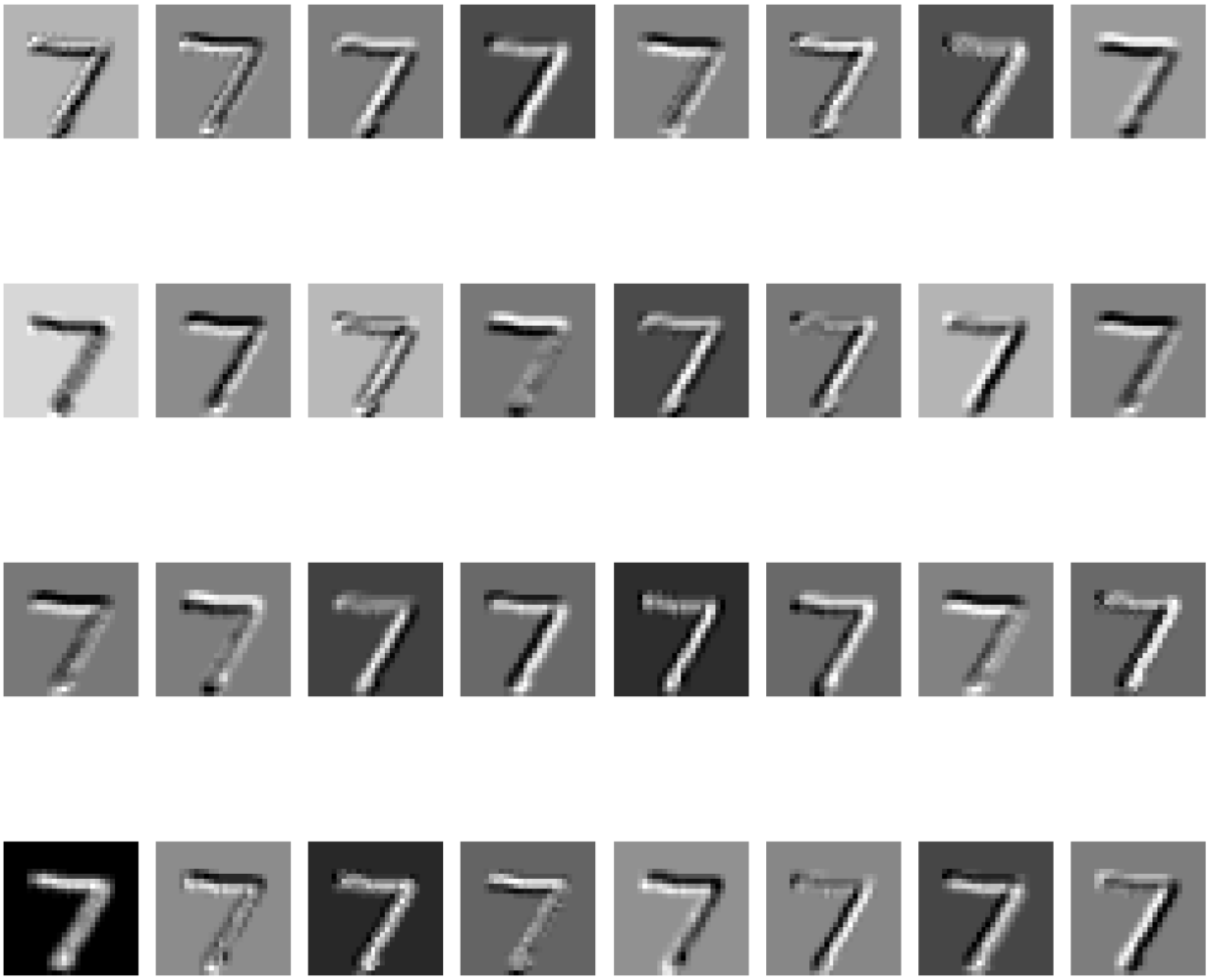
Conv1 layer

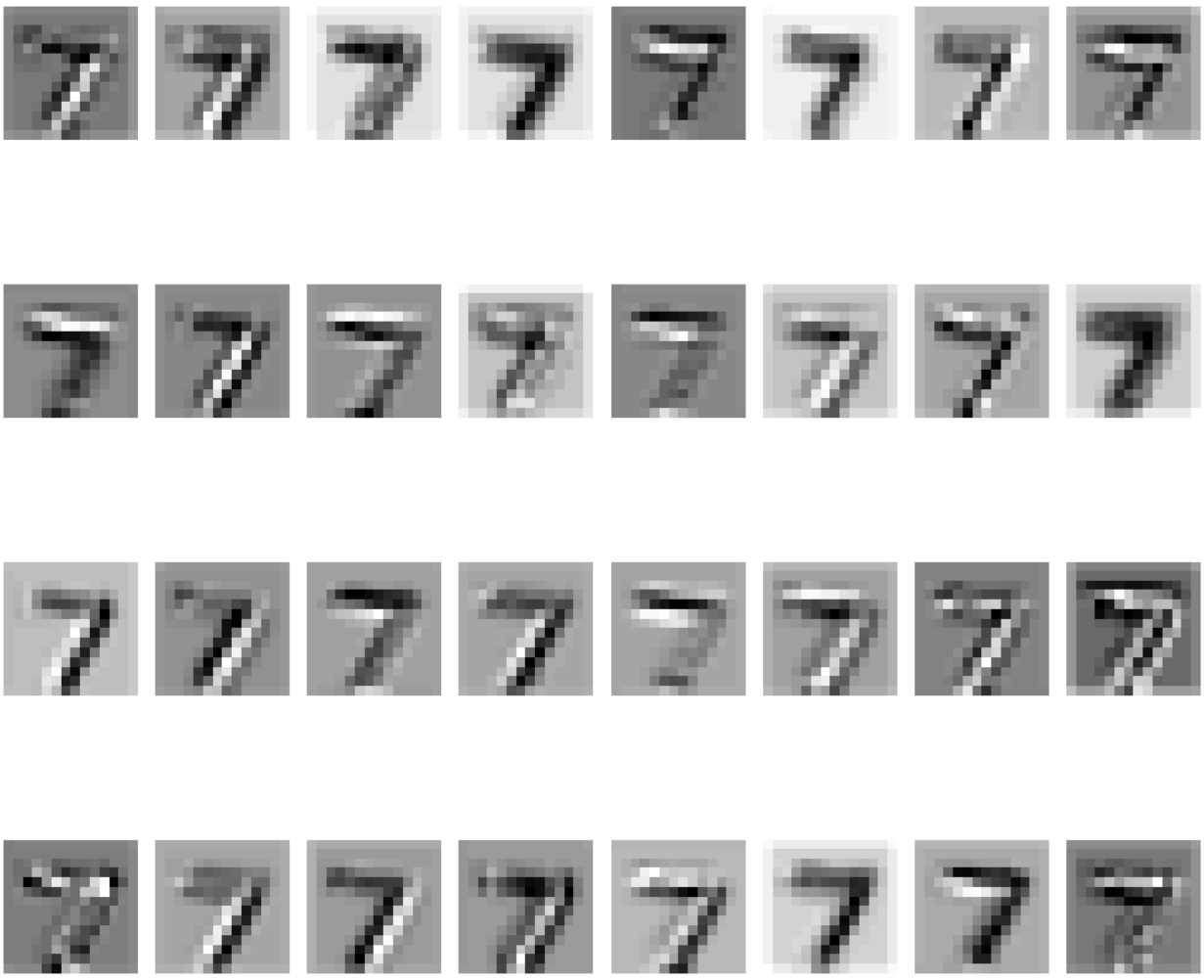


Conv2 layer

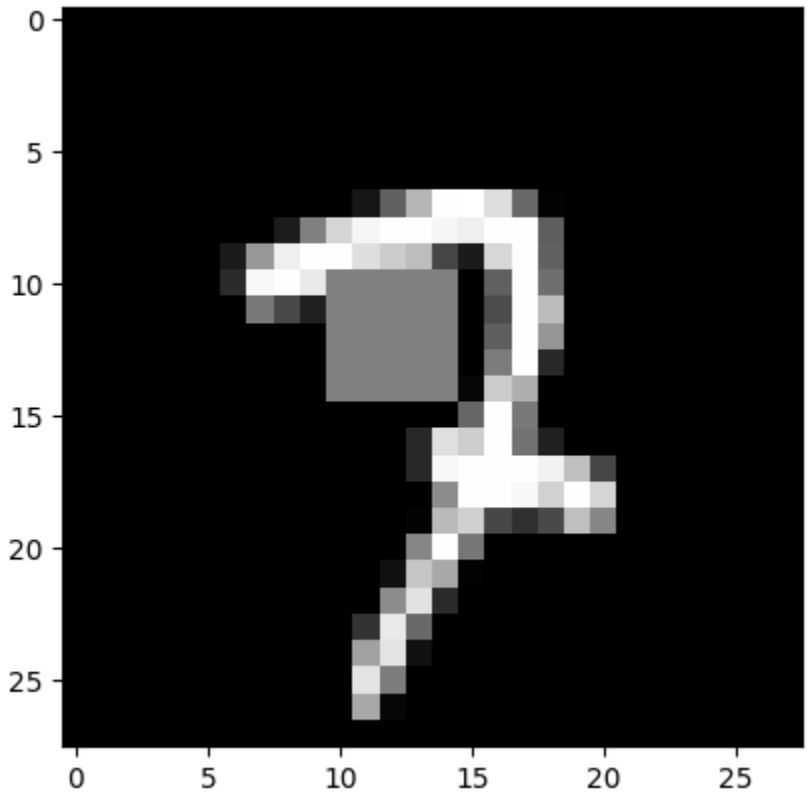


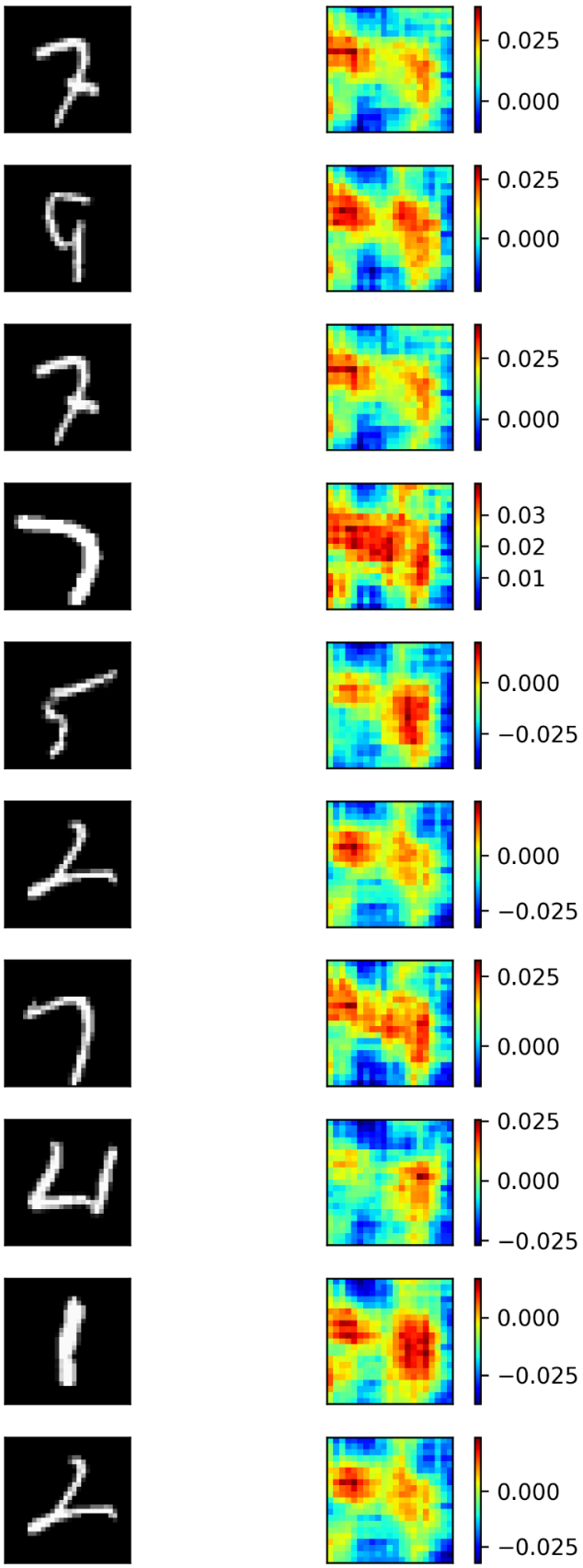
Visualize the activations of the convolutional layers

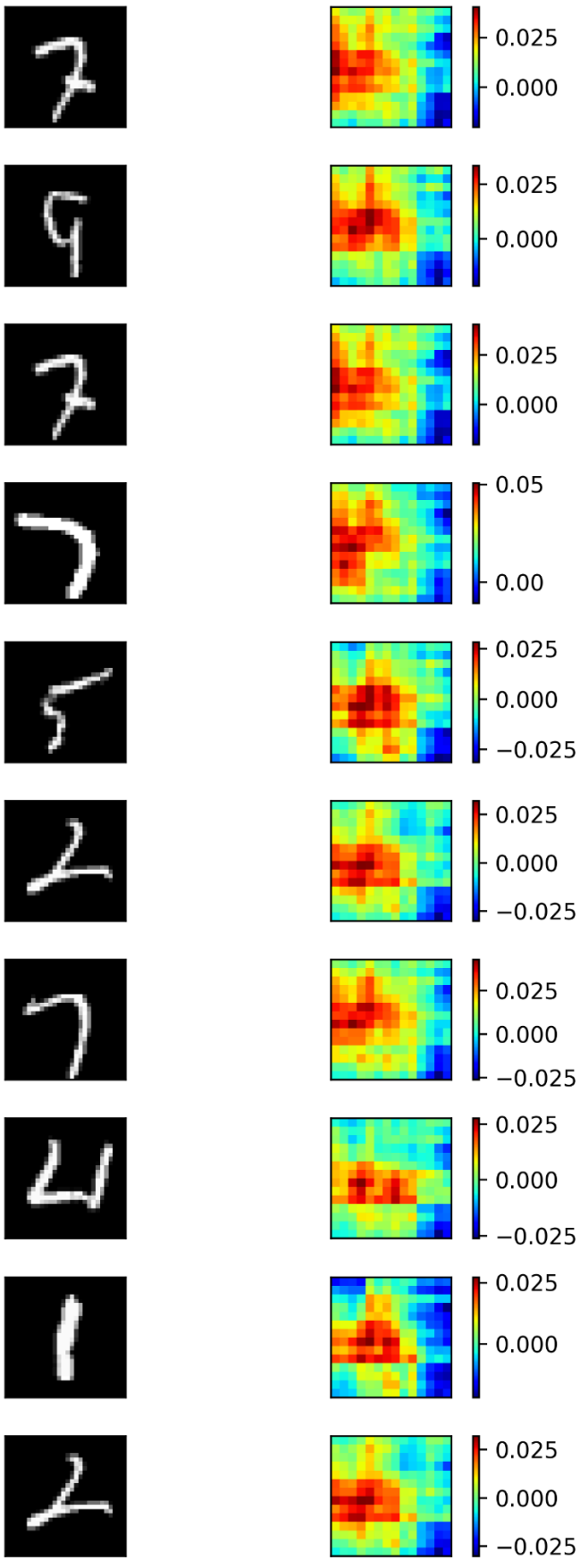




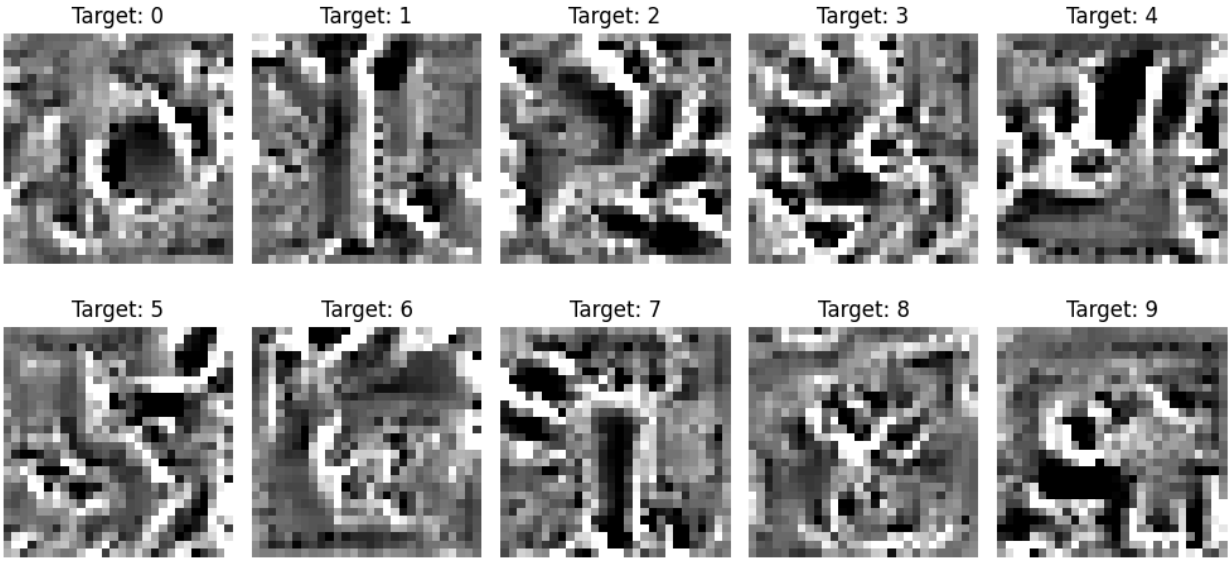
Occluding parts of the image




0.025
0.000
0.025
0.000
0.025
0.000
0.03
0.02
0.01
0.000
−0.025
0.000
−0.025
0.025
0.000
0.025
0.000
−0.025
0.000
−0.025
0.000
−0.025


0.025
0.000
0.025
0.000
0.025
0.000
0.05
0.00
0.025
0.000
−0.025
0.025
0.000
−0.025
0.025
0.000
−0.025
0.025
0.000
−0.025
0.025
0.000
0.025
0.000
−0.025

Non target Example



Cost Function for Target Class 1 over Iterations
Cost Value
Iterations
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000

Targeted Attack