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Hyperparameters:

Batch size: 256

Epochs: 10

Learning rate: [0.005,0.004,0.003,0.001]

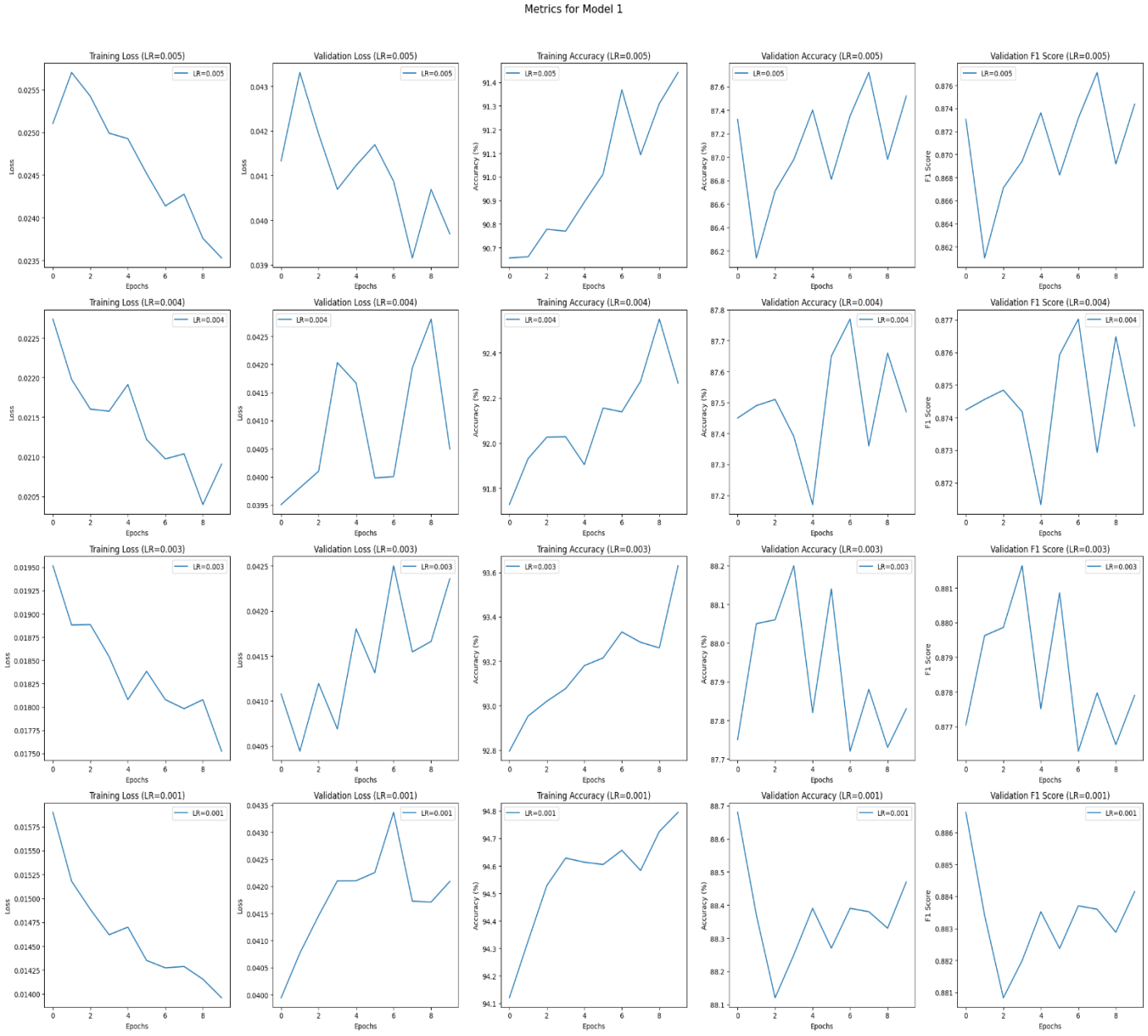
Model 1:

```
FNN([
    DenseLayer(784, 512),
    BatchNormalizationLayer(512),
    ReLU(),
    DropoutLayer(0.5),
    DenseLayer(512, 128),
    ReLU(),
    DropoutLayer(0.25),
    DenseLayer(128, 64),
    ReLU(),
    DenseLayer(64, 10),
    Softmax()
]),
```

Performance metrics per Learning rate:

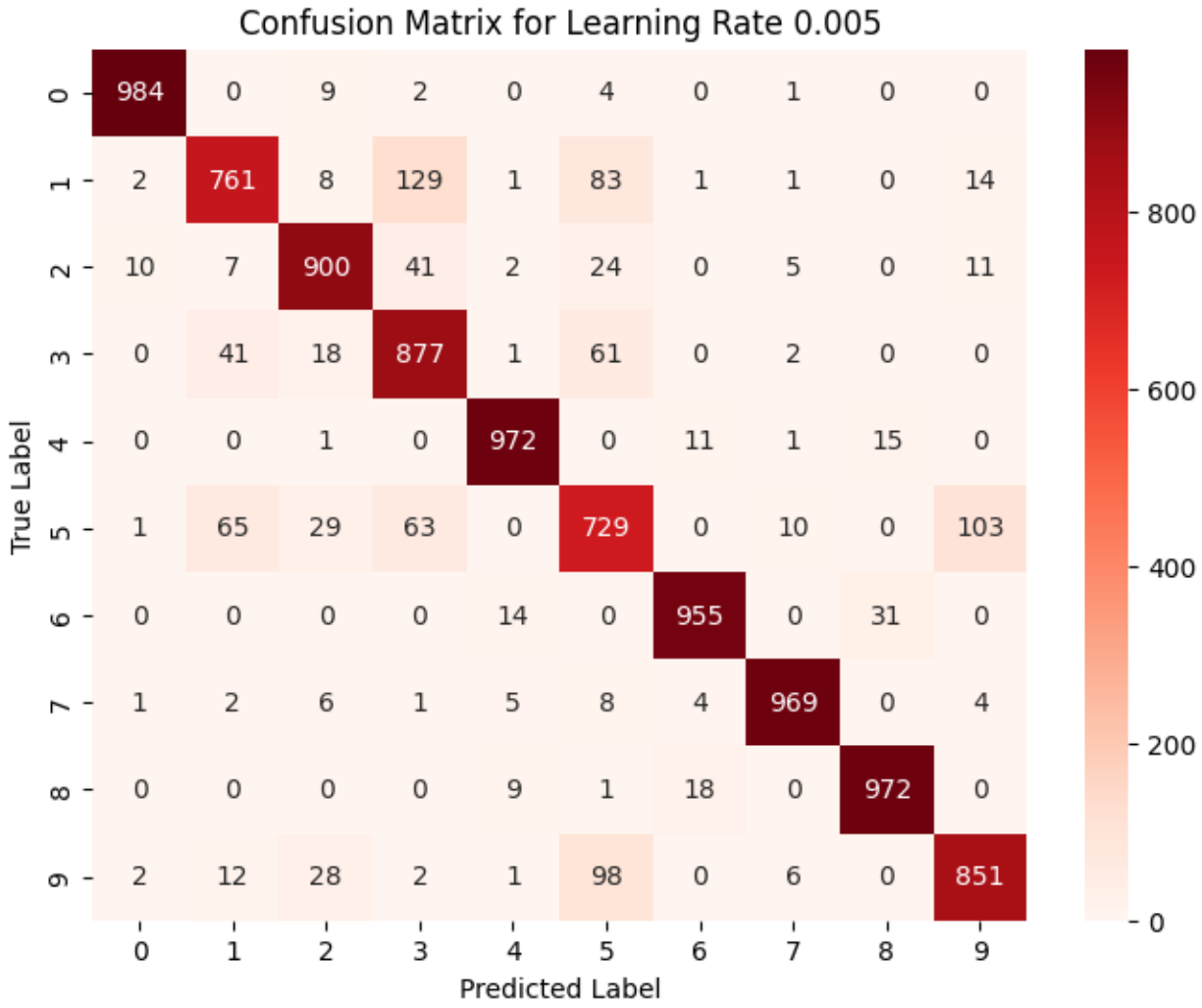
Learning rate	*Performance metrics*
0.005	Test Accuracy: 87.42% Precision: 0.9986928104575163 Recall: 1.0 F1 Score: 0.999345977763244 Specificity: 0.9989572471324296
0.004	Test Accuracy: 88.53% Precision: 0.9987179487179487 Recall: 1.0 F1 Score: 0.9993585631815266 Specificity: 0.9989701338825953
0.003	Test Accuracy: 89.34% Precision: 1.0 Recall: 0.9987405541561712 F1 Score: 0.9993698802772526 Specificity: 1.0
0.001	Test Accuracy: 89.88000000000001% Precision: 0.9975903614457832 Recall: 0.9987937273823885 F1 Score: 0.9981916817359856 Specificity: 0.9979550102249489

Performance Analysis of Model Across Various Learning Rates

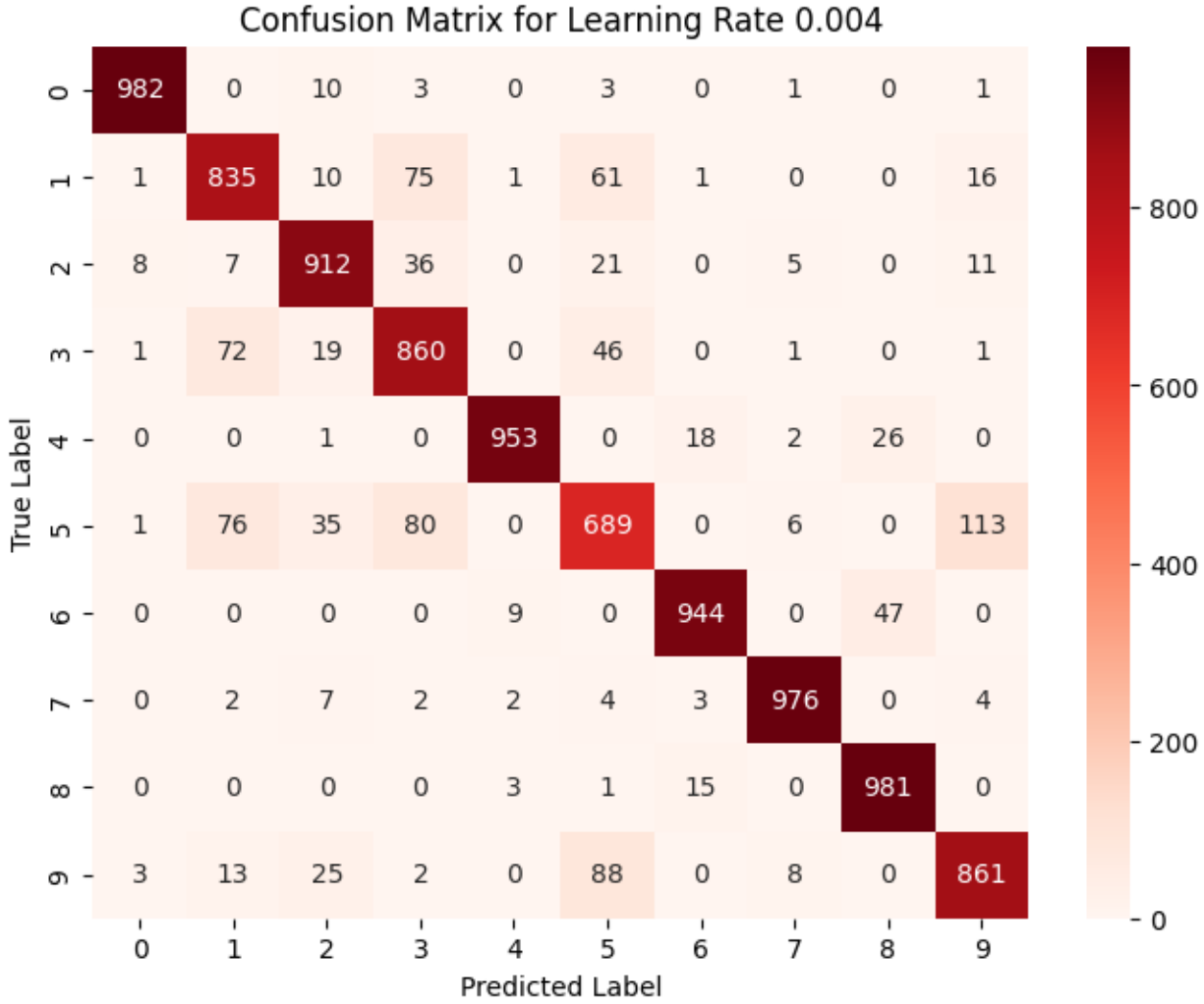


Confusion Matrix per Learning rate

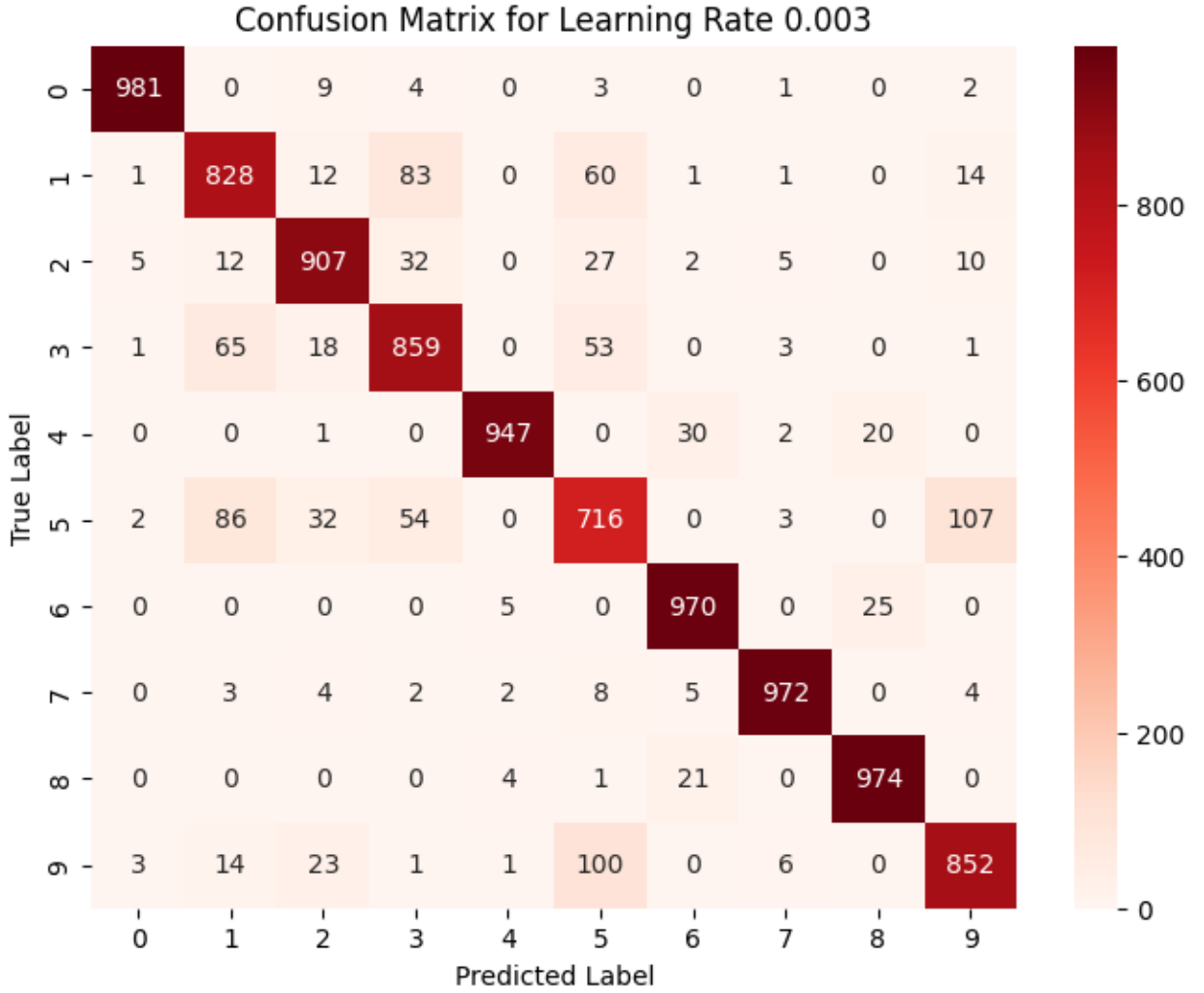
LR - 0.005:



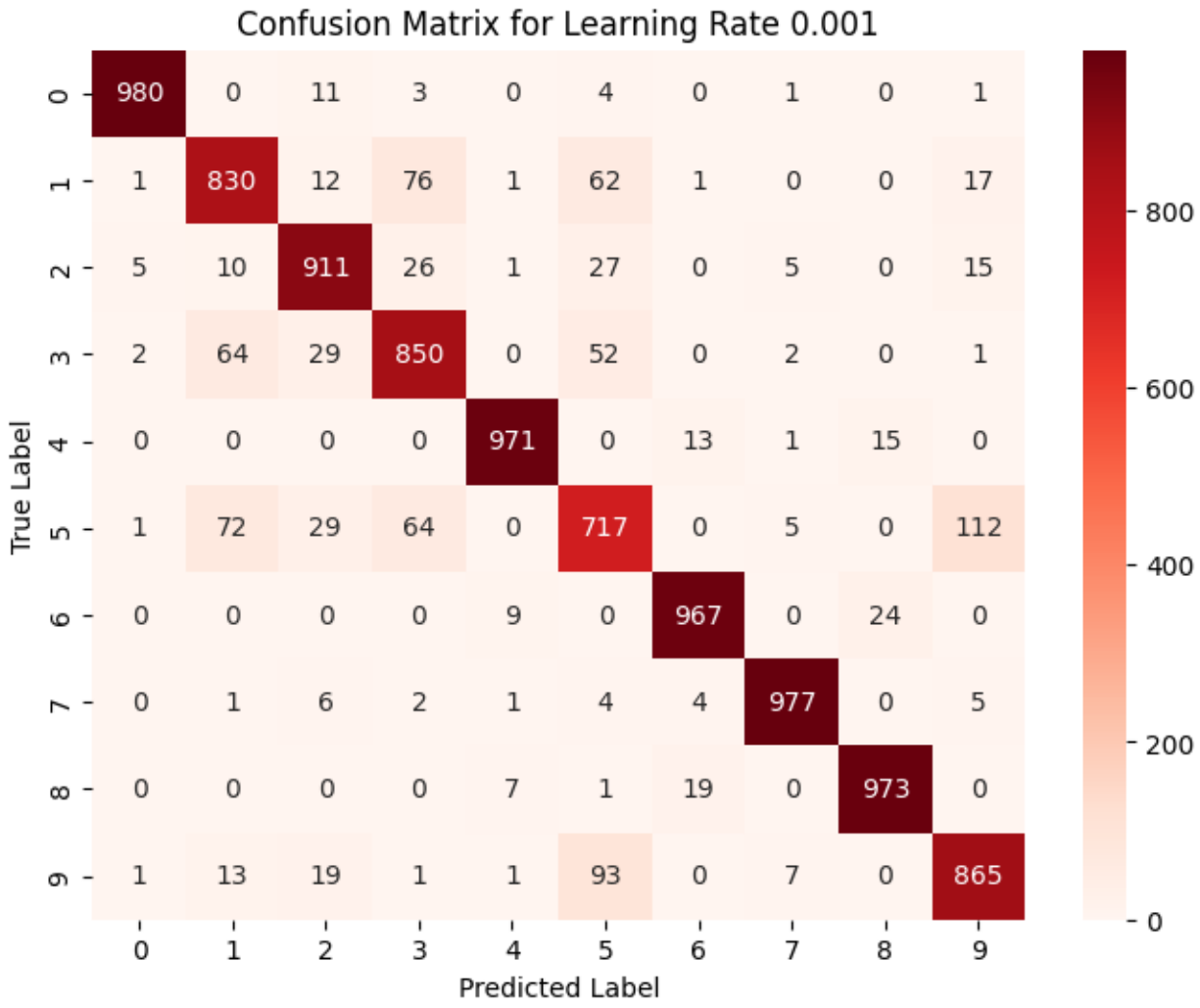
LR – 0.004:


Confusion Matrix for Learning Rate 0.004
True Label
Predicted Label
0 982 0 10 3 0 3 0 1 0 1
1 1 835 10 75 1 61 1 0 0 16
2 8 7 912 36 0 21 0 5 0 11
3 1 72 19 860 0 46 0 1 0 1
4 0 0 1 0 953 0 18 2 26 0
5 1 76 35 80 0 689 0 6 0 113
6 0 0 0 0 9 0 944 0 47 0
7 0 2 7 2 2 4 3 976 0 4
8 0 0 0 0 3 1 15 0 981 0
9 3 13 25 2 0 88 0 8 0 861
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.003:


Confusion Matrix for Learning Rate 0.003
True Label
Predicted Label
0 981 0 9 4 0 3 0 1 0 2
1 1 828 12 83 0 60 1 1 0 14
2 5 12 907 32 0 27 2 5 0 10
3 1 65 18 859 0 53 0 3 0 1
4 0 0 1 0 947 0 30 2 20 0
5 2 86 32 54 0 716 0 3 0 107
6 0 0 0 0 5 0 970 0 25 0
7 0 3 4 2 2 8 5 972 0 4
8 0 0 0 0 4 1 21 0 974 0
9 3 14 23 1 1 100 0 6 0 852
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.001:


Confusion Matrix for Learning Rate 0.001
True Label
Predicted Label
0 980 0 11 3 0 4 0 1 0 1
1 1 830 12 76 1 62 1 0 0 17
2 5 10 911 26 1 27 0 5 0 15
3 2 64 29 850 0 52 0 2 0 1
4 0 0 0 0 971 0 13 1 15 0
5 1 72 29 64 0 717 0 5 0 112
6 0 0 0 0 9 0 967 0 24 0
7 0 1 6 2 1 4 4 977 0 5
8 0 0 0 0 7 1 19 0 973 0
9 1 13 19 1 1 93 0 7 0 865
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

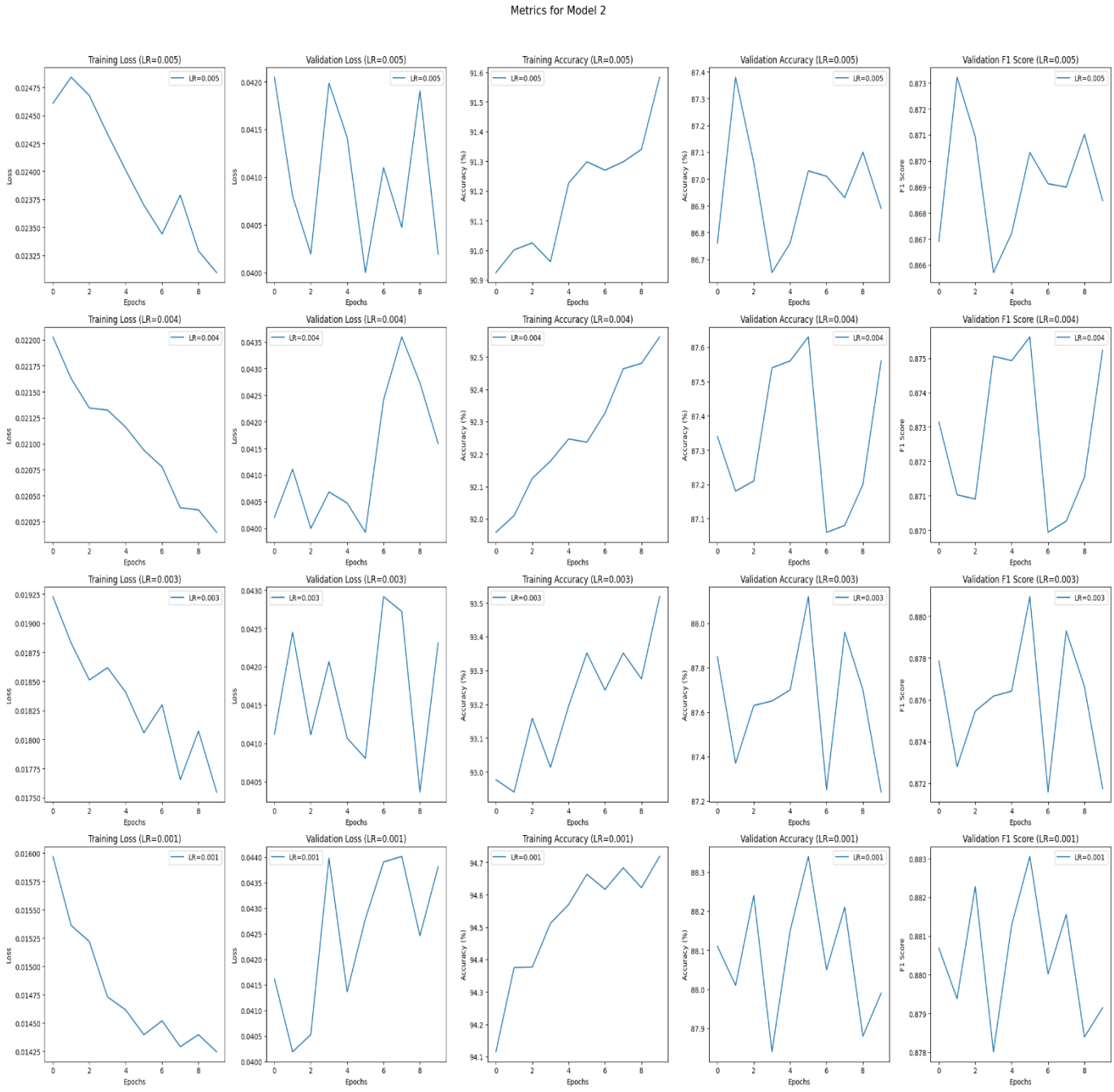
Model 2:

```
FNN([
    DenseLayer(784, 256),
    BatchNormalizationLayer(256),
    ReLU(),
    DropoutLayer(0.4),
    DenseLayer(256, 128),
    ReLU(),
    DropoutLayer(0.3),
    DenseLayer(128, 32),
    ReLU(),
    DenseLayer(32, 10),
    Softmax()
]),
```

Performance metrics per Learning rate:

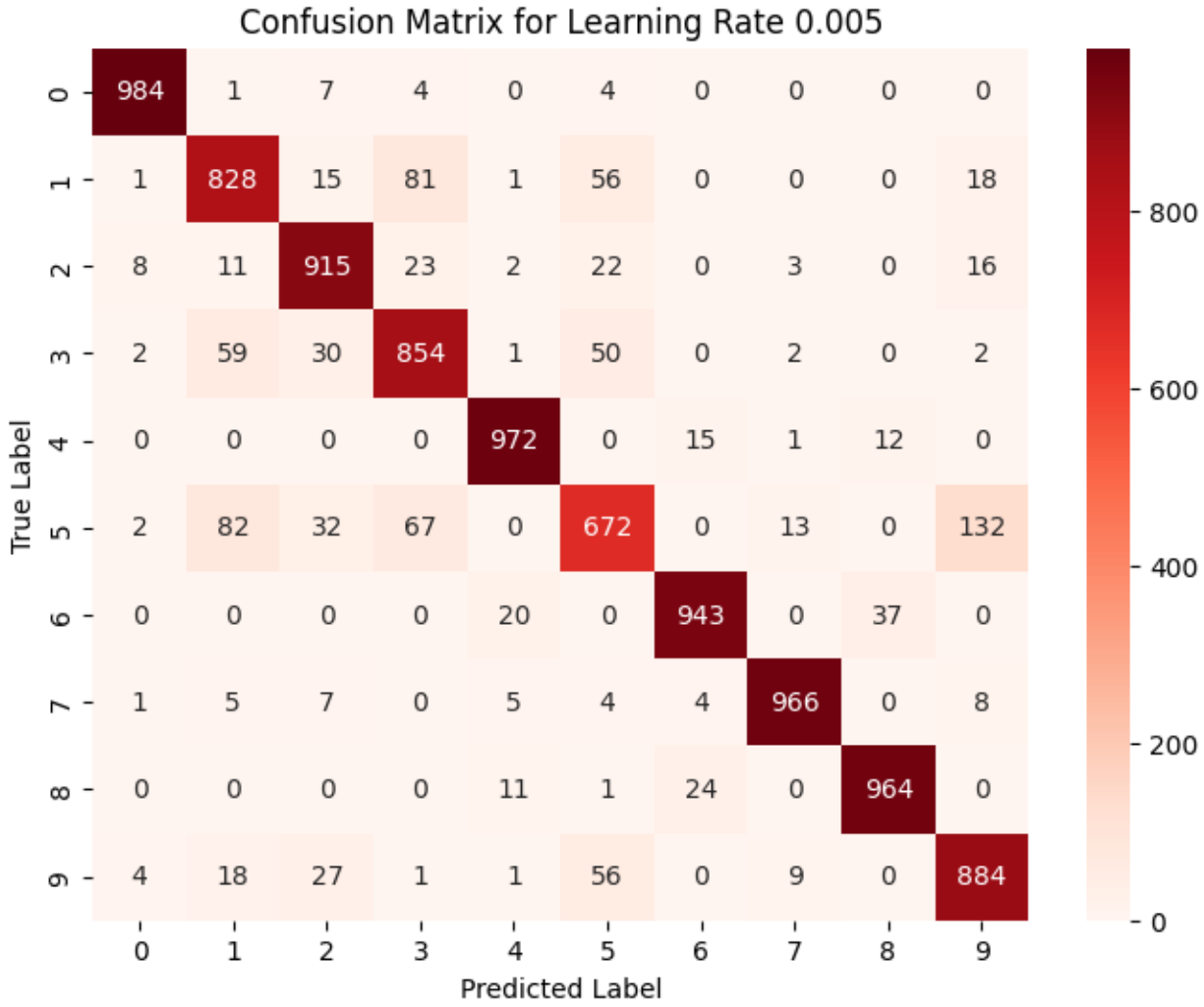
Learning rate	*Performance Metrics*
0.005	Test Accuracy: 87.92999999999999% Precision: 1.0 Recall: 1.0 F1 Score: 1.0 Specificity: 1.0
0.004	Test Accuracy: 88.57000000000001% Precision: 0.9986807387862797 Recall: 1.0 F1 Score: 0.9993399339933994 Specificity: 0.9989690721649485
0.003	Test Accuracy: 89.46% Precision: 1.0 Recall: 1.0 F1 Score: 1.0 Specificity: 1.0
0.001	Test Accuracy: 89.72% Precision: 0.9988009592326139 Recall: 1.0 F1 Score: 0.9994001199760048 Specificity: 0.9989764585465711

Performance Analysis of Model Across Various Learning Rates

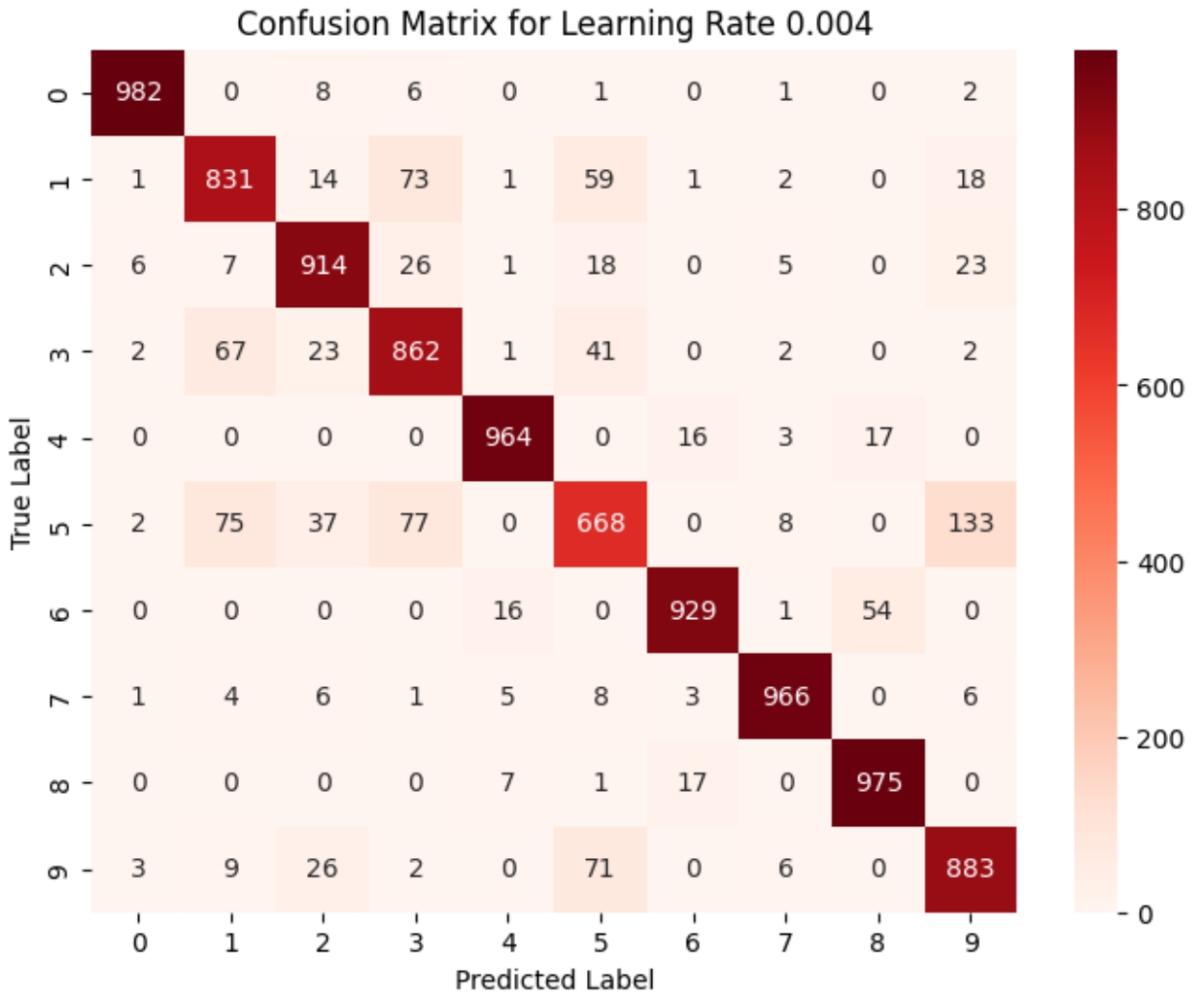


Confusion Matrix per Learning rate

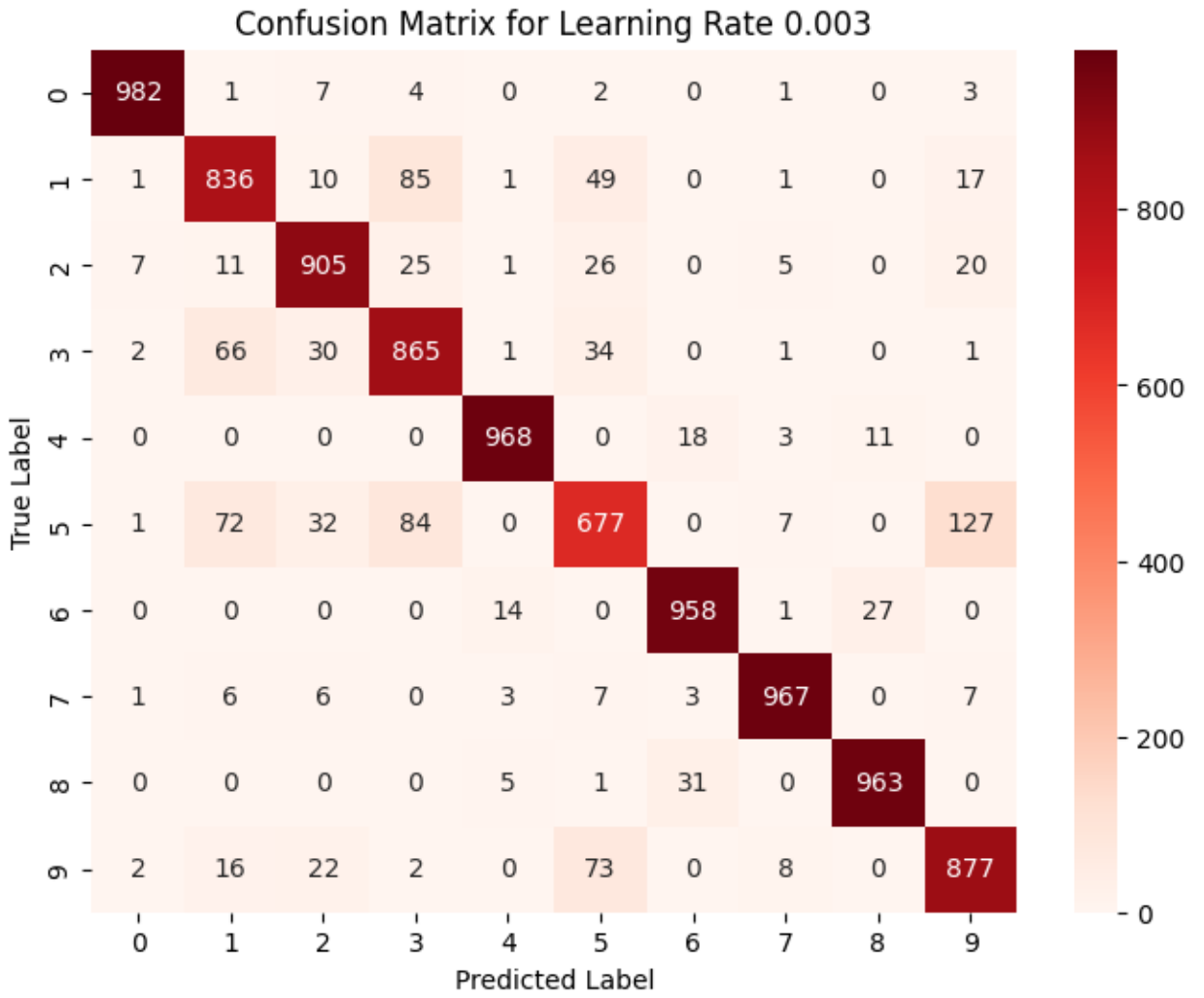
LR – 0.005:



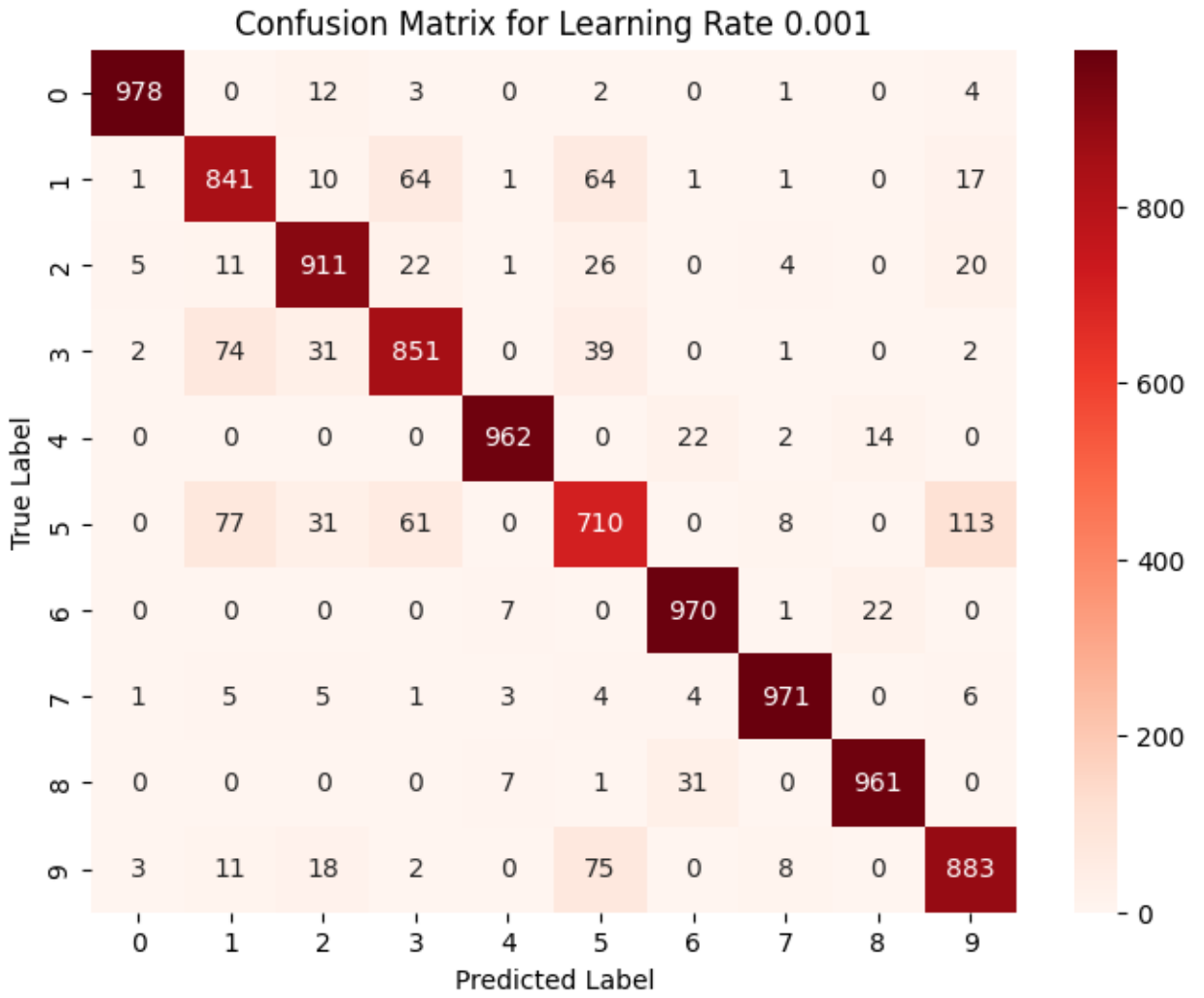
LR – 0.004:


Confusion Matrix for Learning Rate 0.004
True Label
Predicted Label
0 982 0 8 6 0 1 0 1 0 2
1 1 831 14 73 1 59 1 2 0 18
2 6 7 914 26 1 18 0 5 0 23
3 2 67 23 862 1 41 0 2 0 2
4 0 0 0 0 964 0 16 3 17 0
5 2 75 37 77 0 668 0 8 0 133
6 0 0 0 0 16 0 929 1 54 0
7 1 4 6 1 5 8 3 966 0 6
8 0 0 0 0 7 1 17 0 975 0
9 3 9 26 2 0 71 0 6 0 883
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.003:


Confusion Matrix for Learning Rate 0.003
True Label
Predicted Label
0 982 1 7 4 0 2 0 1 0 3
1 1 836 10 85 1 49 0 1 0 17
2 7 11 905 25 1 26 0 5 0 20
3 2 66 30 865 1 34 0 1 0 1
4 0 0 0 0 968 0 18 3 11 0
5 1 72 32 84 0 677 0 7 0 127
6 0 0 0 0 14 0 958 1 27 0
7 1 6 6 0 3 7 3 967 0 7
8 0 0 0 0 5 1 31 0 963 0
9 2 16 22 2 0 73 0 8 0 877
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.001:


Confusion Matrix for Learning Rate 0.001
True Label
Predicted Label
0 978 0 12 3 0 2 0 1 0 4
1 1 841 10 64 1 64 1 1 0 17
2 5 11 911 22 1 26 0 4 0 20
3 2 74 31 851 0 39 0 1 0 2
4 0 0 0 0 962 0 22 2 14 0
5 0 77 31 61 0 710 0 8 0 113
6 0 0 0 0 7 0 970 1 22 0
7 1 5 5 1 3 4 4 971 0 6
8 0 0 0 0 7 1 31 0 961 0
9 3 11 18 2 0 75 0 8 0 883
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

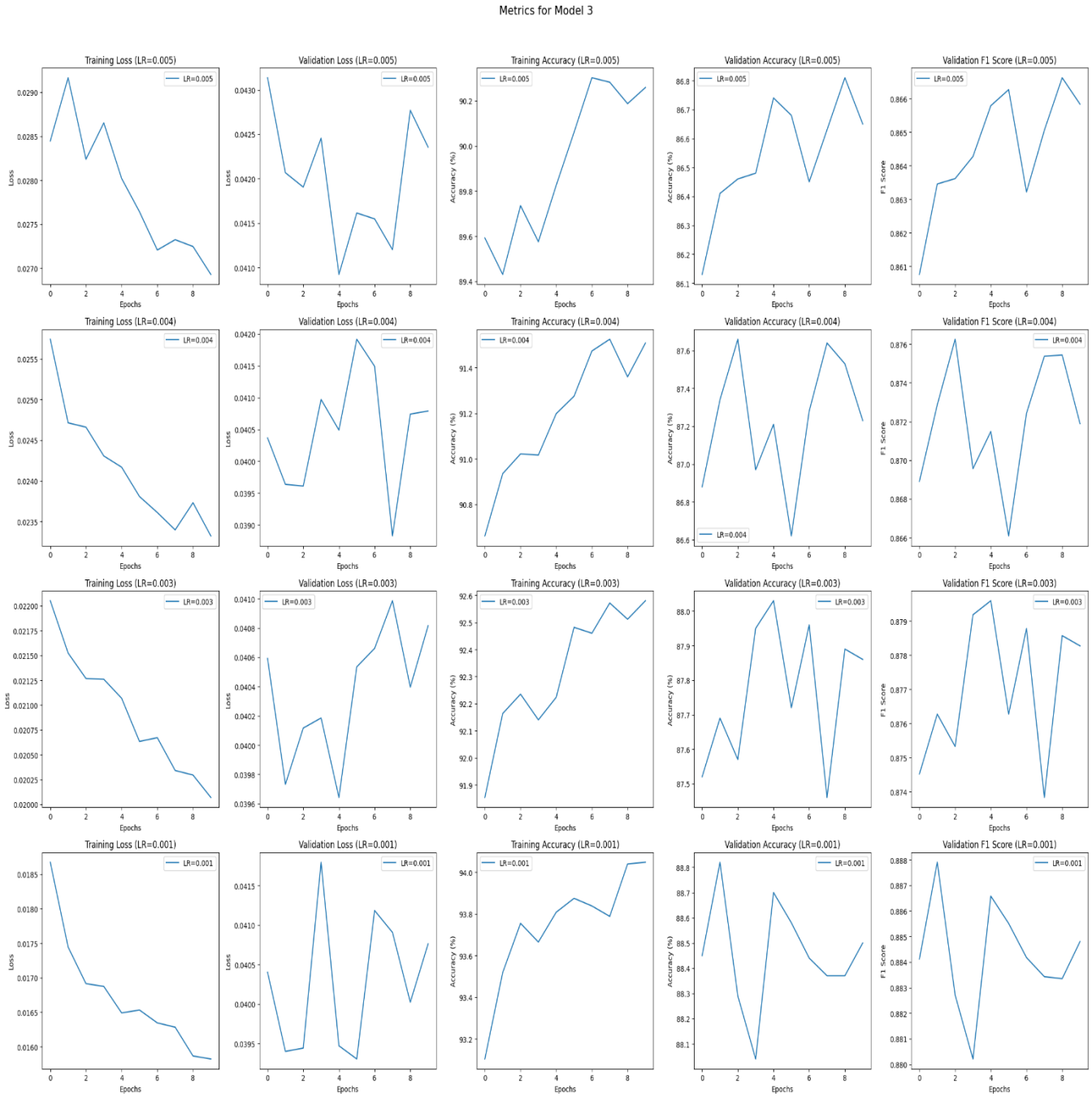
Model 3:

```
FNN([
    DenseLayer(784, 1024),
    BatchNormalizationLayer(1024),
    ReLU(),
    DropoutLayer(0.6),
    DenseLayer(1024, 256),
    ReLU(),
    DropoutLayer(0.35),
    DenseLayer(256, 64),
    ReLU(),
    DenseLayer(64, 10),
    Softmax()
])
```

Performance metrics per Learning rate:

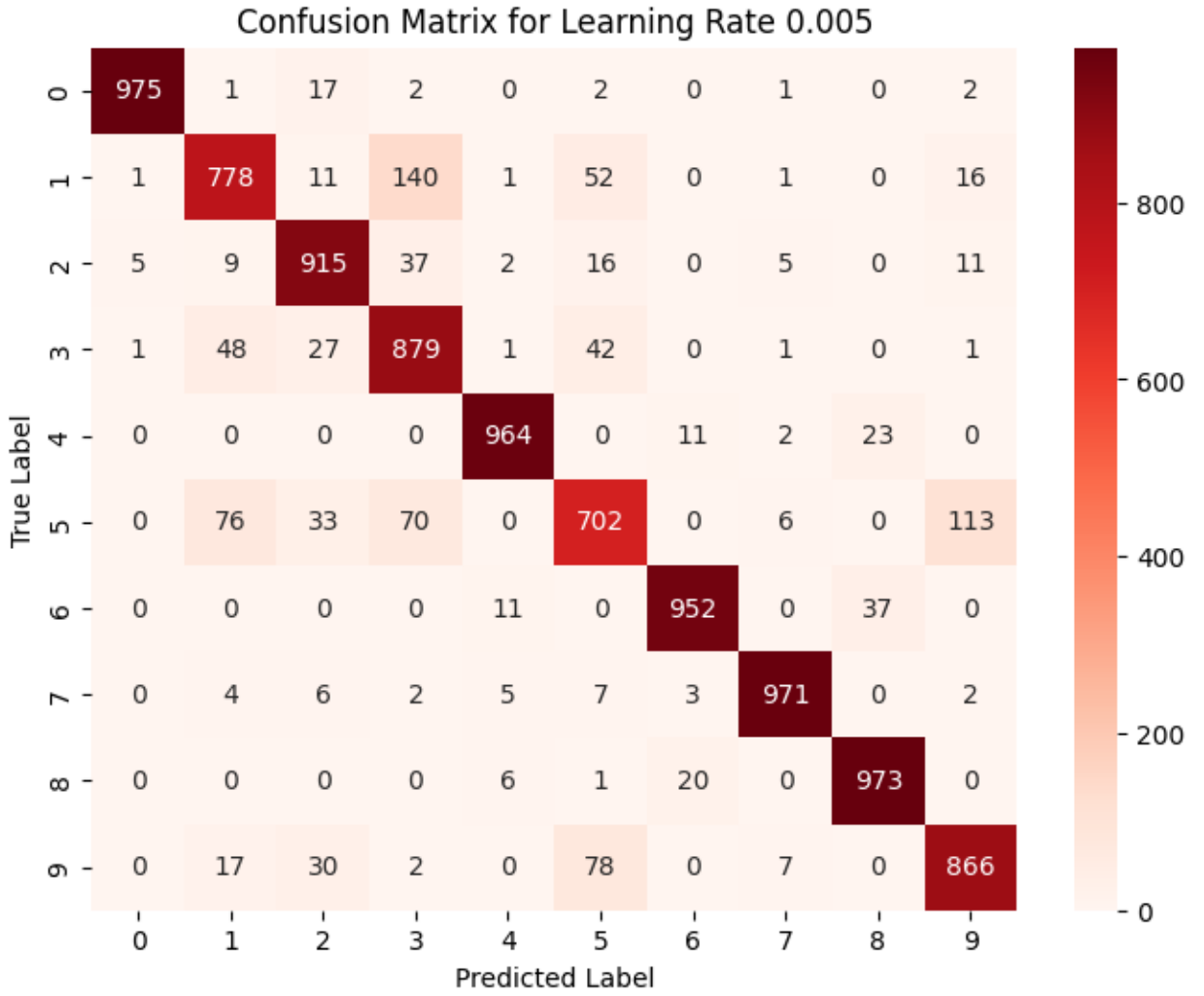
Learning rate	*Performance metrics*
0.005	Test Accuracy: 87.32% Precision: 1.0 Recall: 1.0 F1 Score: 1.0 Specificity: 1.0
0.004	Test Accuracy: 88.21% Precision: 0.9987341772151899 Recall: 1.0 F1 Score: 0.999366687777074 Specificity: 0.9989680082559339
0.003	Test Accuracy: 89.24% Precision: 0.9987654320987654 Recall: 0.9987654320987654 F1 Score: 0.9987654320987654 Specificity: 0.9989775051124744
0.001	Test Accuracy: 89.87% Precision: 0.9987849331713244 Recall: 1.0 F1 Score: 0.9993920972644378 Specificity: 0.9989775051124744

Performance Analysis of Model Across Various Learning Rates

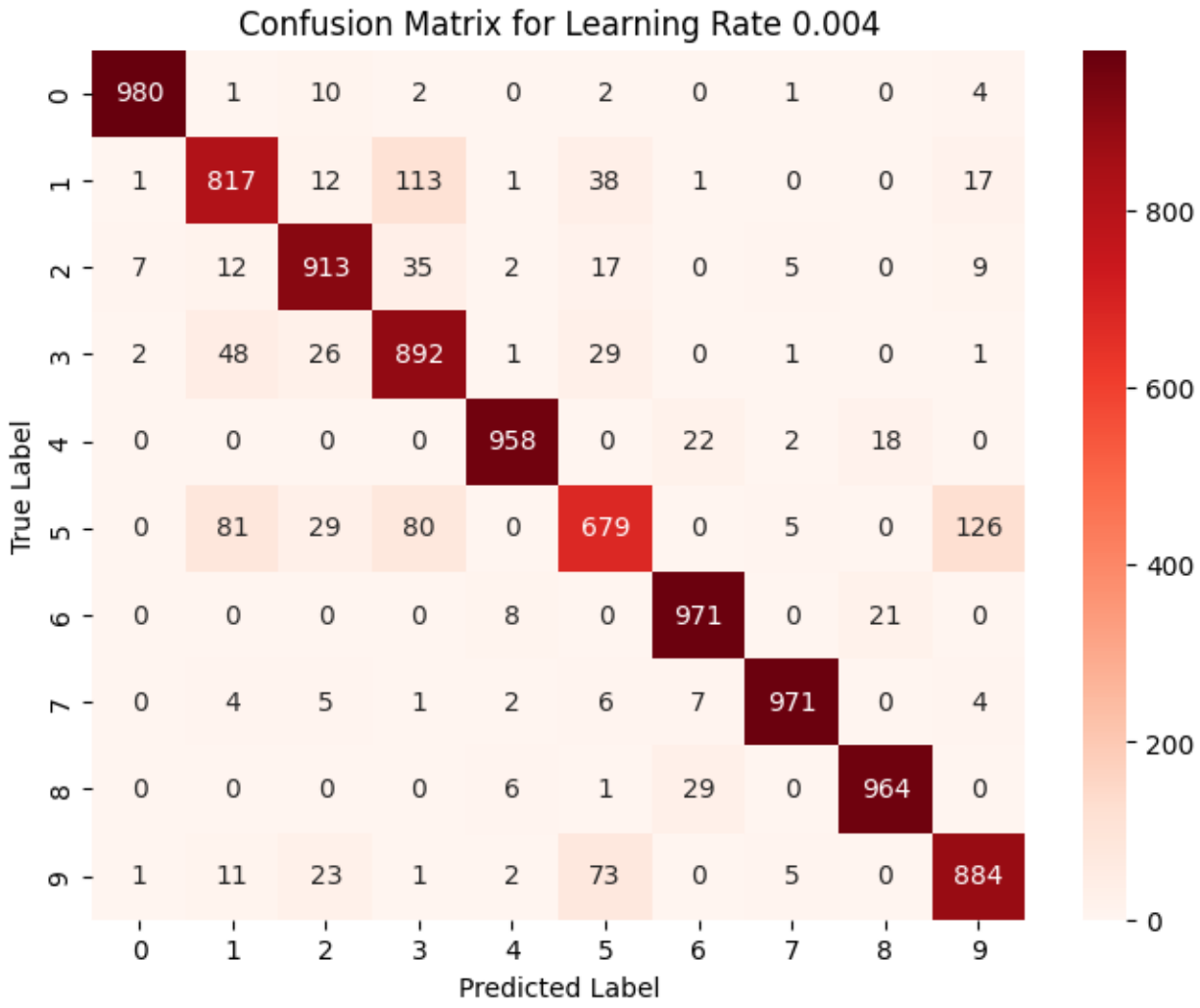


Confusion Matrix per Learning rate:

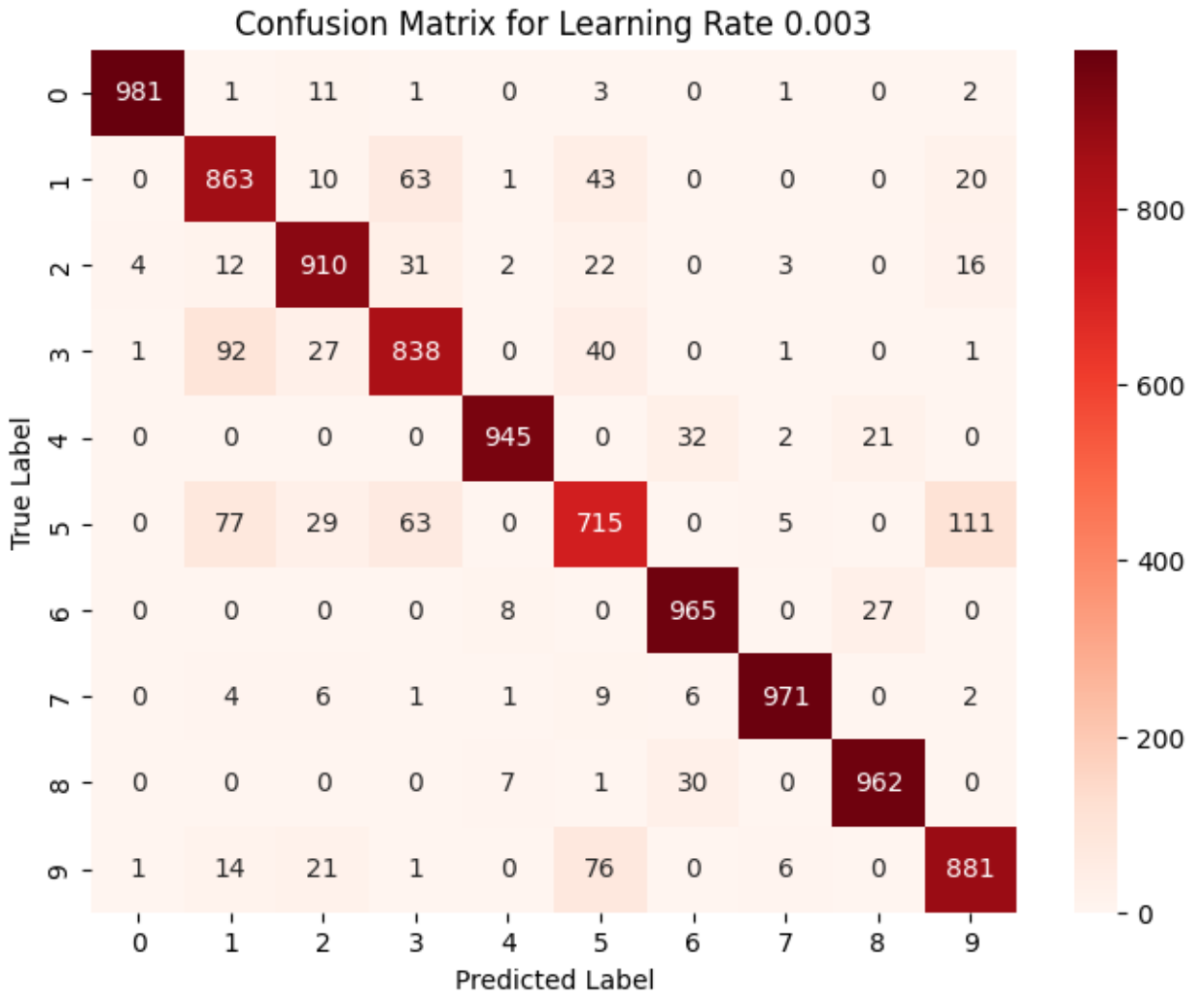
LR – 0.005:



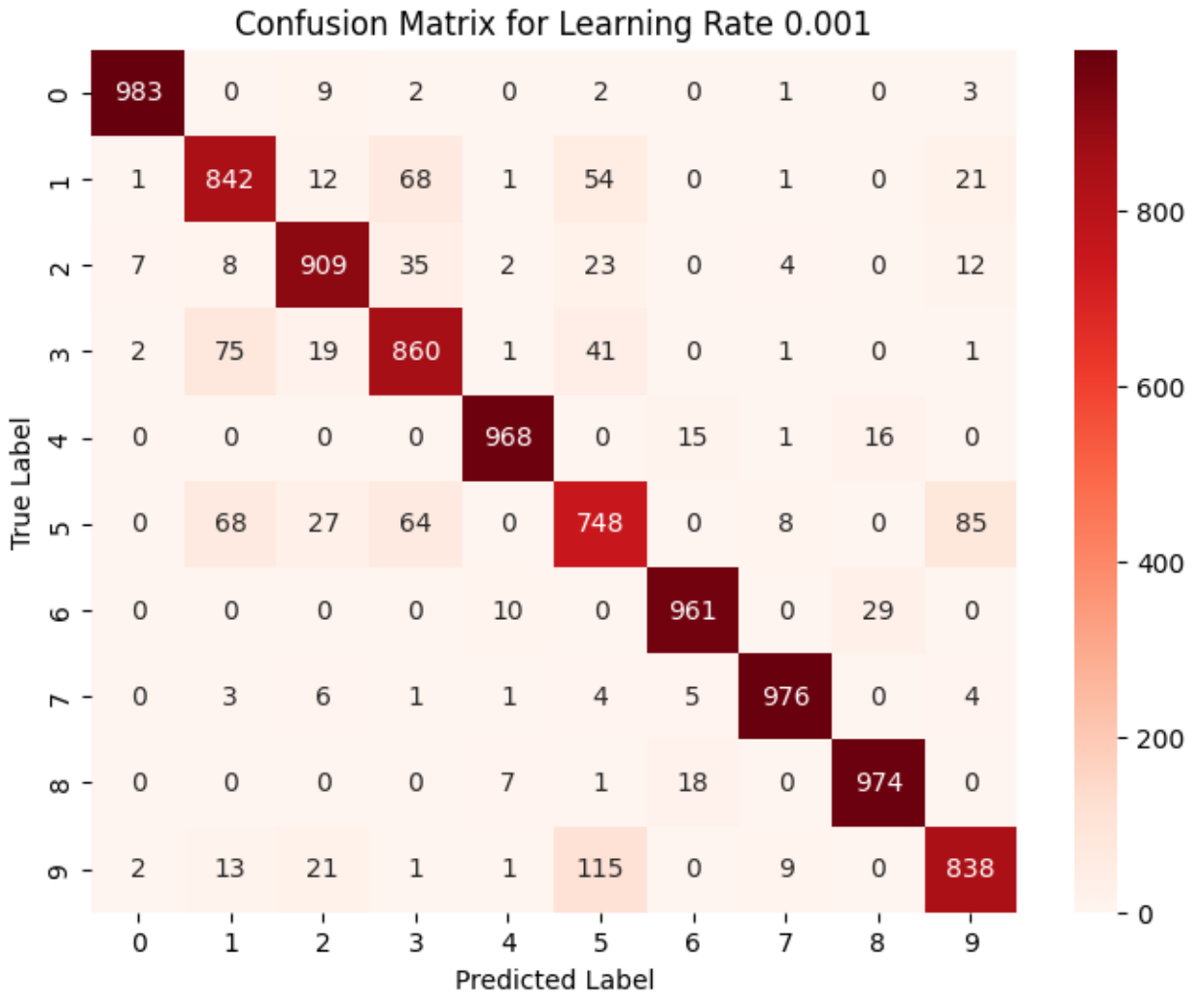
LR – 0.004:


Confusion Matrix for Learning Rate 0.004
True Label
Predicted Label
0 980 1 10 2 0 2 0 1 0 4
1 1 817 12 113 1 38 1 0 0 17
2 7 12 913 35 2 17 0 5 0 9
3 2 48 26 892 1 29 0 1 0 1
4 0 0 0 0 958 0 22 2 18 0
5 0 81 29 80 0 679 0 5 0 126
6 0 0 0 0 8 0 971 0 21 0
7 0 4 5 1 2 6 7 971 0 4
8 0 0 0 0 6 1 29 0 964 0
9 1 11 23 1 2 73 0 5 0 884
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.003:


Confusion Matrix for Learning Rate 0.003
True Label
Predicted Label
0 981 1 11 1 0 3 0 1 0 2
1 0 863 10 63 1 43 0 0 0 20
2 4 12 910 31 2 22 0 3 0 16
3 1 92 27 838 0 40 0 1 0 1
4 0 0 0 0 945 0 32 2 21 0
5 0 77 29 63 0 715 0 5 0 111
6 0 0 0 0 8 0 965 0 27 0
7 0 4 6 1 1 9 6 971 0 2
8 0 0 0 0 7 1 30 0 962 0
9 1 14 21 1 0 76 0 6 0 881
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

LR – 0.001:


Confusion Matrix for Learning Rate 0.001
True Label
Predicted Label
0 983 0 9 2 0 2 0 1 0 3
1 1 842 12 68 1 54 0 1 0 21
2 7 8 909 35 2 23 0 4 0 12
3 2 75 19 860 1 41 0 1 0 1
4 0 0 0 0 968 0 15 1 16 0
5 0 68 27 64 0 748 0 8 0 85
6 0 0 0 0 10 0 961 0 29 0
7 0 3 6 1 1 4 5 976 0 4
8 0 0 0 0 7 1 18 0 974 0
9 2 13 21 1 1 115 0 9 0 838
0 1 2 3 4 5 6 7 8 9
800
600
400
200
0

Best Model Performance:

Learning rate: 0.001

Model: 2

```
Test Accuracy: 90.41%
Precision: 1.0
Recall: 0.9987966305655837
F1 Score: 0.9993979530403371
Specificity: 1.0
```