

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

CSE 472: MACHINE LEARNING SESSIONAL

NAME: FARIA BINTA AWAL

STUDENT ID: 1905012

SECTION: A1

DATE: 8 NOV, 2024

Fashion MNIST Dataset:

We have implemented a feed forward network to predict apparel classes from Fashion MNIST dataset, a vision DL problem.

Different metrics for different models are shown below:

Model Architecture-1:

Composed of 4 different layers (128 nodes, 64 nodes, 32 nodes, 10 nodes). For each layer, activation function is '**ReLU**' except for the output layer where it is '**SoftMax**'. 4 different dropout ratios are taken as 0.4, 0.3, 0.2, 0.0.

Model Architecture-2:

Composed of 3 different layers (256 nodes, 128 nodes, 10 nodes). For each layer, activation function is '**ReLU**' except for the output layer where it is '**SoftMax**'. 3 different dropout ratios are taken as 0.5, 0.4, 0.0.

Model Architecture-3:

Composed of 5 different layers (256 nodes, 64 nodes, 32 nodes, 16 nodes, 10 nodes). For each layer, activation function is '**ReLU**' except for the output layer where it is '**SoftMax**'. 5 different dropout ratios are taken as 0.5, 0.2, 0.2, 0.1.

Learning Rates:

4 different learning rates were explored.

0.02

0.01

0.005

0.001

For the 12 different combinations (3 model architectures and 4 learning rates), confusion matrix is reported as below:

Model -1, LR – 0.001

8.42E+02	1.00E+00	1.00E+01	3.30E+01	2.00E+00	1.00E+00	1.01E+02	0.00E+00	1.00E+01	0.00E+00
4.00E+00	9.57E+02	5.00E+00	2.80E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00
1.60E+01	2.00E+00	7.37E+02	1.50E+01	1.50E+02	0.00E+00	7.70E+01	1.00E+00	2.00E+00	0.00E+00
2.20E+01	7.00E+00	9.00E+00	8.99E+02	2.80E+01	1.00E+00	3.00E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	7.40E+01	3.60E+01	8.26E+02	1.00E+00	5.90E+01	1.00E+00	3.00E+00	0.00E+00
1.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	9.16E+02	0.00E+00	5.40E+01	5.00E+00	2.30E+01
1.39E+02	1.00E+00	9.40E+01	3.20E+01	8.30E+01	0.00E+00	6.39E+02	0.00E+00	1.20E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+01	0.00E+00	9.39E+02	0.00E+00	4.00E+01
1.00E+00	1.00E+00	4.00E+00	1.00E+01	5.00E+00	3.00E+00	6.00E+00	4.00E+00	9.65E+02	1.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E+00	0.00E+00	3.70E+01	1.00E+00	9.53E+02

Model -1, LR – 0.01

8.42E+02	1.00E+00	1.00E+01	3.30E+01	2.00E+00	1.00E+00	1.01E+02	0.00E+00	1.00E+01	0.00E+00
4.00E+00	9.57E+02	5.00E+00	2.80E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00
1.60E+01	2.00E+00	7.37E+02	1.50E+01	1.50E+02	0.00E+00	7.70E+01	1.00E+00	2.00E+00	0.00E+00
2.20E+01	7.00E+00	9.00E+00	8.99E+02	2.80E+01	1.00E+00	3.00E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	7.40E+01	3.60E+01	8.26E+02	1.00E+00	5.90E+01	1.00E+00	3.00E+00	0.00E+00
1.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	9.16E+02	0.00E+00	5.40E+01	5.00E+00	2.30E+01
1.39E+02	1.00E+00	9.40E+01	3.20E+01	8.30E+01	0.00E+00	6.39E+02	0.00E+00	1.20E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+01	0.00E+00	9.39E+02	0.00E+00	4.00E+01
1.00E+00	1.00E+00	4.00E+00	1.00E+01	5.00E+00	3.00E+00	6.00E+00	4.00E+00	9.65E+02	1.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E+00	0.00E+00	3.70E+01	1.00E+00	9.53E+02

Model -1, LR – 0.02

8.42E+02	1.00E+00	1.00E+01	3.30E+01	2.00E+00	1.00E+00	1.01E+02	0.00E+00	1.00E+01	0.00E+00
4.00E+00	9.57E+02	5.00E+00	2.80E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00
1.60E+01	2.00E+00	7.37E+02	1.50E+01	1.50E+02	0.00E+00	7.70E+01	1.00E+00	2.00E+00	0.00E+00
2.20E+01	7.00E+00	9.00E+00	8.99E+02	2.80E+01	1.00E+00	3.00E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	7.40E+01	3.60E+01	8.26E+02	1.00E+00	5.90E+01	1.00E+00	3.00E+00	0.00E+00
1.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	9.16E+02	0.00E+00	5.40E+01	5.00E+00	2.30E+01
1.39E+02	1.00E+00	9.40E+01	3.20E+01	8.30E+01	0.00E+00	6.39E+02	0.00E+00	1.20E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+01	0.00E+00	9.39E+02	0.00E+00	4.00E+01
1.00E+00	1.00E+00	4.00E+00	1.00E+01	5.00E+00	3.00E+00	6.00E+00	4.00E+00	9.65E+02	1.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E+00	0.00E+00	3.70E+01	1.00E+00	9.53E+02

Model -1, LR – 0.005

8.42E+02	1.00E+00	1.00E+01	3.30E+01	2.00E+00	1.00E+00	1.01E+02	0.00E+00	1.00E+01	0.00E+00
4.00E+00	9.57E+02	5.00E+00	2.80E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00
1.60E+01	2.00E+00	7.37E+02	1.50E+01	1.50E+02	0.00E+00	7.70E+01	1.00E+00	2.00E+00	0.00E+00
2.20E+01	7.00E+00	9.00E+00	8.99E+02	2.80E+01	1.00E+00	3.00E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	7.40E+01	3.60E+01	8.26E+02	1.00E+00	5.90E+01	1.00E+00	3.00E+00	0.00E+00
1.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	9.16E+02	0.00E+00	5.40E+01	5.00E+00	2.30E+01
1.39E+02	1.00E+00	9.40E+01	3.20E+01	8.30E+01	0.00E+00	6.39E+02	0.00E+00	1.20E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+01	0.00E+00	9.39E+02	0.00E+00	4.00E+01
1.00E+00	1.00E+00	4.00E+00	1.00E+01	5.00E+00	3.00E+00	6.00E+00	4.00E+00	9.65E+02	1.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.00E+00	0.00E+00	3.70E+01	1.00E+00	9.53E+02

Model – 2, LR – 0.001

8.55E+02	1.00E+00	2.40E+01	3.50E+01	4.00E+00	3.00E+00	6.20E+01	0.00E+00	1.60E+01	0.00E+00
2.00E+00	9.58E+02	9.00E+00	2.40E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	2.00E+00	0.00E+00
2.10E+01	0.00E+00	8.36E+02	1.30E+01	1.10E+02	0.00E+00	1.70E+01	0.00E+00	3.00E+00	0.00E+00
2.40E+01	3.00E+00	1.80E+01	8.94E+02	3.70E+01	1.00E+00	1.90E+01	0.00E+00	4.00E+00	0.00E+00
1.00E+00	0.00E+00	1.31E+02	3.20E+01	8.22E+02	0.00E+00	1.30E+01	0.00E+00	1.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E+02	0.00E+00	2.00E+01	2.00E+00	2.60E+01
1.67E+02	1.00E+00	1.53E+02	3.50E+01	1.23E+02	0.00E+00	5.03E+02	0.00E+00	1.80E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E+01	0.00E+00	9.13E+02	0.00E+00	4.40E+01
3.00E+00	0.00E+00	8.00E+00	6.00E+00	6.00E+00	3.00E+00	0.00E+00	5.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+01	1.00E+00	2.90E+01	0.00E+00	9.59E+02

Model – 2, LR – 0.01

8.55E+02	1.00E+00	2.40E+01	3.50E+01	4.00E+00	3.00E+00	6.20E+01	0.00E+00	1.60E+01	0.00E+00
2.00E+00	9.58E+02	9.00E+00	2.40E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	2.00E+00	0.00E+00
2.10E+01	0.00E+00	8.36E+02	1.30E+01	1.10E+02	0.00E+00	1.70E+01	0.00E+00	3.00E+00	0.00E+00
2.40E+01	3.00E+00	1.80E+01	8.94E+02	3.70E+01	1.00E+00	1.90E+01	0.00E+00	4.00E+00	0.00E+00
1.00E+00	0.00E+00	1.31E+02	3.20E+01	8.22E+02	0.00E+00	1.30E+01	0.00E+00	1.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E+02	0.00E+00	2.00E+01	2.00E+00	2.60E+01
1.67E+02	1.00E+00	1.53E+02	3.50E+01	1.23E+02	0.00E+00	5.03E+02	0.00E+00	1.80E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E+01	0.00E+00	9.13E+02	0.00E+00	4.40E+01
3.00E+00	0.00E+00	8.00E+00	6.00E+00	6.00E+00	3.00E+00	0.00E+00	5.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+01	1.00E+00	2.90E+01	0.00E+00	9.59E+02

Model -2, LR – 0.02

8.55E+02	1.00E+00	2.40E+01	3.50E+01	4.00E+00	3.00E+00	6.20E+01	0.00E+00	1.60E+01	0.00E+00
2.00E+00	9.58E+02	9.00E+00	2.40E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	2.00E+00	0.00E+00
2.10E+01	0.00E+00	8.36E+02	1.30E+01	1.10E+02	0.00E+00	1.70E+01	0.00E+00	3.00E+00	0.00E+00
2.40E+01	3.00E+00	1.80E+01	8.94E+02	3.70E+01	1.00E+00	1.90E+01	0.00E+00	4.00E+00	0.00E+00
1.00E+00	0.00E+00	1.31E+02	3.20E+01	8.22E+02	0.00E+00	1.30E+01	0.00E+00	1.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E+02	0.00E+00	2.00E+01	2.00E+00	2.60E+01
1.67E+02	1.00E+00	1.53E+02	3.50E+01	1.23E+02	0.00E+00	5.03E+02	0.00E+00	1.80E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E+01	0.00E+00	9.13E+02	0.00E+00	4.40E+01
3.00E+00	0.00E+00	8.00E+00	6.00E+00	6.00E+00	3.00E+00	0.00E+00	5.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+01	1.00E+00	2.90E+01	0.00E+00	9.59E+02

Model -2, LR – 0.005

8.55E+02	1.00E+00	2.40E+01	3.50E+01	4.00E+00	3.00E+00	6.20E+01	0.00E+00	1.60E+01	0.00E+00
2.00E+00	9.58E+02	9.00E+00	2.40E+01	4.00E+00	0.00E+00	1.00E+00	0.00E+00	2.00E+00	0.00E+00
2.10E+01	0.00E+00	8.36E+02	1.30E+01	1.10E+02	0.00E+00	1.70E+01	0.00E+00	3.00E+00	0.00E+00
2.40E+01	3.00E+00	1.80E+01	8.94E+02	3.70E+01	1.00E+00	1.90E+01	0.00E+00	4.00E+00	0.00E+00
1.00E+00	0.00E+00	1.31E+02	3.20E+01	8.22E+02	0.00E+00	1.30E+01	0.00E+00	1.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.52E+02	0.00E+00	2.00E+01	2.00E+00	2.60E+01
1.67E+02	1.00E+00	1.53E+02	3.50E+01	1.23E+02	0.00E+00	5.03E+02	0.00E+00	1.80E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E+01	0.00E+00	9.13E+02	0.00E+00	4.40E+01
3.00E+00	0.00E+00	8.00E+00	6.00E+00	6.00E+00	3.00E+00	0.00E+00	5.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+01	1.00E+00	2.90E+01	0.00E+00	9.59E+02

Model -3, LR – 0.001

8.50E+02	2.00E+00	1.30E+01	5.00E+01	6.00E+00	1.00E+00	6.30E+01	1.00E+00	1.40E+01	0.00E+00
2.00E+00	9.68E+02	2.00E+00	2.00E+01	6.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00
1.30E+01	1.00E+00	7.27E+02	1.30E+01	2.04E+02	1.00E+00	3.30E+01	0.00E+00	8.00E+00	0.00E+00
2.30E+01	9.00E+00	1.10E+01	8.89E+02	5.00E+01	0.00E+00	1.40E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	5.80E+01	2.40E+01	9.02E+02	0.00E+00	1.10E+01	1.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	8.48E+02	0.00E+00	7.70E+01	5.00E+00	6.80E+01
1.80E+02	1.00E+00	1.11E+02	4.20E+01	1.95E+02	0.00E+00	4.46E+02	0.00E+00	2.50E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	9.52E+02	0.00E+00	4.40E+01
1.00E+00	1.00E+00	3.00E+00	8.00E+00	7.00E+00	2.00E+00	3.00E+00	6.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00	3.00E+01	1.00E+00	9.67E+02

Model-3, LR – 0.01

8.50E+02	2.00E+00	1.30E+01	5.00E+01	6.00E+00	1.00E+00	6.30E+01	1.00E+00	1.40E+01	0.00E+00
2.00E+00	9.68E+02	2.00E+00	2.00E+01	6.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00
1.30E+01	1.00E+00	7.27E+02	1.30E+01	2.04E+02	1.00E+00	3.30E+01	0.00E+00	8.00E+00	0.00E+00
2.30E+01	9.00E+00	1.10E+01	8.89E+02	5.00E+01	0.00E+00	1.40E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	5.80E+01	2.40E+01	9.02E+02	0.00E+00	1.10E+01	1.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	8.48E+02	0.00E+00	7.70E+01	5.00E+00	6.80E+01
1.80E+02	1.00E+00	1.11E+02	4.20E+01	1.95E+02	0.00E+00	4.46E+02	0.00E+00	2.50E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	9.52E+02	0.00E+00	4.40E+01
1.00E+00	1.00E+00	3.00E+00	8.00E+00	7.00E+00	2.00E+00	3.00E+00	6.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00	3.00E+01	1.00E+00	9.67E+02

Model – 3, LR – 0.02

8.50E+02	2.00E+00	1.30E+01	5.00E+01	6.00E+00	1.00E+00	6.30E+01	1.00E+00	1.40E+01	0.00E+00
2.00E+00	9.68E+02	2.00E+00	2.00E+01	6.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00
1.30E+01	1.00E+00	7.27E+02	1.30E+01	2.04E+02	1.00E+00	3.30E+01	0.00E+00	8.00E+00	0.00E+00
2.30E+01	9.00E+00	1.10E+01	8.89E+02	5.00E+01	0.00E+00	1.40E+01	0.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	5.80E+01	2.40E+01	9.02E+02	0.00E+00	1.10E+01	1.00E+00	4.00E+00	0.00E+00
0.00E+00	0.00E+00	0.00E+00	2.00E+00	0.00E+00	8.48E+02	0.00E+00	7.70E+01	5.00E+00	6.80E+01
1.80E+02	1.00E+00	1.11E+02	4.20E+01	1.95E+02	0.00E+00	4.46E+02	0.00E+00	2.50E+01	0.00E+00
0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E+00	0.00E+00	9.52E+02	0.00E+00	4.40E+01
1.00E+00	1.00E+00	3.00E+00	8.00E+00	7.00E+00	2.00E+00	3.00E+00	6.00E+00	9.69E+02	0.00E+00
0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	0.00E+00	3.00E+01	1.00E+00	9.67E+02

Model -1, LR – 0.001

Class	Precision	Recall	F1-score
Class 0	0.821463	0.842	0.831605
Class 1	0.987616	0.957	0.972067
Class 2	0.789925	0.737	0.762545
Class 3	0.852941	0.899	0.875365
Class 4	0.752277	0.826	0.787417
Class 5	0.962185	0.916	0.938525
Class 6	0.69989	0.639	0.668061
Class 7	0.906371	0.939	0.922397
Class 8	0.962114	0.965	0.963555
Class 9	0.93707	0.953	0.944968
Macro Average	0.867185	0.8673	0.86665

Model -1, LR – 0.01

Class	Precision	Recall	F1-score
Class 0	0.821463	0.842	0.831605
Class 1	0.987616	0.957	0.972067
Class 2	0.789925	0.737	0.762545
Class 3	0.852941	0.899	0.875365
Class 4	0.752277	0.826	0.787417
Class 5	0.962185	0.916	0.938525
Class 6	0.69989	0.639	0.668061
Class 7	0.906371	0.939	0.922397
Class 8	0.962114	0.965	0.963555
Class 9	0.93707	0.953	0.944968
Macro Average	0.867185	0.8673	0.86665

Model – 1, LR – 0.02

Class	Precision	Recall	F1-score
Class 0	0.821463	0.842	0.831605
Class 1	0.987616	0.957	0.972067
Class 2	0.789925	0.737	0.762545
Class 3	0.852941	0.899	0.875365
Class 4	0.752277	0.826	0.787417
Class 5	0.962185	0.916	0.938525
Class 6	0.69989	0.639	0.668061
Class 7	0.906371	0.939	0.922397
Class 8	0.962114	0.965	0.963555
Class 9	0.93707	0.953	0.944968
Macro Average	0.867185	0.8673	0.86665

Model -1, LR – 0.005

Class	Precision	Recall	F1-score
Class 0	0.821463	0.842	0.831605
Class 1	0.987616	0.957	0.972067
Class 2	0.789925	0.737	0.762545
Class 3	0.852941	0.899	0.875365
Class 4	0.752277	0.826	0.787417
Class 5	0.962185	0.916	0.938525
Class 6	0.69989	0.639	0.668061
Class 7	0.906371	0.939	0.922397
Class 8	0.962114	0.965	0.963555
Class 9	0.93707	0.953	0.944968
Macro Average	0.867185	0.8673	0.86665

Model – 2, LR – 0.001

Class 0	0.796831	0.855	0.824891
Class 1	0.994808	0.958	0.976057
Class 2	0.709075	0.836	0.767324
Class 3	0.859615	0.894	0.876471
Class 4	0.743219	0.822	0.780627
Class 5	0.940711	0.952	0.946322
Class 6	0.816558	0.503	0.622525
Class 7	0.944157	0.913	0.928317
Class 8	0.95468	0.969	0.961787
Class 9	0.931973	0.959	0.945293
Macro Average	0.869163	0.8661	0.862961

Model – 2, LR – 0.01

Class	Precision	Recall	F1-score
Class 0	0.796831	0.855	0.824891
Class 1	0.994808	0.958	0.976057
Class 2	0.709075	0.836	0.767324
Class 3	0.859615	0.894	0.876471
Class 4	0.743219	0.822	0.780627
Class 5	0.940711	0.952	0.946322
Class 6	0.816558	0.503	0.622525
Class 7	0.944157	0.913	0.928317
Class 8	0.95468	0.969	0.961787
Class 9	0.931973	0.959	0.945293
Macro Average	0.869163	0.8661	0.862961

Model -2, LR – 0.02

Class	Precision	Recall	F1-score
Class 0	0.796831	0.855	0.824891
Class 1	0.994808	0.958	0.976057
Class 2	0.709075	0.836	0.767324
Class 3	0.859615	0.894	0.876471
Class 4	0.743219	0.822	0.780627
Class 5	0.940711	0.952	0.946322
Class 6	0.816558	0.503	0.622525
Class 7	0.944157	0.913	0.928317
Class 8	0.95468	0.969	0.961787
Class 9	0.931973	0.959	0.945293
Macro Average	0.869163	0.8661	0.862961

Model -2, LR – 0.005

Class	Precision	Recall	F1-score
Class 0	0.796831	0.855	0.824891
Class 1	0.994808	0.958	0.976057
Class 2	0.709075	0.836	0.767324
Class 3	0.859615	0.894	0.876471
Class 4	0.743219	0.822	0.780627
Class 5	0.940711	0.952	0.946322
Class 6	0.816558	0.503	0.622525
Class 7	0.944157	0.913	0.928317
Class 8	0.95468	0.969	0.961787
Class 9	0.931973	0.959	0.945293
Macro Average	0.869163	0.8661	0.862961

Model -3, LR -0.001

Class	Precision	Recall	F1-score
Class 0	0.795136	0.85	0.821653
Class 1	0.985743	0.968	0.976791
Class 2	0.785946	0.727	0.755325
Class 3	0.847474	0.889	0.86774
Class 4	0.658394	0.902	0.761181
Class 5	0.989498	0.848	0.913301
Class 6	0.782456	0.446	0.568153
Class 7	0.892221	0.952	0.921142
Class 8	0.938953	0.969	0.95374
Class 9	0.8962	0.967	0.930255
Macro Average	0.857202	0.8518	0.846928

Model -3, LR – 0.01

Class	Precision	Recall	F1-score
Class 0	0.795136	0.85	0.821653
Class 1	0.985743	0.968	0.976791
Class 2	0.785946	0.727	0.755325
Class 3	0.847474	0.889	0.86774
Class 4	0.658394	0.902	0.761181
Class 5	0.989498	0.848	0.913301
Class 6	0.782456	0.446	0.568153
Class 7	0.892221	0.952	0.921142
Class 8	0.938953	0.969	0.95374
Class 9	0.8962	0.967	0.930255
Macro Average	0.857202	0.8518	0.846928

Model – 3, LR – 0.02

Class	Precision	Recall	F1-score
Class 0	0.795136	0.85	0.821653
Class 1	0.985743	0.968	0.976791
Class 2	0.785946	0.727	0.755325
Class 3	0.847474	0.889	0.86774
Class 4	0.658394	0.902	0.761181
Class 5	0.989498	0.848	0.913301
Class 6	0.782456	0.446	0.568153
Class 7	0.892221	0.952	0.921142
Class 8	0.938953	0.969	0.95374
Class 9	0.8962	0.967	0.930255
Macro Average	0.857202	0.8518	0.846928

Model -3, LR – 0.005

Class	Precision	Recall	F1-score
Class 0	0.795136	0.85	0.821653
Class 1	0.985743	0.968	0.976791
Class 2	0.785946	0.727	0.755325
Class 3	0.847474	0.889	0.86774
Class 4	0.658394	0.902	0.761181
Class 5	0.989498	0.848	0.913301
Class 6	0.782456	0.446	0.568153
Class 7	0.892221	0.952	0.921142
Class 8	0.938953	0.969	0.95374
Class 9	0.8962	0.967	0.930255
Macro Average	0.857202	0.8518	0.846928

Instructions on how to run the model:

The model's flow starts from building a model architecture, which defines the number of layers and each layer's configuration (number of nodes/units per layer, dropout rate, activation function). After that, the model has to be compiled. Here compilation sets the overall optimizer, loss function and learning rate. Now we are all set to train model on training dataset previously prepared. To train up the model, 4 parameters are required. The training features, corresponding target labels, number of epochs and batch size (for mini-batch stochastic gradient update) – these 4 parameters are to pass through the `model.fit()` function. After that, we have prepared our model and we want to test it. We will get the predicted class labels after we pass the `x_test` dataset via the `model.predict()` function. So, now we are ready to check different performance metrics like accuracy, precision, recall, f1-score and confusion matrix.

Saved Model Parameters:

The best model is taken out of different 3 models with 4 different learning rates. The weights and biases of each nodes in each layer has been saved using python's pickle library function which is used to save different object instances. We also needed to save different batch normalization parameters. The parameters are organized into 3 different classes and the `BatchNormalization` class has instances of these parameter classes. After we have saved these, we can reload them again using the pickle code and set our model without even training them again for quick demonstration purpose.

