CSE 472
Offline 4

Bangla Character Recognition Challenge

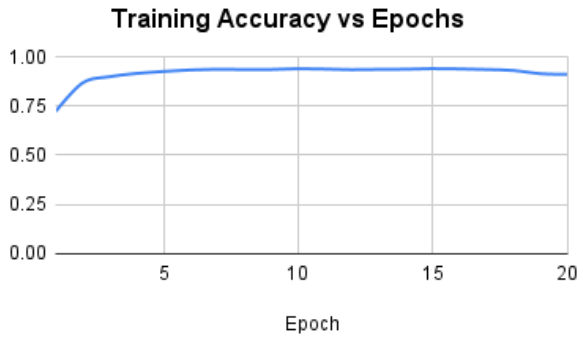
Architecture
(Lenet)

Submitted by:

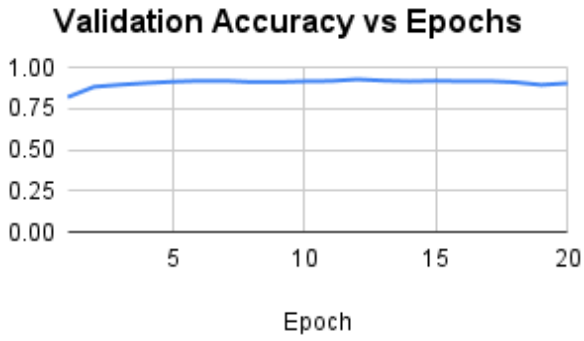
Istiak Bin Mahmod
1705073

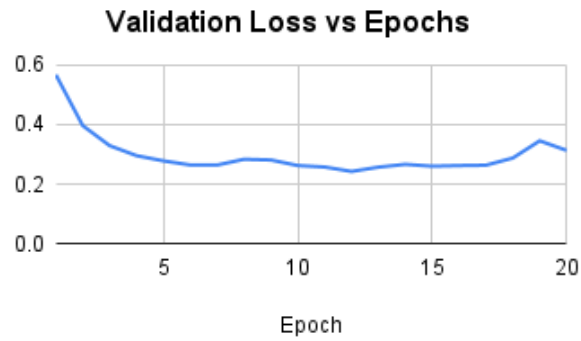
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.0005:

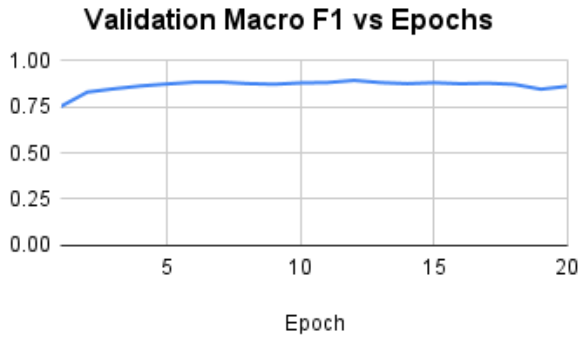
Epoch	Training Accuracy	Training Loss	Validation Accuracy	Validation Loss	Validation Macro F1
1	0.72225	0.8543	0.8192	0.5658	0.7509
2	0.8672	0.4239	0.88196	0.3957	0.8288
3	0.8986	0.3281	0.89455	0.32878	0.8466
4	0.9151	0.27735	0.9046	0.29527	0.8618
5	0.9253	0.2422	0.9129	0.277807	0.8726
6	0.9329	0.219345	0.9181	0.2641	0.88205
7	0.9363	0.2038	0.9179	0.26387	0.88278
8	0.93481	0.20511	0.91074	0.28315	0.87475
9	0.93528	0.201867	0.91074	0.2808	0.87104
10	0.9391	0.19321	0.9152	0.2622	0.878258
11	0.9373	0.19478	0.91704	0.25726	0.88015
12	0.93428	0.20529	0.9269	0.2425	0.89193
13	0.93578	0.199	0.9195	0.2568	0.8799
14	0.9367	0.1943	0.915	0.2662	0.87437
15	0.93957	0.18455	0.9183	0.26	0.8794
16	0.9381	0.19	0.9154	0.2621	0.87381
17	0.9351	0.1957	0.9165	0.2633	0.8766
18	0.9301	0.21247	0.9096	0.2873	0.87053
19	0.9138	0.2616	0.8936	0.34487	0.84429
20	0.91037	0.2723	0.9033	0.31286	0.86025

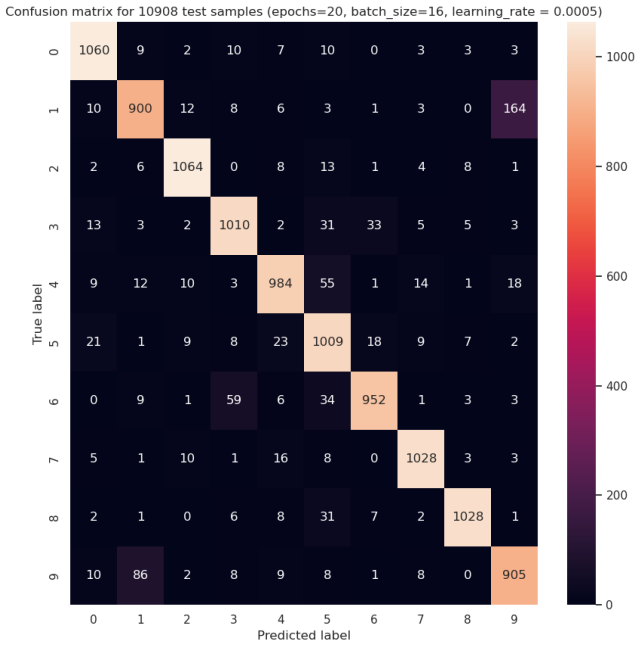

Training Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Training Loss vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Validation Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

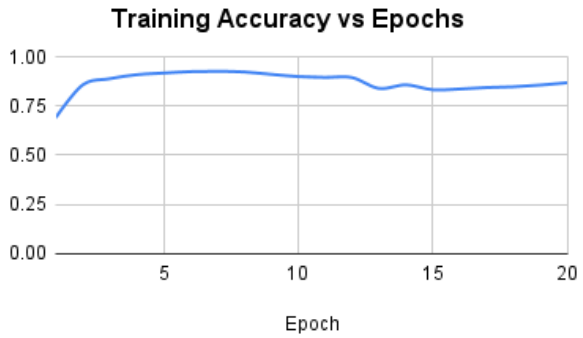

Validation Loss vs Epochs
0.6
0.4
0.2
0.0
5
10
15
20
Epoch


Validation Macro F1 vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

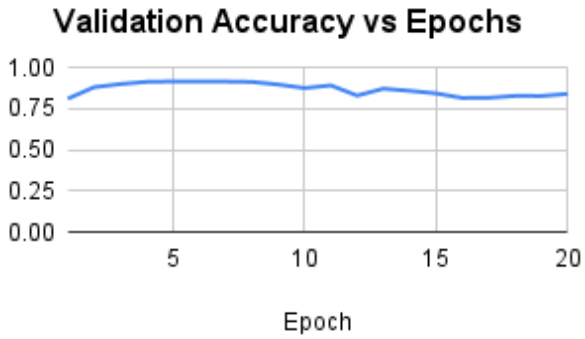

Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.0005)
True label
Predicted label
0 1060 9 2 10 7 10 0 3 3 3
1 10 900 12 8 6 3 1 3 0 164
2 2 6 1064 0 8 13 1 4 8 1
3 13 3 2 1010 2 31 33 5 5 3
4 9 12 10 3 984 55 1 14 1 18
5 21 1 9 8 23 1009 18 9 7 2
6 0 9 1 59 6 34 952 1 3 3
7 5 1 10 1 16 8 0 1028 3 3
8 2 1 0 6 8 31 7 2 1028 1
9 10 86 2 8 9 8 1 8 0 905
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0

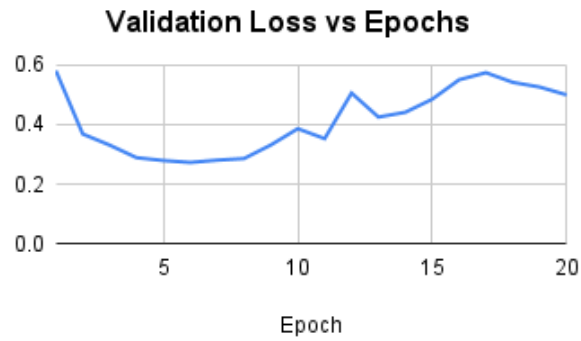
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.00075:

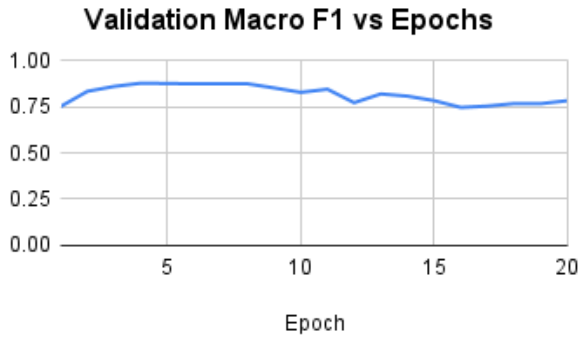
Epoch	Training Accuracy	Training Loss	Validation Accuracy	Validation Loss	Validation Macro F1
1	0.690204	0.94729	0.810026	0.57948	0.75115
2	0.85672	0.44756	0.87949	0.36767	0.8329
3	0.88825	0.3466	0.89860	0.33059	0.8593
4	0.9087	0.28707	0.91209	0.2885	0.87673
5	0.91707	0.261399	0.91434	0.2789	0.87518
6	0.924329	0.238616	0.914118	0.272547	0.87346
7	0.926	0.233438	0.91389	0.28015	0.87415
8	0.9227	0.2433447	0.91164	0.2855	0.87372
9	0.9105	0.277069	0.89568	0.33106	0.85122
10	0.8993	0.31446	0.8743255	0.3854	0.82733
11	0.89503	0.32782	0.890512	0.35218	0.84425
12	0.89405	0.32925	0.82868	0.5047	0.77141
13	0.839	0.48697	0.8707	0.4243	0.81876
14	0.857	0.43729	0.857464	0.44024	0.80685
15	0.83216	0.506305	0.84195	0.484	0.78246
16	0.83601	0.5	0.81429	0.549	0.7458
17	0.84355	0.47336	0.8154	0.5728	0.75314
18	0.84738	0.4627	0.82666	0.5404	0.7666
19	0.8562	0.435687	0.8264	0.5247	0.7663
20	0.86806	0.40298	0.8388	0.4986	0.7824

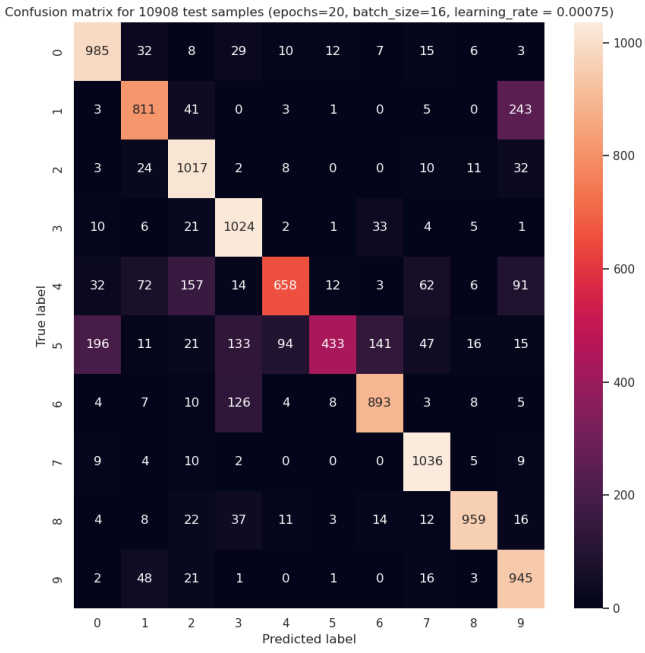

Training Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Training Loss vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Validation Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

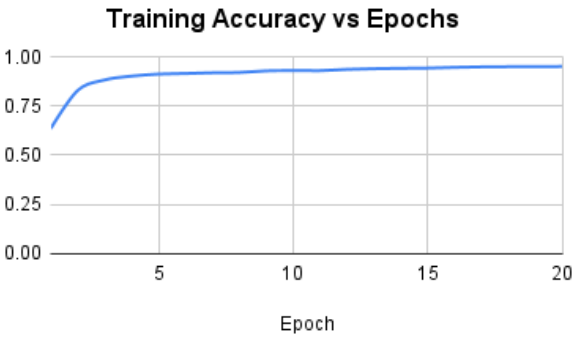

Validation Loss vs Epochs
0.6
0.4
0.2
0.0
5
10
15
20
Epoch

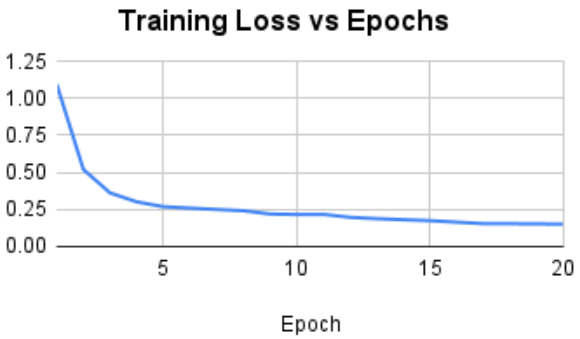

Validation Macro F1 vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

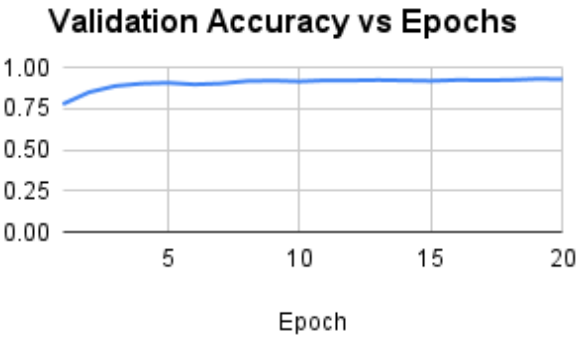

Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.00075)
True label
Predicted label
0 985 32 8 29 10 12 7 15 6 3
1 3 811 41 0 3 1 0 5 0 243
2 3 24 1017 2 8 0 0 10 11 32
3 10 6 21 1024 2 1 33 4 5 1
4 32 72 157 14 658 12 3 62 6 91
5 196 11 21 133 94 433 141 47 16 15
6 4 7 10 126 4 8 893 3 8 5
7 9 4 10 2 0 0 0 1036 5 9
8 4 8 22 37 11 3 14 12 959 16
9 2 48 21 1 0 1 0 16 3 945
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0

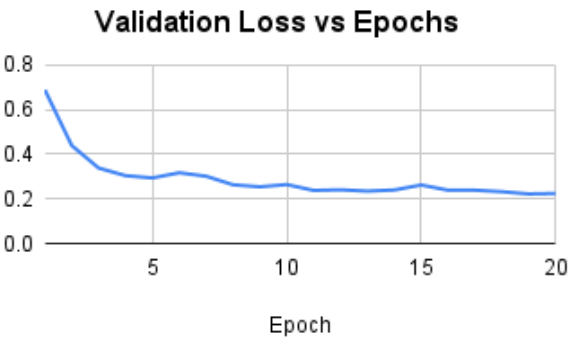
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.001:

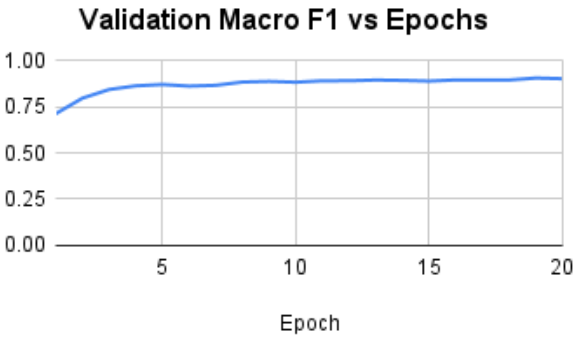
Epoch	Training Accuracy	Training Loss	Validation Accuracy	Validation Loss	Validation Macro F1
1	0.6349	1.09467	0.7769	0.687	0.71184
2	0.8285	0.51979	0.8491	0.4389	0.79582
3	0.8819	0.36162	0.88691	0.33847	0.84262
4	0.9015	0.30106	0.9013	0.3045	0.86253
5	0.91178	0.26845	0.906	0.29427	0.86973
6	0.9149	0.25907	0.89635	0.31739	0.861132
7	0.9184	0.24974	0.90175	0.30197	0.86538
8	0.92009	0.24126	0.91659	0.2638	0.88306
9	0.92818	0.219	0.91928	0.2547	0.88653
10	0.93026	0.2159	0.91456	0.2648	0.88214
11	0.9294	0.21645	0.92108	0.23867	0.88972
12	0.9357	0.19657	0.9206	0.24133	0.88995
13	0.93925	0.1874	0.92288	0.23553	0.89401
14	0.94113	0.18053	0.92041	0.24057	0.89193
15	0.94245	0.1742	0.91771	0.26285	0.88816
16	0.94601	0.163849	0.9231	0.23958	0.894497
17	0.94854	0.154	0.922	0.2396	0.8945
18	0.9495	0.1535	0.923	0.233	0.894
19	0.94952	0.1526	0.9292	0.2229	0.9047
20	0.95062	0.1502	0.928	0.225	0.9012

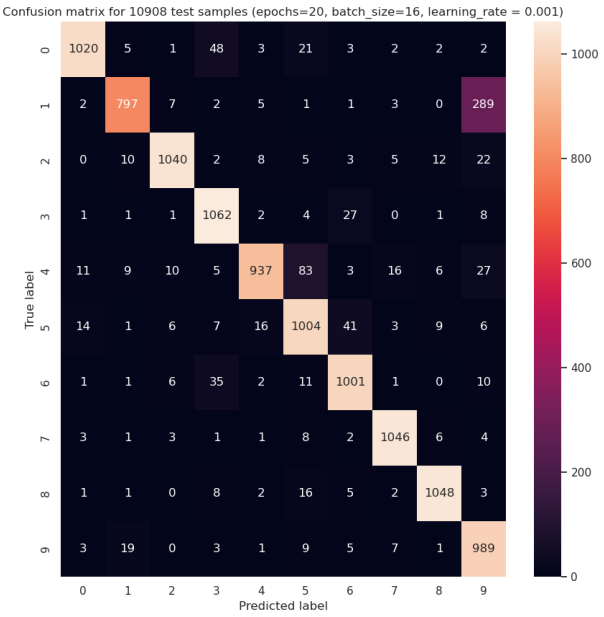

Training Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Training Loss vs Epochs
1.25
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch


Validation Accuracy vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

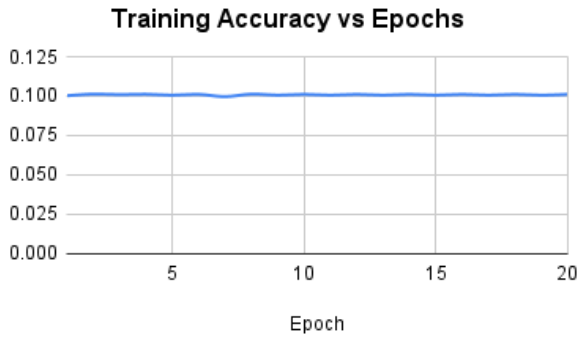

Validation Loss vs Epochs
0.8
0.6
0.4
0.2
0.0
5
10
15
20
Epoch


Validation Macro F1 vs Epochs
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Epoch

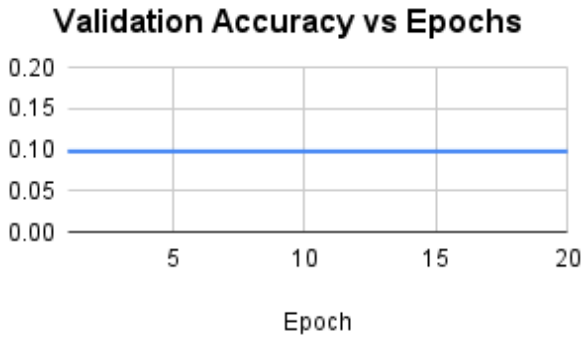

Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.001)
True label
Predicted label
0 1020 5 1 48 3 21 3 2 2 2
1 2 797 7 2 5 1 1 3 0 289
2 0 10 1040 2 8 5 3 5 12 22
3 1 1 1 1062 2 4 27 0 1 8
4 11 9 10 5 937 83 3 16 6 27
5 14 1 6 7 16 1004 41 3 9 6
6 1 1 6 35 2 11 1001 1 0 10
7 3 1 3 1 1 8 2 1046 6 4
8 1 1 0 8 2 16 5 2 1048 3
9 3 19 0 3 1 9 5 7 1 989
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0

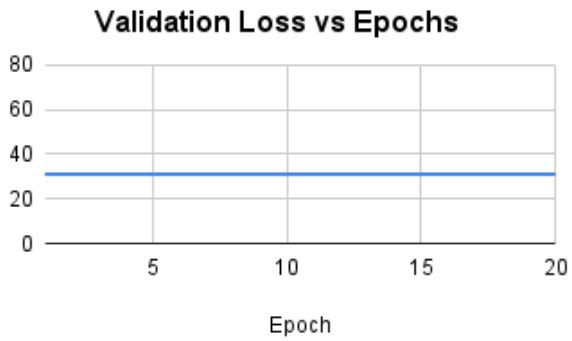
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.005:

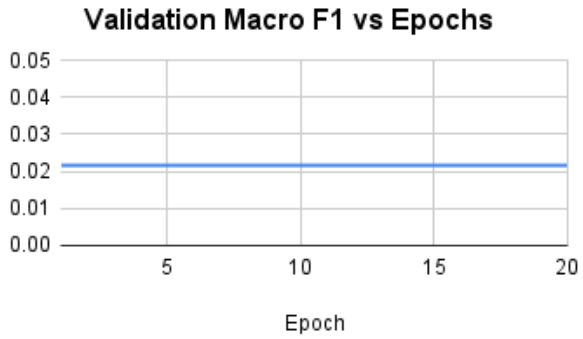
Epoch	Training Accuracy	Training Loss	Validation Accuracy	Validation Loss	Validation Macro F1
1	0.100235	31.06659	0.09802	31.15323	0.02163
2	0.101262	31.0413	0.09802	31.15323	0.02163
3	0.10094	31.05255	0.09802	31.15323	0.02163
4	0.10116	31.04478	0.09802	31.15323	0.02163
5	0.10059	31.06466	0.09802	31.15323	0.02163
6	0.1011	31.0465	0.09802	31.15323	0.02163
7	0.099659	31.097	0.09802	31.15323	0.02163
8	0.10124	31.042175	0.09802	31.15323	0.02163
9	0.100586	31.06466	0.09802	31.15323	0.02163
10	0.1011	31.0465	0.09802	31.15323	0.02163
11	0.100586	31.06466	0.09802	31.15323	0.02163
12	0.1011	31.0465	0.09802	31.15323	0.02163
13	0.100586	31.06466	0.09802	31.15323	0.02163
14	0.1011	31.0465	0.09802	31.15323	0.02163
15	0.100586	31.06466	0.09802	31.15323	0.02163
16	0.1011	31.0465	0.09802	31.15323	0.02163
17	0.100586	31.06466	0.09802	31.15323	0.02163
18	0.1011	31.0465	0.09802	31.15323	0.02163
19	0.100586	31.06466	0.09802	31.15323	0.02163
20	0.1011	31.0465	0.09802	31.15323	0.02163

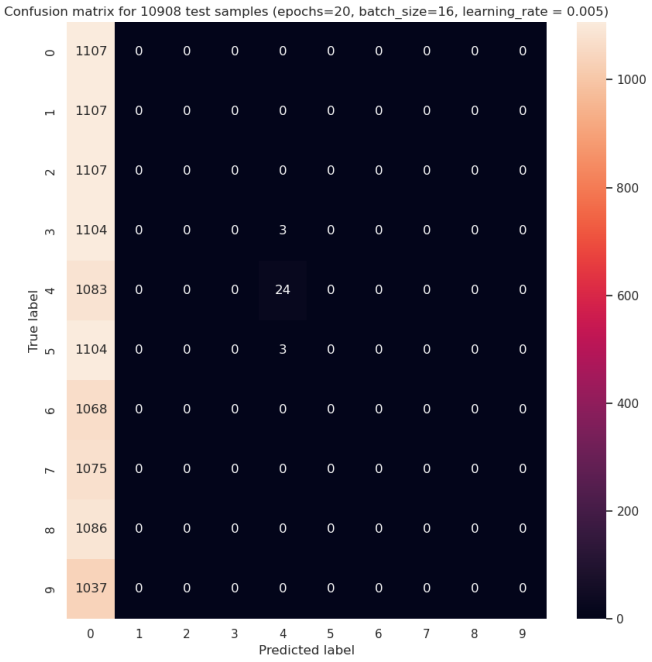

Training Accuracy vs Epochs
0.125
0.100
0.075
0.050
0.025
0.000
5
10
15
20
Epoch


Training Loss vs Epochs
40
30
20
10
0
5
10
15
20
Epoch


Validation Accuracy vs Epochs
0.20
0.15
0.10
0.05
0.00
5
10
15
20
Epoch

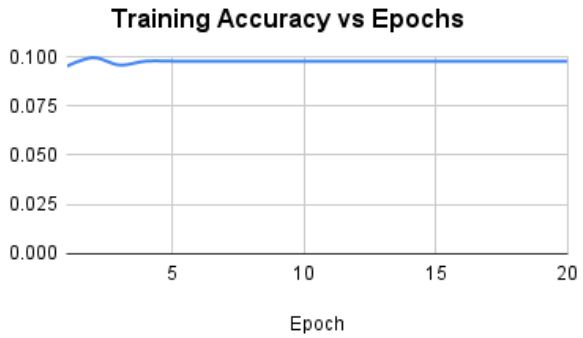

Validation Loss vs Epochs
80
60
40
20
0
5
10
15
20
Epoch


Validation Macro F1 vs Epochs
0.05
0.04
0.03
0.02
0.01
0.00
5
10
15
20
Epoch

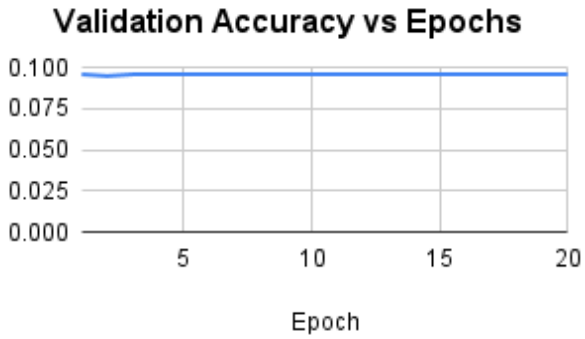

Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.005)
True label
Predicted label
0 1107 0 0 0 0 0 0 0 0 0
1 1107 0 0 0 0 0 0 0 0 0
2 1107 0 0 0 0 0 0 0 0 0
3 1104 0 0 0 3 0 0 0 0 0
4 1083 0 0 0 24 0 0 0 0 0
5 1104 0 0 0 3 0 0 0 0 0
6 1068 0 0 0 0 0 0 0 0 0
7 1075 0 0 0 0 0 0 0 0 0
8 1086 0 0 0 0 0 0 0 0 0
9 1037 0 0 0 0 0 0 0 0 0
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0

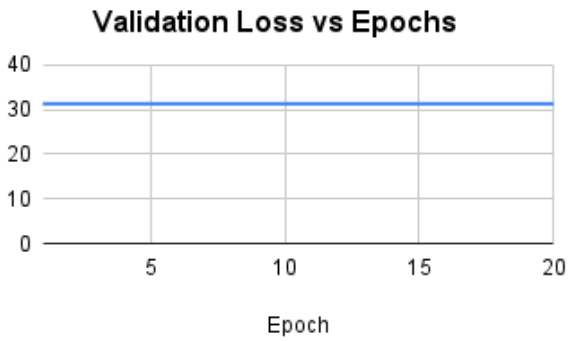
Trained Images = 18000, Batch Size = 32, Learning Rate = 0.01:

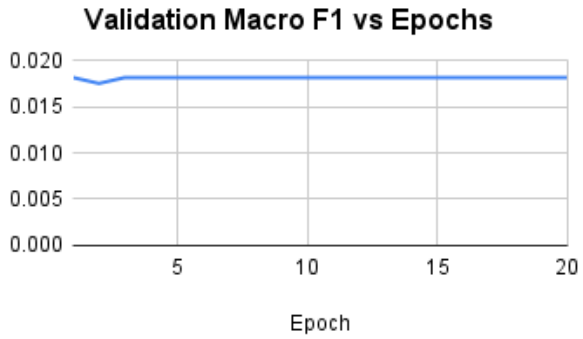
Epoch	Training Accuracy	Training Loss	Validation Accuracy	Validation Loss	Validation Macro F1
1	0.095193	31.220907	0.09573	31.23223	0.01815
2	0.09952	31.101386	0.09474	31.2665	0.01751
3	0.095804	31.229833	0.09573	31.23224	0.01815
4	0.09774	31.16273	0.09573	31.23224	0.01815
5	0.09774	31.16273	0.09573	31.23224	0.01815
6	0.09774	31.16273	0.09573	31.23224	0.01815
7	0.09774	31.16273	0.09573	31.23224	0.01815
8	0.09774	31.16273	0.09573	31.23224	0.01815
9	0.09774	31.16273	0.09573	31.23224	0.01815
10	0.09774	31.16273	0.09573	31.23224	0.01815
11	0.09774	31.16273	0.09573	31.23224	0.01815
12	0.09774	31.16273	0.09573	31.23224	0.01815
13	0.09774	31.16273	0.09573	31.23224	0.01815
14	0.09774	31.16273	0.09573	31.23224	0.01815
15	0.09774	31.16273	0.09573	31.23224	0.01815
16	0.09774	31.16273	0.09573	31.23224	0.01815
17	0.09774	31.16273	0.09573	31.23224	0.01815
18	0.09774	31.16273	0.09573	31.23224	0.01815
19	0.09774	31.16273	0.09573	31.23224	0.01815
20	0.09774	31.16273	0.09573	31.23224	0.01815

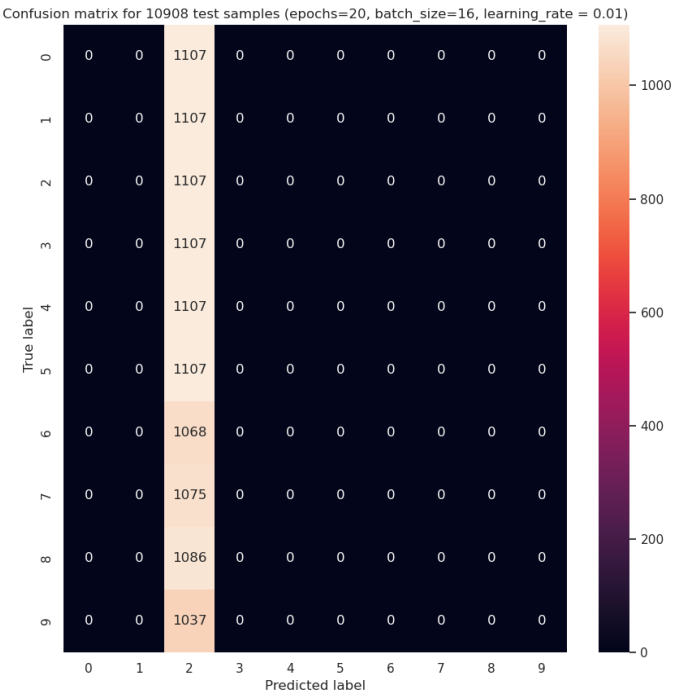

Training Accuracy vs Epochs
0.100
0.075
0.050
0.025
0.000
5
10
15
20
Epoch


Training Loss vs Epochs
40
30
20
10
0
5
10
15
20
Epoch


Validation Accuracy vs Epochs
0.100
0.075
0.050
0.025
0.000
5
10
15
20
Epoch


Validation Loss vs Epochs
40
30
20
10
0
5
10
15
20
Epoch


Validation Macro F1 vs Epochs
0.020
0.015
0.010
0.005
0.000
5
10
15
20
Epoch


Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.01)
True label
Predicted label
0 1 2 3 4 5 6 7 8 9
0 0 1107 0 0 0 0 0 0 0
0 0 1107 0 0 0 0 0 0 0
0 0 1107 0 0 0 0 0 0 0
0 0 1107 0 0 0 0 0 0 0
0 0 1107 0 0 0 0 0 0 0
0 0 1107 0 0 0 0 0 0 0
0 0 1068 0 0 0 0 0 0 0
0 0 1075 0 0 0 0 0 0 0
0 0 1086 0 0 0 0 0 0 0
0 0 1037 0 0 0 0 0 0 0
1000
800
600
400
200
0

Best Learning Rate (for Lenet):

From the above data, the best learning rate = 0.001. The best macro f1 score is 0.9047

But if we take a subset of the training data (for example 27000 images), both the accuracy and macro f1 score of the validation set slightly increases. The macro f1 score rises up to 0.9104.

So, the model that performs best has following properties:
Trained Images = 27000
Batch Size = 16
No. of Epochs = 20
Learning Rate = 0.001

Independent Test Performance:

Test Accuracy: 0.9306573802541543
Test F1 Score: 0.8976116055080237