

CSE 472
Offline 4

Bangla Character Recognition Challenge

Architecture
([Lenet](#))

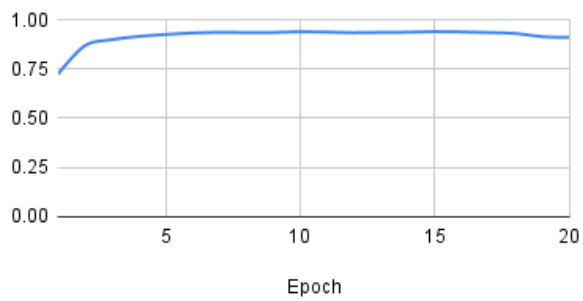
Submitted by:

Md. Tanzim Azad
1705074

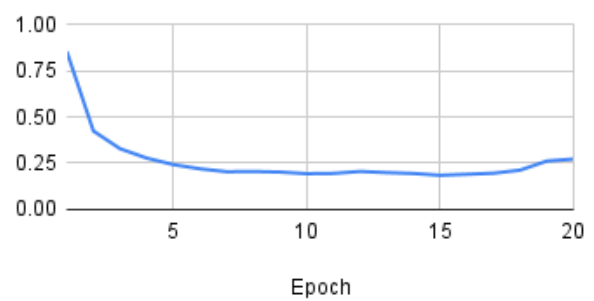
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.0005:

| 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 |

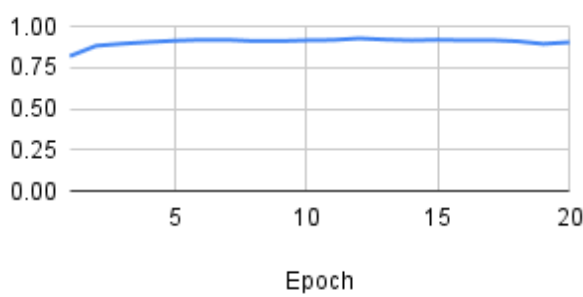
Training Accuracy vs Epochs



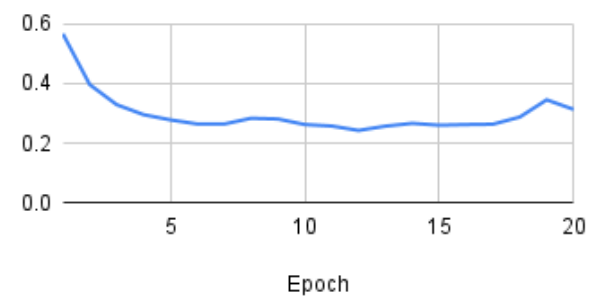
Training Loss vs Epochs



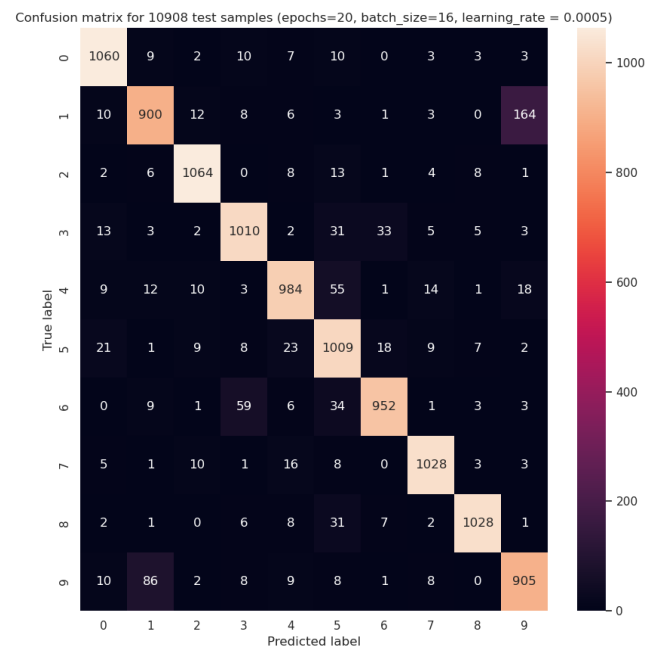
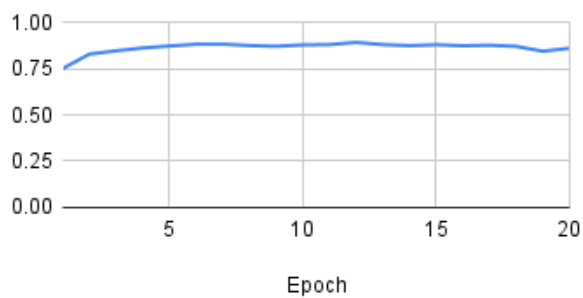
Validation Accuracy vs Epochs



Validation Loss vs Epochs



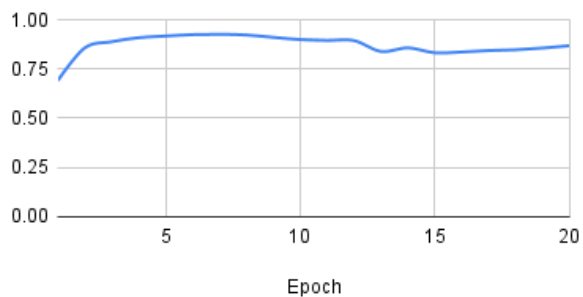
Validation Macro F1 vs Epochs



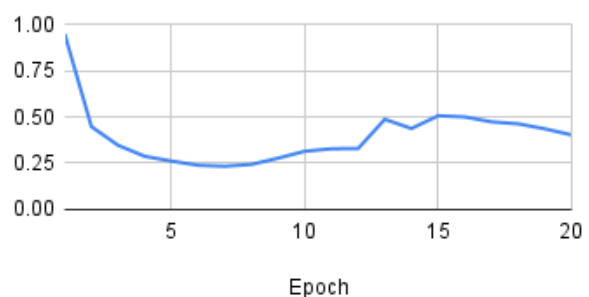
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.00075:

| 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 |

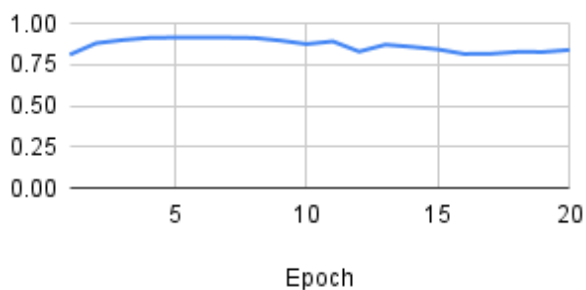
Training Accuracy vs Epochs



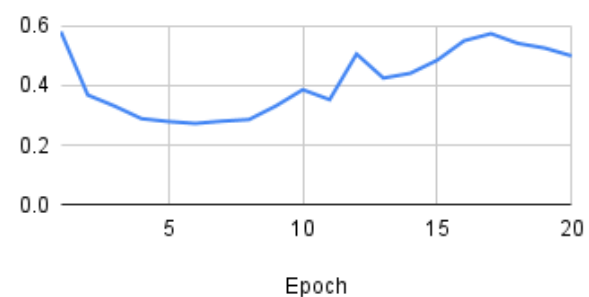
Training Loss vs Epochs



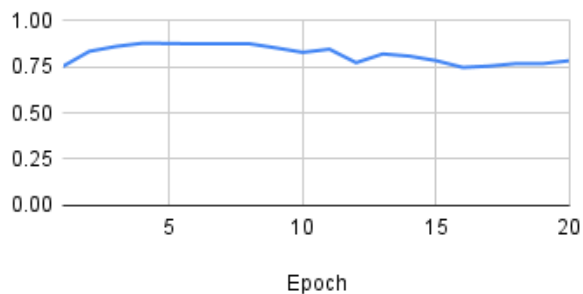
Validation Accuracy vs Epochs



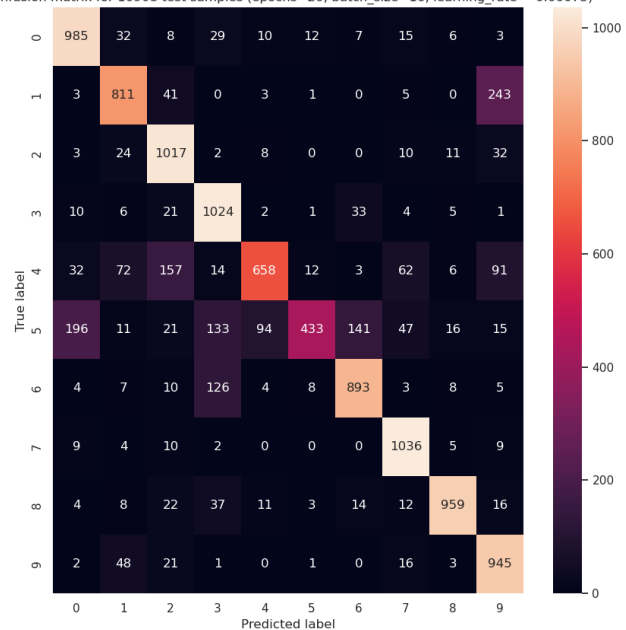
Validation Loss vs Epochs



Validation Macro F1 vs Epochs



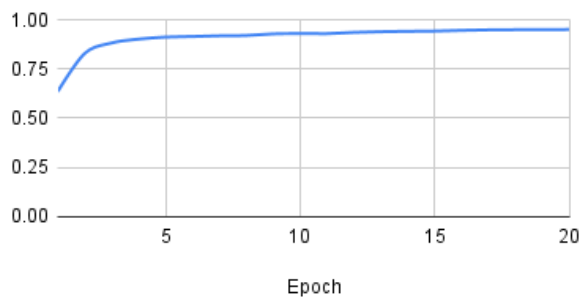
Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.00075)



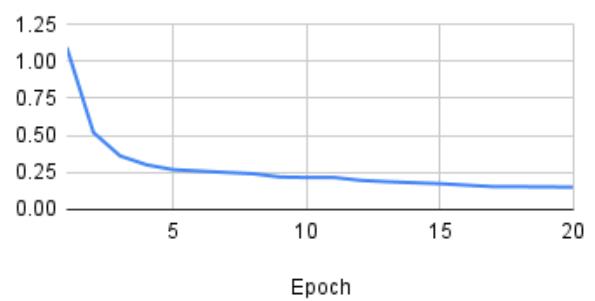
Trained Images = 39923, Batch Size = 16, Learning Rate = 0.001:

| 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 |

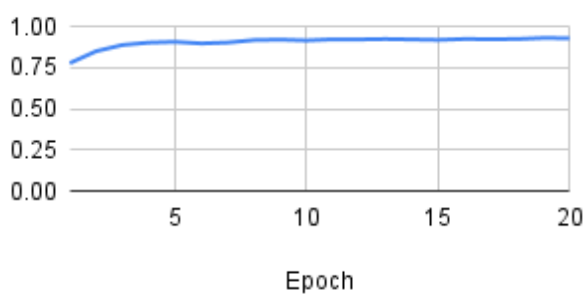
Training Accuracy vs Epochs



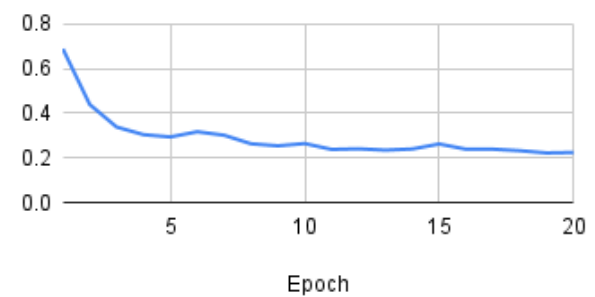
Training Loss vs Epochs



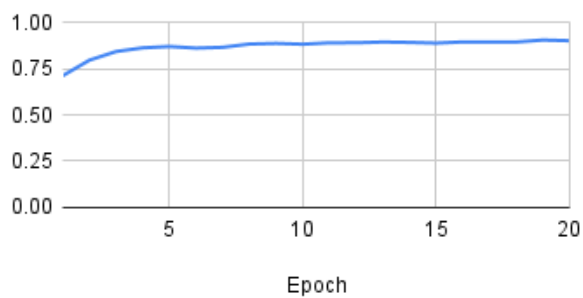
Validation Accuracy vs Epochs



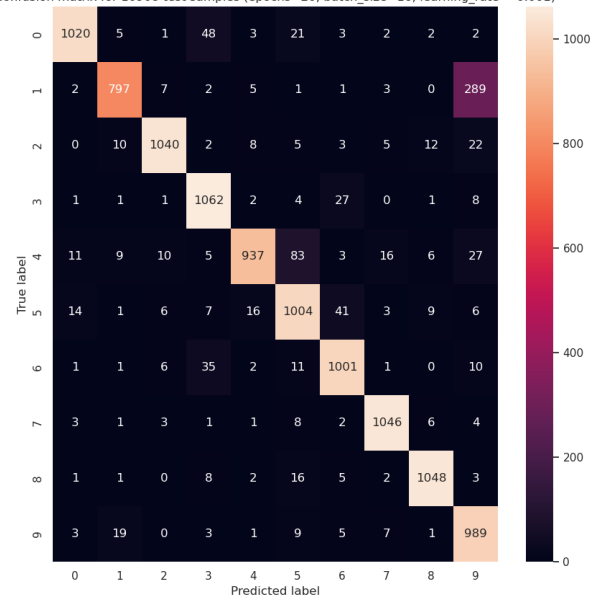
Validation Loss vs Epochs



Validation Macro F1 vs Epochs

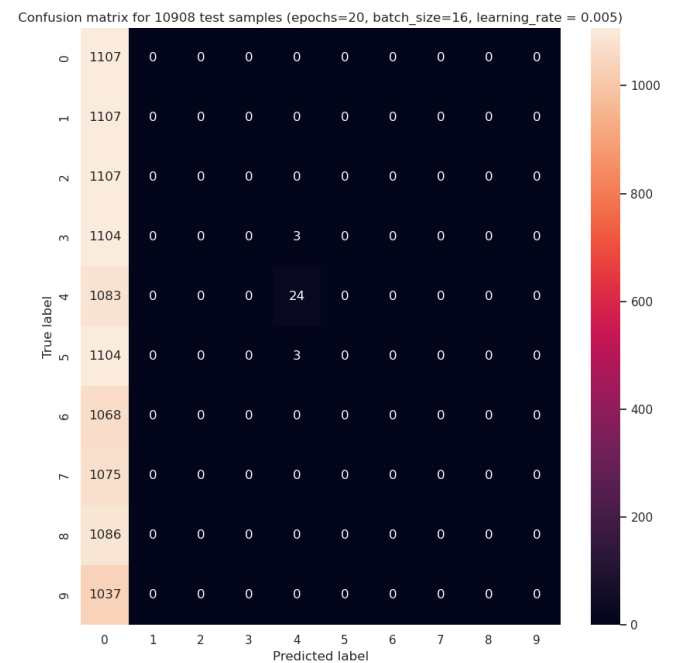
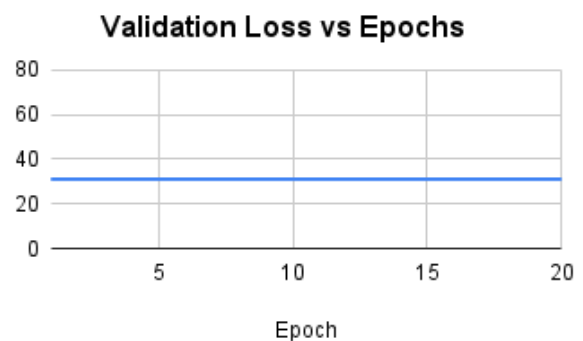


Confusion matrix for 10908 test samples (epochs=20, batch_size=16, learning_rate = 0.001)



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

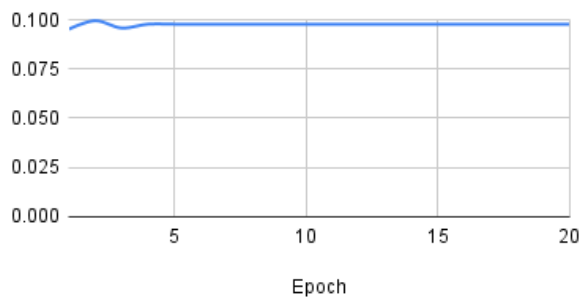
| Epoch | Training Accuracy | Training Loss | Validation Accuracy | Validation Loss | Validation Macro F1 |
|--------------|--------------------------|----------------------|----------------------------|------------------------|----------------------------|
| 1 | 0.100235 | 31.06659 | 0.09802 | 31.15323 | 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 |



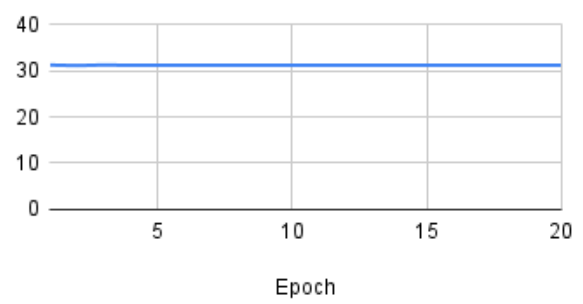
Trained Images = 18000, Batch Size = 32, Learning Rate = 0.01:

| 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 |

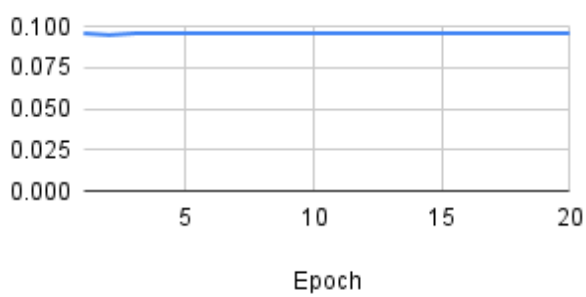
Training Accuracy vs Epochs



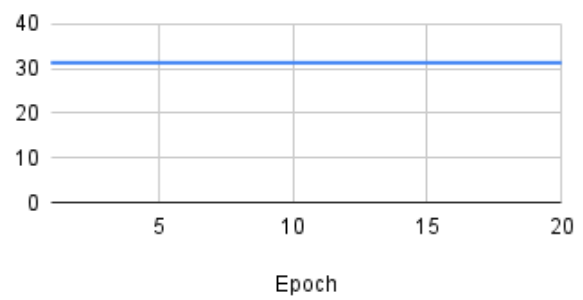
Training Loss vs Epochs



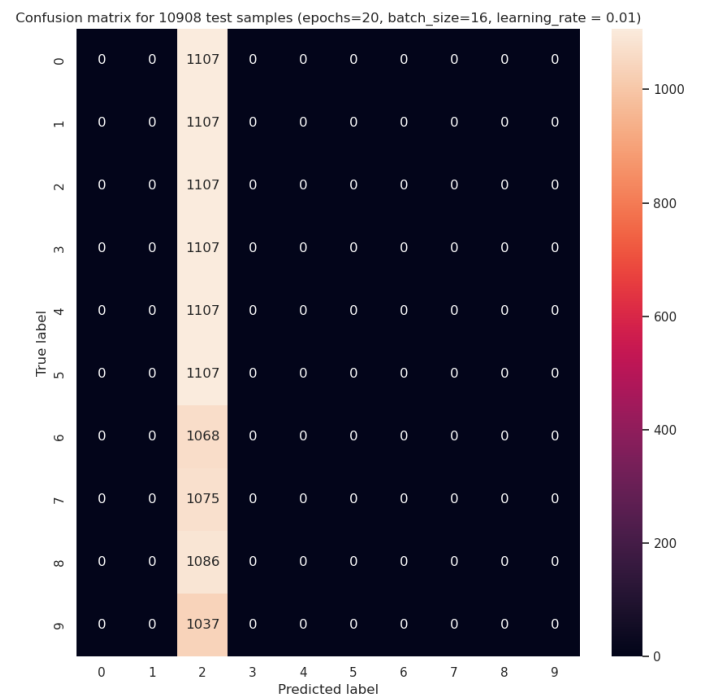
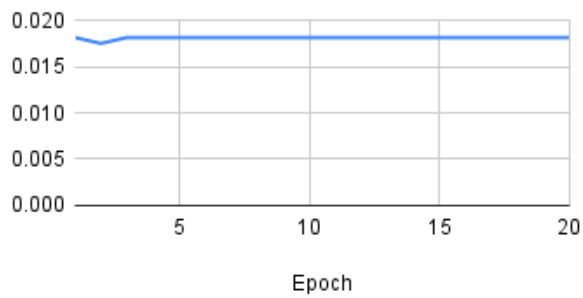
Validation Accuracy vs Epochs



Validation Loss vs Epochs



Validation Macro F1 vs Epochs



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