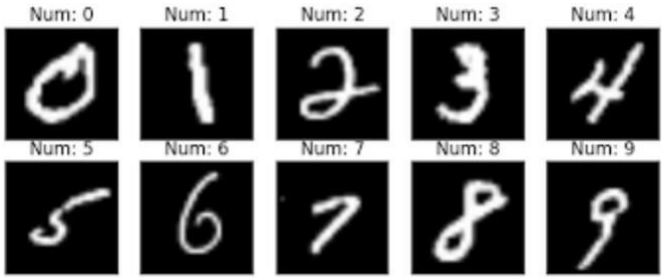
I. Experiments

Datasets

MNIST employed here, is a large hand written database [9] of digits. Its commonly used for training various image classification tasks. It contains training set of 60,000 examples, and a test set of 10,000 examples. With digits in each image being 28 by 28 in size, normalized and centered in a fixed image. With train examples split into train =54000 and validation =6000



Testing Results

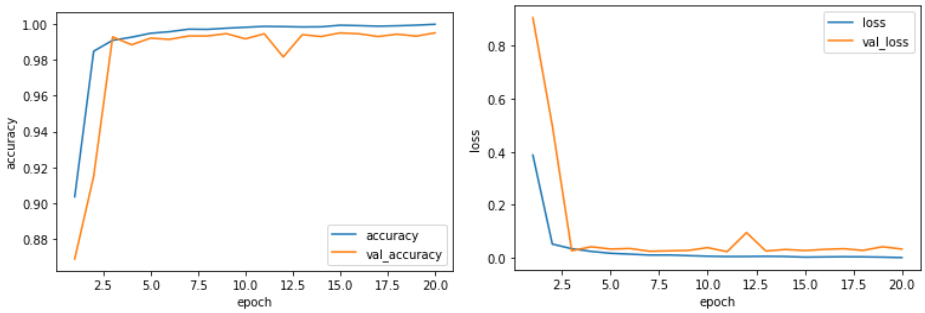
VGGNet –

The experiments for VGGNet were performed with the listed hyperparameter values:
batch_size = 128 num_classes = 10
epochs = 20

Total params: 17,093,578

Test Accuracy	0.9949	Test Loss	0.0359
Validation Accuracy	0.9953	Validation Loss	0.0324
Train Accuracy	0.9994	Train Loss	0.0017

VGGNet accuracy and loss graph



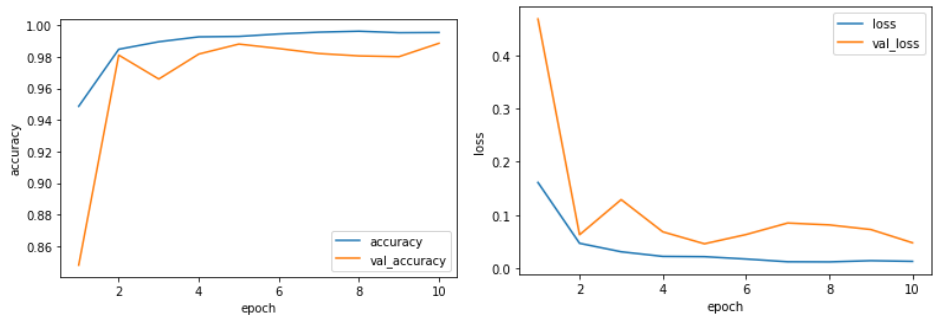
DEEPER NETWORKS FOR IMAGE CLASSIFICATION

ETHAN BAKARE

ResNet –
Total paramaters: 1,458,954

Test Accuracy	0.9880	Test Loss	0.0487
Validation Accuracy	0.9887	Validation Loss	0.0477
Train Accuracy	0.9955	Train Loss	0.0128

ResNet accuracy and loss graph



GoogLeNet –
The experiments were performed with the listed hyperparameter values:
batch_size = 128 num_classes = 10 epochs = 20 learning_rate = 0.0005
dropout_rate = 0.4
activation_type = 'relu'

Discussion
The model had 7,420,878 parameters,

Test Accuracy	0.9907	Test Loss	1.1858
Validation Accuracy	0.9897	Validation Loss	0.4041
Train Accuracy	0.9876	Train Loss	0.1436

Further Evaluation:

Observing the results from resnet, googlenet and vggnet. Vggnet has the best accuracy although ideally googlenet in the base paper performs better, it is obvious that vgggnet works quite with the mnist dataset. It is also noted that vggnet happens to have the most parameters to learn making it the most computationally expensive, followed by google net and then resnet.

II. Conclusion

In conclusion its is observed that all the models possess very high accuracy and really novel classifiers for the MNIST dataset. With VGGnet being the best

Snapshots shown in the appendix

Appendix

VGGNet runtime snapshot

```
Train on 54000 samples, validate on 6000 samples
Epoch 1/20
54000/54000 [==============================] - 36s 658us/step - loss: 0.4209 - accuracy: 0.8986 - val_loss: 1.5355 - val_accuracy: 0.6923
Epoch 2/20
54000/54000 [==============================] - 33s 605us/step - loss: 0.0557 - accuracy: 0.9847 - val_loss: 0.0393 - val_accuracy: 0.9888
Epoch 3/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0336 - accuracy: 0.9901 - val_loss: 0.0318 - val_accuracy: 0.9918
Epoch 4/20
54000/54000 [==============================] - 33s 605us/step - loss: 0.0228 - accuracy: 0.9930 - val_loss: 0.0267 - val_accuracy: 0.9937
Epoch 5/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0175 - accuracy: 0.9947 - val_loss: 0.0275 - val_accuracy: 0.9930
Epoch 6/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0137 - accuracy: 0.9963 - val_loss: 0.0302 - val_accuracy: 0.9932
Epoch 7/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0129 - accuracy: 0.9962 - val_loss: 0.0386 - val_accuracy: 0.9923
Epoch 8/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0114 - accuracy: 0.9965 - val_loss: 0.0337 - val_accuracy: 0.9935
Epoch 9/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0076 - accuracy: 0.9977 - val_loss: 0.0323 - val_accuracy: 0.9933
Epoch 10/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0063 - accuracy: 0.9980 - val_loss: 0.0399 - val_accuracy: 0.9928
Epoch 11/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0074 - accuracy: 0.9978 - val_loss: 0.0348 - val_accuracy: 0.9928
Epoch 12/20
54000/54000 [==============================] - 33s 603us/step - loss: 0.0069 - accuracy: 0.9979 - val_loss: 0.0218 - val_accuracy: 0.9947
Epoch 13/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0041 - accuracy: 0.9988 - val_loss: 0.0399 - val_accuracy: 0.9910
Epoch 14/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0025 - accuracy: 0.9992 - val_loss: 0.0337 - val_accuracy: 0.9945
Epoch 15/20
54000/54000 [==============================] - 33s 602us/step - loss: 0.0047 - accuracy: 0.9987 - val_loss: 0.0317 - val_accuracy: 0.9940
Epoch 16/20
54000/54000 [==============================] - 32s 602us/step - loss: 0.0024 - accuracy: 0.9993 - val_loss: 0.0352 - val_accuracy: 0.9940
Epoch 17/20
54000/54000 [==============================] - 33s 605us/step - loss: 0.0035 - accuracy: 0.9990 - val_loss: 0.0335 - val_accuracy: 0.9933
Epoch 18/20
54000/54000 [==============================] - 33s 608us/step - loss: 0.0024 - accuracy: 0.9993 - val_loss: 0.0331 - val_accuracy: 0.9943
Epoch 19/20
54000/54000 [==============================] - 33s 609us/step - loss: 0.0026 - accuracy: 0.9994 - val_loss: 0.0296 - val_accuracy: 0.9950
Epoch 20/20
54000/54000 [==============================] - 33s 604us/step - loss: 0.0017 - accuracy: 0.9994 - val_loss: 0.0324 - val_accuracy: 0.9953
The test loss: 0.03590568373736891
The test accuracy: 0.9948999881744385
```

DEEPER NETWORKS FOR IMAGE CLASSIFICATION

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GoogLeNet runtime snapshot

```
Train on 54000 samples, validate on 6000 samples
Epoch 1/20
54000/54000 [==============================] - 137s 3ms/step - loss: 1.9065 - main_loss: 0.8021 - aux1_loss: 0.4907 - aux2_loss: 0.6133 - main_accuracy: 0.7558 - aux1_a
Epoch 2/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.3112 - main_loss: 0.1277 - aux1_loss: 0.0817 - aux2_loss: 0.1018 - main_accuracy: 0.9686 - aux1_a
Epoch 3/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.2035 - main_loss: 0.0821 - aux1_loss: 0.0556 - aux2_loss: 0.0659 - main_accuracy: 0.9799 - aux1_a
Epoch 4/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1691 - main_loss: 0.0672 - aux1_loss: 0.0454 - aux2_loss: 0.0564 - main_accuracy: 0.9849 - aux1_a
Epoch 5/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1459 - main_loss: 0.0586 - aux1_loss: 0.0398 - aux2_loss: 0.0475 - main_accuracy: 0.9871 - aux1_a
Epoch 6/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1336 - main_loss: 0.0545 - aux1_loss: 0.0351 - aux2_loss: 0.0440 - main_accuracy: 0.9881 - aux1_a
Epoch 7/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1364 - main_loss: 0.0564 - aux1_loss: 0.0354 - aux2_loss: 0.0446 - main_accuracy: 0.9882 - aux1_a
Epoch 8/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1496 - main_loss: 0.0611 - aux1_loss: 0.0316 - aux2_loss: 0.0569 - main_accuracy: 0.9895 - aux1_a
Epoch 9/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1561 - main_loss: 0.0556 - aux1_loss: 0.0370 - aux2_loss: 0.0635 - main_accuracy: 0.9888 - aux1_a
Epoch 10/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1473 - main_loss: 0.0619 - aux1_loss: 0.0334 - aux2_loss: 0.0520 - main_accuracy: 0.9882 - aux1_a
Epoch 11/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1736 - main_loss: 0.0742 - aux1_loss: 0.0376 - aux2_loss: 0.0619 - main_accuracy: 0.9861 - aux1_a
Epoch 12/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1502 - main_loss: 0.0617 - aux1_loss: 0.0355 - aux2_loss: 0.0532 - main_accuracy: 0.9876 - aux1_a
Epoch 13/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1779 - main_loss: 0.0737 - aux1_loss: 0.0426 - aux2_loss: 0.0617 - main_accuracy: 0.9867 - aux1_a
Epoch 14/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.1674 - main_loss: 0.0661 - aux1_loss: 0.0412 - aux2_loss: 0.0602 - main_accuracy: 0.9875 - aux1_a
Epoch 15/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.2026 - main_loss: 0.0731 - aux1_loss: 0.0447 - aux2_loss: 0.0847 - main_accuracy: 0.9893 - aux1_a
Epoch 16/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.2461 - main_loss: 0.0951 - aux1_loss: 0.0444 - aux2_loss: 0.1065 - main_accuracy: 0.9866 - aux1_a
Epoch 17/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.2844 - main_loss: 0.1103 - aux1_loss: 0.0451 - aux2_loss: 0.1291 - main_accuracy: 0.9861 - aux1_a
Epoch 18/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.2487 - main_loss: 0.0990 - aux1_loss: 0.0471 - aux2_loss: 0.1025 - main_accuracy: 0.9856 - aux1_a
Epoch 19/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.3667 - main_loss: 0.2247 - aux1_loss: 0.0481 - aux2_loss: 0.0939 - main_accuracy: 0.9821 - aux1_a
Epoch 20/20
54000/54000 [==============================] - 125s 2ms/step - loss: 0.3451 - main_loss: 0.1436 - aux1_loss: 0.0671 - aux2_loss: 0.1344 - main_accuracy: 0.9876 - aux1_a
```

ResNet runtime snapshot

```
Train on 54000 samples, validate on 6000 samples
Epoch 1/10
54000/54000 [==============================] - 19s 352us/step - loss: 0.1612 - accuracy: 0.9487 - val_loss: 0.4688 - val_accuracy: 0.8480
Epoch 2/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0468 - accuracy: 0.9849 - val_loss: 0.0628 - val_accuracy: 0.9812
Epoch 3/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0308 - accuracy: 0.9896 - val_loss: 0.1290 - val_accuracy: 0.9660
Epoch 4/10
54000/54000 [==============================] - 13s 239us/step - loss: 0.0221 - accuracy: 0.9927 - val_loss: 0.0683 - val_accuracy: 0.9818
Epoch 5/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0216 - accuracy: 0.9930 - val_loss: 0.0458 - val_accuracy: 0.9882
Epoch 6/10
54000/54000 [==============================] - 13s 237us/step - loss: 0.0172 - accuracy: 0.9946 - val_loss: 0.0632 - val_accuracy: 0.9853
Epoch 7/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0120 - accuracy: 0.9957 - val_loss: 0.0849 - val_accuracy: 0.9822
Epoch 8/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0118 - accuracy: 0.9963 - val_loss: 0.0813 - val_accuracy: 0.9807
Epoch 9/10
54000/54000 [==============================] - 13s 238us/step - loss: 0.0141 - accuracy: 0.9954 - val_loss: 0.0726 - val_accuracy: 0.9802
Epoch 10/10
54000/54000 [==============================] - 13s 237us/step - loss: 0.0128 - accuracy: 0.9955 - val_loss: 0.0477 - val_accuracy: 0.9887
10000/10000 [==============================] - 3s 278us/step
Loss = 0.048728563966415825
Test Accuracy = 0.9879999756813049
Test loss: 0.048728563966415825
Test accuracy: 0.9879999756813049
```