# **Assignment 3**

## Experimental Settings

**IDE**: Google Colab Notebook (<https://colab.research.google.com/notebooks/basic_features_overview.ipynb>)

**GPU**: Tesla P100-PCIE-16GB (Command Line: !nvidia-smi -L)

**RAM**: 12.72 GB

**Alex Network**:

AlexNet is a convolutional neural network that is trained on more than a million images from the ImageNet database. The network is 8 layers deep and can classify images into 1000 object categories, such as keyboard, mouse, pencil, and many animals. As a result, the network has learned rich feature representations for a wide range of images. The network has an image input size of 227-by-227.

## Alex Network from Scratch

1. **Alex Network from scratch on CIFAR-100 dataset:**

Epoch 1/40

1250/1250 [==============================] - 511s 409ms/step - loss: 4.4169 - acc: 0.0473 - val\_loss: 4.0035 - val\_acc: 0.0920

Epoch 2/40

1250/1250 [==============================] - 516s 412ms/step - loss: 4.0032 - acc: 0.0933 - val\_loss: 3.7754 - val\_acc: 0.1264

Epoch 3/40

1250/1250 [==============================] - 510s 408ms/step - loss: 3.8009 - acc: 0.1247 - val\_loss: 3.5144 - val\_acc: 0.1557

Epoch 4/40

1250/1250 [==============================] - 515s 412ms/step - loss: 3.6517 - acc: 0.1468 - val\_loss: 3.3508 - val\_acc: 0.1878

Epoch 5/40

1250/1250 [==============================] - 517s 413ms/step - loss: 3.5403 - acc: 0.1656 - val\_loss: 3.3022 - val\_acc: 0.2002

Epoch 6/40

1250/1250 [==============================] - 527s 422ms/step - loss: 3.4244 - acc: 0.1839 - val\_loss: 3.1251 - val\_acc: 0.2273

Epoch 7/40

1250/1250 [==============================] - 505s 404ms/step - loss: 3.3074 - acc: 0.2047 - val\_loss: 3.0539 - val\_acc: 0.2500

Epoch 8/40

1250/1250 [==============================] - 506s 405ms/step - loss: 3.2075 - acc: 0.2241 - val\_loss: 3.0736 - val\_acc: 0.2481

Epoch 9/40

1250/1250 [==============================] - 506s 405ms/step - loss: 3.1137 - acc: 0.2427 - val\_loss: 2.8126 - val\_acc: 0.2968

Epoch 10/40

1250/1250 [==============================] - 519s 415ms/step - loss: 3.0351 - acc: 0.2534 - val\_loss: 2.8475 - val\_acc: 0.2835

Epoch 11/40

1250/1250 [==============================] - 523s 419ms/step - loss: 2.9827 - acc: 0.2676 - val\_loss: 2.6924 - val\_acc: 0.3121

Epoch 12/40

1250/1250 [==============================] - 502s 402ms/step - loss: 2.9082 - acc: 0.2814 - val\_loss: 2.7359 - val\_acc: 0.3139

Epoch 13/40

1250/1250 [==============================] - 513s 411ms/step - loss: 2.8714 - acc: 0.2886 - val\_loss: 2.5801 - val\_acc: 0.3344

Epoch 14/40

1250/1250 [==============================] - 518s 415ms/step - loss: 2.8150 - acc: 0.3037 - val\_loss: 2.5629 - val\_acc: 0.3464

Epoch 15/40

1250/1250 [==============================] - 513s 410ms/step - loss: 2.7614 - acc: 0.3090 - val\_loss: 2.6362 - val\_acc: 0.3309

Epoch 16/40

1250/1250 [==============================] - 511s 409ms/step - loss: 2.7257 - acc: 0.3181 - val\_loss: 2.4226 - val\_acc: 0.3725

Epoch 17/40

1250/1250 [==============================] - 521s 417ms/step - loss: 2.6837 - acc: 0.3267 - val\_loss: 2.5372 - val\_acc: 0.3478

Epoch 18/40

1250/1250 [==============================] - 525s 420ms/step - loss: 2.6365 - acc: 0.3363 - val\_loss: 2.4414 - val\_acc: 0.3695

Epoch 19/40

1250/1250 [==============================] - 514s 411ms/step - loss: 2.6136 - acc: 0.3437 - val\_loss: 2.3924 - val\_acc: 0.3769

Epoch 20/40

1250/1250 [==============================] - 505s 404ms/step - loss: 2.5857 - acc: 0.3504 - val\_loss: 2.3576 - val\_acc: 0.3779

Epoch 21/40

1250/1250 [==============================] - 515s 412ms/step - loss: 2.5448 - acc: 0.3591 - val\_loss: 2.3115 - val\_acc: 0.3998

Epoch 22/40

1250/1250 [==============================] - 509s 407ms/step - loss: 2.5230 - acc: 0.3628 - val\_loss: 2.3825 - val\_acc: 0.3896

Epoch 23/40

1250/1250 [==============================] - 506s 405ms/step - loss: 2.4929 - acc: 0.3704 - val\_loss: 2.2937 - val\_acc: 0.4097

Epoch 24/40

1250/1250 [==============================] - 516s 413ms/step - loss: 2.4771 - acc: 0.3712 - val\_loss: 2.2653 - val\_acc: 0.4113

Epoch 25/40

1250/1250 [==============================] - 508s 407ms/step - loss: 2.4431 - acc: 0.3784 - val\_loss: 2.2420 - val\_acc: 0.4227

Epoch 26/40

1250/1250 [==============================] - 510s 408ms/step - loss: 2.4269 - acc: 0.3877 - val\_loss: 2.2315 - val\_acc: 0.4197

Epoch 27/40

1250/1250 [==============================] - 506s 405ms/step - loss: 2.4032 - acc: 0.3884 - val\_loss: 2.2700 - val\_acc: 0.4083

Epoch 28/40

1250/1250 [==============================] - 516s 413ms/step - loss: 2.4026 - acc: 0.3908 - val\_loss: 2.2455 - val\_acc: 0.4214

Epoch 29/40

1250/1250 [==============================] - 500s 400ms/step - loss: 2.3692 - acc: 0.3982 - val\_loss: 2.3824 - val\_acc: 0.4094

Epoch 30/40

1250/1250 [==============================] - 494s 395ms/step - loss: 2.3477 - acc: 0.4038 - val\_loss: 2.2434 - val\_acc: 0.4300

Epoch 31/40

1250/1250 [==============================] - 497s 398ms/step - loss: 2.3227 - acc: 0.4109 - val\_loss: 2.2288 - val\_acc: 0.4418

Epoch 32/40

1250/1250 [==============================] - 511s 409ms/step - loss: 2.3119 - acc: 0.4161 - val\_loss: 2.2433 - val\_acc: 0.4282

Epoch 33/40

1250/1250 [==============================] - 518s 415ms/step - loss: 2.3016 - acc: 0.4166 - val\_loss: 2.1580 - val\_acc: 0.4503

Epoch 34/40

1250/1250 [==============================] - 515s 412ms/step - loss: 2.2767 - acc: 0.4204 - val\_loss: 2.0956 - val\_acc: 0.4574

Epoch 35/40

1250/1250 [==============================] - 520s 416ms/step - loss: 2.2821 - acc: 0.4221 - val\_loss: 2.2654 - val\_acc: 0.4347

Epoch 36/40

1250/1250 [==============================] - 506s 405ms/step - loss: 2.2552 - acc: 0.4276 - val\_loss: 2.2068 - val\_acc: 0.4372

Epoch 37/40

1250/1250 [==============================] - 502s 402ms/step - loss: 2.2484 - acc: 0.4297 - val\_loss: 2.1172 - val\_acc: 0.4508

Epoch 38/40

1250/1250 [==============================] - 501s 401ms/step - loss: 2.2248 - acc: 0.4356 - val\_loss: 2.1310 - val\_acc: 0.4528

Epoch 39/40

1250/1250 [==============================] - 515s 412ms/step - loss: 2.2257 - acc: 0.4352 - val\_loss: 2.0923 - val\_acc: 0.4604

Epoch 40/40

1250/1250 [==============================] - 510s 408ms/step - loss: 2.2157 - acc: 0.4403 - val\_loss: 2.1131 - val\_acc: 0.4694

Result:

Testing Accuracy: 46.5244391025641 %

1. Result:

Training Accuracy – 46.94 %

Testing Accuracy – 46.52%

Total Training Time = 22882.74380350113 seconds

## Pre Trained Alex Network (Transfer Learning):

Alex Network pre trained on Cifar-100 dataset

Pretrained 1

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/callbacks.py:1122: The name tf.summary.merge\_all is deprecated. Please use tf.compat.v1.summary.merge\_all instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/callbacks.py:1125: The name tf.summary.FileWriter is deprecated. Please use tf.compat.v1.summary.FileWriter instead.

Epoch 1/15

1250/1250 [==============================] - 518s 415ms/step - loss: 2.2089 - acc: 0.4402 - val\_loss: 2.1739 - val\_acc: 0.4475

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/callbacks.py:1265: The name tf.Summary is deprecated. Please use tf.compat.v1.Summary instead.

Epoch 2/15

1250/1250 [==============================] - 530s 424ms/step - loss: 2.1919 - acc: 0.4435 - val\_loss: 2.1260 - val\_acc: 0.4551

Epoch 3/15

1250/1250 [==============================] - 526s 421ms/step - loss: 2.1713 - acc: 0.4470 - val\_loss: 2.2007 - val\_acc: 0.4415

Epoch 4/15

1250/1250 [==============================] - 517s 413ms/step - loss: 2.1813 - acc: 0.4490 - val\_loss: 2.0748 - val\_acc: 0.4668

Epoch 5/15

1250/1250 [==============================] - 522s 418ms/step - loss: 2.1628 - acc: 0.4531 - val\_loss: 2.0896 - val\_acc: 0.4695

Epoch 6/15

1250/1250 [==============================] - 523s 418ms/step - loss: 2.1468 - acc: 0.4583 - val\_loss: 2.0858 - val\_acc: 0.4724

Epoch 7/15

1250/1250 [==============================] - 531s 424ms/step - loss: 2.1431 - acc: 0.4587 - val\_loss: 2.1771 - val\_acc: 0.4551

Epoch 8/15

1250/1250 [==============================] - 525s 420ms/step - loss: 2.1349 - acc: 0.4598 - val\_loss: 2.1148 - val\_acc: 0.4656

Epoch 9/15

1250/1250 [==============================] - 533s 426ms/step - loss: 2.1238 - acc: 0.4653 - val\_loss: 2.0990 - val\_acc: 0.4726

Epoch 10/15

1250/1250 [==============================] - 537s 429ms/step - loss: 2.1203 - acc: 0.4692 - val\_loss: 2.1595 - val\_acc: 0.4665

Epoch 11/15

1250/1250 [==============================] - 519s 416ms/step - loss: 2.1105 - acc: 0.4668 - val\_loss: 2.1036 - val\_acc: 0.4761

Epoch 12/15

1250/1250 [==============================] - 516s 413ms/step - loss: 2.1064 - acc: 0.4686 - val\_loss: 2.1235 - val\_acc: 0.4658

Epoch 13/15

1250/1250 [==============================] - 510s 408ms/step - loss: 2.0944 - acc: 0.4698 - val\_loss: 2.2238 - val\_acc: 0.4678

Epoch 14/15

1250/1250 [==============================] - 497s 398ms/step - loss: 2.0888 - acc: 0.4737 - val\_loss: 2.0515 - val\_acc: 0.4812

Epoch 15/15

1250/1250 [==============================] - 499s 399ms/step - loss: 2.0808 - acc: 0.4754 - val\_loss: 2.0309 - val\_acc: 0.4868

<keras.callbacks.History at 0x7fa87d2de630>

Result:

Testing Accuracy: 47.88661858974359 %

Pretrained 2:

Epoch 1/15

1250/1250 [==============================] - 514s 412ms/step - loss: 2.0783 - acc: 0.4777 - val\_loss: 2.0373 - val\_acc: 0.4880

Epoch 2/15

1250/1250 [==============================] - 515s 412ms/step - loss: 2.0778 - acc: 0.4787 - val\_loss: 2.0922 - val\_acc: 0.4760

Epoch 3/15

1250/1250 [==============================] - 504s 403ms/step - loss: 2.0632 - acc: 0.4800 - val\_loss: 2.1552 - val\_acc: 0.4712

Epoch 4/15

1250/1250 [==============================] - 515s 412ms/step - loss: 2.0579 - acc: 0.4820 - val\_loss: 2.1090 - val\_acc: 0.4851

Epoch 5/15

1250/1250 [==============================] - 518s 414ms/step - loss: 2.0379 - acc: 0.4846 - val\_loss: 2.0829 - val\_acc: 0.4826

Epoch 6/15

1250/1250 [==============================] - 504s 403ms/step - loss: 2.0434 - acc: 0.4859 - val\_loss: 2.0634 - val\_acc: 0.4884

Epoch 7/15

1250/1250 [==============================] - 508s 406ms/step - loss: 2.0396 - acc: 0.4845 - val\_loss: 2.1032 - val\_acc: 0.4963

Epoch 8/15

1250/1250 [==============================] - 501s 401ms/step - loss: 2.0470 - acc: 0.4846 - val\_loss: 2.1390 - val\_acc: 0.4842

Epoch 9/15

1250/1250 [==============================] - 491s 393ms/step - loss: 2.0188 - acc: 0.4929 - val\_loss: 2.0939 - val\_acc: 0.4779

Epoch 10/15

1250/1250 [==============================] - 505s 404ms/step - loss: 2.0256 - acc: 0.4905 - val\_loss: 2.0913 - val\_acc: 0.4924

Epoch 11/15

1250/1250 [==============================] - 505s 404ms/step - loss: 2.0120 - acc: 0.4945 - val\_loss: 2.0726 - val\_acc: 0.4932

Epoch 12/15

1250/1250 [==============================] - 509s 408ms/step - loss: 2.0168 - acc: 0.4951 - val\_loss: 2.1252 - val\_acc: 0.4876

Epoch 13/15

1250/1250 [==============================] - 500s 400ms/step - loss: 2.0114 - acc: 0.4966 - val\_loss: 2.0975 - val\_acc: 0.4938

Epoch 14/15

1250/1250 [==============================] - 508s 406ms/step - loss: 2.0040 - acc: 0.4974 - val\_loss: 2.1061 - val\_acc: 0.4827

Epoch 15/15

1250/1250 [==============================] - 505s 404ms/step - loss: 1.9984 - acc: 0.5018 - val\_loss: 2.0432 - val\_acc: 0.4987

<keras.callbacks.History at 0x7fa87c1d4ef0>

Result:

Testing Accuracy: 49.05849358974359 %

Pretrained 3:

Epoch 1/25 1250/1250 [==============================] - 536s 429ms/step - loss: 2.0690 - acc: 0.4813 - val\_loss: 2.0262 - val\_acc: 0.4901 WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/callbacks.py:1265: The name tf.Summary is deprecated. Please use tf.compat.v1.Summary instead. Epoch 2/25 1250/1250 [==============================] - 524s 419ms/step - loss: 2.0753 - acc: 0.4785 - val\_loss: 2.0767 - val\_acc: 0.4810 Epoch 3/25 1250/1250 [==============================] - 523s 418ms/step - loss: 2.0534 - acc: 0.4824 - val\_loss: 2.0893 - val\_acc: 0.4770 Epoch 4/25 1250/1250 [==============================] - 524s 419ms/step - loss: 2.0537 - acc: 0.4816 - val\_loss: 2.0773 - val\_acc: 0.4931 Epoch 5/25 1250/1250 [==============================] - 519s 415ms/step - loss: 2.0552 - acc: 0.4845 - val\_loss: 2.0693 - val\_acc: 0.4868 Epoch 6/25 1250/1250 [==============================] - 519s 415ms/step - loss: 2.0424 - acc: 0.4883 - val\_loss: 2.0743 - val\_acc: 0.4845 Epoch 7/25 1250/1250 [==============================] - 523s 418ms/step - loss: 2.0363 - acc: 0.4873 - val\_loss: 2.0223 - val\_acc: 0.4917 Epoch 8/25 1250/1250 [==============================] - 519s 415ms/step - loss: 2.0255 - acc: 0.4930 - val\_loss: 2.0431 - val\_acc: 0.4943 Epoch 9/25 1250/1250 [==============================] - 532s 425ms/step - loss: 2.0226 - acc: 0.4933 - val\_loss: 2.0562 - val\_acc: 0.4895 Epoch 10/25 1250/1250 [==============================] - 526s 421ms/step - loss: 2.0239 - acc: 0.4933 - val\_loss: 2.0650 - val\_acc: 0.4921 Epoch 11/25 1250/1250 [==============================] - 524s 420ms/step - loss: 2.0011 - acc: 0.4966 - val\_loss: 2.0850 - val\_acc: 0.4869 Epoch 12/25 1250/1250 [==============================] - 515s 412ms/step - loss: 1.9906 - acc: 0.4990 - val\_loss: 2.1436 - val\_acc: 0.4927 Epoch 13/25 1250/1250 [==============================] - 524s 419ms/step - loss: 2.0019 - acc: 0.5010 - val\_loss: 2.0443 - val\_acc: 0.4875 Epoch 14/25 1250/1250 [==============================] - 519s 415ms/step - loss: 2.0035 - acc: 0.4968 - val\_loss: 2.1248 - val\_acc: 0.5000 Epoch 15/25 1250/1250 [==============================] - 516s 413ms/step - loss: 1.9982 - acc: 0.5013 - val\_loss: 2.1139 - val\_acc: 0.4820

Result:

Testing Accuracy: 49.78767884615385 %

* For first Run:

Training Accuracy: 48.68%

Testing Accuracy: 47.88%

* For Second Run:

Training Accuracy: 49.8%

Testing Accuracy: 49.05%

* For Third Run:

Training Accuracy: 48.20%

Testing Accuracy: 49.78%

* Average after 3 Run:

Training Accuracy: 49.89%

Testing Accuracy: 48.9%

Note: Log files for Pretrained AlexNet are present separately with name – PretrainedAlexNetLog.rar

## Accuracy Analysis:

Comparison

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | From Scratch (1 run) | Pre Trained (3 runs) |
| CIFAR-100 | Training Accuracy | 46.92 | 49.89 |
| Testing Accuracy | 46.52 | 48.9 |

Analysis

Training AlexNet from scratch, after 40 epoch. we get 46.92% training accuracy and 46.52% testing accuracy.

With Pretrained AlexNet on CIFAR-100 dataset using weights, accuracy increases to 49.89% training accuracy and 48.9% testing accuracy after 15 epoch.

Accuracy in Pretrained Model increases, as it is already trained on cifar-100 dataset with similar AlexNet model. Hence, it take less time on training for CIFAR-100 and provide better accuracy with less epoch (15 epoch).