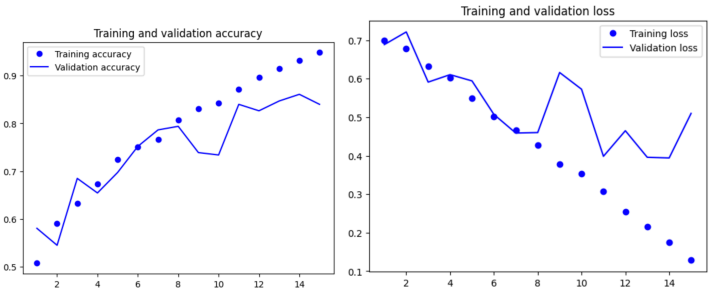
ASSIGNMENT - 2

CONVULUTION NEURAL NETWORKS

1: Initial training the model using 1000 samples and without Drop-out and Augmentation

```
Epoch 1/15
94/94 [==============================] - 3s 18ms/step - loss: 0.6993 - accuracy: 0.5073 - val_loss: 0.6884 - val_accuracy: 0.5805
Epoch 2/15
94/94 [==============================] - 2s 16ms/step - loss: 0.6774 - accuracy: 0.5900 - val_loss: 0.7213 - val_accuracy: 0.5450
Epoch 3/15
94/94 [==============================] - 2s 16ms/step - loss: 0.6317 - accuracy: 0.6330 - val_loss: 0.5910 - val_accuracy: 0.6850
Epoch 4/15
94/94 [==============================] - 2s 16ms/step - loss: 0.6017 - accuracy: 0.6733 - val_loss: 0.6103 - val_accuracy: 0.6545
Epoch 5/15
94/94 [==============================] - 2s 16ms/step - loss: 0.5497 - accuracy: 0.7240 - val_loss: 0.5942 - val_accuracy: 0.6975
Epoch 6/15
94/94 [==============================] - 2s 16ms/step - loss: 0.5019 - accuracy: 0.7513 - val_loss: 0.5071 - val_accuracy: 0.7520
Epoch 7/15
94/94 [==============================] - 2s 17ms/step - loss: 0.4656 - accuracy: 0.7660 - val_loss: 0.4587 - val_accuracy: 0.7865
Epoch 8/15
94/94 [==============================] - 2s 16ms/step - loss: 0.4266 - accuracy: 0.8077 - val_loss: 0.4600 - val_accuracy: 0.7940
Epoch 9/15
94/94 [==============================] - 2s 16ms/step - loss: 0.3780 - accuracy: 0.8303 - val_loss: 0.6159 - val_accuracy: 0.7390
Epoch 10/15
94/94 [==============================] - 2s 16ms/step - loss: 0.3536 - accuracy: 0.8423 - val_loss: 0.5726 - val_accuracy: 0.7340
Epoch 11/15
94/94 [==============================] - 2s 16ms/step - loss: 0.3069 - accuracy: 0.8710 - val_loss: 0.3983 - val_accuracy: 0.8400
Epoch 12/15
94/94 [==============================] - 2s 16ms/step - loss: 0.2546 - accuracy: 0.8963 - val_loss: 0.4647 - val_accuracy: 0.8265
Epoch 13/15
94/94 [==============================] - 2s 16ms/step - loss: 0.2159 - accuracy: 0.9147 - val_loss: 0.3958 - val_accuracy: 0.8470
Epoch 14/15
94/94 [==============================] - 2s 16ms/step - loss: 0.1741 - accuracy: 0.9320 - val_loss: 0.3940 - val_accuracy: 0.8610
Epoch 15/15
94/94 [==============================] - 2s 16ms/step - loss: 0.1282 - accuracy: 0.9483 - val_loss: 0.5097 - val_accuracy: 0.8400
```




```
63/63 [==============================] - 1s 7ms/step - loss: 0.6520 - accuracy: 0.7585
Test accuracy: 0.758
```

Test Accuracy = 75 %

From the plot we can see that the optimal number of epochs =6

2: Tuning the model using Drop-out, Augmentation

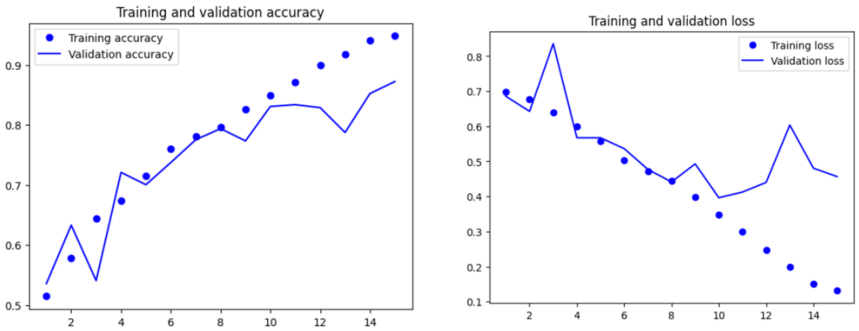
```
Epoch 1/7
94/94 [==============================] - 5s 24ms/step - loss: 0.6860 - accuracy: 0.5523 - val_loss: 0.6755 - val_accuracy: 0.5545
Epoch 2/7
94/94 [==============================] - 2s 22ms/step - loss: 0.6533 - accuracy: 0.6203 - val_loss: 0.7279 - val_accuracy: 0.5665
Epoch 3/7
94/94 [==============================] - 2s 22ms/step - loss: 0.6044 - accuracy: 0.6703 - val_loss: 0.5476 - val_accuracy: 0.7350
Epoch 4/7
94/94 [==============================] - 2s 22ms/step - loss: 0.5437 - accuracy: 0.7243 - val_loss: 0.5970 - val_accuracy: 0.6955
Epoch 5/7
94/94 [==============================] - 2s 23ms/step - loss: 0.4934 - accuracy: 0.7623 - val_loss: 0.5185 - val_accuracy: 0.7330
Epoch 6/7
94/94 [==============================] - 2s 22ms/step - loss: 0.4640 - accuracy: 0.7843 - val_loss: 0.4511 - val_accuracy: 0.7930
Epoch 7/7
94/94 [==============================] - 2s 22ms/step - loss: 0.4293 - accuracy: 0.7990 - val_loss: 0.5888 - val_accuracy: 0.7210
```

```
63/63 [==============================] - 1s 9ms/step - loss: 0.5001 - accuracy: 0.7645
Test accuracy: 0.765
```

Increased the test accuracy from 75 % to 76%

3: Increasing Training Sample from 1000 to 1500 and training the model

```
Epoch 1/15
94/94 [==============================] - 4s 21ms/step - loss: 0.6971 - accuracy: 0.5143 - val_loss: 0.6854 - val_accuracy: 0.5355
Epoch 2/15
94/94 [==============================] - 2s 16ms/step - loss: 0.6777 - accuracy: 0.5780 - val_loss: 0.6425 - val_accuracy: 0.6330
Epoch 3/15
94/94 [==============================] - 2s 16ms/step - loss: 0.6393 - accuracy: 0.6440 - val_loss: 0.8355 - val_accuracy: 0.5405
Epoch 4/15
94/94 [==============================] - 2s 16ms/step - loss: 0.5998 - accuracy: 0.6733 - val_loss: 0.5673 - val_accuracy: 0.7210
Epoch 5/15
94/94 [==============================] - 2s 16ms/step - loss: 0.5570 - accuracy: 0.7147 - val_loss: 0.5671 - val_accuracy: 0.7005
Epoch 6/15
94/94 [==============================] - 2s 16ms/step - loss: 0.5028 - accuracy: 0.7600 - val_loss: 0.5361 - val_accuracy: 0.7375
Epoch 7/15
94/94 [==============================] - 2s 16ms/step - loss: 0.4722 - accuracy: 0.7813 - val_loss: 0.4770 - val_accuracy: 0.7755
Epoch 8/15
94/94 [==============================] - 2s 16ms/step - loss: 0.4443 - accuracy: 0.7963 - val_loss: 0.4413 - val_accuracy: 0.7940
Epoch 9/15
94/94 [==============================] - 2s 16ms/step - loss: 0.3973 - accuracy: 0.8257 - val_loss: 0.4927 - val_accuracy: 0.7735
Epoch 10/15
94/94 [==============================] - 2s 16ms/step - loss: 0.3474 - accuracy: 0.8493 - val_loss: 0.3963 - val_accuracy: 0.8310
Epoch 11/15
94/94 [==============================] - 2s 16ms/step - loss: 0.2996 - accuracy: 0.8713 - val_loss: 0.4124 - val_accuracy: 0.8340
Epoch 12/15
94/94 [==============================] - 2s 16ms/step - loss: 0.2463 - accuracy: 0.8997 - val_loss: 0.4399 - val_accuracy: 0.8290
Epoch 13/15
94/94 [==============================] - 2s 16ms/step - loss: 0.1982 - accuracy: 0.9183 - val_loss: 0.6034 - val_accuracy: 0.7875
Epoch 14/15
94/94 [==============================] - 2s 16ms/step - loss: 0.1503 - accuracy: 0.9417 - val_loss: 0.4804 - val_accuracy: 0.8525
Epoch 15/15
94/94 [==============================] - 2s 16ms/step - loss: 0.1308 - accuracy: 0.9483 - val_loss: 0.4565 - val_accuracy: 0.8725
```

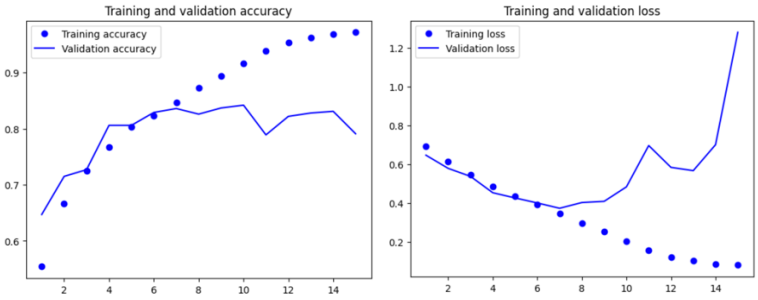



```
63/63 [==============================] - 1s 7ms/step - loss: 0.5248 - accuracy: 0.7570
Test accuracy: 0.757
```

Test accuracy increased from 73% to 75 %

3: Increasing Training Sample from 1500 to 3000 and training the model

```
Epoch 1/15
250/250 [==============================] - 6s 13ms/step - loss: 0.6901 - accuracy: 0.5540 - val_loss: 0.6455 - val_accuracy: 0.6470
Epoch 2/15
250/250 [==============================] - 3s 12ms/step - loss: 0.6135 - accuracy: 0.6659 - val_loss: 0.5775 - val_accuracy: 0.7150
Epoch 3/15
250/250 [==============================] - 3s 12ms/step - loss: 0.5466 - accuracy: 0.7249 - val_loss: 0.5364 - val_accuracy: 0.7270
Epoch 4/15
250/250 [==============================] - 3s 12ms/step - loss: 0.4824 - accuracy: 0.7673 - val_loss: 0.4521 - val_accuracy: 0.8060
Epoch 5/15
250/250 [==============================] - 3s 12ms/step - loss: 0.4336 - accuracy: 0.8037 - val_loss: 0.4252 - val_accuracy: 0.8060
Epoch 6/15
250/250 [==============================] - 3s 12ms/step - loss: 0.3917 - accuracy: 0.8226 - val_loss: 0.3994 - val_accuracy: 0.8290
Epoch 7/15
250/250 [==============================] - 3s 12ms/step - loss: 0.3447 - accuracy: 0.8464 - val_loss: 0.3720 - val_accuracy: 0.8360
Epoch 8/15
250/250 [==============================] - 3s 12ms/step - loss: 0.2949 - accuracy: 0.8724 - val_loss: 0.4015 - val_accuracy: 0.8260
Epoch 9/15
250/250 [==============================] - 3s 12ms/step - loss: 0.2508 - accuracy: 0.8941 - val_loss: 0.4077 - val_accuracy: 0.8370
Epoch 10/15
250/250 [==============================] - 3s 12ms/step - loss: 0.2037 - accuracy: 0.9164 - val_loss: 0.4823 - val_accuracy: 0.8420
Epoch 11/15
250/250 [==============================] - 3s 12ms/step - loss: 0.1548 - accuracy: 0.9391 - val_loss: 0.6953 - val_accuracy: 0.7890
Epoch 12/15
250/250 [==============================] - 3s 12ms/step - loss: 0.1201 - accuracy: 0.9535 - val_loss: 0.5828 - val_accuracy: 0.8220
Epoch 13/15
250/250 [==============================] - 3s 12ms/step - loss: 0.1025 - accuracy: 0.9620 - val_loss: 0.5659 - val_accuracy: 0.8280
Epoch 14/15
250/250 [==============================] - 3s 12ms/step - loss: 0.0832 - accuracy: 0.9682 - val_loss: 0.6996 - val_accuracy: 0.8310
Epoch 15/15
250/250 [==============================] - 3s 12ms/step - loss: 0.0788 - accuracy: 0.9718 - val_loss: 1.2790 - val_accuracy: 0.7910
```




```
32/32 [==============================] - 0s 7ms/step - loss: 0.4292 - accuracy: 0.8200
Test accuracy: 0.820
```

Test Accuracy = 82 %

From the plot we can see that the optimal number of epochs =7

4: Increasing Training Sample from 3000 to 4000 and training the model

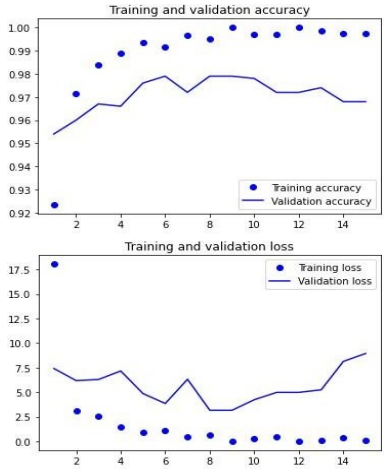
```
Epoch 1/7
250/250 [==============================] - 7s 18ms/step - loss: 0.6540 - accuracy: 0.6070 - val_loss: 0.5928 - val_accuracy: 0.6930
Epoch 2/7
250/250 [==============================] - 4s 18ms/step - loss: 0.5545 - accuracy: 0.7124 - val_loss: 0.4691 - val_accuracy: 0.7950
Epoch 3/7
250/250 [==============================] - 4s 17ms/step - loss: 0.4758 - accuracy: 0.7728 - val_loss: 0.4510 - val_accuracy: 0.8020
Epoch 4/7
250/250 [==============================] - 4s 17ms/step - loss: 0.4231 - accuracy: 0.8046 - val_loss: 0.3798 - val_accuracy: 0.8440
Epoch 5/7
250/250 [==============================] - 4s 17ms/step - loss: 0.3916 - accuracy: 0.8261 - val_loss: 0.4690 - val_accuracy: 0.7940
Epoch 6/7
250/250 [==============================] - 4s 17ms/step - loss: 0.3672 - accuracy: 0.8382 - val_loss: 0.3691 - val_accuracy: 0.8500
Epoch 7/7
250/250 [==============================] - 4s 18ms/step - loss: 0.3442 - accuracy: 0.8470 - val_loss: 0.3581 - val_accuracy: 0.8520
```

```
32/32 [==============================] - 0s 9ms/step - loss: 0.3875 - accuracy: 0.8510
Test accuracy: 0.851
```

Test accuracy increased from 82 % to 85%

1: Using a pretrained network and running the model

```
Epoch 1/15
63/63 [==============================] - 3s 9ms/step - loss: 17.8855 - accuracy: 0.9290 - val_loss: 9.9470 - val_accuracy: 0.9470
Epoch 2/15
63/63 [==============================] - 0s 6ms/step - loss: 5.1980 - accuracy: 0.9700 - val_loss: 5.4119 - val_accuracy: 0.9600
Epoch 3/15
63/63 [==============================] - 0s 6ms/step - loss: 0.7922 - accuracy: 0.9890 - val_loss: 2.5885 - val_accuracy: 0.9770
Epoch 4/15
63/63 [==============================] - 0s 5ms/step - loss: 0.7726 - accuracy: 0.9920 - val_loss: 8.2720 - val_accuracy: 0.9610
Epoch 5/15
63/63 [==============================] - 0s 5ms/step - loss: 2.1407 - accuracy: 0.9895 - val_loss: 3.4311 - val_accuracy: 0.9770
Epoch 6/15
63/63 [==============================] - 0s 5ms/step - loss: 0.7334 - accuracy: 0.9935 - val_loss: 4.6852 - val_accuracy: 0.9750
Epoch 7/15
63/63 [==============================] - 0s 5ms/step - loss: 0.9501 - accuracy: 0.9935 - val_loss: 5.6626 - val_accuracy: 0.9680
Epoch 8/15
63/63 [==============================] - 0s 4ms/step - loss: 0.2308 - accuracy: 0.9960 - val_loss: 4.9018 - val_accuracy: 0.9750
Epoch 9/15
63/63 [==============================] - 0s 5ms/step - loss: 0.5459 - accuracy: 0.9945 - val_loss: 9.0519 - val_accuracy: 0.9580
Epoch 10/15
63/63 [==============================] - 0s 4ms/step - loss: 0.3614 - accuracy: 0.9975 - val_loss: 4.0309 - val_accuracy: 0.9780
Epoch 11/15
63/63 [==============================] - 0s 4ms/step - loss: 0.1224 - accuracy: 0.9985 - val_loss: 4.0075 - val_accuracy: 0.9770
Epoch 12/15
63/63 [==============================] - 0s 5ms/step - loss: 0.2915 - accuracy: 0.9965 - val_loss: 6.0371 - val_accuracy: 0.9710
Epoch 13/15
63/63 [==============================] - 0s 5ms/step - loss: 0.0589 - accuracy: 0.9990 - val_loss: 6.4779 - val_accuracy: 0.9720
Epoch 14/15
63/63 [==============================] - 0s 4ms/step - loss: 0.0855 - accuracy: 0.9990 - val_loss: 4.7639 - val_accuracy: 0.9730
Epoch 15/15
63/63 [==============================] - 0s 4ms/step - loss: 3.2514e-27 - accuracy: 1.0000 - val_loss: 4.7639 - val_accuracy: 0.9730
```




```
63/63 [==============================] - 1s 16ms/step - loss: 4.8000 - accuracy: 0.9710
Test accuracy: 0.971
```

Optimal number of epochs =6, Accuracy = 97.1

2.Incresing the sample size from 1000 to 1500:

```
Epoch 1/6
63/63 [==============================] - 7s 113ms/step - loss: 5.8891 - accuracy: 0.9575 - val_loss: 3.7089 - val_accuracy: 0.9720
Epoch 2/6
63/63 [==============================] - 7s 110ms/step - loss: 3.8952 - accuracy: 0.9705 - val_loss: 3.4797 - val_accuracy: 0.9800
Epoch 3/6
63/63 [==============================] - 7s 107ms/step - loss: 1.0862 - accuracy: 0.9905 - val_loss: 4.1510 - val_accuracy: 0.9700
Epoch 4/6
63/63 [==============================] - 7s 106ms/step - loss: 1.1194 - accuracy: 0.9910 - val_loss: 5.7490 - val_accuracy: 0.9700
Epoch 5/6
63/63 [==============================] - 7s 110ms/step - loss: 0.8732 - accuracy: 0.9915 - val_loss: 3.2642 - val_accuracy: 0.9790
Epoch 6/6
63/63 [==============================] - 7s 107ms/step - loss: 1.7374 - accuracy: 0.9890 - val_loss: 5.9580 - val_accuracy: 0.9750

63/63 [==============================] - 1s 16ms/step - loss: 5.0877 - accuracy: 0.9720
Test accuracy: 0.972
```

Test Accuracy increased from 97.10 to 97.20.

3: Feature Extraction with image augmentation, drop-out on pre-trained network:

```
Epoch 1/6
94/94 [==============================] - 10s 104ms/step - loss: 0.8693 - accuracy: 0.9947 - val_loss: 7.5665 - val_accuracy: 0.9740
Epoch 2/6
94/94 [==============================] - 10s 104ms/step - loss: 0.9980 - accuracy: 0.9913 - val_loss: 6.8725 - val_accuracy: 0.9740
Epoch 3/6
94/94 [==============================] - 10s 104ms/step - loss: 0.2297 - accuracy: 0.9983 - val_loss: 5.5052 - val_accuracy: 0.9840
Epoch 4/6
94/94 [==============================] - 10s 103ms/step - loss: 0.4306 - accuracy: 0.9953 - val_loss: 6.7589 - val_accuracy: 0.9780
Epoch 5/6
94/94 [==============================] - 10s 103ms/step - loss: 0.6950 - accuracy: 0.9943 - val_loss: 6.0469 - val_accuracy: 0.9740
Epoch 6/6
94/94 [==============================] - 10s 101ms/step - loss: 0.4385 - accuracy: 0.9963 - val_loss: 7.5356 - val_accuracy: 0.9760

16/16 [==============================] - 1s 17ms/step - loss: 2.6528 - accuracy: 0.9800
Test accuracy: 0.980
```

Test Accuracy increased to 98.00% from 97.20%

4: Increasing training sample to 2000 and freezing layers with hyper parameter

```
110/110 [==============================] - 15s 106ms/step - loss: 12.0791 - accuracy: 0.9363 - val_loss: 1.8708 - val_accuracy: 0.9860
Epoch 2/6
110/110 [==============================] - 11s 102ms/step - loss: 2.1700 - accuracy: 0.9789 - val_loss: 3.0049 - val_accuracy: 0.9840
Epoch 3/6
110/110 [==============================] - 11s 103ms/step - loss: 1.4318 - accuracy: 0.9871 - val_loss: 1.8526 - val_accuracy: 0.9860
Epoch 4/6
110/110 [==============================] - 11s 102ms/step - loss: 1.1390 - accuracy: 0.9863 - val_loss: 4.5096 - val_accuracy: 0.9780
Epoch 5/6
110/110 [==============================] - 11s 102ms/step - loss: 0.7619 - accuracy: 0.9917 - val_loss: 2.7488 - val_accuracy: 0.9840
Epoch 6/6
110/110 [==============================] - 11s 102ms/step - loss: 0.2109 - accuracy: 0.9963 - val_loss: 2.5792 - val_accuracy: 0.9840
```

```
16/16 [==============================] - 1s 17ms/step - loss: 1.9621 - accuracy: 0.9860
Test accuracy: 0.986
```

Test accuracy increased 98.6%

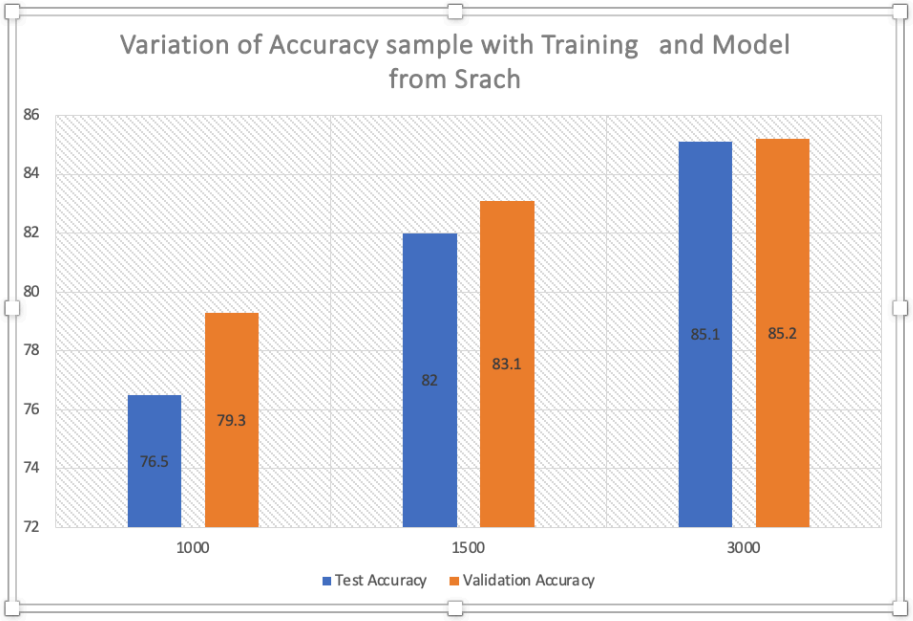
5: Increasing training sample to 3000 and freezing layers with hyper parameter

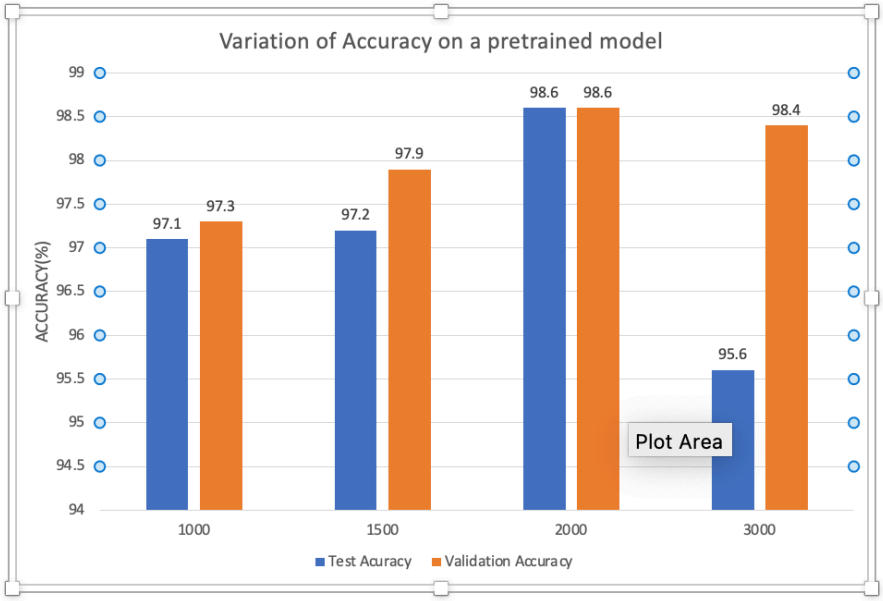
```
32/32 [==============================] - 1s 16ms/step - loss: 5.5635 - accuracy: 0.9560
Test accuracy: 0.956
157/157 [==============================] - 20s 103ms/step - loss: 2.3987 - accuracy: 0.9882 - val_loss: 7.2690 - val_accuracy: 0.9580
Epoch 2/6
157/157 [==============================] - 16s 100ms/step - loss: 2.2742 - accuracy: 0.9872 - val_loss: 7.3012 - val_accuracy: 0.9600
Epoch 3/6
157/157 [==============================] - 16s 100ms/step - loss: 2.0024 - accuracy: 0.9886 - val_loss: 7.2703 - val_accuracy: 0.9600
Epoch 4/6
157/157 [==============================] - 16s 101ms/step - loss: 2.0066 - accuracy: 0.9878 - val_loss: 7.2840 - val_accuracy: 0.9600
Epoch 5/6
157/157 [==============================] - 16s 102ms/step - loss: 2.2211 - accuracy: 0.9886 - val_loss: 7.2210 - val_accuracy: 0.9600
Epoch 6/6
157/157 [==============================] - 16s 101ms/step - loss: 1.8825 - accuracy: 0.9882 - val_loss: 7.2290 - val_accuracy: 0.9620
```

Test Accuracy decreased from 98.60% to 95.60% when training samples are increased to 3000.

Best Accuracy so far obtained is 98.60 % when we use a training sample of size 2000.

Results and Findings





Summary:

- The above results clearly indicate a strong interdependence between the selection of the network model and the size of the training sample.
- With an increase in the size of the training sample, there is a notable improvement in the model's accuracy on the test set. However, beyond a certain point, further increases in the training sample size led to a decrease in accuracy due to model overfitting.
- The ideal training sample size, at which the model achieves its highest accuracy while avoiding both underfitting and overfitting, can be referred to as the optimal size for training.
- The second model in use is based on the VGG16 network architecture, which is a pre-trained model. Such pre-trained models can capture intricate features, and they offer the advantage of reducing training time, given that they have already been trained.
- The pre-trained weights of the VGG16 model are valuable for transfer learning on smaller image classification tasks. This is possible because these weights were initially trained on an extensive dataset comprising over a million images.
- As evident from the above experiment, the pre-trained model achieved an impressive accuracy of 98.60% with relatively smaller training samples. In contrast, the model built from scratch required 3000 training samples to attain an accuracy of 85.1%.