

MIS 64061 Assignment_1: Exploring a Neural Network Model

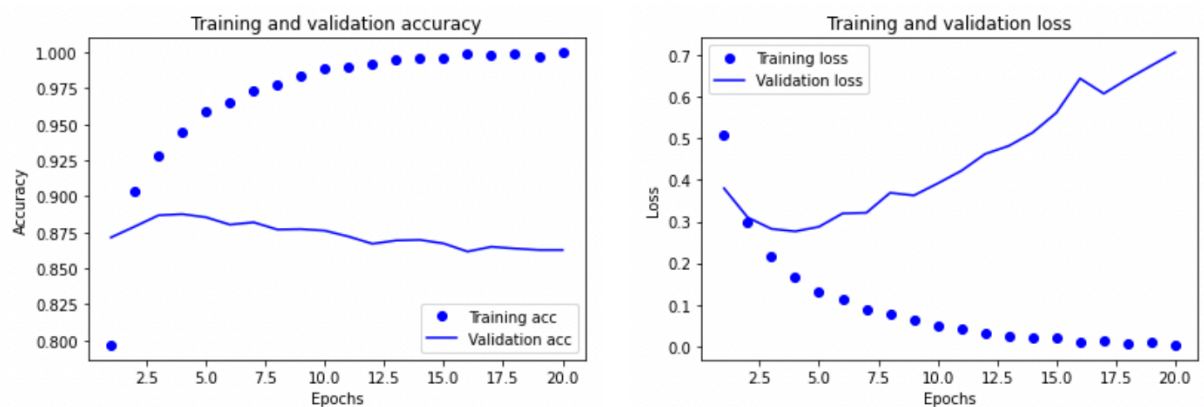
Eyob Tadele

02/20/2022

Project Objective

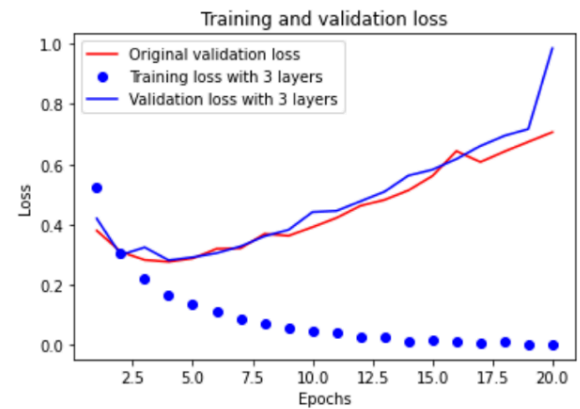
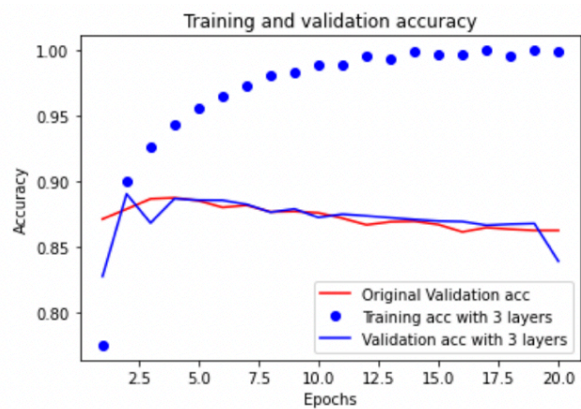
The objective of this assignment is to explore and extend the fundamental concepts of a Neural Network model making use of the IMDB dataset. This is done by changing and modifying some of the neural network components such as layers, loss functions, activations, and analyzing their respective effects on performance.

The baseline model, which will be used as the basis for comparison, is made out of two hidden layers consisting of 16 units each. Accuracy and loss for the training and validation sets are as follows:



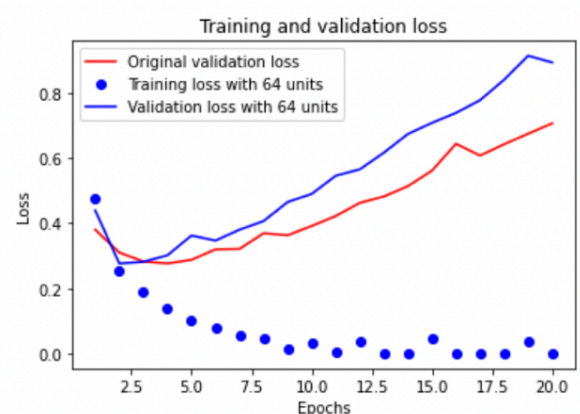
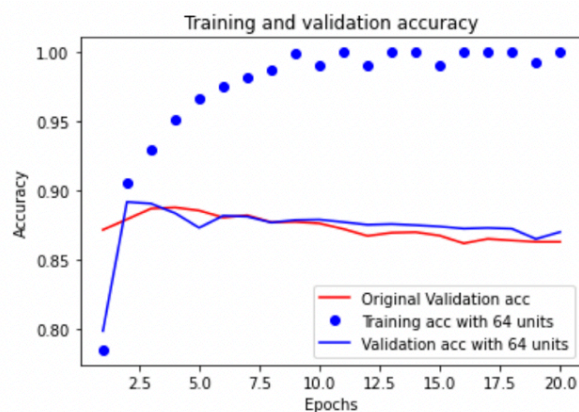
From the graph displayed above, it can be inferred that validation data for the baseline model starts to overfit approximately after about 4 epochs. The subsequent steps below attempt to make changes to the different components of the baseline neural network model and observe its effects on Accuracy/Loss.

1. Modifying the model to use three hidden layers and compare the result to the baseline model:



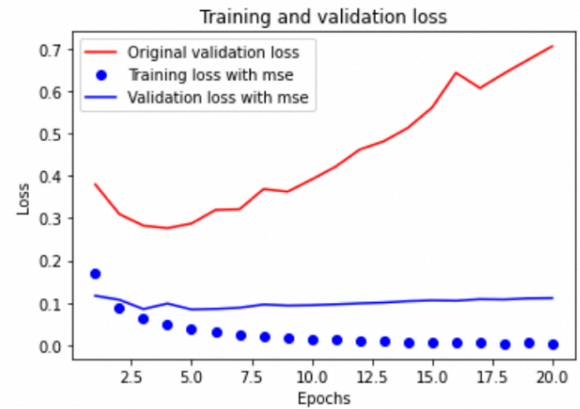
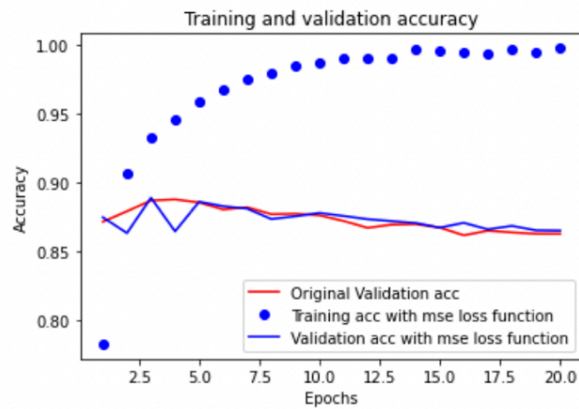
Comparing the accuracy of the three-layer model with the original baseline model, it quickly tends to overfit right after the first epoch. This may indicate that the model might have a bit more capacity than the problem actually warrants. Hence, the immediate overfit of the model. A simpler model might suffice.

2. Modifying the baseline model to use 64 hidden units to each of the existing two layers:



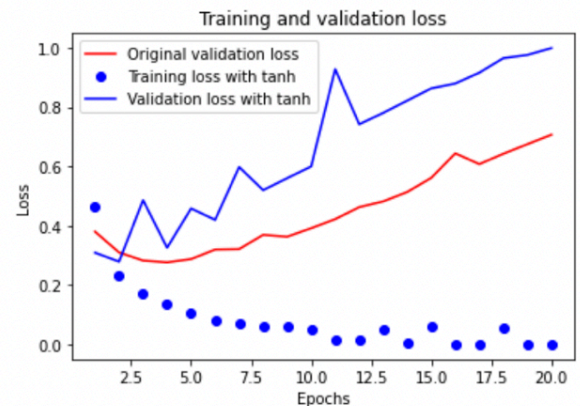
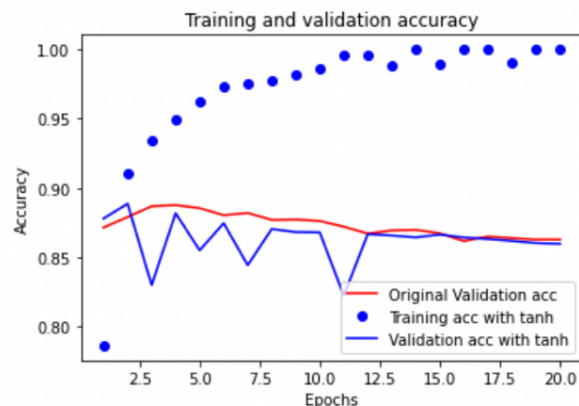
It can be observed from the figure above that the model with 64 hidden units starts to overfit immediately after two epochs. This can again be a sign of model overkill, where it is too complex for the problem space. A less complex model might address this more efficiently.

3. Using 'mse' loss function, instead of 'binary_crossentropy'



Applying the mse loss function has the impact of making the validation set more resistant to overfitting than the baseline model that used `binary_crossentropy`. This might be due to the fact that mse does not penalize misclassifications enough. Additionally, mse is more suited towards regression problems. This specific problem is a multi-class classification and `binary_crossentropy` is a better measure.

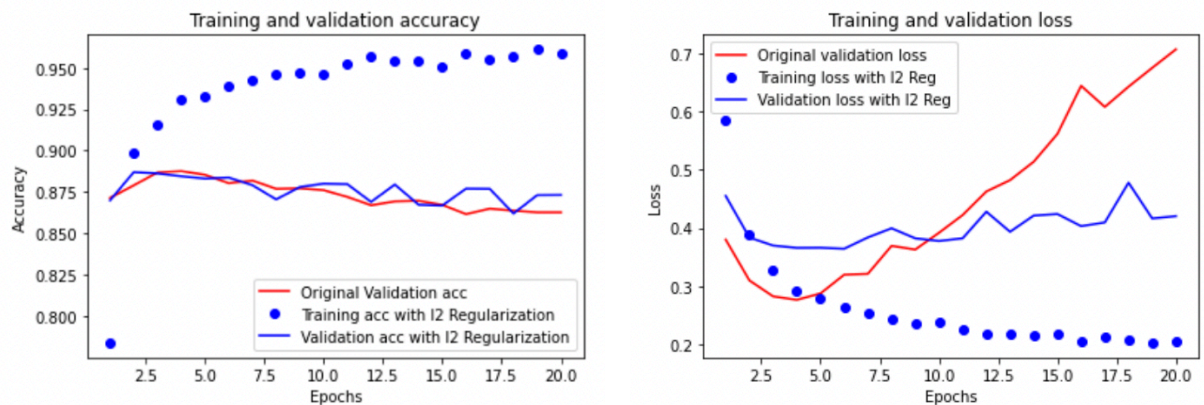
4. Modifying the baseline model by changing the activation of the layers to 'tanh', instead of 'relu'.



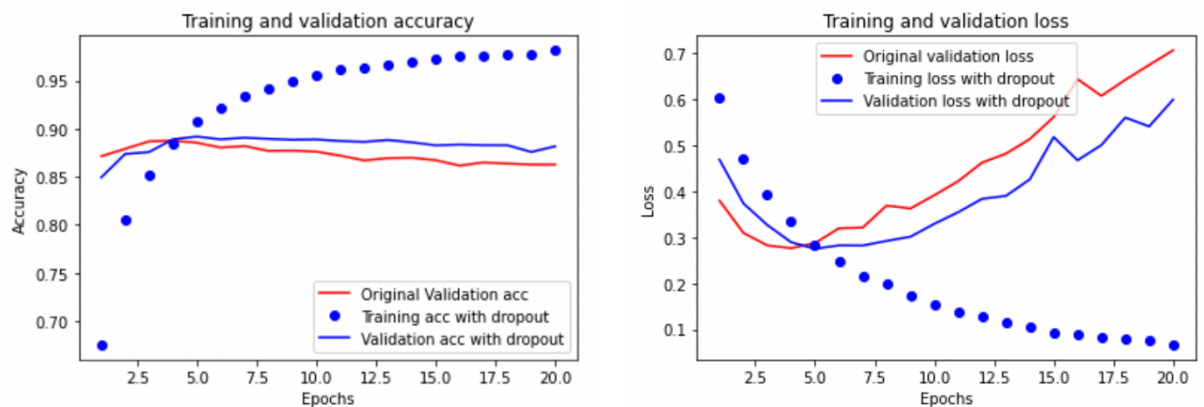
It can be inferred from the accuracy and loss graphs above that 'relu' appears to be better suited for this model. It tends to overfit rather quickly when using 'tanh' activation. This may be due to the fact that tanh is not best suited when it is essential to remove unimportant neurons to reduce complexity (i.e., tanh usually produces non-sparse models that usually produce output values). From the previous iterations of changes, we can see that this problem requires a less complex model.

5. Improving the baseline model to perform better on the validation set by applying different techniques.

Based on what has been observed from the previous steps that applied different alternatives, it is a good idea to make the model a little less complex. This can be achieved through regularization, where a cost is tied to the model to penalize complexity. Also, adding dropout to the model can help in improving the performance.



With the application of L2 regularization penalty, the new model is more resistant to overfitting when compared with the baseline model. However, a definitive improvement on accuracy is not observed. An alternative method is used below to see if there is a marked improvement.



Applying dropout as the regularization method above shows a clear improvement in accuracy/loss. We can see a longer curve before overfitting and an overall improvement in accuracy, when compared with the baseline validation.

Reference

A detailed run of all the code is indicated below as reference for more information.

Metal device set to: Apple M1 Pro

```
2022-02-27 12:00:51.241779: I tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:305] Could not identify NUMA node of platform GPU ID 0, defaulting to 0. Your kernel may not have been built with NUMA support.
```

```
2022-02-27 12:00:51.241949: I tensorflow/core/common_runtime/pluggable_device/pluggable_device_factory.cc:271] Created TensorFlow device (/job:localhost/replica:0/task:0/device:GPU:0 with 0 MB memory) -> physical PluggableDevice (device: 0, name: METAL, pci bus id: <undefined>)
```

Epoch 1/20

```
2022-02-27 12:01:05.733314: W tensorflow/core/platform/profile_utils/cpu_utils.cc:128] Failed to get CPU frequency: 0 Hz
```

```
1/30 [>.....] - ETA: 15s - loss: 0.6938 - accuracy: 0.5000
```

```
2022-02-27 12:01:06.071952: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
30/30 [=====] - 1s 25ms/step - loss: 0.5090 - accuracy: 0.7967 - val_loss: 0.3799 - val_accuracy: 0.8714
```

Epoch 2/20

```
1/30 [>.....] - ETA: 0s - loss: 0.3371 - accuracy: 0.9023
```

```
2022-02-27 12:01:06.819888: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.
```

```
30/30 [=====] - 0s 13ms/step - loss: 0.2979 - accuracy: 0.9038 - val_loss: 0.3098 - val_accuracy: 0.8790
```

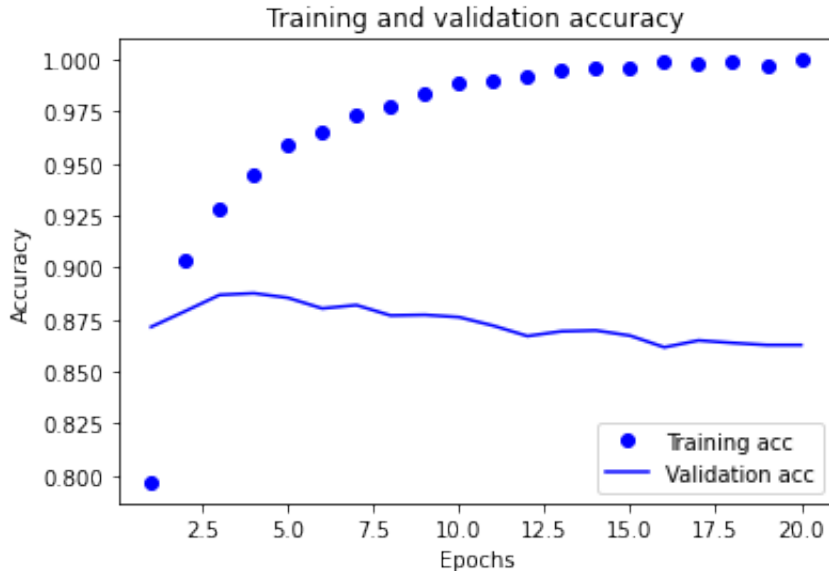
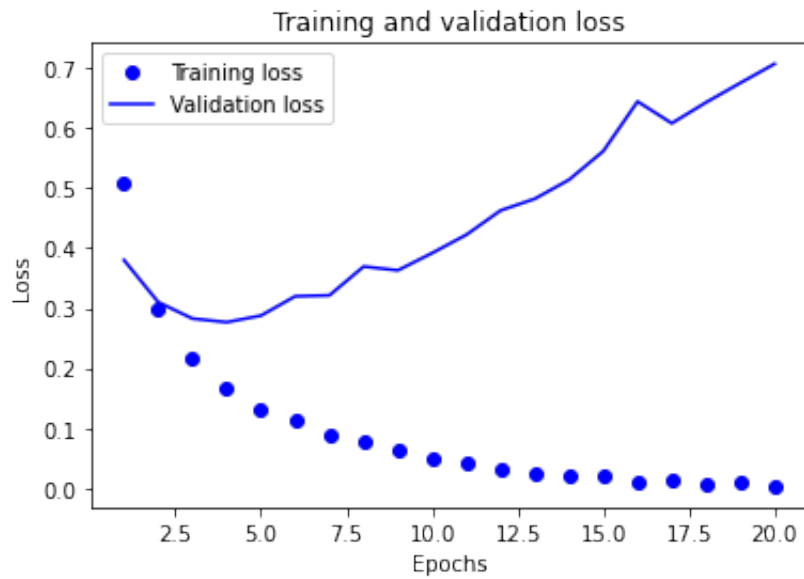
Epoch 3/20

```
30/30 [=====] - 0s 13ms/step - loss: 0.2151 - accuracy: 0.9282 - val_loss: 0.2824 - val_accuracy: 0.8868
```

Epoch 4/20

```
30/30 [=====] - 0s 14ms/step - loss: 0.1660 - accuracy: 0.9443 - val_loss: 0.2764 - val_accuracy: 0.8876
```

```
Epoch 5/20
30/30 [=====] - 0s 13ms/step - loss: 0.1321
- accuracy: 0.9594 - val_loss: 0.2874 - val_accuracy: 0.8854
Epoch 6/20
30/30 [=====] - 0s 13ms/step - loss: 0.1135
- accuracy: 0.9656 - val_loss: 0.3196 - val_accuracy: 0.8803
Epoch 7/20
30/30 [=====] - 0s 13ms/step - loss: 0.0896
- accuracy: 0.9737 - val_loss: 0.3211 - val_accuracy: 0.8819
Epoch 8/20
30/30 [=====] - 0s 13ms/step - loss: 0.0775
- accuracy: 0.9780 - val_loss: 0.3691 - val_accuracy: 0.8769
Epoch 9/20
30/30 [=====] - 0s 13ms/step - loss: 0.0619
- accuracy: 0.9837 - val_loss: 0.3628 - val_accuracy: 0.8772
Epoch 10/20
30/30 [=====] - 0s 13ms/step - loss: 0.0492
- accuracy: 0.9883 - val_loss: 0.3916 - val_accuracy: 0.8761
Epoch 11/20
30/30 [=====] - 0s 13ms/step - loss: 0.0421
- accuracy: 0.9893 - val_loss: 0.4221 - val_accuracy: 0.8720
Epoch 12/20
30/30 [=====] - 0s 14ms/step - loss: 0.0331
- accuracy: 0.9923 - val_loss: 0.4625 - val_accuracy: 0.8670
Epoch 13/20
30/30 [=====] - 0s 14ms/step - loss: 0.0256
- accuracy: 0.9947 - val_loss: 0.4820 - val_accuracy: 0.8693
Epoch 14/20
30/30 [=====] - 0s 13ms/step - loss: 0.0224
- accuracy: 0.9955 - val_loss: 0.5137 - val_accuracy: 0.8697
Epoch 15/20
30/30 [=====] - 0s 13ms/step - loss: 0.0193
- accuracy: 0.9964 - val_loss: 0.5614 - val_accuracy: 0.8672
Epoch 16/20
30/30 [=====] - 0s 14ms/step - loss: 0.0102
- accuracy: 0.9993 - val_loss: 0.6439 - val_accuracy: 0.8616
Epoch 17/20
30/30 [=====] - 0s 13ms/step - loss: 0.0133
- accuracy: 0.9979 - val_loss: 0.6077 - val_accuracy: 0.8649
Epoch 18/20
30/30 [=====] - 0s 14ms/step - loss: 0.0060
- accuracy: 0.9995 - val_loss: 0.6424 - val_accuracy: 0.8637
Epoch 19/20
30/30 [=====] - 0s 15ms/step - loss: 0.0114
- accuracy: 0.9968 - val_loss: 0.6748 - val_accuracy: 0.8627
Epoch 20/20
30/30 [=====] - 0s 14ms/step - loss: 0.0032
- accuracy: 0.9999 - val_loss: 0.7066 - val_accuracy: 0.8627
```



Epoch 1/20

1/30 [>.....] - ETA: 10s - loss: 0.6937 - accuracy: 0.4922

2022-02-27 12:02:00.281977: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 26ms/step - loss: 0.5230 - accuracy: 0.7753 - val_loss: 0.4197 - val_accuracy: 0.8278

Epoch 2/20

2022-02-27 12:02:01.023523: I tensorflow/core/grappler/optimizers/cus

tom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

```

30/30 [=====] - 0s 14ms/step - loss: 0.3050
- accuracy: 0.9006 - val_loss: 0.2992 - val_accuracy: 0.8906
Epoch 3/20
30/30 [=====] - 0s 14ms/step - loss: 0.2192
- accuracy: 0.9264 - val_loss: 0.3243 - val_accuracy: 0.8684
Epoch 4/20
30/30 [=====] - 0s 14ms/step - loss: 0.1667
- accuracy: 0.9436 - val_loss: 0.2816 - val_accuracy: 0.8870
Epoch 5/20
30/30 [=====] - 0s 14ms/step - loss: 0.1358
- accuracy: 0.9553 - val_loss: 0.2916 - val_accuracy: 0.8858
Epoch 6/20
30/30 [=====] - 0s 14ms/step - loss: 0.1101
- accuracy: 0.9646 - val_loss: 0.3053 - val_accuracy: 0.8857
Epoch 7/20
30/30 [=====] - 0s 14ms/step - loss: 0.0868
- accuracy: 0.9730 - val_loss: 0.3276 - val_accuracy: 0.8826
Epoch 8/20
30/30 [=====] - 0s 14ms/step - loss: 0.0708
- accuracy: 0.9806 - val_loss: 0.3616 - val_accuracy: 0.8766
Epoch 9/20
30/30 [=====] - 0s 14ms/step - loss: 0.0552
- accuracy: 0.9837 - val_loss: 0.3824 - val_accuracy: 0.8791
Epoch 10/20
30/30 [=====] - 0s 14ms/step - loss: 0.0445
- accuracy: 0.9885 - val_loss: 0.4416 - val_accuracy: 0.8726
Epoch 11/20
30/30 [=====] - 0s 14ms/step - loss: 0.0394
- accuracy: 0.9891 - val_loss: 0.4455 - val_accuracy: 0.8751
Epoch 12/20
30/30 [=====] - 0s 14ms/step - loss: 0.0242
- accuracy: 0.9953 - val_loss: 0.4774 - val_accuracy: 0.8738
Epoch 13/20
30/30 [=====] - 0s 16ms/step - loss: 0.0255
- accuracy: 0.9935 - val_loss: 0.5091 - val_accuracy: 0.8724
Epoch 14/20
30/30 [=====] - 0s 15ms/step - loss: 0.0114
- accuracy: 0.9992 - val_loss: 0.5628 - val_accuracy: 0.8710
Epoch 15/20
30/30 [=====] - 0s 15ms/step - loss: 0.0153
- accuracy: 0.9965 - val_loss: 0.5823 - val_accuracy: 0.8699
Epoch 16/20
30/30 [=====] - 0s 14ms/step - loss: 0.0128
- accuracy: 0.9963 - val_loss: 0.6177 - val_accuracy: 0.8695
Epoch 17/20
30/30 [=====] - 0s 14ms/step - loss: 0.0045
- accuracy: 0.9997 - val_loss: 0.6610 - val_accuracy: 0.8667
Epoch 18/20

```


Epoch 18/20

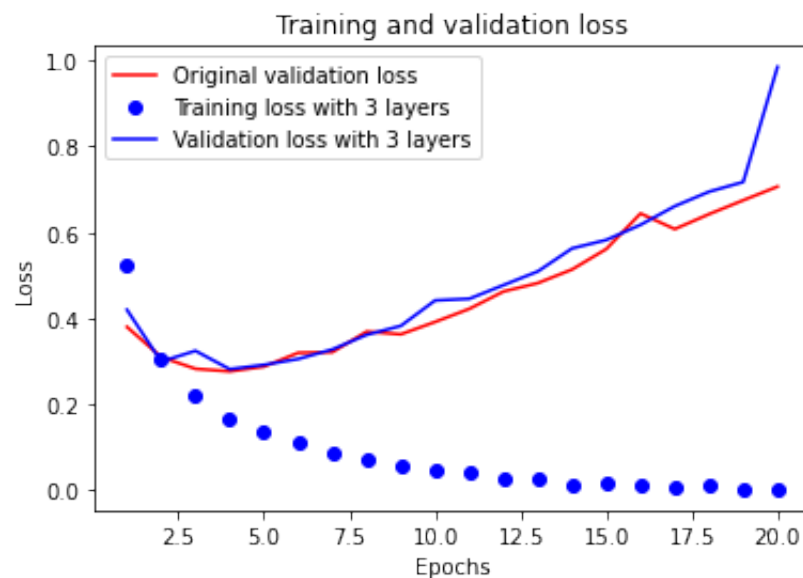
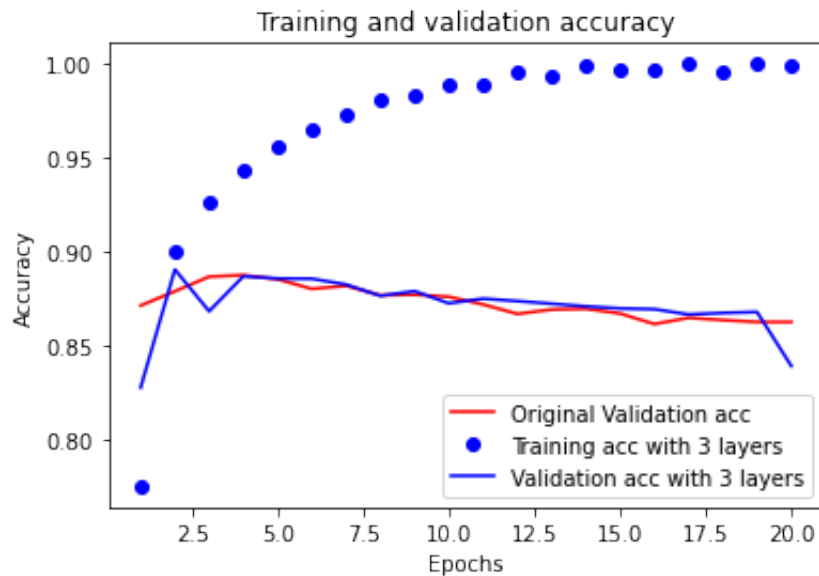
30/30 [=====] - 0s 14ms/step - loss: 0.0135
 - accuracy: 0.9961 - val_loss: 0.6947 - val_accuracy: 0.8675

Epoch 19/20

30/30 [=====] - 0s 14ms/step - loss: 0.0020
 - accuracy: 0.9999 - val_loss: 0.7173 - val_accuracy: 0.8680

Epoch 20/20

30/30 [=====] - 0s 14ms/step - loss: 0.0026
 - accuracy: 0.9995 - val_loss: 0.9852 - val_accuracy: 0.8393



Epoch 1/20

1/30 [>.....] - ETA: 8s - loss: 0.6947 - acc
 uracy: 0.4961

2022-02-27 12:07:56.553578: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 25ms/step - loss: 0.5014
- accuracy: 0.8001 - val_loss: 0.4081 - val_accuracy: 0.8526
Epoch 2/20
1/30 [>.....] - ETA: 0s - loss: 0.3687 - accuracy: 0.8711

2022-02-27 12:07:57.220678: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 0s 13ms/step - loss: 0.3217
- accuracy: 0.9020 - val_loss: 0.3299 - val_accuracy: 0.8763
Epoch 3/20

30/30 [=====] - 0s 13ms/step - loss: 0.2502
- accuracy: 0.9230 - val_loss: 0.2920 - val_accuracy: 0.8880
Epoch 4/20

30/30 [=====] - 0s 13ms/step - loss: 0.2051
- accuracy: 0.9367 - val_loss: 0.2991 - val_accuracy: 0.8792
Epoch 5/20

30/30 [=====] - 0s 12ms/step - loss: 0.1743
- accuracy: 0.9460 - val_loss: 0.2824 - val_accuracy: 0.8876
Epoch 6/20

30/30 [=====] - 0s 12ms/step - loss: 0.1503
- accuracy: 0.9557 - val_loss: 0.2787 - val_accuracy: 0.8865
Epoch 7/20

30/30 [=====] - 0s 13ms/step - loss: 0.1310
- accuracy: 0.9619 - val_loss: 0.2932 - val_accuracy: 0.8840
Epoch 8/20

30/30 [=====] - 0s 12ms/step - loss: 0.1145
- accuracy: 0.9683 - val_loss: 0.2851 - val_accuracy: 0.8874
Epoch 9/20

30/30 [=====] - 0s 13ms/step - loss: 0.1022
- accuracy: 0.9719 - val_loss: 0.2952 - val_accuracy: 0.8844
Epoch 10/20

30/30 [=====] - 0s 12ms/step - loss: 0.0894
- accuracy: 0.9777 - val_loss: 0.3158 - val_accuracy: 0.8821
Epoch 11/20

30/30 [=====] - 0s 12ms/step - loss: 0.0806
- accuracy: 0.9800 - val_loss: 0.3208 - val_accuracy: 0.8817
Epoch 12/20

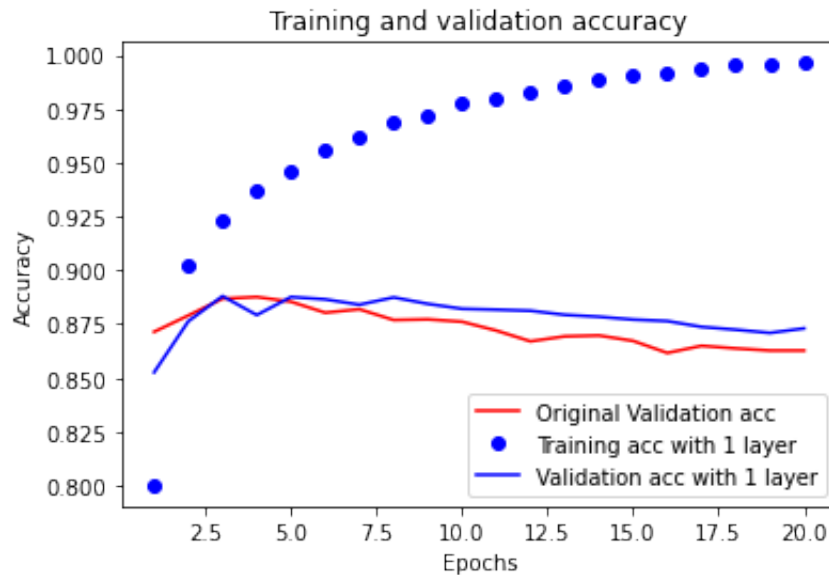
30/30 [=====] - 0s 12ms/step - loss: 0.0709
- accuracy: 0.9825 - val_loss: 0.3304 - val_accuracy: 0.8812
Epoch 13/20

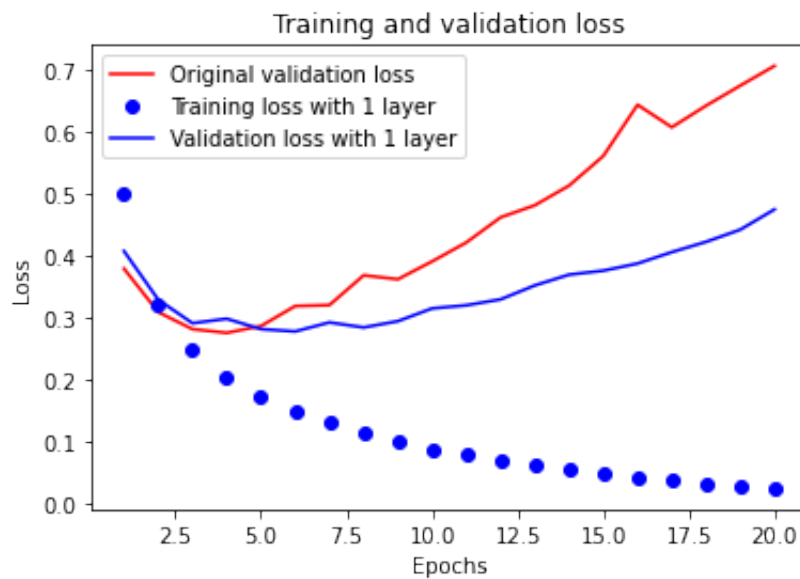
30/30 [=====] - 0s 12ms/step - loss: 0.0627
- accuracy: 0.9861 - val_loss: 0.3529 - val_accuracy: 0.8793
Epoch 14/20

```

30/30 [=====] - 0s 12ms/step - loss: 0.0554
- accuracy: 0.9891 - val_loss: 0.3702 - val_accuracy: 0.8784
Epoch 15/20
30/30 [=====] - 0s 13ms/step - loss: 0.0493
- accuracy: 0.9903 - val_loss: 0.3766 - val_accuracy: 0.8771
Epoch 16/20
30/30 [=====] - 0s 13ms/step - loss: 0.0440
- accuracy: 0.9915 - val_loss: 0.3881 - val_accuracy: 0.8764
Epoch 17/20
30/30 [=====] - 0s 13ms/step - loss: 0.0382
- accuracy: 0.9936 - val_loss: 0.4065 - val_accuracy: 0.8737
Epoch 18/20
30/30 [=====] - 0s 13ms/step - loss: 0.0337
- accuracy: 0.9952 - val_loss: 0.4230 - val_accuracy: 0.8724
Epoch 19/20
30/30 [=====] - 0s 13ms/step - loss: 0.0298
- accuracy: 0.9957 - val_loss: 0.4427 - val_accuracy: 0.8709
Epoch 20/20
30/30 [=====] - 0s 13ms/step - loss: 0.0260
- accuracy: 0.9963 - val_loss: 0.4753 - val_accuracy: 0.8730

```





2. Modifying the baseline model by applying 32 and 64 hidden units respectively, and compare training and validation accuracies.

Epoch 1/20

1/30 [>.....] - ETA: 11s - loss: 0.6975 - accuracy: 0.4531

2022-02-27 12:38:22.402812: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - ETA: 0s - loss: 0.4956 - accuracy: 0.7837

2022-02-27 12:38:23.189058: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 28ms/step - loss: 0.4956 - accuracy: 0.7837 - val_loss: 0.3579 - val_accuracy: 0.8707

Epoch 2/20

30/30 [=====] - 0s 14ms/step - loss: 0.2788 - accuracy: 0.9047 - val_loss: 0.2875 - val_accuracy: 0.8887

Epoch 3/20

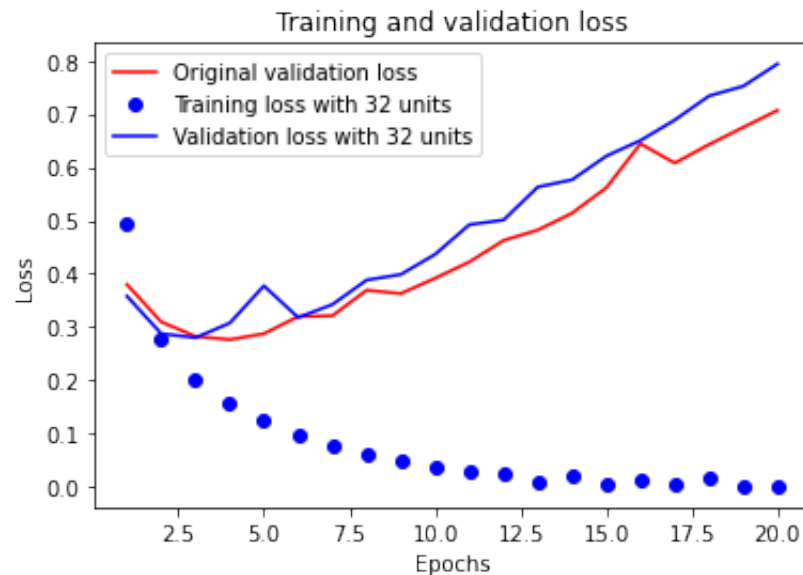
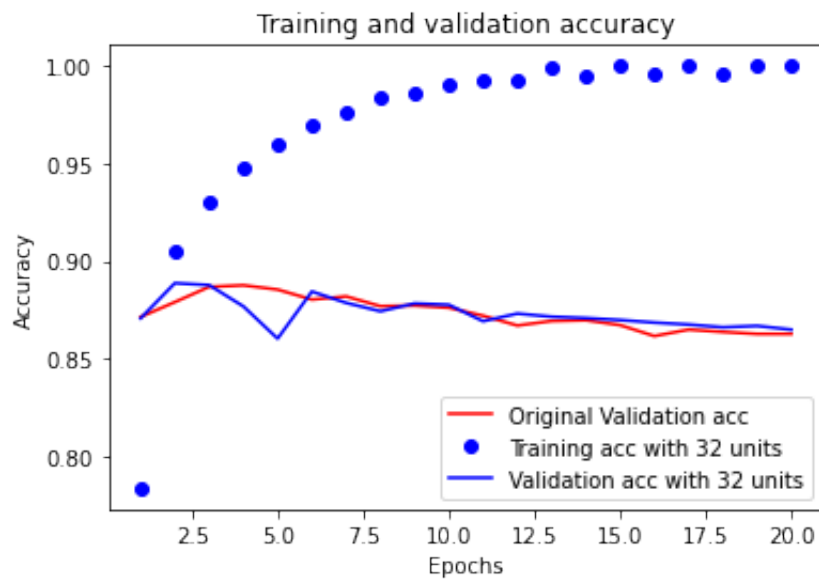
30/30 [=====] - 0s 14ms/step - loss: 0.2022 - accuracy: 0.9307 - val_loss: 0.2799 - val_accuracy: 0.8877

Epoch 4/20

30/30 [=====] - 0s 15ms/step - loss: 0.1557 - accuracy: 0.9475 - val_loss: 0.3073 - val_accuracy: 0.8768

Epoch 5/20

```
30/30 [=====] - 0s 15ms/step - loss: 0.1237
- accuracy: 0.9598 - val_loss: 0.3773 - val_accuracy: 0.8603
Epoch 6/20
30/30 [=====] - 0s 15ms/step - loss: 0.0967
- accuracy: 0.9697 - val_loss: 0.3178 - val_accuracy: 0.8844
Epoch 7/20
30/30 [=====] - 0s 15ms/step - loss: 0.0772
- accuracy: 0.9766 - val_loss: 0.3422 - val_accuracy: 0.8786
Epoch 8/20
30/30 [=====] - 0s 15ms/step - loss: 0.0609
- accuracy: 0.9834 - val_loss: 0.3882 - val_accuracy: 0.8743
Epoch 9/20
30/30 [=====] - 0s 14ms/step - loss: 0.0489
- accuracy: 0.9859 - val_loss: 0.3986 - val_accuracy: 0.8783
Epoch 10/20
30/30 [=====] - 0s 14ms/step - loss: 0.0373
- accuracy: 0.9903 - val_loss: 0.4364 - val_accuracy: 0.8776
Epoch 11/20
30/30 [=====] - 0s 14ms/step - loss: 0.0298
- accuracy: 0.9920 - val_loss: 0.4920 - val_accuracy: 0.8692
Epoch 12/20
30/30 [=====] - 0s 15ms/step - loss: 0.0253
- accuracy: 0.9930 - val_loss: 0.5008 - val_accuracy: 0.8731
Epoch 13/20
30/30 [=====] - 0s 14ms/step - loss: 0.0106
- accuracy: 0.9991 - val_loss: 0.5628 - val_accuracy: 0.8715
Epoch 14/20
30/30 [=====] - 0s 15ms/step - loss: 0.0227
- accuracy: 0.9942 - val_loss: 0.5763 - val_accuracy: 0.8708
Epoch 15/20
30/30 [=====] - 0s 16ms/step - loss: 0.0056
- accuracy: 0.9998 - val_loss: 0.6208 - val_accuracy: 0.8698
Epoch 16/20
30/30 [=====] - 0s 15ms/step - loss: 0.0140
- accuracy: 0.9961 - val_loss: 0.6501 - val_accuracy: 0.8685
Epoch 17/20
30/30 [=====] - 0s 15ms/step - loss: 0.0028
- accuracy: 0.9999 - val_loss: 0.6885 - val_accuracy: 0.8675
Epoch 18/20
30/30 [=====] - 0s 14ms/step - loss: 0.0182
- accuracy: 0.9954 - val_loss: 0.7336 - val_accuracy: 0.8661
Epoch 19/20
30/30 [=====] - 0s 15ms/step - loss: 0.0015
- accuracy: 0.9999 - val_loss: 0.7519 - val_accuracy: 0.8668
Epoch 20/20
30/30 [=====] - 0s 14ms/step - loss: 0.0012
- accuracy: 0.9999 - val_loss: 0.7938 - val_accuracy: 0.8649
```



Epoch 1/20

2022-02-27 12:39:38.967830: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - ETA: 0s - loss: 0.4763 - accuracy: 0.7845

2022-02-27 12:39:39.716868: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

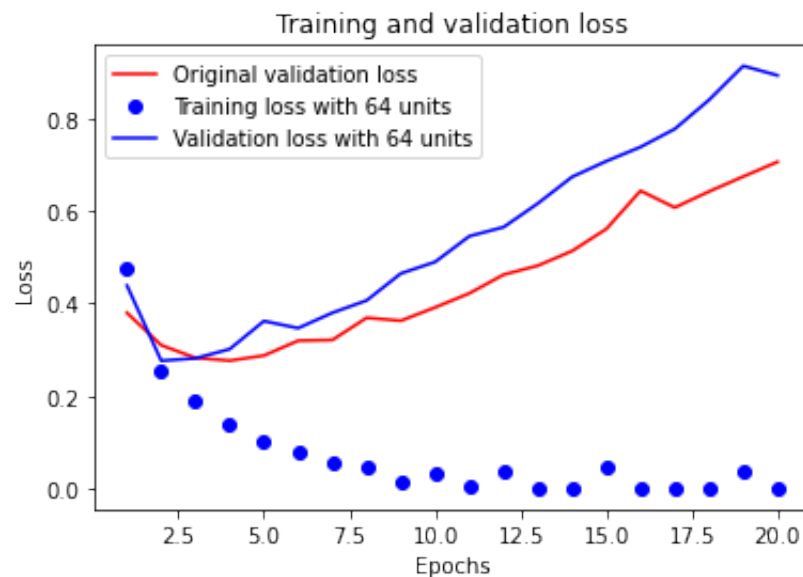
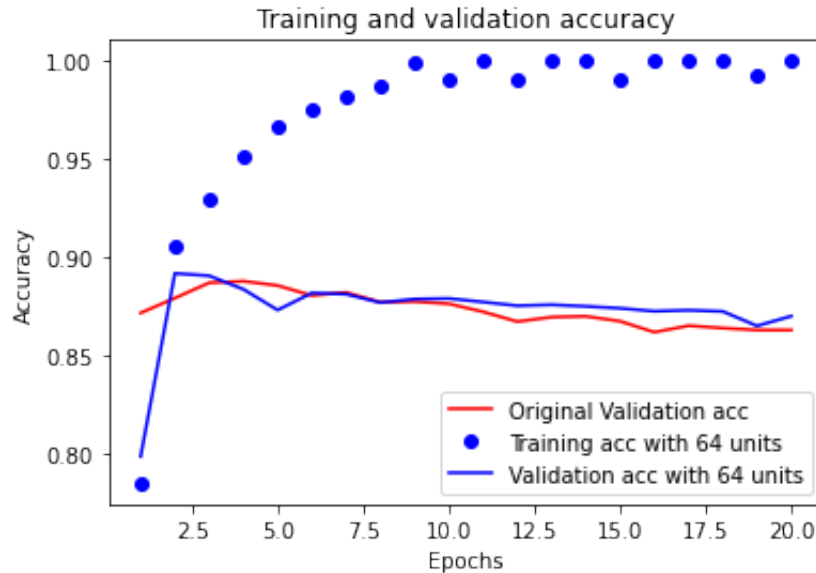
30/30 [=====] - 1s 25ms/step - loss: 0.4763


```
-----
- accuracy: 0.7845 - val_loss: 0.4389 - val_accuracy: 0.7982
Epoch 2/20
30/30 [=====] - 0s 15ms/step - loss: 0.2553
- accuracy: 0.9055 - val_loss: 0.2762 - val_accuracy: 0.8916
Epoch 3/20
30/30 [=====] - 0s 15ms/step - loss: 0.1913
- accuracy: 0.9299 - val_loss: 0.2814 - val_accuracy: 0.8904
Epoch 4/20
30/30 [=====] - 0s 15ms/step - loss: 0.1403
- accuracy: 0.9508 - val_loss: 0.3013 - val_accuracy: 0.8835
Epoch 5/20
30/30 [=====] - 0s 14ms/step - loss: 0.1012
- accuracy: 0.9661 - val_loss: 0.3621 - val_accuracy: 0.8729
Epoch 6/20
30/30 [=====] - 0s 15ms/step - loss: 0.0782
- accuracy: 0.9749 - val_loss: 0.3467 - val_accuracy: 0.8816
Epoch 7/20
30/30 [=====] - 0s 15ms/step - loss: 0.0574
- accuracy: 0.9821 - val_loss: 0.3800 - val_accuracy: 0.8810
Epoch 8/20
30/30 [=====] - 0s 15ms/step - loss: 0.0471
- accuracy: 0.9867 - val_loss: 0.4066 - val_accuracy: 0.8767
Epoch 9/20
30/30 [=====] - 0s 14ms/step - loss: 0.0133
- accuracy: 0.9987 - val_loss: 0.4651 - val_accuracy: 0.8785
Epoch 10/20
30/30 [=====] - 0s 15ms/step - loss: 0.0337
- accuracy: 0.9901 - val_loss: 0.4900 - val_accuracy: 0.8788
Epoch 11/20
30/30 [=====] - 0s 15ms/step - loss: 0.0049
- accuracy: 0.9998 - val_loss: 0.5458 - val_accuracy: 0.8770
Epoch 12/20
30/30 [=====] - 0s 15ms/step - loss: 0.0383
- accuracy: 0.9907 - val_loss: 0.5653 - val_accuracy: 0.8751
Epoch 13/20
30/30 [=====] - 0s 15ms/step - loss: 0.0020
- accuracy: 0.9999 - val_loss: 0.6166 - val_accuracy: 0.8756
Epoch 14/20
30/30 [=====] - 0s 14ms/step - loss: 0.0013
- accuracy: 0.9999 - val_loss: 0.6740 - val_accuracy: 0.8748
Epoch 15/20
30/30 [=====] - 0s 15ms/step - loss: 0.0445
- accuracy: 0.9910 - val_loss: 0.7081 - val_accuracy: 0.8738
Epoch 16/20
30/30 [=====] - 0s 15ms/step - loss: 5.1274e
-04 - accuracy: 1.0000 - val_loss: 0.7387 - val_accuracy: 0.8723
Epoch 17/20
30/30 [=====] - 0s 15ms/step - loss: 3.5862e
-04 - accuracy: 1.0000 - val_loss: 0.7778 - val_accuracy: 0.8728
Epoch 18/20
```

```

30/30 [=====] - 0s 15ms/step - loss: 2.3319e
-04 - accuracy: 1.0000 - val_loss: 0.8406 - val_accuracy: 0.8722
Epoch 19/20
30/30 [=====] - 0s 15ms/step - loss: 0.0360
- accuracy: 0.9930 - val_loss: 0.9143 - val_accuracy: 0.8648
Epoch 20/20
30/30 [=====] - 0s 15ms/step - loss: 2.0970e
-04 - accuracy: 1.0000 - val_loss: 0.8937 - val_accuracy: 0.8698

```



3. Modifying the baseline model by using mse for the loss function

Epoch 1/20

2022-02-27 13:03:01.382968: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 24ms/step - loss: 0.1697
- accuracy: 0.7828 - val_loss: 0.1164 - val_accuracy: 0.8746

Epoch 2/20

1/30 [>.....] - ETA: 0s - loss: 0.0986 - accuracy: 0.9102

2022-02-27 13:03:02.090334: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 0s 14ms/step - loss: 0.0889
- accuracy: 0.9067 - val_loss: 0.1071 - val_accuracy: 0.8632

Epoch 3/20

30/30 [=====] - 0s 14ms/step - loss: 0.0638
- accuracy: 0.9322 - val_loss: 0.0850 - val_accuracy: 0.8888

Epoch 4/20

30/30 [=====] - 0s 14ms/step - loss: 0.0491
- accuracy: 0.9452 - val_loss: 0.0982 - val_accuracy: 0.8644

Epoch 5/20

30/30 [=====] - 0s 14ms/step - loss: 0.0389
- accuracy: 0.9580 - val_loss: 0.0841 - val_accuracy: 0.8859

Epoch 6/20

30/30 [=====] - 0s 13ms/step - loss: 0.0316
- accuracy: 0.9670 - val_loss: 0.0854 - val_accuracy: 0.8827

Epoch 7/20

30/30 [=====] - 0s 14ms/step - loss: 0.0252
- accuracy: 0.9749 - val_loss: 0.0882 - val_accuracy: 0.8809

Epoch 8/20

30/30 [=====] - 0s 13ms/step - loss: 0.0215
- accuracy: 0.9795 - val_loss: 0.0958 - val_accuracy: 0.8734

Epoch 9/20

30/30 [=====] - 0s 13ms/step - loss: 0.0175
- accuracy: 0.9844 - val_loss: 0.0934 - val_accuracy: 0.8754

Epoch 10/20

30/30 [=====] - 0s 14ms/step - loss: 0.0147
- accuracy: 0.9866 - val_loss: 0.0942 - val_accuracy: 0.8778

Epoch 11/20

30/30 [=====] - 0s 14ms/step - loss: 0.0124
- accuracy: 0.9896 - val_loss: 0.0963 - val_accuracy: 0.8756

Epoch 12/20

30/30 [=====] - 0s 14ms/step - loss: 0.0107
- accuracy: 0.9903 - val_loss: 0.0986 - val_accuracy: 0.8733

Epoch 13/20

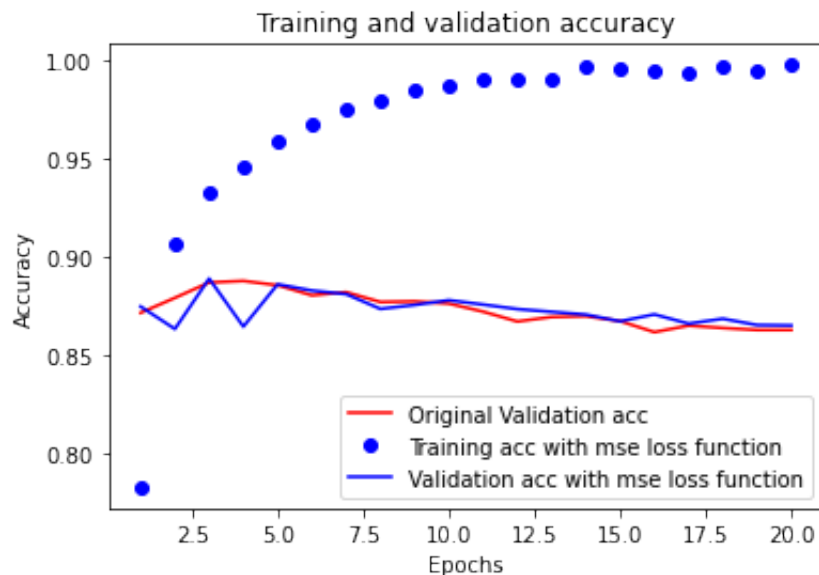
30/30 [=====] - 0s 14ms/step - loss: 0.0101
- accuracy: 0.9904 - val_loss: 0.1004 - val_accuracy: 0.8719

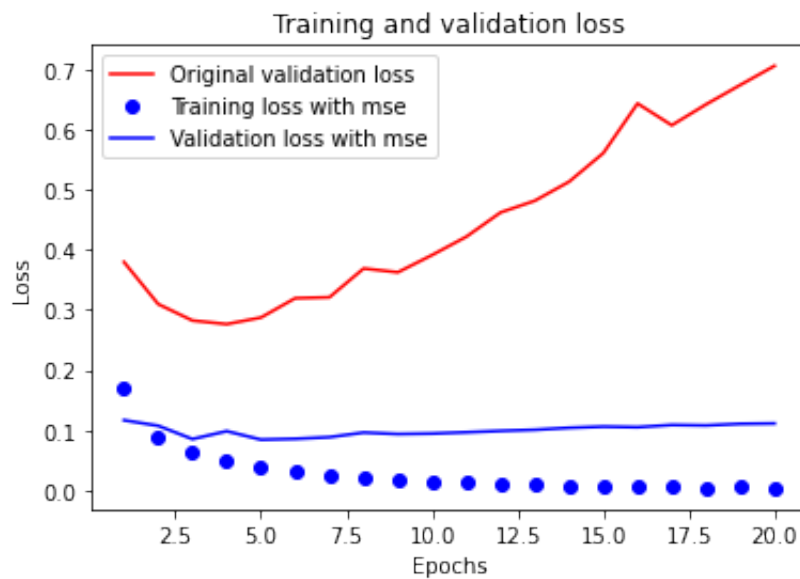
Epoch 14/20

```

30/30 [=====] - 0s 14ms/step - loss: 0.0057
- accuracy: 0.9961 - val_loss: 0.1037 - val_accuracy: 0.8705
Epoch 15/20
30/30 [=====] - 0s 14ms/step - loss: 0.0063
- accuracy: 0.9957 - val_loss: 0.1057 - val_accuracy: 0.8671
Epoch 16/20
30/30 [=====] - 0s 14ms/step - loss: 0.0067
- accuracy: 0.9942 - val_loss: 0.1048 - val_accuracy: 0.8706
Epoch 17/20
30/30 [=====] - 0s 14ms/step - loss: 0.0064
- accuracy: 0.9933 - val_loss: 0.1085 - val_accuracy: 0.8659
Epoch 18/20
30/30 [=====] - 0s 14ms/step - loss: 0.0036
- accuracy: 0.9969 - val_loss: 0.1077 - val_accuracy: 0.8684
Epoch 19/20
30/30 [=====] - 0s 13ms/step - loss: 0.0055
- accuracy: 0.9945 - val_loss: 0.1104 - val_accuracy: 0.8652
Epoch 20/20
30/30 [=====] - 0s 13ms/step - loss: 0.0031
- accuracy: 0.9973 - val_loss: 0.1110 - val_accuracy: 0.8650

```





4. Modifying the baseline model using tanh activation, instead of relu.

Epoch 1/20

2022-02-27 13:41:04.296548: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

29/30 [=====>.] - ETA: 0s - loss: 0.4656 - accuracy: 0.7852

2022-02-27 13:41:05.037736: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 25ms/step - loss: 0.4641 - accuracy: 0.7861 - val_loss: 0.3090 - val_accuracy: 0.8779

Epoch 2/20

30/30 [=====] - 0s 15ms/step - loss: 0.2305 - accuracy: 0.9104 - val_loss: 0.2787 - val_accuracy: 0.8886

Epoch 3/20

30/30 [=====] - 0s 15ms/step - loss: 0.1697 - accuracy: 0.9345 - val_loss: 0.4860 - val_accuracy: 0.8298

Epoch 4/20

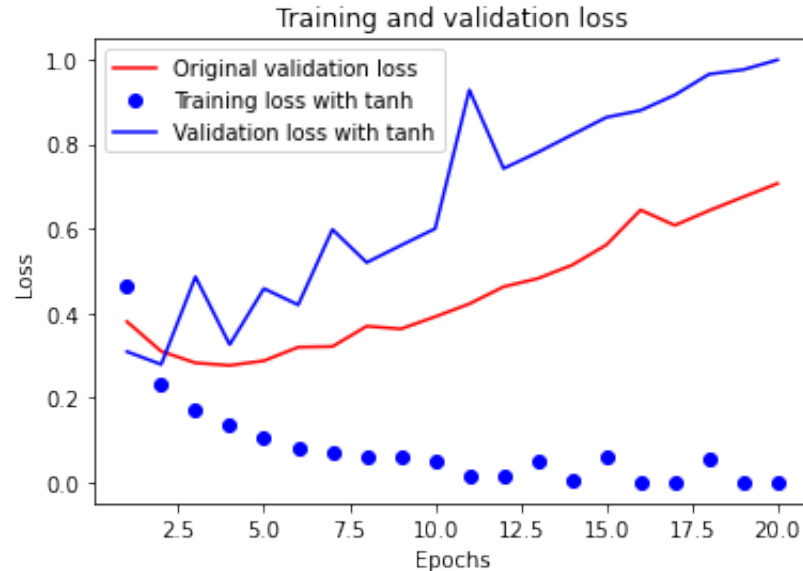
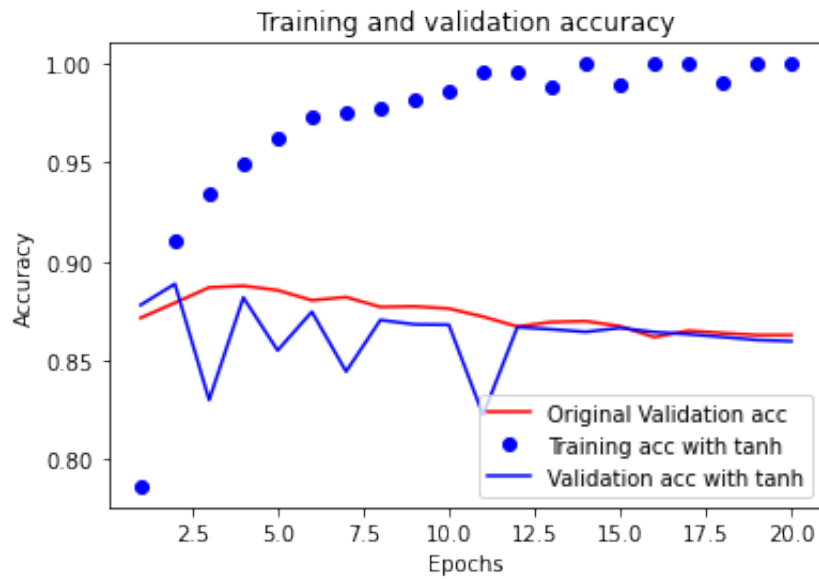
30/30 [=====] - 0s 15ms/step - loss: 0.1387 - accuracy: 0.9495 - val_loss: 0.3256 - val_accuracy: 0.8817

Epoch 5/20

30/30 [=====] - 0s 14ms/step - loss: 0.1045 - accuracy: 0.9627 - val_loss: 0.4581 - val_accuracy: 0.8549

Epoch 6/20

```
30/30 [=====] - 0s 14ms/step - loss: 0.0830
- accuracy: 0.9732 - val_loss: 0.4196 - val_accuracy: 0.8745
Epoch 7/20
30/30 [=====] - 0s 15ms/step - loss: 0.0712
- accuracy: 0.9754 - val_loss: 0.5978 - val_accuracy: 0.8442
Epoch 8/20
30/30 [=====] - 0s 14ms/step - loss: 0.0613
- accuracy: 0.9779 - val_loss: 0.5198 - val_accuracy: 0.8703
Epoch 9/20
30/30 [=====] - 0s 14ms/step - loss: 0.0586
- accuracy: 0.9823 - val_loss: 0.5603 - val_accuracy: 0.8681
Epoch 10/20
30/30 [=====] - 0s 14ms/step - loss: 0.0523
- accuracy: 0.9858 - val_loss: 0.5998 - val_accuracy: 0.8679
Epoch 11/20
30/30 [=====] - 0s 14ms/step - loss: 0.0164
- accuracy: 0.9962 - val_loss: 0.9278 - val_accuracy: 0.8222
Epoch 12/20
30/30 [=====] - 0s 14ms/step - loss: 0.0157
- accuracy: 0.9957 - val_loss: 0.7420 - val_accuracy: 0.8667
Epoch 13/20
30/30 [=====] - 0s 14ms/step - loss: 0.0512
- accuracy: 0.9886 - val_loss: 0.7803 - val_accuracy: 0.8656
Epoch 14/20
30/30 [=====] - 0s 14ms/step - loss: 0.0025
- accuracy: 0.9997 - val_loss: 0.8218 - val_accuracy: 0.8643
Epoch 15/20
30/30 [=====] - 0s 14ms/step - loss: 0.0617
- accuracy: 0.9892 - val_loss: 0.8629 - val_accuracy: 0.8663
Epoch 16/20
30/30 [=====] - 0s 14ms/step - loss: 0.0010
- accuracy: 0.9999 - val_loss: 0.8794 - val_accuracy: 0.8642
Epoch 17/20
30/30 [=====] - 0s 14ms/step - loss: 5.9252e
-04 - accuracy: 1.0000 - val_loss: 0.9158 - val_accuracy: 0.8631
Epoch 18/20
30/30 [=====] - 0s 14ms/step - loss: 0.0543
- accuracy: 0.9902 - val_loss: 0.9650 - val_accuracy: 0.8617
Epoch 19/20
30/30 [=====] - 0s 14ms/step - loss: 4.1376e
-04 - accuracy: 0.9999 - val_loss: 0.9757 - val_accuracy: 0.8602
Epoch 20/20
30/30 [=====] - 0s 14ms/step - loss: 2.1334e
-04 - accuracy: 1.0000 - val_loss: 0.9988 - val_accuracy: 0.8596
```

5. Getting Regularization and Dropout to improve the performance on the validation set.

Epoch 1/20

2022-02-27 14:50:11.887996: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - ETA: 0s - loss: 0.5859 - accuracy: 0.7839

2022-02-27 14:50:12.757405: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

tom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 29ms/step - loss: 0.5859
- accuracy: 0.7839 - val_loss: 0.4549 - val_accuracy: 0.8699

Epoch 2/20

30/30 [=====] - 0s 15ms/step - loss: 0.3878
- accuracy: 0.8989 - val_loss: 0.3834 - val_accuracy: 0.8870

Epoch 3/20

30/30 [=====] - 0s 15ms/step - loss: 0.3268
- accuracy: 0.9157 - val_loss: 0.3697 - val_accuracy: 0.8862

Epoch 4/20

30/30 [=====] - 0s 15ms/step - loss: 0.2912
- accuracy: 0.9313 - val_loss: 0.3657 - val_accuracy: 0.8845

Epoch 5/20

30/30 [=====] - 0s 15ms/step - loss: 0.2785
- accuracy: 0.9325 - val_loss: 0.3659 - val_accuracy: 0.8831

Epoch 6/20

30/30 [=====] - 0s 15ms/step - loss: 0.2644
- accuracy: 0.9393 - val_loss: 0.3642 - val_accuracy: 0.8837

Epoch 7/20

30/30 [=====] - 0s 15ms/step - loss: 0.2527
- accuracy: 0.9427 - val_loss: 0.3836 - val_accuracy: 0.8791

Epoch 8/20

30/30 [=====] - 0s 15ms/step - loss: 0.2437
- accuracy: 0.9461 - val_loss: 0.3993 - val_accuracy: 0.8705

Epoch 9/20

30/30 [=====] - 0s 15ms/step - loss: 0.2353
- accuracy: 0.9475 - val_loss: 0.3820 - val_accuracy: 0.8780

Epoch 10/20

30/30 [=====] - 0s 15ms/step - loss: 0.2388
- accuracy: 0.9459 - val_loss: 0.3774 - val_accuracy: 0.8800

Epoch 11/20

30/30 [=====] - 0s 15ms/step - loss: 0.2260
- accuracy: 0.9525 - val_loss: 0.3821 - val_accuracy: 0.8797

Epoch 12/20

30/30 [=====] - 0s 15ms/step - loss: 0.2182
- accuracy: 0.9565 - val_loss: 0.4278 - val_accuracy: 0.8690

Epoch 13/20

30/30 [=====] - 0s 15ms/step - loss: 0.2191
- accuracy: 0.9545 - val_loss: 0.3933 - val_accuracy: 0.8795

Epoch 14/20

30/30 [=====] - 0s 15ms/step - loss: 0.2153
- accuracy: 0.9545 - val_loss: 0.4212 - val_accuracy: 0.8673

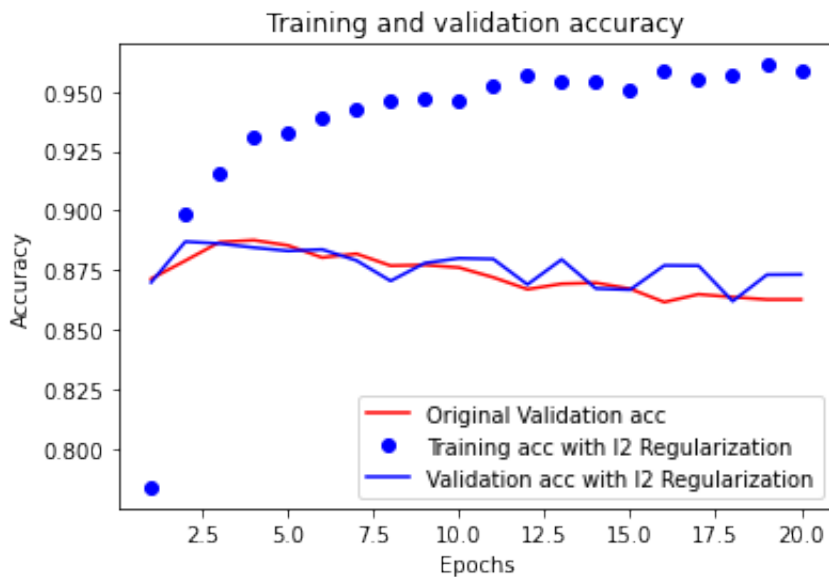
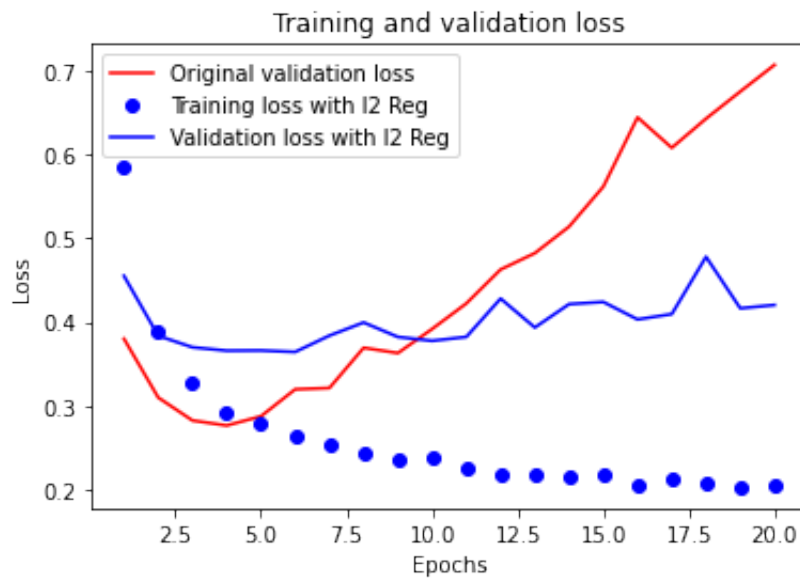
Epoch 15/20

30/30 [=====] - 0s 15ms/step - loss: 0.2186
- accuracy: 0.9510 - val_loss: 0.4238 - val_accuracy: 0.8668

Epoch 16/20

30/30 [=====] - 0s 15ms/step - loss: 0.2054
- accuracy: 0.9589 - val_loss: 0.4030 - val_accuracy: 0.8770

```
accuracy: 0.9555 - val_loss: 0.4093 - val_accuracy: 0.8769
Epoch 17/20
30/30 [=====] - 0s 15ms/step - loss: 0.2122
- accuracy: 0.9555 - val_loss: 0.4093 - val_accuracy: 0.8769
Epoch 18/20
30/30 [=====] - 0s 15ms/step - loss: 0.2064
- accuracy: 0.9568 - val_loss: 0.4777 - val_accuracy: 0.8620
Epoch 19/20
30/30 [=====] - 0s 15ms/step - loss: 0.2028
- accuracy: 0.9612 - val_loss: 0.4162 - val_accuracy: 0.8731
Epoch 20/20
30/30 [=====] - 0s 14ms/step - loss: 0.2053
- accuracy: 0.9588 - val_loss: 0.4201 - val_accuracy: 0.8732
```



Epoch 1/20

2022-02-27 14:52:28.295109: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - ETA: 0s - loss: 0.6051 - accuracy: 0.6755

2022-02-27 14:52:29.311563: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:113] Plugin optimizer for device_type GPU is enabled.

30/30 [=====] - 1s 31ms/step - loss: 0.6051 - accuracy: 0.6755 - val_loss: 0.4689 - val_accuracy: 0.8494

Epoch 2/20

30/30 [=====] - 0s 15ms/step - loss: 0.4712 - accuracy: 0.8060 - val_loss: 0.3739 - val_accuracy: 0.8737

Epoch 3/20

30/30 [=====] - 0s 15ms/step - loss: 0.3922 - accuracy: 0.8524 - val_loss: 0.3269 - val_accuracy: 0.8757

Epoch 4/20

30/30 [=====] - 0s 15ms/step - loss: 0.3337 - accuracy: 0.8835 - val_loss: 0.2894 - val_accuracy: 0.8889

Epoch 5/20

30/30 [=====] - 0s 15ms/step - loss: 0.2842 - accuracy: 0.9073 - val_loss: 0.2750 - val_accuracy: 0.8918

Epoch 6/20

30/30 [=====] - 0s 15ms/step - loss: 0.2490 - accuracy: 0.9218 - val_loss: 0.2825 - val_accuracy: 0.8889

Epoch 7/20

30/30 [=====] - 0s 15ms/step - loss: 0.2153 - accuracy: 0.9336 - val_loss: 0.2822 - val_accuracy: 0.8906

Epoch 8/20

30/30 [=====] - 0s 15ms/step - loss: 0.2004 - accuracy: 0.9410 - val_loss: 0.2922 - val_accuracy: 0.8894

Epoch 9/20

30/30 [=====] - 0s 15ms/step - loss: 0.1727 - accuracy: 0.9499 - val_loss: 0.3014 - val_accuracy: 0.8885

Epoch 10/20

30/30 [=====] - 0s 15ms/step - loss: 0.1531 - accuracy: 0.9550 - val_loss: 0.3294 - val_accuracy: 0.8888

Epoch 11/20

30/30 [=====] - 0s 15ms/step - loss: 0.1382 - accuracy: 0.9610 - val_loss: 0.3547 - val_accuracy: 0.8872

Epoch 12/20

30/30 [=====] - 0s 15ms/step - loss: 0.1270 - accuracy: 0.9629 - val_loss: 0.3837 - val_accuracy: 0.8863

Epoch 13/20

30/30 [=====] - 0s 15ms/step - loss: 0.1144 - accuracy: 0.9665 - val_loss: 0.3901 - val_accuracy: 0.8882

Epoch 14/20

30/30 [=====] - 0s 15ms/step - loss: 0.1056
- accuracy: 0.9692 - val_loss: 0.4260 - val_accuracy: 0.8858

Epoch 15/20

30/30 [=====] - 0s 15ms/step - loss: 0.0928
- accuracy: 0.9726 - val_loss: 0.5180 - val_accuracy: 0.8827

Epoch 16/20

30/30 [=====] - 0s 16ms/step - loss: 0.0880
- accuracy: 0.9751 - val_loss: 0.4675 - val_accuracy: 0.8835

Epoch 17/20

30/30 [=====] - 0s 15ms/step - loss: 0.0839
- accuracy: 0.9749 - val_loss: 0.5007 - val_accuracy: 0.8829

Epoch 18/20

30/30 [=====] - 0s 15ms/step - loss: 0.0789
- accuracy: 0.9771 - val_loss: 0.5605 - val_accuracy: 0.8828

Epoch 19/20

30/30 [=====] - 0s 15ms/step - loss: 0.0753
- accuracy: 0.9777 - val_loss: 0.5411 - val_accuracy: 0.8758

Epoch 20/20

30/30 [=====] - 0s 15ms/step - loss: 0.0666
- accuracy: 0.9814 - val_loss: 0.5993 - val_accuracy: 0.8816

